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IMPACT ASSESSMENT

Accompanying the document

Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)

{COM(2016) 767 final}
{SWD(2016) 419 final}

Contents

Abstract accompanying the Impact Assessment

1. Policy Context And Key Challenges

The Energy Union framework strategy puts forward a vision of an energy market 'with citizens at its core, where citizens take ownership of the energy transition, benefit from new technologies to reduce their bills, participate actively in the market, and where vulnerable consumers are protected'.

The Energy Union with a sustainable, low-carbon and climate-friendly economy includes President Juncker's political ambition to become the world leader in renewable energy, the global hub for developing technically advanced and competitive renewable energies[1].

To live up to this vision, a series of legislative proposals have been prepared, following the objectives of secure and competitive energy supplies and building on the EU's 2030 climate commitments reconfirmed in Paris last year.

Renewables in Europe – good results so far

As a result of Directive 2009/28/EC (2009 RES Directive), with currently 16% of renewable energy in its final energy consumption[2], the European Union is on track to achieve its 20% renewables target by 2020. This piece of EU legislation, along with other EU and Member State complementary measures, has boosted European investment in renewable technologies at a domestic level. Renewables are now being deployed across the various sectors (electricity, transport, and heating and cooling) in all Member States. Economies of scale and innovation have reduced significantly the related costs[3].

The renewable energy sector already delivers an important dividend to EU energy security with around €20 billion saved in fuel import costs in 2014 for the whole EU. The sector also remains key to EU objectives to sustain and improve growth, employment and competitiveness. The EU renewable energy industry employed in 2014 around 1.1 million workers[4], and European companies held 30% of all patents for renewable technologies globally in 2013[5].

Taking renewables to the next level – the 2030 framework and EU leadership in renewables

The EU has set itself a target to reach, collectively, a share of at least 27 % in the final energy consumption by 2030.

While the EU is today well on track to achieve its 2020 renewables target, yet, investments in renewable have dropped by more than half since 2011 to $48.8 billion last

1 The development of new and renewable forms of energy by means of EU energy policy is a Treaty obligation enshrined in Art 194 TFEU. EU policies promoting renewables date back to 2001 (Directive 2001/77/EC)

2 2014 data, Eurostat, with an estimated renewable energy share of 17% of gross final energy consumption in 2015

3 *E.g.* solar module prices have been reduced by 80% between 2008 and 2012 (JRC, PV Status Report, 014) and wind turbine prices declined by 30% between 2008 and 2015

4 EurObserv'ER, 15th Eurobserv'ER report, 2015 (2014 figures)

5 OECD Statistics database

year. The EU now accounts for only 18%[6] of global total investment in renewables, down from close to 50% only 6 years ago. This calls for concrete and decisive actions to put the EU back on track in pioneering world efforts.

While the Renewables Directive, together with the Market Design and Energy Union Governance initiatives, will be a central element for the EU to pursue its ambition of a world leadership role in renewables, this political goal needs to be further supported in a holistic approach by policies and initiatives also in areas outside the scope of this package, such as financing (including ESIF and EFSI), regional development, research and innovation, international cooperation and industrial policy.

Key challenges and opportunities going forward

The costs for a number of renewable energy technologies have rapidly declined, this shifting the need for policy intervention from cost-competitiveness issues to market integration aspects - at least for most mature technologies.

The EU policy framework for renewable electricity (RES-E) has successfully turned solar and onshore wind technologies from niche technologies into central players in the power sector. However, the heating and cooling, and the transport sectors continue to rely heavily on fossil energy imports.

The move from national binding targets set by the current 2020 framework, towards an EU-level binding target for renewables for 2030, opens up new challenges, but also new opportunities for the EU to achieve the target collectively and in a cost-effective, sustainable way.

New technologies like smart grids, smart homes, increasingly competitive roof-top solar panels and battery storage solutions make it possible for energy consumers to become active players on the market and this opportunity should be harnessed.

Markets for renewable energy are opening across the world. Whilst global investments in renewable energy are growing, the investments in renewables in the European Union are declining, jeopardising the EU leadership ambition.

2. PROBLEM DEFINITION

The EU as a whole is currently on track to reach a share of renewable energy of **24.3%** by 2030, **falling short of the 2030 ambition**. This result shows that we risk following a development path that is insufficient to achieve the 2050 decarbonisation scenarios.

Several obstacles still prevent a cost-effective achievement of an at least 27% renewable energy target within the European Union in a business as usual scenario.

Investor uncertainty

For the EU, the investment needs are estimated to be around or above €1 trillion from 2015 to 2030 in renewable electricity generation alone[7]. It is unclear at which point in

[6] Frankfurter School-UNEP Centre/BNEF, 2016. Global Trends in Renewable Energy Investments 2016, http://www.fs-unep-centre.org

[7] Source: Bloomberg New Energy Finance (2014). 2030 Market Outlook; International Energy Agency (2014). World Energy Investment Outlook.

time an enhanced market design and a strengthened EU ETS, alongside other factors such as further cost reductions, will provide sufficient incentives for renewable energy investments, without any additional support to cover investment gaps. Further uncertainty for investors comes from the future evolution of rules on support schemes. In addition, the uncertainty regarding the EU sustainability criteria post-2020 is not conducive for investment in the bioenergy sector, including in advanced biofuels.

Lack of cost-effectiveness

Renewable technologies are being deployed across various sectors - electricity, heating and cooling, and transport, with different levels of cost-effectiveness. Over the past decade, a lot of emphasis was put on the development of renewable electricity. The 2030 and 2050 decarbonisations scenarios require however also accelerated renewables deployment in heating and cooling, and transport.

Renewable technologies, their cost and potentials vary significantly. Ignoring these differences might result in either underinvestment or overcompensation. There are also clear benefits to be reaped from a more Europeanised approach to renewables support, in order to facilitate cost-effective deployment of renewable electricity across the EU. Last but not least, differences in cost of capital and national approaches to other investment conditions such as grid connection fees undermine the optimal allocation of renewable electricity generation capacity across the EU.

Imperfect markets

Well-functioning internal energy markets are crucial for the deployment of renewables. However, the markets in the electricity, transport and heating and cooling sectors are at different phases of development or integration and require different measures to ensure their correct functioning. In the case of the electricity sector, where renewables are expected to reach around 50% market penetration by 2030, the electricity market should be redesigned to support the integration of renewables as proposed in the framework of the Market Design initiative. In the heating and cooling market, the challenge is to ensure access to existing infrastructure and sufficient incentives for the expansion of renewables. In the transport sector, renewable energy uptake is still hampered by a lack of clear market signals for low-carbon and renewable fuels.

Update of the regulatory framework

The renewable energy target of at least 27% is expressed as a binding target at EU level. This is a policy change from the previously binding targets at national level on which the current EU legislation and in particular the 2009 RES Directive is built. Furthermore there will be no specific sectorial targets as it is the case with the current 10 % target in the transport sector. This calls for an update of the regulatory framework so that it is adapted to the new approach.

Lack of citizen buy in

Existing rules do not sufficiently enable citizens and communities to have sufficient buy in into the energy transition. This can lead to lack of public acceptance at local level, resulting in higher development costs and slower renewable development. Empowering consumers and energy communities, and providing them with reliable information about renewables, are therefore fundamental preconditions for deploying renewable energies in a cost-effective way.

3. OVERARCHING GOALS OF THE REVISED RENEWABLE ENERGY DIRECTIVE

Renewable energy is central to the five dimensions of the Energy Union: energy security, energy efficiency, competitiveness, emission reduction, and global leadership through innovation. As such, the new EU-wide renewable energy target for 2030 set by the European Council in October 2014, based on the Commission's proposal and underpinning analysis presented in the 2030 Framework for Climate and Energy[8] and the Energy Union Framework Strategy[9], is key for achieving the Energy Union priorities.

Therefore, the ambition is to **increase the share of renewable energy consumed in the EU to at least 27% by 2030 in line with the cost-effective pathway described in the** 2030 Framework for Climate and Energy, and further reduce greenhouse gas emissions (at least 40% by 2030) and save at least 27% energy by 2030 compared to 2007 baseline projections.

The specific goals are:

First, the renewables deployment should contribute to **greenhouse gas emissions reduction** of at least 40% compared to 1990 levels, including a reduction of 30.2% of emissions in the non-ETS sector compared to 2005 levels. It should bring the EU economy closer to the required decarbonisation pathway to achieve the objective of 80-95% emissions reduction by 2050.

Second, the revised Directive should **improve energy security by diversifying the energy mix and reduce EU's dependence on imported fossil fuels,** particularly in the heating and cooling sector and the transport sector, as outlined in the 2030 Framework for Climate and Energy. Overall, the specific measures proposed for these two sectors could lead to a reduction in import dependency.

Third, renewable energies should further contribute to the integration **of the internal energy market**. The results show that a continuation of nationally-based support schemes would lead to less efficient deployment of renewable energy, a concentration of renewables investments in three countries, and a 25% increase in the average electricity prices in 2030 compared to 2010[10]. In contrast, a consolidated framework that builds upon a good market functioning, a more coordinated regional approach and addressing the costs of capital can achieve a more balanced deployment of renewables across the EU and reduce energy system costs.

Finally, the proposed options should foster innovation in renewables deployment and ensure that the EU can truly **become a global leader in renewables**. The proposed measures would strengthen both technology and market driven innovation, support the creation of flexible and integrated infrastructure, and create healthy supply chains, thereby enhancing the EU technological leadership role in this sector. With this experience, European companies will be able to position themselves to support the global transformation towards a more sustainable energy system.

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8 COM(2014)015 - "A policy framework for climate and energy in the period from 2020 to 2030", 21 January 2014

9 COM(2015)80 final - "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy", 25 February 2015

10 Results based on Current Renewables Arrangement – CRA Scenario

4. INTERLINKAGES WITH OTHER INITIATIVES

The preparation of this Impact Assessment has been done in close coordination with, and is complementary to, other related Commission initiatives. First and foremost, this includes the Market Design and Energy Union Governance proposals but also the revision of the Energy Efficiency and Energy Performance of Buildings Directives, the EU ETS and the Effort Sharing Regulation, the LULUCF Regulation and the Bioenergy Sustainability Policy.

These other pieces of legislation mutually complement the Directive. However, they are not by themselves sufficient to allow the EU to reach, collectively, a share of at least 27 % in the final energy consumption by 2030 in a cost effective way and to deliver on the EU political priority of becoming the world's number one in renewables.

The **Market Design initiative** will, *inter alia*, facilitate the development of an electricity market fit for renewable energies, where short term markets are fully developed and integrated and flexibility plays a key role in enhancing the market value of renewables. This enhanced electricity market design, together with the strengthened EU ETS, will be a key foundation of the 2030 framework and will ensure that renewable energy generators can earn a higher fraction of their revenues from the energy markets. The revision of the Renewables Directive will build on this approach and complement it by introducing different measures aimed at attracting the necessary investments cost-efficiently and in a timely manner.

The **Energy Union Governance** frames the Integrated National Energy and Climate Plans, which set out national contributions to the legally binding EU-level RES target. The revision of the Renewables Directive complements the Energy Union Governance by considering different options to fill a potential gap either on ambition or delivery of the EU target. At the same time, the Governance initiative streamlines and integrates the existing planning, reporting and monitoring obligations of the energy acquis including those for renewable energy post 2020.

The **Energy Efficiency Directive (EED)** and **Energy Performance for Buildings Directive (EPBD)** aim, respectively, at facilitating the achievement of the energy efficiency target and at enhancing the energy performance of buildings. The provisions in the heating and cooling section are consistent with and complement the measures in both the EED and the EPBD, in particular by tackling existing buildings, tertiary and industry, as well as by including specific requirements on renewables.

The **EU Emission Trading Scheme (EU ETS)** will be reformed for the period after 2020[11]. Existing legislation includes the Market Stability Reserve to address the current surplus of allowances and to improve the ETS resilience to major shocks by adjusting the supply of allowances to be auctioned. The strengthened EU ETS will play an increasing role in providing a stronger investment signal for lower carbon technologies, including renewables, and will ensure that synergies between renewable energy and climate policies are better exploited. Furthermore, the proposed **Effort Sharing Regulation**[12]

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11 COM(2015)337 final - Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments

12 COM(2016)482 final - Proposal for a Regulation of the European Parliament and of the Council on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 for a resilient Energy Union and to meet commitments under the Paris Agreement and amending

makes proposals for setting national binding emission reduction targets for greenhouse gases for the sectors outside the EU ETS and on Land Use, Land Use Change and Forestry (LULUCF).

The **LULUCF Regulation** aims at integrating carbon emissions credits and debits form agriculture and forestry into the EU 2030 climate and energy framework. In addition, the Bioenergy Sustainability Policy aims at guaranteeing the climate and environmental benefits of EU bioenergy consumption for the period after 2020, focusing in particular on biomass in heating/cooling and electricity. The provisions in the transport sector of this Impact Assessment build and complement these approaches, by promoting higher direct greenhouse gas saving for new biofuels and bioliquid installations.

5. SUBSIDIARITY

EU level action is needed to ensure that Member States' contribute to the at least 27% EU level binding renewable energy target and that this is collectively and cost-effectively met. Common principles to govern support of renewable electricity are needed to address fragmentation of the internal market and ensure cross-border tradability. Thus also a case for common rules for transport fuel could be made.

EU-level action on heating and cooling is necessary due to the high share of the sector in energy consumption, however given the limited cross-border dimension, the options are designed with a significant degree of flexibility for Member States. Member States' shares of heating and cooling in overall energy mix may differ, as does the relative importance of heating versus cooling. However, the fundamental market failures are similar, particularly due to technology lock-in (*i.e.* existing fossil fuel heating systems) and lock-out (consumers cannot individually change fuels in collective supplies such as gas grid, district heating, etc.).

Action only at Member States' level would likely lead to a more limited deployment of renewables and create additional costs that can be reduced through complementary EU-level action. It would also lead to more fragmentation of, and distortions in, the energy internal market and put the achievement of the EU renewable energy target at risk.

6. DESCRIPTION OF POLICY OPTIONS AND ANALYSIS OF IMPACTS

The overarching goals of the revision of the Directive can only be achieved through a systematic approach, which results in renewables being deployed cost-effectively in all Member States and in all sectors.

A balanced and stable set of measures aimed at facilitating renewables investments across the electricity, transport and heating and cooling sectors in the 28 Member States will enhance regulatory certainty. They should also improve the conditions for renewables investment to take place where needed. In addition, measures oriented towards empowering and informing consumers also mobilise private capital for investments in renewable energy and increase social acceptance of renewable energy projects. Lastly, given the binding nature of the EU level target it is necessary to make sure the target is achieved in a timely manner, in a way that is complementary to the

Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change

Governance Initiative. The latter defines the iterative process between Member States and the Commission in order to ensure the respective national contributions to the target.

6.1 Expanding renewable electricity cost-effectively

Amongst all sectors that make up our energy system, electricity is the most cost-effective to decarbonize. In 2014, 27.5% of Europe's electricity is produced using renewable energy and the modelling shows that close to half of our electricity will come from renewables by 2030. Yet, the necessary investments in renewable power generation are declining, concentrated in a small number of countries[13] with low weighted cost of capital (WACC) and policy frameworks perceived as most stable, and are insufficient to achieve the 2030 target.

Consistent with *'The vision for the EU electricity market in 2030 and beyond'*[14], the Commission's ambition for the post-2020 context is that renewable electricity generators can earn a high fraction of their revenues from energy markets. Such a market would be based on an enhanced electricity market design – where short term markets are fully developed and integrated and flexibility plays a key role in enhancing the market value of renewables – as well as a strengthened EU ETS. These are no regret solutions that need to be at the core of the decarbonisation of the power system.

However, despite such market enhancement, in some cases energy market revenues alone will remain insufficient to attract renewable investments in a timely manner and at the required scale. Where limited, specific financial support is still needed, the market – via competitive tenders – will confirm its necessity and the level of support through tender mechanisms, which will act as a natural phase-out for support measures. Ensuring regulatory certainty is paramount to ensure cost-effective deployment of renewables electricity.

The findings of the Renewable Energy and the Electricity Market Design Impact Assessments and the proposed policy options

The results of modelling work undertaken for the Electricity Market Design and Renewable Energy Impact Assessments **indicate that the improved electricity market, in conjunction with a revised ETS with a functioning Market Stability Reserve, could, under certain conditions, deliver investments in the most mature renewable technologies** (such as solar PV and onshore wind) **by 2030.** However, less mature renewable electricity technologies, such as off-shore wind, ocean energy, will likely need some form of support throughout the period. The analysis shows that the picture is dynamic, with the enhanced market design and the strengthened EU ETS gradually improving renewable electricity profitability over the 2021-2030 period. At the beginning of the period, over-capacity, the imbalance on the ETS market and low wholesale electricity market prices and high renewable electricity technology costs, make the case for market only driven investment in renewable electricity technologies more difficult. However, a stronger carbon price signal, a more flexible and dynamic electricity market and technology cost reductions gradually facilitate market investment over this period.

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[13] For example, only two Member States (the UK and Germany) received over two thirds of all investments into renewable electricity new investments as well as M&A and refinancing activity in 2014 and 2015.

[14] Provided in a separate document together with the Market Design Impact Assessment

The picture also depends on regions. RES-E technologies could be more easily financed by the market in the regions with the highest potential (*e.g.* onshore wind in the Nordic region or solar in Southern Europe), while RES-E continue to largely require support in the British Isles and in Central Europe. Conditions however also depend on the cost of capital.

At the same time it has to be acknowledged that whether and at what point in time financing of renewables through markets alone will actually take off remains difficult to predict. This is because financing of capital intensive technologies such as most renewables through markets based on marginal cost pricing will remain challenging. In particular, higher penetration of renewables with low marginal cost could further reduce the market value that such renewables can actually achieve (so-called cannibalisation effect). Further flexibilisation of demand stands out as a key measure in this regards in order to further stabilise the revenue of renewables producers from the market.

On the other hand, the future capacity of renewables to be financed through the market will also depend on certain conditions outside of the market design and ETS prices, such as continued decrease in the costs of technologies, availability of (reasonably cheap) capital, social acceptance and sufficiently high and stable fossil fuel prices.

While the market reforms described above are therefore no regret options to facilitate renewables investment, support schemes will still be needed at least for a transitional period. It is therefore essential to further reform such schemes to make them as market-oriented as possible.

Against this background, the RES Impact Assessment investigates options to ensure that if and where support is needed, (i) support is cost-effective and kept to a minimum, and (ii) creates as little distortion as possible in the functioning of electricity markets.

As a first measure, the RES Impact Assessment suggests **creating a common European framework for support schemes**. The framework would be effective as it would define design principles (i) that ensure sufficient investor certainty over the 2021-2030 and (ii) require the use (where needed) of market-based and cost-effective schemes based on emerging best practice design (including principles that are not covered by the current state aid guidelines). At the same time, the framework would be proportionate by leaving actual implementation to the state aid guidelines (*e.g.* for the definition of thresholds applicable for any foreseen exemptions) and, most importantly, to the case by case, evidence-based, in-depth assessment of individual schemes by the services of DG Competition.

Importantly, the framework would enshrine in legislation and expand the requirement to tender support; it would define tender design principles, based on emerging best practice, to ensure the highest cost-efficiency gains. The framework would thus strengthen the use of tenders as a natural phase-out mechanism for support, by which a competitive bidding process determines the remaining level of support required to bridge any financing gap – such level of support being expected to disappear for the most mature technologies over the course of the 2021-2030 period.

The second measure addresses the need for a **more coordinated regional approach** to ensure a healthy investment portfolio of different renewable power generation technologies and investment locations. The results of the Impact Assessment shows that these measure would result in reduced energy system costs ranging from €1.0 billion (partial opening) and €1.3 billion (mandatory regional schemes) annually for the period 2021-2030, and renewable energy support costs paid by the consumer are reduced by 3% and 5% respectively.

The third measure proposes a **renewables-focused financial instrument** to address the high costs of capital for investments in renewable power. The risk is that overall investments may be insufficient to meet the 2020 and 2030 targets, a sub-optimal medium- and long-term deployment at EU-level, and a lack of exploitation of the renewable energy potential of countries with a higher cost of capital. Two different financial instruments have been assessed. A financial instrument that reduces the cost of capital in a number of Member States and regions will reduce energy system costs by €1.5 billion and achieves a more balanced deployment of renewables across the EU. A financial instrument that addresses only high risk projects would result in an increase of energy system costs, but could lead to technological breakthroughs in technologies like offshore wind and tidal.

The fourth measure addresses the **varying administrative costs between Member States**, which can account for around 15% of the overall development costs of wind projects. Administrative barriers bring uncertainty and delay to investors, artificially increase the costs of renewable energy projects, create distortions in the allocation of investments within the EU, and therefore hamper building a single integrated market for renewable energy and reaching a cost-effective deployment.

Building on the existing provisions on administrative procedures in the 2009 RES Directive, regulations and codes and on the TEN-E Regulation, the Impact Assessment proposes additional options to address the remaining obstacles including the introduction of a one-stop-shop and a time range for permitting procedures and facilitated procedures for repowering.

6.2 Improve energy performance and energy security with renewables in the heating and cooling sector

Heating and cooling represents the largest energy sector in the EU, consisting of around half of the European energy demand. It is made up of 75% fossil fuel and accounts for 68% of the EU's gas imports. There are currently limited heating and cooling measures across the sector in EU legislation[15], leading to slow progress, an absence of a long-term policy vision and investor uncertainty. On top of this situation, the negative externalities of the fossil fuel use in the heating and cooling sector[16] are not internalised and reflected in the energy prices for most parts of the heating and cooling sector, which hinders market uptake of highly efficient renewable energy technologies.

While the share of renewable energy in electricity has increased by more than 8 percentage points between 2009 and 2015, the share of renewables in the heating and cooling sector has only expanded by less than 3 percentage points in the same period[17]. The EU Strategy for Heating and Cooling also highlights the important impact of

15 Contrary to electricity and transport

16 Such as climate change and air pollution, with environmental and health consequences

17 EUROSTAT, and “Renewable Energy Progress Report”, Öko Institute [to be published], draft preliminary figure

renewables deployment in district heating and cooling systems to reduce the costs and increase the flexibility of the EU energy system[18].

The findings of the Impact Assessment and proposed policy options

In the absence of additional and coordinated policies, the current slow rate of progress in Member States is **incompatible with a cost-effective achievement** of the EU renewable energy target by 2030[19] and long-term decarbonisation goals[20]. Given its large share in total energy consumption, measures intended to increase renewables use in the heating and cooling sector are crucial for the EU to meet its renewable target in a cost-effective manner.

The impact assessment has evaluated a number of measures – consistent with the enhanced EED - to improve the renewables deployment in the heating and cooling sector as well as in district heating and cooling systems.

For the **heating and cooling supply**, an obligation on all fuel suppliers[21] is considered to increase the amount of renewable energy that they supply. This should enable the cost-effective deployment of renewables in heating and cooling at EU-level, and reduce investor uncertainty. Two design variants are compared:

- A gradual increase in the obligation every year, or
- The obligation to reach a certain share of renewables by 2030

Given the fact that the heating and cooling sectors are very diverse across the EU, Member States would be allowed to have **significant flexibility** to design the obligation (*e.g.* choice of obligated parties, the possibility to exempt SMEs from the scheme).

The promotion of **efficient and renewable district heating and cooling** aims to address the market uptake of renewables, empower the citizens and reinforces the provisions above by:

- Making it possible for renewables suppliers to access of district heating and cooling networks through energy performance certification; and
- Facilitating consumers' choice of high performance energy supplies (be it centralized or decentralized).

These options introduce an obligation to allow open access rights to infrastructure for RES and waste heat and cold, an obligation to certify the district heating system performance using an existing standard[22], and the right for consumers to pursue higher efficiency by disconnecting from the district grid. The Impact Assessment shows that if the renewable supply increases in existing district heating and cooling systems by 20% roughly, an additional 2 Mtoe renewable heating and cooling could be delivered by 2030.

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[18] An EU Strategy on Heating and Cooling, COM (2016) 51/2

[19] In absence of additional policies, the EU would only reach 24.7% renewable energy share in the heating and cooling by 2030, and due to the size of the heating and cooling sector in the overall energy consumption, and combined with absence of additional policies in other related climate and energy fields, that would result in only 24,3% overall share of renewables in 2030 – Source : PRIMES REF2016

[20] Between 2015 and 2050, the GHG intensity of the residential and tertiary sectors would be divided by 4, and the renewable energy share in heating and cooling would reach 41.6% - source: PRIMES EUCO30.

[21] With possible exemptions

[22] The CEN Standards (Comité Européen de Normalisation)

The risk of disconnection is deemed limited at the EU level, but could vary depending on the Member State. Both options result in new compliance costs linked to the certification which could not be quantified, but are estimated to be minimal if streamlined with the new provisions in the Energy Efficiency Directive.

6.3 Renewable fuels in the transport sector

Transport consumes a third of EU's total energy demand and it is almost entirely dependent on oil. While the transition to low-emission alternative energy in transport has already begun, spurred by the current Renewable Energy Directive, the sector is significantly lagging behind the other sectors. There is high potential for increasing renewable energy use in transport through electrification and development of advanced renewable fuels. It is also an opportunity for Europe to develop leadership in new bio-based products, such as advanced biofuels.

The work on the Impact Assessment has been developed in full consistency with the European Strategy for Low-Emission Mobility. This strategy already indicated that the Commission was examining how to provide a strong incentive to innovate in energies needed for the long-term transport decarbonisation by, for example, introducing an obligation for fuel suppliers to provide a certain share of renewable alternative energy.

The findings of the Impact Assessment and proposed policy options

Modelling-based analysis shows that, under the EU Reference Scenario 2016, the deployment of alternative fuels (including renewable fuels) in transport will slow down. It will be insufficient for achieving the 2030 climate and energy target and contributing to the EU's long-term decarbonisation goals. The main reasons for this under-performance include, amongst other: the high dependence of the sector on liquid fossil fuels, lack of economic viability of alternative fuels, the variable GHG emission performance of biofuels and specific barriers in aviation, waterborne (inland waterways and maritime) and heavy duty vehicles.

Against this background, this Impact Assessment analyses **four policy options to promote innovation and significant market uptake of alternative and renewable fuels in the transport sector**, including different paths to phase out food-based biofuels. These options include:

- EU incorporation obligation for renewable fuels, under the revised Renewable Energy Directive;
- EU incorporation obligation for renewable fuels, plus an EU-wide cap on the use of food-based biofuels. Two types of caps are analysed: a full phase out of food-based biofuels by 2030 or, alternatively, a phase down to pre-2008 levels. An additional sub-option consists of a faster phasing out of seed crop-based biodiesel and an increase in the direct greenhouse gas saving threshold of 70% for new installations;
- GHG emission reduction obligation, under the Fuel Quality Directive[23].

The impact assessment indicates that, under the same decarbonisation ambition, a complete phase out of food-based biofuels by 2030 would require higher shares of

[23] The Fuel Quality Directive requires Member States to oblige transport fuel and energy suppliers to reduce the GHG intensity of the fuel and the energy they supply.

advanced biofuels. This outcome would increase **annual investment costs by over 60% compared to a gradual phase out scenario**. This cost increase would be partially offset by lowered feedstock costs.

Furthermore, a complete phase out of food-based biofuels by 2030 would lead to job losses in the production facilities, and related industries such as crushing plants and refineries. This would occur particularly in the biodiesel sector where there are lower synergies between conventional and advanced biofuel production technologies. In addition, rape seed production could decline substantially. On the other hand, employment would increase in the production of advanced biofuels and fuels of non-biological origin, including technology development and use of feedstocks such as wastes, energy crops and lignocellulosic material. The net impact of the biofuels options is uncertain.

The analysis also shows that **emissions from indirect land use change (ILUC) can be significantly reduced through a gradual phase out of conventional biofuels by 2030**, focusing primarily on oil-crop based that are associated with higher ILUC impacts, combined with a higher greenhouse gas emission saving threshold for new biofuel installations.

The assessment finds that an **EU-wide incorporation obligation** would have the advantage of building on the extensive policy and administrative experience developed by Member States in implementing the Renewable Energy Directive and their national renewable fuel mandates. Furthermore, administrative burden for economic operators would be minimised, as they would continue to use mainly default values.

6.4 Empowering and informing consumers

The Energy Union Strategy places the consumer at its centre. Consumers should have the possibility to sell, consume and store self-generated energy. At the same time consumers should be informed about the energy they buy, as some might wish to purchase renewable energy and are prepared to pay a premium for such energy suppliers. Consumer empowerment could help mobilise additional private capital for investments in renewable energy sources.

However, in the absence of a European framework, Member States have addressed renewable energy self-consumption individually. This situation has led to differing degrees of consumer empowerment, unstable legal frameworks, and few incentives for citizens to invest in renewable energy sources when self-consumption is not facilitated. Equally, consumers wishing to be informed about the energy they buy must be absolutely certain that the renewable energy products are trustworthy. This requires an effective tracking system.

The findings of the Impact Assessment and proposed policy options

In line with the vision on consumers presented in the Energy Union strategy, two sets of measures have been proposed to empower consumers.

Regarding **self-consumption** three possible options are put forward:

- EU guidance on self-consumption
- Framework principles empowering consumers to self-consume and store renewable electricity

- Distance self-consumption for municipalities

The Impact Assessment finds that the option of including framework principles empowering consumers could drive PV deployment, increase the share of self-consumed electricity and might create 10 000 to 20 000 additional jobs in roof-top solar by 2030 compared to the baseline scenario. An EU guidance is unlikely to have a strong impact, whilst allowing for distance self-consumption[24] could have a negative impact on grid financing.

Regarding **consumer information**, the proposed measures aim at strengthening and extending the existing "guarantees of origin" (GO) system. Although GOs covered 45 % of all renewable electricity generated in the EU in 2015, the majority of power generation is outside of the system. Furthermore, Member States have implemented the GO system in widely differing ways[25], which increased the risk of double counting of renewable electricity.

For the electricity sector, the GO system could become the only means for disclosure of renewable electricity consumption to consumers. Furthermore, the GO system could be extended to renewable liquid and renewable gaseous fuels used in the heating and cooling and transport sectors. Such a system could be built on the existing sustainability requirements for biofuels. In addition to providing information to consumers, it would also facilitate cross border trade.

6.5 Making sure the EU will be on track on its ambitions by 2030

The new EU-wide binding target for 2030 set by the European Council in October 2014, is to increase the share of renewable energy consumed in the EU to at least 27% by 2030. In the absence of binding national targets for renewable energy post-2020, one main challenge is how to achieve this target in a cost-effective way through EU, regional and national level actions. This would need to take into account differing national capacities to produce renewable energy, whilst building on the renewable shares achieved in 2020.

In this context, Member States' Integrated National Energy and Climate Plans, to be developed as part of the initiative on Energy Union Governance, will play an important role, as they will include contributions to the EU-level 2030 target for renewable energy. Furthermore, the Energy Union Governance initiative aims, *inter alia*, via an iterative process with Member States, at addressing in first instance the possibility that contributions do not add up to the binding EU target (by means of recommendations on National Plans). However, the Governance process anticipates that further incentives for target achievement would be included in the Renewable Energy Directive should a gap in the target remain despite of the iterative process.

There are four overarching concerns that may warrant the need for additional and specific mechanisms to be included in the revised Renewable Energy Directive:

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24 For example, a municipality would be allowed to consume energy that is produced on one municipal building, for instance on the school, in another building, for instance in the swimming pool.

25 In particular, some Member States only issue GOs for electricity provided not benefiting form support schemes, whilst others issue GOs for all renewable electricity. Furthermore, some Member States have already extended the GO system to all types of electricity generated in their territory.

- How to ensure that – in line with the European Council conclusions of October 2014 – 2020 target are fully met?
- How to ensure a continued project pipeline from 2021 onwards – the year after the end of the binding 2020 requirement – to restore and maintain investor certainty?
- How to incentivise Member States to contribute appropriately and cost-effectively to the EU level binding target?
- How to ensure that Member States deliver on their contributions?

The findings of the Impact Assessment and proposed policy options

The first measure proposes the **2020 national targets as a mandatory floor** for the period 2021 to 2030, providing certainty to investors and creating a virtuous circle of higher levels of investments. This measure would need to be reflected in the requirements for the Integrated National Energy and Climate Plans set out under the Energy Union Governance, and requires a continuation of the existing co-operation mechanisms.

A **number of EU trajectories** have been examined to ensure a continued project pipeline between 2021 and 2030. The assessment suggests that there are sufficient mature technologies available to warrant a linear uptake of renewables over the 2020-2030 timeframe. This would result in a more consistent stream of investments, bring forward investments that have the opportunity to reduce the levelised cost of electricity, and has a positive impact on greenhouse gas emission reductions.

To avoid an "**ambition gap**", the proposed options include the iterative process under the Energy Union Governance, a review clause of the legislation to propose additional measures at a later stage, EU wide measures to ensure target achievement included in sectorial legislation, or other measures. The impacts of the options may vary depending on the size and the reason for the gap. The three considerations assessed are the impact of the options on investment certainty, the administrative burden and the political feasibility.

The "**delivery gap**" can be addressed with the same options considered for the "ambition gap". The key difference is that progress reporting under the Energy Union Governance will be a crucial element to detect delivery gaps at an early stage, that the options for the "delivery gap" and the "ambition gap" are consistent, and any corrective measure can be introduced effectively and without time delays to ensure investor certainty.

7. OVERVIEW OF MEASURES AND LINKAGE TO IDENTIFIED PROBLEMS

The Impact Assessment considers measures that can respond to one or more of the specific problems that prevent achievement of the overarching objectives of greenhouse gas emissions reduction, energy security, internal market, and global leadership.

As a conclusion, the table below presents a summary of the main measures considered in the impact assessment and their linkage to the identified problems.

Table 1: Overview of measures and linkage to the identified problems

	Electricity	Heating & cooling	Transport	Governance
Reduce investor uncertainty	- Consolidated framework: EU toolkit for support schemes	- Mainstream renewables: obligation on heating and cooling	- Increase renewables: obligation on renewable fuels	- 2020 Baseline - Trajectory towards 2030 target - Avoid and fill delivery gap
Improve cost-effectiveness	- Consolidated framework: tendering design principles - Reducing cost of capital - Administrative simplification	- Facilitate renewables in district heating and cooling: Energy performance		
Create functioning market	- Consolidated support framework: market-based design principles - Consolidated framework: energy communities	- Facilitate renewables in district heating and cooling: Access rights	- Increase renewables: obligation in aviation and maritime	
Update regulatory framework	- Coordinated regional approach		- Increase renewables: phase-out of food based biofuels	- Avoid an ambition gap - Avoid and fill delivery gap
Ensure citizen buy-in	- Empower consumers: self-consumption and storage-consumption - Consolidated support framework: fair tendering for small producers - Disclose information on electricity generation	- Facilitate renewables in district heating and cooling: Consumer rights - Trace origins of renewable fuels in heating and cooling	- Trace origins of renewable fuels in transport	

1. INTRODUCTION

1.1. Background and scope of the initiative

The Renewable Energy Directive[26] (the "**RES Directive**") establishes a European framework for the promotion of renewable energy and constitutes the most relevant measure to deliver on the EU's mandate to *promote the development of new and renewable form of energy* as set out in Article 194 TFEU. It has been the main driver for European investment in renewable technologies at a domestic level, economies of scale and innovation driving down significantly the related costs[27]. It has also had a spill-over effect worldwide, triggering the adoption of renewable energy policies outside the European Union[28] and helping renewables towards becoming a cost-competitive energy source.

GHG emissions reduction	Gross avoided CO_2 emissions between 380 Mt[29] and 767 Mt[30] in 2014
Fossil fuel displacement	Reduction in fossil fuels consumption by 114 Mtoe in 2014[31] (c. 10 % of total fossil fuel consumption)
Avoided imported fuel costs	Around €20bn in 2014[32,33]
Employment	EU renewable energy industry currently employs in 2014 c. 1.1 million workers[34]
Innovation and technology leadership	European companies held 30% of all patents for renewable technologies in 2013[35]

26 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance), OJ L 140/16, 5.6.2009. The RES Directive was amended in 2015 by Directive (EU) 2015/1513, in order to reduce the greenhouse gas emissions (GHG) from indirect land use change (ILUC) caused by conventional food based biofuels and from crops grown as main crops primarily for energy purposes on agricultural land and to prepare the transition towards advanced renewable fuels that can avoid these impacts.

27 *E.g.*, solar module prices have been reduced by 80 % between 2008 and 2012 (JRC, PV Status Report, 2014) and wind turbine prices declined by 30% between 2008 and 2015

28 Regulatory policies in the electricity, heating and cooling and transport sectors cover over 87%, 50% and 73% of the world population, respectively, Renewables 2016 Global Status Report, REN21, 2015

29 "Renewable Energy in Europe 2016 – Recent growth and knock-on effects", EEA, 2016, No 4/2016

30 JRC, 2016 available at: http://iet.jrc.ec.europa.eu/remea/news/third-progress-reports-renewable-energy-development- eu2013-2014

31 This figure represents the total contribution of renewables to fossil fuel savings in a given year compared with the situation in 2005. This should not be compared with 234-300 Mtoe/year figure in 2020 from the 2006 impact assessment, which has been calculated for the whole energy system.

32 "Renewable Energy Progress Report", Öko Institute [to be published]

33 This figure represents the total contribution of renewables to fossil fuel import savings in a given year compared with the situation in 2005. This should not be compared with 50-57 billion EUR/annum from the 2007 impact assessment, which has been calculated for the whole energy system.

34 EurObserv'ER, 15th Eurobserv'ER report, 2015 (2014 figures)

35 OECD Statistics database

The RES Directive establishes, *inter alia*, national mandatory targets for the share of renewables in final energy consumption for each Member State. It also includes biennial indicative trajectories, as partial milestones to ensure that actual developments are not lagging behind in view of the achievement of the 2020 targets. A holistic approach is ensured by covering the three sectors: electricity, heating and cooling and transport, but the split of the national target and trajectories between the sectors is left to the discretion of the Member States (apart from a separate mandatory 10% sub-target for the 2020 share of renewable energy in the transport sector).

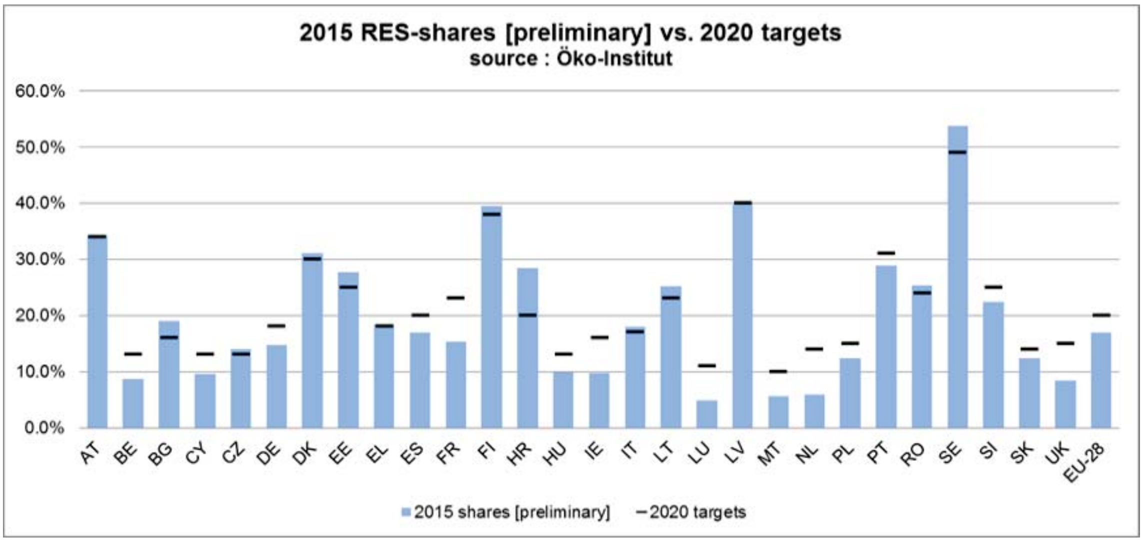


Figure 2: Based on 2016 Interim Progress Report - Oeko-Institute

With an estimated renewable energy share of 17% of gross final energy consumption in 2015[36], if the effort continues, the EU and an overwhelming majority of Member States are expected to achieve the 2020 targets set in the RES Directive[37]. More specifically, in the *electricity* sector (RES-E), 30% of the EU's power was estimated to be generated from renewables in 2015, with 11% of the total EU electricity sourced from variable renewable electricity[38]. In the *heating and cooling* sector (RES-H&C), the renewables share is estimated to reach 18,5% in 2015[39]. However, in the *transport* sector (RES-T), with a renewables share of 6,2% in 2015, the EU and the majority of Member States are still estimated at half-way towards the 10% target for 2020[40].

36 Eurostat for renewables shares for 2014, and 2015 estimates for the forthcoming 2016 Renewable Energy Progress Report. Eurostat 2014 data show a 16% renewable share in the EU

37 As highlighted in the 15th annual overview barometer, EurObserv'ER, 2015

38 Wind and Solar Photovoltaic, as % of total final electricity demand, ESTAT shares 2015

39 "Renewable Energy Progress Report", Öko Institute [to be published]. draft preliminary figure

40 "Renewable Energy Progress Report", Öko Institute [to be published]. draft preliminary figure

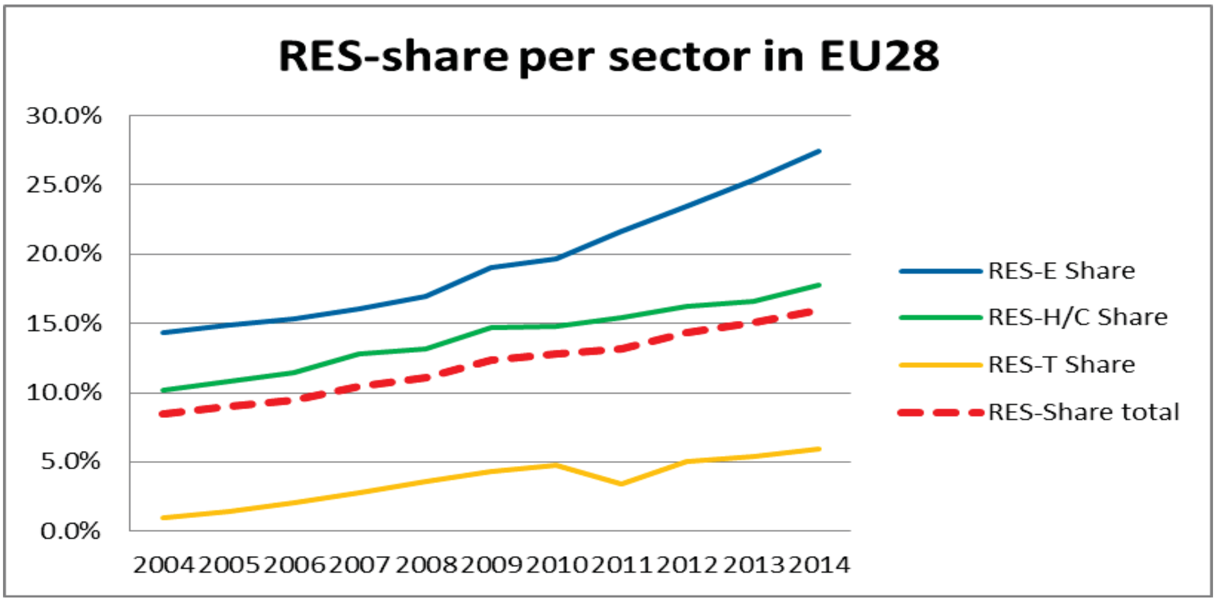


Figure 3: based on ESTAT Shares 2014

Some provisions of the RES Directive effectively end in December 2020, notably on national binding targets.

Finally the electricity sector is at this stage at an important crossroad with the Emission Trading System being reformed to address the surplus in allowances, the electricity market (including rules on generation adequacy) being redesigned and the new Energy Union Governance to be set up. The renewables electricity sector is also still recovering from abrupt, sometimes retroactive, changes that occurred in the aftermaths of the financial crisis and the biofuels sector need clarity on the post 2020 policies for biofuels. Re-establishing regulatory certainty for renewables producers and investors is therefore paramount at this point in time where the EU is falling behind global competitors in terms of absolute investments. There is equally a need to clarify the future policy on biofuels for investors in that sector.

The question this Impact Assessment aims to address is which additional measures and policies should be included in the RES Directive post-2020 to **promote the necessary long-term investments that will allow for further reduction in technology costs and the achievement of the 2030 renewable energy target[41] in a timely and cost effective way**.

1.2. Context of the initiative

The 2030 Framework for Climate and Energy[42] and the Energy Union Framework Strategy[43] establish the EU commitment to further reduce greenhouse gas emissions (at least 40% by 2030) in line with the cost-effective pathway described in the 2050

[41] As decided by the European Council in October 2014 with regard to a binding EU-level target of at least a 27% share of renewable energy consumed in the EU in 2030

[42] COM(2014)015 - "A policy framework for climate and energy in the period from 2020 to 2030", 21 January 2014

[43] COM(2015)80 final - "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy", 25 February 2015

Roadmaps[44], to increase the share of renewable energy consumed to at least 27%, and to save at least 27% energy by 2030 at EU level compared to 2007 baseline projections as quantitative headline targets of the Energy Union, in particular to increase Europe's energy security, achieve a moderation of energy demand and progress in the decarbonisation of the economy.

The Energy Union Framework Strategy stated the need, *inter alia*, for an integrated governance and monitoring process, to ensure that all energy-related actions at European, regional, national and local level contribute to the Energy Union's objectives and to secure the delivery of the 2030 Framework for Climate and Energy. This is also in line with the EU commitments at the COP21 Climate Summit in December 2015, which adopted the first-ever global and legally-binding climate agreement with the aim to hold the global warming well below 2°C and to pursue efforts to limit it to 1.5°C.

Integrated National Energy and Climate Plans, together with comprehensive monitoring and reporting at the EU and national levels, and an iterative political process between the Commission and Member States on the implementation of national plans will be essential elements of such a governance framework. These provisions will be reflected in the Commission's initiative on the Energy Union Governance.

In February 2014, the European Parliament called for a 40% cut in CO_2 emissions, a 30% target for renewable energy and a 40% target for energy efficiency by 2030, under the EU's long-term climate-change policy[45]..

With a view to the period beyond 2020, in October 2014 the European Council agreed on a binding EU-level target of at least a 27% share of renewable energy consumed in the EU in 2030. Furthermore, in February 2015 the Commission confirmed the political commitment for the European Union to become the world leader in renewable energy[46].

The roadmap for delivering the Energy Union, launched in November 2015 as part of the first Report on the State of the Energy Union, foresees a new Renewable Energy Package for the period after 2020, containing a revised Renewable Energy Directive (the "**Revised RES Directive**"), and including a bioenergy sustainability policy for the period 2021-2030[47].

1.3. Links with parallel initiatives, approach taken for modelling, data gaps and other limitations

1.3.1. Links with parallel initiatives

The Commission has already tabled legislative proposals of relevance to an EU policy on renewable energy, such as the revision of the EU Emission Trading Scheme (ETS) for

[44] COM(2011)112 - "A Roadmap for moving to a competitive low carbon economy in 2050", 8 March 2011 and COM(2011)885 final - "Energy Roadmap 2050 ", 15 December 2011

[45] European Parliament resolution 2013/2135(INI) - "A 2030 framework for climate and energy policies", 5 February 2014, as recalled in European Parliament resolution 2015/2112(INI) - "Towards a new international climate agreement in Paris", 14 October 2015

[46] COM(2015)80 final - "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy", 25 February 2015.

[47] The bioenergy sustainability policy for 2030 is assessed in a separate Impact Assessment

the period after 2020[48], including, *inter alia*, a Market Stability Reserve to address the current surplus of allowances and improve the ETS resilience to major shocks by adjusting the supply of allowances to be auctioned. It also made proposals as regards setting national binding emission reduction targets for greenhouse gases (GHG) for the sectors outside the ETS (the so called "Effort Sharing Regulation")[49] and on Land Use, Land Use Change and Forestry (LULUCF)[50]. In addition, legislative initiatives are being tabled as regards the revision of the directives on energy efficiency (EED)[51] and energy performance of buildings (EPBD)[52], and a policy communication was published on the European strategy for low-emission mobility[53]. Finally, this Impact Assessment has been prepared in parallel with the Impact Assessments accompanying the initiatives on Electricity Market Design[54], Governance of the Energy Union[55] as well as Bioenergy Sustainability[56]. In relation to the latter, sustainability issues associated to bioenergy, particularly in heating/cooling and electricity, are specifically dealt with in that impact assessment. This Impact Assessment addresses only issues related to the climate performance of biofuels, and in particular indirect land use change impacts of conventional food-based biofuels which are not captured by the sustainability criteria.

As regards *electricity* in particular, the failures causing an inefficient integration of renewables in electricity markets are analysed in Chapter 2 as they are closely related to renewable electricity deployment. However, for sake of completeness, it should be stressed that policy options related to (i) the priority dispatch and priority access to the grid of electricity produced from renewable sources, (ii) balancing and other market responsibilities imposed on renewable electricity generators, (iii) grid connection charges and grid access tariffs applicable to renewable electricity generators as well as (iv) network planning obligations are assessed as part of the Electricity Market Design Impact Assessment. Various measures aimed at making electricity markets fit for integrating a large share of variable renewable generation, as well as facilitating the participation of renewables in all markets and all timeframes (including as regards the provision of ancillary services) are also assessed in the Market Design Impact Assessment, whereas policy options related to the promotion of renewable electricity will be assessed as part of this Impact Assessment.

For the *heating and cooling* sector, this Impact Assessment reflects, as appropriate, the Commission's intentions included in its EU Strategy on Heating and Cooling, notably with regard to promoting renewable energy through a comprehensive approach to speed up the replacement of obsolete boilers, including by encouraging the uptake of renewable energy in heat production and increasing the deployment of renewable energy in district

[48] COM(2015)337 final - Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments

[49] COM(2016)482 final - Proposal for a Regulation of the European Parliament and of the Council on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 for a resilient Energy Union and to meet commitments under the Paris Agreement and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change

[50] COM(2016) 479 final

[51] COM(2016) 761

[52] COM(2016) 765

[53] COM(2016) 501

[54] COM(2016) 864, COM(2016) 861 and COM(2016) 863

[55] COM(2016) 759

[56] COM(2016) 418

heating and combined heat and power generation (CHPs), as well as supporting planning for renewable energy deployment at local level also taking into account the need to reduce emissions of air pollutants such as Particulate Matters (PM) and Nitrogen Dioxide (NO^2). In this respect, some relevant measures are included in the Commission's proposal for the revision of the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) and assessed in the impact assessments supporting these initiatives[57].

For the *transport* sector, this Impact Assessment builds on the work carried out in the Staff Working Document accompanying the Commission's communication on a European strategy for low-emission mobility and additionally takes into account the reduction of the carbon intensity of transport fuels in the framework of the Fuel Quality Directive (FQD)[58]. Furthermore it focuses on the sustainability issues of biofuels, particularly the GHG emissions.

The absence of binding national renewable energy targets as a policy tool in a post-2020 timeframe requires the exploration of other policy avenues to ensure an adequate ambition and distribution of Member States' efforts to contribute to the EU-level target of at least 27% renewable energy in 2030. The legislative initiative on the Governance of the Energy Union aims to contribute to addressing this issue together with the revision of the RES Directive. The general approach is that governance provides the framework for planning, reporting and monitoring the development of renewable energy, whilst corrective measures if required would be part of the RES Directive, which is a simple approach applied with other aspects of climate and energy policy such as the Effort Sharing Regulation and the Energy Efficiency Directive. The interaction between the governance process and the RES Directive and the specific issues to be addressed are further explained in Chapters 2 and 5[59].

1.3.2. Approach taken for modelling and limitations

Annex 4 describes in detail the models used for the quantitative analysis presented in this IA, as well as the scenario descriptions. It also presents the interactions in the modelling work undertaken for this Impact Assessment and for the other related Impact Assessments on the 2016 Energy Union initiatives.

The problem definition and the policy options assessed in this Impact Assessment build on the outcomes of energy-system modelling scenarios. More specifically, the starting point for this Impact Assessment, as for all other related Impact Assessments, is the EU Reference Scenario 2016 ("REF2016"), which provides 2030 energy-system projections, based on current trends and policies[60].

This Impact Assessment makes also use of a central policy scenario also used for the Impact Assessments supporting the proposal for a revision of the Energy Efficiency Directive (as a baseline scenario) and for the proposal on the Effort Sharing Regulation, as well as in the Staff Working Document published together with the EU Strategy on

57 COM(2016) 765, COM(2016) 761, SWD(2016) 414 and SWD(2016) 405.

58 The FQD (Article 7a) obliges fuel suppliers to reduce the GHG intensity (gCO_2/MJ) of fuels supplied by 6% in 2020 compared to 2010.

59 See especially Section 5.5.3.

60 Annex 8 describes in more detail the interaction with other policy initiatives, sensitivity scenario and renewables decomposition, with the key results of energy-system modelling scenarios.

low-emission mobility (as one of the two central policy scenarios - in both initiatives), which are in line with 2030 minimum ambition levels as stated by Heads of States and Governments in October 2014. This scenario (called "EUCO27") projects the expected developments across sectors to reach the 2030 targets and help identify the scale of the economic, social and environmental challenges to cost-effectively reach an at least 27% renewable energy share. The second policy scenario (called "EUCO30" as its only difference from EUCO27 is a more ambitious energy efficiency target of 30%) is also used in analysis of transport sector options.

Building on the REF2016 and the EUCO27 scenario, specific baseline scenarios are then prepared, which highlight the expected implications of the continuation of current policies and practices on the developments in the specific sectors subject to policy interventions, assuming that all other sectors and policies are in line with the central policy scenario.

This approach, building on a common policy scenario and then focusing on 'one issue at a time', was deemed the only operational way to assess the impacts of specific policy options in the general context of various far-reaching initiatives put forward by the Commission as part of the 2016 Energy Union initiatives.

However, this approach has some limitations. First, assumptions have to be made about what the continuation of current practices mean in each sector. Second, the implications of a failure in one sector to deliver on agreed policies or targets on other policies or sectors cannot be directly modelled. Finally, since some of the policy options presented in this Impact Assessment cannot be properly addressed in an integrated energy system model, the analysis is complemented by other modelling or analytical tools and qualitative assessment when necessary, as further elaborated in the document.

2. WHAT IS THE PROBLEM AND WHY IS IT A PROBLEM?

2.1. Evolution of the problem and need to act post-2020

The EU and the world are moving towards a more sustainable and renewable energy system. Addressing concerns about greenhouse gas emissions, local air pollution[61], cost-competitiveness, and security of energy supply are among the main reasons for this global shift.

The Lisbon Treaty enshrined in the treaties of the European Union that "*Union policy on energy shall aim, in a spirit of solidarity between Member States, to […] promote […] the development of new and renewable forms of energy*"[62]. In this context, the European Council in October 2014 set a binding EU-level target of at least 27% for the share of renewable energy consumed in the EU in 2030. It also invited the European Commission to further examine instruments and measures capable of reducing emissions and dependency on energy imports in the transport sector, including measures for the promotion of energy from renewable energy sources. Taking action to curb energy use and boost renewables in the heating and cooling sector would reduce EU energy costs, help cut the EU's dependence on imported fossil fuels[63] and reduce carbon dioxide emissions, especially if highly efficient heating and cooling systems replace old ones, together with district heating deployment[64].

REF2016 projects a greenhouse gas reduction of 35% in 2030 compared to 1990 and a renewable energy share by 2030 of 24.3% in 2030[65]. Although this scenario does not assume any additional dedicated renewables policies, the combination of long-lasting effects of current policies, improved cost-competitiveness associated with technological progress, and the continuation of the ETS[66], lead to an increase in renewables share even post-2020. However, this increase still falls short of the minimum share of renewables agreed, and more generally highlights the potential risk of not reaching the 2030 EU climate and energy objectives, in the absence of additional policies.

The initiatives on the ETS and non-ETS sectors, Electricity Market Design, Governance and Energy Efficiency are expected to contribute to increasing the level of renewables as a share of final energy consumed in 2030. They will also facilitate the integration of renewable energy in relevant markets, and provide economic signals for the uptake of

61 Notably from particulate matters and NO2

62 Article 194 of the Treaty on the Functioning of the European Union

63 Although the heating and cooling sector is moving to renewable energy, in 2012 some 75% of the fuel it uses still came from fossil fuels, and heating and cooling accounted for 68% of the EU gas imports, COM(2016)51 final - "An EU Strategy on Heating and Cooling", 16 February 2016.

64 Heating and cooling is responsible for about half of the EU's final energy consumption and represents the largest energy end-use sector, ahead of transport and electricity. Meanwhile, in 2014 renewables only accounted for 17.7% of energy in the heating and cooling sector. The use of renewable energy in the industry sector is limited to biomass, despite the market maturity - at least for low temperature heat - of heat pumps, solar and geothermal. Significant potential for energy efficiency and renewable energy use remains. It is possible to reduce energy costs in industry by 4-10% by using existing technologies (see COM (2016)51 final - "An EU Strategy on Heating and Cooling", 16 February 2016).

65 EU Reference Scenario 2016, which assumes 2020 binding targets to be at least reached

66 Based on the currently applicable 1.74% linear reduction factor and the Market stability reserve. The increase of the linear reduction factor to 2.2%, as proposed by the Commission and currently in co-decision is not included in REF2016

renewable energy in line with the EU's climate and energy objectives, in the context of an improved internal energy market.

However, such initiatives cannot address the full range of specific issues that hamper the needed expansion of renewable energy in all sectors to ensure achievement of the 2030 renewables' target in the most cost-effective, proportionate and least distortive way for the ultimate benefit of the European taxpayers and energy actors, notably the consumers. Moreover, they will not suffice to provide clear signals to Member States, investors, and citizens and address President Juncker's ambition for the European Union to become "*the world number one in renewables*"[67].

Against this background, this Impact Assessment identifies the following five problem areas:

1. Investor uncertainty
2. Need to improve cost-effectiveness of renewables deployment
3. Absence of functioning markets
4. Need to update the policy framework
5. Risk of loss of citizen-buy in during transition

2.2. The problem areas and underlying main drivers

2.2.1. Problem 1 - Investor uncertainty

Investor certainty will be crucial for attracting the significant private investments needed to reach the at least 27% EU-level target. For the EU, these are estimated around or above EUR 1 trillion from 2015 to 2030 in renewable electricity generation alone[68]. As explained above, the regulatory framework is much wider than the RES Directive only, in particular for electricity.

<u>Driver 1: Uncertainty as to when energy-only market will provide sufficient investment signals</u>

European electricity markets were designed in the past for conventional, centralised power plants. In most Member States, electricity systems and markets are today not fit for a large penetration of variable renewable generation. Certain subsets of the electricity market are not designed to accommodate variable renewable generation. For instance, short term markets such as intraday and balancing do not run as close to real time as necessary[69] and in many cases market rules do not facilitate, or even impede, the integration of renewables (*e.g.* definition of market products). Existing rules create significant barriers to market entry, especially for new and/or small market entrants (in

67 http://juncker.epp.eu/my-priorities

68 Bloomberg New Energy Finance (2014). 2030 Market Outlook; International Energy Agency (2014). World Energy Investment Outlook

69 Gate closure time in intraday markets (where they exist) range from 5 minutes (in Belgium and the Netherlands) to 120 minutes (in Hungary). The closer to real time the gate closure, the more accurate are resource forecast for solar and wind producers, the lower are total system balancing costs, and – all other things being equal – the lower are retail prices

particular variable generation) and create a non-level playing field in favour of larger incumbents. Furthermore, system service markets are often not designed in a way that allow the participation of variable renewables, nor value and monetise the system services that distributed resources can bring. Secondly, energy systems as a whole lack the required flexibility crucial for the cost-efficient deployment of variable renewables sources. The further cost-efficient penetration of variable renewables depends on a sufficient and timely deployment of all sources of system flexibility, such as interconnectors, demand response, storage, flexible plants, electrical vehicle charging, and power-to-heat or to other energy carriers. System flexibility is crucial in limiting the renewables market value gap – by reducing the occurrence of both low/negative prices when renewables are dispatching and of high prices when renewables are not dispatching – and ensuring that adding variable renewable generation translates into net benefits to the system as a whole, *i.e.* the avoided costs minus increased costs. At the same time, it should be noted that flexibility measures also tend to suppress price spikes that could be necessary to recoup fixed costs of generating assets. These issues will be addressed in the market design Impact Assessment.

Indeed, variable renewable electricity suffers from a "cannibalisation" effect in the market based on marginal cost financing logic, creating a renewables "market value gap"[70]. Due to the merit order effect pricing mechanisms[71], prices during hours of peak production of variable renewable sources tend to be lower than average market prices. While this effect is already visible today in certain Member States[72], it is expected to become even more relevant as renewables penetration further increases[73]. As an order of magnitude, recent research suggests that, in the absence of hydro reservoirs and demand response, when its market share will reach 30% of total generation on a given market, the revenues that a wind plant can get through the market could fall to only 50% to 80% of the average market price. These factors may be reached by solar power when it reaches only 15% of total generation[74]. This is a market indication of the changes in market values of renewables as they are deployed. As renewables are further gaining market shares in the coming decade, the regulatory framework should not only incentivise the deployment of renewables where costs are low (*e.g.* due to abundant wind or solar resources), but also where the value of the produced electricity is the highest.

The Commission's ambition for the post 2020 context is that renewable electricity generators can earn an increasing fraction of their revenues from the energy markets based on an enhanced market design – where short term markets are fully developed and integrated and flexibility plays a key role in enhancing the market value of renewables – and a strengthened EU ETS.

The incentive provided by the ETS has been limited in recent years due to the large surplus of allowances on the market, resulting from the imbalance between supply and

[70] The inherent variability of wind exposure and solar radiation affects the price that variable renewable electricity generators receive on the market (market value). During windy and sunny days the additional electricity supply reduces the prices. Because the drop is larger with more installed capacity, the market value of variable renewable electricity falls with higher penetration rate, translating into a gap to the average market value of all electricity generators over a given period (See Hirth, Lion, "The Market Value of Variable Renewables", Energy Policy, Volume 38, 2013, p. 218-236).

[71] Also as a consequence of the priority dispatch of renewables

[72] Lion, Hirth, "The Market Value of Variable Renewables", 2013

[73] On the other hand, solar PV in particular helped to stabilize or even decrease daytime peak prices in countries with high air-conditioning load, or autumn prices in wind-rich countries

[74] Lion, Hirth, "The Market Value of Variable Renewables", 2013

demand for allowances. A large surplus confounds the signal for investments, which are necessary for the transition towards a low-carbon economy, including energy supply. Additionally, the current behaviour of many investors on power generation markets seems to be driven by myopia looking primarily at current price levels. Overall, even though the ETS carbon price can be expected to increase as scarcity in the carbon market will resume, in the short term prevailing myopic views and the uncertainty on long term CO_2 price development may remain an impediment for investors to fully factor in future prices in investment decisions.

This imbalance between supply and credit of allowances resulted from several economic and policy factors, such as the reduction in emissions following the economic crisis and the higher use of international credits than was expected. At the same time, specific support for renewables has shown to be a strong driver for investment, and, for a given CO_2 cap in the ETS, a fast deployment of renewable electricity can contribute (among other factors) to a lower carbon price by weakening the demand for emission allowances in the EU ETS. In view of such potential impacts, various stakeholders have recently argued that there is a need to ensure that adjustments can be made in the ETS to address the full impact of general economic conditions as well as overlapping EU and national policies on the ETS price[75].

The strengthened and revised EU ETS, with a functioning Market Stability Reserve (MSR), will play an increasing role in providing a stronger investment signal for lower carbon technologies including renewables, and will ensure that synergies between renewable energy and climate policies are better reaped. However, such impact will only build up gradually.

From 2019, the introduction of a MSR will respond to major changes in the demand of allowances, regardless of whether these are the result of economic factors or due to policy developments. The architecture of the reserve is such that it automatically and in a gradual manner reduces the auction supply if there is a significant oversupply of allowances. However, as the reduction realised by the MSR will be gradual, if, for any reason (including a fast deployment of renewable electricity), the existing imbalance between supply and demand would not be reduced, it might need to be considered as part of the first review of the MSR parameters foreseen by 2021 whether this justifies a change to the parameters (*e.g.* an increased MSR feeding rate) to preserve the overall policy coherence in delivering the climate objective in a cost effective manner, as agreed by European leaders.

The ETS will provide an increasingly stronger investment signal as the scarcity in the carbon market will gradually resume and a reformed energy only market would support the integration of renewables, but ETS may in itself not ensure that all necessary investments in renewables would occur, in particular for certain non-mature technologies.

Overall, a number of elements, normally beyond the control of renewables producers, will determine the moment when "RES parity" is achieved – *i.e.* the moment when the levelised cost of electricity (LCOE) decreases to the level of the actual market value of the asset to be financed. Such conditions include: (i) continued decrease in technology costs; (ii) the availability of (reasonably cheap) capital, which is a function of many

[75] For example, see Eurelectric, Reform of the EU ETS, May 2016 http://www.eurelectric.org/media/278460/20160531_statement_on_eu_ets_reform_final-2016-030-0299-01-e.pdf

variables, including project-specific and renewables framework-specific risks, but also general country risks; (iii) social acceptance (which could impact the availability of high potential locations); (iv) sufficiently high and stable fossil fuel prices.

Additionally, the "RES parity" moment will depend on the extent to which and the speed at which the market re-design and the reformed ETS deliver on: (i) addressing the current surplus of carbon allowances that would strengthen the carbon price signal; (ii) reducing the occurrence of low or negative market prices; (iii) reducing balancing costs for renewables producers; (iv) bringing additional revenues to renewables producers in balancing and ancillary services markets; (v) ensuring a timely and sufficient deployment of all sources of flexibility limiting the renewables "cannibalisation effect"; (vi) any electricity over-capacity effectively exiting the market; (vii) renewables market integration not translating in a substantial upward pressure on renewables projects' access to and cost of capital.

Until these conditions are in place, a funding gap for investments in renewables will remain, as evidenced by both the Market Design and this Impact Assessment, and is dependent also on future price expectations that may be uncertain. This is the starting point of the this Impact Assessment, which then will consider the best way of addressing investment uncertainty against this funding gap.

Driver 2: Uncertainty over the post-2020 policy framework for support schemes

Investors, Member States and other stakeholders have called on various occasions for clarity to be provided in the revision of the RES Directive on the future framework for support schemes after 2020 by spelling out framework principles on support schemes that facilitate a Europeanised and market based approach to renewables[76].

The RES Directive allows Member States to opt for support schemes to facilitate renewables deployment and target achievement, but leaves the choice of support scheme design entirely to Member States, reflecting the consensus at time of adoption that there was no one-size-fits-all system. State aid rules set out general requirements until 2020, but for instance do not contain any principles on the design of tenders (apart from the technology-neutrality principle), nor on cross-border co-operation. They also leave an element of regulatory uncertainty as assessment is done on a case-by-case basis after a state aid scheme has been put in place.

Support for renewable energy may conflict with system-friendly and market-responsive dispatch, investment decisions and technological designs – in particular through insufficient exposure to market price signals that, together with an adequate definition of bidding zones, reflects the value of generation to the system depending on time and location. The type and level of support needed to promote emergent technologies representing a small share of the power generation mix, such as what was required to promote initial deployments of wind onshore and solar PV in the second half of the last decade, is not justified anymore when such technologies become much more mature and deployment reaches a significant scale. This is all the more true in view of the negative impact this might have on market functioning and investment incentives across power generation markets, including downward pressure on ETS prices.

[76] See, *e.g.* the conclusions of the European Electricity Regulatory Forum, Florence, 13-14 June 2016

Retroactive changes and retrospective moratoria on renewable-related support have taken place in several Member States[77]. These changes took place for several different reasons but often led to uneven fees and subsidies distribution, loss of confidence in the sector, sometimes even bankruptcies and employment losses. This insecurity in the renewables sector and the lack of access to finance for new renewables installations may similarly not only endanger achievement of the binding 2020 national renewable energy target of the respective Member State and the overall renewables target of the EU, but make it more expensive. These measures also resulted in numerous lawsuits at national, European and international level[78].

Several Member States were able to negotiate with investors a deal which diminished the amount of support provided in exchange for regulatory stability, while other Member States made changes that eventually led to a complete stop of any new investment in renewables on their territory, due to the uncertainty they created.

Rules on renewables support finally have to consider the type and nature of all categories of investors.

Renewable energy communities

A specific issue relates to the framework applicable to renewable energy communities. Renewable energy communities are entities through which citizens and/or local authorities own or participate in the production and/or use of renewable energy. With more than 2500 initiatives EU-wide[79], renewable communities have been key in triggering the energy transition in Europe. The local anchorage and ownership of such initiatives have brought substantial benefits in terms of social acceptance for renewable energy projects, especially for wind energy[80]. They have contributed not only to increasing renewable shares and to reaching the targets, but also to lowering the cost of renewable energy deployment by making available the most adequate sites and providing access to cheap capital.

In Germany for instance, where 50% of the renewable power capacity is owned by private individuals[81], the levelized cost of electrical capacity owned by energy communities and farmers is competitive with utility-owned renewables.

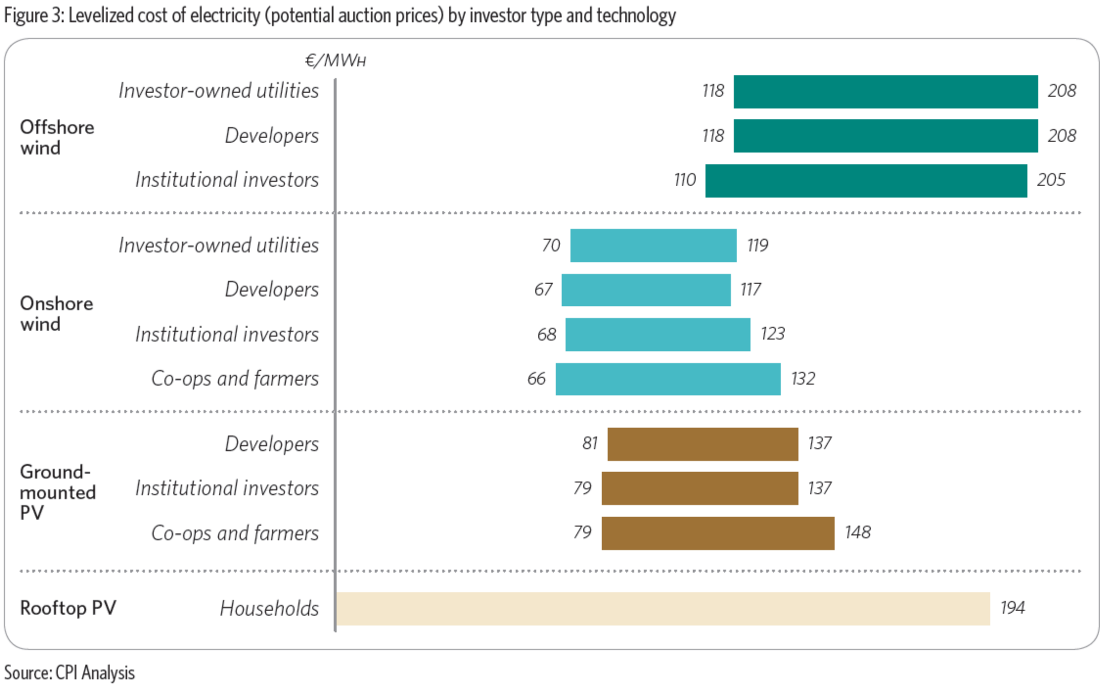
[77] *E.g.* Bulgaria, Czech Republic, Estonia, Greece, Italy, Poland, Spain and the UK, Retroactive and retrospective changes and moratoria to RES support, Keep on Track!, 2015

[78] Retroactive and retrospective changes and moratoria to RES support, Keep on Track!, 2013

[79] *Foster social acceptance of RES by Stakeholder engagement*, ResCoop202020, 2015

[80] *Inter alia*, *Local acceptance of wind energy: Factors of success identified in French and German case studies*, Jober et ali, 2007; *Public acceptance of renewable energies: Results from case studies in Germany*, Jan Zoellner et ali, 2008; *What drives the development of community energy in Europe*, Thomas Bauwen et al., 2015

[81] German Renewable Energy Agency, based on trend: research study, 2013. 2012 figure



[82]

Figure 4: LCOE by investor type and technology

Currently, most renewables communities remain small-scale, either in terms of numbers of projects, members, turnover or capacity installed. This leads to specific issues, such as difficulties to face grid connection costs, especially for non-shallow costs[83]. In addition, some specific elements of support schemes design such as tendering support might create some barriers to the development of community-owned energy, and therefore reduce local acceptance of projects[84]. There is even a downwards tendency in the share of community-owned renewable energy in the system, mostly due to competitive tendering process where community schemes have difficulties in competing on equal footing with other projects[85].

This has been confirmed by the results of the public consultation where 31% of respondents agreed upon the fact that support schemes, levies and/or administrative procedures should be adapted to the size of local projects and access to finance facilitated to enable cooperatives to compete on equal footing with other projects in the market. This analysis was mostly shared by cooperatives (91%), NGOs (69%) and public authorities (43%).

<u>Driver 3: Uncertainty around individual Member States' contributions to the EU level renewables target and future governance</u>

Whilst currently national targets provide a clear indication on each Member State's development, it is unclear how the collective effort for post 2020 will be shared among

82 Policy and investment in German renewable energy, CPI, 2016
83 *E.g.* in UK, "Renewable Energy Progress Report", Öko Institute [to be published]
84 *Community Wind Perspectives from North-Rhine Westphalia and the World*, WWEA, 2016
85 The potentially negative influence of such processes have been underlined *e.g.* in the WWEA report Headwind and Tailwind for Community Power, 2016

Member States. The absence of binding national renewable energy targets as a policy tool in a post-2020 timeframe requires the exploration of other policy avenues to ensure an adequate ambition and distribution of Member States' efforts to contribute to the EU-level target of at least 27% renewable energy in 2030. Also detailed rules for the governance set up between the EU and Member States and monitoring are still being defined (the latter in the parallel Governance IA).

The general approach is that governance provides the framework for planning and monitoring the development of renewable energy, whilst corrective measures if required would be part of the Revised RES Directive, which is a simple approach applied with other aspects of climate and energy policy such as the Effort Sharing Regulation and the Energy Efficiency Directive. The interaction between the governance process and the Revised RES Directive and the specific issues to be addressed are further explained in Chapter 5.

Driver 4: Uncertainty regarding the sustainability rules applying to biofuels, including the role of food-based biofuels post-2020

As both the REFIT evaluation and the public consultation demonstrates, the policy discussion on Indirect Land Use Change (ILUC) associated to food-based biofuels and the prolonged adoption process of the ILUC Directive have negatively affected investments in biofuels, including in advanced biofuels. There is now a need to provide regulatory certainty and predictability concerning the role of food-based and advanced biofuels in general and, specifically, regarding the sustainability rules applying to bioenergy post-2020, including the role of conventional biofuels (see more below).

Regarding the sustainability rules, there is a need to improve the sustainability criteria and the traceability rules in order to improve their effectiveness. In this respect, the European Court of Auditors found in an audit[86] that the way biofuel sustainability is currently verified entails weaknesses for instance regarding the supervision of voluntary certification schemes. The competences of the Commission and the Member States in this area are not set out clearly in current legislation. Furthermore, some provisions of the sustainability scheme and the traceability rules have proven to be difficult to implement and may need to be improved in a view to facilitate their implementation.

Driver 5: Uncertainty regarding actions in the heating and cooling sector

Even if the situation is quite homogenous at EU-level, with 18 Member States having heating and cooling shares representing more than 40% of total energy, there is currently an absence of promotion of heating and cooling measures across the sector in EU legislation, contrary to electricity and transport. In the absence of additional and coordinated policies, the current slow rate of progress in Member States is incompatible

[86] http://www.eca.europa.eu/Lists/ECADocuments/INSR16_18/INSR_BIOFUELS_EN.pdf

with a cost-effective achievement of the EU renewable energy target by 2030[87] and long-term decarbonisation goals[88].

From the analysis of the public consultation, lack of integrated energy strategy and planning at the national and local level, lack of targeted financing and lack of supportive policies for decentralised energy, self-consumption and thermal storage in buildings and district systems are perceived as the three most important barriers to renewables expansion in the heating and cooling sector (respectively, mentioned in 84%, 80% and 74% of the public consultation replies).

2.2.2. Problem 2 - Need to improve cost-effectiveness of deployment of renewable energy

The importance of a transition towards fully-market based and self-eliminating support of renewables has already been addressed in the previous chapter. In addition to that, there remain substantial benefits to be reaped by adapting the way in which renewables are currently deployed in the EU.

Driver 1: Projected contribution of heating and cooling and transport sector not in line with cost-effective decarbonisation path

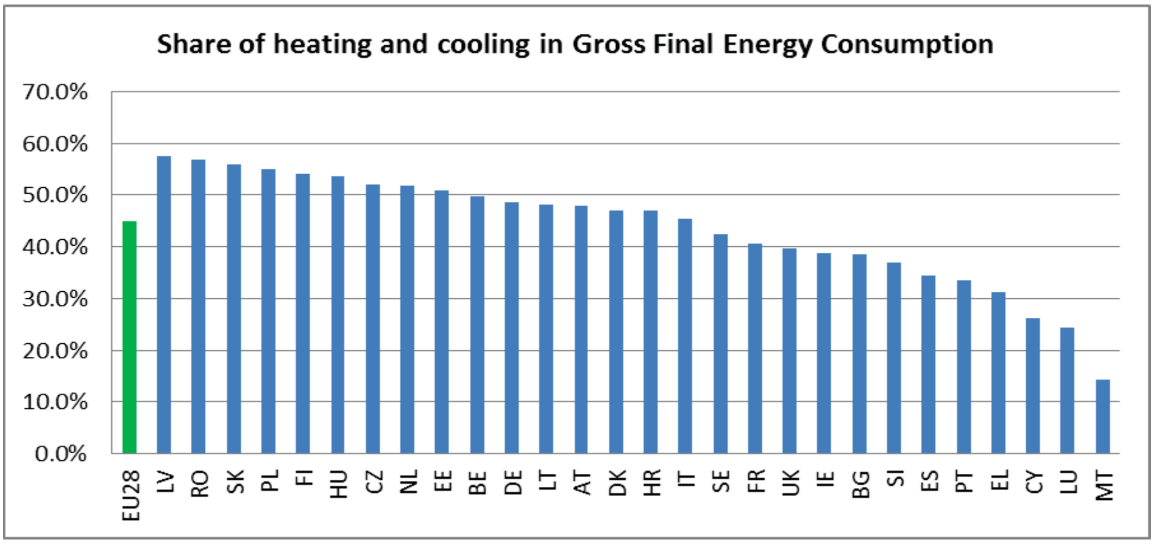
Renewable technologies are being deployed across the three sectors - electricity, heating and cooling, and transport. Over the past decade, a lot of emphasis was put on the development of reneable electricity, possibly driven *inter alia* by the parallel efforts to open up EU's electricity markets. The 2030 and 2050 decarbonisations scenarios require however also accelerated reneables deployment in heating and cooling, and transport.

Heating & cooling

In the REF2016, renewable heating and cooling shares fall 2.3% points short of what would be needed for an overall cost effective path to 2030. Heating and cooling currently represents the most important single energy sector in the EU, with around half of the European energy demand. As explained in Section 2.2.1, there is currently an absence of promotion of heating and cooling measures across the sector in EU legislation, contrary to electricity and transport.

[87] In absence of additional policies, the EU would only reach 24.7% renewable energy share in the heating and cooling by 2030, and due to the size of the heating and cooling sector in the overall energy consumption, and combined with absence of additional policies in other related climate and energy fields, that would result in only 24,3% overall share of renewables in 2030 – source : PRIMES REF2016.

[88] Between 2015 and 2050, the GHG intensity of the residential and tertiary sectors should by divided by 4, and the renewable energy share in heating and cooling should reach 41.6% - source : PRIMES EUCO27



Therefore, while the share of renewable energy in electricity has increased by more than 8 percentage points (pp) between 2009 and 2015, the share of renewables in the heating and cooling sector has only expanded by less than 3 pp in the same period[89]. In the absence of additional and coordinated policies, the current slow rate of progress in Member States is incompatible with a cost-effective achievement of the EU renewable energy target by 2030[90] and long-term decarbonisation goals[91]. In the absence of additional policies in heating and cooling, there might also be a risk that the entire burden would be transferred to the electricity and the transport sectors, which might jeopardize the cost-effective achievement of our 2030 target.

Transport

Energy efficiency, electrification and the use of renewable energy in transports have all been identified as important elements in order to contribute towards the reduction of the EU oil import dependency and of transport decarbonisation in a cost-effective manner[92].

89 EUROSTAT, and "Renewable Energy Progress Report", Öko Institute [to be published], draft preliminary result

90 In absence of additional policies, the EU would only reach 24.7% renewable energy share in the heating and cooling by 2030, and due to the size of the heating and cooling sector in the overall energy consumption, and combined with absence of additional policies in other related climate and energy fields, that would result in only 24,3% overall share of renewables in 2030 – source : PRIMES Ref2016

91 Between 2015 and 2050, the GHG intensity of the residential and tertiary sectors would be divided by 4, and the renewable energy share in heating and cooling would reach 41.6% - source : PRIMES EUCO27

92 . Transport continues to rely nearly entirely on oil and oil products. Gasoline and diesel consumption makes up for 94% of energy use in road transport. Diesel accounts for almost the entirety of the commercial fleet, and a growing proportion of private cars. Maritime and aviation continue to rely entirely on fuel oil and kerosene, whereas in rail some further electrification has taken place in the last decade. Europe imports 87% of its crude oil from abroad, and its crude oil import bill is estimated at around €187 billion in 2015. This makes transport, and hence the wider economy of Europe, very reliant on the availability of oil and petroleum products on world markets. Road transport sector is not covered by the EU Emission Trading Scheme. The Energy Taxation Directive (ETD) stipulates minimum rates for excise duties for unleaded petrol of €359 per 1000 litres and €330 per 1000 litres for diesel (gasoil) used in transport. Excise duty rates differ between Member States. In 2011, the European Commission proposed a revision of the Energy Taxation Directive, which distinguished a CO2-related component and an energy-related component in the excise duty. Applying this principle would have implied a minimum rate on

Modelling looking at options to achieve the 2030 climate and energy targets[93] indicates the share of biofuels in transports is projected to increase up to 7.8%[94] of total transport energy demand by 2030 (from 3.7% in 2010). Beyond 2030, modelling suggests the share of biofuels in liquid and gaseous transport fuels will need to increase significantly further, reaching around 46% by 2050 (equal to 36-37% of total transport energy demand). This also requires substitution of food-based biofuels by advanced biofuels with low effects on indirect land use change (ILUC) emissions. In particular, advanced biofuels are required to decarbonize the heavy duty, waterborne transport and aviation sectors that cannot be electrified with current technologies[95].

Respective contributions from the various sectors

As described under the EUCO27 scenario[96], the challenge for the renewable energy sector is to increase the share of renewables in all the RES-E, RES H&C and RES-T sectors, compared to 2020 levels. Compared to projected developments under the REF2016, the increased use of renewables in the electricity sector would be substantial contribution to the overall increase in renewables. Contributions from the heating and cooling and transport sectors would also be necessary in absolute terms, and are will have to take place in the context of significant reductions in final consumption in these sectors, mainly driven by improved energy efficiency. These reductions imply that increases in RES-H&C and RES-T shares will not only come from additional assets (as is partly the case for RES-E), but also from replacement of incumbent technologies that will be pushed out of their respective markets through a mix of demand reduction and fuel-switching.

In terms of evolution of energy consumption (Mtoe), this shows that: i) it is in the electricity sector that renewables consumption is projected to increase the most in absolute terms; ii) in the heating and cooling and transport sectors, in the context of an overall significant decrease in final consumption, an increase in renewables is still needed in absolute terms to reach the at least 27% target; iii) in the transport sector, the evolution presented in the table below also reflects the formula used to measure renewable energy consumption in transport, including double counting for renewable electricity for instance.

Evolution of gross final energy	REF2016	EUCO27	Diff EUCO27/ REF

diesel of €390 if the minimum rate on petrol would have been €359 per 1000 litres. The analysis accompanying this Commission proposal showed that CO2-based taxation drives consumption away from fossil energy sources. However, in 2014 the European Commission decided to withdraw its proposed revision of the Energy Taxation Directive, given that the draft compromise text was de facto void of all constituting elements of the original Commission proposal. This shows the difficulties in moving forward on taxation issues which require unanimity in the European Council

93 See scenarios analysed in SWD underpinning the European strategy for low-emission mobility; SWD (2016) 244 final

94 All shares in this paragraph are without double-counting as currently applied for RES-T calculations

95 These sectors are relying on diesel, kerosene and heavy fuel oil. Electrification of these transport modes does not seem feasible unless a major breakthrough in battery technology is achieved.

96 EUCO27 is a central policy scenario used in all Impact Assessments referred to in section 1.2 and projects energy system developments when reaching the relevant 2030 climate and energy targets. It provides an indication of the projected determinants of the changes in renewable energy necessary to reach the 27% target

consumption (total and for renewables) across sectors - Mtoe	2020	2030	Diff	2020	2030	Diff	2030
Gross Final Energy Consumption - Electricity	289	302	+13	290	302	+12	-0.4
Gross final consumption of electricity from RES	103	128	**+25**	103	143	**+40**	+15
Gross Final Energy Consumption - Heating and Cooling	540	485	-55	541	454	-87	-31
Gross final consumption of RES for heating and cooling	123	124	**+1**	124	128	**+4**	+4
Gross Final Energy Consumption - Transport	287	274	-13	287	256	-31	-18
Final consumption of energy from RES in transport	32	39	**+7**	32	46	**+14**	+7

Source: PRIMES

To conclude, this short descriptive analysis confirms that all renewable energy sectors are expected to contribute to the increased use of renewables by 2030, but in a differentiated manner, as this contribution is also influenced by the projected evolution of final energy demand.

Driver 2: RES-E support not fully responsive to different technology potential and maturity

Renewable technologies and potentials vary significantly. Ignoring these differences - *e.g.* by applying a strict technology-neutral approach - might result in either underinvestment or overcompensation.

Certain long-established (*e.g.* biomass co-firing) or fast-growing (*e.g.* onshore wind, solar photovoltaic) renewable electricity technologies have now reached a considerable share of market thanks to the inductive regulatory framework. They may be considered as technologically mature according to certain metrics, for instance being broadly commercially available and their share of total installed capacity[97]. It might however be sub-optimal for other reasons such as the energy system as a whole or land use concerns to only have these technologies as the winning tender.

Other renewable technologies, like offshore wind and concentrated solar power, are increasing their market share, or are still in an earlier stage of the innovation chain, like tidal stream energy, ocean wave energy, deep geothermal, highly performing advanced PV and building-integrated PV. The same applies to most technologies capable of storing electric power. As these technologies have the potential, in a medium- to long-term perspective, to largely contribute to a decarbonised, secure and cost-efficient energy system, the combination of public support (in line with the priorities identified in the

[97] According to Eurostat (May 2015), hydropower represented in 2013 15.7% of the total installed electricity capacity in the EU and 12.3% of total electricity generation in the EU. These figures were respectively 12.3% and 7.2% for wind and 8.3% and 2.6% for solar PV.

SET Plan and coordinated with the Member States' support) and private support is geared towards bridging the cost gap and pushing further technological and system innovation in Europe. The new renewable support framework will need to ensure that less mature technologies can continue their path towards market integration without abrupt stops.

Driver 3: RES-E support not fully responsive to different potentials across Member States/regions

There are clear benefits to be reaped from a more regional approach to renewables support.

Energy systems, and electricity systems in particular, were historically built on a national or even sub-national basis. From an infrastructure point of view, this has translated into limited interconnections between, or within, Member States. Insufficient transmission grid capacities limit the flexibility of energy systems, and hinder further renewable penetration. From an institutional and political point of view, this is one of the reasons that have contributed to policies supporting renewables being largely developed on a national basis. Financial support for renewable generation, in particular, has taken the form of national support schemes. This has led to a situation where renewables are deployed where support is the strongest and the most secure, rather than where the most cost-effective potential from an EU perspective is available. What is more, the fragmentation of markets leads to higher transaction costs, as developers and investors have to apply substantially different models for investments across Europe and build the related capacity.

The cooperation mechanisms introduced by the RES Directive allowed Member States to agree on cross-border support of renewables and to take advantage of another country's more cost-efficient potentials in renewables and achieve efficiency gains in view of their renewable energy targets. However, Member States have so far not engaged in joint support schemes with the exception of Norway and Sweden. This is due to a number of reasons ranging from administrative complexities (regarded as important or very important by 74% of respondents in the public consultation[98]) to political considerations, such as Member State reluctance to see their taxpayers money used for investments outside their country (94% - by far the most important consideration mentioned in the RES Directive public consultation[99]). In particular, it is especially difficult to ask consumers to support renewables deployment in a different country when they do not see a direct benefit out of it.

The opportunity given by the RES Directive of sharing the effort of the renewable energy targets more cost-effectively was, therefore, as of the time of this Impact Assessment, not yet utilised, despite ongoing negotiations between several Member States[100] and declared intentions to finalise these negotiations in 2016 and 2017.

However, a number of Member States are in the process of partially opening up their support schemes to cross-border participation[101]. Within the context of a reformed market design, a more interconnected and integrated electricity market, all of which are important components for the further deployment of renewables, the renewables policy

[98] By those respondents who expressed an opinion on the question
[99] By those respondents who expressed an opinion on the question
[100] Such as, for instance, Lithuania, Luxembourg and Portugal
[101] *E.g.*, Germany and Denmark

framework should facilitate a more cost-effective deployment of renewable electricity across the EU. This process of regionalisation of renewable policy is further underpinned by the political dialogue of Member States at regional level through, *inter alia*, the High Level Groups such as BEMIP and North Seas.

<u>Driver 4: Differences in cost of capital, national approaches to grid connection fees and administrative procedures undermine optimal RES-E allocation across EU</u>

There are significant benefits to be reaped from reducing national differences with regard to rules beyond support schemes affecting overall project cost, in the case of renewables mainly cost of capital, grid connection fees and administrative procedures. These differences can effectively undermine joint support schemes as was shown for the example of the NO-SE joint scheme in the evaluation. Addressing them for renewables specifically could be justified given the technologies' capital-intensity and linked higher risk premiums.

Cost of capital

Renewable electricity technologies face a number of factors that may make it hard for them to attract sufficient and affordable funding from investors, including but not limited to: capital intensity, resource risk, real or perceived technology risk, under-recognition of the long-term value of reducing variable fuel cost exposure. In the absence of perfect foresight (leading to myopic requirements for short term returns) and/or the presence of poor or asymmetric information or understanding (leading to overestimation of risks), renewables typically only have access to scarcer and/or more expensive capital than more conventional energy technologies. Such failures can apply to both large-scale and small-scale investors (*e.g.* households).

Additionally, in the post-2020 context with high shares of renewables and deeper market integration, renewables should be increasingly integrated into the market and face obligations similar to those of conventional generators. This entails additional costs and risks for renewables investors (balancing costs, market price volatility), as these costs have so far been transferred to other entities, which translate into higher cost of capital, higher LCOE for the individual investor, and higher renewables deployment costs – all elements to be taken into account when assessing the benefits of better market functioning[102].

Only in a limited number of Member States some of the most mature renewables technologies have today access to capital at a cost that is comparable to that of more conventional technologies, although investments conditions for fossil fuel power plants have also been affected by higher operating costs and combined effect of low carbon and low wholesale electricity prices[103]. Funding remains limited and/or costly for mature technologies in many Member States as well as for a number of less-mature technologies. As way of illustration, recent research[104] estimated that the weighted average cost of capital (WACC) of a typical onshore wind project varied in 2015 from 3.5% to 12%

102 See the Market Design Initiative Impact Assessment
103 World Energy Investment Outlook, 2014
104 The impact of risks in renewable investments and the role of smart policies, Diacore, 2016

depending on Member States[105]. Given the capital-intensity of most renewable technologies, a higher WACC significantly increases the overall cost of a given renewable project.

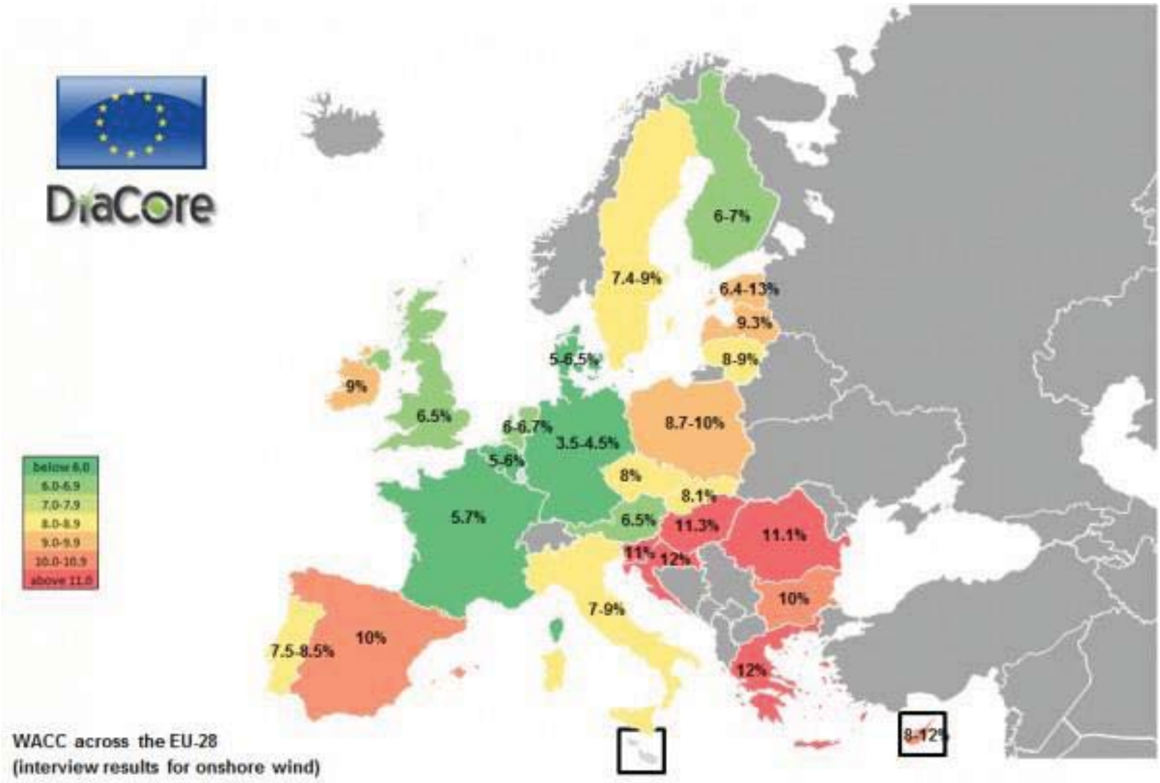


Figure 5: Diacore

Additionally, it should be noted that significant variations in the level of WACC across Europe may hamper the deployment of renewables in the EU where the economic potential is otherwise the highest. A mere 1% WACC difference can increase the total cost of the project by 5%.

Finance also typically remains scarce for the fragmented, smaller-scale renewable projects, which face high transaction costs relative to the amount of funding required – in addition to often facing split incentives between tenants and owners.

The estimation of the required amount of capital expenditure in RES-E capacity to reach European targets varies a lot depending on the source and scope of the research[106]. For instance, Bloomberg New Energy Finance estimates investments in new renewables electricity generation capacity to amount to USD 1.0 trillion over 2015 to 2030 (around EUR 57 billion per year)[107], while the World Energy Investment Outlook concludes that

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105 In addition to the generic country risk, other factors affecting the difference in WACC across the EU are the policy-induced risk, hence the design and the reliability of renewable energy support, the administrative costs, the grid connection costs, etc.

106 Most of the researches have a broad scope, providing insight in the total costs of decarbonising the energy sector, including both investments in renewables, and investments in the necessary expansion and reinvestments in grid infrastructure and potential back-up facilities.

107 Source: Bloomberg New Energy Finance (2014). 2030 Market Outlook

roughly USD 1.2 trillion is required in the EU between 2014 and 2035 (around EUR 52 billion per year)[108].

Currently, there are no EU-level facilities dedicated to providing debt or equity financing to renewables generation projects only. The EU budget is supporting certain demonstration projects of new technologies under the Secure, Clean and Efficient Energy Challenge of Horizon 2020[109]. European Structural and Investment Funds (ESIF) have a strong focus on low-carbon investments in the 2014-2020 period, including support for renewable energy projects and related research and innovation, which can take the form of grants or financial instruments (*e.g.* loans, guarantees or equity). Additionally, the NER300, funded through the sale of 300 million emission allowances from the ETS, is a funding programme for the development of innovative low carbon energy demonstration projects, including innovative RES technologies in the EU[110]. For the period after 2020, an Innovation Fund would be set up through the sale of 450 million emission allowances that could fund innovative RES projects[111]. The EU is also indirectly investing in renewable generation projects via facilities such as the Marguerite Fund and the European Energy Efficiency Fund. Finally, the European Investment Bank (EIB) is providing debt and equity for renewable energy generation and grid projects, across all Member States – and the European Fund for Strategic Investments (EFSI) is providing the EIB with additional risk-bearing capacity[112].

Public support in the form of debt or equity support is mostly taking place at national or sub-national level. Some Member States have developed specific renewables financing programmes, often through their National Promotional Banks (NPBs)..

Existing funds such as the Marguerite Fund and the European Energy Efficiency Fund currently have their investment strategy defined not only by the EU, but also by their other sponsors (national public banks or private investors). EIB's renewables investments are driven by the EIB's sectorial strategies and credit policies. As for the EFSI guarantee, while renewable projects have to date represented a large share of total EFSI funding, its use is governed by the overall economic recovery-focused objectives of the EFSI; importantly, the EFSI is currently not foreseen to exist post-2020.

Costs related to administrative procedures

Administrative costs vary between Member States but non-economic barriers can be costly. They currently account for around 15% of the overall development costs of wind projects in the Member State analysed[113]. Administrative barriers[114] bring uncertainty and delay to investors, artificially increase the costs of renewable energy projects, create distortions in the allocation of investments within the EU, and therefore hamper building a single integrated market for renewable energy and reaching a cost-effective deployment. Given that the Revised RES Directive will not feature binding national

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108 Source: International Energy Agency (2014). World Energy Investment Outlook. See http://www.iea.org/publications/freepublications/publication/weio2014.pdf

109 C(2016)1349 of 9 March 2016

110 http://ec.europa.eu/clima/policies/lowcarbon/ner300/index_en.htm

111 http://ec.europa.eu/clima/policies/ets/revision/index_en.htm

112 The EIB is also managing with the Commission the "NER 300" programme for innovative low-carbon energy demonstration projects

113 “Renewable Energy Progress Report”, Öko Institute [to be published]

114 *E.g.* lengthy administrative procedures, complex licensing procedures, fragmented or unclear responsibilities, institutional overlaps, etc

targets but only a binding European target, enablers for a cost-effective deployment of renewables also at national level become more relevant.

Article 13 of RES Directive mandates streamlining, expediting and coordinating administrative procedures but more progress in the EU needs to be made. There is overwhelming support for a further reduction of administrative barriers among stakeholders. 79 % of respondents to the public consultation who expressed an opinion on the issue identified the creation of a one stop shop as the centrepiece of this simplification and 85% are in favour of fixed time limits. The REFIT Evaluation of the RES Directive found that depending on the Member State, region or technology, issuing of renewables permits can take from less than 5 weeks in one Member State to 7 years in other Member States[115]

Additionally, the current Article 13 of the RES Directive does not take into account the repowering of existing projects, which will become of key importance in the next decade, especially for wind power. As 76 GW of today’s 142GW installed capacity will need repowering between 2020 and 2030, repowering can offer a cost-effective solution and its facilitation could be sensible.

On the other hand, stakeholders' responses to the public consultation and the REFIT evaluations of both the RES Directive and the energy acquis emphasised the positive role played by the national plans for ensuring investment certainty and target achievement and the administrative cost reduction achieved by having a binding uniform template for renewables planning.

Differences in grid connection charges

Other costs applicable to renewables generators, in particular grid connection fees, may lead to investment distortions. Some Member States apply a "deep" model, where the renewables generator bears the costs of grid connection, grid reinforcement and extension. Other Member States apply a "shallow" model, where the generator only bears the costs of grid connection, while grid reinforcement and extension are built into the grid tariffs (and thus paid in the end by customers). Such differences have an impact on the costs of the projects and increase the distortion in allocation of investments across the EU. This issue will be addressed in the market design Impact Assessment.

2.2.3. Problem 3 - Absence of functioning markets

Well-functioning internal energy markets are crucial for the deployment of renewables. However, markets in the electricity, transport and heating and cooling sectors are at different phases and require different measures to ensure their functioning.

In the case of the electricity sector, where renewables are expected to reach around 50% market penetration, the market is being redesigned to support the integration of renewables. In the heating and cooling market, the challenge is to ensure access and sufficient incentives for the expansion of renewables. In some of the segments of the transport sector, new markets for renewable fuels have to be created.

Heat markets are inherently local, but across the EU are not fully functional due to the following main drivers.

[115] REFIT evaluation of the RES Directive

Driver 1: External costs of competing technologies not properly internalised

Heating & cooling

The negative externalities of the fossil fuel use in the heating and cooling sector[116] are not internalised and reflected in the energy prices for most parts of the heating and cooling sector, which hinders market uptake of highly efficient renewable energy technologies at centralised (district heating) and decentralised (building) level. When the vast majority of individual heating is based on fossil-fuel solutions, out of which more than 40% on gas only, renewable alternatives are not able to compete on equal footing with existing solutions, which often leads to technology lock-in at individual level. The market, as currently designed, does not provide sufficient incentives for fuel-switching and therefore hampers the fulfilment of the objectives above.

Transport

Road transport sector is not covered by the EU Emission Trading Scheme. The Energy Taxation Directive stipulates minimum rates for excise duties for unleaded petrol of €359 per 1000 litres and €330 per 1000 litres for diesel (gasoil) used in transport. Excise duty rates differ between Member States[117]. In 2011, the European Commission proposed a revision of the Energy Taxation Directive, which distinguished a CO2-related component and an energy-related component in the excise duty. Applying this principle would have implied a minimum rate on diesel of €390 if the minimum rate on petrol would have been €359 per 1000 litres, in addition Member States would have been asked to mirror the Commission's minima in their national rates. The analysis accompanying this Commission proposal showed that CO2-based taxation drives consumption away from fossil energy sources. However, in 2015 the European Commission decided to withdraw its proposed revision of the Energy Taxation Directive, given that the draft compromise text was *de facto* void of all constituting elements of the original Commission proposal. This shows the difficulties in moving forward on relatedissues which require unanimity in the European Council.

Driver 2: Transition towards renewables can in many occasions only be done at sector/system level

Heating & cooling

The lack of an EU-wide strategy has led to very fragmented local markets, where consumers have difficulties in making choices based on their preferences and lack of regulatory policies creating incentives for decentralised energy, self-consumption and thermal storage in buildings and district systems.

At EU-level, natural gas with a share of 45% is by far the most important heating fuel. Other energy carriers are relatively equally distributed: electricity with 12%, heating fuel oil with 12%, biomass with 12%, coal with 9% and district heating with 8%. Less important are ambient heat and waste non-renewables with about 1% and solar energy, waste renewables and geothermal energy, all with below 1%.

116 Such as climate change and air pollution, with environmental and health consequences

117 For petrol, they range from just over the minimum to €766 per 1000 litres in the Netherlands. For diesel actual rates are generally lower and closer to the minimum, the highest rate reaching €674 in the United Kingdom

The picture is a lot more diverse when looking at the heating fuel mix at Member State level (see Figure 6). Member States are sorted according to their total final energy demand for heating and cooling, starting with the largest consumer on the left, *i.e.* Germany. Natural gas is the major energy carrier in many Member States, reaching up to 68% in the United Kingdom, 66% in the Netherlands and 59% in Hungary. Countries with a natural gas share of below 5% are Finland, Sweden (and Norway and Iceland), plus Malta and Cyprus. Poland has an exceptionally high share of coal with 38%, followed by Slovakia (20%) and the Czech Republic (17%). On the other side, in 24 out of 31 countries the share of coal is below 10%.

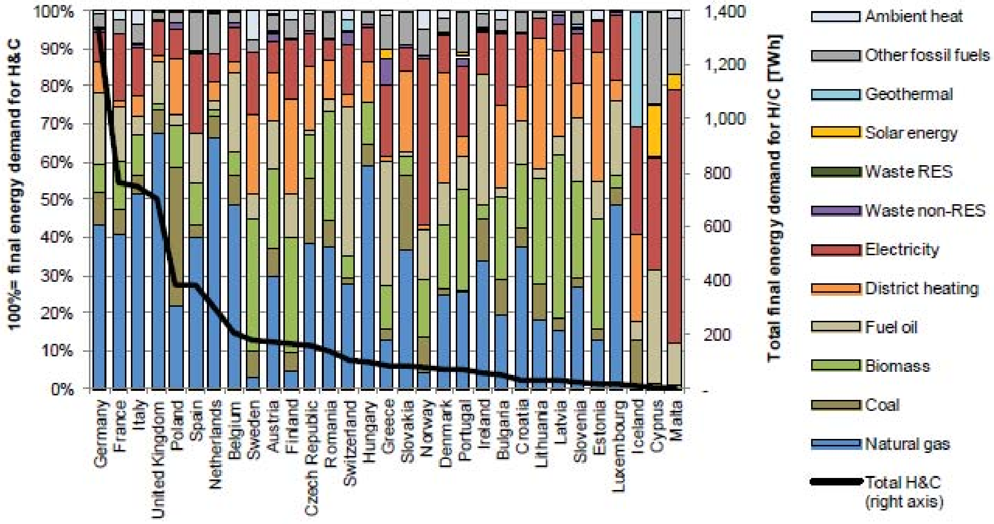

Figure 6: Final energy demand for heating and cooling in the EU28+3 countries by energy carrier in 2012 [TWh][118]

While natural gas suppliers are mostly large-scale and concentrated[119], the European heating oil market is predominantly supplied by around 12,500 small and medium-sized enterprises[120], the coal market being even more heterogeneous[121]. About 10,000 district heating systems were operating across the EU-28 for district heating in 2015[122]. However, since several district heating suppliers run more than one system, the total number of district heating systems represents the upper limit of suppliers in the EU[123].

An EU intervention in this sector might help create an integrated EU market for renewables in heating and cooling, especially for gas suppliers that represent more than 40% of the total supply.

118 Source: Fraunhofer, 2016
119 Fraunhofer, 2016. With exception for DE and IT
120 UPEI, 2015
121 Fraunhofer, 2016
122 Euroheat&Power (2015)
123 For instance in Finland the 400 district heating systems are operated by about 100 district heating suppliers (Energiateollisuus 2014). In Germany in 2014 the nearly 1400 district heating systems were operated by about 550 companies (BMWI 2016). In Lithuania about 50 district heating suppliers (33 municipal companies and 17 undertakings operating on the basis of leasing agreements) were operating about 360 district heating systems in 2013

Transport

Aviation and maritime sectors pose particular challenge as with current state of technology only biokerosene and biomethane are a viable decarbonisation pathway. These two sectors contribute an increasing share to the total transport emissions over time, going up from 19 to 23% during 1990-2014. Direct emissions from aviation account for about 3% of the EU’s total greenhouse gas emissions. Furthermore, international aviation and shipping are the transport sectors where emissions of air pollutants have actually experienced the strongest increase since 1990 (except for SOx and PM from shipping). Since the start of 2012, emissions from all flights from, to and within the European Economic Area (EEA) have been included in the EU Emissions Trading System. These emissions form part of the EU's internal 20% and 40% greenhouse gas (GHG) emission reduction targets for 2020 and 2030 respectively.

The development of alternative and renewable fuels for these two sectors has been hampered by the a) lack of commercial viability of such fossil fuel alternative; coupled with b) over-supply of fossil fuel-powered shipping and aviation in recent years and the related depressed investment market. In aviation, the traditional fuel is a hydrocarbon, almost exclusively obtained from the kerosene fraction of crude oil. Fuel specifications for aviation fuels are also very stringent. In this context, advanced liquid biofuels appear to be the only low carbon option for substituting kerosene, as they have high specific energy content. However, advanced biofuels are today significantly more expensive to produce compared to the cost of kerosene today. An additional challenge in the maritime sector is given by the existence of split incentives between ship owners and operators resulting in limited motivation for deployment of clean energy solutions in this sector.

Driver 3: No incentives for district heating systems to become more efficient and no access rights to the infrastructure for new entrants (including RES)

District heating currently provides around 10% of the EU's heating, with natural gas (40%) and coal (29%) being the main fuels used for district heating, followed by 16% of biomass[124]. However, the share might be substantially higher for single Member States, as illustrated in figure 7.

[124] An EU Strategy on Heating and Cooling, COM (2016) 51/2

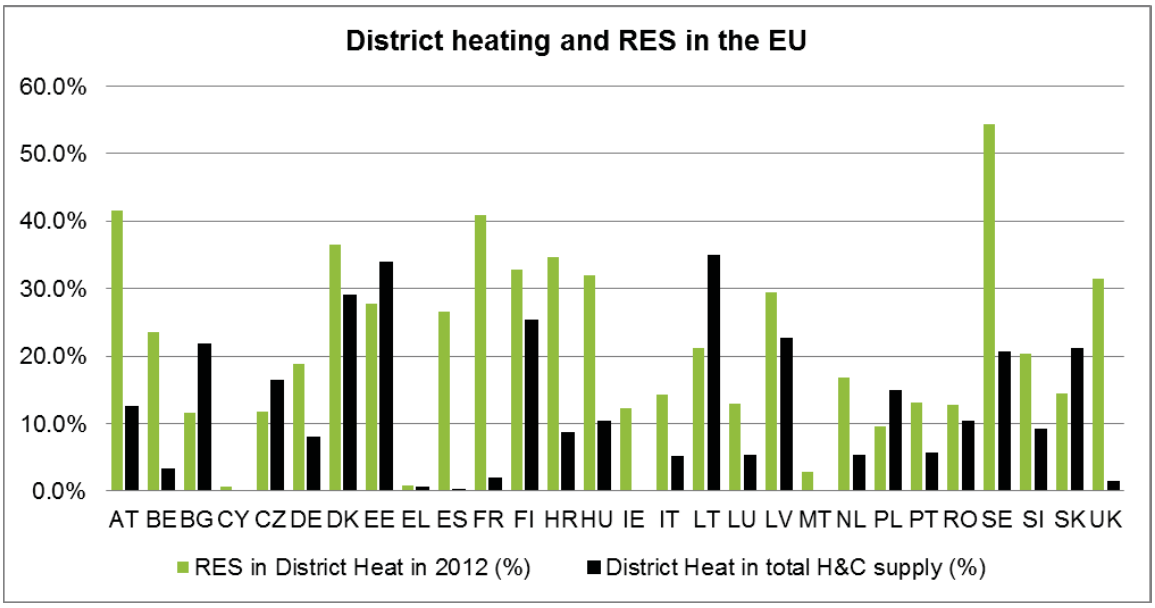

Figure 7: District Heating and renewables in the EU[125]

The EU Strategy for Heating and Cooling clearly identifies the cost reduction potential for the EU energy system, by improving the performance of district heating and cooling systems. According to Fraunhofer ISI et al. (2016), 53% of the total capacity of CHP plants exceeding 1 MW_{th} was installed before 1992; while 26% was installed between 1992-2002; and 21% after 2002. The older district heating and cooling systems must evolve to accommodate the increase of renewable energy supply.

District heating and cooling have also the potential to contribute to balancing the electricity grid. According to Eurostat in 2013, about 72% of district heating and cooling systems were fuelled by combined heat and power plants, which means that most of heating and cooling systems are linked with the electricity network. Measures such as targeted urban planning and integrated heat mapping, which facilitate the move towards an integrated energy system approach and local heat markets, received wide support (88% of stakeholders in the public consultation[126]).

Neither the current RES Directive nor the EED directly empowers consumers to prompt district heating or cooling systems to improve their efficiency and/or increase the use of renewable energies. There is currently also no access for new entrants (including renewables) to the infrastructure in several Member States.

2.2.4. Problem 4 - Need to update the regulatory framework

<u>Driver 1: Current RES Directive built on national targets and to be adjusted to ensure collective RES target attainment</u>

Current legal provisions and monitoring set up were developed for an EU instrument underpinned by national binding targets not in order to equip the Commission with the best tools for facilitating most cost-effective collective attainment.

125 Source: Fraunhofer, 2016. 2012 figures

126 See RES Public consultation results: https://ec.europa.eu/energy/en/consultations/preparation-new-renewable-energy-directive-period-after-2020

The European Council concluded that the European Union needs to achieve at least a 27% share of renewable energy sources and that it will be based on an EU level binding target as opposed to the existing EU and national binding targets in the current framework.

In the absence of binding national targets for renewable energy post-2020, one main challenge is how the at least 27% share in 2030 will be delivered in a cost-effective way through EU, regional and national level actions, taking into account differing national capacities to produce renewable energy, whilst building on the renewable shares achieved in 2020.

In this context, Member States' Integrated National Energy and Climate Plans, to be developed as part of the initiative on Energy Union Governance, will play an important role, as they will include national contributions to the EU-level 2030 target for renewable energy. This part will be addressed by the parallel initiative on Energy Union Governance. However certainty for all Member States the other Member States also deliver with their post cost effective potential can be further enhanced.

Despite the approach taken under the Governance process, an ambition gap might emerge if Member States' collective contributions eventually fell short of the at least 27% target. This is a special issue requiring consideration given the fact that the target is binding at EU level. A similar issue arises in the case of a delivery gap, which would occur if the Member States do not manage to meet their planned national trajectories. The issue of ambition and delivery gaps do not arise under the current legislation that foresees national binding targets. Therefore there is no mechanism in place to avoid such gaps happening. The Energy Union Governance initiative aims, *inter alia*, via an iterative dialogue with Member States, at addressing those issues. However, there is a question on whether additional and specific mechanisms should also be included in the revised RES Directive to complement this work by providing a backstop and to make sure that the target is delivered in a timely manner. Such mechanisms should be key to ensure investors certainty as regards a continued project pipeline and also by providing Member States with the right incentives to contribute appropriately to the EU level binding target.

A specific issue in this overall context concerns the fact that, in the absence of an adequate legal framework, Member States may decide to reduce their efforts to encourage renewable energy from 2021, the year after the end of the binding 2020 requirements. This could jeopardise the collective achievement of the 2030 EU renewable energy target and it also disincentives the use of cooperation mechanisms in the form of projects rather than statistical transfer to meet the 2020 targets. It could also be in contradiction with the European Council conclusions of October 2014 which reconfirmed that the 2020 targets needed to be fully met.

Another question concerns the potential trajectory of efforts to be considered between 2020 and 2030. The RES Directive contains an accelerating, non-linear, trajectory for each Member State and at EU-level for achievement of the 2020 national targets. This implies that greater amounts of renewables need to be produced in the years close to the targets' year, relative to the early years. An accelerating trajectory at EU-level is appropriate in an era where renewable technology is fast developing and significant cost reductions can be anticipated over time. From 2021 to 2030, many renewables technologies will be mature with much smaller potential for significant cost reduction[127] potentially requiring a different approach to define the trajectory.

The options under consideration aim to create together a comprehensive framework for achieving the EU wide at least 27% renewable energy target. A framework that is transparent and which provides positive incentives for Member States to further develop renewables. It seeks to do this in a way that does not involve mandatory national targets for Member States.

Driver 2: Lack of specific RES-transport target post-2020 and uncertainty regarding future demand for alternative fuels (including renewable fuels)

The REFIT evaluation on the RES Directive and the public consultation highlighted that the uncertainty about the policy framework for renewables in transport after 2020 is a significant barrier for future investments in renewable fuels, particularly in capital intensive advanced biofuels. Without a clear and predictable EU policy framework, the required economies of scale and technology learning effects needed to bring technology costs down while ensuring robust GHG savings are unlikely to materialize within the next 15 years.

Key advanced biofuel technologies such as lignocellulose ethanol, synthetic Bio DME, Bio-Methane and pyrolysis oils are ready to be deployed at commercial scale (see box below). The EU has been investing significant funds in research and development of these innovative technologies through Horizon 2020 programme, and its predecessor the 7th Framework Programme for Research and Innovation. This has been complemented by national R&D programmes and private research performed by traditional fuel suppliers and new market entrants. As a result, in 2015 the EU accounted for 9% of global installed capacity of advanced biofuels (130.83 million litres). Current production plants of advanced biofuels are located in Finland, Germany, Italy, Sweden and the Netherlands. This capacity has to develop further and timely for transport to contribute to 2030 targets and 2050 decarbonisation objectives. Timely development at a right scale will enable to lower the costs in the long term.

Box 1: Advanced biofuels – state of play

- *Ethanol from lignocellulosics*: This value chain is the closest to achieving market deployment. There are two main reasons for this: the number of competing technologies and the technology breakthroughs achieved in the last years. However, fragmented fuel markets, lack of technical standards and lack of vehicle fleet for ethanol content higher than 10% hamper the market deployment.
- *Pyrolysis oils*: Pyrolysis oils can be fed directly into a petroleum refinery after some upgrading and be processed with oil, thus eliminating the cost of building a dedicated plant. The first of-a-kind plants have already been developed.
- *Synthetic biofuels:* Synthetic biofuels are still facing technical hurdles. The main reason behind is that the corresponding scale for first-of-a-kind-plants is larger than that of lignocellulosic ethanol (lignocellulosic ethanol plants are economically viable from a capacity range of about 100 to 120 ktons/y while synthetic biofuel plants are economically viable from a capacity range of about 175 to 250 ktons/y). Synthetic biofuels can be used for both road and air transport (*e.g.* jetfuel).

[127] Solar PV cost reduction of 59% , onshore wind 26%, and offshore wind 35% by 2025, The Power to Change: solar and wind cost reduction potential to 2025, IRENA, 2016

- *Biofuels from algae:* Algae technologies are at the early stages of development, however, they are making significant advances[128]. Algae can produce a variety of biofuels and at present algal fuels produced from combined operations with waste water purification, is the preferred route. Such applications are expected to enter the market by 2020.
- *Biofuels from microbial conversion*: This value chain addresses various technologies that are at the early stages of development. However, they are very attractive since they are expected to have better efficiencies than current technologies.
- *Power to gas and power to liquid fuels.* These fuels are currently in the development phase. Fuel production from power to gas (methane) or power to liquid (methanol) is under development for application to heavy duty, maritime transport and aviation fuel[129].

Biofuels and biomethane are the main option for transport decarbonisation but other alternative energies have also role to play. Electrification of transports is, today, mainly taking place in non-road transport, most notably in rail transport. Due to recent technology improvements in batteries, the limited range of battery electric vehicles (BEV) is becoming today less of a constraint to their use. Also a minimum infrastructure coverage is to be provided under Directive 2014/94/EU, and some Member States have ambitious national strategies for the deployment of electric vehicles and dedicated infrastructure for the coming years. However, several barriers need to be addressed in order to enable widespread electrification of road transport, including improvements in battery costs, Vehicle-to-Grid communication, payment issues and broader integration of electric vehicles within the electricity grid.

The use of hydrogen in transport is today almost negligible. Major car manufacturers have announced that fuel cell propelled cars are to be produced at commercial scale in the future and few models are already available now. However, their high price and the lack of availability of refuelling infrastructure are representing major barriers for the widespread use of hydrogen in transport. It should be noted that a minimum infrastructure provision is optional under Directive 2014/94/EU, and some Member States have national strategies for the deployment of hydrogen infrastructure for the coming years. Hydrogen is currently projected to grow significantly beyond 2030 albeit maintaining a limited share of transport fuels.

<u>Driver 3: Variable climate performance of conventional biofuels (due to ILUC)</u>

Conventional biofuels have been promoted to both increase the EU energy security and contribute to reduce GHG emissions in transport compared to fossil fuels. According to the EU biofuels sustainability criteria (laid down both in the RES Directive and the Fuel Quality Directive), existing biofuel plants need to reduce direct GHG emissions by at least 35% and new by at least 50% compared to fossil fuels. While these criteria address only direct emissions from cultivation, transport and processing, in recent years, research

128 In a relatively short period of time the industry was able to move to large scale demonstration and all 3 projects supported under FP7 are on 10 ha area

129 Several shipping companies and ship-engine manufacturers (MAN, Wartsila and Meyer Werft) are exploring the potential use of methanol (either bio or power to gas origin) in ferry operations. Stena is already operating a methanol powered ferry from Hamburg to Stockholm and Maersk is contracting another one. Tests have also been done with biodiesel but the preferred alternative fuel beyond LNG for the maritime sector appears to be methanol. In Nordic countries the MARINA project aims to reduce emissions and increase the use of alternative fuels in the marine sector. To do so, the project aims to create a network between key players in all the Nordic countries to identify policy and roadmap recommendations for Nordic policy and decision makers on how to increase the use of alternative fuels and reduce emissions from marine applications.

has shown that, due to market mediated effects, food based biofuels can also lead to significant Indirect Land Use Change (ILUC) emissions that can off-set their direct GHG savings (see table below).

In particular the increase in demand for crops for biofuels can contribute indirectly to growing pressure on forests and other carbon-rich ecosystems, and therefore increase emissions from land use change. Such emissions are mostly expected to take place in third countries, where the additional production is likely to be realised at the lowest cost. The GLOBIOM study[130] carried out for the Commission has indicated that ILUC emissions can be expected to be much higher for biofuels produced from vegetable oils compared to biofuels produced from starch or sugar. This is due to the specific characteristics of global vegetable oil markets, which are highly integrated. As result increasing demand for vegetable oils in Europe for biofuel production can lead to increased palm oil imports and, therefore, in an extension of palm oil plantations in South-East Asia. Typically, these developments take place on organic soils, which can result in a significant release of GHG emissions. On the contrary, research has pointed out that advanced biofuels from non-food crops have generally very low or no ILUC emissions.

Table 2: ILUC emissions from GTAP[131], MIRAGE[132], GLOBIOM[133]

	GTAP 2014 [1]	MIRAGE 2011 [2]	MIRAGE 2013 [3]	GLOBIOM 2015 [4]
Biofuel	iLUC emissions(gCO2/MJ)			
Corn Ethanol	20	10	12	14
Sugarcane Ethanol	12	13	14	17
Soy Biodiesel	29	56	56	150
Canola=Rapeseed Bi	15	54	55	65
Palm Biodiesel	71	54	55	231

To mitigate this issue, the ILUC Directive[134] has introduced a cap of 7% on the contribution of food-based biofuels towards transport energy consumption, and Member States have the ability to apply this cap to their FQD targets. Member States are also required to set out by 6 April 2017 an indicative target for advanced biofuels, with a reference value of 0.5% of transport energy consumption in 2020[135]. In addition, the ILUC Directive aims at promoting the use of other, non-ILUC renewable energy options in transport, such as biofuels not based on food crops, and renewable electricity.

The ILUC Directive also introduced the concept of "low indirect land-use change-risk biofuels and bioliquids". The idea behind this concept is that ILUC risks of conventional food-based biofuels can be avoided if measures are taken that compensate for the increase in demand for crops *e.g.* by applying measures that increase crop yields through improved inputs and management practices or by expanding agriculture on previously

130 Valin et al., 2015, GLOBIOM study http://www.globiom-iluc.eu/
131 New GTAP results in CARB website: http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appi.pdf
132 Laborde, 2011. Results of MIRAGE model (per crop group) are used in the 'ILUC Directive' (Directive 2015/1513); JRC, 2014
133 Valin et al., 2015, GLOBIOM study http://www.globiom-iluc.eu/
134 Directive (EU) 2015/1513
135 The following MS have adopted indicative targets: Italy: 1.2% by 2018 yearly increased to 2% by 2022; Denmark: 0.9% by 2020, France: 1.6% in petrol and 1% in diesel by 2018 and 3.4% in petrol and 2.3% in diesel by 2023

non-agricultural land with low carbon stocks and low biodiversity value. In a recent study from Ecofys a methodology for certification of low indirect land-use change-risk biofuels was developed[136]. The practical implementation of this concept, however, is still largely untested and uncertainty concerning the related costs and the robustness of approach remain. Therefore, the approach cannot be considered as a viable solution at this stage but the further exploration of the concept for instance by voluntary certification schemes could be encouraged.

In its July 2016 Low-emission mobility strategy, the Commissions reaffirms that that food-based biofuels have a limited role in decarbonising the transport sector and should be gradually phased out and replaced by low emission alternative energy, including advanced biofuels. Research suggests that advanced biofuels can lead to significant direct GHG savings of 76-95%[137] compared to fossil fuels and are not associated with significant ILUC risks[138]. Modelling work that underpins the strategy shows significant role of advanced bio-fuels, especially in achieving 2050 decarbonisation targets.

The production of biofuels from non-land using feedstocks in the EU is increasing, the majority of which is produced from used cooking oil or waste animal fat. The share of food crop-based biofuels in the EU market is decreasing. However, the biofuel industry argues that double-counting provisions have so far only assisted the deployment of inexpensive conversion of used oils and waste fats.

Furthermore, it should be recalled that the REFIT evaluation on the RES Directive and the public consultation results highlighted that regulatory uncertainty remains problematic for many stakeholders in the transport sector. In fact, the main barrier to investment in the sector as identified by industry, investors, associations and other stakeholders was the uncertainty about the policy framework for biofuels after 2020 and the long-led debate before adopting Directive (EU) 2015/1513 (ILUC Directive).

2.2.5. Problem 5 - Lack of citizen-buy in during transition

<u>Driver 1: Risk that small scale investors are disadvantaged in market-based renewables support (tendering) and thus result in lower public acceptance</u>

If renewable energy benefits from an overall positive opinion by most European consumers[139], some specific renewable energy projects face strong opposition at local level. In Wallonia for instance, in 2014, 37 wind projects, representing 215 wind mills and 592MW[140] were challenged by opponents[141]. In Denmark, there are more than 200 local groups opposing wind power[142]. In France, around one third of wind projects are

136 Ecofys 2016: Methodologies for the identification and certification of Low ILUC risk biofuels
137 Annex V RES Directive
138 For instance, the GLOBIOM study for instance did not find significant negative impact for advanced biofuels produced from short rotation coppice, Valin et al., 2015
139 Nine in ten Europeans (90%) think that it is important for their government to set targets to increase the amount of renewable energy used by 2030, Special Eurobarometer 409, European Commission, 2013
140 For around 150MW installed in 2014
141 Propriété coopérative et acceptabilité sociale de l’éolien terrestre, Thomas Bauwen, 2015
142 What drives the development of community energy in Europe, Thomas Bauwen et al., 2015

brought to the court, creating lengthy procedure (between 6 and 8 years) and increasing costs of development[143].

This lack of public acceptance therefore leads to an untapped use of the most cost-efficient renewable potential (both in terms of locations and feedstocks), creates lengthy and uncertain procedures, increases overall cost and hinders access to cheap capital. Among the factors influencing local acceptance of renewables, lack of access to project ownership or finance, lack of information and lack of participation for local communities (including municipalities) have been identified as key issues[144].

In several Member States, the creation of energy communities has been a solution to enhance social acceptance of renewable technologies at local level[145] and diminished opposition[146]. In Germany, a case study has shown that, in the absence of local participation, negative opinions towards additional wind energy could reach 60%, while this share would drop to 12% in case of the presence of energy communities[147].

Reinforcing local acceptance, *e.g.* through the promotion of local energy communities, is therefore a fundamental precondition for deploying renewable energies in a cost-effective way[148].

However, even if local involvement of communities is proven to substantially increase public acceptance of renewables and often reduce costs as co-owners do not demand same returns as classic investors, their specific situation is currently not reflected in renewables support rules. Administrative barriers are particularly relevant for communities and prosumers, who often lack the critical mass and knowledge to overcome them. In addition, such actors may have difficulties integrating in the market or participating in competitive bidding processes, especially for energy cooperatives and small-scale projects[149].

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143 La politique de développement des énergies renouvelables, Cour des Comptes, 2013

144 Jober et al., *Local acceptance of wind energy: Factors of success identified in French and German case studies*, 2007; Jan Zoellner et ali, *Public acceptance of renewable energies: Results from case studies in Germany*, 2008; Thomas Bauwen et al., *What drives the development of community energy in Europe*, 2015; Joyce McLaren Loring, *Wind energy planning in England, Wales and Denmark: Factors influencing project success*, 2006

145 Thomas Bauwen, *Propriété coopérative et acceptabilité sociale de l'éolien terrestre*, 2015; Thomas Bauwen et al., *What drives the development of community energy in Europe*, 2015; David Toke et al., *Wind power deployment outcomes: How can we account for the differences?*, 2006; Fabian David Musall, Onno Kuik, *Local acceptance of renewable energy - A case study from southeast Germany*, 2011

146 Thomas Bauwen et al., *What drives the development of community energy in Europe*, 2015

147 Fabian David Musall et al, "Local acceptance of renewable energy —A case study from southeast Germany", 2011. Considering negative and very negative together

148 Projects with high levels of public acceptance are more likely to succeed in receiving planning permission, while projects with low levels of public acceptance are more likely to fail, Joyce McLaren Loring *Wind energy planning in England, Wales and Denmark: Factors influencing project success*, 2006

149 The upcoming auctions are expected to put a strong competitive disadvantage upon Community Wind projects. WWEA, *Community Wind Perspectives from North-Rhine Westphalia and the World*, 2016

Driver 2: Lack of consumer empowerment in the energy transition

Self-consumption of renewable electricity is expected to be the main driver for the uptake of roof-top PV. With decreasing feed-in tariffs, around 50 % of the roof-top PV capacity could be driven by self-consumption.

Renewable energy self-consumption, mostly driven by the deployment of residential solar PV, and to a lesser extent small wind power systems, has become an important trend since the implementation of the RES Directive. With an 80% drop in PV module prices in five years[150], the installed residential PV capacity has quadrupled since 2009 in the EU[151] and it is expected to continue to increase thanks inter alia to further reductions in technology costs. As a result, businesses and households, either individually or collectively in apartment blocks, could be able to produce and consume, some or all of, their own electricity, either instantaneously or in a deferred manner through decentralised storage. Passive consumers are therefore becoming active *'prosumers'* (*i.e.* producers and consumers of renewable energy).

Member States have addressed this phenomenon in different ways which has led to a fragmented market, different degrees of consumer empowerment across the Union and a high degree of regulatory instability. In particular, nine Member States do not yet have a legal framework for self-consumption[152]. In 8 Member States the regulatory framework was established within the last three years[153]; and 7 changed their rules at least once since 2013[154], in certain cases retroactively. This situation led high regulatory uncertainty among investors across the EU[155] and generates market fragmentation across the EU. In some Member States consumers are effectively not able to self-consume their own renewable electricity and it is often difficult or impossible for tenants to benefit from self-consumption. In addition, retroactive changes in regulatory and financial schemes for prosumers have led to an unreliable investment climate. This has a negative impact on the deployment of renewables at local level and its contribution to target achievement, especially because with lowering feed-in tariffs self-consumption is expected to drive 50 % of rooftop solar capacity[156].

Driver 3: Lack of clear, comparable and credible information to energy customers

Renewable energy sources are subject to significant information failures: new technologies that are applied at plant and household level (*e.g.* solar water heating, heat

150 PV Status Report, JRC, 2014

151 Bloomberg New Energy Finance 2014

152 *I.e.* Bulgaria, Czech Republic, Estonia, Finland, France, Ireland, Luxembourg, Romania, Slovakia

153 *I.e.* Cyprus, Spain, Croatia, Greece, Lithuania, Latvia, Malta and Poland

154 *I.e.* Austria, Belgium, Germany, Denmark, Italy, Hungary, and Portugal

155 Furthermore, there are different interpretations in the EU regarding the status of the self-consumer. For instance, the recent Royal Decree 900/2015 in Spain does not recognize the status of prosumer. To export surplus electricity to the grid, the residential promoter needs to be registered as an entrepreneur for which administrative barriers can deter residential investors. Similarly in case of recognition of a producer status, grid-access charge and revenue taxes are also applicable to surplus electricity unless exempted. In France, the status of prosumer is not yet defined. So far photovoltaic installation exporting to the grid can be registered under the *micro-entrepreneur* regime or a "*régime réel d'imposition*". In Germany, the Ministry of finance has published in 2014 a guidance on sales tax when there is self-consumption. As soon as there is a remuneration of part or all the production from the PV system, the fiscal regime of businesses applies.

156 *Bloomberg New Energy Finance*, 2016

pumps) can be slow to find public acceptance, and the market for installation and maintenance services is often inadequately informed and trained, resulting in technology breakdowns and a perception of unreliable technologies. In the case of biomass, users are often unaware of how to operate the heater in such a way that emissions of air pollutants are minimised.

The poor information flows can also occur during production, when energy suppliers are unaware of quality standards, regulators fail to create the right legal or institutional framework (*e.g.* municipal planning rules), and capital markets fail to acknowledge technology learning and reductions in risk. Such failures can also result in poor supply chain development.

Under Article 15 of the RES Directive, the Guarantees of Origin (GO) system provides a means of demonstrating the origin of renewable electricity to consumers. It is a virtual "book and claim" system where the renewable attribute of energy trades separately from the physical energy. With electricity such certification systems are desirable as it is not possible to track electrons from renewable sources through the power grid. Disconnecting GOs from the physical flow of electricity is a less complicated approach than tracking the supply of renewable electricity through contract based tracking and allows for trade in large volumes of renewables across the EU. The GO system is not intended to be a support scheme for encouraging new renewable generation capacity or be used as a means of achieving national renewable energy targets.

Requirements for energy companies to disclose sources of electricity, and the associated emissions and waste to consumers are contained in the existing Electricity Market Directive. Consumer bills have to include that information. However it is not mandatory in the Electricity Market Directive for energy suppliers to use the GO system for renewable energy disclosure purposes. This has led to the GO system covering less than half of the total renewable energy production. Furthermore, the GO system does not currently include data on emissions and waste.

Many electricity suppliers offer "green" contracts to consumers offering environmental benefits relative to regular electricity. When these tariffs are based on renewable energy, sometimes the renewable content is demonstrated by purchasing GOs. Corporate consumers often source renewable electricity to meet corporate sustainability objectives. This can be through direct investment in renewable electricity production, but many are increasingly focused on using such GO systems for corporate reporting purposes and to quantify their GHG emissions[157].

Evidence so far suggests that the GO and disclosure systems in place are not consistent between all Member States as the legislation provides wide discretion as to how national systems are designed and implemented[158] . Furthermore, GOs do not apply to all energy sources only to renewable energy and high efficiency CHP[159]. There have been mixed views as to the functioning of the GO systems amongst stakeholders. Many support the

157 GOs are recognised in the CDP corporate carbon accounting requirements. https://www.cdp.net/Documents/Guidance/2016/CDP-technical-note-Accounting-of-Scope-2-Emissions-2016.pdf

158 Chapter 6 of RE-DISS final report http://www.reliable-disclosure.org/static/media/docs/RE-DISSII_Final-Report_online.pdf

159 See Directive 2012/27/EC

system in principle, but some consider that the system can result in greenwashing[160], as it enables consumers to use renewable electricity far away from where it is produced. For example, there is a large trade in hydropower GOs from Norway to other parts of Europe which is seen by some as unrealistic given the distances involved. Many Norwegian consumers have typically not bought GOs to demonstrate use of renewable power. As a consequence of this, there is an effective transfer of renewables consumption in that it results in Norwegian consumers having a residual mix of fossil and nuclear power which is not popular locally[161].

With the GO system there is also a risk of double counting the production of renewables in the absence of reliable tracking systems and concerns that a poorly designed and implemented system could be susceptible to such issues[162]. This risk arises as in theory, it is possible that Member States could issue GOs for renewables under the RES Directive, but then may not require their use for disclosure purposes under the Electricity Market Directive, allowing other methods to be used. This could mean that the GOs generated are exported to another country, whilst the energy supplier is still able to claim use of that same volume of renewables under the national disclosure system.

Given some of the issues associated with the GO system, one approach could be to abolish the system entirely. Such a deregulation would mean that there would be no EU mechanism for recognising the renewable origin of electricity. In such circumstances it is likely that energy companies would continue to offer green tariffs, based on renewables, to consumers. Similarly, some businesses and corporations would still like to demonstrate publically that they consume renewables in their operations. The consequence is that parallel systems would likely develop as a way of tracing consumption of renewable energy. These could be a series of national GO system, or perhaps greater use of bilateral contracts between consumers and generators. It is possible that these systems would have no common standards and would not operate very effectively across borders; it is therefore hard to see benefits for taking such an approach in increasingly integrated energy markets.

In most Member States the GO system applies for renewable electricity only. Austria and Sweden have extended the system to all sources of power generation, including nuclear and fossil sources. Some observers have noted that the narrow scope of the system as provided by EU legislation means that the cost of disclosure is put on renewable generators only, many of which are small installations. Other less sustainable forms of electricity production, often large installations, do not participate in the energy disclosure system and therefore do not share its associated overhead cost.

The current system of GOs applies only to renewable electricity. There is no equivalent EU wide system for guaranteeing the origin of renewable gaseous fuels (in particular,

160 The expressions ‘environmental claims’ and ‘green claims’ refer to the practice of suggesting or otherwise creating the impression (in a commercial communication, marketing or advertising) that a good or a service has a positive or no impact on the environment or is less damaging to the environment than competing goods or services. This may be due to its composition, how it has been manufactured or produced, how it can be disposed of and the reduction in energy or pollution expected from its use. When such claims are not true or cannot be verified, this practice is often called ‘greenwashing’. (Guidance of the Unfair Commercial Practices Directive, SWD(2016) 163 final)

161 http://www.tu.no/artikler/industri-opprinnelsesgarantier-gjor-norsk-industri-klimafiendtlig/232980

162 See, *e.g.*, http://www.beuc.eu/publications/beuc-x-2016-002_jmu_trustworthy_green_electricity_tariffs. pdf

biomethane) that are injected into the natural gas grid, although the case is similar to electricity.

The lack of a robust tracking mechanism could be an obstacle for cross border trade of renewable gaseous fuels. Levels of trade should increase over time as European gas grids become more integrated and production of biomethane rises or if injection of renewable hydrogen becomes common. Challenges have been encountered so far with regard to cross border trade, in the implementation of the sustainability scheme for biofuels, which has proved to be complex for injected renewable gaseous fuels. This is because the rules for the mass balance system that is currently applied to ensure traceability of biofuels were developed primarily for liquids biofuels, leaving a degree of uncertainty regarding the implementation for gaseous fuels.

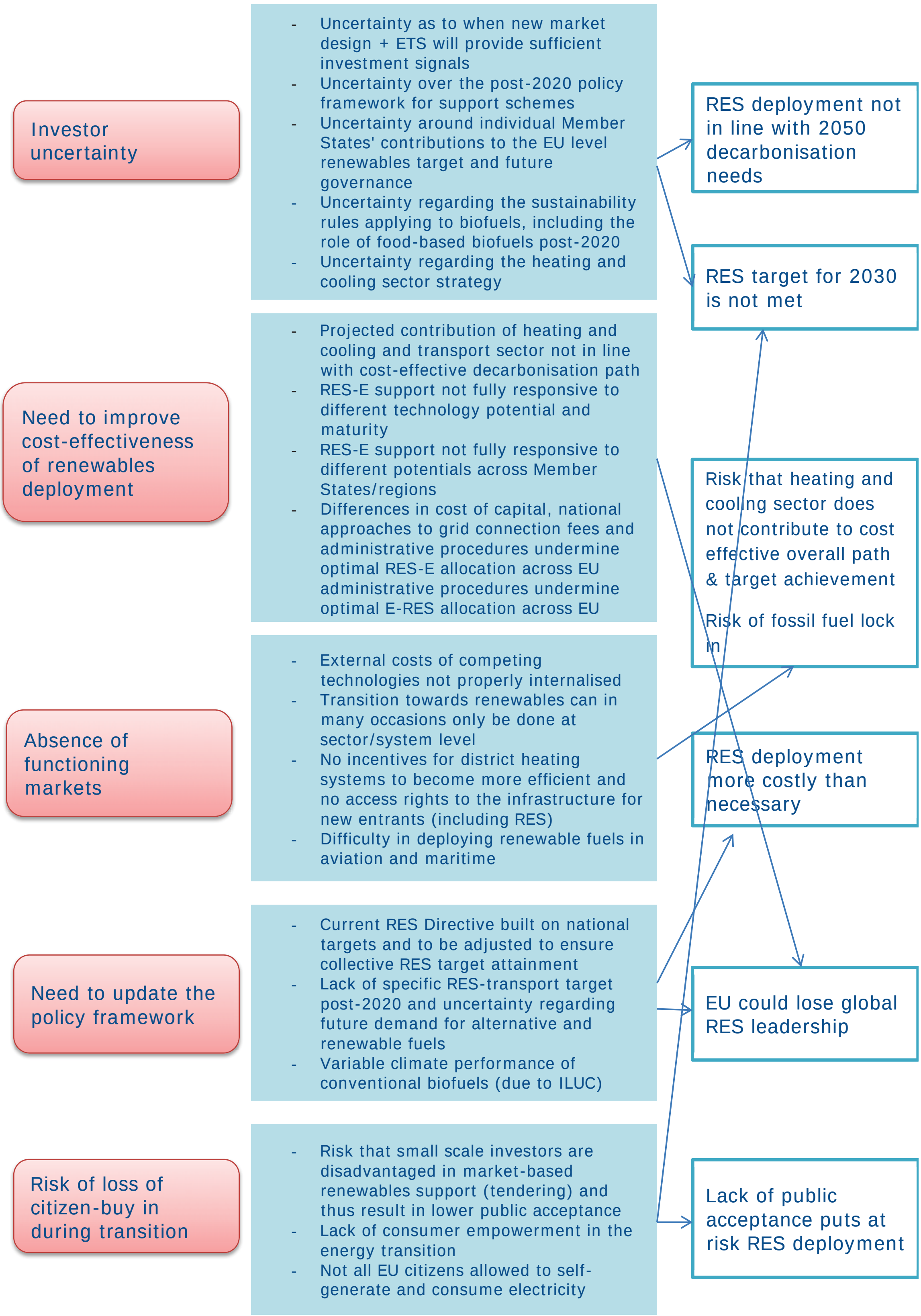
In some Member States systems that are similar to GOs have been developed for gaseous fuels partly as private initiatives. There are also initiatives to facilitate cross-border trade of biomethane by mutually recognising each other's national GO systems. A number of stakeholders are also developing an EU wide approach to design a GO scheme for green hydrogen[163].

Liquid renewable fuels are also not covered by the GO system or a similar centralised tracking system[164]. Private initiatives have also developed systems for guaranteeing the origin of liquid fuels, however they are not widely used as they are not mandatory.

The need to have in place resilient tracking mechanisms for liquid renewable fuels can be considered to increase in the future, since volumes used are likely to increase in the future. For liquid fuels the main problem is an increasing risk of fraud. There is a political agreement that the focus of the development of renewable transport fuels should shift towards non-food biofuels with a low impact on indirect land use change (ILUC) and food security[165]. However, advanced renewable fuels are initially expected to be more expensive than conventional food based biofuels but will in most cases by physically identical. In absence of a solid mechanism that allows tracing these advanced renewable fuels it cannot be excluded that economic operators make false claims on the characteristics of renewable fuels *e.g.* regarding the feedstock which was used to produce the fuel.

The following problem tree summarises the identified problem areas across all sectors their main underlying drivers and consequences:

[163] CertifHy project (www.certifhy.eu)
[164] Some national databases exist, such as in Austria, Belgium, Germany and Luxembourg
[165] See also the State aid guidelines (point 113)



2.3. The EU dimension of the problem

As the European Union needs to achieve at least a 27% share of renewable energy sources in final energy consumption in 2030 for reasons of climate change mitigation, security of supply and competitiveness, as well as to promote the EU as a global leader in the renewables industry, this effort necessarily needs to have an EU dimension. The new framework for the post 2020 period will be based on an EU level binding target as opposed to the existing national binding targets in the current framework. This fundamental change makes the problem necessarily "European", opening new challenges and new opportunities in addressing it. And this is not only a question of ensuring a collective and timely delivery of the target but doing so cost-effectively which makes the need to address the problem at EU level even more critical.

This commitment has been re-confirmed through the EU joint submission with its Member States in the proposed contribution towards COP21 with an ambitious legally binding commitment of GHG emission reductions of at least 40% by 2030 below 1990 levels[166].

Many provisions of the current EU framework effectively end in December 2020. The uncertainty about renewable energy market volumes post-2020 in the entire Union and the support schemes for renewables may therefore lead to commercialisation problems for new capital intensive renewables technologies where investments are marked by long lead times.

Decarbonising the economy - and particularly the energy system - is crucial for the achievement of the EU-wide GHG emission reduction targets and combating the effects of climate change and renewable energy is an essential part of this effort. Additionally, the renewable energy sector contributes to the overarching goal of the European energy policy strategy to ensure secure, affordable and sustainable energy for all EU citizens and businesses by taking full advantage of the opportunities offered by a powerful internal energy market. The development of the internal electricity market and the additional deployment of renewable energy in the power generation sector are two challenges that can only be addressed in conjunction.

2.4. Who is affected and how

The Revised RES Directive (jointly with the initiative on Governance for the Energy Union) should reflect the new character of the EU-wide renewables 2030 target and the new balance established between the overall target on the one hand, and regulatory measures to achieve the target on the other hand.

Annex 6 to this Impact Assessment elaborates in detail the impact on stakeholders[167].

2.5. REFIT Evaluation of the RES Directive

A regulatory fitness programme (REFIT[168]) evaluation of the RES Directive was carried out between 2014 and 2016. The results of this evaluation are submitted in a separate REFIT evaluation Staff Working Document presented together with this Impact Assessment and are used as input for the present section on the problem definition.

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[166] See the submission by Latvia and the European Commission on behalf of the European Union and its Member States - http://ec.europa.eu/clima/news/docs/2015030601_eu_indc_en.pdf

[167] *i.e.* Member States, local communities, municipalities, non-renewables energy producers and suppliers, renewables projects developers, renewables technology producers, renewables installers, investors, financial sector, businesses, transmissions service operators, distribution service operators, energy consumers, energy service providers (ESCOs), aggregators, citizens at large.

[168] In line with (COM(2013)685 final) - "Regulatory fitness and performance: results and next steps"

Annex 9 to this Impact Assessment illustrates in detail the conclusions of the evaluation.

3. SUBSIDIARITY AND THE DIVERSE SITUATIONS IN MEMBER STATES

3.1. Legal base

Article 194 TFEU states that "*Union policy on energy shall aim, in a spirit of solidarity between Member States, to […] promote […] the development of new and renewable forms of energy. […] the European Parliament and the Council, acting in accordance with the ordinary legislative procedure, shall establish the measures necessary to achieve the objectives in paragraph 1. Such measures shall be adopted after consultation of the Economic and Social Committee and the Committee of the Regions*".

3.2. Necessity of EU action

EU level action is needed to ensure that Member States' contributions to the at least 27% EU level binding renewable energy target is collectively and cost-effectively met and the Union can deliver on the commitments it made at the COP21 Climate Summit in December 2015. Experience has shown that uncoordinated actions at Member State level can lead to a more limited and more expensive renewable energy sources development and the fragmentation and distortion of the internal energy market.

An EU wide European market for renewables, set in the context of a more integrated electricity market, can facilitate the balancing of the electricity system, reduce the need for back-up capacities and encourage renewables production where it economically makes most sense. Large scale investments necessitate big markets which also justify one EU wide market. A bigger market can also better encourage development of innovative products and systems.

EU level action can help ensure achievement of the at least 27% EU renewable energy target through increasing investors certainty in an EU-wide regulatory framework. It will also enhance a consistent development of EU renewable energy policy across the EU leading to a more cost-efficient renewable energy deployment and a smooth and efficient operation of the internal energy market whilst fully considering the differing capacities of the Member States to produce different forms of renewable energy. Together with the Electricity Market Design legislative proposal, this initiative should enable the further integration of renewable energy sources into the internal energy market alongside other generation technologies.

Sole action at Member States' level would likely lead to a more limited deployment of renewables and create additional costs that can be reduced through complementary EU-level action. It would also lead to more fragmentation of, and distortions in, the energy internal market and put the achievement of the EU target at risk.

As regards the electricity sector, the EU has set up a single integrated power market where main principles, rules for common problems and rules regarding cross-border aspects are being established at EU-level. It follows that rules on renewables touching upon market functioning also need to be addressed at EU level. The same rationale applies to self-consumption, as *prosumers*, either individually or collectively, could be able to produce and consume their own electricity reducing their energy costs and participating to the electricity markets. Since Member States have addressed self-consumption adopting divergent policies, a significant number of energy consumers in the EU currently do not enjoy clear rules on production of their own electricity and self-consumption. This undermines the empowerment and increasing involvement of

European citizens, who would not be able to reap the benefits from being market players of energy markets. Moreover, lack of clear rules on self-production and self-consumption would undermine *prosumers* ability to contribute to the effort to achieve the 2030 EU target for renewables. This effect is significant as self-consumption is expected to be the main driver for the uptake of roof-top PV. With decreasing feed-in tariffs, around 50 % of the roof-top PV capacity could be driven by self-consumption.

Heating and cooling consumes half of EU's energy and 75% of the EU's fuel needs for heating and cooling still come from fossil fuels. As such, decarbonising the heating and cooling sector is necessary if the EU is to stay on the path of our long term decarbonisation objectives and improve security of supply. Heating and cooling consumption patterns are already directly affected by EU legislation, such as the EED or the EPBD Directives. In addition, the EU Strategy on Heating and Cooling[169] provided a framework for integrating efficient and sustainable heating and cooling into EU energy policies. This should focus the future EU and Member State action on stopping the energy leakage from buildings through a comprehensive approach to speed up the replacement of obsolete boilers with efficient and clean renewable energy heating and a commitment to increase the deployment of renewable energy in district heating and CHP. In this respect, EU-level action can trigger the necessary confidence of investors for a mass roll-out of heating and cooling technology cost-effectively.

Transport consumes a third of EU's total energy demand and this demand is almost entirely met by liquid fossil fuels. Whilst electrification seems a good way forward to replace fossil fuels for light duty vehicles, motorbikes and rail, current technology development pathways suggest that electrification on its own cannot address all the decarbonisation challenges, in particular as regards aviation, waterborne and heavy duty transport. Advanced renewable fuels will need to contribute to achieve our long term climate and energy objectives. The EU has heavily invested into research and technology development of advanced biofuels, which resulted in the operation of first-of-a-kind plants. Incentives for early commercialization can pull technologies further down the learning curve. National measures cannot guarantee market volumes that are sufficiently large to both achieve economies of scale and spoor manufacturing innovation. The introduction of a promoting measure at EU level is more likely to create such a market pull, while ensuring that the costs of technology innovation and development are sufficiently shared across European economies. A common EU action will also ensure that that the objectives of the policy (*e.g.* making advanced fuels cost-competitive) are achieved at least costs. An EU approach can better prevent market distortion and fragmentation, that is more likely to result from national measures.

EU-level action is also needed to remove administrative barriers[170] as these bring uncertainty and delay to investors, artificially increase the costs of renewable energy projects, create distortions in the allocation of investments within the EU, hampering to build a unified EU market for renewable projects and reaching a cost-effective deployment of renewable energy.

Member States are free to develop the renewable energy sector that corresponds best to their national situation, preferences and potential, provided they collectively reach the at least 27% target. Important national prerogatives, such as the Member State's right to

[169] COM(2016)51 final - "An EU Strategy on Heating and Cooling", 16 February 2016

[170] *E.g.* lengthy administrative procedures, complex licensing procedures, fragmented or unclear responsibilities, institutional overlaps, etc

determine the conditions for exploiting their energy resources, their choice between different energy sources and the general structure of their energy supply, remain untouched. The following graph illustrates the use of renewables in the different energy sectors.

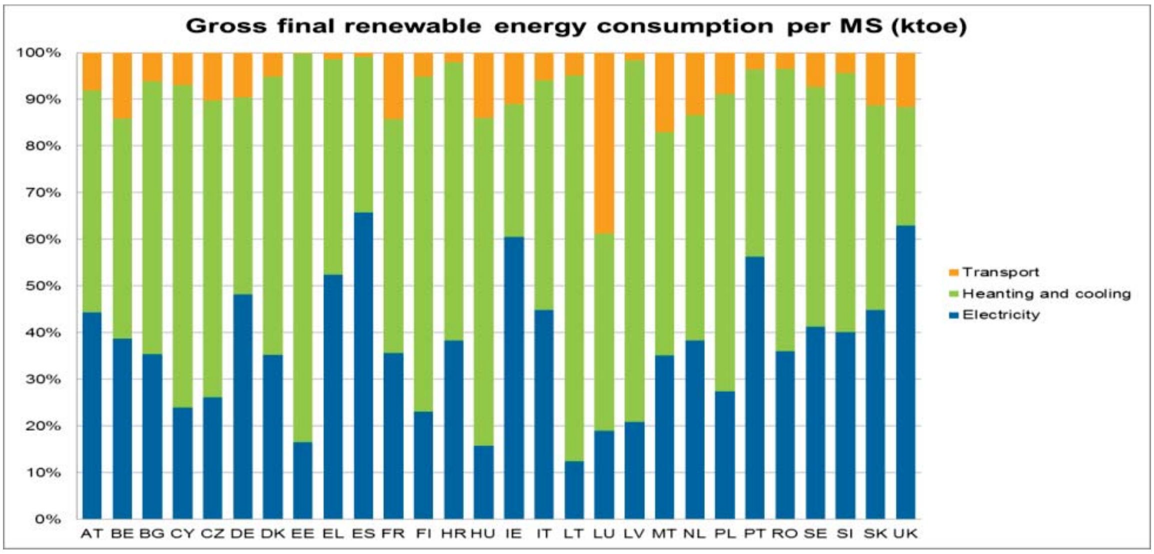

Figure 8: Gross Final Renewable Energy Consumption per sector (ktoe),
***based on* "Renewable Energy Progress Report", Öko Institute [to be published]**

Additionally, proportionality will be ensured by striking a balance between objectives of competitiveness, security of supply and sustainability, and by considering the long term benefits beyond 2030 of the proposed course of action– and not only be based on short to medium term impacts.

The level of constraint is thus proportionate to the objective aimed at.

3.3. EU added-value

In January 2014, the European Commission presented its policy framework for climate and energy in the period from 2020 to 2030 (COM/2014/015) which complements GHG reduction policies with a powerful internal energy market, a self-standing chapter on energy security of supply and reinforced emphasis on R&D and innovation. The analysis at the time indicated that the least cost pathway to achieve greenhouse gas reduction targets in 2030 and 2050 is for the entire EU to attain a share of at least 27% of energy consumed from renewable sources in 2030, without differentiating between the electricity, transport or heating and cooling sectors.

Due to the existence of specific market failures and barriers, the impact assessment that underpinned the 2030 policy framework for climate and energy[171] pointed out to the risk of not reaching this target in a business as usual scenario, and therefore not being able to reap of the economic, social and environmental benefits of renewables. Therefore the impact assessment of the 2030 framework concluded on the benefits of a specific target be set for the deployment of renewables at EU-level in 2030.

171 SWD(2014) 15

An EU-wide energy and climate framework for renewable energy in 2030 will also contribute to steer Member States energy policies to achieve a sustainable, secure and affordable energy system for European citizens. With a predictable EU regulatory framework leading the renewables' sector towards 2030, Member States can better design national policies towards the 2020 target if EU-wide headline targets are agreed on, which ensures that renewable energy policies are coherent with other energy and climate objectives, namely the ETS, the Effort-Sharing Regulation and the EU energy efficiency target for 2030. An EU-level framework for support schemes would also provide investor certainty, which may have been impacted in the past by the stop and go policy – and sometimes retroactive measures – taken by certain Member States.

By acting at EU-level, several barriers to public and private investments (*e.g.* related to authorisation procedures) could be tackled, addressing the lack of coordination between various authorising bodies at national level and stimulating the administrative capacity to implement cross-border projects and support schemes.

The cost-effective deployment of renewables until 2030 can thus best be achieved by a combination of action at Member States-level and at EU-level. Uncoordinated renewables' support policies at Member State level bears the risk of increasing the cost of reaching at least 27% renewables by 2030 for the consumers, for the investors and for the system as a whole.

To sum up, EU level action is needed to ensure that the at least 27% EU-level binding renewable energy target is collectively met by Member States, and is met in the most cost-effective and least distortive manner.

4. OBJECTIVES

4.1. General objectives

- Contribute to "*the development of new and renewable forms of energy*" as stipulated in Article 194 TFEU, having in mind the Commission's political ambition to be global leader on renewables;
- contribute to the EU's climate change commitments in the context of COP 21;
- contribute to the energy security ambitions set out in the Energy Union strategy;
- ensure cost-effective deployment of renewables and the functioning of the internal energy market.

4.2. Specific objectives

- Address investment uncertainty, along a path that takes account of medium and long term decarbonisation objectives;
- ensure cost-effective deployment and market integration of renewable electricity;
- ensure collective attainment of the EU-wide target for renewable energy in 2030, establishing a policy framework in coordination with the Energy Union Governance that avoids any potential gap;
- clarify role of food-based biofuels post 2020;
- correct heating & cooling market failures;
- ensure citizen buy-in for the post-2020 period, empowering consumers to receive clear, comparable and credible consumer information on all energy sources and to self-consume the electricity they generate, while respecting the principle of cost-efficiency.

5. POLICY OPTIONS

The present chapter describes and assesses the policy options which have been developed to address the problem described in Chapter 2[172].

The options are grouped according to the following areas:

- electricity sector (RES-E);
- heating and cooling sector (RES-H&C);
- transport sector (RES-T);
- empowering and informing consumers of renewable energy;
- achievement of at least 27% renewable energy in 2030.

Each group of policy options is assessed in detail, with an analysis of the impacts in accordance to key indicators.

5.1. Options to increase renewable energy in the electricity sector (RES-E)

The table below summarizes the group of options that are discussed in this section.

Challenges	Drivers	Policy Options
Delivering a framework for cost-effective and market based support for electricity renewables	Uncertainty up until revised market design and ETS deliver adequate investment signals Uncertainty on post 2020 rules for support schemes RES-E support not fully responsive to different technology potential and maturity Risk that small-scale investors are disadvantaged in market based RES support (tendering)	0. Baseline - No specific provisions on support schemes in the Revised RES Directive (only EEAG) 1. Prohibit support schemes for Renewable Electricity 2. Clarify the principles for the use of support schemes based on market-based principles 3. Mandatory move towards Investment Aid
A more coordinated Europeanised approach to renewables support	RES-E support not fully responsive to different technology potential and maturity RES-E support not fully responsive to different	0. Baseline 1. Mandatory partial opening of support schemes to cross border participation 2. Mandatory Regional

172 For better readability, this chapter merges the chapters usually referring to the presentation of the policy options and their assessment, including an overall comparison of the options for each area of intervention.

	potentials across MS	Support Schemes
Reducing the cost of capital for renewable generation projects	Differences in cost of capital undermine optimal RES-E allocation across EU	0. Baseline 1. EU Financial instrument with wide eligibility criteria 2. EU Financial Instrument in support for higher risk projects
Reducing administrative barriers	Differences in administrative procedures undermine optimal RES-E allocation across EU • Investor uncertainty • Reduce Costs of Renewable projects	0. Baseline - Extension of current provisions (article 13.1) until 2030 1. Introduce One Stop Shop + time limits with range for duration of permitting process + facilitated procedures for repowering 2. Option2+ more stringent time limits and deadlines for permitting process + Project development manuals + compulsory simple notification for small household projects + facilitated procedures for medium size projects

The assessment of options is structured as follows:

- A starting point: the REF2016 – lessons learned for the electricity sector
- Baseline scenario: the continuation of current national Member States' policies and of currently differentiated access to capital for RES electricity projects
- Options about the potential need and design of support schemes
- Options about the potential geographical scope of support schemes
- Options about addressing the various access to capital conditions for RES-E projects
- Options aimed at reducing administrative barriers

All specific policy options are compared to the baseline scenario. Discussions on these options compared to the central policy scenario results (EUCO27) are also included. Where relevant, the implications of a 30% energy efficiency target are also presented.

Starting point	Baseline scenario	Other policy scenarios	Central policy scenario

REF2016	Option 0 CRA scenario	Option 1	No support to RES-E projects	EUCO27 scenario
		Option 2	Toolkit for support schemes	
		Option 3	Investment aid mandatory – no more operational aid	
		Option 1	Mandatory partial opening of support schemes to cross-border participation	
		Option 2	Mandatory regional support schemes	
		Option 1	EU-financial instrument with wide eligibility criteria	
		Option 2	EU-financial instrument in support of higher-risk RES projects	
		Option 1	One stop shops, time ranges	
		Option 2	One stop shops, time limits, automatic approvals and simple notifications for small projects	

Table 3: Interaction logic between scenarios and policy options

Starting point: the EU Reference Scenario 2016

Overall, REF2016 falls short of the overall ambition level in terms of renewable energy share by 2030. Still, some important lessons can be learned in terms of renewable electricity developments.

By 2020, renewables in power generation are projected to increase to 35.5% (RES-E indicator[173]) or 37.2% of net electricity generation, of which 52% are projected to be variable renewables – wind and solar. Beyond 2020 support schemes are assumed to be phased out and further investments in renewables are more limited (reaching 43% in 2030), driven by market forces such as the ETS and the improvement in the techno-economic characteristics of the technologies.

While renewables provide growing shares in electricity generation, the contribution of variable renewables (solar, wind as well as tidal/wave in the definition used here) remains significantly lower. These variable renewables reach 19% of total generation in

173 Calculated according to the definitions of the RES Directive used also for the pertinent provisions of Eurostat statistics

2020, and 25% in 2030. Wind off-shore capacities stagnate, as in the absence of support schemes this technology is not projected to be competitive.

Wind provides the largest contribution from renewables supplying 14.4% of total net electricity generation in 2020, rising to 18% in 2030. A share of 24% of total wind generation is produced from wind off-shore capacities in 2020 (33GW installed capacity), but the share of offshore wind declines thereafter. Total wind capacities increase to 207 GW in 2020, and 255 GW in 2030, up from 86 GW in 2010. Wind onshore capacity and generation increases because of exploitation of new sites but also because of the progressive replacement of wind turbines with newer taller ones which are assumed to have higher installed capacity and higher load hours. Generation from PV contributes 4.8% in net generation by 2020. Beyond 2020, PV generation continues to increase up to 7% in 2030. PV capacity is projected to reach 137.5 GW in 2020 and 183 GW in 2030, up from 30 GW in 2010. Investment is mostly driven by support schemes in the short term and the decreasing costs of solar panels and increasing competitiveness in the long term, in particular where the potential is highest, *i.e.* Southern Europe. The use of biomass and waste combustion for power generation also increases over time, both in pure biomass plants (usually of relatively small size) and in co-firing applications in solid fuel plants. Biomass attains a share in fuel input in thermal power plants of 17.3% in 2020, and 22% in 2030[174]. Pure biomass/waste plant capacities (excluding co-firing) reach 51.6 GW in 2020 and 53.2GW in 2030, up from 21.7 GW in 2010. The relative contribution of hydro generation remains rather constant at 10-11% of total net generation, with small hydro slightly increasing.

The Baseline scenario: the current renewables arrangement (CRA) scenario

The first assumption that this scenario considers is that Member States continue supporting renewable electricity projects, on a national basis, with no additional provision considered in the Revised RES Directive. Potential provisions would be left entirely to the revised, post-2020 State Aid guidelines. Therefore, a continuation of nationally-based support schemes is assumed, while complying with the current State-Aid guidelines provisions. The second assumption made is that Member States support renewable electricity projects in such a way that the overall 27% RES target is achieved. The third assumption made for the preparation of this baseline scenario is that current distortions in the financing cost of renewable electricity projects across countries[175] remains in place up until 2030. Regarding other assumptions, this scenario assumes, as in the central policy scenario (EUCO27) an improved functioning of the ETS, in line with the Commission's proposal for a revised ETS for the period after 2020, as well as efficient energy market functioning[176]. In other words, this scenario differs in its design compared to the EUCO27 scenario via two main features: i/ the cost-effective incentives for renewables reflected by the use of similar RES-E values across Member States in the EUCO27 scenario is replaced by explicit, nationally-based and differentiated support schemes; and ii/ financing conditions for RES projects differ per Member State.

Under this scenario, the RES-E share reaches 49% in 2030. In terms of installed capacity, this means about 733 GW of renewables capacity installed, and 245 GW of additional

[174] Calculated following Eurostat definitions, *i.e.* excluding energy consumed by Industrial sectors and refineries for on-site CHP steam generation

[175] For additional details on the scenario design, see Annex 4

[176] Dedicated measures necessary to achieve this efficient market functioning are assessed in detail in the Market Design Impact Assessment

installed capacity over the 2021-2030 period. In terms of investment, this corresponds to annual investment expenditures of about EUR 40 billion per year over the 2021-2030 period, higher than for the EUCO27 and EUCO30 scenarios. This can be explained by a series of factors. First, there are fewer investments in RES-E in 2020 in the baseline scenario than in EUCO27, as financing costs distortions as well as impacts of different support schemes among Member States are reflected for 2020 in the baseline scenario, as opposed to EUCO27. Therefore, a catching up effect takes place post-2020. In addition, the RES-E share in 2030 in CRA is higher than in EUCO27[177]. Finally and importantly, the RES-E generation mix changes, as continuation of differentiated nationally-based support schemes and different financing conditions lead to RES deployment that is less efficient, and therefore more costly, than in EUCO27. This scenario also implies an increase in average electricity prices, by 25% in 2030 as compared to 2010. It must also be noted that this analysis does not consider the fact that the absence of provisions on support schemes would provide less visibility to Member States and investors as to the framework applicable post-2020, with possible negative impacts on investments.

Some renewables investments can be financed without public support, while others require some. The CRA results show that 59% of renewables investments over the 2021-2025 and 51% of investments over the 2026-2030 (as measured in % of GW installed) are financed via some support covering at least a fraction of total project costs[178].This result is influenced by the initial assumption that Member States would continue supporting RES-E projects, in line with past practices. This support is reflected in final electricity prices, as it affects the power generation mix, as well as in the renewables supporting costs component of electricity prices passed on to consumers, which is estimated at 24.9 EUR per MWh in 2030.

The use of more direct support for renewables than in EUCO27 also leads to lower ETS carbon price (EUR 38 in 2030 in CRA compared to EUR 42 under EUCO27), reducing incentives for decarbonisation within the other parts of the power sector and in other economic sectors covered by the EU ETS, such as energy intensive industry, overall leading to a more costly delivery of GHG emission reductions.

The overall average increase in annual energy system costs compared to the Reference of this scenario over the 2021-2030 is estimated at €24 billion while for the EUCO27 scenario this is only €15 billion, resulting in a significant increase in costs to achieve the overall targets.

An important element of this scenario concerns the distribution of renewables deployment across Member States and technologies. First, regarding technologies, 35% of the overall RES-E generation in 2030 comes from on-shore wind, 22% from hydro, 17% from solar, 16% from biomass and waste, and 15% from off-shore wind. About 70% of the necessary investments to reach the renewables target in this scenario are investments in wind technologies; only 18% of overall investments are in solar and 8% in biomass-waste.

[177] This is mostly due to calibration issues. In fact, the intention was to maintain a RES-E share as close as possible to the EUCO27 scenario, but energy system interactions in the model made this objective difficult to achieve.

[178] As mentioned in section 2 and in annex 4,this scenario takes into account the increase in the linear reduction factor for the ETS post 2020 to achieve -43% as proposed by the Commission, as well as the impact of the Market Stability Reserve.

Second, regarding the geographical distribution of investments, 67% of total RES-E investments are concentrated in three countries, while in the EUCO27 scenario this is only 47%, with investments being more widely and cost-effectively distributed across Member States. This ratio increases to 74% for wind investments. Conversely, the combined share of investments in the ten Member States investing least over the period is only 0.6% of total investments.

A set of policy options is then compared against this baseline.

Key results from the central policy scenario (EUCO27)

It is important to recall the main results for renewable electricity embedded in the central policy scenario, as it corresponds to a cost effective deployment of additional renewables investments, compared to REF2016.

This scenario leads to a lower share of renewable electricity in the overall mix than the baseline scenario. The contribution of on-shore wind is more important than under the baseline, while it is the opposite for offshore wind. The average electricity prices as well as electricity generation costs are also lower. In this scenario, the ETS carbon price is higher than in the baseline, indicating that sub-optimal direct support to RES investments has a negative impact on CO_2 prices. This would reduce profitability for all power producers as well as limiting incentives for decarbonisation within the power sector and in other economic sectors covered by the EU ETS, such as energy intensive industry. Total average annual energy system costs over the period 2021-2030 increase in the EUCO27 scenario (central scenario) by €15 billion compared to REF2016 while the baseline (CRA) sees costs increase by €24 billion.

This scenario also leads to overall lower investments in renewable electricity projects than in baseline over the 2021-2030 period. This is partly explained by the fact that in 2020 this scenario achieves a bit less RES-E in 2020 compared to EUCO27. It is also explained by the fact that financing conditions for RES-E projects are assumed to reflect more explicit existing support schemes and associated country risks in the baseline CRA projection than in the EUCO27. RES-E investments are also much more widely and cost-effectively distributed across the EU, as the share of the top 3 Member States in overall investments only represent 47% of total investments, as opposed to 67% in the baseline. Renewables supporting costs passed on to final consumers is also lower than in baseline, while industry also benefits from lower electricity prices.

Looking now at the implications of higher energy efficiency levels, it can be seen that the implications of moving to 30% energy efficiency for the electricity sector are relatively limited. Although the overall renewable energy share in electricity increases compared to the central scenario, overall investment levels remain broadly similar in the electricity sector. It has also no major implications on the renewable electricity mix or the geographical distribution of investments.

Overall, the EUCO27 scenario offers a good benchmark when testing policy options in the electricity sector, as policy options which help moving from a baseline scenario towards the central policy scenario would help achieve a cost-effective deployment of renewable electricity.

5.1.1. Consolidating a framework for cost-effective, and market-oriented and Europeanised support to renewable electricity to promote regulatory certainty

Option 0	Option 1	Option 2	Option 3
• Baseline - **No provisions** on support schemes in the Revised RES Directive	• **No support** for renewable electricity - investments only spurred by **market mechanisms**	• Clarifying the principles through **a toolkit for designing support schemes**	• Further market-orientation through **mandatory move towards investment aid**

➢ ***Option 0:*** *Baseline - No provisions on support schemes in the revised RES Directive*

The current approach would be kept, *i.e.* the Revised RES Directive would not include specific provisions on the design of support schemes beyond allowing the possibility for Member States to opt for having support schemes. This would be left entirely to the revised, post-2020 state aid guidelines and the 2013 Guidance (or any new guidance) for the design of renewables support schemes.

➢ ***Option 1: No support*** *for renewable electricity - investments only spurred by market mechanisms*

The Directive would contain a provision effectively prohibiting any form of operating or investment aid in support of renewable electricity projects. Member States would not be able to opt for renewable support schemes in order to foster deployment of renewables electricity. Investments would only be spurred by a revised market design and a strengthened ETS framework.

➢ ***Option 2:*** *Include strengthened market-based design principles through an EU toolkit*

Building on the principles expressed in the 2013 Guidance for the design of renewables support schemes, as well as the Guidelines on State aid for environmental protection and energy 2014-2020 (EEAG), the Revised RES Directive would provide for the 2021-2030 period a toolkit for the design of RES-E support schemes. The principles expressed would be without prejudice to State aid rules that apply to Member States.

Such European toolkit for market-based and cost-effective support would provide framework principles for Member States to use in designing support schemes including *inter alia* the possibility for Member States to use market-based support schemes, the obligation to tender support in order to achieve value for money or the technology neutrality principle for tenders unless a technology specific approach is preferable (*e.g.* for technology with long term potential).

It would also include provisions to enable the emergence of community-owned schemes in the electricity market and through competitive bidding processes, in order to fully exploit the untapped local potential for the deployment of additional renewable capacity. This would require the introduction of principles aiming at promoting renewable energy communities, including a definition with a minimal set of objective and subjective criteria, the empowerment to consume and produce renewable electricity, specific procedures and grid connexion, and the participation of energy communities in market-based supports schemes (*e.g.* tenders), including *e.g.* simplified administrative procedures enabling them to compete on equal footing with other generators.

Importantly, the framework would enshrine in legislation and expand the requirement to tender support; it would define tender design principles, based on emerging best practices, to ensure the highest cost-efficiency gains. The framework would thus strengthen the use of tenders as a natural phase-out mechanism for support, by which a competitive bidding process determines the remaining level of support required to bridge any financing gap – such level of support being expected to go to zero for the most mature technologies over the course of the 2021-2030 period.

Additionally, the Revised RES Directive would explicitly enshrine the principle that support schemes designed in line with EU indications cannot be revised in a way that retroactively impact the rights related to the level of support received by renewables projects, taking into due account the falling production costs and the need to avoid over-compensation or to address unforeseen technological developments.

The framework would be effective as it would define design principles (i) that ensure sufficient investor certainty over the 2021-2030 and (ii) require the use (where needed) of market-based and cost-effective schemes based on emerging best practice design (including principles that are not covered by the current state aid guidelines). At the same time, the framework would be proportionate by leaving actual implementation to the state aid guidelines (*e.g.* for the definition of thresholds applicable for any foreseen exemptions) and, most importantly, to the case by case, evidence-based, in-depth assessment of individual schemes by the services of DG Competition.

- ***Option 3:*** *Mandatory move towards investment aid*

In addition, the Revised RES Directive would require Member States to design support schemes in such a way that support is not linked to the amount of electricity being generated. Possible investment-based supports include (i) direct capex subsidies per MW or (ii) loan subsidy/guarantee schemes. A progressive transition could be designed, *e.g.* Member States would be required to provide a minimum share of renewables support in the form of investment aid by a certain date. Such support should also be conditional on the actual production of the capacity installed to avoid stranded assets.

5.1.1.1. Introduction to the assessment

Currently, the RES Directive leaves the choice of support scheme design entirely to Member States, subject to Article 107-108 TFUE. In practice, convergence in design occurs, as Member States learnt from each other, and as support schemes need to comply with State aid rules, in particular the Guidelines on State aid for environmental protection and energy 2014-2020[179].

The Commission's ambition for the post 2020 context is that renewable electricity generators can earn an increasing fraction of their revenues from the energy markets based on an enhanced market design – where short term markets are fully developed and integrated and flexibility plays a key role in enhancing the market value of renewables – and a strengthened EU ETS. At the same time, it has to be assessed to what extent energy

[179] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014XC0628%2801%29

and carbon market revenues alone will be sufficient to attract renewable investments at the required scale, in a timely manner.

It is established that a growing penetration of renewables, while not leading to a failure of energy-only markets as such, can aggravate underlying market conditions potentially detrimental to investment incentives, in two ways[180]. First, higher low-marginal-cost variable renewable shares lead to lower average prices (due the so-called "merit order effect"). Second, large shares of variable renewables increase price volatility, in particular leading to the more frequent occurrence of very high as well as very low or even negative prices.

Research also suggests that the behaviour of renewables in electricity markets – and thus their impact on market functioning – is determined by the kind of support they receive[181]. The degree of price exposure determines the trading behaviour of renewables generators, but also plant design and investment decisions[182].

Additionally, empirical evidence (of past tenders) shows that the way support is allocated impacts the cost-efficiency of support. The analysis of past auctions in eight EU-countries and four non-EU countries showed that all those auctions schemes reported efficiency gains in terms of the contracted price or discounts achieved: *E.g.* a price of €84.9/MWh was applied in the second round of the German auction (led in 2015 on ground-mounted solar PV), which is significantly below the ceiling price of €112.9/MWh.[183] Recent auctions for offshore wind in the Netherlands and in Denmark have resulted in strike prices of, respectively, €72.7/MWh[184] and €60.0/MWh[185] – yielding significant reductions in the level of support relative to support awarded in other recent comparable projects.

Against this background, the Revised Renewables Directive could set out framework principles for the design of support schemes in the post-2020 context, laying down common principles ensuring that, when and if support is needed, such support be provided in a form that is (i) cost-effective, (ii) as little distortive as possible for the functioning of electricity markets, and (iii) fosters regional approaches through greater convergence in the design of support.

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180 See for instance Edenhofer et al. (2013), Rubin and Babcock (2013), Winkler (2012)

181 Winkler & al, "Impact of renewables on electricity markets – Do support schemes matter?", Energy Policy 93 (2016)

182 As shown in case studies on Latin America by Battle and Baroso (2011) and Germany by Jâgemann (2014)

183 AURES, *"Auctions for Renewable Support: Lessons learnt from International experiences"* (June 2016). The analysis of past auctions in eight EU-countries and four non-EU countries showed that all those auctions schemes reported efficiency gains in terms of the contracted price or discounts achieved: *E.g.* a price of €84.9/MWh was applied in the second round of the German auction (led in 2015 on ground-mounted solar PV), which is significantly below the ceiling price of €112.9/MWh

184 http://www.dongenergy.com/en/media/newsroom/news/articles/dong-energy-wins-tender-for-dutch-offshore-wind-farms

185 https://corporate.vattenfall.com/press-and-media/press-releases/2016/vattenfall-wins-danish-near-shore-wind-tender/

5.1.1.2. Detailed assessment

Against this background, detailed modelling work was undertaken to assess whether renewables will be able to finance themselves in the energy-only market over the period 2021-2030, *taking into account* (i) the revised ETS framework, (ii) the market re-design foreseen as part of the Market Design Initiative, (iii) expected further declines in the levelised cost of energy (LCOE) of renewables technologies, and (iv) forecasts of wholesale prices. As regards the ETS framework in particular, modelling results presented in the paragraph below assume an increase of ETS linear factor to 2.2% for 2021-30 and implementation of the Market Stability Reserve. This translates into an ETS price reaching 15 EUR/t in 2020, 25 EUR/t in 2025 and 42 EUR/t in 2030 in the EUCO27 scenario, and lower prices of 15 EUR/t in 2020, 22.5 EUR/t in 2025 and 38 EUR/t in 2030 in the baseline (CRA) scenario. Results are presented in more details in Annex 4.

Under Option 1, the implications of the absence of support schemes on the viability of investments in RES-E generation are tested[186]. First, it can be recalled that the EU Reference Scenario 2016 models, *inter alia*, renewables developments post-2020 in absence of dedicated support schemes for new projects. Under this scenario, RES-E developments are below the ones necessary to reach the overall at least 27% target by 2030. However, REF2016 does not reflect the potential impacts that reformed electricity markets, or a reformed ETS including the Commission proposal on a revised linear reduction factor, could have on renewables developments. It also does not consider additional energy efficiency policies needed to achieve 27% energy savings.

As opposed to REF2016, the EUCO27 scenario was constructed with a cost-effective achievement of the 2030 climate and energy targets in mind. This scenario suggests that under the right framework conditions, in particular a reformed ETS, good electricity market functioning, a cost effective set of energy efficiency policies, and equal financing conditions across the EU, it is possible for the majority of renewables investments to develop such that they effectively contribute to the overall achievement of the renewables target. Least cost options are selected, and all costs are recuperated. However, some support is still needed, reflected in the model by the use of RES-E values, which corresponds to a set of unspecified cost-effective incentives promoting investments in renewable electricity projects.

This scenario demonstrates that little support would be needed, and that renewable technologies may be competitive, under the right framework conditions.

It should additionally be noted that the PRIMES model simulates emission reductions in ETS sectors as a response to current and future ETS prices, taking into account, in particular, a perfect foresight of the carbon price progression in the period 2025-50.

It also assumes that investment decisions can be based on a power generation portfolio approach, where profitability of investments is assessed on a portfolio rather than a project by project basis. Because of this portfolio approach, the EUCO27 scenario may not capture that some investments cannot be recuperated when income is only dependent on wholesale markets where high renewable penetration exactly tends to lower the wholesale price.

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186 Annex 5 provides a detailed analysis on viability of RES projects in absence of support schemes.

Therefore, a complementary analysis is provided below, looking more specifically at potential profitability issues for the renewables investments projected to be necessary (in the EUCO27 scenario) to reach the renewables target, when looked at on a project per project basis, and assuming revenues are only based on the wholesale market.

First, this can be assessed by making use of the results of the WESIM model. This model was used to assess investment profitability of RES projects, but did not consider implications of RES developments on other power generation technologies, which is the object of the MD IA. The analysis performed with this model concludes that the investment gap (aggregated capital expenditure for RES-E projects that are not viable without support) would amount to c. EUR 13 billion in 2020, EUR11 billion in 2025 and EUR9 billion in 2030[187]. For the whole 2020-2030 period, this means a cumulative investment gap of about EUR 116 billion. This investment gap represents the amount of investments that would require some support, in case renewable electricity projects are to only receive market revenues from the wholesale electricity market only. It does not mean that public support would need to cover all the investment costs, as it could be that only a marginal support would be sufficient to complement electricity market revenues to make those investments profitable.

More specifically, the WESIM model results show that while only 40% of investments in 2020 as projected in EUCO27 could be financed by wholesale electricity market revenues only, this share increases to 66% in 2030. Onshore and solar PV become gradually profitable and by 2030, and could be financed entirely by the markets. Conversely, technologies such as offshore wind investments cannot be yet fully financed on the markets by 2030. It should be noted at the same time that rapid penetration of renewables has a decreasing effect on both the wholesale price as well as on the CO_2 price (for a given number of ETS allowances on the market), thereby reducing the ability of the market to act as the driver for investments in both renewables and flexible generation.

Table 4: Evolution of required annual investment and investment gap over the 2020-2030 period

Required annual investment (€ bn)	**Biomass**	**Geothermal**	**Hydro reservoir**	**Hydro ROR**	**Offshore wind**	**Onshore wind**	**Solar PV**	**Tidal**	**TOTAL**
2020	0.48	0.00	0.26	0.04	5.54	7.21	8.09	0.24	**21.88**
2025	0.77	0.00	0.41	0.14	8.74	9.43	5.33	0.37	**25.19**
2030	0.94	0.23	0.09	0.69	9.61	8.93	6.75	0.50	**27.74**
Total investment gap (€bn)	**Biomass**	**Geothermal**	**Hydro reservoir**	**Hydro ROR**	**Offshore wind**	**Onshore wind**	**Solar PV**	**Tidal**	**TOTAL**
2020	0.48	0.00	0.23	0.00	5.54	3.55	2.91	0.24	**12.95**
2025	0.00	0.00	0.34	0.00	8.74	0.00	2.26	0.37	**11.71**
2030	0.00	0.00	0.00	0.00	8.99	0.00	0.00	0.50	**9.49**
Share of investment financed solely by the wholesale market revenues[188]	**Biomass**	**Geothermal**	**Hydro reservoir**	**Hydro ROR**	**Offshore wind**	**Onshore wind**	**Solar PV**	**Tidal**	**TOTAL**

187 For additional details on viability gap of RES-e technology assessed with WESIM methodology, see Annex 5

188 Even for those cases where wholesale market revenues are not sufficient to finance solely renewables, they are expected to contribute to provide an increasing fraction of the necessary revenues reducing the need for specific support.

2020	1%		12%	100%	0%	51%	64%	0%	41%
2025	100%		18%	100%	0%	100%	58%	0%	54%
2030	100%	100%	100%	100%	6%	100%	100%	0%	66%

Source: CEPA, central WESIM27 scenario

Such figures are affected by changing some key assumptions. As explained in Annex 4, removing priority dispatch tends to decrease this investment gap, as overall market functioning improves; also increased investors' confidence vis-à-vis ETS price developments decrease it. In fact, the PRIMES model simulates emission reductions in ETS sectors as a response to current and future ETS prices, taking into account, in particular, perfect foresight of the carbon price progression in the period 2025-50. Sensitivities have been performed with the WESIM model to try and capture the impact of imperfect foresight on renewables generators anticipated revenues, which results in a lower share of investments in renewables being viable without support – see Annex 5 for detailed results.

Second, the issue of whether wholesale electricity market revenues would be sufficient to finance investments in power generation is addressed in detail in the Market Design Impact Assessment. First, the MD IA simulates market revenues taking as a constant the level of investments provided by the EUCO27 scenario (PRIMES/IEM). Focusing on the most important results from a RES generators perspective, the analysis shows first that onshore wind across the EU from 2025 and solar PV in the South Europe (excluding small scale) from 2030 make profits on energy-only markets. However, this is not the case of the other RES technologies.

To complement this analysis, it is important to also look at the dynamic behaviour of markets and how markets can also provide investment signals. A different model was used, PRIMES/OM. It confirms that mature RES technologies are among the profitable technologies by 2030. Conversely, less mature technologies, such as wind offshore or solar thermal, remain unprofitable.[189].

All modelling approaches therefore confirm that support needs will gradually phase out over the 2020 decade, once sufficiently high ETS prices and better market functioning are in place, but that for some technologies, even this will not be sufficient.

Under Option 2, a toolkit for market-based and cost-effective support would be defined. These principles would be without prejudice to State aid rules that apply to Member States. The principles would include, *inter alia*, the possibility for Member States to use support schemes, the obligation to tender support in order to achieve value for money, the facilitation of participation of energy communities in the electricity system and in tendering schemes, the technology neutrality principle for tenders unless a technology specific approach is preferable and the protection for investors against 'retroactive' changes.

In particular, the framework would enshrine in legislation and expand the requirement to tender support; it would define tender design principles, based on emerging best practice, to ensure the highest cost-efficiency gains. The framework would thus strengthen the use of tenders as a natural phase-out mechanism for support, by which a competitive bidding process determines the remaining level of support required to bridge any financing gap –

189 For additional details refer to annex 4: Wholesale electricity market revenues and investment in RES-e generation

such level of support being expected to go to zero for the most mature technologies over the course of the 2021-2030 period (see above).

Additionally, the Revised RES Directive would explicitly enshrine the principle that support schemes designed in line with EU indications cannot be revised in a way that retroactively impact the rights related to the level of support received by renewables projects.

Although the direct impacts of implementing this toolkit have not been tested via modelling scenarios, the framework is expected to be effective as it would define design principles (i) that ensure sufficient investor certainty over the 2021-2030 and (ii) require the use (where needed) of market-based and cost-effective schemes based on emerging best practice design (including principles that are not covered by the current state aid guidelines). At the same time, the framework would be proportionate by leaving actual implementation to the state aid guidelines (*e.g.* for the definition of thresholds applicable for any foreseen exemptions) and, most importantly, to the case by case, evidence-based, in-depth assessment of individual schemes by the services of DG Competition.

To support this assessment, one can make use of existing analysis. Recent research has evaluated the impact of various support scheme designs on the dispatch of renewables generators, based on the case of Germany. It found that moving from a feed-in-tariff (FIT) to schemes exposing producers to short term and long term price signals (feed-in-premia and, more so, capacity-based support) resulted in (i) higher average market prices, (ii) lower price volatility, and (iii) a higher market value of renewable – especially in markets characterised by high renewables penetration and low flexibility[190]. These three factors combined can contribute to reducing the need for support for renewables – and missing money issues in general.

At the same time, it is also well documented[191] that support schemes exposing producers to market risks translate, all else equal, into higher cost of capital and thus higher renewables deployment costs. Modelling using the WESIM model shows for instance that moving from support in the form of feed-in tariffs (FIT) to support in the form of floating feed-in premiums (FIP) increases the total cost of support by 5% to 6%, while moving from FIT to fixed FIP increases to total cost of support by 9% to 13%[192]. Overall, the net impact on both total system costs and renewables support costs is difficult to quantify. However, such an analysis does not consider the overall positive impacts on electricity market functioning, and therefore other types of power generation producers, that more market-oriented support schemes would have as opposed to fixed feed-in-tariffs.

As regards tendering, analysis of past tenders suggests that tenders can yield significant cost-efficiency gains[193] - to the extent that they are well-designed. As an increasing

190 In a reference case scenario, moving from FIT to capacity-based support could resulted in 2030 in a c. 8% average price increase, in a 26% average price volatility decrease and an increase of market value for all renewable technologies, *e.g.* from below 20€/MWh to about 40€/MWh for solar PV. Winkler & al, "Impact of renewables on electricity markets – Do support schemes matter?", Energy Policy 93 (2016)

191 See for instance Gawel and Purkus (2013), Kitzing (2014), Klessman et al. (2008)

192 CEPA, "*Supporting investments into renewable electricity in context of deep market integration of RES-e after 2020*", Second interim report (June 2016)

193 AURES, *"Auctions for Renewable Support: Lessons learnt from International experiences"* (June 2016)

number of Member States are introducing tenders, best practice is emerging[194]. Introducing certain best practice principles would (i) support the use of efficient tender designs, while respecting the need to ensure sufficient flexibility, and (ii) through partial harmonisation facilitate the design of joint tenders. The extension of tendering to investment aid would expand such benefits beyond operating aid.

Research also suggests that the behaviour of renewables in electricity markets – and thus their impact on market functioning – is determined by the kind of support they receive[195]. The degree of price exposure determines the trading behaviour of renewables generators, but also plant design and investment decisions[196].

Additionally, empirical evidence (of past tenders) shows that the way support is allocated impacts the cost-efficiency of support. The analysis of past auctions in eight EU-countries and four non-EU countries showed that all those auctions schemes reported efficiency gains in terms of the contracted price or discounts achieved: *e.g.* a price of €84.9/MWh was applied in the second round of the German auction (led in 2015 on ground-mounted solar PV), which is significantly below the ceiling price of €112.9/MWh[197]. Recent auctions for offshore wind in the Netherlands and in Denmark have resulted in strike prices of, respectively, €72.7/MWh[198] and €60.0/MWh[199] – yielding significant reductions in the level of support relative to support awarded in other recent comparable projects.

Against this background, the Revised Renewables Directive could set out framework principles for the design of support schemes in the post-2020 context, laying down common principles ensuring that, when and if support is needed, such support be provided in a form that is (i) cost-effective, (ii) as little distortive as possible for the functioning of electricity markets, and (iii) fosters regional approaches through greater convergence in the design of support.

The RES Directive and the baseline do not open up the potential that could empower energy communities across the EU. Until today energy communities have only developed in a few countries: around 75% of all energy cooperatives are located in AT, DE, DK.

In addition to wider benefits for the local economy, energy communities could increase local acceptance of renewable energy projects and help mobilise the private capital that is needed for the energy transition.

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194 AURES, *"Auctions for Renewable Support: Lessons learnt from International experiences"* (June 2016). Best practices emerge in terms of general auction implementation, auction procedures and awards, eligibility requirements and project realisation

195 Winkler & al, "Impact of renewables on electricity markets – Do support schemes matter?", Energy Policy 93 (2016)

196 As shown in case studies on Latin America by Battle and Baroso (2011) and Germany by Jâgemann (2014)

197 AURES, *"Auctions for Renewable Support: Lessons learnt from International experiences"* (June 2016). The analysis of past auctions in eight EU-countries and four non-EU countries showed that all those auctions schemes reported efficiency gains in terms of the contracted price or discounts achieved: *E.g.* a price of €84.9/MWh was applied in the second round of the German auction (led in 2015 on ground-mounted solar PV), which is significantly below the ceiling price of €112.9/MWh

198 http://www.dongenergy.com/en/media/newsroom/news/articles/dong-energy-wins-tender-for-dutch-offshore-wind-farms

199 https://corporate.vattenfall.com/press-and-media/press-releases/2016/vattenfall-wins-danish-near-shore-wind-tender/

In order to enable energy communities to develop across the European Union, measures are considered to balance the competitive disadvantages that energy communities face in a competitive market. Often energy communities as groups of engaged citizens are less professionalised than commercial project developers. Generally, they only develop one project that could participate in public tenders for support, and by nature they are linked to one geographical location.

Therefore, energy communities might face difficulties competing on equal footing with large-scale players, *i.e.* competitors with larger projects or portfolio[200]. Such tendencies are already observed, *e.g.* for small-scale community power[201]. The trend in renewable support schemes towards market-based mechanisms is most likely to create an increasingly difficult economic environment for community energy projects, severely hampering their development conditions[202].

Measures to offset these disadvantages include enabling condition for energy communities, facilitating participation of energy communities in open, transparent and non-discriminatory tenders for support schemes, and facilitated market integration.

Such regulatory and legislative provisions require precise definitions. These should be as inclusive as possible to prevent excluding actors that should be supported, but as exclusive as necessary to prevent abuse[203]. This is made difficult by the fact that energy communities vary significantly in size and legal form which depends on the company or association laws of the Member States. For this reason the definition considered proposes a list of criteria of which a minimum number needs to be met in order to qualify as an energy community. In any case, only energy communities for energy generation are considered. Supplier cooperatives are not within the scope of these measures. The definition would be based on existing entities (such as SMEs) and for the only purposes of creating an enabling framework. Member States will still have freedom to have their own definition of energy communities.

By 2030, more than 50 GW wind and more than 50 GW solar[204] could be owned by energy communities, *i.e.* respectively 17% and 21% of installed capacity[205], bringing a substantial additional amount of local capital to renewable projects. Opening markets and creating enabling framework for energy communities could therefore help exploit this potential.

Under Option 3, the possibilities for support would be more limited and would require all future support to renewable electricity to be provided in the form of investment support (capacity-based support), not linked to production which would be fully supportive to the new market design. Such an approach would maintain the pricing signal in line with the new market design, and provides incentives for renewables production to fully support the energy market. It may however increase the need for administrative controls to avoid abuse and ensure that assets are properly maintained, and does not provide incentive to maximise renewables production – making reaching a production-based target more

200 Under the Guidelines on State aid for environmental protection and energy 2014-2020

201 Esp. in MS with already high community shares (*e.g.* DE). WWEA,"Headwind and Tailwind for Community Power", February 2016

202 “Renewable Energy Progress Report”, Öko Institute [to be published]

204 The potential of Energy Citizens in the European Union, CE Delft, 2016

205 Based on PRIMES EUCO27 scenario

difficult. It would also result in significant budgetary implications for Member States, as payments would have to be frontloaded. There is finally also little actual experience with supporting renewables through upfront investment aid.

Social impacts

Under Option 1 (prohibition of support), RES-E investments would be insufficient to reach the overall at least 27% target by 2030. It is likely that not reaching the 27% target would have negative social impacts in terms of job creations, growth and security of supply, as compared to the other policy options, and notably the baseline.

As explained above, net impacts on total costs of support are unclear under Option 2 and Option 3, making it difficult to quantify the social impacts implications of such scenarios.

Environmental impacts

In terms of environmental impact, missing the at least 27% target by 2030 will result under Option 1 to a lesser GHG reduction in the power sector from renewables than under Options 0, 2 and 3. At the same time, since the EU ETS cap sets a binding ceiling on the emissions within the sectors covered by the system, missing the RES target would not impact in absolute terms the EU level GHG emission reductions, which would be achieved in any case. It will lead to higher ETS carbon prices to achieve the overall GHG target, which will reduce emissions in other sectors.

However, some environmental impacts are to be expected depending on the type and location of RES-E power generation being deployed. A concentration of RES-E investments in specific countries or regions might create issues in terms of land availability for such projects, or could even in some cases put additional pressure on environmental protection rules for dedicated areas[206]. In the case of the baseline scenario, it projects an increase in electricity generation from biomass, notably as compared to the central policy scenario. Such results can be explained by the assumption of dedicated Member State support included in the baseline scenario. As such, this might create specific environmental issues.

Political feasibility /opportunity

Option 1 would not seem politically feasible, since the prohibition of support schemes would prevent Member States from bridging the funding gap of RES-E and seriously jeopardise the achievement of the 2030 target. Other Options seem to respect the principles of subsidiarity and proportionality.

Stakeholders' opinion

Respondents to the public consultations largely considered that support mechanisms should encourage greater market responsiveness, resulting in gradually decreasing support levels as technologies become mature. Several respondents regard regional

[206] The issue of environmental constraints for the deployment of RES power generation technologies is however reflected in the modelling, via comments received from Member States during the preparation of REF2016. For instance, if a country has an environmental legislation in place banning the deployment of offshore wind in protected areas, this is taken into consideration.

cooperation and consultation as a useful method to reduce differences and facilitate convergence amongst national support schemes.

Discarded options

Option 1 can be discarded as it would materially jeopardise the attainment of the EU-level at least 27% target by 2030, and additionally raises subsidiarity and proportionality issues.

5.1.2. A more coordinated regional approach to renewables support

Option 0	Option 1	Option 2
• Baseline - Continuation of current EU policies	• Mandatory **partial opening of support schemes to cross-border participation**	• Mandatory **regional support schemes**

➢ ***Option 0:*** *Baseline*

The Revised RES Directive would still leave it to Member States to decide the extent to which they want to open their support schemes to cross-border participation, and to enter into joint support schemes or joint projects. However, because such options have not been significantly used to date by Member States, the modelling work conducted in the baseline scenario makes the assumption that no use is made of such cross-border participation, or joint support schemes or projects.

➢ ***Option 1:*** *Mandatory partial opening of support schemes to cross-border participation*

The Revised RES Directive would make it mandatory for Member States to partially open their national support schemes to cross-border participation, up to a level to be defined but representative of the level of physical cross-border interconnections.

Under this option, the general principles for such opening would be set out, *e.g.*: (i) reciprocity, (ii) no double-compensation, (iii) cooperation agreement to allocate support towards each Member States' renewables pledges. A more detailed "blueprint" laying down possible forms of cross-border participation (joint auctions, mutually-opened auctions) could be provided in an annex to the Revised RES Directive (similar to the approach followed for capacity mechanisms).

➢ ***Option 2:*** *Mandatory regional support schemes*

The Revised RES Directive would stipulate that only regional support schemes are allowed and possibly define such regions.

5.1.2.1. Introduction to the assessment

The rationale for "regionalising" support schemes is that a more regional approach limits negative impacts on the energy market and can help Member States to achieve the EU target cost-effectively.

The current Renewables Directive foresees the possibility of cooperation mechanisms in the form of joint support schemes, but such possibility has not been used to date, at the exception of the joint scheme between Sweden and Norway. The current Directive also leaves it to Member States to decide to which degree they want to open their support schemes to non-domestic production. Certain Member States are however working on opening their support schemes to the participation of project developers located in neighbouring countries, also to ensure compliance with other Treaty provisions[207]. In the absence of a common framework for such cross-border access, Member States may implement different solutions, possibly leading to market fragmentation.

5.1.2.2. Detailed assessment

Two options for further regional cooperation are assessed, namely (Option 1) a mandatory partial opening of support schemes to cross-border participation (CRA_crossborder), and (Option 2) mandatory regional support schemes (CRA_regio). Both options have been modelled using as starting point the baseline (CRA) scenario. The WESIM model was also used to test the impacts of cross-border participation. The full description of these scenarios is presented in Annex 4 of this Impact Assessment, while Annex 5 presents detailed results.

This assessment is also based on results from a recent Ecofys study[208] that considers three different scenarios for the development of regional support schemes, *i.e.* (i) limited cooperation, (ii) moderate cooperation and (iii) strong cooperation[209].

Economic impacts

Fostering cross-borders cooperation could lead to a decrease of capital expenditures, thanks to geographical shifts towards better sites that require less renewables capacity to produce the same amount of electricity[210], as shown by several case studies. According to Ecofys, a joint quota system in Scandinavia, which would extend the existing joint quota system between Norway and Sweden to Denmark and Finland, could for example lead to a reduction in capital expenditures of about EUR 680 million over 2015-2020[211]. Optimisation of resource allocation in the case of a joint feed-in premium system in

207 Article 30 and/or 110 TFEU

208 Ecofys, "Cooperation between EU Member States under the RES Directive" (January 2014)

209 In the first case, the used of cooperation mechanisms is reduced to necessary minimum, *i.e.* if a MS cannot fulfil by itself its RES-E target. The "moderate cooperation" scenario, cooperation occurs when country-specific support per MWh RES is limited to €17/MWh. In the "strong cooperation" case, difference in country-specific mechanisms is limited to a maximum of €4/MWh. Although this economic approach doesn't correspond with the three options expressed in terms of different legal frameworks, it is a good proxy to evaluate the impact of fostering cross-borders cooperation

210 Potential cost savings should be assessed against expenditures for additional grid expansion

211 Bush et al., 2014. Cooperation under the RES Directive. Case studies: Joint Support Schemes

Central and Eastern Europe could reduce capital expenditure by about EUR 325 million over 2015-2020[212].

Modelling based on the WESIM model[213] also confirmed the reduction in support costs allowed by a partial opening of support schemes to cross-border participation. The study simulated the impact of France partially opening floating feed-in premium support to Germany for projects completing construction in 2025[214]. The study finds an annual cost saving in the French auction of EUR 90 million over the fifteen-year life of the subsidy.

Comparing PRIMES scenarios, the first element to be observed concerns the change in the renewable energy mix. The 'CRA_crossborder' scenario, and even more 'CRA_regio', scenarios lead to a significant shift between offshore wind investments and solar investments. This is due to the relatively cost-effective potential, under the right framework conditions, *e.g.* financing costs, for solar investments. By further regionalising support schemes, and by harmonising the financing conditions for investments in RES-E projects within a region, more cost-effective investments can be financed, as opposed to the baseline scenario, where each Member State supports its own projects, with its own financing conditions. Yet, the impacts of these changes in the power generation mix are rather marginal when looking at the average electricity prices and average cost of electricity generation. The ETS price remains stable in CRA_crossborder while it increases in CRA_regio[215].

In terms of energy system costs, it can be observed than both scenarios lead to lower system costs than the baseline scenario. CRA_cross border leads to an average reduction of energy system costs of EUR 1.0 billion annually, for the period 2021-2030. Under CRA_regio, the reduction reaches EUR 1.3 billion annually. These benefits continue post-2030, although they slowly fade away in 'CRA_crossborder' while they keep increasing in 'CRA_regio'. Two main factors influence the results: i) first, an allocation of investments where they make more economic sense, as support to RES is harmonised within regions and therefore optimises investments over the availability of RES resources; ii) second, the creation of broad markets at regional level implies broadening the funding, procedures and guarantees at regional level, which can lead to economies of scale and slightly lower access to finance conditions.

Focusing now on the distributional issues, across countries and across technologies, the first element that can be mentioned is that 'CRA_Regio' and 'CRA_crossborder' provide a more balanced renewables power generation mix than the baseline scenario. This is notably visible in the case of 'CRA_regio', where significant solar PV investments take place, as mentioned above. The distribution of investments across Member States is also more balanced than in EUCO. The top three Member States represent 67% of investments in the baseline scenario. This share decreases to 58% in 'CRA_regio'. Conversely, the share of the smallest contributors increases.

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212 The cooperation mechanisms would involve Austria, the Czech Republic, Hungary and Slovakia. Ecofys, Cooperation under the RES Directive - Case studies: Joint Support Schemes (2014)

213 CEPA, "*Supporting investments into renewable electricity in context of deep market integration of RES-e after 2020*", Second interim report (June 2016)

214 The auction is considered technology-neutral and includes only technologies not viable without support. The study assumes an opening corresponding to 10% of the physical interconnection capacity between the host and the off-taker. In the case of France and Germany, under WESIM assumptions for 2025, 10% of the physical interconnection equals 330MW.

215 Detailed comparison tables of the main scenarios are provided in Annex 4

Finally, it can be expected – although the impact has not been explicitly quantified – that regionalisation of support would limit the "cannibalisation" effect, by allowing greater flexibility in the operation of the electricity system and thus reducing the number of low or negative hours when renewables are producing. All else equal, this would reduce the need for support for renewables.

Social impacts

Member States may be reluctant to enter into cooperation mechanisms due to – anticipated or actual – low public acceptance, in particular difficulties in explaining to national taxpayers or consumers that part of their funds may be used to support renewables projects in other countries[216]. Thus, opening schemes may lead to public acceptance issues.

On the other hand, enhancing regional cooperation would have a positive impact on the total cost of support passed on to the final customers. Support cost reduction could be tangible[217]. For instance, the Central and Eastern European joint FIP system could generate cumulative support cost savings of EUR 400 million (2015-2020)[218]. Overall, the need for support at a EU-level between 2011 and 2020 would be reduced by 5.8% in a moderate cooperation scenario and by 10,8% in a strong cooperation scenario, compared to a limited cooperation scenario[219]. This decrease in financial support would enable a decrease in the charge passed on to end-customers.

The comparison of the various scenarios performed using PRIMES does show overall lower renewables supporting costs passed on to consumers in 'CRA_crossborder', and even more so in 'CRA_regio', compared to the baseline scenario. In the case of 'CRA_crossborder, this is reinforced by the fact that the share of investments financed by the market increases compared to baseline, while it does not change significantly in the case of 'CRA_regio'. This is in part because the scenario considers that further regionalisation of support schemes lead to a reduced country risk for investors, and therefore easier access to finance for renewables project developers. However, the additional renewables investments in power generation still need to be financed, and will generally interact and compete with other power generation technologies to determine prices. In the case of the 'CRA_regio' scenario, this translates in an overall increase in electricity prices for households.

Environmental impacts

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216 See for instance the lessons learnt from the Pilot Opening auction between Germany and Denmark (AURES, "The role of auctions in the new renewable energy directive", June 2016) and the case for envisaged cooperation between the UK and Ireland which was put on hold in late 2014, according to some observers because of lack of public acceptance (Ecofys, "Driving regional cooperation forward in the 2030 renewable energy framework", September 2015)

217 NB: Depending on the design of support schemes, the existence of windfall profits at cheaper sites[217] may mean that capital expenditures savings are not fully be passed on through reduced support costs. Indeed, in a technology neutral support scheme, all the RES producers would receive the same support. The level of support is defined by the marginal technologies, *i.e.* the most expensive sites and technologies. Those who have very favourable production sites due to the geographical reallocation encouraged by regional joint support might received more support that actually needed (Ecofys, "Driving regional cooperation forward in the 2030 renewable energy framework", September 2015)

218 Bush et al., 2014. Cooperation under the RES Directive. Case studies: Joint Support Schemes

219 Ecofys, "Cooperation between EU Member States under the RES Directive" (January 2014)

Regional cooperation is likely to encourage renewables deployment in countries with large fossil fuel shares in their energy mix, resulting in a reduction of fossil fuels and CO_2 emissions in those countries. According to the Ecofys scenario[220], a strong cooperation (resp. moderate) would lead between 2011 and 2020 to a fossil fuel avoidance by 0.4% (resp. 0.3%) and a CO_2 emission avoidance by 0.7% (resp. 0.2%) in the power sector[221], without taking into account the impact of the EU ETS. Regional cooperation may also reduce pressure on environmentally protected areas, as mentioned in the previous section, by providing a larger pool of potential sites for RES investments projects than what would be possible if based on national approaches only.

Political feasibility /opportunity

Options 0 and 1 seem politically feasible as they respect principles of proportionality and subsidiarity. Due to its enlarged scope, Option 2 may be more challenging politically and may be seen as contradicting Member States' right to decide on their energy mix. Importantly, additional interconnections could facilitate the political feasibility of moving towards more regionalised support schemes.

Other impacts (competitiveness, markets, innovation…)

No significant impact on SMEs. Nevertheless, they could benefit from some positive impact if part of the projected solar deployment is based on small-scale installations.

It is possible to compare the impact of the various scenarios on electricity prices and energy costs for industry. The impacts of the various options compared to baseline are relatively marginal for industry. Although electricity prices slightly decrease for industry, the energy related production costs slightly increase.

Stakeholders' opinion

Regarding the geographical scope of support schemes, there is a wide variety of opinions across the stakeholder community. While the preferred option by stakeholders (34 %) is a gradual alignment of national support schemes through common EU rules, there is some willingness (17 %) to move further and consider a progressive opening of national support schemes to energy producers in other Member States under some conditions such as, for instance, obligation of physical delivery of the electricity, or having a bilateral cooperation agreement in place. The reasons given to sustain this position generally lie on the fact that the natural conditions of the location in terms of abundancy of the resource (wind or solar) are only one element to be looked at to minimize the cost of deployment of renewable energy (*e.g.* grid issues, market development). As for Member States, those generally believe that cross-border participation to support schemes should be on a voluntarily basis. Overall, the development of a concrete framework for cross border participation is generally welcomed.

Moving towards even further integration by introducing a EU-wide level support scheme, or a regional support scheme, is supported by 24 % and 12 % of the respondents respectively, while keeping national level support schemes that are only open to national

[220] Ecofys, "Cooperation between EU Member States under the RES Directive" (January 2014)

[221] At the same time, since the EU ETS cap sets a binding ceiling on the emissions within the sectors covered by the system, such change would not impact in absolute terms the EU level GHG emission reductions.

renewable energy producers is the preferred option for 13 % of the respondents. Several respondents highlight some possible risks and political sensitivities associated with schemes entailing further integration, as those could imply citizens in one Member State having to contribute to renewables' development in another Member State.

Discarded options

Option 2 may raise issues of proportionality and can be regarded as politically unfeasible.

5.1.3. Reducing the cost of capital for renewable electricity projects

Option 0	Option 1	Option 2
• Baseline	• EU-financial instrument with **wide eligibility criteria**	• EU-financial instrument in support of **higher-risk RES projects**

➢ ***Option 0:*** *Baseline*

No specific financial instrument in support of renewables generation projects. Public investment support would continue to be provided in certain Member States through national or sub-national programmes (using national and sub-national budgets and/or structural funds), and through any EU-level facilities and instruments having an investment period going beyond 2020.

➢ ***Option 1:*** *EU-level financial instrument with wide eligibility criteria*

An EU-level financial instrument would be created or, preferably, existing instruments would be prolonged post-2020 (in particular EFSI), which would support investments in renewables projects. As under current EFSI, renewables would (i) compete against other sectors for funding, and (ii) eligibility criteria for support would be defined widely and allow for a large variety of technologies and all Member States to benefit from support.

➢ ***Option 2:*** *EU-level financial instrument in support of higher-risk renewables projects*

As under Option 1, but support would go to various "high cost of capital" renewable projects, which may be (i) projects using less mature technologies, (ii) projects in Member States facing a high cost of capital, and/or (iii) projects of regional dimension. Option 2 could be stand-alone, or, preferably, come *in addition* to Option 1 – for instance through a dedicated "high risk" guarantee and different eligibility criteria.

As an optional feature, access to such guarantee could be limited to certain Member States having ambitious renewables national commitments – according to criteria to be defined.

5.1.3.1. Introduction to the assessment

Renewable electricity projects are capital intensive - they require large upfront capital investments combined with low operation and maintenance costs. Given this frontloaded cost structure, the weighted average cost of capital (WACC), which reflects the perceived risk of a project from an investor point of view, is decisive to the viability of a RE project[222]. A high cost of capital thus materially increases the overall investments required to meet a given deployment target.

WACCs of renewables projects are driven by several risk factors that could be classified into three main categories, namely (i) country-specific risk, (ii) sector-specific risk and (iii) project specific risk[223]. Significant differences in WACC for renewables projects are found across the EU. WACC of onshore wind projects, for example, were estimated in 2014 to vary between 3.5% (in Germany) and 12% (in Greece)[224]. Country-specific and sector-specific risks explain a large share of this gap.

Currently, investments in renewables tend to focus in mature renewables technologies in countries with low perceived risks corresponding to low cost of capital, with only two Member States (the UK and Germany) receiving over two thirds of all investments into RES-E new investments as well as mergers, acquisitions and refinancing activity in 2014 and 2015[225].

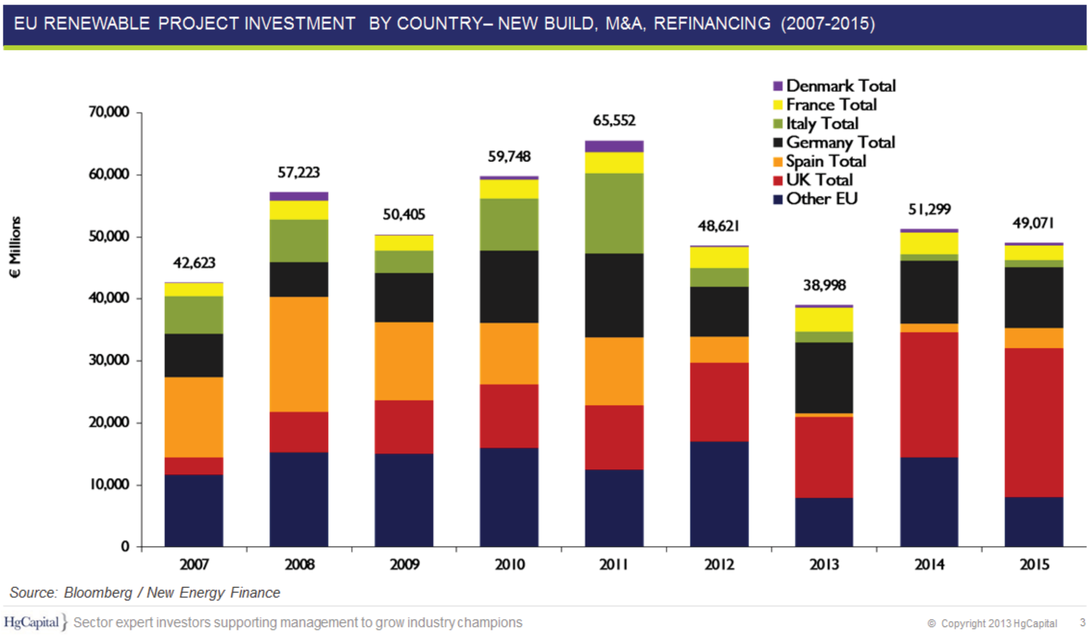

Figure 9
Source: Bloomberg New Energy Finance / Hg Capital

222 For a typical utility-scale solar PV project, financing costs represent 50% of total projects costs when the WACC reaches 9%. Source: IEA-RETD, "RE-COST Study on Cost and Business Comparisons of Renewable vs. Non-renewable Technologies", July 2013

223 REBEL, "Study on the impact assessment for a new Directive mainstreaming deployment of RE and ensuring that the EU meets its 2030 renewable energy target", Interim report (Part II), April 2016

224 Dia-core study; full report available on: http://diacore.eu/images/files2/WP3-Final%20Report/diacore-2016-impact-of-risk-in-res-investments.pdf

225 UNEP and Bloomberg New Energy Finance, "Global Trends in Renewable Energy Investment 2016"

The risk is twofold: (i) overall investments into renewables generation projects may be discouraged by high cost of capital and thus be insufficient to meet the 2030 target; (ii) and/or investments may concentrate in mature technologies in low perceived risk countries, leading to a sub-optimal medium- and long-term deployment at EU-level and a lack of exploitation of the potential of higher WACC countries.

Financial instruments can help lower the WACC of renewables projects, decreasing the overall investment cost required to meet the 2030 target. As way of illustration, a recent study found that risk-sharing schemes could reduce the WACC of offshore wind projects by 14% to 23%, depending on Member States[226] – which in turn would translate into material investment cost reductions.

Options related to the creation of renewables-focused financial instruments have been primarily assessed using variants to the baseline scenario.

5.1.3.2. Detailed assessment

Economic impacts

The impact of Option 1 (regional projects) is difficult to assess quantitatively as this may only concern a limited number of projects and installed capacity. Therefore, results would very much depend on overall funding available and on the pipeline of projects being developed. Still, projects of cross-border dimension tend to have higher administrative complexities and costs (in relation *e.g.* to environmental permitting and grid connection), typically translating into higher cost of capital relative to similar, non cross-border projects. As such, they would be expected to benefit materially from a guarantee scheme.

Option 2 considers a scenario where a subset of riskier projects (see Annex 4 for more details) can benefit from an EU-guarantee for part of the project financed through debt. It has been declined in two variants and assessed in detail via modelling work. In the first variant ('CRA_countryspec'), the modelling assesses the impacts of concentrating access to the EU financial instrument to a subset of Member States, the ones with the initial highest cost of capital for renewables projects, for all technologies. In the second variant, ('CRA_techspec') the focus is put on a limited number of riskier technologies having a high cost of capital[227], but in all Member States. In both cases, a reduction in the WACC for indivdual projects benefiting from the guarantee of 15%[228] compared to the baseline is assumed and put as an exogenous change in the model.

Regarding the power generation mix, at EU level, the changes are marginal in the 'CRA_countryspec' scenario as compared to the baseline (CRA) scenario. Average costs of electricity generation are slightly lower. The share of wind onshore and biomass slightly decreases. The decrease in the share of wind is confirmed when observing investment cost patterns, since such investments decrease as well. However, the

[226] CEPA, "Supporting investments into renewable electricity in context of deep market integration of RES-e after 2020", Second interim report (June 2016)

[227] Namely tidal, geothermal, offshore wind, biogas, biomass solid and bioliquids

[228] CEPA, "Supporting investments into renewable electricity in context of deep market integration of RES-e after 2020", Second interim report (June 2016) – the study estimates for instance a reduction in WACC through "development finance" of 14 to 23% for offshore wind

dispersion of investments across Member States is more balanced, when compared to CRA scenario.

Changes are more significant when considering the 'CRA_techspec variant'. This scenario leads to significantly more investments in wind offshore, which translate into an important increase in the overall RES-E share. However, this has no major impact on electricity prices or on average cost of electricity generation. In terms of investments, this scenario generates much more RES-E investments than the baseline scenario, in particular in the areas where dedicated support is concentrated, namely wind offshore and tidal. It also leads to much more concentration of investments in specific countries, the ones with the highest wind offshore potential. Finally, it should be noted that the ETS price is significantly negatively affected by the deployment of additional RES technologies under these conditions, if we are to keep the same overall GHG emission reductions in the ETS sector. This would limit the role of the energy-only market to drive investments in renewables.

The 'CRA_countryspec' scenario leads to lower energy system costs than in baseline. On average, energy system costs are EUR 1.5 billion lower in this scenario than in CRA. This result is also confirmed by looking at developments post-2030. Conversely, the CRA_techspec scenario translates into significantly higher energy system costs. This is the result of a combination of factors: i) a significant increase in RES-E investments compared to baseline; and ii) a concentration of such investments in more expensive technologies. It must be noted that the potential benefits of such concentration of investments on technological progress and cost reduction, notably if this leads to technological breakthrough, may not be fully captured by the model. For instance, as regards offshore wind in particular, recent tenders have cleared with a cost of support of around 80€/MWh, which is below the cost assumptions made under REF2016 and other policy scenarios conducted for this and other related Impact Assessments.

Finally, it is also worth comparing the RES-E shares across Member States between the baseline and CRA_country spec. As expected, the RES-E share increases in the countries benefitting from the support, to the detriment of other Member States with better initial financing conditions but lower renewables potential. In other words, this scenario achieves a more balanced deployment of renewables across the EU at a lower cost than continuation of purely national-based practices.

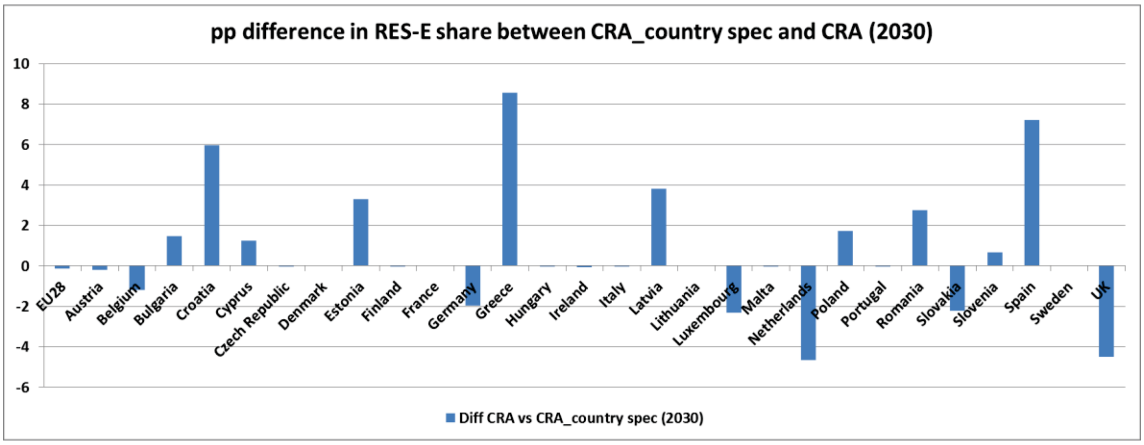

Figure 10 – Percentage points difference in RES-E share between CRA_country spec and CRA (2030)
Source: PRIMES

Under all options, it should be noted that unconditional access to financial instruments may reduce the need for Member States to improve financing conditions via better framework conditions, and would therefore question the initial assumptions considered in the modelling of a clear reduction in the WACC for all projects financed. Such underlying framework conditions are essential for the results to hold. This may imply that access to the funds is made conditional upon Member States delivering on certain measures (*e.g.* administrative procedures for renewables).

Social impacts

'CRA_countryspec' shows overall lower renewables supporting costs passed on to consumers. This is also explained by the fact that a higher share of investments can be financed by the markets. As some countries receive additional guarantee to finance investments, the need to rely on operational support becomes of course more moderate. The overall impact on electricity prices is also positive, as prices for households slightly decrease compared to the baseline. Financial tools that reduce the WACC of the project would decrease the need for direct financial support, alleviating the financial cost of support for end costumers. Net gain would however depend on the exact structure and cost of the guarantee scheme itself (capital cost of opportunity, portfolio losses, and administrative costs).

'CRA_techspec' shows overall much higher renewables supporting costs passed on to consumers. The impact is however much more limited on electricity prices, due to the overall factors influencing the electricity mix and therefore price formation.

Environmental impacts

The option of support chosen will have an impact on the renewables energy mix by unleashing investment in certain resources abundant in higher-cost of capital Member States. However, no impact can be observed on GHG emissions since all scenarios reach a 40% GHG emission reduction by 2030.

Political feasibility /opportunity

All options can be seen as respecting the principles of proportionality and subsidiarity. Political feasibility however depends on the amount of funding foreseen, without pre-empting discussions on the future multiannual financial framework of the Union.

Other impacts (markets, innovation…)

The options designed will not have a significant impact on SMEs at EU level. Nevertheless, they could benefit from some positive impact if part of the solar deployment is based on small-scale installations[229]. No significant impact was identified as regards impacts on energy costs and electricity prices for industry.

5.1.4 Administrative simplification

Renewable Electricity Directive 2001/77/EC and the RES Directive oblige Member States to streamline administrative procedures for renewable energy. However, administrative barriers remain an obstacle to the deployment of renewables. With the upcoming revision, the issue becomes even more relevant on EU level, as the Revised

[229] http://ec.europa.eu/energy/sites/ener/files/documents/1_EN_autre_document_travail_service_part1_v6.pdf.

RES Directive will not contain national targets. The options proposed in the section build on Article 13 of the RES Directive and on Article 8 of Regulation 347/2013 (the "TEN-T" Regulation) for projects of common interest. Article 13 obliges Member States to clearly define permitting procedures with transparent timetables, provide comprehensive information, streamline and expedite administrative procedures and provide facilitated procedures for small projects.

Option 0	Option 1	Option 2
• Baseline - current provisions (Article 13 (1)) apply until 2030	• Reinforced provisions with "one-stop-shop" • Introduction of time limits with a range of possible duration of permitting process • Facilitated procedures for repowering	• All of Option 2 + • Maximum time limits for permitting with automatic approval after deadline • Publication of project developer manuals • Compulsory simple notification procedures for small household-size projects • Facilitated procedures for medium-sized projects

➢ ***Option 0:*** *Baseline*

This option consists in the extension of current Article 13 (1) rules on administrative procedures (no-change) until 2030. With such an option, the subsidiarity principle will be respected, since Member State will be free to find the most effective way of streamlining administrative procedures for renewables. However, the current provisions have been too vague to be enforced effectively and administrative barriers continue to exist.

➢ ***Option 1:*** *Reinforced provisions with "one-stop-shop", time ranges and facilitated procedures for repowering*

This option consists of a reinforced Article 13(1). In addition to the current obligation to ensure that '*certification and licensing procedures … are clearly coordinated and defined, with transparent timetables*' this option proposes a maximum time range is specified after which the competent authority needs to give a decision on the application. Furthermore, this option requires Member States to designate a single administrative contact point (one-stop-shop) for permit granting similar to the provisions of the TEN-E Regulation. In order to respect the subsidiarity principle, Member States would nevertheless have the freedom to choose the most appropriate implementation rules. Moreover, this option proposes facilitated procedures for the repowering of renewable energy projects in order to ensure that assessments that have been conducted do not need to be repeated.

➢ ***Option 2:*** *Reinforced provisions with "one-stop-shop" and time limits, automatic approval, and compulsory simple notification for small projects*

This option would consist of all the elements of Option 1. However, instead of a time range for the permitting process, this option prescribes a fixed deadline. A "*defined maximum time-limit for permitting procedures, and effective consequences if deadline is missed*" as called for by 85% of stakeholders who expressed a view on this topic in the public consultation. In order to improve the enforceability of this deadline, the option also includes an automatic approval if no answer is received by the end of the deadline. The option also includes simple notification (instead of authorisation process) for household-size renewable energy projects and facilitated procedures, such as shorter time limits, for medium-size renewable energy projects.

5.1.4.1. Introduction to the assessment

Article 13 (1) of the current RES Directive mandates simplified, streamlined, expedited and coordinated administrative procedures. However, the current directive was only partly successful in reducing these barriers and streamlining the various elements of the permitting process. The REFIT evaluation and the Renewable Energy Progress Report of the European Commission found that several administrative barriers continue to exist across Member States and have a negative effect on the costs and the deployment of renewables. It is concluded that greater administrative simplification is needed.

Administrative costs contribute significantly to the overall project cost: In France, for instance, the administrative costs of a wind project account for 15% of project costs[230]. Project delays are also expensive: a one-year delay results in 50 % of additional regulatory costs and a 0.25 % increase in the cost of debt when feed-in tariffs are digressive. Reducing administrative burden through simplification (based on best practices and existing legislation) can therefore reduce the costs for the deployment of renewables.

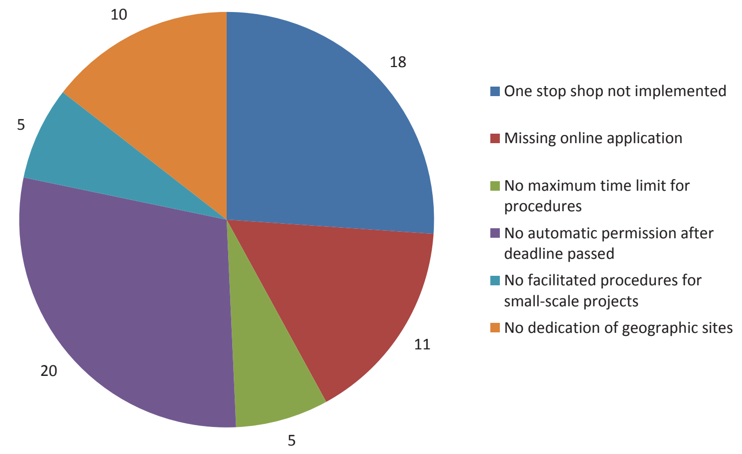

Figure 11: Administrative barriers present in European Member States in 2014[231]

[230] Interim RES Report, section 2.3.

[231] “Renewable Energy Progress Report”, Öko Institute [to be published]

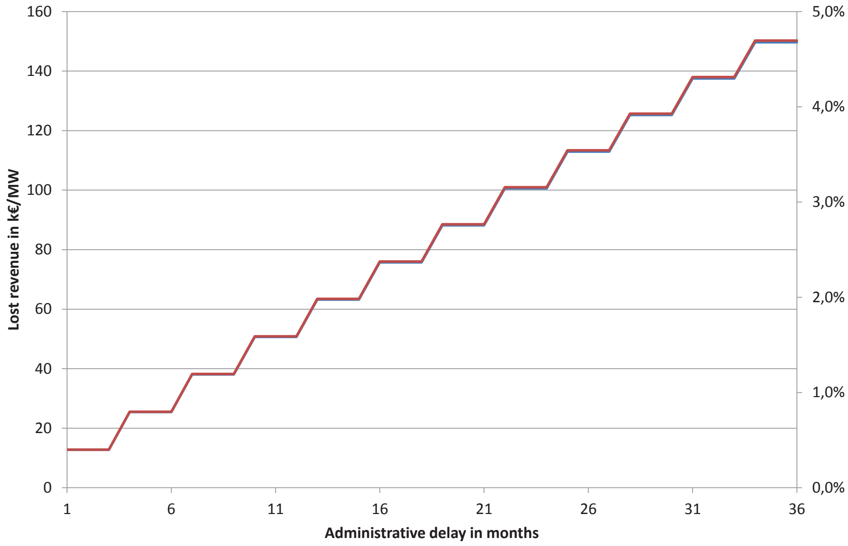

Figure 12: Lost revenue due to administrative delay[232]

5.1.4.2. Detailed assessment

The proposed options precise requirements that already exist in the current article 13: it requires Member States to provide comprehensive information (addressed through development of manuals) and streamlining, coordinating and expediting the permitting process (addressed through one-stop-shops). Similar requirements exist in the TEN-E Regulation (EU) No 347/2013: Article 8.3 proposes one-stop-shops and Article 9.1 requires manuals.

Both measures are regarded as best practice for permitting procedures across sectors by other EU legislation[233] and by OECD publications[234] and are requested by stakeholders in the public consultation. Yet, several Member States have not implemented them for the permitting of renewable energy projects[235]. Manuals are a low-cost no-regret option as the knowledge required for such a manual should already exist in the administrations of Member States.

Time limits for authorisation projects exist in more than half of the Member States and are regarded as best practice for administrative procedures generally[236]. They can also be found in Article 10 of the TEN-E Regulation (EU) No 347/2013. In particular in combination with an automatic approval after the deadline, they are the most effective way to limit the time for permit granting.

232 Source: "Renewable Energy Progress Report", Öko Institute [to be published]

233 Services Directive 2006/123 EC

234 OECD, "From red tape to smart tape. Administrative simplification in OECD countries", Paris, France, p. 30: "*the one-stop shop concept has been implemented in a vast number […] combinations. There is evidence that many of the variations of this basic idea have been successful in reducing administrative burdens on businesses and the general public. These gains have been experienced as reductions in the time and cost invested in seeking information, especially on licence and permit requirements*"

235 "Renewable Energy Progress Report", Öko Institute [to be published]

236 "Renewable Energy Progress Report", Öko Institute [to be published]taken from OECD, "From red tape to smart tape. Administrative simplification in OECD countries", Paris, France, p. 11

The automatic approval under Option 2 would only be possible when it does not collide with requirements rooted in other European legislation, such as the potential need for an environmental impact assessment[237]. Even though automatic approval does not necessarily improve certainty for project developers who might see their project challenged in courts after a permit is granted automatically, such a provision would set clear performance standards for national administrations and would increase the enforceability of time limits. However automatic approval is questionable with regards to subsidiarity.

Economic impacts

The experience of introducing a one-stop-shop for so-called ICPE projects[238] in seven French regions in 2014 shows the effects of a one-stop-shop on permitting times. The one-stop-shop reduced the average permitting duration for ICPE projects to 259 days compared to 431 days for projects without this measure[239].

Simple notification for household-sized projects and tighter deadlines for medium-sized projects as proposed in Options 1 and 2 are expected to facilitate the uptake of distributed generation. The impact of these particular measures is expected to be felt in Member States that do not have measures in place for small-scale projects yet. According to the RES Report, this was the case in Bulgaria, Estonia, Latvia, Slovenia and Slovakia in 2014[240].

Simplified procedures for repowering, as proposed in Option 1 and 2, should make repowering projects less costly. According to industry estimates up to 76GW of the EU's onshore and offshore wind energy capacity will come to the end of their operational life between 2020 and 2030 (of today's installed capacity is 142GW)[241] showing that there is significant potential for the continued deployment of renewables when repowering is simplified. The business as usual option does not contain any specific provisions on repowering.

Social impacts

It is expected that a more efficient administration will not have an immediate social impact.

The maximum time limits for permit granting are not expected to have a negative social impact. Time limits already exist in 23 Member States and a limit of 3.5 years allows sufficient time to consult stakeholders also for large projects.

Environmental impacts

Administrative simplification is expected to contribute to a favourable environment for renewable energy projects. However, it is difficult to relate the direct impact of

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237 Strategic Environmental assessment under the SEA Directive (2001/42/EC- OJ L 197, 21.7.2001, p. 30–37), Environmental impact assessment under the EIA Directive (2011/92/EU, OJ L 26, 28.1.2012, pp. 1-21, as amended by Directive 2014/52/EU, OJ L 124, 25.4.2014, pp. 1-18) and appropriate assessment under the Habitat Directive (92/43/EEC , OJ L 206, 22.7.1992, p. 7)

238 facilities classified in view of protecting the environment

239 "Renewable Energy Progress Report", Öko Institute [to be published]

240 RES Report, p. 41

241 Figures provided by WindEurope

administrative measures proposed to environmental results, such as the replacement of fossil fuel generation with renewable energy generation.

Political feasibility /opportunity/subsidiarity

The options are in line with existing legislation (article 13 of the current RES Directive, TEN-E Regulation) and with common practice in a number of Member States. Administrative simplification was supported by a large majority of respondents in the public consultation, including some Member States.

All options, with the exception of an automatic permit granting in Option 2, respect the subsidiarity principle. The measures do not require changing the content of the permitting process but they oblige Member States to set up coherent administrative structures at the appropriate level. This leaves Member States room to develop measures that are best suited to local circumstances while at the same time specifying the existing provisions and thus making them more enforceable.

Action needs to be taken at European level since the EU RES target for 2030 is mandatory for the EU as a whole and because the reduction of administrative burden can contribute significantly to achieving this target. The existing measures were not specific enough to be enforced effectively.

Impact on SMEs

A simpler permitting procedure is particularly helpful for small actors which have fewer resources and less experience in dealing with different administrative responsibilities.

5.1.5. Overall comparison of the options to increase renewable energy in the electricity sector (RES-E)

	Overall impact			**Key objectives**		
Policy option	Social	Economic	Environmental	Effectiveness	Efficiency	Coherence
Consolidating a framework for a cost-effective, market-oriented and Europeanised support to renewable electricity to promote regulatory certainty						
Option 0 - Baseline	0	0	0	0	0	0
Option 1 - No support for renewable electricity - investments only spurred by market mechanisms	- -	- -	- -	- - -	0	- - -
Option 2 – Clarifying the	+/-	+	0	++	++	++

rules through a toolkit						
Option 3 - Mandatory move towards investment aid	+/-	+	0	-	+	++
	A more coordinated regional approach to renewables support					
Option 0 - Baseline	0	0	0	0	0	0
Option 1 - Mandatory partial opening of support schemes to cross-border participation	+	+	0	+	+	++
Option 2 - Mandatory regional support schemes	+	++	0	+/-	+	++
	+,++,+++ : positive impact (from moderately to highly positive) 0 : neutral or very limited impact -, --, --- : negative impact (from moderately to highly negative)					
	Reducing the cost of capital for renewable generation projects					
Option 0- Baseline	0	0	0	0	0	0
Option 1 - EU-level financial instrument with wide eligibility criteria	not assessed in details	not assessed in details	not assessed in details	not assessed in details	not assessed in details	not assessed in details
Option 2 - EU-level financial instrument in support of higher-risk RES projects	+	+	0	++	++	+++

Administrative Simplification						
Option 0 - Baseline	0	0	0	0	0	0
Option 1 - Reinforced provisions with "one-stop-shop", time ranges and facilitated procedures for repowering	Not assessed	++	n/a	++	++	++
Option 2 - Reinforced provisions with "one-stop-shop" and time limits, automatic approval, and simple notification for small projects	Not assessed	+++	n/a	+++	+++	+++
+,++,+++ : positive impact (from moderately to highly positive) 0 : neutral or very limited impact -, --, --- : negative impact (from moderately to highly negative)						

5.2. Options to increase renewable energy in the heating and cooling sector (RES-H&C)

The table below provides an overview of the options discussed in this section.

Challenge	Drivers	Policy Options
Mainstreaming Renewables in H&C supply	Uncertainty regarding the heating and cooling sector strategy Projected contribution of H&C not in line with cost effective decarbonisation path Lack of cost internalisation: market failures due to inexistence of ETS signal for the bulk of H&C sector hence no incentive for fuel switch	0. Baseline - Continuation of Current EU policies including indirect RES measures in the EPBD and EED 1. RES H&C obligation on fossil fuel suppliers a. Gradual approach b. Universal Approach 2. RES H&C obligation on all energy suppliers a. Gradual approach b. Universal Approach

Facilitating of RES in District Heating and cooling Systems	Projected contribution of H&C not in line with the high potential of District Heating for cost-effective decarbonisation No incentive to improve performance of / grant access to to district heating/cooling system	0. Baseline - Continuation of Current EU policies 1. Continuation of current requirements with best market sharing 2. Energy Performance Certificates and creating access rights to local H&C systems 3. Option 2+ further reinforced consumer rights

5.2.1. *Mainstreaming renewables in heating and cooling supply*

Option 0	Option 1	Option 2
• Baseline - Continuation of current EU including **indirect RES measures in the EPBD and EED**	• **RES heating and cooling obligation on fossil fuel suppliers**	• **RES heating and cooling obligation on all energy suppliers**

The purpose of the proposed measures is twofold: on the one hand, address persisting market failures in the area of heating and cooling, and on the other hand, contribute as a 'gap-avoider', and ultimately (following mid-term review of EU progress towards 27% target) as a 'gap-filler', to the achievement of at least 27% renewables share at the EU level by 2030.

The following options are closely interrelated with measures on energy efficiency and energy performance in buildings, which are respectively addressed within the initiatives for the revision of the Energy Efficiency Directive and the Energy Performance of Buildings Directive. However, as detailed below, the impact of these legislations on renewable deployment has so far remained limited, and is not expected to substantially increase post-2020. Therefore a complementary initiative targeted on heating and cooling across all energy users (industrial, residential and tertiary) is deemed necessary.

➢ ***Option 0:*** *Baseline*

The RES Directive requirements with regard to renewable heating and cooling as well as information and training (Article14) are included in the Revised RES Directive and continue after 2020. The provisions of revised EED and EPDB concerning renewables as currently proposed are implemented, therefore renewable energy technologies in buildings will be indirectly promoted through legal requirements on building energy performance, including nearly zero energy buildings, methodologies for calculating the energy performance of buildings and building renovation and energy efficiency measures as included in the initiatives for the revision of the Energy Efficiency Directive and the Energy Performance of Buildings Directive.

Specific support for RES-H&C technologies that were present in 2020 at national level continue to be in place, with however a slight decrease in volume due to the absence of post-2020 targets. Renewable energy technologies will need to compete with fluctuating fossil fuel prices and distortive subsidies for fossil fuels with no corrections through ETS in this sector.

Synergies with energy efficiency initiatives and Article 13

The **Energy Efficiency Directive** requires Member States to carry out comprehensive assessments of national potentials for high-efficiency cogeneration and/or efficient district heating and cooling, updating these assessments every five years. Should these assessments identify a potential, Member States are obliged to take adequate measures for efficient district heating and cooling infrastructure to be developed and/or to accommodate the development of high-efficiency cogeneration and the use of heating and cooling from waste heat and renewable energy sources. The Directive also targets energy end use efficiency, requiring Member States to achieve annual energy savings. However, taken in isolation, these provisions of the EED do not include explicit requirements to Member States to foster renewable energy deployment in the heating and cooling sector. Member States may promote efficient district heating and cooling, *i.e.* using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat. Since district heating covers **around 8%** of the heating and cooling energy mix in the EU[242] such provisions are **not sufficient to capture the renewable energy potential** in the largest segment of the EU heating and cooling market – the individual boilers at building level, and in the industry sector, where significant potential for fuel-switching remains. Almost 50% of the EU's buildings are equipped with inefficient, fossil fuel based boilers, many beyond their technical lifetime[243].

The **Energy Efficiency Directive** also allows end –use savings generated by renewable energy sources under Article 7 (promoted by measures under the Energy Efficiency Obligation Schemes or alternative measures), as long as they trigger genuine end-use savings as required by this policy focusing on reduction of energy needs by buildings and other end-use sectors. By 2020, a proposed amendment to the Energy Efficiency Directive would allow Member States to count certain amount of renewable energy generated on/in buildings for own use as a result of new RES heating or cooling installation (as exemption subject to 25% cap) to fulfil their end-use energy saving requirement. This possibility will come on the top of the current 3 exemptions that Member States are already using and might therefore have limited impact. The expected impacts would be all the more limited as the use of exemption would be optional, and limited to 25% of the Energy Efficiency Obligation.

Under the revised RES Directive, Member States which already have designated obligated parties under the energy efficiency obligation schemes (so far put in place in 15 Member States, but a couple more of MS intend to set the scheme in near future) in line

[242] 8% in 2013 – source : Fraunhofer, 2016
[243] An EU Strategy for Heating and Cooling, COM (2016) 51/2

with Article 7 of the Energy Efficiency Directive[244], will also have the possibility to define the same obligated parties in the heating and cooling obligation scheme under the amended RES Directive. While energy efficiency obligation schemes and renewable energy schemes for heating and cooling would contribute to two distinct, but mutually reinforcing objectives of reducing the overall energy end use and increasing the share of renewable energy and fuels in the heating and cooling, using existing implementation structures where they have already been established for the purposes of compliance with the EED can substantially reduce the administrative implementation burden at Member State level.

The **Energy Performance for Buildings Directive** (EPBD) incentivises building level energy performance improvements for new and deeply renovated buildings. The energy performance of building EPBD does not specifically target renewable energy promotion. The contribution of renewable energy sources to the improvement of the energy performance of buildings competes, ideally, on an equal footing with measures to reduce the energy needs (*e.g.* insulation) and to improve technical building systems' efficiency (*e.g.* switch from oil based to gas condensing systems).

In line with this principle and in order to make sure that the implementation of the EPBD simultaneously ensure the transformation of the building stock and the shift to a more sustainable energy supply, a proposed amendment in the EPBD IA will ensure that energy performance of buildings equally treats: (a) the energy from renewable sources that is generated on-site (behind the individual meter, *i.e.* not accounted as supplied), and (b) the energy from renewable energy sources supplied through the energy carrier. Fair competition of technologies will contribute to upfront cost reduction with positive impact on cost-effectiveness, resulting in a continuous tightening of minimum energy performance requirements, with positive impacts on the uptake of renewables. Under the current Article 8, the EBPD also covers existing buildings, by introducing performance requirements on the replacement/upgrade of technical building systems. When undertaken out of a major renovation, the interventions on technical building systems are limited to individual component of the system. Despite the actual improvement in efficiency, such upgrades remain in the same technology and are therefore not likely to trigger fuel-switching to renewables.

However, between 2020 and 2030, new buildings will only account for **6% of the building stock**, with the same order of magnitude[245] for deep renovations. Therefore, the majority of the residential sector, *i.e.* the existing building stock, will remain untouched over the period. Since buildings only represent around 55%[246] of all heating and cooling consumption, the EPBD would at very best tackle between 6% and 10% of the heating and cooling demand[247]. Dedicated complementary measures to support the development of RES and the relevant industrial sector are therefore needed.

In addition, **Article 13(4)** of the renewable energy directive requires Member States, where appropriate, to define minimal levels of renewables for new and deeply renovated buildings. As of February 2016, 22 out of 28 Member States had minimum renewables

244 Directive 2012/27/EU

245 6% to 14%, EC draft calculation

246 Included commercial buildings, Eurostat 2016

247 Considering EBPD will only address heating and cooling, which is very unlikely. These figures should therefore be considered maxima.

requirements in their national building regulations[248]. However, requirements vary between building types, renewables technologies and compliance thresholds[249]. Additionally, on all aspects of Article 13, given its still fragmental application and the lack of research, it is difficult at this stage to assess the additional impacts from the RED in terms of effectiveness[250].

The **Ecodesign and Energy Labelling directives**[251] create an enabling framework for the uptake of more efficient products on the market, by establishing minimum energy efficiency standards for manufacturers and by helping consumers choose energy efficient products (*e.g.* a heat pump or condensing gas boilers vs. a traditional gas boiler). While these measures prevent the most inefficient boilers from being placed on the market and contribute to raise consumer awareness, they do not *per se* accelerate the market uptake of renewable energy based heating and cooling systems.

- ***Option 1:*** *Renewable energy obligation on fossil fuel and fossil fuel based energy suppliers for heating and cooling*

A renewables heating and cooling obligation could be included in Revised RES Directive, requiring that each Member State oblige their designated energy suppliers who sell fossil fuels or fossil energy for heating and cooling to achieve a mandatory share of renewables in the total fuel/ energy sales volume for heating and cooling.

However, given that energy and fuel suppliers who already have renewables in their portfolio would not be required to be part of this obligation, this could lead to fictive renewables share claims in order to gain exemption from the obligation scheme. Eventually this might not lead to increased renewables consumption volumes in a given Member State as energy and fuel suppliers who already partially sell renewables and could trade their renewables component with fossil fuel suppliers would not necessarily be motivated to continue to expand their renewable production or deployment.

If the renewables heating and cooling obligation addressed only the non-renewable part of the heating/cooling market, about 83%[252] of the total EU final energy demand for heating and cooling (excluding electricity) could be potentially covered.

- ***Option 2:*** *Renewable energy obligation on all fuel and fuel based energy suppliers for heating and cooling, including those already supplying renewables*

A renewables heat and cooling obligation could be included in Revised RES Directive, requiring that each Member State oblige their designated energy suppliers for heating and cooling to achieve an increase in the share of renewables in their total annual sales volume by 2030. Unlike in Option 1, in Option 2 every supplier would in principle be obliged with the exemption of those supplying 100% renewables.

If all non-renewable and mixed portfolio (including renewable fuel and technology) suppliers would be covered in the renewable energy obligation scheme, about 98%[253] of the EU heating and cooling market (excluding electricity) could be potentially addressed.

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248 Concerted Action on Energy Performance of Buildings and ECOFYS, 2014
249 CE Delft, *Mid-term evaluation of the Renewable Energy Directive*, 2015
250 source : Refit Study, 2015, CE Delft
251 Respectively, Directive 2009/125/EC and Directive 2010/30/EU
252 Data and calculations from Fraunhofer ISI et al. 2016 and Oeko-Institute et al. 2016. This estimate is a maximum and excludes potential exemptions for small-scale suppliers

For both options, two variants of this obligation could be envisaged:

- ***Variant 1 Gradual obligation***: fossil fuel or fossil fuel based energy suppliers would be required to ensure that each year from 2021 to 2030, an additional share[254] of the fossil fuel part of the energy sold or distributed to end-consumers for heating and cooling come from renewables;

- ***Variant 2 Universal obligation:*** fossil fuel or fossil fuel based energy suppliers would be required to ensure that by 2030 at least a certain[255] share of the energy sold or distributed to end-consumers for heating and cooling comes from renewables.

Under both approaches, energy suppliers in Member States could comply with these obligations either through:

(i) physical incorporation of renewable energy, including bioenergy made from waste, in the energy supplied for heating and cooling[256],

(ii) direct mitigation measures such as installation of highly efficient renewables heating and cooling systems in buildings and/or renewable energy use for industrial heating and cooling processes or

(iii) indirect mitigation measures proven by tradable certificates (carried out by another economic operator such as independent renewable technology installer or ESCO providing renewable installation services).

With natural gas representing more than 40% of the total EU heating and cooling supply in 2012[257], the physical incorporation option (i) would allow suppliers to gradually increase their share of biogas injected into the network and tackle the untapped potential of the sector.

For the technology implementation options, a methodology is required to calculate the amount of heat a RES-H&C installation is delivering into the obligation scheme. The mechanism applied must ensure that the calculated or metered output of a RES-H&C installation is accurate, replicable and not open to abuse. This will be vital for protecting the scheme from gaming and fraud.

<u>Mitigation of the impact on obligated parties (esp. SMEs)</u>

In order to reduce the burden on small-scale operators, Member States would also benefit from a range of mitigation measures:

(i) the possibility to designate as obligated parties either retail or wholesale suppliers, which latter are typically large-scale;

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253 Data and calculations from Fraunhofer ISI et al. 2016 and Oeko-Institute et al. 2016. This estimate is a maximum and excludes potential exemptions for small-scale suppliers

254 To be determined based on EU cost-effective deployment – see 5.2.1.1.

255 To be determined based on EU cost-effective deployment – see 5.2.1.1.

256 *E.g.* through integration of renewable energy in district heating or feed-in of biogas in natural gas grids and renewable electricity in the electricity used for heating and cooling needs

257 Fraunhofer, 2012

(ii) the possibility to exempt SMEs from the scheme, as long a minimal share of the supply is represented. The small-scale supplier exemption should be designed to mitigate the impact on SMEs while avoiding to put disproportionate burden on the remaining eligible ones. Considering these elements, 50% of the total heating and cooling supply could be exempted from the obligations;

(iii) the possibility for obligated parties to jointly deliver on the scheme as one single obligated party, therefore enabling a "critical mass effect" among energy suppliers;

(iv) the possibility for obligated parties to comply with the obligation on a 3-year average basis rather than a yearly mandatory increase.

5.2.1.1. Introduction to the assessment

With the current legal requirements as set out in Articles 3(1) to (3), 4, 13(3) to (6) and 16(11) of the RES Directive, the EU is expected to achieve around 22% of RES-H&C share by 2020.

In EUCO27 scenario, a cost-effective level of RES-H&C deployment by 2030 is projected to be around 27%. Under a continuation of current practices, including additional renewables-at building level (option 0), the EU might only reach around 25% renewables in H&C in 2030[258]. The assessment of potential impacts on renewable energy deployment of Option 0 is based on REF2016, on which the contribution of EPBD measures in the field on renewables has been added. On the basis of the assessment presented in 5.2.1., RES-related measures in the EPBD could potentially tackle between 6% and 10%[259] of the total heating and cooling supply.

Energy efficiency can also play a role in increasing the share of renewables in heating and cooling by lowering the overall demand. However, energy efficiency alone will not be sufficient to reach a cost-optimal share of renewable in heating and cooling in the residential sector[260]. Between 2021 and 2030, energy efficiency could tackle around 50% of the additional effort needed to reach cost-efficient renewable deployment in the heating and cooling sector[261]. Energy savings should mostly affect non-renewable heating, while the overall consumption of renewables in final heat should remain constant. The rest of the effort will be supported mostly by heat pumps. Therefore additional measures will be needed to ensure that renewables will gradually replace fossil fuels in heating and cooling, and address the untapped potential in terms of electrification and heat pumps deployment. The role of heat demand savings would obviously increase in case of more ambitious energy efficiency target, as explained in Annex 4. However, the influence of a 30% target in energy savings by 2030 would not substantially change the cost-effective share of renewables to be reached by 2030[262], therefore the level of suppliers' obligation should not be affected.

The proposed renewable energy heating and cooling obligation scheme (HCOS) will therefore provide additional incentives to fuel-switching from fossil to renewable energy mostly at the building level and also at the industrial, currently not sufficiently stimulated

[258] Based on PRIMES REF2016
[259] Draft estimations based on available data
[260] PRIMES EUCO27 scenario
[261] PRIMES EUCO27 scenario
[262] 26,3% in heating and cooling by 2030 according to EUCO30 scenario

by the EU energy efficiency framework. The total intended volume of the obligation should result in 27% renewables share in the heating and cooling at EU level, which is deemed the most cost-effective deployment to reach the at least 27% overall renewables target by 2030[263].

Level of the obligation

In order to determine the required level of the obligation to reach a cost-effective target of 27% renewables in heating and cooling by 2030, the following methodology was used:

- For variant 1, the share of renewables in heating and cooling would have to increase by 5%[264] between 2021 and 2030. Given that 50% of the heating and cooling supply could be exempted; the remaining eligible parties would have to increase their RES-shares by 10% in 10 years, *i.e.* by 1 percentage point (pp) every year[265].

- For variant 2, the EU as a whole will have to reach 27% renewables in heating and cooling by 2030. Taking into account, on the one hand, early achievers[266], and on the other hand, exempted parties, the level of the obligation would be 27% by 2030 for each obligated party.

5.2.1.2. Detailed assessment

Important note

In the following assessment, all renewable energy shares and deployments have been measured at EU- and Member State-level in comparison with the EUCO27 scenario. This has been performed in order to measure the distortion (in terms of additional effort at member-State level) vs. the cost-effective scenario. The impacts of options 0 (continuation of current practices) are mostly elaborated on in the introduction above.

The below assessment uses the REF2016 as the starting point in terms of projected renewables shares in heating and cooling for 2020 for each Member State, on the basis of the overall legal obligation for each Member State to reach their national target for 2020. It implies for a number of countries an acceleration of renewables heating & cooling deployment before 2020. Under the assumption that a number of Member States could not reach their target, or could reach their targets by additional efforts in other sectors, extra efforts towards meeting the EU 2030 target would be larger, and this could also have consequences for the heating & cooling sector. Notably, the level of obligations post 2020 needed to reach 27% RES-H&C might need to be higher.

Social impacts

Impact on small-scale suppliers

263 Based on PRIMES EUCO27 results

264 From 22% to 27% based on EUCO27 results

265 These levels have been calculated assuming (i) non-obligated parties keep their H&C shares constant between 2020 and 2030 (ii) at national level, the sum of suppliers will reach at least PRIMES Ref scenario level by 2030

266 *I.e.* Member State where suppliers are – on average – already reaching 27% or above

Due to the extremely fragmented nature of the heating and cooling supply across Europe, the mitigation of the impact on small-scale suppliers is one of the priorities when considering the design of different options.

In order to simplify the analysis, our calculation assumes all natural gas suppliers are large-scale and 50% of coal, gas, district heating and biomass are small-scale[267]. Electricity and heating and cooling generation at residential level (solar thermal, geothermal and heat pumps) are not eligible under the obligation schemes. Since option 1 only includes fossil fuel suppliers, the share of potentially eligible parties is lower than in option 2.

In order to minimize the impact on small-scale suppliers, each option introduces the possibility for Member States to exempt parties from the obligation as long as these exempted parties do not exceed a 50% of the heating and cooling supply.

With these assumptions, the heating and cooling supply profile can be broken down as shown on Figure 14 and Figure 15. These figures represent the assumed breakdown of heating and cooling suppliers in terms of shares of total heating and cooling supply.

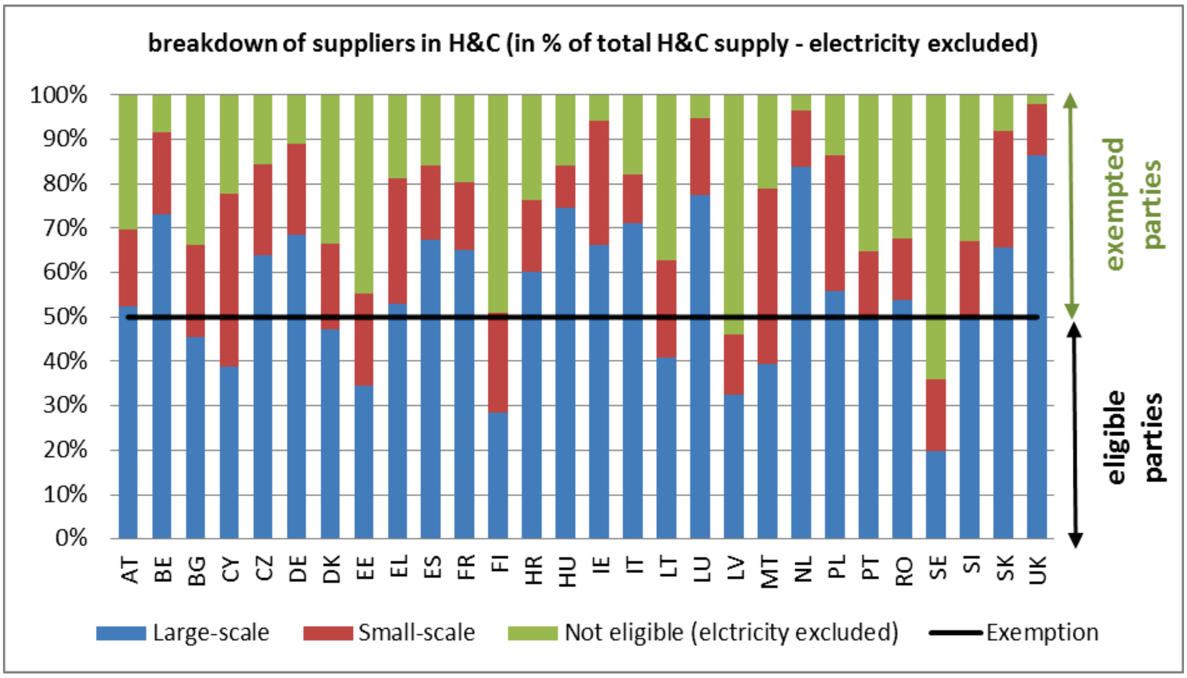
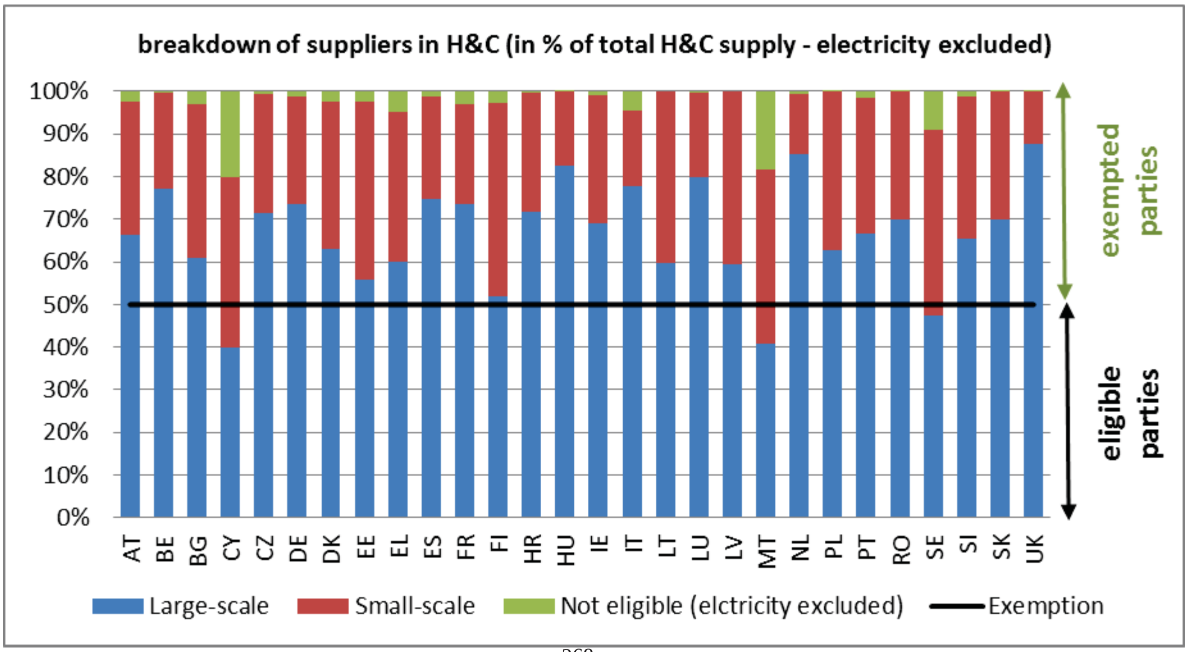


Figure 14: breakdown of suppliers in H&C (Option 1: fossil fuel only)

267 Based on Fraunhofer, 2016. In the absence of more precise breakdown of heating and cooling suppliers at EU and Member States- level



268

Figure 15: breakdown of suppliers in H&C (Option 2: all suppliers)

From the figures above, it clearly appears that Option 1 (fossil fuel only) could have a substantial impact on small-scale suppliers, where for some Member States, potentially all or the majority of small-scale suppliers might fall under the obligation[269].

Considering all of the above, and even factoring in possible exemptions, it is likely that the potential burden of Option 1 would be too high compared with the expected results, therefore this option will not be considered in the rest of the analysis.

On the contrary, Option 2 (all suppliers) could have a more limited impact on small-scale suppliers. Under this option, the most impacted Member States would be Malta and Cyprus, due to a small and oil-dominated market. The overall impact across the EU should however remain limited, all the more as Member States will benefit from a range of mitigation measures, as described above.

Impact on retail prices[270]

Another potentially important impact of additional measures in heating and cooling would be the energy prices for households. A first analysis on the expected evolution of energy prices at household level shows an overall increase of energy prices between 2021 and 2030 (around 19% on average[271] - see Figure 16). This increase is partially due to market developments, and partially due to climate and energy policies. In order to insulate the effect of heating and cooling measures, we have to assume constant energy prices from 2021 onwards.

268 Given data availability, for option 2, all renewable heating and cooling suppliers have been considered and not only suppliers whose RES-shares are below 90%.

269 EE, FI, LV, SE

270 Even though the industry and tertiary might be also affected, the focused has been put on household, which represent better individual consumers.

271 Based on PRIMES EUCO27 results – non-weighted average of electricity, biomass, diesel oil, natural gas and solids

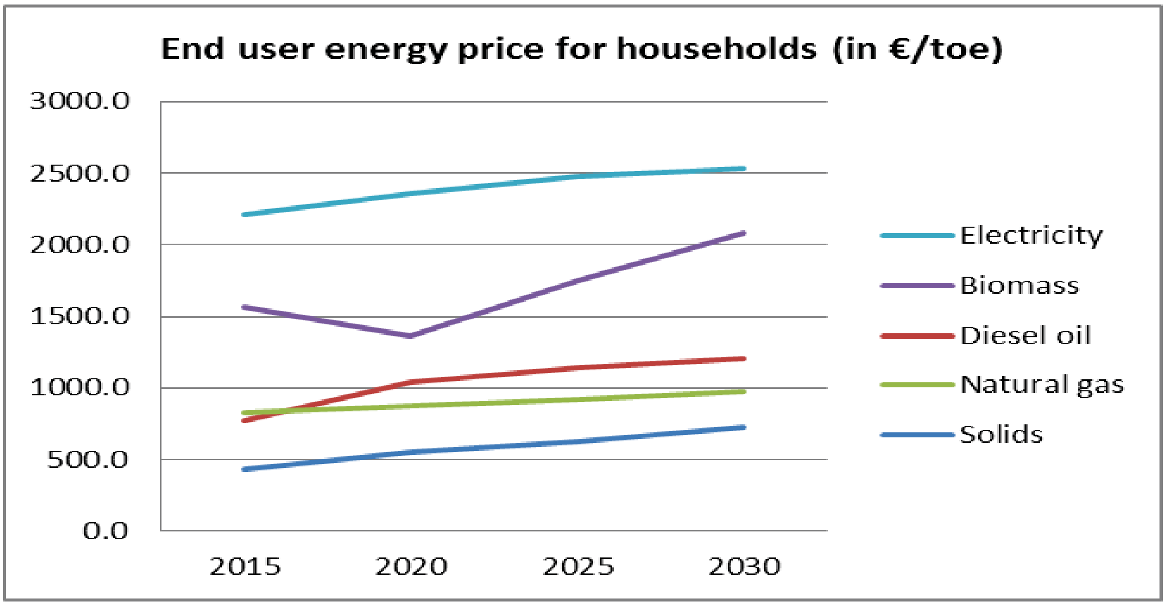


Figure 16: end user energy prices for households (based on PRIMES EUCO27 results)

With this assumption, the overall impact of measures has been assessed by multiplying the energy price by the final energy consumption of household per energy carrier. The positive influence of energy efficiency has also been eliminated, by considering the overall energy consumption of households constant between 2020 and 2030. With these assumptions, the change in fuel mix (assumed to be triggered by measures in the heating and cooling sector) will be the only driver of price evolution. The result is the overall energy expenditures per household as shown in Figure 17.

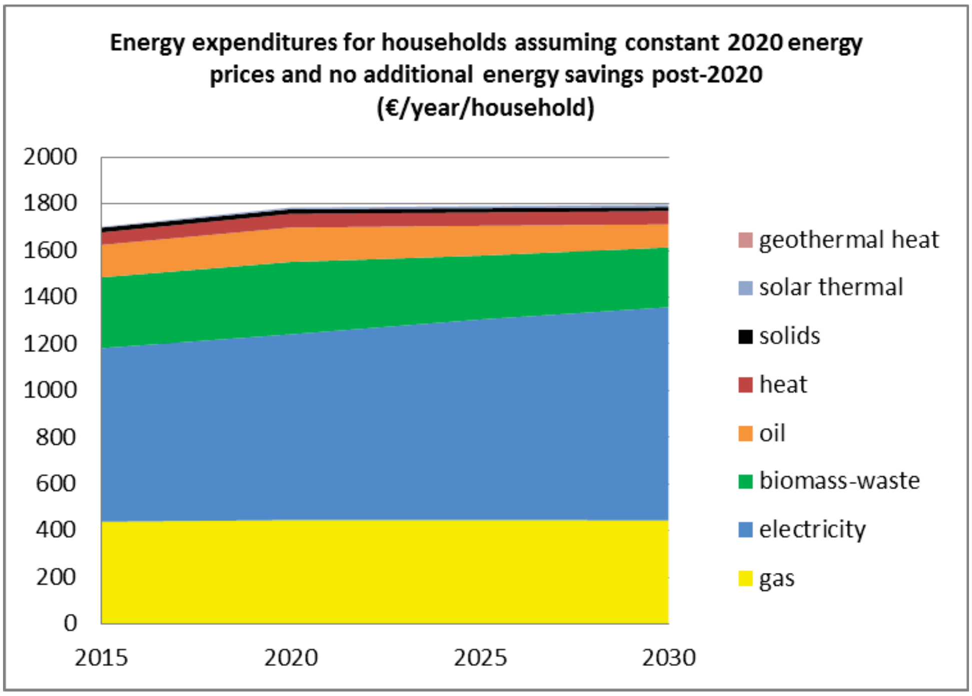


Figure 17: energy expenditure for households[272]

As shown in Figure 17, if prices are assumed constant and if energy efficiency measures are eliminated, the impact of additional renewables on household energy expenditures

[272] Based on PRIMES EUCO27 scenario and EC own calculations

would remain limited (+ EUR 11/year/household between 2020 and 2030). In this case, the increase of electricity expenditures due to higher electrification is compensated by the decrease in fossil fuel use. However, if we consider an increase in fuel and electricity prices as expected[273], the impact on household expenditures would be higher, but mostly due to external factors.

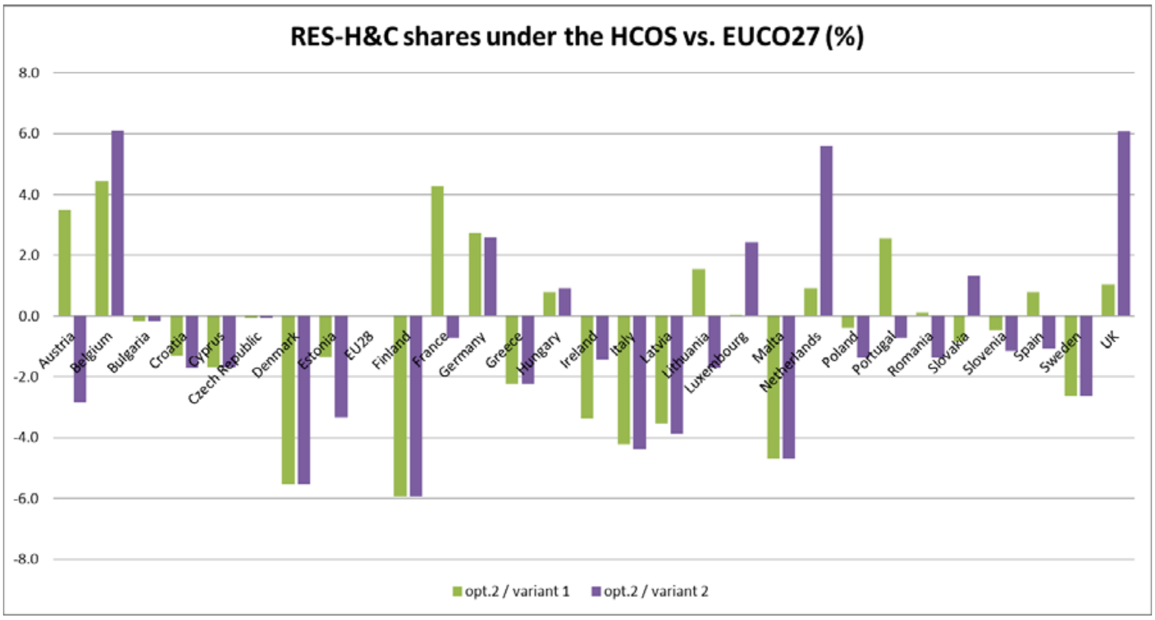
Economic impacts

In the absence of a detailed modelling of the heating and cooling supply chain[274], the economic impacts have mostly been measured assessing the gap between heating and cooling deployment at EU-and Member State-level triggered by the obligation scheme, and cost-effective deployment[275], outcome of the main scenarios used in this Impact Assessment.

For this assessment, the focus has been on the progression of additional RES-H&C deployment at Member State level (as renewables share in the total H&C consumption) compared to cost-effectiveness, and especially the standard deviation of additional effort in terms of RES-H&C shares at Member State level compared to the central scenario, *i.e.* how the obligation could divert from a balanced approach across Member States.

The following two figures illustrate the modelled impact of 2 variants of proposed Option 2 of HCOS (option 1 has been disregarded for the reasons stated above). The following options and variants are assessed:

- Variant 1 stands for yearly increase of 1% of addition renewables for each supplier by 2030,
- Variant 2 stands for universal obligation of 27% renewables share in the total volume of heating and cooling fuel/energy sold to end consumers in 2030.



273 Based on PRIMES EUCO27 scenario

274 The PRIMES model does not fully capture all the diversity in companies along the heating and cooling supply chain

275 As measured by PRIMES EUCO scenario

Figure 18: Renewable heating and cooling shares under the HCOS vs. EUCO27

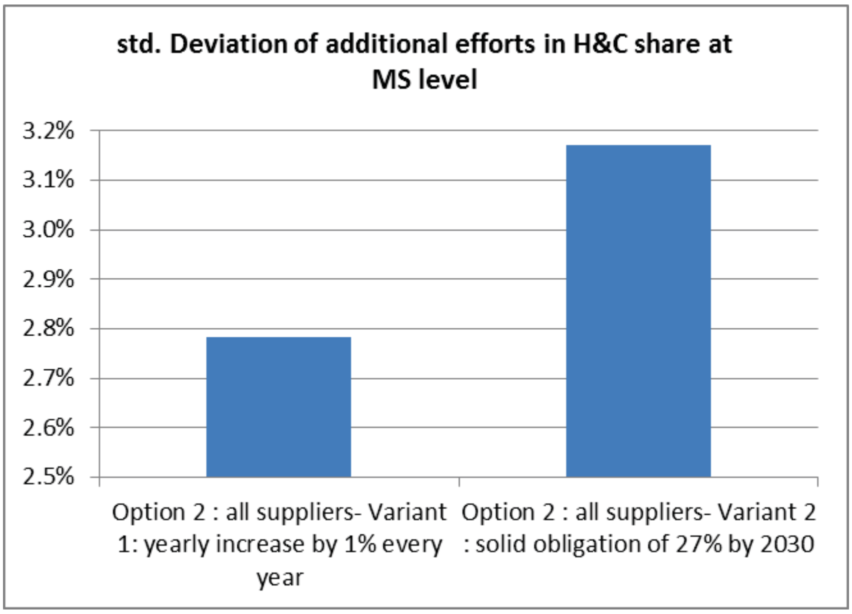


Figure 19: Standard deviation of additional effort in H&C share at MS level[276]

The analysis of the figures above shows that variant 2 (universal obligation of 27% of RES-H&C in 2030 for each supplier) is the most distortive approach. This is explained by the absence of inclusion of any starting point: in variant 2 obligated parties will have to reach 27%, regardless if their share in 2020 is 0% or 20%. Therefore option 2 would be detrimental to suppliers with a low starting point[277], and variant 1 (gradual increase) will guarantee higher proportionality and cost-effectiveness compared with variant 2.

On the other hand, the impact of variant 1 on early achievers[278] (*i.e.* Member States that were already above EU average in 2020) would be higher than in option 2. This is explained as the gradual obligation (variant 1) would apply to every supplier equally, *i.e.* the renewable energy share in heating & cooling would have to increase by 1% between 2020 and 2030 independently from the starting point. On the other hand, a universal obligation (variant 2) would have no effect on suppliers which are already reaching 27% of renewables in heating and cooling. Figure 20 below summarizes this distributional effect.

276 Vs. PRIMES EUCO27, based on EC calculations
277 See *e.g.* Figure 18 for BE, DE, LU, NL, UK
278 AT, BG, CY, DK, EE, FI, FR, EL, LV, LT, MT, PT, RO, SI, ES, SE

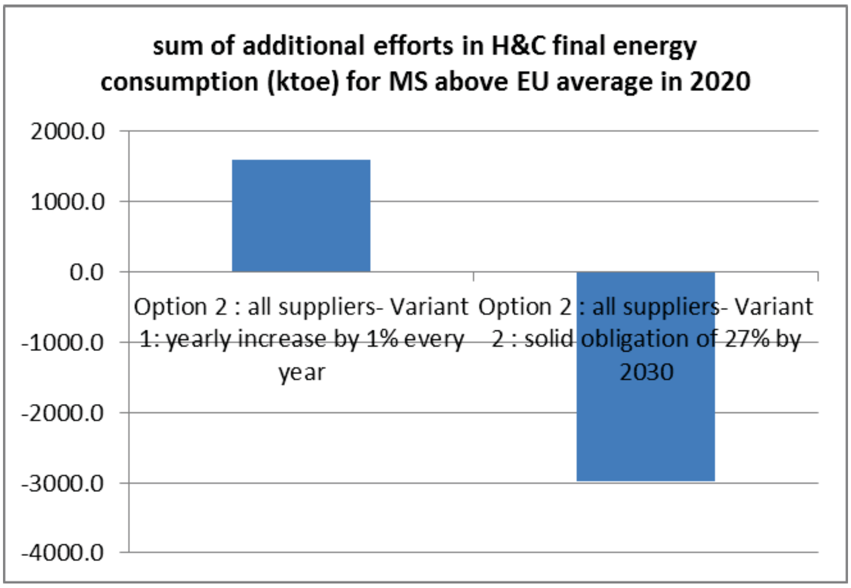


Figure 20: Sum of additional efforts for early achievers

On the top of it, additional administrative costs may occur, including costs for the management of potential funding programs, motivation campaigns to incentivise RES-H&C installations, costs for audits and verification or costs associated to establishing regional networks delivering RES-H&C installations. Since a certain share of the administration costs are fixed costs that are independent from the size of the obligated company, small companies might have a systematic competitive disadvantage. This fact justifies an exemption for small scale companies. For the variable administrative costs large companies might have a further competitive advantage due to potential scaling effects, *e.g.* regarding the search for eligible RES-H&C projects.

Environmental impacts

The HCOS have been considered to have no or very limited influence on the rest of the energy system. This assumption allows isolating the impact of the HCOS while every other parameter is being kept equal.

However, a potentially significant environmental impact of the HCOS – together with other measures targeted at renewable heating and cooling – is biomass deployment. Depending on the technologies used, biomass might have potential adverse impacts *e.g.* on air quality, that should not counterbalance the benefits in terms of renewable energy deployment and GHG reduction. In order to assess the impact of the set of RES-H&C-targeted policy options[279] on biomass deployment, we have used the EUCO27 scenario, which mirrors cost-effective deployment of renewables in heating and cooling at Member States and EU-level.

The focus has been put on the final energy use for heating and cooling demand in the residential sector, given its importance in overall heating and cooling consumption. Figure 21 depicts the potential evolution of the fuel mix used at residential level. The outcome of this analysis is that the biomass use remains constant (and even decreases in absolute terms) between 2020 and 2030, while oil and solid fuel use substantially decrease. This is mostly due to additional energy efficiency measures and overall electrification in the heating and cooling sector. On the top of it, without prejudice to the

[279] *I.e.* HCOS, measures for district heating and measures at building level

outcome of the bioenergy sustainability initiative, the remaining biomass used for heating and additional post-2020 might need to comply with enhanced sustainability criteria.

Hence, the overall combined impacts of policies targeting heating and cooling on the environment is expected to be positive.

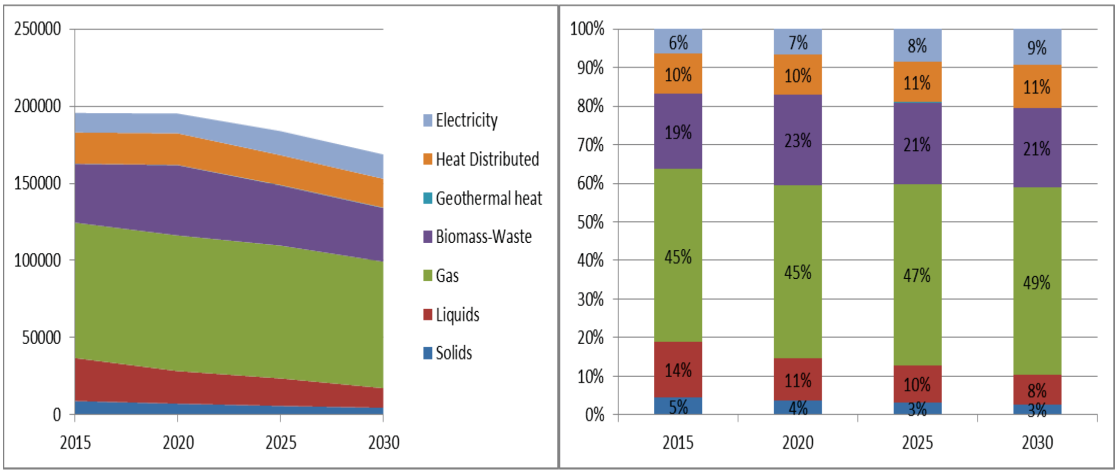


Figure 21: Final Energy per energy use (Ktoe)
in residential heating and cooling demand – EUCO27 scenario
Source: PRIMES

Political feasibility /opportunity

The subsidiarity is ensured through the freedom left to each Member State to define obligated parties, as long as they encompass a certain share of the heating and cooling supply. For this reason, there will be no EU-wide obligation scheme: each MS will have the possibility to design its own scheme, as long as the design corresponds to the minimum set of common principles defined at the EU level. Also the obligation leaves it up to the Member State/obligated party to choose the most cost-effective measure in its given context, hence the instrument adapts to specific conditions. The possibility for Member States to choose between a range of mitigation measures also allows flexibility at national level and ensures proportionality through the mitigation of impacts on smaller suppliers. However, each option will have different effect on the RES-H&C deployment at MS-level. As assessed in the *economic impacts* section, variant 2 (universal obligation) has a higher impact at Member State-level than a gradual obligation, especially on Member States with a low starting point in 2020.

Of the options under consideration, it is difficult to see how Option 0 of continuing with current practice should be selected. Given the importance of the heating and cooling sector in reaching the EU target for renewable energy, a measure accompanying the increase in the renewable share in the sector is desirable.

5.2.2. Facilitating the uptake of renewable energy and waste heat in district heating and cooling systems

As elaborated in 5.2.1, most of the district heating suppliers at EU-level are considered small-scale, and therefore might not fall under the heating and cooling obligation scheme. This option is therefore considered complementary to the HCOS.

Option 0	Option 1	Option 2	Option 3
• BASELINE - Continuation of current EU policies	• Continuation of current requirements, **with best practice sharing**	• **Energy performance certificates** and creating **access rights to local H&C systems**	• Option 2 + further **reinforced consumer rights**

➢ ***Option 0:*** *Baseline*

The RES Directive requirements with regard to RES-H&C are not included in the Revised RES Directive and expire in 2020. Member States decide individually if and how they wish to promote the increase of renewables in the district heating and cooling systems. Financial support, if put in place at national level, will need to comply with State aid rules. Renewable energy technologies will need to compete with fluctuating fossil fuel prices and distortive subsidies for fossil fuels. The obligations under Article 14 EED will remain.

➢ ***Option 1:*** *Continuation of current requirements, with best practice sharing*

The RES Directive requirements on promotion of urban planning and renewables integration in the district heating and cooling infrastructure (*e.g.* Articles 13(3) to (6) and 16(9) and (11)) are extended to 2030. Best practice sharing on measures facilitating integration of renewables in the urban heating and cooling infrastructure, integration of local electricity and heating and cooling systems and best practice in financing of sustainable urban energy projects is further encouraged.

➢ ***Option 2:*** *Energy performance certificates and access rights to local H&C systems*

The RES Directive requirements on promotion of renewables integration in the district heating and cooling (DHC) infrastructure (*e.g.* Articles 13(3) to (6) and 16(9) and (11)) would be reinforced and amended, requiring Member States to subject their district heating systems to energy performance assessment[280] thus supporting the energy performance framework developed to support EPBD and RES Directive implementation. A European standard for district heating systems is currently under approval by the CEN[281]. This methodology should be used, to the extent possible, for district heating performance assessment. This performance assessment should be made available to end-consumers.

Open access rights to local heating and cooling systems for residual/waste heat/cold and for producers of renewables heating and cooling (as appropriate also from variable renewable electricity producers especially for balancing purposes) would be established, along with such rights for third parties acting on their behalf (*e.g.* aggregators, traders). Temporary exemptions could be considered for new district heating or cooling systems with a high energy performance. National Regulatory Authorities would be tasked to oversee access rights. These reinforced provisions would also require Member States to oblige district heating/cooling companies, electricity and gas DSOs and providers of

280 A European standard for district heating systems is currently under approval by CEN
281 Comité Européen de Normalisation

infrastructure for electric mobility (if relevant) to make common investment plans (or consult each other on investment plans). National Regulatory Authorities (NRAs) would be tasked to ensure that investment plans of DSOs and district heating and cooling's are optimised in terms of overall costs, result in increase of renewables and improvement of overall energy (system) efficiency (*e.g.* by using district heating/cooling systems to help balancing variable renewable electricity production). In case no district heating/cooling is in place, the DSO shall, based on the assessment according to Article 14 EED, analyse the business potential for a district heating and/or cooling network.

- ***Option 3:*** *Option 2 + further reinforced rights for consumers*

As described in Option 2. In addition, consumers would have a right to disconnect from the district heating and cooling system if the system's energy performance is lower than what a consumer could achieve by alternative means *e.g.* renewables on-site or through energy communities formed in neighbourhoods. The comparison should be allowed by disclosure of district heating performance assessment to the end-consumer. This would allow neighbourhoods or individual owners of buildings to take responsibility for their own sustainable heat/cold supply. Reinforced provisions would propose a strengthened role of NRAs in ensuring that renewable and waste heat based suppliers have non-discriminatory access to the district heating/cooling network and the protection of consumers, in particular in relation to connection to and disconnection from networks. Consumers would have the right to fair and competitive prices/tariffs in line with the potential energy performance of the system while incentivising investments in highly efficient district heating and cooling and fuel switching from fossil to renewable energy.

5.2.2.1. Introduction to the assessment

District heating and cooling represent around 8-10% of the total H&C energy supply, out of which around ¼ are renewables[282]. The situation varies substantially across Member States, as illustrated by Figure 22.

[282] Fraunhofer, 2016. 2012 figure

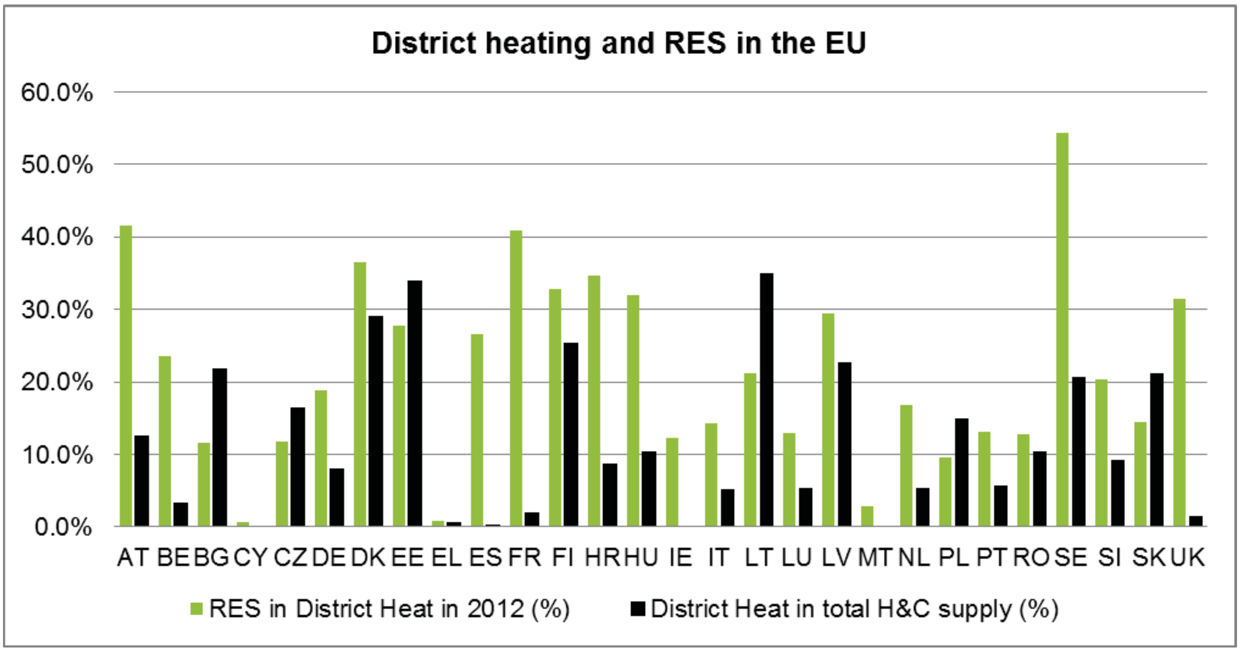


Figure 22: District Heating and renewables in the EU[283]

Option 0 relies on the Directive on Energy Efficiency[284], which requests Member States to carry out, by 31 December 2015, a comprehensive assessment of the potential for efficient district heating and cooling, which is defined as 'a district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat". These assessments need to be updated every five years and Member States are requested to include strategies, polices, and measures to realise the potential.

The rationale for option 1 to 3 is to support action at EU-level. The rationale for option 1 is to allow for collaboration and information sharing among Member States regarding the opportunities to support higher shares of renewable energy and waste heat in district heating and cooling systems. For option 2 and 3, the rationale is to develop an enabling framework for consumers and energy suppliers that would complement the provisions of the EED by allowing effective fuel-switching at district level.

Figure 22 shows the large variations across Member States in terms of heating and cooling shares in the district heating sector. Based on market shares of district heating and cooling and the level of renewables in district heating and cooling, Sweden, Denmark, Finland and the 3 Baltic States are frontrunners in renewables deployment in the district heating and cooling. On the other hand, a number of Member States have less than 5% of renewables in their district heating and cooling systems.

Option 1 is a continuation of the current requirements upon Member States to assess the need to build new infrastructure for renewable district heating and cooling in their national renewable energy action plans and provide guidance to relevant actors to consider the optimal combination of renewable energy resources, including those provided through district heating and cooling, in the planning, design, building and renovation of industrial or residential areas. As outlined in the EU strategy on Heating

283 Source : Fraunhofer, 2016. 2012 figures
284 Directive 2012/27/EU

and Cooling[285], option 1 could be strengthened by promoting sharing experiences and best practices across Member States, support for local authorities in preparing strategies for heating and cooling, and setting up a website with price comparison tools on lifetime costs and benefits of heating and cooling systems. Some small initiatives to exchange best practices are already on their way[286].

Option 2 consists of the introduction of district heating and cooling Energy Performance Certificate compliance requirement and creating open access rights to local district heating and cooling infrastructure. The rationale is that district heating and cooling network infrastructure provides an opportunity to integrate heating and cooling from independent renewable energy producers (incl. biomass, geothermal, solar thermal), waste heat from industry and municipal waste, renewable electricity (through heat pumps), in a flexible way. Furthermore, flexible district heating and cooling systems provide a cost-effective option to integrate the heating and cooling sector witht he electricity sector. Requirement for district heating and cooling system operators to certify the energy performance of their district heating system, using a CEN standard[287], will provide additional incentives to district heating and cooling system operators to improve the energy performance and reduce the CO_2 emissions from their district heating system, through improved system efficiency and higher share of renewables in the district heating and cooling fuel mix.

The requirement of district heating and cooling energy performance certificates for district heating and cooling operators would be particularly relevant for improving the overall energy system efficiency and promoting circular economy by engaging independent renewables and waste heat producers, industry and industrial clusters located in vicinity of urban areas with high heating and cooling demand. Industrial clusters often foresee energy efficiency and renewable energy programmes as part of overall sustainability and circular economy objectives. The requirement for district heating and cooling operators to certify their district heating and cooling systems, based on standard methodology included in the CEN standard for district heating and cooling energy performance[288] that is currently in approval stage, would contribute to increased competition on the local heating and cooling markets and provide transparent and comparable data on energy performance of district heating and cooling systems, enabling households and industry to make informed choice on most appropriate energy solutions for their heating and cooling needs.

District heating and cooling energy performance certificates would also provide the financing sector with a benchmark to support the upgrading, expansion or construction of the most efficient district heating and cooling systems. This would also complement the national strategies for efficient district heating and cooling developed under the energy efficiency directive, by providing more granular data on the opportunities for increasing the share of renewables at a local level.

Option 3 would support a more active role of consumers in promoting high shares of renewable energy in district heating and cooling through consumer right to compare the district heating and cooling energy performance data (based on district heating and cooling energy performance certificates) with building level energy performance

285 COM(2016)51
286 http://www.smartreflex.eu/
287 CEN/TC 228 standard prEN 15316-4-5
288 CEN/TC 228 standard prEN 15316-4-5

certificates, and disconnection rights from district heating and cooling at building level. This option is relevant for incentivising the competition between most efficient energy performance solutions at the energy system or building level. Such competition is increasingly relevant as consumers are encouraged to invest in local renewable heating solutions, such as solar thermal systems, wood-pellet systems or heat pumps, under the energy performance of buildings directive[289]. These local solutions could be complemented with renewables-based district heating and cooling systems to provide additional flexibility.

5.2.2.2. Detailed assessment

Economic impacts

Given the fragmented markets of the district heating and cooling supply in Member States, the main concern regarding potential economic impacts will be the effect of the options on small-and medium-scale suppliers and the overall cost-efficiency and business case for district heating investments . While option 1 would leave progress up to the discretion of local and regional administrative bodies, options 2 and 3 might affect local district heating and cooling suppliers and district heating and cooling system operators, either through the integration of new generation (technical adaptation costs, competition between independent producers and incumbent district heating companies and owners of the district heating and cooling network, business case for new investments and upgrades of existing district heating and cooling networks) under option 2 or through potential disconnections (loss of revenues, questionable incentives for investments) under option 3.

Regarding the integration of new generation, considering the rather long lead times for planning and licensing new district heating and cooling systems and high upfront investment costs, in the short-term the impact of the measure would be restricted to existing district heating and cooling systems which make up for about 10-15% of the current European heat market for buildings in the residential and service sector while the corresponding market share for the industrial sector is about 9%. Assuming that the measure would trigger the renewables increase in existing district heating and cooling systems to be increased by 20 % roughly in 10 years, additional 2 Mtoe RES-H&C would enter the heating and cooling market by 2030[290].

Regarding potential disconnections, the estimate of the potential impact of introducing a district heating and cooling disconnection right is mainly based on data provided by Fraunhofer ISI et al. (2016), Eurostat and Euroheat&Power, although there are considerable differences between the figures provided by these sources.[291]

- According to Fraunhofer ISI et al. (2016) in 2012 district heating and cooling was contributing about 480 TWh to the final energy demand in the heating sector, corresponding to a district heating and cooling share of about 7.6% of the total heating and cooling market[292];

289 Directive 2010/31/EU
290 Öko Institute, draft interim results
291 A discussion of the differences can be found in the WP1 report of ISI et al. (2016), *Mapping and analyses of the current and future heating/cooling fuel deployment* (2016).
292 8,6% including electricity

- According to Eurostat in 2013 about 28% of all district heating and cooling was produced by heat only plants while the remaining 72% were contributed by CHP;
- According to Fraunhofer ISI et al. (2016) 53% of the total capacity of CHP plants > 1 MW_{th} was installed before 1992 while 26% of the capacity was installed between 1992-2002 and 21% after 2002.

Since no data is available on how different district heating and cooling systems can be distributed among different efficiency categories (incl. the efficiency of production in the heat only and CHP plants as well as the efficiency of the distribution) and the CEN methodology only provides a standard calculation methodology, but does not include minimum energy performance thresholds, we need to do an assumption on how many district heating and cooling systems would fall in the category of low performing district heating and cooling systems and could thus be affected by wave of disconnection requests. For reasons of simplification we assume that all heat only plants and all CHP plants that have been installed before 1992 (these plants are now older than 24 years) would underperform. This would correspond to a maximum disconnection potential in the range of 320 TWh.

If we further assume that per annum about 1% of all customers that are connected to district heating and cooling systems that underperform will use their right to disconnect in favour of a more efficient decentralised heating system, in the first year in principle a heating and cooling volume of about 3.2 TWh could potentially be open to be replaced by on site-building level RES-H&C solutions. Between 2020 and 2030 this potential would sum up to 32 TWh.

If we finally assume that about 25% of all disconnected costumers will decide for a RES-H&C technology (*e.g.* a heat pump or wood pellet boiler instead of a gas or fuel oil boiler), this would result in additional RES-H&C of about 0.8 TWh (= 0.07 Mtoe) in the first year. Between 2020 and 2030 this would sum up to 8 TWh (0.7 Mtoe) additional RES-H&C compared to a scenario without disconnection right[293].

The total estimated ratio of such disconnections shall therefore remain below 2% of total district heating supply in the EU, which is deemed limited at the EU level, but could vary significantly at the Member State level. Higher disconnection risk and impacts could be expected in those Member States that proportionally have higher district heating and cooling market shares and lower energy efficiency of such systems[294]. In comparison, district heating and cooling networks will be proportionally more affected by the reduction in final heat demand that have been envisioned under the EED. The creation of flexible district heating and cooling systems is therefore important for both the future of district heating and cooling systems as well as renewable energy integration.

To conclude, the much higher economic impacts and higher upfront investment costs on district heating operators are therefore assumed due to integration of renewable generation at district level (option 2 and 3) rather than from the possible fuel-switching and therefore loss of revenue form the disconnected district heating and cooling customers. However, the magnitude of this impact shall be counterbalanced by the positive effects at energy consumer level, most notably in resulting reduction in heating

293 Based on Öko-Institut, draft interim results

294 Based on Öko-Institut, draft interim results

and cooling prices and enhanced energy consumer choice and possibilities to require better quality service.

Social impacts

In a number of Member States, more than 50% of the citizens are connected to district heating and cooling systems[295]. At the same time, low awareness of alternative RES-H&C systems and lack of transparent and comparable data and energy performance indicators of such systems with district heating and cooling energy performance prevent energy consumers and other relevant stakeholder groups such as installers, builders, architects from making informed choices on best performing, most suitable and least cost heating and cooling solutions. Options 2 and 3 would engage both potential suppliers of heat and consumers, and provide them with the relevant information to make informed decisions about the use of district heating and cooling to support higher shares of renewable energy. Availability of transparent energy performance data will become increasingly important as district heating and cooling network systems move towards higher flexibility and integration within the overall energy system, integrating multiple renewable heating sources, and residual heat and renewables electricity from buildings. Option 3 will also enable consumers at building level to make a choice between producing their own renewable energy at the building level or relying on efficient and renewable energy based district heating system.

In cities, the planning of key infrastructure is rarely coordinated with other urban planning aspects that could be used to deploy renewable energies and energy efficient heating and cooling, *e.g.* when building refurbishment programmes are implemented and/or new district heating and cooling and electricity distribution system investments are being undertaken. Sustainable energy programmes targeting the decarbonisation and energy efficiency of buildings and the heating and cooling supply are often overlooked during the urban planning and design phase. Also decisions on investments in infrastructures and buildings at municipal or commercial levels may take place in an isolated manner without any consideration of the feasibility of long term sustainable solutions and without performing a life cycle cost analysis to assess the long-term cost-competitiveness of a portfolio of options. In addition, new built and refurbishment rate of buildings are low, around 1% and 1.4% per annum, respectively, which is not conducive to a more rapid diffusion of these technologies.

Environmental impacts

The proxy used to measure the potential environmental impact is the influence on RES-H&C deployment. The main trigger to enhance RES-H&C deployment is the disconnection from fossil-fuel based district heating and cooling to individual renewable solutions.

One other potentially significant environmental impact is the effect of measures targeted at renewable heating and cooling on additional biomass deployment. The assessment of the overall combined impacts of policies targeting heating and cooling on the environment has been presented in 5.2.1.2.

Political feasibility /opportunity

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[295] Euroheat, 2015. Country by Country Statistics Overview 2015. http://www.euroheat.org/wp-content/uploads/2016/03/2015-Country-by-country-Statistics-Overview.pdf

Option 0 has no additional administrative burden, and Option 1 could actually make the accounting requirement at a Member State level more efficient by disseminating the information to the relevant stakeholders.

Options 2 and 3 would rely on the requirement for district heating and cooling system operators to certify their systems based on standard CEN methodology. Obtaining such energy performance certificates and regularly renewing them will result in compliance costs for establishing such certification scheme and carrying out regular system audits. However, there are possible synergies in linking the energy performance certification with existing systems for energy performance certificates for buildings. This would substantially reduce the administrative burdens.

Of the options under consideration, Options 0 and 1 should be discarded, as they would have a negligible to minor impact on the effort to make district heating and cooling part of the cost-efficient renewable uptake leading to 2030 EU-wide target.

5.2.3. Overall comparison of the options to increase renewable energy in the heating and cooling sector (RES-H&C)

	Overall impact			Key objectives		
Policy option	Social	Economic	Environmental	Effectivness	Efficiency	Coherence
Mainstreaming renewables in the heating and cooling supply						
Option 0-partial continuation of current RED requirement + EPBD + EED	0	0	0	0	0	0
Option 1-RES H&C obligation for fossil fuel suppliers	--	+	++	++	+	+
Option 2-RES H&C obligation on all fuel suppliers	-	+	++	++	++	+
Facilitating the uptake of renewable energy and waste heat in DHC systems						
Option 0-baseline	0	0	0	0	0	0
Option 1-continuation of current requirements, with best practice sharing	+	0	0	-	0	0
Option 2-Energy performance certificates and creating access to local H&C	+	-	+	+	0	+
Option 3-Option 2 + reinforced consumer rights	++	-	+	++	-	+
+,++,+++ : positive impact (from moderately to highly positive) *0 : neutral or very limited impact* *-, --, --- : negative impact (from moderately to highly negative)*						

5.3. Options to increase renewable energy in the transport sector (RES-T)

The table below provides an overview of the options discussed in this section.

Challenge	Drivers	Options
Increase deployment of advanced renewable fuels in transport		Option 0: Baseline – No additional EU Action on renewables in transport
	Projected deployment of renewables that is not cost-effective. Lack of internalisation of external costs of transport Lack of specific RES transport target post-2020 Uncertainty regarding future demand for renewable fuels Investors' uncertainty over future role of biofuels	Option 1: Building on baseline, EU incorporation obligation for renewable fuels (including advanced biofuels and electricity)
	Variable climate performance of conventional biofuels (due to ILUC)	Option 2: EU incorporation obligation for renewable fuels plus phase-out of food-based biofuels Three sub options on speed of phase-out
	Difficulty in deploying renewable fuels in aviation and maritime sectors.	Option 3: Option 2 plus a specific EU incorporation obligation for renewable fuels for aviation and maritime
	All of the above	Option 4: GHG emission reduction obligation (under FQD) Different sub-options on the share of advanced biofuels

Option 0	Option 1	Option 2	Option 3	Option 4
• ***Baseline- No additional EU action (business as usual)***	• ***EU incorporation obligation for renewable fuels***	• ***EU incorporation obligation for renewable fuels, plus phase-out of food-based biofuels*** • Three sub-options for the phase out food based biofuels	• ***Option 2 plus a specific incorporation obligation for renewable fuels in aviation and maritime***	• **GHG emission reduction obligation (FQD)** • Three suboptions besides baseline: • 4B) Excludsion of upstream emissions reductions and non-waste fossil fuels • 4C) Focus on advanced fuels and electricity • 4D) Focus on advanced biofuels, electricity, and lower GHG conventional fuels

5.3.1.1. Introduction to the assessment

The baseline scenario (REF2016) shows that national action alone will lead to some deployment of renewable fuels in the transport sector which will be, however, insufficient to reach the EU 2030 RES target and the 2050 decarbonisation objective. National measures cannot guarantee market volumes that are sufficiently large to both achieve economies of scale and spur manufacturing innovation to further lower the costs. The introduction of a binding measure at EU level is more likely to create such a market pull, while ensuring that the costs of technology innovation and development are sufficiently shared across European economies and market fragmentation is avoided.

The promotion of renewable energy in the transport sector can be pursued through two alternative policy instruments:

- *A renewable energy incorporation obligation*, such as those introduced already by 25 Member States in order to meet the 10% renewable in transport target set by the RES Directive. According to the REFIT evaluation report, the 10% target has been very effective to increase the share of renewable energy in the transport sector which reached 5.9% in 2014.

- *A GHG emission reduction obligation*, such as the one implemented thus far only by one Member State (*i.e.* Germany) in order to meet the Fuel Quality Directive requirement, according to which Member States shall require fuel suppliers to reduce the GHG intensity of the fuel they supply by 6% in 2020.

In the public consultation on the revised renewables Directive, the majority of stakeholders expressed the view that energy obligations are effective, or very effective, in promoting renewable fuels in transport and in increasing the uptake of electric vehicles. NGOs did not support an incorporation obligation including conventional biofuels. Furthermore, a number of industrial stakeholders and Member States highlighted that, in the period after 2020, the increase of low-carbon and renewable energy in transport should be promoted through only one EU-wide policy instrument, with the view to avoid double regulation and minimize administrative burden.

In this Impact Assessment, apart from option 0 (baseline) which is common to both instruments, options 1, 2 and 3 would be implemented through the Revised RES Directive, while option 4 would be implemented through the revised FQD approach.

Description of identified policy options

- ***Option 0:*** *No additional EU action (Baseline)*

This Option foresees that the 2030 EU climate and energy targets are achieved. The renewable transport target expires in 2020 and so it does the double-counting rule, currently applied to electric vehicles and advanced bio-fuels. The 7% cap for contribution of food-based biofuels in the overall national renewable "contribution" continues. Similarly, the FQD GHG intensity reduction target would not be prolonged post-2020. Member States would decide individually if and how to promote renewable energy in transports, in compliance with the relevant EU state aid rules. The EU biofuels sustainability criteria continue to apply post-2020. The EU research and innovation policy would continue to support non-mature technologies, along with national programmes. This option is described by the EUCO30 scenario (see Annex 4).

Energy-based policy options (1-3)

- ***Option 1:*** *EU incorporation obligation for advanced renewable fuels*

Option 1 foresees the introduction of an EU-level incorporation obligation, whereby Member States oblige fuel suppliers to include a minimum share (*e.g.* 4% by 2030[296]) of renewable fuels, including advanced biofuels, renewable electricity use din road transport and CCU and e-fuels in the fuels they place on the market[297]. As fuel suppliers would be best suited to supply electricity at the pump or along roads the contribution of renewable electricity is limited to road vehicles charged at publically accessible charging points. The obligation would increase over time and would be tradable. In case of non-compliance, Member States would apply financial penalties on fuel suppliers. In order to support advanced biofuels and electro-mobility, technology banding would be applied[298]. Apart from the 7% cap and the sustainability criteria, policy on food-based biofuels would be left to the Member States.

- ***Option 2:*** *EU incorporation obligation for advanced renewable fuels plus phase-out of food-based biofuels*

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296 The policy options included in the impact assessment vary with regard to their ambition level. Options 1, 2A and 2C and 3 aim to increase the level of advanced biofuels to approx. 4% of all liquid and gaseous transport fuels while Option 2B foresees with a share of 6.8% advanced biofuels a complete replacement of food-based biofuels. The sub-options under Option 4 also remain in this range. The level of ambition remains in the scope of what is considered feasible by the Sub Group of Advanced Biofuels (SGAB) of the Sustainable Transport Forum (STF) and other recent scientific work such as the report "Wasted Europe's untapped resource"

297 The contribution of the electricity would be still limited in 2030 taking in account low energy consumption of electric road vehicles (2.2% of transport energy consumption of which approx. 50% is of renewable origin). In modelling, the electricity was not included in mandates. Likewise e-fuels and CCU fuels are expected to play limitedrole in 2030 and they were not modelled

298 All policy options except the business as usual scenario make a distinction between different types of fuels. The contribution from biofuels produced from waste oils such as used cooking oil and CCU fuels would for instance be limited to take the state of technological development into account and to promote in particular innovative renewable fuels with a high potential. Otherwise fuel suppliers would aim to fulfil the obligation only with the cheapest fuels available on the market and the policy would likely fail to achieve its innovation objective

Option 2 would imply an EU-level incorporation obligation for advanced renewable fuels that is structured in the same way as Option 1 but would ensure the gradual replacement of food-based biofuels by an annually decreasing cap. This option includes three variants:

A. *Partial phase-out:* the cap for food-based biofuels is gradually reduced to pre-2008 level, by 2030.

B. *Full phase-out:* the cap on food based biofuels is reduced to zero by 2030.

C. *Hybrid approach*: option 2A plus a faster phase-out of vegetable oil biofuels and a higher GHG savings threshold (*e.g.*70%) for new biofuel installations, respectively in order to reduce ILUC emissions and increase direct carbon savings. Furthermore, the existing EU sustainability criteria are streamlined and improved[299].

➢ ***Option 3:*** *Option 2 plus a specific incorporation obligation for advanced renewable fuels suitable for aviation and maritime*

Option 3 would consist in Option 2 plus a specific EU-level incorporation obligation on renewable fuels consumed in aviation and maritime such as biokerosene and biomethane [300]. These sectors need a dedicated approach given that it is more costly and complex to replace fossil fuels.

Emissions-based option (4)

➢ ***Option 4:*** *GHG emission reduction obligation*

Option 4 would imply a continuation of the current approach of the FQD where Member States oblige transport fuel and energy suppliers to reduce the GHG intensity of the fuel and the energy they supply[301]. After 2020 a narrower approach would be taken to the fuels that are supplied, with different variations (described below) depending on which objective is maximised. Under all of the variations Upstream Emissions Reductions (UERs), LNG and CNG would be excluded.

a) Option 4 A: No additional EU policy (same as option 0);

b) Option 4 B: Continue the approach of the current FQD, supporting liquid and gaseous fuels and electricity.

299 In particular, the clarity of the provisions concerning sustainability and traceability are improved and the competences of the Commission with regard to the supervision of voluntary schemes are strengthened in order to ensure a harmonised implementation of the sustainability framework with a low administrative burden

300 The option was modelled with a specific incorporation obligation as this provides the highest assurance that renewable fuels will be consumed. Other options such as promoting the consumption of renewables in these sectors via specific incentives such as a higher weight for the fulfilment of the obligation can achieve similar outcomes

301 The current FQD (Article 7a) requires suppliers of fuel/ energy to reduce the GHG intensity of fuel/energy they supply by 6% in 2020 (relative to the 2010 baseline) and a number of fuels can contribute. A number of elements can currently contribute to the target including: biofuels from food crops, biofuels from wastes using commercial technologies, 'advanced biofuels', electricity, other renewable fuels and waste fossil fuels

This option consists of continuing the current approach of the FQD while narrowing the focus by excluding the contribution of lower GHG fossil fuels and Upstream Emissions Reductions (UERs)[302].

c) Option 4 C: *Continue the approach of the current FQD with a focus on advanced fuels and electricity*.

These options seek to maximise the achievement of objectives on driving innovation, supporting the uptake of electric vehicles and avoiding ILUC. They seek to maximise the support for innovation and electrification by focusing the mandate on 'advanced fuels' as defined by Annex IX(a) of the RES Directive (as amended by the ILUC Directive), including electricity. Three sub-options were assessed, 4C1, with a 2% GHG reduction and 4C2 and 3 which have a 2% GHG reduction but also allow Member State levels mandates for food based biofuels at 6% or 3% respectively. Within these options, option 4C3 was selected as the preferred option as 4C1 was too restrictive, while 4C2 allowed a very high contribution of crop biodiesel with high ILUC risks.

d) Option 4 D: Continue the approach of the current FQD with a focus on advanced fuels, electricity and low GHG first generation fuels when ILUC impacts are taken into account.

These options seek to maximise the achievement of objectives on driving innovation, supporting the uptake of electric vehicles and avoiding ILUC by focusing the mandate on 'advanced fuels' as defined by Annex IX(a) of the RES Directive (as amended by the ILUC Directive), including electricity and on those biofuels from food crops believed to have the lowest ILUC emissions, *i.e.* crop ethanol, while biodiesel is excluded. 4 D1 has a 2.5% overall GHG reduction target, 1.6% GHG reduction sub-target for advanced fuels, while 4 D2: 3% overall GHG reduction target, 2.3% GHG reduction sub-target for advanced fuels. 4D2 was selected as the preferred option as it has a higher level of ambition which is needed to drive the uptake of advanced fuels.

5.3.1.2. Detailed assessment

The following modelling tools have been used to assess the impacts of energy-based policy options 0, 2 and 3 (see further information in Annex 4):

- The PRIMES model was used to model impacts of options 0, 2 and 3. Option 1 was not quantitatively modelled as the outcome would depend on the policy choices of the Member States regarding food based biofuels. PRIMES is an energy model used for modelling all policy elements of the RES Directive included in this Impact Assessment and also *e.g.* Market Design Initiative and Energy Efficiency Impact Assessments.

302 UERs and non-waste fossil fuels (LNG, CNG) are excluded from the options. This is to ensure the options focus on delivery of the policy objectives above and provide a focused objective on delivery of advanced fuels to meet 2030 targets. Currently UERs are not required to take place within the EU and as the 2030 GHG reduction target is domestic for the EU, this approach changes the scope of the mandate to match this. In addition, the focus is on increasing the supply of fuels, increasing certainty for suppliers and reducing the complexity of the FQD mandate. As UERs are expected to be cheaper to deliver than fuels, removing them from the mandate sends a clearer signal to suppliers

- The GLOBIOM model[303] was used for assessing the ILUC impacts of the sub-Options 2A and 2C *e.g.* a gradual or full phase out of conventional biofuels. GLOBIOM is a global recursive dynamic partial equilibrium model with a bottom-up representation of agricultural, forestry and bioenergy sectors used also in the Impact Assessment on Bioenergy Sustainability.

- Bespoke analysis undertaken by the ICCT[304] was used to assess the impacts of Option 4 based on a GHG saving obligation.

Due to the significant differences in the assessment tools and underlining assumptions, the results are not directly comparable and therefore the impacts of options 0 to 3 (energy obligation) are presented separate from the assessment of option 4 (GHG reduction obligation).

Energy impacts of options 0 to 3

Under Option 0, by scenario construction, advanced biofuels would reach a 1.9% share of all liquid and gaseous fuels by 2030, compared to approx. 1% in 2014[305]. Under Options 2A, 2C and 3 (gradual phase out of food-based biofuels), advanced biofuels would reach respectively approximately a 4.0% share by 2030 (approximately 12 Mtoe). This would represent a significant increase compared to the projected level in 2020. Option 2B (full phase out of food-based biofuels) would require a quite significant growth in the deployment of advanced biofuels, which would increase to 21 Mtoe to reach a share of 6.8% of all liquids and gaseous transport fuels by 2030.

The share of biofuels has a direct impact on the amount of oil products consumed in transport. A decrease in oil imports of almost 2.0% is projected under the energy-based Options 2A, 2C and 3 and 0.9% under Option 2B. While renewable fuels can be both produced in Europe and imported, the economic modelling indicates high potential for the domestic production of ligno-cellulosic stocks used for advanced renewable fuels. As oil prices are assumed to grow steadily in a long-term perspective, savings in oil consumption would have increasingly beneficial effect for the European economy.

Table 5: Impacts on EU energy demand of options 0-3

303 GLOBIOM is a global recursive dynamic partial equilibrium model with a bottom-up representation of agricultural, forestry and bioenergy sectors. The model effectively represents the world's agricultural and forestry sectors and most relevant economic and demographic indicators and trade relations. GLOBIOM is an equilibrium model, meaning that the supply and demand sides of the agricultural and forestry sectors are represented, with supply and demand being equal at a certain price level. It was used in previous studies in order to quantify ILUC effects: https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf

304 "Service contract for technical assistance facilitating implementation of Art. 7a of the fuel quality directive 98/70/EC", contract no 340201/2015/706549/SER/CLIMA.C.2. with ICCT - International Council on Clean Transportation Europe

305 This includes mainly biofuels produced from waste oils such as used cooking oil which are produced with conventional technologies but a treated as advanced biofuels because they are produced from waste. The potential of such 1G waste based biofuels is limited though due to limited availability of the feedstock

	2030				
	Option-0	Option-2A	Option 2B	Option 2C	Option-3
Consumption of liquid and gaseous fuels(Mtoe)	308.7	307.7	307.2	307.7	307.8
Total consumption of renewable fuels(Mtoe)	20.4	24.8	21.0	24.7	24.8
Oil consumption in Option-0(Mtoe)/ % change in policy scenarios	279	-2.0%	-0.9%	-2.0%	-1.6%
Total share of renewables fuels	6.6%	8.1%	6.8%	8.0%	8.1%
share of food-based bio-fuels	4.7%	4.3%	0.0%	4.0%	4.1%
share of advanced RE fuels	1.9%	3.8%	6.8%	4.0%	4.0%
share of bio-methane	0.2%	0.2%	0.2%	0.2%	0.6%
share of bio-kerosene	0.0%	0.0%	0.0%	0.0%	0.7%

Source: PRIMES, 2016

Energy impacts of option 4

Figure 23 shows the share of renewable fuels under option 4 according to the ICCT analysis. The 4C sub-option examines the impact of a focused advanced fuel target at EU level, with and without Member State mandates that would support biofuels from food crops. The different sub-options of 4D examine the impact of supporting biofuels with lower ILUC emissions. These options exclude crop-based biodiesel but allow crop-based ethanol. As a result both options show a significant proportion of advanced fuels and electricity.

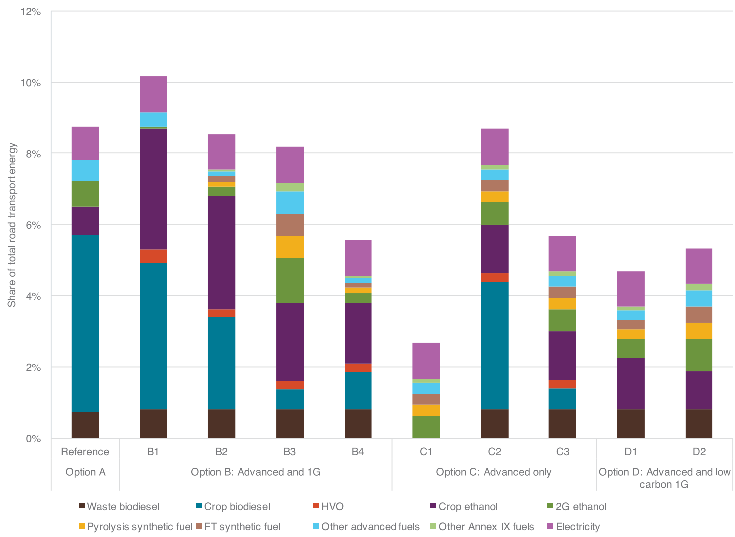


Figure 23: Share of total road transport energy by alternative fuel type under option 4

Environmental impacts

The environmental impact of the policy options is assessed according to their Climate performance taking into account both direct emission savings and indirect effects

Direct GHG emission impacts of options 0 to 3

Table 6 shows the impacts on WTW GHG emission savings of options 2 and 3, compared to the baseline. Options 2A, 2C and 3 have similar direct GHG savings (around 1.5% reduction compared to the baseline). This is due to the same overall share of biofuels.

Option 2B (rapid phase out of food based biofuels) has a lower share of biofuels. However this option still leads to under 1% reduction in direct GHG emissions compared to the baseline due to higher savings of advanced biofuels (in production and processing).

Table 6: Direct GHG emissions (% change vs EUCO30 scenario)[306]

	2030				
Emission savings	Option-0	Option-2A	Option 2B	Option 2C	Option-3
WTW Co2 emissions(Mt) /% change compared to Option-0	970	-1.5%	-0.8%	-1.5%	-1.6%

Source: PRIMES

Indirect GHG emission impacts of options 0 to 3

The Table below and Figure 24 show the GHG emission impacts of Options 2A and 2C (gradual phase out of all food based biofuels and biodiesel respectively), compared to option 0 (baseline)[307], as modelled by GLOBIOM[308]. The results indicate that maintaining food-based biofuels at the level of 2020 as projected in Option 0 would not address ILUC as it would cause additional emissions even after 2020. These emissions mainly come from peatland which was drained to produce palm oil in order to satisfy the additional feedstock demand stemming from biodiesel production. Production of palm oil on this land will continue to cause massive carbon emissions as, due to the drainage of the land, the soil itself, the peat, is slowly s oxidising. This effect would risk eliminating all GHG emissions achieved by biofuel production.

In contrast Option 2A (gradual phase out of food based biofuels by 2030) can significantly reduce ILUC emissions lowering the average ILUC factor from 64 to 27 g gCO_2/MJ. After 2020, ILUC impacts associated to peat land oxidation and natural vegetation conversion could be expected to cease. However, the balance of emissions remains positive due to lower carbon sequestration as result of less palm plantations (which mirrors the increase before 2020). Still, under this scenario the phase down of conventional biofuels would avoid unintended effects associated to biofuel growth, while resulting in significant direct GHG savings.

Option 2 C could be even more effective in addressing ILUC than Option 2A as it involves a more rapid phase out of vegetable oil based biofuels – associated with the highest ILUC emissions. It would reduce the average ILUC factor from 64 to 17 g gCO_2/MJ. In addition, this option implies a 70% GHG emission savings target for new installations – that, with a few exceptions, only advanced biofuels will be able to comply with.

The full phase out of food based biofuels under option 2B is projected reduce ILUC emissions further, as it would make additional land available to meet the growing demand for food and feed stemming from other sectors. However, the effect can be expected to be less pronounced as not only biodiesel, but also bioethanol (with much lower ILUC emissions) would be phased out. Furthermore, it should be noted that the amount of indirect emissions will also depend on the scale of biodiesel consumption in EU. Smaller quantities can be expected to result in lower indirect land use change

306 Direct emission do not include indirect land use change emissions

307 The scenarios were compared to a baseline representing the biofuel mix in 2008 which was also used in the GLOBIOM study from 2015. Keeping the same baseline ensured that the result remain comparable with previous studies on ILUC.

308 Valin et al., 2015, GLOBIOM study http://www.globiom-iluc.eu/

impacts because they can be met largely through domestic feedstock, while with increasing demand more imports are necessary and the related ILUC risks increase.

Finally, it should be noted that a GHG emission reduction obligation (that incentivises operators to maximize direct emission savings) could have the unintended effect of promoting the use of those biofuels that also have very high ILUC impacts. This would be the case of palm oil biodiesel which has higher direct GHG savings than, for instance, rape seed biodiesel (62% compared to 45%) but it is associated with much higher indirect GHG emissions[309].

Table 7: ILUC effect of options 0, 2A and 2C

Scenario	Biofuel demand of EU 2020 policy	Total emissions 20 years ($MtCO_2$-eq)[a]	Gross ILUC value of EU 2020 mix (gCO_2/MJ)[b]	Repaid CO_2 debt 2020-2030 (gCO_2/MJ)	Net effect (gCO_2/ MJ)
Baseline (Option 0)		330		0	64
Phase down food based biofuels (option 2A	6.2 Mtoe (261 PJ)	140	64	-37	27
Phase down biodiesel (option 2C)		90		-47	17

Figure 24: Cumulated GHG emissions of phase out of food-based biofuels (2008-2020, 2020-2030, $MtCO_2eq$)
Source: GLOBIOM

309 See Valin et al. 2015, Globiom report

Direct and indirect GHG emission impacts of option 4

The relative GHG impacts of Option 4 and related sub-option are shown in Figure 25. No dedicated GLOBIOM model runs were undertaken for this policy Option, instead the feedstock specific ILUC factors obtained from the GLOBIOM study (Valin et al. 2015) were used. These have been presented in order to demonstrate the relative GHG impact of the Option 4 sub-options. These ILUC factor values were derived by determining the increase of ILUC emissions that result from an increase of biofuel consumption by 1% against the 2008 baseline (3.2% biofuel use in the EU). It should be noted, however, that this simplified approach assumes that the scale of production has no effect on the ILUC risk, *e.g.* that replacing 1% of transport fuels with food based biodiesel has the same effect as increasing the share from 3% to 4%.

In each scenario under Option B, the GHG reduction targets and reportable reductions would be fairly high (4-7%), but a much lower GHG reduction would be achieved when accounting for ILUC due to the very high estimated ILUC emissions associated with using oil crops for biofuel.

In contrast, the scenarios under sub-Options 4.C and 4.D, which exclude crop biodiesel, would deliver real GHG savings similar to or above their targets of 2-3%. In sub-Options 4.C2 and 4.C3, actual GHG reductions achieved would be higher than reported under the FQD because national mandates would contribute some GHG savings through conventional biofuels. If first generation fuels are included in the same target as advanced fuels, competition with first generation fuels may to slow investment in the advanced fuel industry. Option 4D3, which includes a sub-target for advanced fuels, would help mitigate this uncertainty.

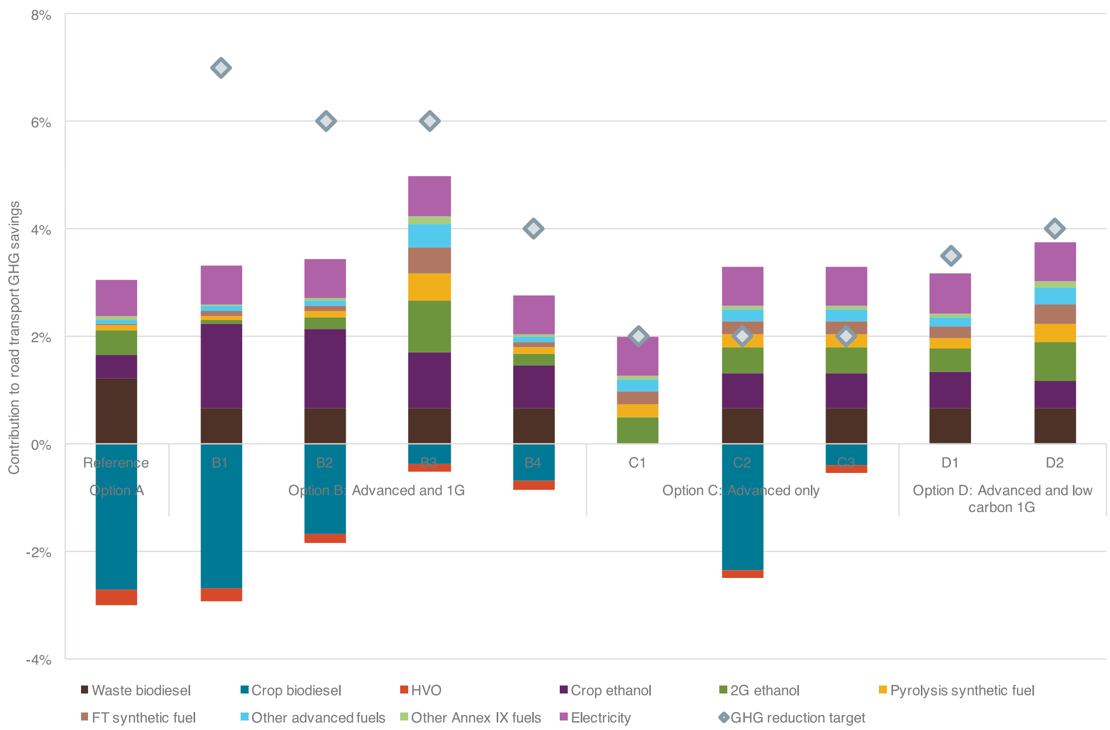


Figure 25: GHG impacts of sub-option 4 (% difference to the GHG reduction target, 2030)

Source ICCT 2016

Economic impacts

Economic impacts include investment costs which need to be compared against the savings on fossil fuel imports. Additional economic impacts can result from the impact of the policy options on global fuel prices.

As shown in Table 8 Options 0 to 3 will require significant increase in investment in advanced biofuels and construction of a sizable number of bio-refineries across the EU. This will also lead to an increase in capital costs. The unit capital cost of such bio-refineries is higher than that of conventional ones. However, increased production of advanced renewable fuels drives a reduction in the unit capital costs of these installations over time, as a result of learning effects.

In particular, given that advanced facilities have higher capital costs than conventional facilities, Option 2B (full phase out of conventional biofuels) would lead to the highest additional (compared to the baseline) capital costs, in the range of €1.5 billion per year. This would correspond to the installation of 200 additional advanced biofuel plants, assuming an annual production capacity of 100 Ktoe[310]. For Options 2A, 2C and Option 3 (gradual phase out of conventional biofuels) additional investments costs are reduced by more than 40%, down to € 0.9 billion/year.

Table 8: Annual capital costs (€ billions/yr) and capacity needs (Mtoe/yr)

	2030					
Advanced biofuels production chains	REF 2016	Option-0	Option-2A	Option 2B	Option 2C	Option-3
Average annual investments in bio-refineries for advanced RE fuels in REF/ additional investments for policy scenarios (bn €'13)	1.8	0.1	0.9	1.5	0.9	0.9
Capacity needs for advanced RE fuels bio-refineries in 2030	6.5	0.1	8.2	20.9	8.7	8.2
capacity (Mtoe/yr) available in 2030	6.5	6.6	14.3	27.4	15.2	14.7

Source: PRIMES

Impact on fuel prices of options 0- 3

Table 9 shows the impacts on fuel prices of the Options 0 to 3. Option 2B would result in the highest fuel costs in 2030 due to the significantly higher share of advanced biofuels, which are assumed to remain significantly more costly in the medium term (2030) than food based biofuels. On the other hand, the price increase is lower in Options 2A and 2C, reflecting a more gradual phase out of conventional biofuels. All scenarios show that, the fuel costs in Options 2 and 3 decline by 2050, compared to the baseline (as the learning effects lead to lower costs of advanced biofuels).

Under Option 3, jet fuel prices slightly increase in 2030 due to the higher cost for bio-kerosene, that fuels suppliers would be obliged to incorporate. In return the increase in costs for petrol and diesel (which include costs for blended biofuels) is less pronounced. By 2050 kerosene prices decrease in all scenarios compared to the baseline due to the fact that bio-fuels enable to avoid purchasing of ETS emission allowances which price is projected to grow steeply in all decarbonisation scenarios. Furthermore, it can be observed that the decreasing prices of feedstocks for bio-methane over the long term would also contribute to offset the initially higher fuel prices in the heavy duty and maritime sectors.

310 The capacity of biofuel production plants will vary significantly depending on process technology and feedstock availability.

Table 9: Fuel price impacts (% changed to the baseline)

	2030				
Impact on fuel costs (€ per ton and changes compared to Option-0)	Option-0	Option-2A	Option 2B	Option 2C	Option-3
Petrol prices 2030	2101	1.6%	3.6%	2.0%	1.0%
Diesel prices 2030	1836	2.1%	3.0%	2.1%	1.6%
Jet fuel prices 2030	994	0.0%	0.0%	0.0%	2.0%
Petrol prices 2050	2363	-0.3%	-0.7%	-0.4%	-0.5%
Diesel prices 2050	2061	-0.7%	-0.5%	-0.6%	-0.7%
Jet fuel prices 2050	1244	-1.1%	-0.9%	-1.0%	-1.1%

Source: PRIMES

Impacts of fuel prices of option 4

The relative costs of option 4 and its sub-options are shown in Figure 26. These costs represent the difference in fuel price between alternative fuels and fossil fuels (petrol and diesel) for the entire volumes that would be achieved in each scenario.

This analysis assumes that operating costs are higher for advanced facilities compared to conventional facilities – partly due to the costs of higher employment. Major cost savings of advanced facilities compared to conventional facilities are related to lower fuel costs compared to conventional biofuels and to a credit for valuable co-products from advanced processes (*e.g.* lignin). While cost estimates assume technological improvements that reduce the cost of advanced biofuel production over time, it should be noted that cost estimates for the year 2030 are used in this analysis.

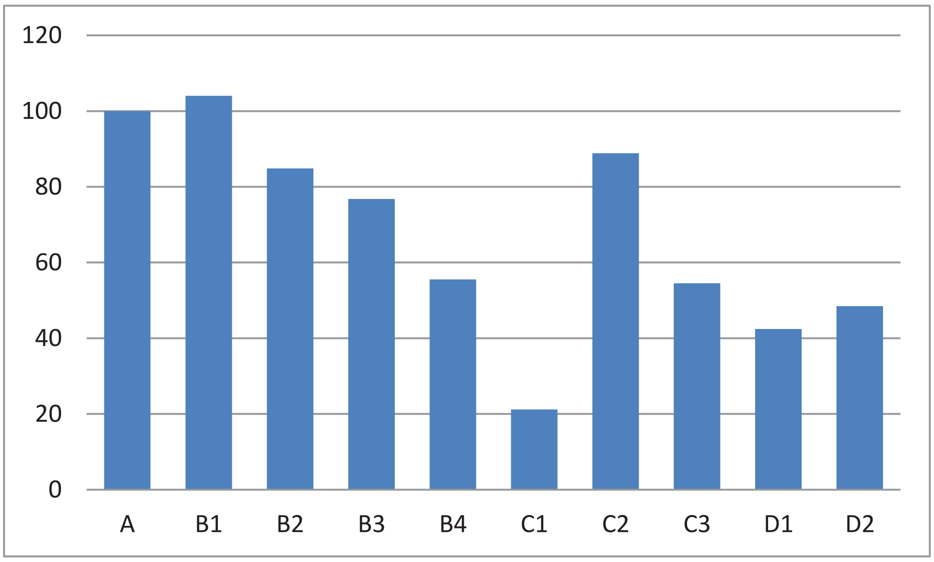


Figure 26: Relative total costs of option 4 (relative to the policy baseline A, euro billions)
Source ICCT0 2016

Social impacts

Employment impacts of options 0 to 3

As the models used are not covering employment impacts, the following analysis is qualitative.

Employment impacts include direct impacts in biofuel generators and supporting industries (*e.g.* engineers and plant operators, employees in marketing and distribution of biofuels, researchers and technology developers of technology and innovation, etc.), and indirect impacts in agriculture and forestry for feedstock production (farmers and forestry workers, etc.).

In 2014, the European conventional food-crop based biofuels industry had a turnover of EUR 13.4 billion and work force of around 110,000 jobs (direct and indirect)[311]. These job levels could be maintained under Option 0 as the production of conventional biofuel can be extended to continue unchanged. Option 2B (full phase out of food based biofuels by 2030) could lead to losses in direct jobs in conventional biofuel production in the short term. However, a transition from food based to advanced biofuels could lead to the creation of new jobs and economic activity in the production chain of advanced biofuels. Under Option 2A and similarly options 2C and 3 (a partial phase out of food based biofuels), any potential job losses in the food-based biofuel sector could be lower, and may not occur, as there would be more time for industry to re-structure.

When assessing the employment impacts of the phase out of conventional biofuels, one important element to be considered is the feasibility of converting a part of the current production capacity to produce advanced biofuels. Significant synergies for bioethanol sites exist through co-location of the new separate second generation plant adjacent to the first generation facility and through retrofitting by altering an existing first generation production line for producing advanced alongside conventional biofuels. In this way, existing jobs are preserved and new jobs are created while generating 40% CAPEX savings which represents roughly a 20% total cost reduction.

On the contrary, fewer synergies for biodiesel sites exist as the retrofitting of renewable diesel HVO sites to ones using second generation feedstock is less attractive. Moreover, integration of first and second generation biodiesel sites faces a rather limited technical feasibility.

Employment impacts of option 4

Table 10 shows the employment impacts of option 4 as calculated by ICCT. This table presents permanent direct jobs that would be supported by alternative fuel production under the various sub-options.[312]. In all scenarios, most jobs that would be supported by alternative fuel policy are in feedstock production and collection, with fewer permanent jobs supported in facility operation.

The cultivation of food crops tends to require more labour than collection of crop residues. However, cellulosic feedstocks such as wheat straw that are used for biofuel are much more likely to be produced entirely in the EU, supporting EU jobs. We note that the number of feedstock production jobs in Option 4B1 (152 000) is fairly close to the number (190 000) predicted in a JRC study modelling a similar biofuel scenario [313].

Table 10: Employment impacts of option 4 (1000, 2030), Source ICCT 2016

Source ICCT 2016

[311] EurObserv'ER 2015

[312] These estimates do not fully account for all jobs that would be created through transportation of feedstock and fuel, waste collection, and energy crop production. They do not include temporary construction jobs

[313] De Santi, 2008

Impacts	Option 4 A	Option 4 B				Option 4 C			Option 4 D	
Impacts	Ref.	B1: 7%, no cap	B2: 6%, 6% cap	B3: 6%, 3% cap	B4: 4%, 3% cap	C1: 2%	C2: 2%, 6% national mandates	C3: 2%, 3% national mandates	D1: 2.5%, 1.6% sub-target	D2: 3%, 2.3% sub-target
Feedstock production jobs (thousands)	88	122	101	82	55	17	93	51	39	43
Facility operation jobs (thousands)	21	22	20	25	14	10	23	16	13	17
Total direct permanent jobs (thousands)	109	144	121	107	69	26	116	68	53	60
Jobs per 1,000 tCO_2 abated	3.4	3.9	3.0	2.0	2.3	1.3	3.1	1.9	1.6	1.5
Jobs per million Euros of policy cost	11.2	14.4	14.5	13.9	12.6	12.4	13	12.5	12.5	12.5

Impacts on rural development

The impact on rural development depends on trends in demand and supply of agriculture feedstock. It should be noted that in 2015, 61 % of oilseed and 3.7 % of cereal cultivated in the EU were used for the production of conventional biofuels. In the same year, 13% of domestic sugar beet was used for the production of ethanol, of which virtually all was used for biofuels[314]. A complete phase out of food-based biofuels by 2030 is expected to have significant impacts on the rape seed production which would decline substantially and also sugar beet producers would also be impacted negatively. On the contrary, impacts on cereal producers are expected to be limited, given that only a fraction is used for the production of biofuels and the impact of European bioethanol production on commodity prices is very limited (1-2% impact on cereals prices[315]). Positive impacts are expected from the production and mobilization of feedstocks for advanced biofuels (including wastes, energy crops and lignocellulosic material).

On the other hand, it can be expected that a more gradual reduction of crop-based biofuels would allow the European agricultural sector to adjust, for instance, by shifting crops and by changing rotation plans, as well as through increase in production of lignocellulosic feedstock from dedicated energy crops (*e.g.* miscanthus or short-rotation coppice), provided that existing information and technical barriers are overcome.

Impact on third countries

314 EU agriculture Mid-Term Overview 2015
315 Renewable Energy Progress report 2015

Impact of third countries depends on how the policy options would biofuels/feedstock international trade flows. It is estimated that in 2014 the EU consumed between 1.6 and 3.2 Million tonnes of palm oil for its biodiesel production, corresponding to a share between 2.7% and 5.3% of the global palm oil production in the same year. Under REF2016, net EU imports of vegetable oil, mostly palm oil, are projected to amount to 2 Mtoe by 2030. This would correspond to approx. 20% of all vegetable oil used for biodiesel production in the EU in that year.

Under option 2B (full phase out), these imports of crop-based biofuels are expected to be discontinued, with resulting negative impacts in the short term on trading partners in Latin America (Argentina, Brazil) and Asia (Indonesia, Malaysia). On the other hand, a more gradual reduction of crop-based biofuels would allow the agricultural producers in third countries to adjust to the new market reality.

Administrative burden

It is expected that the administrative burden for public authorities would be similar for an energy based obligation and a GHG based obligation. However, the majority of Member States[316] has already introduced energy based incorporation obligations to promote renewable transport fuels along with other support mechanisms, such as tax measures. Therefore, the administrative changes and additional burden stemming from an EU-wide obligation would be somewhat limited because it would be implemented by the same public authorities that are currently implementing national measures.

Under the FQD Member States are required to implement a GHG emission reduction obligation before 2020, although so far only Germany has implemented it. In any case both options would be implemented by the Member States in a similar manner. Differences would mainly affect the economic operators. Furthermore, reporting requirements under the Fuel Quality Directive with regards to reporting on fuels origin and place of purchase will be streamlined and overlaps with other existing reporting requirements will be avoided.

Options 1 to 3 are expected to reduce the administrate burden for economic operators operating across the EU. Under these options, producers of advanced biofuels could simply apply default values to demonstrate compliance with the sustainability criteria avoiding an excessive administrative burden.

Under a GHG emission reduction obligation –which incentivises the calculation of the actual emission savings– significant simplifications could be obtained by a modification to the EU GHG calculation methodology. For instance, the option to calculate actual values could need to be limited to those parts of the life cycle – chiefly processing and transport – that can be effected by the biofuels producers.

Changing the methodology, however, could be criticised as the pre-calculated values would not reflect the situation in different regions or countries and economic operators could no longer adjust the figures according to their individual situation. As some types of feedstock are grown exclusively or mainly in Third countries, assumptions on the related emission could be challenged in the context of international trade obligations. Furthermore, a simplification could also have an impact on the feasibility of the current GHG emission savings thresholds.

[316] See Annex 7

Subsidiarity assessment

Implementation of an obligation on fuel suppliers is justified by the competence the EU has in the field of energy and climate policy. The political will of the Member States to act collectively on this matter was confirmed in the conclusions of the October 2014 European Council which established new energy and climate targets including a binding EU target for renewable energy of at least 27% by 2030.

A minimum EU wide energy based supply obligation for advanced renewable fuels is such a measure that promotes the increase of renewables in the transport sector, thus contributing to ensure that the binding renewable target is met. Given the environmental impacts of food-based biofuels, their contribution to the EU 2030 renewable energy target would be capped to a maximum of 7% of transport fuels. However Member States could set lower caps in case they wish to do so.

5.3.1.3. Overall findings

As discussed in the above analysis, both the RES Directive and FQD could contribute to the objective of increasing the share of renewables in transports and help decarbonizing this sector, albeit in a different way.

One first policy choice concerns the cap on food based biofuels for the period after 2030 as a means to address ILUC emissions. This includes a complete phase out by 2030, or a partial phase out. The analysis above points to the following considerations:

- Under the same decarbonisation ambition, a complete phase out of food crop biofuels by 2030 would require high shares of advanced biofuels and other renewable fuels and would likely require significant increased public support in order to deliver the needed technology and economic development in the advanced biofuel industry.

- Reducing the share of food-based biodiesel by 2030 combined with a higher GHG emission saving threshold and measures to incentivise advanced fuels would be effective for reducing ILUC emissions and promoting higher direct savings.

- A complete phase out of food based biofuels by 2030 would primarily lead to job losses in the production facilities, particularly in the biodiesel sector where there are lower synergies between conventional and advanced biofuel production technologies. These losses could be compensated by increased employment in the production of advanced biofuels, although the net impact is uncertain.

- The impacts on indirect jobs in agriculture and forestry are also uncertain, with some modelling suggesting potential positive impacts associated with the production and mobilization of feedstocks for advanced biofuels (including wastes, energy crops and lignocellulosic material).

A second key element of the analysis concerns the choice of policy instrument for increasing the share of renewable energy in transport. This objective can be pursued either through an energy-based incorporation obligation or, alternatively, through a GHG emission reduction obligation. Both approaches have their strengths and weaknesses. The analysis above points to the following considerations:

An energy based obligation would:

- Promote greater penetration of biofuels on the basis of the energy density of fuels relative to cost, and ensure GHG savings based on minimum, possibly increased, emission saving thresholds;

- Build on the extensive policy and administrative experience developed by Member States in implementing the RES Directive and their national renewable fuel mandates;

- Minimize the administrative burden for economic operators, which would continue to use mainly default values and not requiring a change in the EU GHG saving methodology.

A GHG intensity reduction obligation would:

- Incentivize fuels with the greatest direct GHG reduction relative to costs, as well as the continuous improvement in the GHG efficiency of fuels throughout the whole period up to 2030 as the instrument is optimised to GHG reduction.

- Continue the FQD policy approach currently being implemented by the Member States for the period up to 2020, thus ensuring policy continuity.

- Allow fuel suppliers compliance choices depending on costs. Where this is economically advantageous it is expected to encourage suppliers to report actual GHG values, instead of GHG default values, in order to maximise the GHG savings of their fuels.

Among the energy-based options (options 1 to 3) Options 0 can be discarded as it could not ensure that food based biofuels are gradually replaced by more advanced biofuels.

Among the options based on the Fuel Quality Directive (option 4), option 4A and option 4B can be discarded on the basis of the preceding analysis. These options maintain a mandate for food-based biofuels up to 2030, which significantly lowers their GHG performance.

5.3.1. *Overall comparison of the options to increase renewable energy in the transport sector (RES-T)*

	Overall impact			Key objectives		
Policy option	Social	Economic	Environmental	Effectiveness	Efficiency	Coherence
Option 0 - Baseline	0	0	0	0	0	0
Option 1 - EU incorporation obligation for advanced biofuels	+	-	+	0	+	+
Option 2 - EU obligation for all biofuels consumed in transport						
Option 2A partial phase out food based biofuels by 2030	0/+	-	++	++	++	+
Option 2 B: total phase out food based biofuels by 2030	+	- -	+++	++	+	+

Option 2C: faster phase out of food based biodiesel and higher GHG savings by 2030	+	-	+++	++	++	++
Option 3 - EU obligation for biofuels consumed in aviation and maritime	+	-	+	++	++	+
Option 4 – GHG reduction obligation						
4B- overall fuels and electricity GHG reduction obligation	+	- -	+	+	+	+
4C- advanced fuels and electricity GHG reduction obligation	+	-	+++	++	++	+
4D-: advanced fuels, electricity and crop-ethanol GHG reduction obligation	+	-	+++	++	++	++
+,++,+++ : positive impact (from moderately to highly positive) 0 : neutral or very limited impact -, --, --- : negative impact (from moderately to highly negative)						

5.4. Options to empower and inform consumers of renewable energy

The table below provides an overview of the options discussed in this section.

Challenges	Drivers	Policy Options
Empower Consumers to generate, self-consume and store renewable electricity	Overall lack of consumer empowerment in the energy transition • Investment uncertainty due to absent, unstable, or constantly changing legal frameworks for self-consumption in several Member States • Not all EU citizens are enabled to self-generate and consume • Unleash potential of self-consumption for solar deployment	0. Baseline - No EU intervention 1. EU Guidance on self-consumption of renewable energy 2. Empower citizens to self-consume and store renewable electricity 3. Distance Self Consumption for municipalites
Disclosing Information on the sources of electricity generation	Lack of clear and consistent information provided to consumers on renewable electricity sources • Scope for improvement of the GO system	0. Baseline - Continuation of EU current policies 1. Improve functioning of GO system 2. Option 1 + make GOs mandatory for disclosure 3. Option 2 + extend GOs to all sources of electricity generation
Tracing Origins of renewable fuels used in	Lack of clear and consistent consumer information on sources of	0. Baseline - Continuation of EU

H&C sector	renewable fuels • Lack of a robust tracking mechanism on renewable sources of liquid and gaseous renewable fuels • Lack of information inhibiting cross border trade of renewable fuels	current policies (no GOs for renewable fuels) 1. Extend GOs to renewable gaseous fuels 2. Extend GOs to renewable liquid and gaseous fuels 3. Develop alternative tracking system for renewable liquid and gaseous fuels

5.4.1. Empower consumers to generate, self-consume and store renewable electricity

Option 0	Option 1	Option 2	Option 3
• Baseline - no EU intervention	• EU guidance on **self - consumption of renewable energy**	• Empower citizens to **self-consume and store renewable electricity**	• **Distance self-consumption** for municipalities

➢ ***Option 0:*** *Baseline*

Under this option, no EU policy framework for self-consumption of renewable energy is developed. Member States decide individually if and how to promote renewable energy self-consumption systems. Support schemes will have to comply with the State aid rules. The regulations in some Member States discourage self-consumption and would continue to be in place.

➢ ***Option 1:*** *EU guidance on self-consumption of renewable energy*

Under this option, the Commission would develop a revised non-binding guidance on self-consumption, building on and further expanding the Staff Working Document (2015)141. Given the non-binding nature of the guidance, it is uncertain that this option would address existing legal barriers to renewable energy self-consumption effectively, with the risks of different levels of consumer empowerment across the EU.

➢ ***Option 2:*** *Empower citizens to self-consume and store renewable electricity*

The Revised RES Directive would set out framework principles enabling consumers to generate renewable electricity for their own use without their supplier's permission, and would limit the administrative burdens of doing this. This option responds to the concerns of 79 % of stakeholder who expressed an option on the matter in the public consultation and believed that there are administrative barriers to self-consumption. More specifically, this option would include the following provisions:

- Introduce a EU-wide definition of renewable energy prosumers;

- Empower consumers (below a certain capacity threshold) to generate and store renewable electricity for their own use, without requiring the supplier's permission, and limit the administrative burden by requiring a simple notification to the DSO;
- Enable consumers to sell excess renewable electricity and to participate in all relevant energy markets either directly or through market aggregators.

At the same time, there are a number of aspects relevant for self-consumption that will need to be addressed in the Market Design Initiative, such as ensuring that consumers who generate their own renewable energy electricity have access to wholesale and balancing markets through aggregators and that wholesale market rules do not discriminate against renewables, in particular small-scale producers. In addition, grid tariffs should reflect the cost-benefits of self-consumption systems for the electricity network and incentivise cost-effective consumer behaviour from a system point of view.

➢ ***Option 3:*** *Distance self-consumption for municipalities*

Option 3 would further expand Option 2 by enabling also distant self-consumption of renewable energy, specifically for municipalities, *i.e.* renewable plants installed in one municipal building could provide electricity for other municipal buildings. This option would help municipalities fully engage in the energy transition.

5.4.1.1. Introduction to the assessment

Thanks to the drop of PV module prices, decentralised generation of solar energy has reached grid parity in most Member States, *i.e.* self-generated electricity is as cheap as or even cheaper than electricity from the grid, at retail price. In many Member States this new trend allows consumers to actively engage in the energy transition while saving on their electricity bill.

Self-consumption (*i.e.* the simultaneous generation and consumption of electricity) can provide benefits to the entire electricity system, chiefly when there is a good match between renewable electricity generation and consumption. This is for instance often the case for commercial buildings and supermarkets when the generation profile of solar panels matches the consumption pattern (day consumption) or when air conditioning is used during sunny days. At the same time, the wide-spread deployment of self-consumption can bring a challenge in terms of adaptation of grid tariffs. To the extent that grid costs are passed on to consumers through volumetric billing of the grid (as opposed to capacity-based charging), the increase in self-consumption rates may reduce revenues for grid operators, which in turn may need to recoup these losses via increased charges on traditional consumers. Once the levelised costs of rooftop solar reach the level of wholesale market prices, it can compete on the electricity element of the retail electricity price. Until then, investments in distributed solar generation depend on the pricing regime (*e.g.* on gird tariffs, RES levies or taxes). In the absence of support schemes, self-consumption is economically only viable in those Member States where distributed generation can produce at least at retail level prices[317].

As the RES Directive does not contain any specific provisions on self-consumption, Member States have developed different legal frameworks that led to a high degree of

[317] European Commission (Report on Investments in investments in solar panels in the residential sector in EU Member States, to be published in Q4 2016)

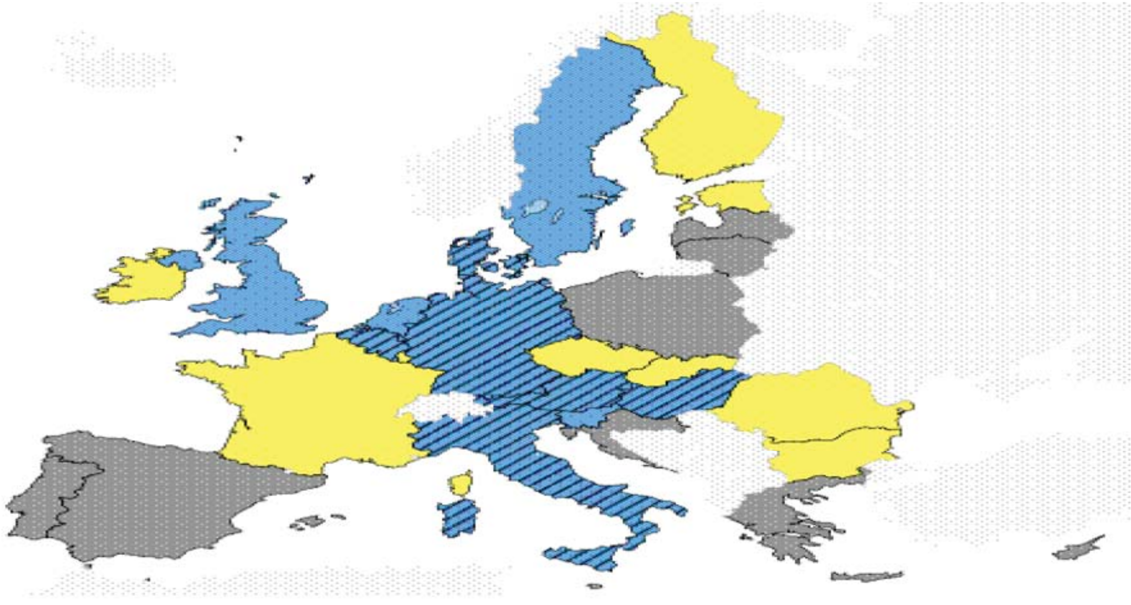
fragmentation and different levels of consumer empowerment in Europe. Some Member States put in place feed-in tariffs, such as Bulgaria, Denmark, Germany, Estonia, France, Greece, Croatia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Slovenia, and Sweden. The level of these feed-in tariffs varies and is sometimes below the levelised costs of electricity. The UK offers an export tariff and Romania works with Green Certificates. Denmark put in place an hourly net metering scheme, in other Member States it is annual but with lower price for electricity which is fed in to the grid. An overview of different degrees of consumer empowerment is provided in the graph below.

Table 11: Overview of self-consumption schemes in Member States

	Net metering	Grid fees	Taxes and levies	Support scheme
BE Wal	Yes	No	No	Yes
BE Bru	Yes	No	No	Yes (Green Certificates)
BE Fla	Yes	Yes - prosumer tariff	Yes - prosumer tariff	No
BG				
CZ				
DK	Yes	No	No	No
DE	No	No	Yes (but for PV>10kW)	FiT for excess electricity
EE				
IE				
EL	Yes	No	No	No
ES	No	Yes – prosumer charges	No	No
FR	No	No	No	FiT for excess electricity
HR	No	No	No	FiT for excess electricity
IT	Yes	Yes (>20 kWp)	No	No
CY	Yes	No	No	No
LV	Yes	Yes	Yes	No
LT	Yes	Yes	No	No
LU				
HU	Yes	Yes	No	No
MT	No	No	No	FiT for excess electricity
NL	Yes	No (below 5000 kWh)	No	No
AT	No	No (below 25 MWh)	No	Private Purchase Agreement for excess electricity

PL	No	No	No	FiT for excess electricity
PT	No	Yes (above self-consumption level in PT > 1%)	No	Yes (Wholesale price - 10% for grid fees) for excess electricity
RO				
SI	No	No	No	Yes (FiT)
SK				
FI				
SE	No	Yes (fixed part, only variable part exempted)	No	Green certificates for excess electricity
UK	No	No	No	Yes (FiT + export tariff)

Furthermore, in the absence of European legal framework national regulations have been highly unstable[318], which significantly reduced investor certainty in many Member States and led many respondents to the public consultation, in particular from the renewables industry, NGOs and cooperatives, to call for a clear European framework and a European vision on self-consumption. In the figure below (map), the Member States with a dotted line have made changes to their national framework since 2013 and the Member States in yellow only established a legal framework after that year.



[318] 9 Member States do not yet have a legal framework for self-consumption (Bulgaria, Czech Republic, Estonia, Finland, France, Ireland, Luxembourg, Romania, Slovakia) and the legal framework changed at least once in 15 Member States over the past three years (Austria, Belgium, Croatia, Cyprus, Denmark, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Spain).

Figure 27: Regulatory frameworks for self-consumption
Source: European Commission (Report on Investments in investments in solar panels in the residential sector in EU Member States, to be published in Q4 2016)

Blue: Member States with a regulatory framework established before 2013
Yellow: Member States with a regulatory framework dating after 2013.
Dotted line: Changes to a regulatory framework existing before 2013 and implemented after 2013
Grey: Member States that do not have a dedicated support framework for self-consumption, although self-consumption can be allowed

5.4.1.2. Detailed assessment

In the future, it is likely that the uptake of small-scale solar will be mostly driven by decision taken at household and business levels looking to offset retail power tariffs and reduce costs[319]. Based on this assumption, this impact assessment tries to assess the gap of renewable energy generation that would result from a support phase-out and that would have to be filled by self-consumption. According to the model, growth will first take place in small-scale solar designed for self-consumption during daytime. With storage becoming more widely and cheaply available, a higher level of self-consumption throughout the day and larger solar panels will be installed.

In order to assess the impact of the different options, this Impact Assessment focuses on the deployment of rooftop solar PV generation[320] as well the share of self-consumed electricity among overall rooftop PV generation. For this, the following PRIMES scenarios and assumptions are used:

- For Option 0 and Option 1, REF2016 was used to assess the continuation of current practices in the absence of enabling framework at Member State level. Within these options, the self-consumption ratio[321] ranges between 33% and 64%[322].
- For option 2, EUCO27 has been used, mirroring cost-effective deployment of renewables within a harmonized enabling framework. The self-consumption ratio ranges between 37% and 67%[323].
- For option 3, EUCO27 has been used, mirroring cost-effective deployment of renewables within a harmonized enabling framework. The self-consumption ratio ranges between 41 % and 72 %. The increased self-consumption ratio is an illustrative draft estimation assuming an additional 9 % of energy potentially self-consumed at municipal level[324].

Based on these assumptions, the solar PV generation by 2030 would break down as below:

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319 Bloomberg's New Energy Outlook, 2016
320 Rooftop solar PV capacity and generation based on PRIMES is to be consider indicative
321 Corresponding to self-consumed electricity vs. overall rooftop PV production
322 Based on EC analysis, resp. without or with batteries deployment
323 Based on EC analysis, resp. without or with batteries deployment, and factoring the possibility to self-consume within multi-apartment blocks
324 9% is the estimated share of locally produced energy in municipal energy consumption of selected municipalities, based on EC, The Covenant of Mayors in Figures, 2015.

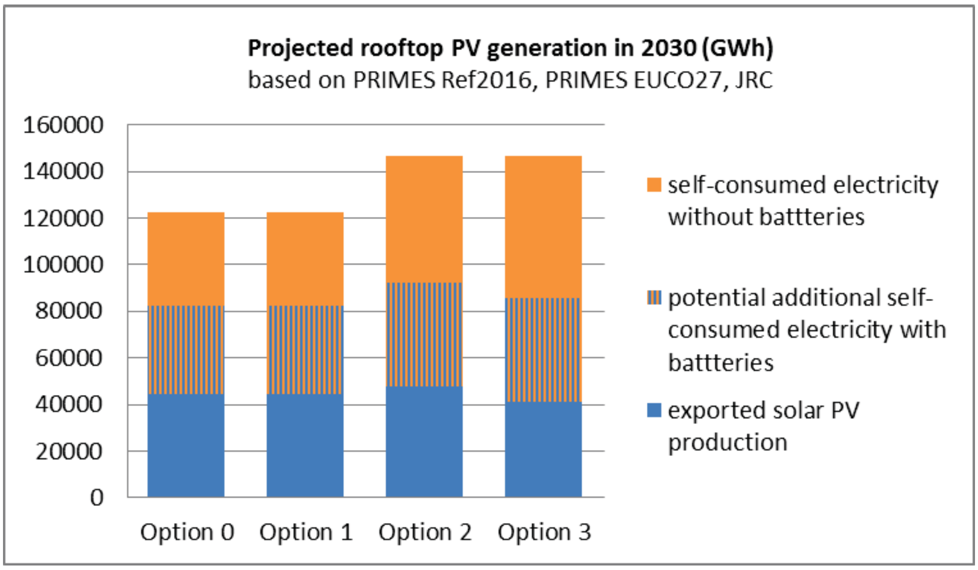

Figure 28: projected rooftop PV generation in 2030

The effect of the enabling measures under Option 2 and Option 3 is, as depicted in Figure 29, twofold:

- An increase in overall rooftop solar PV deployment, driven by self-consumption. By 2030, this increase is expected to be 20% compared to options 0 and 1, and 50 % compared to 2020.
- An increase in self-consumed electricity. By 2030, the maximal increase (assuming no battery deployment) is 26 % to 34 % compared to options 0 and 1. This increase could be however substantially higher[325] when compared to 2020, mostly due to a possible uptake of batteries.

However, all of these options will have a relatively moderate impact on the electricity consumption and generation pattern at EU-level, as shown in Figure 33.

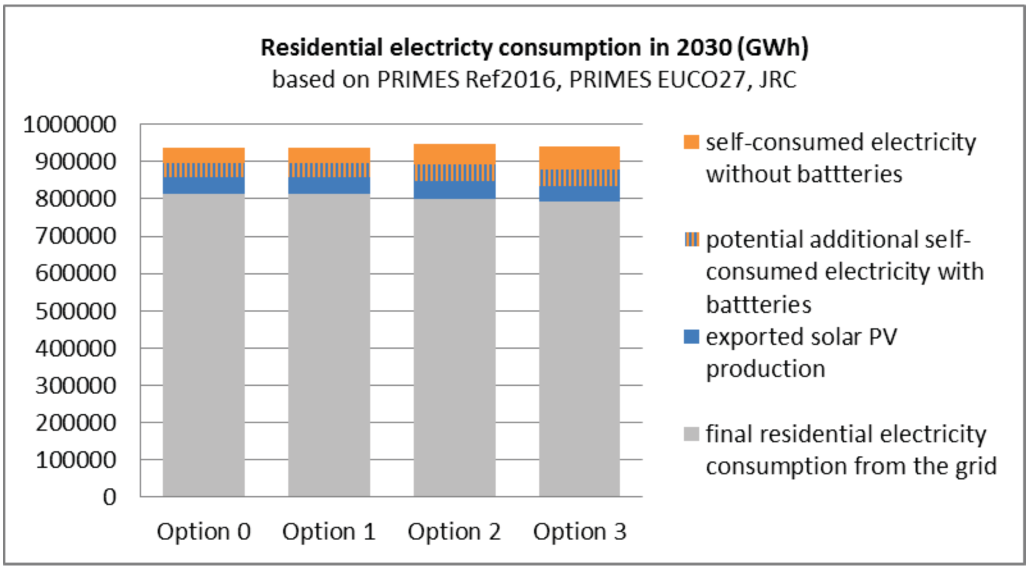

Figure 29: residential electricity consumption in 2030

325 Around +200%

Economic impacts

Self-consumption allows consumers to lower their electricity bill. With an average self-consumption rate of 30 % a consumer a four-person household with a 4 kWp PV system and with an average annual electricity consumption of 3 600 kWh could save almost € 320 a year due to self-consumption[326].

These savings are partly due to self-produced electricity which does not have to be bought and to a lesser extent due to the grid charges that are saved. This has led to concerns about lost revenue for the TSO that might impact the grid charges to be paid by other users that do not self-consume. However, due to the low self-consumption rates this problem is of theoretical nature today. Although today no statistics are available regarding self-consumption in the EU, German statistics for PV self-consumption indicate that it represents about 2.5 TWh (or 0.5 % of the final German electricity consumption) and seems to remain constant overtime from 2012 -2016. The same report assumes that even if the maximum potential of roof top solar according to PRIMES is used for self-consumption, the reduction amounts to 7.2 % of the 2013 distribution revenues and 1.1 % of the total electricity revenues. This calculation is based on the current rate design. Further analysis can be found in the MDI Impact Assessment, according to which on the one hand, a potential 'flight from the grid' could see the remaining connected ratepayers bear an increasing share of the burden of contributing to public finances and financing the electricity network. On the other hand, grid costs may actually fall as distributed generation and storage assets enable network operators to more efficiently manage the grid and connect remote customers. Cost-reflective distribution tariffs, *i.e.* tariffs that allocate the costs of the grid fairly amongst system users, are analysed in the MDI Impact Assessment.

Option 0 is expected to have the lowest impact on additional self-consumption of solar electricity, as business as usual continues. Option 2 and 3 are expected to have the largest impact because more actors are enabled to resort to solar generation. However, under Option 3, municipalities would be allowed to consume electricity that was produced on one building in a municipal building in another location, in order to better match their own production and consumption and increased their self-consumption ratio. By increasing the distance between the points of production and consumption by using the distribution grid, potential benefits of self-consumption for grid demand and grid losses would diminish, especially when the consumer is supplied via the distribution grid. It could however motivate municipalities to invest in renewable energy sources but it seems doubtful that this solution would be cost-efficient.

Option 0 and Option 1 would have the smallest impact on revenues. However, they would also fail to empower consumers. Option 3 appears to be most costly because it does not provide the potential benefits of self-consumption but reduces financing and tax revenues.

Social impacts

The Energy Union places citizens at its core. This includes giving consumers a wider choice of action when choosing their participation in energy markets and enabling them to generate and consume their own energy under fair conditions in order to save money,

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326 European Commission Staff Working Document SWD (2015)141, "*Best practices on Renewable Energy Self-consumption*"; ECFIN paper, "*Investments In Solar Panels in the Residential Sector in EU Member States*", to be published Q4 2016

help the environment, and ensure security of supply. Engaging consumers can also help mobilise private investments for the energy transition and increase the sense of ownership. As the large number of petitions at the European Parliament on self-consumption show[327], the business as usual scenario fails to achieve that objective in at least some Member States.

Option 1 is unlikely to improve the situation in all Member States as guidance would remain voluntary. Option 2 is likely to improve the situation across the EU as a European legal framework could establish a minimum degree of consumer empowerment in all Member States. Option 3 would indirectly involve a very large share of the population in self-consumption if municipalities started to install solar panels for virtual self-consumption on schools, swimming pools and other public buildings. However, virtual self-consumption over the grid would raise new challenges with regards the financing of the grid.

In addition to consumer empowerment, enabling self-consumption could also create new jobs. In 2014, the PV sector in Europe represented nearly 110.000 full-time jobs most of which in the installation and maintenance sector[328.] Yearly installed capacities in Europe have a significant impact on job creation as there is a direct impact on and services needed. Rooftop solar creates nearly three times as many jobs as ground-mounted installations. As self-consumption is likely to be a key driver for the uptake of solar (and other renewable) energy generation, this would also be the driver for new jobs. Option 0 and Option 1 are not expected to have a strong impact. Option 2 and 3 could trigger higher investments in the sector and thus contribute to higher job creation. Options 2 and 3 might create 10 000 to 20 000 additional jobs[329] in roof-top solar by 2030 compared to the business as usual scenario.

Grid defection from households that can cover their entire energy needs through self-produced electricity is not expected. In Northern Europe, this would require seasonal storage in order to match the consumption peak in winter with the production peak in summer. Even in Southern Europe, it is questionable if self-sustainable prosumers would choose to disconnect from the grid as this would prevent them from using electricity from the grid when their own generation does not function (*e.g.* for rooftop panels when the sun does not shine) and from selling excess electricity to the market (*e.g.* in times of long sunny periods). Should a prosumer however wish to disconnect from the grid, it would be fair if he does not contribute to the grid costs as he does not use it. This question is analysed more substantially in the MDI Impact Assessment.

Environmental impact

Environmental impacts are mostly influenced by the additional renewable energy generation in the system. In this case, the difference in rooftop PV generation between options 0 and 1 and enabling option 2 and 3 is 24 TWh, *i.e.* around 1.4 % of all renewable electricity by 2030[330]. Therefore these options are expected to have an overall moderate but still positive impact on renewable electricity deployment.

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327 In June 2016, the PETI Committee of the European Parliament discussed 16 petitions linked to self-consumption.

328 Solar Europe and EY, “Solar Photovoltaics Jobs & Value Added in Europe”, November 2015

329 Based on average figures per MWp and GWh from Wei, Patadia, and Kammen, 2010, and PRIMES results

330 PRIMES EUCO27 scenario

5.4.2. Disclosing information on the sources of electricity generation

Option 0	Option 1	Option 2	Option 3
• BASELINE - Continuation of current EU policies	• Improve functioning of GO system	• Option 1 plus make GOs mandatory for disclosure	• Option 2 plus extend GOs to all sources of electricity generation

➢ ***Option 0:*** *Baseline*

There would be no change in the current system, it would continue to function as presently designed.

➢ ***Option 1:*** *Improve functioning of GO system*

Improvements are made to the functioning of the GO system by making current good practice approaches of Member States in the operation of the system a mandatory part of the legislation. This would create a better single EU market for GOs from renewable energy.

➢ ***Option 2:*** *Option 1 plus GOs mandatory for disclosure*

In addition to improving the functioning of the system, GOs become the only means for disclosure of renewable electricity consumption to consumers. Energy suppliers would therefore need to use GOs if they are to make any claims about the renewable content of the electricity. The disclosure requirements set out in the Electricity Directive may need to be amended accordingly for this purpose. For this more comprehensive approach to work, Member States would need to issue GOs for electricity subject to a national support scheme in a way would not provide these generators with additional compensation.

➢ ***Option 3:*** *Option 2 plus extend GOs to all sources of electricity generation*

The GO system is expanded to provide a system of full disclosure of all energy sources, so enabling the origins of fossil and nuclear energy to be tracked in the same way. This would also mean that data such as CO_2 emissions from electricity consumption could be reported to consumers in a consistent way. In addition to making cancellation of GOs mandatory to energy suppliers, this option could also make issuance of GOs mandatory to all electricity producers, requiring all such energy sources to have GOs issued for them. However, such an expansion could be implemented in a voluntary manner, where Member States issue GOs to such electricity producers only at their request. There would be no obligation for GOs to be issued if the electricity generator does not want them.

5.4.2.1. <u>Introduction to the assessment</u>

The guarantee of origin (GO) system helps to disclose to consumers the share or quantity of energy from renewable sources in an energy supplier's energy mix. It provides a pan-European information system for the final consumer as to the origin of electricity, so enables producers to demonstrate the share or quantity of electricity produced from renewable sources and from high efficiency CHP[331].

GOs may be used for energy mix disclosure requirements by energy suppliers (*e.g.* set out under the Electricity Market Directive 2009/72/EC), but their use is not compulsory under this legislation.

GOs are electronic certificates that prove that energy is generated from renewable sources or CHP. The key features are:

- GOs prove that a certain amount of renewable energy was produced somewhere in Europe – they do not prove that a certain amount of renewable energy has been physically consumed by the purchaser;
- The legislation creates a single market for GOs - they are traded separately from the physical power so they can move around Europe;
- A GO represents 1 MWh of energy; GOs need to be used and cancelled within 12 months; each GO has unique identifier which gives standardised information on factors such as: date and country of issue, date of energy production, age of installation, location;
- Member States have to recognise GOs issued by another Member State.
- A common hub has been developed to enable such electronic transfers by the Association of Issuing Bodies (AIB). Refusal to recognise a GO from another Member State is possible, in case of doubts about its quality, in which case it must be notified to the Commission.
- Each Member State has a national competent body for electronic issuing, transfers and cancellations of GOs:
    - they must be issued upon request to producers of renewable and high efficiency CHP electricity[332];
    - it is optional for Member States to issue them for renewable heating and cooling;
    - it is possible for Member States to only issue GOs to renewable electricity not receiving support under any other national support mechanism. This was to avoid concerns as to double subsidy of renewable energy.

In theory, a book and claim approach for GOs is an efficient system enabling renewable energy to be produced in more cost efficient locations and consumed remotely. They are low cost and efficient relative to other certification models and fit well with diverse supply chains across multiple countries. However, to retain credibility, it is essential that such an approach has well-functioning systems for issuing and retiring GOs and that the central registry is robust. In addition, the system can be more vulnerable to fraud and gain a poor reputation with consumers if the systems are not resilient[333].

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331 In some European states the GO system is applicable to all other sources of electricity generation (*e.g.* AT, CH and SE) and similar national or privately initiated systems for renewable fuels (*e.g.* bio-methane in AT, DE, DK, FR, UK and CH).

332 Article 14(10) of Directive 2012/27/EU on energy efficiency that creates guarantees of origin for high efficiency co-generation but does not prescribe a use for them.

333 Characteristics of book and claim systems described in: "Sustainability Journal - Certification of Markets, Markets of Certificates: Tracing Sustainability in Global Agro-Food Value Chains –Mol and Oosterveer"

Use of GOs is growing over time. Figure 30 shows that increasing volumes of GOs have been issued and cancelled over recent years. In 2011, GOs were issued for about 22% of the renewable electricity generated in the EU. By 2015 issuance had grown to covering around 45% of the renewable electricity generated.

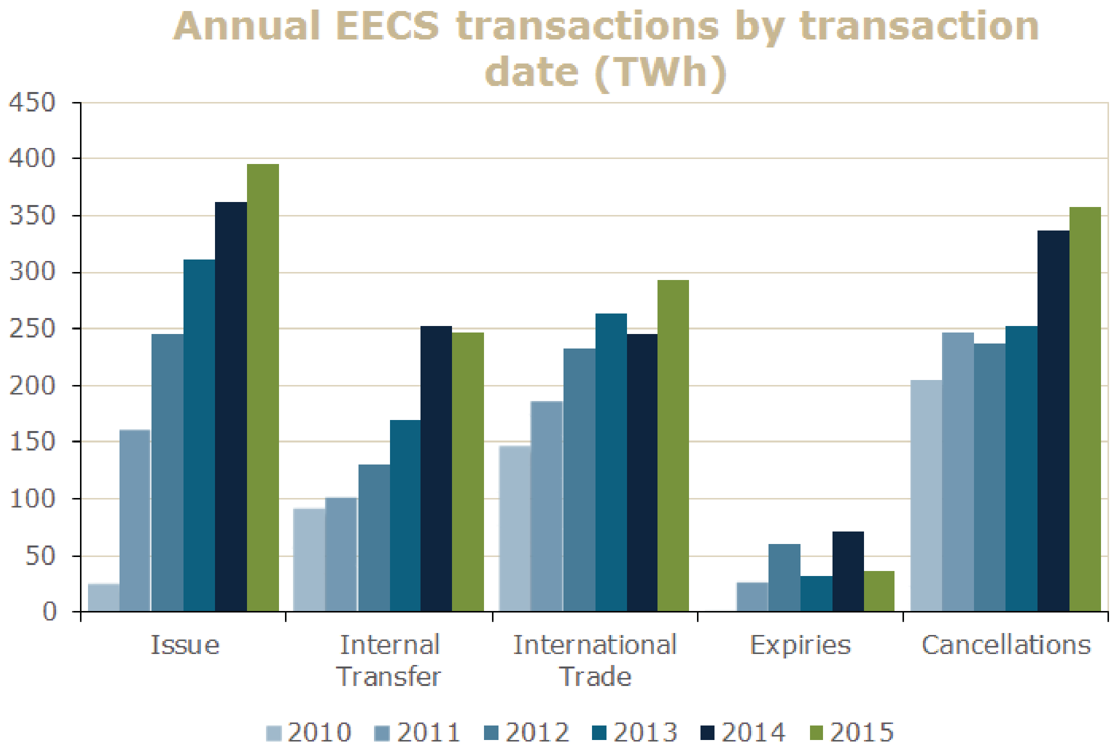

Figure 30: Total volume of GOs using EECS standard transacted through the AIB hub [334]

Although an increasing amount of renewable electricity is covered by GOs, Figure 31 shows that the majority of power generation is outside of the GO system.

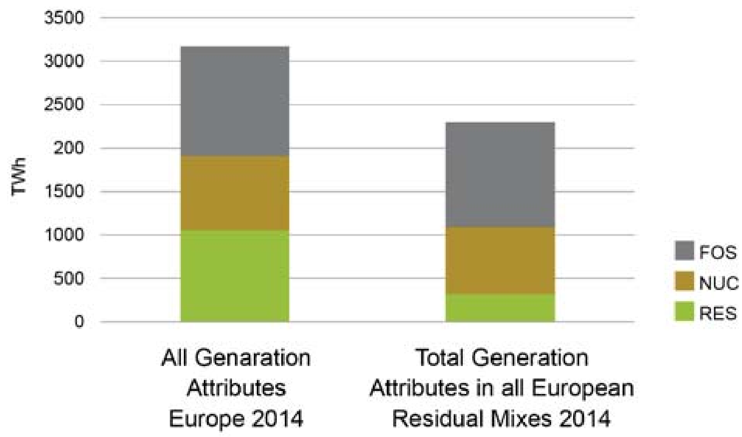

Figure 31: Total Generation (left) and non-tracked generation (right) in 2014 [335]

The trend for increased use of GOs demonstrates that there is strong and growing consumer demand for green energy products in recent years. Green electricity tariffs

334 The Association of Issuing Bodies – Annual Report 2015

335 RE-DISS II Final Report

based on renewables and backed by GOs are common in many Member States. The growth in the issuance and cancellation of GOs suggests that abolition of the system could be counterproductive, possibly resulting in the need for alternative mechanisms to be developed. Furthermore, it was notable that there was little call for such an approach in the public consultation.

Growth in demand for GOs has also come from corporate consumers seeking to satisfy corporate environment, social and governance (ESG) requirements. Indeed one important driver of the GO market is the recent recognition of GOs by the main corporate carbon accounting standard organisation CDP (formerly Carbon Disclosure Project). Their technical guidance now states: *"you can reflect specific policies on contracting renewable energy into your disclosure on emissions performance, namely if your […] emissions have reduced as a consequence of buying RECs or GOs you can consider that as a emission reduction activity"*[336]. The endorsement of GOs by such a body is likely to increase demand from the corporate sector for GOs over the coming years as they start to implement the latest guidance. The guidelines also demonstrate that a core demand for the GOs from these corporate consumers is for CO_2 accounting reasons, rather than the renewable character of the energy itself. The GO is valued primarily for the reason that it represents low carbon energy.

The most developed case of such renewable consumption can be found in Luxembourg, where it is reported that the number of 'green' electricity contracts accounts for 100% of the retail market[337]. In the Netherlands 63% of all contracts are now green[338]. This high level of consumption, contrasts strongly with the low renewable energy generation. In 2014, just 5.9% of the electricity produced in Luxembourg was from renewable sources and 10% in the Netherlands demonstrating significant imports of the GOs from other countries[339].

As a consequence of this, Norway which generates virtually all of its electricity from renewable sources and exports the associated GOs ends up importing a residual mix of electricity from fossil and nuclear power generated in other parts of Europe. In accordance with the principles of the Electricity Market Directive, this resulting mix is shown to consumers on their bills.

GOs have a relatively low value, generally trading for under a Euro for each MWh of electricity. Finding prices of GOs is not straight forward as there are no published indices since most GOs are traded over the counter. One publically available source is the results of the auctions made by GME which sells GOs on behalf of the Italian Government[340]. Prices achieved in the three 2016 auctions averaged between 15-29 cents per MW/h.

The data on the GME website shows that prices have remained low over time, suggesting that there is little scarcity in the market, *i.e.* supply through issuance has grown at slightly higher rate than the demand for cancellation. However, there have been cases reported of certain specific types of GOs selling at much higher prices (*e.g.* anecdotal evidence that

336 https://www.cdp.net/Documents/Guidance/2015/Accounting-of-scope-2-emissions.pdf

337 BEUC Mapping Report - Current practices in consumer-driven renewable electricity market, January 2016, p. 17

338 BEUC Mapping Report - Current practices in consumer-driven renewable electricity market, January 2016, p. 17

339 Eurostat, 2016.

340 http://www.mercatoelettrico.org/En/Esiti/GO/EsitiGOAste.aspx

GOs from wind energy generated in the Netherlands has sold at over EUR 2 a MW/h). Such prices are likely to be driven by consumers expressing demand for certain types of renewables in certain locations.

It is apparent that there are differences across the EU in the way in which Member States have implemented the GO system. A 2014 consultant's report for DG Energy on progress in renewable energy[341] found that:

- There were considerable differences between the national systems due to different approaches to implementing the requirements;
- Not all Member States had decided to join the Association of Issuing Bodies (AIB) which provides a standardised system for the exchange of GOs between Members;
- 2 Member States did not have an electronic registry;
- Practices for fraud avoidance varied, many Member States have put in place a system of verification; and
- Only 3 Member States had decided to introduce GOs for heating and cooling, however neither seemed to have any activity in that sector.

Some of the variations in the implementation of the system between Member States, reflects the flexibility inherent in the legislation. Many of these differences persist. For example, at the end of 2015, AIB had a total of 18 EU and EEA-EFTA countries as members[342]. Whilst membership of the AIB is voluntary for Member States, it provides a convenient and robust means for the trade of GOs. The absence of some Member States from the AIB indicates differences in implementation of the GO system around the EU and an incomplete internal market.

A key variation is the relationship between GO issuance and national support schemes. In line with an option in the Directive, many Member States restrict issuance of GOs to electricity not benefiting from support schemes to avoid double compensation to electricity producers. As a result, GOs are only issued for the unsupported part of the renewable electricity production. Other Member States issue GOs for all renewable electricity. For example, Italy auctions the GOs associated with supported electricity. This ensures full issuance of GOs for all renewable electricity, but prevents double compensation for energy generators who already received payment from the national support scheme.

As described in the problem definition section, the current legal structure risks double counting of renewable electricity, as use of GOs is not required for disclosure purposes. To prevent such risks, the hub system developed by the AIB for exchange of GOs across the EU has at times disconnected some Member States[343] from trading GOs with other countries, if risks of double counting are perceived in the structure of national legislation related to GOs and disclosure.

From a consumer perspective, there have been concerns about misleading green claims and "greenwashing" by the GO system given the risk of double counting and also as it enables imports of renewable electricity across the whole of the EEA. For example, renewable electricity from Norway can be consumed in Greece, when in reality it is

[341] Renewable energy progress and biofuels sustainability – Ecofys et al, November 2014
[342] AIB Annual Report 2015
[343] *e.g.* Czech Republic

unlikely to travel that far. In essence this is a criticism of the use of "book and claim" systems for certification purposes, rather than credibility of the GO system itself. Clearly robust implementation of the system across the EU should help build confidence in the system and allay concerns that the origin of the electricity is not double counted in any way.

The partial use of the GOs for just renewable electricity means that residual mix calculations need to be carried out each year to calculate the consumption of non-renewable sources as a result of the GO transfers. This is quite a complex statistical exercise and cannot be as accurate as the tracking function provided by a well-designed GO system.

The current system design means that in effect those covered by the GO system generate the data for disclosure and effectively pay for the residual mix calculations. As a consequence, fossil and nuclear generators do not directly contribute towards producing data for disclosure that is produced through the GO system. This also means that the system applies to smaller generation sites, but not to some of the large ones, as renewable installations have a much smaller average output compared to large thermal power plant. Data for the UK[344] shows that in May 2015, 78% of the electricity generation installations operating were renewable (362 installations including co-firing, excluding small scale) and 12% were purely fossil or nuclear (100 installations). In 2014, 19.1% of the UK's electricity generation was from renewable sources.

There are also variations in the scope of the GO system. Austria, Sweden and Switzerland[345] have extended a GO system to all types of electricity generated in their territory. Data from some of these states shows that extension to large thermal generators has modest additional administrative impact as both countries have a relatively high share of renewable generation. In Austria, fossil plants represent about 1% of the total installations on their registry, but represent around 30% of electricity production. Similarly in Switzerland, fossil and nuclear generation represents about 10% of the number of installations, but over 40% of the total power generated.

Evaluation work[346] by consultants was carried out to support the REFIT assessment of the RES Directive. The conclusions and recommendations included:

- Continue to stress the importance of Member States to move towards a GO system based on the European Energy Certificate System (EECS) operated by the Association of Issuing Bodies (AIB). Also, continue to monitor progress, to ensure full implementation of this aspect throughout the EU;
- Assess the benefits of following the Best Practice Recommendations formulated by RE-DISS[347], such as streamlining the use of tracking mechanisms at Member States level and clarifying the relation between support schemes and the tracking systems used for purposes of disclosure;

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344 https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes

345 Switzerland is not part of the GO system that operates across the EEA, but has enacted similar legislation

346 Mid-term evaluation of the Renewable Energy Directive – CE Delft et al, April 2015

347 The RE-DISS projects (Reliable Disclosure for Europe) funded by Intelligent Energy Europe sought to provide guidance to competent bodies and legislators implementing the GO system.

- Investigate the possible extension of the use of GOs beyond RES-E and high-efficient cogeneration to all types of power generation *i.e.* including electricity from fossil and nuclear generation.

These recommendations are captured by the options under consideration.

5.4.2.2. Detailed assessment

Economic impacts

Increasing issuance and cancellation of GOs will result in changes in financial flows. The overall economic impacts are likely to be low as GOs trade at very low prices relative to the price of electricity.

- The economic impact of the option for improving the functioning of the existing system will be negligible relative to a business as usual scenario, as it may not shift the supply and demand balance for GOs very much.
- Making the system mandatory will increase supply and demand for GOs, and may result in more financial flows to generators. However, if a consistent approach is adopted to prevent double compensation, say by Governments auctioning GOs associated with supported electricity, then the impact should be neutral. Especially if the auction revenues are returned to those who pay for the support scheme in the first place.
- With a system of full disclosure, the additional financial flows are likely to be minimal as GOs from fossil and nuclear sources may trade at very low prices as they could have little value to energy consumers. Nuclear may have more value than fossil GOs due to it low carbon character, so nuclear electricity generators may benefit more than those producing electricity from fossil fuels.

Improving the functioning of the single market for GOs should make the market more efficient and less costly. The different options under consideration should improve the coordination and robustness of the schemes and create a liquid, functional market. They should bring in more consumers to a properly functioning GO disclosure market, so should make green energy purchasing a more effective consumer driven market. This would be expected to improve the responsiveness of energy companies to green consumer preferences. It could help supplement or possibly in the longer term supersede public support for renewable energy. This should result in system based on green consumer pricing which is less distorting and more efficient.

Improving the functioning of the system also seems to be preferable to abolition. It is difficult to see how abolition could create a more efficient outcome and more reliable information to consumers and producers as to preferences for renewables.

The administrative costs of changing the scope of the system should be moderate. All Member States currently have the administrative infrastructure in place from the existing GO system, so extra administrative costs will be incremental. The highest additional administrative costs would result from expanding the system to fossil and nuclear generators. These costs would increase further if CO_2 emissions data from power plants is included in some way in the GO system.

Social impacts

The ultimate impact of the GO system is that it as a means to provide reliable data to consumers as to the sources of the electricity that they consume. The more reliable and comprehensive the data provision, the bigger the social impact. A poorly designed and implemented system could have negative impacts on consumers by reducing levels of trust in the information that is provided to them and raising suspicions of misleading green claims and "greenwashing".

Compared to the business as usual option, improving the functioning of the GO system should have positive social impacts, in that it should improve levels of trust and confidence in the mechanism through creating a more transparent system. The impacts should be larger with the more ambitious options. Making the system mandatory for disclosure purposes should therefore have a bigger positive impact, as the system would cover the whole range of renewable electricity generation sources. Positive impact should come from extending the system from only renewables to all sources of electricity.

Abolition of the system would also seem to make the quality of the information provided to consumers worse.

Environmental impacts

The environmental benefits of the improving the GO system relate to consumers being empowered to make more informed choices regarding their energy consumption. An improved and more comprehensive GO system could have the effect of increasing the demand for renewable and low carbon energy by enabling consumers to express more clearly their willingness to pay for different types of electricity.

The options of making the system mandatory and that of expanding its scope to other energy sources could both result in larger environmental benefits relative to a business as usual approach. Improved information about the character of energy consumption, may increase demand for greener tariffs. It is possible therefore possible that there could be an increase in price of GOs and result in more renewable energy brought to the market. The incentive impact is likely to be small given the very low prices at which GOs trade relative to wholesale market prices. However, the reported much higher prices paid for specific types of renewable technology in specific locations indicate that there could be a more pronounced impact for certain types of projects.

There should also be other positive environmental impacts from expanding the system to fossil and nuclear plants, as this would enable emissions data to be attached to GOs. Consumers would therefore be able to choose with greater confidence electricity supply tariffs with low CO_2 emissions (*e.g.* nuclear and renewables) in addition to pure renewables based tariffs. In particular, this would help satisfy the growing demand for such products from the business sector. The additional price incentive that this provides to power generators is likely to be very small given the price that GOs trade for, however at the margin it would create a small amount of additional revenues for low carbon electricity.

Political feasibility /opportunity

Further development of the GO system is compatible with the development of broader European energy market and the objectives of the Energy Union. As cross border flows in energy increase with greater interconnection and more coupled markets, the need for a robust systems to track production and consumption of renewable electricity will increase. The need for, and benefits of, an effective pan European GO system should increase over time. Abolition of the system would have a negative effect of reducing the potential for trade for renewable energy across Europe.

Other impacts (markets, innovation…)

The current system just applies to renewable generators. Most renewable energy generation sites are owned by large corporations, however it is possible that some of these installations are small, so could be owned by SMEs. Expansion of the system to large thermal power generation plants will result in further coverage of mainly larger energy generators and companies.

Of the options under consideration, it is difficult to see how Option 0 of continuing with current practice should be selected. Given the increases in the amount of renewable energy that is generated, the greater cross border trade in renewables and the growing interest in disclosure, an improved system of guaranteeing the origin of renewable electricity is desirable.

5.4.3. *Tracing origins of renewable fuels used in heating and cooling and transport*

Option 0	Option 1	Option 2	Option 3
• BASELINE - Continuation of EU current policies (no GOs for renewable fuels)	• Extend GOs to renewable gaseous fuels	• Extend GOs to renewable liquid and gaseous fuels	• Develop alternative tracking system for renewable liquid and gaseous fuels

➢ ***Option 0:*** *Baseline*

No change from the current legislation, the requirements for a mass balance system to be used for sustainability criteria for biofuels and bioliquids remain and no additional EU wide system of guaranteeing the origin of renewable fuels is implemented. Some Member States may choose to continue with or develop national GO systems.

➢ ***Option 1:*** *Extend GOs to renewable gaseous fuels*

In addition to continuing the approach towards sustainability criteria for biofuels and liquids which ensures sustainable feedstock is used, an EU wide system for guaranteeing the origin of renewable gaseous fuels is developed. This would primarily concern developing a mechanism for tracing biomethane that is injected into the European gas grid from the point of injection to the point of consumption. It could also concern other pathways such as the production of gas from renewable electricity and renewable hydrogen.

➢ ***Option 2:*** *Extend GOs to renewable liquid and gaseous fuels*

An EU wide system for guaranteeing the origin of gaseous fuels under Option 1 is expanded to liquid fuels, covering such fuels from the point of production or import to the final consumer. This would primarily concern bioethanol and biodiesel for road transport, but could also cover heating oils and fuels in aviation and maritime transport.

➢ ***Option 3:*** *Develop alternative tracking system for renewable liquid and gaseous fuels*

An EU wide system for tracing the origin of gaseous and liquid renewable fuels is developed that builds on the existing mass balance requirements for sustainable biofuels to enable more visibility and cross border trade. This could comprise economic operators entering data about the movement of gaseous and liquid renewable fuels into an electronic registry when documenting compliance with the sustainability requirements.

5.4.3.1. Introduction to the assessment

For biofuels and bioliquids there are requirements in the RES Directive related to the sustainability of the fuels and the obligation for Member States to implement a mass balance system as a means of providing a chain of custody. These systems provide a means of tracking the sustainability of fuels all the way from feedstock to final consumers. Such systems are considered stringent and effective means for meeting sustainability requirements[348].

However, beyond these sustainability requirements implemented at a national level, there are no EU wide systems in place for guaranteeing the origin of renewable gas (*e.g.* biomethane injected into the gas grid) or for renewable transport fuels to energy consumers. Such a system could be beneficial when there is significant trade in such sustainable fuels across borders. It would not replace the sustainability requirements, but act in a complimentary manner and build on the systems in place to provide consumers with additional information.

With volumes of renewable fuels being introduced onto the European market likely to increase in the coming years, the desirability of having such systems should be considered. These could take the form of an EU wide guarantee of origin system being implemented, similar to the system for renewable electricity, or alternative systems that facilitate the provision of information to consumers and enhanced cross border trade.

Table 12: Growth in biogas forecast in selected Member States[349]

Country	Current situation (TWh)	National plans or targets (TWh)			Technical realisable potential (TWh)
		2 020	2 025	2 030	
Denmark	1.5	4.7			44.9
Finland	0.6		~2.6		42
France	5.4	6-8		70	100
Germany	78.1	123			264
Italy	2.1	3.2			9.5
Netherlands	3.2	6.7		30	

348 Report on the operation of mass balance verification method for biofuels and bioliquids SEC(2011) 129 final

349 Sources: 1. Greengasgrids, 2015. Market platform country overview, www.greengasgrids.eu; 2. IEA Bioenergy Task 37 Country Reports Summary 2015., www.iea-biogas.net; 3. http://www.biogasheat.org/wp-content/uploads/2012/10/2012-10-18_D.2.1_WIP_EN_Final.pdf; 4. EurObserv'ER (2014). Biogas Barometer 2014. http://www.eurobserv-er.org/biogas-barometer-2014/

Sweden	1.6			15	69-74
UK	21				37

Tracking systems and GOs for gaseous renewable fuels

The existing sustainability requirements in the RES Directive already require Member States to implement a system for ensuring the sustainability of biofuels and bioliquids. These systems should enable consumers to have good assurance as to the origin and quality of the renewable fuels that they buy.

A key issue going forward for renewable gaseous fuels is likely to be the functioning of such systems across national borders. This issue will be most significant with biomethane injected into the grid, where tracing the origin of the fuel from the point of injection to the offtake by final consumer will be important. With the increasing interconnection of the gas grids across Europe and an increase in cross border trade flows, the desirability of having an EU wide tracking system for biomethane that is injected into the grid will increase. This system should be capable of transmitting information about the nature of the biomethane that is distributed.

A robust system would enable consumers to be provided with accurate information regarding the renewable content of their gas taken from the grid. Acting in a similar manner to the electricity GOs, a EU defined GO system for biomethane could stimulate consumer demand for green gas and enable energy suppliers to develop new consumer energy products based on biomethane. It would also provide an EU wide means of assuring the quality of existing green gas products that are marketed to consumers today.

In the short term, the main focus should be on biomethane which is already injected into the European gas grid. Power to gas injected into the grid should also be capable of being included, if the electricity used is of renewable origin. Furthermore, other pathways such as hydrogen could become increasingly important and would benefit from a GO system. Indeed initiatives to design such a system are already under way[350]. The rationale for extending the system to biomethane that is not mixed into the grid is lower, as the issues of determining origin of the fuel and cross border trade are not the same.

There are already a range of national initiatives in place that help guarantee the origin of biomethane. Austria, Denmark, Germany, France, Italy, Netherlands, Poland, Slovakia, Sweden, and the UK are developing or have already introduced national GO style certification schemes for biomethane. These national certification schemes have mostly been set up through private initiatives, although some are regulated by public institutions. The existence of national systems demonstrates that much infrastructure for an EU wide system already exists. Furthermore, some of the platforms developed for the electricity GOs may be suitable for use by a system covering renewable fuels.

The desirability of having cross-border recognition of national guarantees of origin is already apparent. Some of the national systems (Germany, France, UK, Austria, Denmark and also Switzerland) have already agreed to mutually recognise each other's

[350] http://www.certifhy.eu/

GO systems for biomethane[351] to facilitate cross-border trade and disclosure. This demonstrates the need for mutual recognition of national GOs in the era of connected gas markets and that further action at a European level could be justified to create a single market for such certificates.

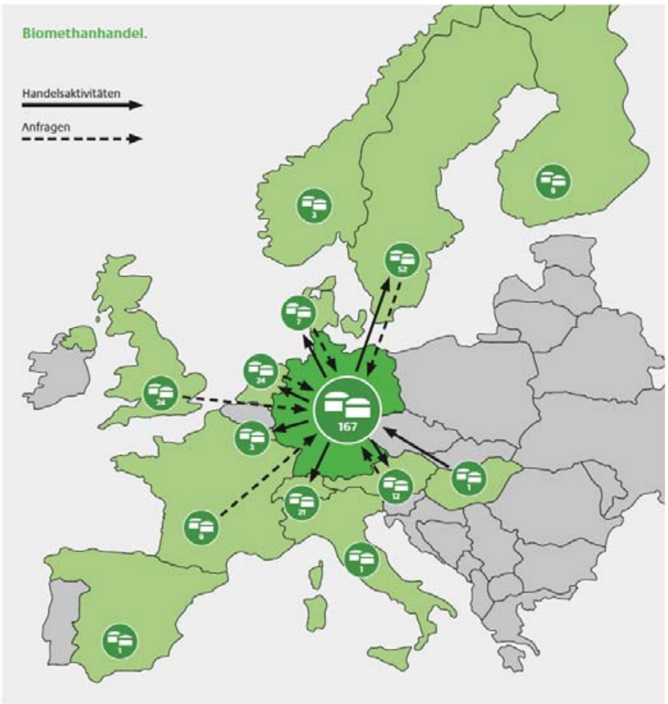

Figure 32: Biomethane trade between Germany and other countries in Europe in 2014[352].

The national registration schemes adopted a mass balance approach[353] reflecting the sustainability requirements in Article 18(1) of the RES Directive This means that they do not allow the separate trade of the physical gas and the guarantee of origin when the gas passes a boundary between balancing zones. These balancing zones are frequently aligned with national boundaries, so could increase the cost and complexity of cross border trade.

There are a number of issues that need to be taken into consideration for an EU-wide system. First, uniform quality standards for gaseous renewable fuels are a necessary condition to support cross-border trade[354]. The RES Directive, the Fuel Quality Directive and the Communication on Biofuels and Bioliquids Sustainability Scheme[355] already provide sustainability criteria for biomethane used as transportation fuels[356]. Furthermore, the Directive on the Deployment of Alternative Fuels Infrastructure[357]

351 http://energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Gas/Letter%20Of%20Intent%20Biomethane%20registries.pdf
352 Source: DENA (2014). Zukunft Biomethan http://www.biogaspartner.de/fileadmin/biogas/Downloads/Broschueren/20150521_15-14-89_Broschuere_Zukunft_Biomethan_WEB.pdf
353 For example, the registries in Austria, Denmark, France, Germany, Sweden, the UK as well as Switzerland
354 IEA Bioenergy (2014).
355 2010/C 160/01
356 BIOSURF, 2015. Guideilnes for creating the European Biomethane Guarantee of Origin.
357 2014/94/EU, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094&from=EN

already references quality specifications[358] for the injection of biomethane into the natural gas grid. As long as these sustainability criteria are adhered to in the creation of Guarantees of Origin for gaseous renewable fuels, no additional sustainability verification is required for cross-border trade.

Another consideration is the relationship with sustainability verification covering the transportation up to the release of the fuels for consumption[359]. In the RES Directive, Member States should use a mass balance system for biofuels and bioliquids to track sustainability verification from the point of production to the point of use by the end-user. A review of the mass balance system for biofuels concluded that the mass balance system was a fair compromise between administrative burden and effectiveness in monitoring sustainability [360].

With network supplies of biomethane such sustainability information needs to capable of being transmitted across national borders, from the point that the gas is injected into the grid to the point of consumption. This would require mutual recognition between Member States of the biomethane registered in another Member State, enabling consumers to easily purchase in one Member State and consume in another. For this to work effectively under the current approach, all Member States would need to establish GOs for biomethane. Furthermore, these national GO certification systems would need to recognise the whole European gas grid as a single mass balance system and be able to properly account for biomethane in another national registry to avoid double counting. Further developing the mass balance approach would mean that GOs for biomethane could not be traded in isolation from the physical gas.

An alternative system is to replace part of the current mass balance approach for network supplied biomethane with a "book and claim" system, as used for cross-border trade of Guarantees of Origin of renewable electricity. This system would only function from the point of injection into the grid to the point of consumption. It would not replace the mass balance sustainability tracking system which would continue to operate from the point of injection all the way back to the original feedstock. Indeed, information on the sustainability characteristics of the biomethane gas introduced onto the grid should feature in the information provided on the GO.

In such a book and claim model, Member States would issue GOs to those actors introducing biomethane into the gas grid. The GOs would trade separately from the physical gas, so they can therefore be sold to final consumers as a way to demonstrate the consumption of biomethane. Such GOs issued in one Member State would need to be recognised in another. Such an EU wide book and claim model would enable transfers of biomethane GOs to take place across Europe in a relatively simple way, so is compatible with the further development of the single energy market. In theory, it should also be cheaper and more efficient to operate than a mass balance approach. Like all book and claim systems, it is important that it is robust and well enforced to retain credibility.

In summary, to facilitate cross border biomethane trade within the European gas grid, a functional system of information transfer between national systems for registering

358 Specifications developed by the Technical Committee CEN/TC 408

359 COM 2010/C 160/01

360 Ecofys, 2012. Analysis of the operation of the mass balance system and alternatives. https://ec.europa.eu/energy/sites/ener/files/documents/2013_task_1_mass_balance_and_alternatives.pdf

biomethane seems desirable. This system could build on and complement the existing national systems established under the RES Directive for compliance with the sustainability criteria. A core building block could be to ensure that all Member States issue a guarantee of origin for biomethane introduced into the gas grid and that these GOs would be mutually recognised by other Member States. The design of the EU GO system for biomethane could continue to develop the mass balance approach applied for the sustainability criteria, though this would be more complex to make operational. The GOs would not trade in isolation from the physical gas and the EU gas network would need to be considered as a single mass balance system. Alternatively, the GOs for biomethane could follow the approach used in electricity, where once injected into the grid, the GO trades separately from the biomethane. Such systems have lower administrative costs, but need to be robust to retain credibility.

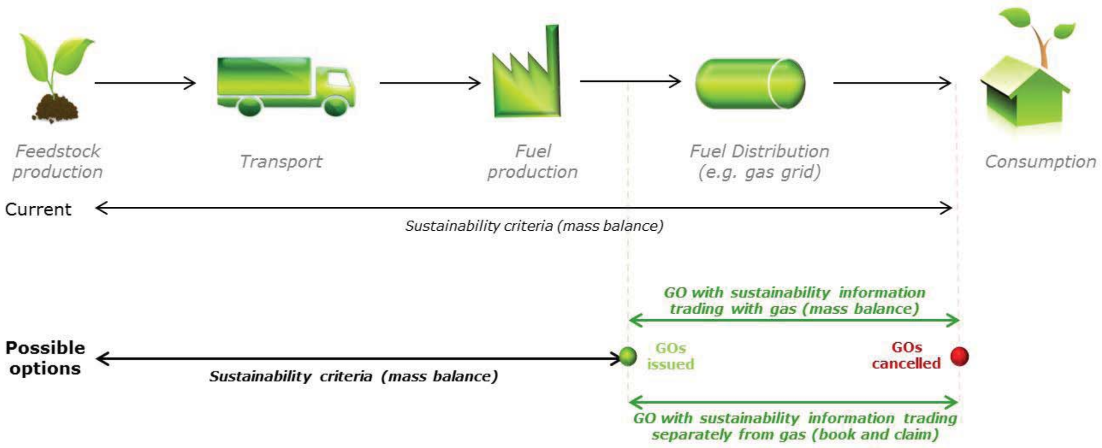

Figure 33: Characterisation of options identified for tracking grid injected biomethane

Tracking systems and GOs for liquid renewable fuels

A tracking system for renewable liquid fuels would primarily concern bioethanol and biodiesel used in transport and renewable heating oils. It would also cover advanced renewable fuels introduced in the future as technology and markets develop. Similar issues would apply to biogas that is not injected into the grid.

Many renewable fuels are chemically identical, so distinguishing between sustainable and non-sustainable variants can be difficult once the fuel is blended and distributed through the supply chain. A robust tracking mechanism should help prevent fraud and the associated risk that consumers are mis-sold unsustainable fuel products and increase confidence in the products being sold.

A core issue with renewable fuels is sustainability. As with biomethane, these liquid fuels are covered by the sustainability criteria that apply to biofuels and bioliquids in the RES Directive, which requires the use of a mass balance system by Member States.

The issues associated with tracing the origins of such fuels are different from biomethane, in that the fuels are not mixed into a network with other fuels for distribution purposes. Therefore it should be simpler for final fuel customers to rely on the system developed for the sustainability criteria to understand the origins of their fuel and for the certification of the fuels to be attached to trades in the physical product. The need for a guarantee of origin system for such fuels is much less clear, especially one based on a book and claim approach as applied to renewable electricity.

With these national systems, a key question is the ease to which cross border trade between entities in different Member States can take place for sustainable biofuels. Is the sustainability information of the fuel that is inherent in the national systems transferable along with the fuel?

So far, it seems that five Member States have implemented four national electronic registries which store such sustainability data, these are Austria, Germany, the UK and a shared system between Belgium and Luxembourg, These systems provide a means to have a clear overview of the volumes of fuel produced. It is understood that the Austrian, German and the Belgium/Luxembourg systems are capable of transferring data between them to reflect cross-border trades in sustainable fuels.

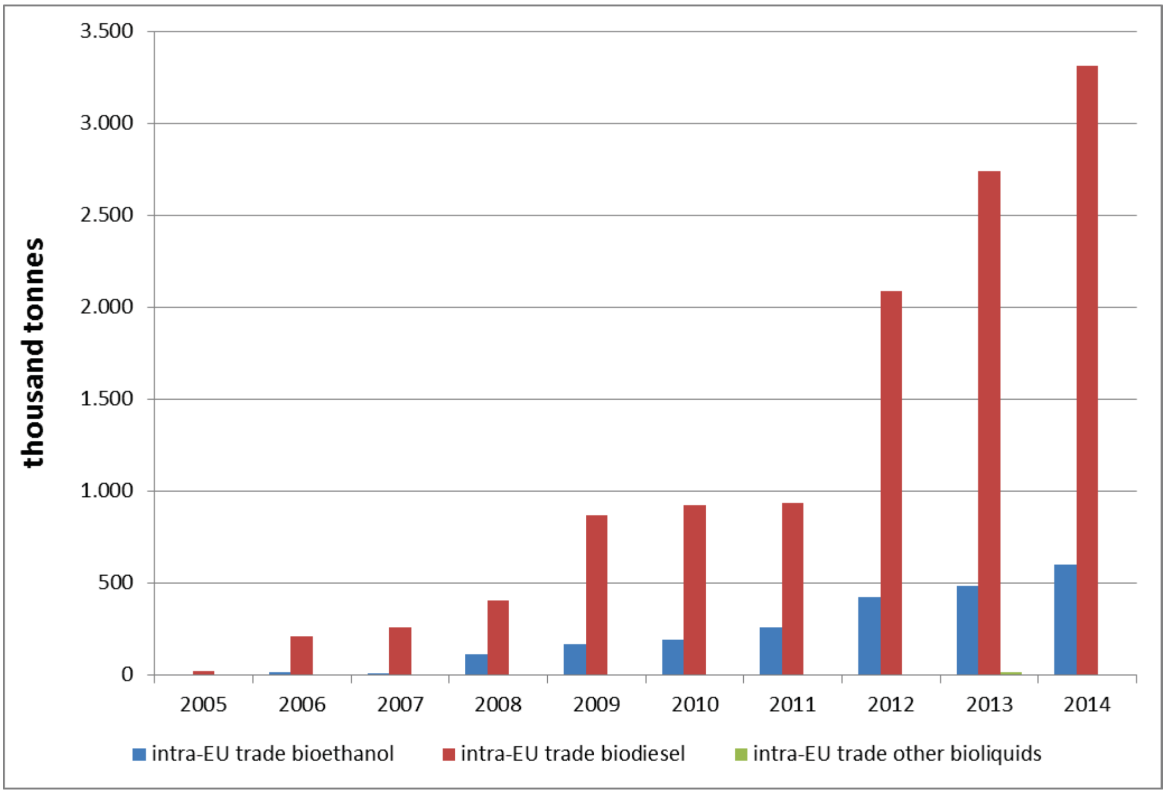

Figure 34: Intra EU trade in biofuels

To facilitate further trade is sustainable fuels, an EU wide system could reflect current good practice and require all Member States to ask economic operators to enter data about the movement of such renewable fuels into a national electronic registry when documenting compliance with the sustainability requirements. Moreover, there it would be necessary for registries to accept transfers with other registries when fuels are transferred across borders. This should create a robust tracking system.

Producers and traders of biofuels are currently obliged to keep thorough documentation of the amount and the sustainably characteristics of the biofuels they source and sell. However, given the variations in the level of support for different types of biofuels there is a concern that some operators could be tempted to make false claims about the sustainability characteristics (*e.g.* whether they are advanced biofuels or produced from food crops). Currently, these claims are verified by sporadic audits of the mass balance documentation. An approach of requiring data to be visible in a national database and the linking the databases to enable cross border transfers should improve the robustness of the information on the sustainability characteristics of biofuels. It could improve the consistency of sustainability information across the EU. Therefore the system would not only provide customers with better information but should support Member States in enforcing the implementation of any support schemes for renewable fuels in particular advanced biofuels.

5.4.3.2. Detailed assessment

Economic impacts

From an economic perspective the three options will have benefits in terms of reducing the risk of fraud occurring in the production and sale of biofuels. A reliable system of guaranteeing the origin of fuels would help provide greater transparency to the market and consumers. Fraud is a concern in relation to fuels as sustainable renewable fuels can be chemically identical to fossil and non-sustainable equivalents, so having a system of guaranteeing the origin of these fuels will be a benefit. A more robust system for fuels may help to reduce slightly the risks associated with investment in advanced fuels, if the system provide more certainty that the market is less susceptible to fraud.

There will be additional administrative burden from such systems as opposed to the do nothing option. Experience in Germany and the Netherlands suggest a typical transaction costs for a cycle of issuance, trading action, and cancellation of 1 MWh of biomethane (based on a mass balance system) are higher than 1 MWh of electricity (based on a book and claim system). In the Netherlands, the costs are EUR 0.067 for renewable electricity and EUR 0.246 for biomethane in 2014. In Germany, the costs are roughly EUR 0.04 for green electricity and EUR 0.16 for biomethane.[361] The higher administrative costs for biomethane trading are not only due to the different system being used, but more importantly relate to the volume of trade.

Administrative costs on an EU wide GO system for biomethane based on a mass balance approach would be expected to be lower than the costs reported in Germany and the Netherlands. In a number of countries these administrative costs will not be additional as they already exist for national GO systems or with private initiatives. In other Member States much infrastructure for GOs exists in relation to renewable electricity, the on-cost of extending the system to renewable fuels will be reduced as there will be some synergies with the renewable electricity system.

There is also evidence that the market price of GoO for biomethane in the German and Dutch markets is providing additional revenue in the order of EUR 4-8 per MWh. As these GOs trade with the physical gas it can be difficult to identify that value that consumers place on the renewable attributes of the fuels.

Costs of developing an electronic registry for biofuels are difficult to estimate. A number of Member States already have such systems developed, so the on costs for these Member States should be minimal.

[361] Spijker et al. (2015). A level playing field for the European biogas and biomethane markets. http://jin.ngo/images/jin/publications/final_report_interreg.pdf

Social impacts

A key social impact will be to increase the choice for consumers in relation to the fuels that they use, as highlighted by some of the submissions during the stakeholder consultation. Currently in many Member States it is not so easy for consumers to express a preference for such renewable fuels in the natural gas and transport fuels markets. A robust EU-wide approach should help build consumer confidence in the renewable character of gaseous and liquid fuels.

The development of a robust system for GOs related to renewable natural gas will enable green tariffs for such fuels to be developed as well as facilitating cross border trade. Similarly such tracking systems should enable a wider range of transport fuels products to be sold to consumers.

Furthermore, the biogas industry has resulted in a large number of additional jobs. In Germany alone, jobs associated with biogas technology (including electricity production) increased from 30,900 in 2009 to 50,600 in 2011[362].

Environmental impacts

The main environmental impact of the options will be to increase the level of confidence in the sustainability of renewable fuels. The impact will be positive across all options relative to the do nothing option. Increased confidence in the system and a reduced risk of fraud should ensure that the environmental benefits of sustainable fuels can be counted with more certainty. At the margin, these policies may also encourage greater consumer demand for such fuels by providing greater assurance as to the quality of the fuels being consumed.

This impact is likely to be of biggest significance for the options related to the liquid transport fuels, where sustainability concerns with feedstock are most common. Option 3 is likely to have the biggest impact in this respect, as the tracking system would be clearly linked to the existing sustainability criteria used for biofuels.

Political feasibility /opportunity

The options under consideration involve creating an EU wide approach to guaranteeing the origin of renewable gas and enabling greater visibility as to the nature of the liquid fuels. The options are in line with the further development of a European energy market and enabling greater cross border trade in renewables. The preferred options for renewable gas and fuels would build on the national systems that exist in a number of Member States.

Other impacts (markets, innovation…)

The requirements will apply equally to all renewable fuel producers, irrespective of their size. It is possible that some producers of biomethane which is injected into the grid will be small and medium sized businesses so they would be impacted by the system. However, the GO system for electricity shows that GOs from renewables attract a positive price premium so they should represent an additional source of income for

[362] http://www.greengasgrids.eu/fileadmin/greengas/media/Downloads/Documentation_from_the_GreenGasGrids_project/Biomethane_Guide_for_Decision_Makers.pdf

SMEs. The renewable fuel industry is understood to have a structure where more key market players are larger organisations, so small companies may not be impacted as much.

With the likely growth in renewable fuels, the option of continuing without an EU wide tracking system does not appear attractive. The benefits of implementing such systems for gas and liquid fuels seem to outweigh the costs. On that basis Option 0 can be discarded.

5.4.4. Overall comparison of the options to empower and inform consumers of renewable energy

	Overall impact			Key objectives		
Policy option	Social	Economic	Environmental	Effectiveness	Efficiency	Coherence
Empower consumers to generate, self-consume and store renewable electricity						
Option 0 - No EU intervention	0	0	0	0	0	0
Option 1 - EU guidance on self -consumption	+	-	-	-	-	+
Option 2 - Empower citizens to self-consume and store renewable electricity	++	-	+	+	+	0
Option 3 - Distance self-consumption for municipalities	++	-/---	+	++	0	0
Disclosing information for renewable electricity						
Option 0 - BASELINE	0	0	0	0	0	0
Option 1 - Improve functioning of GO system	+	0	+	+	+	
Option 2 - Option 1 plus GOs mandatory for disclosure	++	+	+	++	+	
Option 3 - Option 2 plus extend GOs to all sources of electricity generation	++	-	+++	++	-	
Tracing renewable fuels used in heating and cooling and transport						
Option 0 - BASELINE	0	0	0	++		
Option 1 – Extend GOs to renewable gaseous fuels	++	+	+	+		
Option 2 – Extend GOs to renewable liquid and gaseous fuels	+	+	++	+		
Option 3 - Develop alternative tracking system for renewable liquid and	+	+++	+++	+		

gaseous fuels
+,++,+++ : positive impact (from moderately to highly positive)   *0 : neutral or very limited impact*   *-, --, --- : negative impact (from moderately to highly negative)*

5.5. Options to ensure the achievement of at least 27% renewable energy in 2030

The table below summarizes the group of options that are discussed in this section.

Challenges	Drivers	Policy Options
Baseline of 2020 targets	Uncertainty around individual MS contributions to EU level RES target Current policy framework & monitoring designed for national targets, not collective attainment	0. BASELINE - 2020 targets lapse 1. Make 2020 national targets the basis for further increases in RES through to 2030
EU Trajectory 2021 - 2030 for achievement of the EU renewables target	Uncertainty around individual MS contributions to EU level RES target Current policy framework & monitoring designed for national targets, not collective attainment	0. BASELINE- No trajectory 1. Linear trajectory towards the 2030 target 2. Non-linear trajectory towards the 2030 target
Mechanism to avoid an "ambition gap" to the EU renewables target	Uncertainty around individual MS contributions to EU level RES target Current policy framework & monitoring designed for national targets, not collective attainment	0. BASELINE - No EU mechanism 1. Require Member States to revise ambition of national plans under the Energy Union Governance 2. Include a review clause to propose additional EU level delivery mechanisms at a later stage 3. Increase the ambition of proposed EU wide measures or introduce additional EU wide measures 4. Introduce binding national targets

Mechanism to avoid and fill a "delivery gap" to the EU renewables target	Uncertainty around individual MS contributions to EU level RES target Current policy framework & monitoring designed for national targets, not collective attainment	0. BASELINE - No EU mechanism 1. Require Member States below their pledge level to revise the delivery of their plan under the Energy Union Governance 2. Include a review clause to propose additional EU level delivery mechanisms at a later stage 3. Increase the ambition of EU wide measures proposed in the legislation 4. Introduce binding national targets

5.5.1. *Baseline of 2020 targets*

Option 0	Option 1
• BASELINE - 2020 targets lapse	• Make 2020 national targets the basis for further increases in RES through to 2030

➢ ***Option 0:*** *BASELINE*

The 2020 national targets lapse from 2021 onwards. The existing legislation encourages Member States to increase their share of renewable energy beyond the 2020 target, but it contains no requirement that they provide a minimum floor for national renewables policy.

➢ ***Option 1:*** *2020 national targets as basis for further increases*

The 2020 national targets will be mandatory as a floor for the period 2021 to 2030 in line with the collective efforts needed. They would therefore provide a clear threshold for which the national share of renewables could not fall below. These thresholds would need to be reflected in the requirements for Integrated National Energy and Climate Plans set out under the Energy Union Governance.

This would mean that the co-operation mechanisms contained in the current Directive would need to continue. These mechanisms provide flexibility in the ways in which Member States can meet their target similarly to the non-ETS sector flexibility.

5.5.1.1. Introduction to the assessment

As there are no national targets after 2020, a key question is what should be the status of these targets in period up to 2030. Two options are under consideration, either allowing the targets to lapse, or continuing the targets as a backstop through to 2030.

The question on whether the 2020 Member State specific target should be considered as the minimum renewables share to be achieved by all Member States over the 2020-2030 period can be illustrated by looking at the EU Reference Scenario results.

In the 2016 EU reference scenario, Member States are assumed to achieve their binding 2020 target (including through use of cooperation mechanisms), and no dedicated additional policies are modelled post-2020. The results show that for all but one Member State, the renewables share in 2025 is projected to increase compared to 2020 levels. This means that as long as Member States make sufficient efforts to reach their 2020 targets, it should be possible without excessive additional cost to at least maintain this share post-2020. Some investments will still need to take place, as illustrated by the table below. However, the modelling suggests that such investments could take place without additional dedicated policy intervention in terms of support schemes.

This impact assessment uses the EU Reference Scenario 2016 as the starting point for projecting renewable energy shares in 2020 for each Member State, on the basis of the overall legal obligation for each Member State to reach their 2020 national target. This implies that for a number of countries an acceleration of RES deployment before 2020 is needed. Without this accelerated deployment, there might be a risk that some Member States would fall below their 2020 targets. In the situation where some Member States would not reach their 2020 target, the extra effort needed for meeting the EU 2030 target would be even larger.

Table 13: Investments in renewables required under REF2016

Investment indicators (2030)	**Ref2016**
Investment expenditures in renewables (average annual 2021-2030 period)	14516
Investment expenditures in wind (average annual 2021-2030 period	9324
Investment expenditures in solar (average annual 2021-2030 period	4406
Investment expenditures in biomass-waste (average annual 2021-2030 period	527

Source: PRIMES

5.5.1.2. Detailed assessment

Economic impacts

The economic impacts of retaining the target could be positive relative to the alternative option of no obligation in that regard. The 2020 targets are already mandatory under EU law, so this policy provides more certainty to investors that renewables policies in Member States will need to be sustained. Lower policy risk could reduce the cost of capital for new renewables investment relative to a scenario where the targets disappear. Lower cost of capital provides a better investment climate for renewables, so could help create a virtuous circle of higher levels of investment. Improving the overall cost effectiveness of achieving our renewable energy goals. Not retaining any obligation in this regard might disincentive Member States to meet their 2020 targets if they know that efforts will not need to be sustained post-2020.

Social impacts

The social impact of the policy options are expected to be limited. There should be limited distributional impact between consumers from the two options.

Environmental impacts

The environmental benefits of the retaining the target are better than having no carry-over of the target. This is because it provides a stronger guarantee as the level of renewable energy that will be produced in the EU. Not carrying over the target risks a lower level of renewables and an associated reduction in environmental benefits. Emissions of greenhouse gas emissions and local air quality pollutants could be higher under this scenario, especially if the renewable energy was displaced by fossil fuels.

Political feasibility /opportunity

The 2020 targets have been agreed politically, so continuation of the targets beyond 2020 as a baseline should be acceptable to most parties. It should also provide a mean to transition from the old system of national targets to the EU wide target approach, helping overcoming political concerns from some quarters that the new approach will not be as robust. In addition, this measure is needed to ensure that 2020 targets are fully met as reconfirmed by the European Council in October 2014.

Other impacts (markets, innovation…)

The option of keeping the 2020 target as a baseline should provide more market certainty to investors as it provides assurance that national policies in place to deliver the 2020 targets will be sustained for some years afterwards. It may also benefit SMEs which are active in the renewable energy market.

5.5.2. EU Trajectory 2021 - 2030 for achievement of the EU renewables target

Option 0	Option 1	Option 2
•BASELINE- No trajectory	•Linear trajectory towards the 2030 target	•Non-linear trajectory towards the 2030 target

➢ ***Option 0:*** *BASELINE*

This option would mean that there would be no trajectory at EU level for the EU renewables target from 2021 to 2030. Such an outcome would make tracking progress towards the 2030 target difficult and it would mean that little if any advance action could be taken to ensure that the target is achieved.

➢ ***Option 1:*** *Linear trajectory*

A simple linear EU trajectory would be set out in the Revised RES Directive as a means to track progress across all Member States in increasing from 20% renewables in 2020 through to at least 27% renewables in 2030.

- ***Option 2:*** *Non-linear trajectory*

A more complex non-linear EU trajectory is developed as part of the Revised RES Directive following the iterative process with Member States through their integrated national energy and climate plans for the Energy Union Governance. This would probably result in less renewable energy being needed to be added in the early part of the decade, with more coming on stream closer to 2030.

5.5.2.1. Introduction to the assessment

The simplest option would be to have no overarching EU trajectory for the target from 2021 to 2030. However, such an option would make monitoring progress towards achievement of the 2030 target very difficult, as there would be no way of assessing if the EU is on track towards the target. Any additional measures that should be implemented to ensure target achievement would therefore be back loaded and implemented after 2030 data has been collated. This could make achieving the target in 2030 very difficult to ensure.

A fixed EU wide trajectory would help with monitoring progress and enable appropriate rectifying measures to be implemented. The potential trajectory towards reaching the 27% target is available in PRIMES for a five year period. The projected evolution in the share of renewable energy across the whole of the EU shows quite a linear increase. In fact, total EU renewable energy is projected to increase by 14% between 2020 and 2025 in EUCO27 (14% in EUCO30) and by 12% between 2025 and 2030 (13% for EUCO30). This suggests that there is no real need to consider an exponential increase in renewables developments towards the end of the period, as was done in the RES Directive. There are sufficient mature technologies available for the gradual uptake of renewable energy in the early 2020s, in line with the achievement of the 2030 target.

5.5.2.2. Detailed assessment

Economic impacts

Setting out an EU wide trajectory for achieving the 2030 targets is likely to have positive economic impacts. It will provide greater certainty to the renewable energy industry as to the likely build out of new renewable energy capacity. Providing a long term signal on capacity needs reduces uncertainty and increases investor confidence. It should enable longer term investment decisions to be made due to the lower risk of change. Such signals could be important in driving down the cost of deploying certain types of renewable energy, where economies of scale are important.

A linear trajectory should have more positive impacts compared to a non-linear trajectory that results in an acceleration of capacity in later years. The linear approach will result in a more consistent stream of investment across the time period, rather than back loading it to a later point in time. The linear trajectory should help bring forward investments that have the opportunity to reduce the levelised cost of energy, so result on cost reductions sooner than with a non-linear approach.

Social impacts

The social impacts of the EU wide trajectory options are likely to be limited. There should be limited distributional impacts on consumers. A trajectory may have positive benefits to consumers if it results in more stable renewable energy policies and reduces risks of significant change close to 2030 compared to the option of no trajectory. Similarly, the linear approach may be better if it provides a more consistent framework than a non-linear approach that results in more activity closer to 2030.

Environmental impacts

Providing a trajectory should result in environmental benefits as it provides more certainty to the build out of new renewable energy capacity. The linear trajectory should have high environmental benefits than a back loaded trajectory as it introduces low emission energy technologies to the EU at an earlier point in time.

Political feasibility /opportunity

Defining an EU wide trajectory should help Member States in preparation of national commitments as it will provide a consistent signal by which progress can be measured. It should result in adjustments being made to national renewables policies at various stages through to 2030, rather than risk a lot of changes towards the end of the period.

The linear EU wide trajectory should be politically feasible as compared with the 2020 target, renewable energy technologies are mature, so there is little benefit from a steeper trajectory close to 2030.

Other impacts (markets, innovation…)

As with the analysis of the economic impacts, the trajectory approach should be beneficial for renewable energy companies. It should be beneficial for small and medium sized enterprises active in the market.

Overall, the option of not defining an EU wide trajectory does not look very attractive as it will make monitoring progress towards the 27% target more subjective. The risk of undershooting the target is therefore higher.

5.5.3. Mechanism to avoid an "ambition gap" to the EU renewables target

Option 0	Option 1	Option 2	Option 3	Option 4
• BASELINE - No EU mechanism	• Require Member States to revise ambition of national plans under the Energy Union Governance	• Include a review clause to propose additional EU level delivery mechanisms at a later stage	• Increase the ambition of proposed EU wide measures or introduce additional EU wide measures	• Introduce binding national targets

➢ ***Option 0:*** *BASELINE*

The existing legislation related to the Energy Union Governance and renewable energy has no relevant provisions for this issue. This option would therefore be that no action is taken in response to a gap in ambition, either under the Energy Union Governance process or the Renewable Energy Directive.

➢ ***Option 1:*** *Revise ambition of national plans*

This option would implement, as foreseen by the initiative on Energy Union Governance, a dedicated iterative process of review by the Commission of draft national plans and subsequent resubmission by Member States. This process would include resubmission of revised national contributions on renewables so that the EU wide target can be collectively met. This option could include criteria for Member States to apply when developing their contributions to the renewables target in their national plans.

➢ ***Option 2:*** *Review clause to propose additional EU level delivery mechanisms at a later stage*

This option would build on Option 1 with the additional inclusion of a review clause to be included in the Revised RES Directive to support the governance process. The clause would state that a review would be carried out by the Commission after the national plans have been finalised in order to assess if additional measures are needed to correct any remaining ambition gap. As a result of the review, if it was decided necessary, additional EU-level delivery mechanisms would be proposed by the Commission.

➢ ***Option 3:*** *Increase the ambition of EU wide measures*

This option would also build on Option 1 and seek to address any remaining ambition gap after finalisation of the national plans through measures contained in the Revised RES Directive:

(i) further use of EU wide measures contained in the Directive (*e.g.* obligations developed for transport and heating and cooling, respectively) or

(ii) specific measures developed especially for filling any ambition gap (*e.g.* EU wide auctions for renewable electricity support based on an EU-level fund financed by Member States contributions replacing the need to comply with measures under (i) above as a further flexibility, or a supplier obligation for renewable electricity).

The ambition level of these measures would be automatically increased to fill any resulting gap to the target that can be seen after the national plans have been finalised. A means of distributing the required increase in ambition between the measures applying to electricity, transport and heating/cooling would need to be defined. For any measure involving EU funding, provision would need to be made under the MFF.

➢ ***Option 4:*** *Introduce binding national targets*

This option would build on Option 1 by addressing any remaining ambition gap through the introduction of binding national targets for renewable energy in 2030 consistent with the EU-level target of 27%.

5.5.3.1. Introduction to the assessment

The default option would be to have no mechanism in place for avoiding the ambition gap. This would mean that there would be no action taken if Member State policies commitments are insufficient to deliver the 2030 target. In effect the result would be that the at least 27% renewable energy target would be aspirational rather than mandatory.

The Energy Union Governance process will be an important foundation for achieving the renewables target. It is likely to result in a review process of national plans and one iteration to be completed by 2019 to improve the ambition of the plans. This review should provide a useful first step in avoiding a gap emerging. However, there is no guarantee that such a process will definitely deliver the EU wide renewables target; it is still possible that an ambition gap remains once this has been completed. In this case, further measures may need to be considered.

In order to provide correct incentives for the national commitments and to strengthen the effectiveness of the governance process, the revision of the RES Directive could include criteria for Member States to use when developing their contributions to the renewables target in their national plans and/or potentially including a formula to calculate those. They could provide a means of assessing the relative level of ambition of each national plan and contribute to ensure a cost effective and equitable outcome of the process.

A further option would be to have a review clause in the Revised RES Directive that requested the Commission to come forward with a proposal for corrective measures in the event that a gap is detected once the plans produced in the governance process are complete. The impact of such an option is difficult to assess at this stage, as it is not clear as to what type of measures would be proposed and then agreed by the co-legislators. Furthermore, there could be some time lag between detecting an ambition gap, then developing, negotiating and implementing corrective measures. In this case such a mechanism may only come into effect some years after the national plans have been finalised by the governance process so its applicability and effectiveness for solving an ambition gap is unclear.

There are additional gap filling measures that could be implemented in the Renewable Energy Directive in the event of such an ambition gap emerging from the Energy Union governance process. One option would be to automatically increase the impact of any EU wide policy measures contained in the Revised RES Directive according to a formula set out in the legislation. For example, this could include increasing the level of EU wide measures for heating and cooling as well as transport. Additional finance could be considered to invest in electricity generation capacity, however a source of finance would need to be identified either coming from the EU budget or through mechanisms allowing Member States to contribute. If such a mechanism is to involve EU budget, then this would need to be discussed under the framework of the preparations for the next MFF.

In addition, this option could also be designed to implement specific policy instruments developed purely for filling the ambition gap. This could include for example an EU fund to tender renewables support for new electricity generation. Such measures could in principle be relatively cost effective if they focus on the lowest cost forms of renewable energy generation. However, such a mechanism is dependent on funding being made available to ensure that it can function appropriately.

An alternative option to having gap filling instruments would be to return to a system of binding national targets for Member States. This would ensure target achievement. However, the political agreement was not to have national targets in 2030 so this option does not seem a viable solution.

The results of the modelling scenarios can help identify some important features regarding the projected contributions Member States could make to achieve the 2030 target. Table 14 illustrates the overall renewables shares across all Member States for a range of different scenarios based on modelling together with those emanating from the application of different criteria for Member States to use when developing their contributions to the renewables target in their national plans (using the RES Directive method and an alternative approach).

Table 14: Renewables shares per Member State under various criteria

	2020 Target	REF2016	EUCO27	RED-I method (50% flat rate, 50% GDP)	Alternative method 50% flat rate, 25% GDP & 25% land area
Belgium	13	16	17	19	18
Bulgaria	16	28	31	22	25
Czech Republic	13	15	18	19	19
Denmark	30	39	44	38	38
Germany	18	21	23	26	24
Estonia	25	28	31	30	34
Ireland	16	18	22	25	25
Greece	18	30	34	26	28
Spain	20	27	31	28	28
France	23	26	26	30	30
Croatia	20	25	28	27	30
Italy	17	24	28	25	24
Cyprus	13	18	20	20	21
Latvia	40	42	46	47	54
Lithuania	23	25	27	30	34
Luxembourg	11	8	10	18	17
Hungary	13	14	15	19	20
Malta	10	13	14	19	17
Netherlands	14	16	16	21	19
Austria	34	37	41	41	41
Poland	15	18	20	21	22
Portugal	31	38	42	39	40
Romania	24	30	33	31	34
Slovenia	25	28	30	31	32
Slovak Republic	14	15	16	20	20
Finland	38	49	53	44	49
Sweden	49	61	66	55	60
United	15	17	20	23	22

Kingdom					
EU	**20**	**24**	**27**	**27**	**27**

The impacts of the options may vary depending on the reason for the gap in the first place and the way in which it is corrected. For example, if the gap is due to a reduced level of investment in renewable electricity than originally projected, then the gap filler could have an impact if it results in corrective measures elsewhere, such as shifting the burden to heating and cooling and also to transport. There may also be cost implications if for example the EU measure in transport focuses on advanced renewable fuels which are generally more expensive than other forms of renewable energy. Increasing such a mandate would therefore increase the cost of achieving the target.

From an administrative perspective, the options increasing the EU wide obligations may be simplest. They are legal provisions that require no finance. Finance for any such gap filler would need to be identified for such a measure to be realistic.

5.5.3.2. Detailed assessment

Economic impacts

The options that are most likely not to correct the ambition gap should result in the largest economic impact on the renewable energy industry, as volumes of investment will be lower than anticipated.

There are economic impacts associated with the ineffective gap filling measures. Lower than forecast levels of renewable energy could have economic impacts in terms of likely reductions in energy security, increases in import dependency and a lower rate of decarbonisation.

The impact of the individual options are difficult to distinguish at this stage as it is not clear precisely how some options would operate in practice and which exact measures would be introduced. With the option that involves automatic increase in the stringency of EU-wide measure, then the specific economic impacts would be those associated with the measure in question.

Social impacts

All of the options under consideration should have limited social impacts. If successfully implemented, all of the options should be able to ensure that the EU remains on track to achieve its 2030 targets. The social impact of the precise policy measures may vary, however these are discussed in other sections of the document.

The social impact may be greatest from any options that result in the ambition gap not being corrected. In this case, lower renewable energy than anticipated would be produced, with associated impacts on energy imports, security of supply and a slower rate of decarbonisation. All of these factors could have negative social impacts.

Environmental impacts

The biggest environmental impact will come from ensuring that the at least 27% renewable energy target is delivered. Divergences from the target will have environmental impacts as energy will be sourced from other sources, so this will result in an increase in emissions when the other sources include fossil fuels. The most stringent options (such as Option 4) are likely to have the smallest negative environmental impact.

Political feasibility /opportunity

Regarding ambition level, it is worth noting that a number of Member States (such as France, Germany and Sweden) have introduced ambitious binding targets in national legislation for the period after 2020.

Option 4 which introduces national targets in event of an ambition gap, is not considered politically feasible given the move away from such targets in the 2030 climate and energy framework.

Furthermore, option 3 that could rely on EU financing does not seem feasible in advance of discussions over the EU budget. These options could also comprise of increasing the stringency of EU wide measures agreed in the Directive. It is not clear yet that increasing the stringency of such measures will be feasible at this stage.

Other impacts (markets, innovation…)

There are no specific impacts on SMEs apparent with these options.

Overall, the Option 0 and Option 4 cannot be considered favoured options. Option 0 would provide no means of ensuring that the EU wide renewable energy target is met, while Option 4 includes national targets that have been rejected politically.

5.5.4. Mechanism to avoid and fill a "delivery gap" to the EU renewables target

Option 0	Option 1	Option 2	Option 3	Option 4
• BASELINE - No EU mechanism	• Require Member States below their pledge level to revise the delivery of their plan under the Energy Union Governance	• Include a review clause to propose additional EU level delivery mechanisms at a later stage	• Increase the ambition of EU wide measures proposed in the legislation	• Introduce binding national targets

➢ ***Option 0:*** *BASELINE*

The existing legislation related to the Energy Union Governance and renewable energy has no relevant provisions for this issue. This option would therefore be that no action is taken in response to a delivery gap.

➢ ***Option 1:*** *Revise delivery of national plans*

This option would implement, as foreseen by the planned initiative on Energy Union Governance, a dedicated iterative process of the Commission reviewing Member States' integrated national energy and climate progress reports. Under this approach, a Member State would be legally required to implement revised policies and measures on renewables if it was below the trajectory it originally planned to achieve. The requirement would need to be defined in such a way that any updated plan and revised policies should make good any previous under delivery so as to ensure that the original pledge is met.

- ***Option 2:*** *Review clause to propose additional EU level delivery mechanisms at a later stage*

This option would comprise a review clause to be included in the Revised RES Directive. This clause would require that a review of progress in delivering national plans would be carried out after 5-7 years in order to assess if additional measures are needed to correct any delivery gap. The timing of the review should be aligned with the governance cycle of the Energy Union. As a result of the review, if it was decided necessary, additional EU-level delivery mechanisms to correct the delivery gap would be proposed by the Commission.

- ***Option 3:*** *Increase the ambition of EU wide measures*

This option would address the delivery gap through measures contained in the Revised RES Directive, such as:

(i) further use of EU wide renewables measures contained in the Revised RES Directive (*e.g.* obligations developed for transport and heating and cooling, respectively) or

(ii) specific measures especially for filling any delivery gap (*e.g.* EU wide auctions for renewable electricity support based on an EU-level fund financed by Member States contributions replacing the need to comply with measures under (i) above as a further flexibility, or a supplier obligation for renewable electricity).

The ambition level of these measures would be automatically increased to fill any emerging gap. A means of distributing the required increase in ambition between the measures applying to electricity, transport and heating/cooling would need to be defined. It may also be appropriate to vary the intensity of the increase in the measures between Member States to avoid incentives for free riding. For any measure involving EU funding, provision would need to be made under the MFF.

- ***Option 4:*** *Introduce binding national targets*

This option would address the delivery gap through the introduction of binding national targets for renewable energy in 2030 consistent with the EU-level target of 27%.

5.5.4.1. Introduction to the assessment

The Energy Union Governance process will be central for detecting any delivery gap. The possibility of delivery gap arising would be measured periodically under the reporting made for the Energy Union Governance process. In the event that a gap is detected, there are a number of possible options for dealing with this.

If no action were to result, the gap would persist. This would risk achievement of the binding 2030 target.

The Energy Union Governance process will provide a first check on the situation. This process is still to be agreed politically so it is uncertain as to what exactly it will comprise. However there should be an assessment every 2 years and recommendations would be made if any gaps in delivery are apparent. If following the recommendations there remains insufficient collective action to correct the gap, further provisions in the Revised RES Directive could be considered.

A further option would be to have a review clause in the Revised RES Directive that requests the Commission to come forward with a proposal for corrective measures in the event that a gap is detected. The impact of such an option is difficult to assess at this stage, as it is not clear as to what type of measures would be proposed and then agreed by the co-legislators. Furthermore, there could be some time lag between detecting a delivery gap, then developing, negotiating and implementing corrective measures. In this case such a mechanism may only come into effect close to the target achievement date and provide little time to correct any under achievement.

As discussed in the context of the ambition gap, the delivery gap could also be corrected by an increase in magnitude of EU wide measures, specific EU measures or binding national targets. In such a case similar considerations apply as in the section above on ambition gap measures. Therefore a series of specific measures contained in the Revised RES Directive could provide a meaningful response.

A key issue for the design of the legislation is how to provide sufficient incentives for continued delivery of national commitments and also sufficiently ambitious pledges in the first instance. Without correct incentives there is a risk of free riding by Member States, who may choose to do little and instead rely on the efforts of others. The revised Renewables Directive could include criteria or formula for Member States to use when developing their contributions to the EU renewables target in their national plans in order to provide a positive incentive framework.

A positive incentive could be provided for high national commitments, by introducing a system that in the case of failure to deliver of one Member State against a high commitment results in corrective measures being applied across the EU. On the contrary, a delivery gap that emerges in relation to a low initial national commitment would result in corrective measures being applied in that Member State only. In such a system, the criteria (and/or formula) selected for Member States to use when developing their contributions to the EU renewables target in their national plans would be used to assess the ambition level of the initial commitment. This would help to determine which type of corrective measures should apply.

Gap filling measures based on EU finance would need to be structured so that there is no incentive for Member States to have less ambitious plans. Reliance on such measures may be limited under the Directive as there is no guarantee at this stage that suitable EU budget will be available.

5.5.4.2. Detailed assessment

Economic impacts

There are economic impacts associated with the ineffective gap filling measures. Lower than forecast levels of renewable energy could have economic impacts in terms of likely reductions in energy security, increases in import dependency and a lower rate of decarbonisation than is cost-effective in meeting the EU's climate and energy objectives.

The impact of the individual options are difficult to distinguish at this stage as it is not clear precisely how some options would operate in practice and which exact measures would be introduced. With the option that involves automatic increase in the stringency of EU-wide measure, then the economic impacts would be those associated with the measure in question.

Social impacts

All of the options under consideration should have limited social impacts. If successfully implemented, all of the mechanisms should be able to ensure that the EU remains on track to achieve its 2030 targets. The social impact of the precise policy measures may vary, however these are discussed in other sections of the document.

The social impact may be greatest from any options that result in the delivery gaps not being corrected. In this case, lower renewable energy than anticipated would be produced, with associated impacts on energy imports, security of supply and a slower rate of decarbonisation. Factors which all could have negative social impacts.

Environmental impacts

The most significant environmental impact will result from options that do result in any delivery gap being corrected. Not achieving the 2030 renewable energy as planned would result in increased emissions from other energy sources. This would include both greenhouse gas emissions and local air quality pollutants if less renewable energy production results in increased use of fossil fuels.

It is difficult to distinguish significant differences between the options if they all meet the objective of correcting the delivery gap. The stronger the gap filling measure is, the more certainty there is that the environmental impact will be positive. Options that are less certain risk a high environmental impact.

Political feasibility /opportunity

The option related to reintroducing national targets does not seem feasible politically. This is because the whole structure of the 2030 climate and energy targets is for no national targets for renewables should be included.

The option that involves automatic introduction of enhanced EU measures could also be politically difficult, as it involves activation of new mechanisms and instruments at the EU level.

Other impacts (markets, innovation…)

There are no specific impacts on SMEs apparent with options under consideration.

Overall, Option 0 and Option 4 cannot be considered favoured options. Option 0 would provide no means of ensuring that the EU wide renewable energy target is met, while Option 4 includes national targets that have been rejected politically.

5.5.5. Overall comparison of the options to ensure the achievement of at least 27% renewable energy in 2030

	Overall impact			**Key objectives**		
Policy option	Social	Economic	Environmental	Effectiveness	Efficiency	Coherence
Baseline of 2020 targets						

Option 0 - BASELINE	0	0	0	0	0	0
Option 1 - 2020 national targets as basis for further increases	0	+	+	++	++	++
EU Trajectory 2021 - 2030 for achievement of the EU renewables target						
Option 0 - BASELINE	0	0	0	0	0	0
Option 1 - Linear trajectory	++	++	++	++	+	++
Option 2 - Non-linear trajectory	+	+	+	+	++	+
Mechanism to avoid an "ambition gap" to the EU renewables target						
Option 0 - BASELINE	0	0	0	0	0	0
Option 1 - Revise ambition of national plans	+	+	+	0	0	0
Option 2 - Increase the ambition of EU wide measures	+	++	++	++	+	++
Option 3 - Introduce binding national targets	+	++	++	++	+	+
Mechanism to avoid and fill a "delivery gap" to the EU renewables target						
Option 0 - BASELINE	0	0	0	0	0	0
Option 1 - Revise national plans	+	+	+	0	0	0
Option 2 - Include review clause to propose additional EU level delivery mechanisms at a later stage if needed	+	+	+	0	0	0
Option 3 - Increase the ambition of EU wide measures	+	++	++	++	+	++
Option 4 - Introduce binding national targets	+	++	++	++	+	+
+,++,+++ : positive impact (from moderately to highly positive) *0 : neutral or very limited impact* *-, --, --- : negative impact (from moderately to highly negative)*						

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COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)

{COM(2016) 767 final}
{SWD(2016) 419 final}

Contents

6. MONITORING AND EVALUATION

The Commission will monitor the transposition of the Revised RES Directive and its implementation in the Member States under the Energy Union Governance process. For this purpose, the Commission will be supported by yearly Member States reporting as described below.

6.1. Reporting by the Member States

Every two years starting from 2021 onwards, Member States will report under the Energy Union Governance process on key monitoring indicators and dimensions, among which:

- progress on the implementation of national trajectories
  - for renewables as a whole
  - in the electricity, heating and cooling, and transport sector;
  - by renewable energy technology
  - if applicable, share of renewable energy in district heating, renewable energy use in buildings, renewable energy produced by cities, energy communities and self-consumers).
- progress on the implementation of policies and measures
  - implementation of heating and cooling and transport measures
  - Specific measures for regional cooperation;
  - Specific measures on financial support for renewable
  - Specific measures on admninistrative procedures, information and training, and grid access
  - Specific measures on the promotion of the use of energy from biomass
- and the following further information:
  - the functioning of the system of guarantees of origin
  - aggregated information on biofuels, renewable transport fuels of non-biological origin, waste-based fossil fuels and electricity placed on the market by fuel suppliers
  - developments in the availability, origin and use of biomass resources for energy purposes;
  - changes in commodity prices and land use within the Member State associated with its increased use of biomass and other forms of energy from renewable sources;
  - the estimated excess production of energy from renewable sources which could be transferred to other Member States
  - the estimated demand for energy from renewable sources to be satisfied by means other than domestic production until 2030;
  - the development and share of biofuels made from feedstocks listed in Annex IX
  - the estimated impact of the production of biofuels and bioliquids on biodiversity, water resources, water quality and soil quality within the Member State;
  - risks or observed cases of fraud in the chain of custody of biofuels or bioliquids;

- information on how the share of biodegradable waste in waste used for producing energy has been estimated, and what steps have been taken to improve and verify such estimates;
- the energy produced in buildings, as well as the share of self-consumed energy for electricity and heating and cooling.
- the share of renewable energy in locally generated energy, as well as the renewable capacity and annual generation by energy communities as defined in Article 2 of Directive 2009/28/EC.

6.2. Reporting by the Commission

The Commission will proceed to a compilation of, among others, the elements above to be integrated in the yearly State of the Energy Union Report. It will also asses progress in terms of renewables shares in the EU as a whole against projected trajectory, as well as individual Member States achievements against contributions. On the basis of the elements above, the European Commission will also assess Member States progress in creating renewable enabling framework in all sectors.

A particular focus of the commision report will be cast on the cost-effective deployment of renewable energy, in particular the impact on end consumers and industry. This evaluation shall also assess to what extent the Revised RES Directive has contributed to the achievement of the pledge to make the EU "world number one in renewables", through an analysis of the five key dimensions, *i.e.*:

- citizen empowerement
- energy security
- technology leadership
- overall deployment in each sector
- jobs and added value

For the purpose of the above analyses , the Commission will also promote independent studies and reports, including in collaboration with the industry and the academics, to survey sector-specific aspects of the directive, including the impact on employment, growth, technology imports/export and effect on SMEs.

6.3. Evaluation of the Directive

The Commission will proceed to a fully-fledged evaluation of the impact of the Revised RES Directive in 2025, based on 2023 data. The evaluation report will include, inter alia, an assessment of whether the operational objectives of the Revised RES Directive have been reached, in terms of trajectory towards the 2030 EU-target, as well as in each of the following sectors:

- Electricity
- Heating and cooling
- Transport
- Consumers empowerement

The evaluation report will be developed by the Commission with the assistance of external experts, on the basis of terms of reference developed by the Commission services. Stakeholders will be informed of and consulted on the evaluation report, and they will also be regularly informed of the progress of the evaluation and its findings. The evaluation report will be made public.

ANNEX 1 - PROCEDURAL INFO

Identification

(1) Lead DG: DG ENER

(2) Agenda planning/WP references: AP 2016/ENER/025

Organisation and timing

The Inception Impact Assessment was published in November 2015.

An online public consultation was launched on 18 November 2015 and remained open until 10 February 2016. The main results of this consultation are provided in a separate annex.

Inter-service group:

An Inter-service group meeting was used comprising the Legal Service, the Secretariat-general, DG Budget, DG Agriculture and Rural development, DG Climate action, DG Communications Networks, Content and Technology, DG Competition, DG Economic and Financial Affairs, DG Employment, Social affairs and Inclusion, DG Energy, DG Environment, DG Financial stability, Financial services and Capital markets, DG Internal market, Industry, Entrepreneurship and SMEs, the Joint Research Centre, DG Justice and Consumers, DG Mobility and Transport, DG Regional and urban development, DG Research and innovation, DG Taxation and Customs Union.

Not all Directorate-generals did participate in each ISG.

Meetings of this ISG were held on: 25 April 2016 and 14 July 2016.

Consultation of the RSB:

The draft IA was submitted to the Regulatory Scrutiny Board (RSB) on 25 July and was discussed at the RSB hearing on 14 September 2016, following which the RSB asked for a revised submission.

The issues raised by the RSB, with the relevant actions undertaken on the text of the Impact Assessment, are summarised in the following table.

Revised Impact Assessment of the revision of directive 2009/28/EC on the promotion of the use of energy from renewable sources	
Issues Raised	**Changes introduced in the revised version**
Support Schemes for RES	
Issue cross cutting to other impact assessments **The two IAs on electricity market design and renewable energy present different assessments about the investment that**	This issue has been addressed in the abstract of this Impact Assessment under "The findings of the RES and MDI Impact Assessments" as well as in section 2.2.1. (driver 1). In addition the document, *'The vision for the EU electricity market in 2030*

the market will provide to support renewable electricity. It is not clear whether a funding gap arises because expected investment is too low, or whether a "safety net" is needed to mitigate the risk that the market might not provide enough investment to reach the EU target on renewables.	*and beyond'*, presented together with the MDI IA include the same assessment.
In addition, the state of commercialisation and maturity of the different renewable energy technologies and their differing need (if any) for public support is not addressed.	This issue has been addressed in the abstract of this Impact Assessment under "The findings of the RES and MDI Impact Assessments", as well as in section 2.2.1. (driver 1), 2.2.2. (driver 2) and sections 5.1.1.2 and 5.1.3.2. An analysis for the 2020-2030 period of the required investments and investment gaps for the different technologies is also available in section 5.1.1.2 as well as in Annex 5 (section 1.1.).
It is also unclear how tendering procedures to procure renewable electricity cost-efficiently (and based on the principle of technology neutrality) can address the needs of immature renewable energy technologies and avoid overgenerous support schemes in a rapidly changing environment.	This topic is covered in section 2.2.2 (driver 2). Under option 2 of section 5.1.1, the common framework on support schemes with the 'EU toolkit' aims to address these issues ensuring that the use of tenders keeps support costs to their minimum and by considering the possibility to have technology-specific tenders in certain circumstances (*e.g.* for technology with long term potential).
The IA report also does not explain why new legislative provisions are needed beyond the Commission's current guidelines on energy and environment state aids and their future review in relation to the period after 2020.	This issue is covered in section 2.2.1. (driver 2) and in section 5.1.1.2. new legislative provisions are needed in complementarity with State Aid Guidelines to ensure investor certainty.
Sustainability of Biofuels	
Issue cross cutting to other impact assessments **This IA addresses biofuels while bioenergy as a whole is the subject of another impact assessment. Given that the issues for biofuels are not different from the issues for other sources of bioenergy, the reference to the impact assessment on renewables should**	The sustainability of biofuels, particularly GHG emissions, in addressed in section 2.2.4 and the implications for the existing sustainability criteria, particularly the cap but also the GHG emission saving target, are addressed in section 5.3. The link to the Impact Assessment on bioenergy sustainability is explained in section 1.3.1.

demonstrate the coherence or the possible differences in policy approach. **In particular, consistency should apply to sustainability criteria, expectations as to the role of bioenergy/biofuels in relation to the overall target for renewables, assumptions on the role of subsidies, and the cost-benefits of any feasible policy at this stage.**	
Address the sustainability of biofuels (and the need to revise the existing sustainability criteria in the RES Directive) in a manner coherent with the approach taken in the IA on bioenergy.	The variable climate performance of conventional biofuels due to ILUC is addressed as part of the problem definition in section 2.2.4 and the options for the future treatment of food-based biofuels, particularly the cap, are assessed in section 5.3. The link to the Impact Assessment on bioenergy sustainability is explained in section 1.3.1.
Explain why the IA report does not distinguish between food-based bioethanol and biodiesel given their different greenhouse gas emissions performance	The difference in GHG performance between food-based bioethanol and biodiesel is explained in section 2.2.4. Furthermore it is also discussed in section 5.3.
Explain why options which require frontloading advanced biofuels which are unlikely going to be mature over the 2020-30 period are not discarded.	As explained in section 2.2.4 several production pathways for advanced biofuels are ready for large scale commercialization provided the right policy framework is in place. Section 5.3 discards Option 0 (baseline) and Option 1 (obligation covering only advanced renewable fuels) for not contributing effectively to the gradual replacement of food based biofuels by advanced biofuels and by not addressing ILUC.
The IA report should look at whether national measures would be more appropriate in respect of subsidiarity, effectiveness and efficiency.	The IA analyses whether national measures would be appropriate to increase renewable in transport in section 5.3. In particular, it finds that Option 0 (baseline), which includes a continuation of national mandates and taxation policies, is projected not to sufficiently develop advanced biofuels which are required to decarbonise transport. It also highlights that both energy based obligations and GHG reduction obligations are widely applied by the Member States and EU measures could thus built on existing administrative

	capacities. Furthermore, section 2.2.2 explains in a footnote the difficulties in making progress on energy taxation at EU-level.
Baseline Scenario	
The content and assumptions of the baseline scenario should be clarified, including the differences between the PRIMES 2016 reference scenario and the scenario extending the "current renewable arrangements". The IA should also explain the implications of the scenarios for the cost of the policies and for the energy mix, in particular on bioenergy, which affects negatively the CO_2 target.	Under section 1.3.2. further clarifications are provided regarding the modelling scenarios considered for assessment of the various policy options and their link with other initiatives. In all policy sections the baseline scenario has been clarified. In the electricity section, a table has been introduced in 5.1, which provides an overview of the scenarios considered for assessing the various policy options. A dedicated section has also been added in Annex 4 to explain in more details the choice of the baseline scenario, and the interactions with the EU Reference Scenario. Additional details have been provided when interpreting the results of the scenario, in particular the impacts on the use of bioenergy in the baseline (CRA) scenario (Section 5.1. – introductory part).
Report Length	
An IA report should not generally exceed 40 pages in length, otherwise its usefulness in the decision making process is impaired. The current report substantially exceeds this limit. A short abstract of the IA report should be presented at the beginning of the revised report. This abstract should cover the main elements of the IA (problems, objectives, options, impacts and trade-offs, how options compare) focussing in on the critical points for political decision-making. It should be approximately 10-15 pages in length.	An abstract/executive summary has been included at the beginning of the revised Impact Assessment. It summarizes its key elements, providing the context of revision of the renewables directive, identifying the problems requiring action, the policy options put forward and the main results of their assessment. Furthermore, the Impact Assessment has also been revised with a view to improve its readability and provide further clarity on problem drivers and their link with policy options. To this end, the following changes are highlighted: - In chapter 2, a problem tree is included providing a link between the problem, its drivers and possible consequences - In chapter 5, under each section, a table

	has been included providing the link between challenges, drivers and policy options - The sections on energy communities and administrative barriers have been included under the electricity sector, as they mostly focus on this sector.
Preferred options	
Many different options are discussed but no preferences are expressed. It is difficult, therefore, to gauge the overall balance and proportionality of the intended approach towards attainment of the EU-level target and to assess coherence with other initiatives and Union policies. While it is not mandatory to express a policy preference, the usefulness of the IA report would be enhanced if preferences were stated or if options that compare less well in the analysis could be discarded.	In all policy sections, a number of options to be discarded have been identified, reducing the number of potentially preferred options.
Subsidiarity and proportionality	
The discontinuation of national targets introduces more uncertainty regarding the collective attainment of the EU-level target and the individual contributions of the Member States. However, the principles of subsidiarity and proportionality remain relevant. The current impact assessment has only investigated options for action at the EU level notwithstanding that national measures may be less costly, more effective or simply more appropriate from a subsidiarity perspective. The IA should look at a wider range of options including action at Member State level particularly in the transport and heating and cooling sectors. Moreover, the extension of the scope of the directive to cover administrative issue for permits and the legal definition of energy communities is questionable on subsidiarity grounds.	To provide further clarity on the need for EU intervention a section on subsidiarity has been included in the abstract and Chapter 3 has been revised. With regard to the **transport section**, as mentioned above, the Impact Assessment analyses whether national measures would be appropriate to increase renewables in transport in section 5.3. In particular, it finds that Option 0 (baseline), which includes a continuation of national mandates and taxation policies, is projected not to sufficiently develop advanced biofuels which are required to decarbonise transport. It also highlights that energy based obligations are widely applied by the Member States and EU measures could thus built on existing administrative capacities. Furthermore, section 2.2.2 refers in a footnote to the difficulties in making progress on energy taxation at EU-level. With regard to **heating and cooling**, as explained in section 5.2.1.1, the heating and cooling obligation scheme is designed

	to reflect a cost-effective set of measures at national level in order to reach a 27% renewables target. In the absence of further EU incentives, it is likely that Member States would fall below this cost-effective share. In section 5.2.1, a range of mitigation measures have been introduced to leave sufficient flexibility for Member States when designing the obligation *i.e.* to limit the burden on small-scale suppliers and ensure proportionality and subsidiarity of the option. On the top of it, the most far-reaching option (option 1) has been disregarded. The option to include a definition of **energy communities** has been introduced as a necessary step to ensure that a certain category of actors, that bring added value in terms of cost-efficient renewable deployment, are able to play a role and compete on equal footing with other market players. Such definition would be based on existing entities (such as SMEs) and will ensure, to the extent possible, that all energy communities across Europe are encompassed. Member States would still have freedom to have their own definition of energy communities, as long as entities falling under the RED definition are granted the right to operate on equal footing within the energy system. This topic is addressed in section 5.1.1. With respect to **administrative procedures**, the relation between the existing measures (current article 13 of the RES Directive), the TEN-E Regulation and the proposed options was made clearer (please see section 5.1.4). Furthermore, clarifications on subsidiarity were added in section 5.1.4, explaining why EU action is required and that the options proposed leave enough freedom for Member States to define the solutions that are best suited for local circumstances. It should be noted that elements of options that are not in line with subsidiarity are pointed out in order to be discarded.
Governance and mid-term review	

Issue cross cutting to other impact assessment **The IA report should explain why it is necessary now to anticipate the potential failure of the envisaged governance system without any evidence or understanding as to why the Union may not be on track to attain the EU's target of 27% renewables in 2030.**	Further explanation is provided in the section concerning links with other initiatives (section 1.3.1). The problem definition and assessment of the options for correcting gaps have been edited to make clearer the roles of the respective initiatives (please see sections 2.2.1, 2.2.3, 5.5.3 and 5.5.4).
The option of having a mid-term review should be considered, which would be based an evaluation of the RES Directive using the information generated by the governance process to assess the causes for any non-attainment and the need for additional measures. Such an evaluation would in any event be required under the Commission's better regulation policy.	The IA report contains options for a review process to address any potential gaps in achieving the target. The options related to review clauses have been revised so that these options are made clearer (please see sections 5.5.3 and 5.5.4).
The report should justify why all sectors (electricity, heating and cooling, transport) should contribute more or less equally to reaching the overall RES target, and it should explain how this would be the most efficient approach.	Section 2.2.2., driver 1, clarifies the expected cost-effective contribution of the various sectors to the overall increase in the RES share by 2030. The Impact Assessment does not conclude that all sectors should contribute more or less equally, but rather according to their potential, which depends on various factors, including evolution of energy demand in the various sectors. Addition details on the model specifications leading to these results can be found in Annex 4.

Consideration of the 2nd Regulatory Scrutiny Board Opinion issued on 4 November

RSB comments	How the Proposal of a recast of the Renewables Directive addresses the RSB comments
B) Overall opinion: NEGATIVE	
The Board acknowledges the improvements in the resubmitted impact assessment report. It provides a useful abstract, an improved problem definition, a better quantified baseline, more details on the options. In particular it establishes the investment gap in renewables for power generation and makes the case for the continuation of market based support	**The assistance of the Board and the guidance offered during the process contributed to an improved problem definition, a better quantified baseline, as well as more details on the options. In particular, the confirmation that the IA clearly establishes the investment gap in renewables for power generation and convincingly makes the case for the**

schemes.	**continuation of market based support schemes is acknowledged.**
However, the Board maintains its negative opinion because the revised report still contains significant shortcomings as listed below:	**The Proposal has been significantly reviewed in order to take into account the concerns expressed by the Board in its opinions, in particular regarding (i) the proportionality of the measures initially foreseen in relation to RES support schemes; and (ii) the proportionality of the measures initially foreseen in the heating and cooling sector..** **Detailed responses are provided below.**
The report fails to assess sufficiently the principles of subsidiarity and proportionality. The case for EU-level legal obligations in several areas is not clear. Options for action at Member State level have not been considered. A different mix of EU and national measures might arguably be more efficient and effective, notably in light of the following: **– the political decision of the European Council to move away from national legally binding targets for renewable energy;** **– the extent to which national measures are already in place;** **– the relatively limited additional efforts required to reach the EU target as compared to the baseline, as well as the generally underestimated trend of renewables growth;** **– the need to ensure coherence with the various climate and energy policy instruments (such as the proposal on effort sharing in sectors not covered by the emissions trading system, energy efficiency and energy performance of buildings and the initiative on electricity market design).**	**There is a fundamental shift in the policy framework for 2030: while the 2020 framework was based on legally binding national targets, allowing Member States large discretion on their national measures, the 2030 framework is based on a legally binding target placed at the level of the European Union. The Union's target can be best achieved through a partnership with Member States combining their national actions supported by a framework of EU measures. Such a mix of national and EU measures will ensure the achievement of the binding nature of the 2030 Union-level target in a cost efficient way.** **Relying solely on national measures would lead to a non-cost efficient and unevenly spread efforts across the EU, leading to an insufficient deployment of renewables in the EU internal energy market falling short of the agreed target. EU level action is necessary to create a robust and stable framework that enables the collective and cost-efficient achievement of the Union's binding objective of at least 27% renewable energy in 2030, with a fair distribution of efforts by Member States.** **This is a minimum target. While the EU is today well on track to achieve its 2020 renewables target, modelling shows that the EU is not on track to meeting the 2030 target. The IA (Reference scenario), which assumptions have been built in close**

	cooperation with Member States, points to a likely achievement of 24.3% RES in 2030 on the basis of a continuation of current measures at Member State level. This would not fulfil the legally binding objective of at least 27%. **Moving from 24.3% to the minimum target of 27% requires very substantial additional investments. For RES-E generation only, moving from 24.3% to 27% would require an additional investment of 254 bn EUR over 2021-2030. This figure is the difference between the RES-E investment needs in the Reference scenario (assuming continuation of Member States measures, leading to 24.3%) and the Current Renewables Arrangement (CRA) scenario (assuming by design that the 27% target is met through unspecified additional measures at Member States level, but no additional measures in the recast Directive) – see Annex 5 of the IA.** **Against this background, it is important to note that investments in renewables have dropped by more than half since 2011 to $48.8 billion last year. The EU now accounts for only 18%[1] of global total investment in renewables, down from close to 50% only 6 years ago. Uncertainty over the EU and, consequently, national frameworks that will be in place after 2020 is affecting the the project pipeline for after 2020. This calls for the prompt establishment of a clear and stable policy framework to make it possible for the EU to achieve its 2030 targets and its ambition to lead the world on renewables.** **The Proposal aims at ensuring that a sufficient mix of measures is in place at EU and national levels to meet the at least 27% target. It also aims at reducing the overall cost of meeting the target through the use of EU-level measures, as illustrated by the reduction in RES-E investment needs**

[1] Frankfurter School-UNEP Centre/BNEF, 2016. Global Trends in Renewable Energy Investments 2016, http://www.fs-unep-centre.org

	between the CRA and the EUCO scenarios - see Annex 4 of the IA. **The additional investments need to be triggered through a consistent development of EU renewable energy policy across the EU, leading to a more cost-efficient deployment and a smooth and efficient operation of the internal energy market whilst fully considering the differing resource capacities of the Member States to produce different forms of renewable energy. Where EU measures are proposed, Member States retain a wide flexibility and discretion to further develop renewables in any sector of their economies that suits best their national circumstances and preferences.** **The Commission's Proposal is an integral part of the 2030 Energy and Climate Framework. A single basis for modelling and analysis has been used for all legislative proposals (the Board has already given positive opinions on the Impact Assessments for these), which takes into account cross legislative interactions and builds on the confirmed input of Member States (including their national actions). This has ensured coherence, complementarity and consistency for all proposals. In developing the 'package' there is full consistency across all legislative proposals. Thus, for example, aspects of governance including dialogue, preparation and finalisation of national plans, biannual review and evaluation, recommendations to Member States, and ultimately any legislation revisions are all within the Governance Regulation. Hence there is no accumulation or contradiction in the draft proposals.**
More specifically:	**Detailed explanations are provided below**
Proportionality is particularly relevant for the options in the heating and cooling sector. Impacts and costs of the different obligations have not been assessed against their small contribution to the overall target.	**The legislative proposal has been adjusted following the opinion of the Board. The mandatory nature of the provision has been abandoned; instead, Member States are provided orientations on how to address the untapped potential in the heating and cooling sector.**

	On the substance of the Board comment regarding the proportionality of the obligations assessed in the Impact Assessment, it shall be noted that heating and cooling represents 50% of final energy consumption, is essential to the ultimate achievement of the Union's decarbonisation goals, and in fact contributes close to half of the at 27% share RES in 2030. **Modelling shows that, for the heating and cooling sector to cost-effectively contribute to the 27% target, the RES-HC share would reach 27% in 2030 (EUCO27). Continuation of national measures (reference scenario) would lead to a RES-HC share of only 24.7%. In the absence of further incentive post-2020, the current national policies would not be sufficient to reach the long-term decarbonisation goals.** **The gap in terms of RES consumption in the H&C sector between 2020 and 2030 is moderate when looked at in *net* terms (+4 Mtoe according to modelling undertaking in this assessment, under EUCO27 scenario). However, such unit of measure does not take into account the fact that energy efficiency improvements are likely to proportionally affect existing RES sources in the sector – for instance, reducing the heat consumption in a house will proportionally reduce the energy consumption attributed to the biomass boiler of this house. This means that, in the absence of new investments, RES consumption in the H&C sector can be estimated to decrease by around 20 Mtoe due to energy efficiency improvements only. The effort required to meet the cost-efficient contribution of RES in H&C is thus around 24 Mtoe (4 + 20 Mtoe), even before taking into account the need to replace existing units reaching the end of their life. This compares to an overall effort required in the electricity sector of c 39 Mtoe (EUCO27), where overall demand will increase over the period.** **Cost-efficiently reaching the target will also require a significant change in the energy mix for the heating and cooling**

	sector. Between 2020 and 2030, the H&C will need to see: a high uptake of heat pumps (x2 in final consumption); a high deployment of solar thermal (+50% in consumption at residential level); a reduction in overall biomass consumption in the residential sector (-25%); and an uptake in biogas production (up to +2/3). **Currently most Member States have heating and cooling policies in place, mainly focussed on efficiency. However, the instability of the schemes, the technology lock-in due to the absence of specific RES-targeted support along with the uncertainty of continuation of such policies post-2020 means that the EU will not reap the full potential of heating and cooling in meeting the overall RES target cost effectively.** **Regardingproportionality and subsidiarity, the Proposal now foresees that Member States shall endeavour to achieve an annual increase of 1% in the share of renewable energy in heating and cooling supply. Member States will decide how to implement this measure. This provision will contribute to reaching cost-effective contribution of the H&C sector (c. 27% RES-H&C share in 2030) towards meeting the overall RES target. Additionally, full flexibility is left to Member States as to the manner by which they will seek to meet this objective.** **It can be noted that, where Member States decide to introduce supplier obligations, related costs can be expected to be limited. The IA addresses the administrative burden associated with obligations - for national administrations the implication is very moderate, particularly when combined with e.g. administration of the Article 7 EED measures. In light of additional information from recent studies, the annual additional costs on fossil fuel sales could be around 0.32 €/MWh, which represents around 0.5% of the price of natural gas for households in 2030[2].**

[2] EU average. Draft interim results from Fraunhofer.

	Furthermore, the provisions on heating and cooling have been carefully aligned across all the legislative texts. The proposed EED and EPBD focus on new and renovated buildings and individual consumer choice, while RED addresses the large thermal suppliers where consumers are unable to make individual choice. The risk of unintended consequences, such as a worsening of air quality due to the use of biomass has been fully assessed through the policy scenario (EUCO27) on the *Environmental impacts* section of chapter 5.2.1. of the IA and found, focusing on the residential sector, that biomass use remains constant (and even decreases in absolute terms) between 2020 and 2030, thanks mostly to energy efficiency and electrification.
Proportionality is also a consideration regarding the cumulative requirements under the new RES Directive, the Effort Sharing Decision and the revised Energy Union Governance (especially with regard to national trajectories and corrective measures). Together these might be a disproportionate way to deliver the Union's target for renewable energy.	**The Proposal establishes EU-wide measures that are complementary to the new Effort Sharing Regulation (ESR) proposed in July 2016. While the ESR establishes binding GHG emission targets for each Member State without defining how to get there, the Proposal establishes EU-wide measures only in certain sectors covered by the ESD (heating and cooling and transport) where the added value of EU action is demonstrated and where subsidiarity and proportionality principles are respected. This approach is similar to other EU-wide measures impacting sectors covered by the ESD, such as CO2 emission standards for new cars and vans, or restrictions on fluorinated industrial gases. This approach has also been accepted and successful with respect to 2020 targets where despite an effort sharing decision[3] with binding national targets, it was decided to have dedicated legislation for renewables.** **As part of the investment requirements for the period 2020 – 2030, a number of trajectories have been examined. The assessment confirms that a clear profile of demand, across all technologies, would**

[3] Reference to legislative act

	result in a consistent stream of investments, allow for industrialisation of the supply chain, continued cost reduction, whilst supporting jobs and growth in the renewables sector. Combined this also has a positive impact on greenhouse gas emission reductions. **Should corrective measures be needed to make sure the EU as whole achieves the target this would be done through the Energy Union Governance.**
The existing state aid guidelines already address most of the issues that the IA report examines and already acknowledge the 2030 climate and energy targets. It is not clear, therefore, why the IA addresses the design of public support schemes for renewable electricity.	**The legislative proposal has been adjusted following the opinion of the Board, in close cooperation with DG COMP and the Legal Service, in order to ensure that provisions contained in the Proposal are fully compatible with and complementary to State aid rules and do not impinge on EC competencies in the field of State aid.** **The proposed principles are general principles requiring the use (where needed) of market-based and cost-effective schemes. This is fully consistent with the new market design and helps to minimise costs for tax payers and electricity consumers. The provisions further support the investor certainty over the 2021-2030 period created by the regulatory framework of the Directive.** **Industry, regulators and several Member States have stressed the need for a stable regulatory framework to ensure the cost-effective achievement of the renewable at least 27% target. Some stakeholders stressed the need for a strenghtened ETS price signal, full integration of renewables in the market and, if needed, market based renewables support, encouraging common rules to be developed in the Directive. These rules should also allow Member States to develop the renewable technologies needed for instance for diversification reasons, and ensure that Member States retain the capacity to determine their energy mix, as per the Treaty. The same Member States finally stress that the basic requirements of support schemes for Europe need to be agreed in the Council and the European Parliament, which will build legitimacy**

and public acceptance for the market integration agenda. The Proposal builds on national support schemes and does not introduce an EU support scheme for renewables, leaving Member States discretion on how to incentivise renewables. On the other hand, the Proposal does provide clarity that support schemes can be used if needed and sets out general principles in line with the objective of the market design initiative to integrate renewables in the electricity market and in line with the overall objective to achieve decarbonisation at least costs to consumers.

The principles also respect subsidiarity as they do not interfere with Member States' right to determine their energy mix.

If follows directly from the Treaty that the Commission must ensure that State aid does not distort the internal market to an extent contrary to the common interest. It also follow directly from the Treaty that Member States shall promote the development of renewable forms of energy and have the right to determine their energy mix.

The Commission provides a clear and predictable framework on how it assesses State aid schemes in its State aid guidelines. The Commission in its assessment is bound by its guidelines and reviews them regularly after consultation of Member States and stakeholders in order to adapt them to market developments.

Additionally and crucially, the state aid guidelines and existing legislation have not been designed to prevent retroactive changes impacting the economics of existing projects, and harming investor's confidence in the soundness of the European framework in support of renewables. The Proposal introduces a specific provision aimed at preventing the use of such retroactive changes.

Finally, the Proposal introduces a requirement on Member States to open support to cross-border participation

	which will ensure that renewables are increasingly deployed where their potential and other conditions are most favourable – again leading to most cost-effective support (see Section 5.1.1 of the IA).
Moreover, the sustainability of biofuels and their potential contribution to the Union-level target is unclear. The issues have not been assessed in the same way as for other forms of bioenergy in the related impact assessment on bioenergy sustainability. Possible changes to the sustainability criteria of biofuels might be appropriate, but this has not been assessed.	**Building on the analysis developed in the IA to the ILUC Directive, this Impact Assessment assesses a number of options for strenghtening the existing sustainability framework for biofuels, including by extending and further reducing the existing cap on food-based biofuels to the period after 2020 in order to minimise ILUC emissions.** **At the same time, the IA on bioenergy assessed options for strengthening the overall sustainability criteria for bioenergy, including a new sustainabilty criteron for forest biomass (used also for biofuel production) and an extension of the sustainability criteria to biomass used for heat and power.**
Finally the report does not provide sufficient clarity concerning the preferred set(s) of options and associated policy trade-offs to facilitate decision-making by the College of Commissioners.	**The impact of each option has been analysed in the Impact Assessment, providing a basis for a comparison of the impacts of the different options analysed. The Impact Assessment did not present a set of preferred options, as allowed under the current practice.**
(C) Main requirements for adjustment	
(1) In relation to renewable electricity, the IA should explain why new legal provisions are needed on how to design state aid schemes beyond what exists already in the Commission's state aid guidelines on energy and the environment (e.g. tendering obligations and opening of tenders to EEA).	**See above.**
(2) The text should better explain how a single uniform (technology-neutral) approach to auctions/tenders for supporting renewable electricity will be able to accommodate the different situations of the various RES technologies. Conversely, if technology-specific tenders are permitted, how would these avoid over-generous subsidies (particularly given the intention to prevent retroactive action by Member	**The Board has confirmed that the IA establishes the investment gap in renewables for power generation and makes the case for the continuation of market based support schemes.** **It should be noted in this context that the Proposal, in view of the Board's opinion relating to a possible duplication between the Proposal and State aid rules, does not**

States).	**include any provisions related to the use of tenders.**
3) The approach presented in the IA is primarily to deliver the 27% EU renewables target with EU-level instruments. While the revised report raises subsidiarity-related issues in the context of providing "flexibility" for implementing the EU instruments, options for Member State action should also be considered.	**The IA builds on the assumption that current EU and Member States policies and measures will only lead to 24.3% in 2030. The IA has considered a number of options across the different sectors (heating and cooling, transport, electricity). Member States have full flexibility to select and implement actions in sectors most appropriate to their situation. EU instruments are proposed only for actions in which operators can trade between themselves, across borders, and across sectors in order to meet the EU-level binding target collectively and cost-efficiently in view also of long term technological development for decarbonisation of the economy. The approach retained in the proposal creates a European framework which supports Member States, particularly in heating and cooling, and in transport. This can subsequently be complemented by further action at Member State level.**
(4) The report should better justify the proportionality of the obligations in the heating and cooling sector: **– The report should analyse likely costs and benefits to justify the level of the particular renewable fuel obligation imposed on fuel suppliers.** **– The report should assess the administrative burden associated with certification regarding district heating and fuel obligations in particular for SMEs. .** **– The risk of unintended consequences should be analysed, such as a worsening of air quality due to the use of biomass instead of clean fuels such as natural gas.** **– The report should better consider consistency with other legislation on energy efficiency, non-ETS GHG emissions reduction and new proposals on the energy efficiency of buildings (EPBD). Article 13 of the existing RES Directive already obliges Member States to ensure that their national buildings codes promote a minimum level of renewables for near-zero energy buildings and buildings undergoing a major**	**The legislative proposal has been adjusted following the opinion of the Board. The mandatory nature of the provision has been abandoned; instead, Member States are provided orientations on how to address the untapped potential in the heating and cooling sector.** **On the substance of the Board comment regarding the proportionality of the obligations assessed in the Impact Assessment, it shall be noted that heating and cooling represents 50% of final energy consumption, is essential to the ultimate achievement of the Union's decarbonisation goals, and in fact contributes close to half of the at 27% share RES in 2030.** **Modelling shows that, for the heating and cooling sector to cost-effectively contribute to the 27% target, the RES-HC share would reach 27% in 2030 (EUCO27). Continuation of national measures (reference scenario) would lead to a RES-HC share of only 24.7%. In the absence of further incentive post-2020, the current**

renovation. In addition, the envisaged revision of the EPBD aims to promote "own production" of renewable energy as a way to meet near-zero energy standards for buildings. In addition, each Member State also has a different target for greenhouse gas emission reduction in the non-ETS sector, which might imply less stringent obligations to reduce greenhouse gas emissions.

national policies would not be sufficient to reach the long-term decarbonisation goals.

The gap in terms of RES consumption in the H&C sector between 2020 and 2030 is moderate when looked at in *net* terms (+4 Mtoe according to modelling undertaking in this assessment, under EUCO27 scenario). However, such unit of measure does not take into account the fact that energy efficiency improvements are likely to proportionally affect existing RES sources in the sector – for instance, reducing the heat consumption in a house will proportionally reduce the energy consumption attributed to the biomass boiler of this house. This means that, in the absence of new investments, RES consumption in the H&C sector can be estimated to decrease by around 20 Mtoe due to energy efficiency improvements only. The effort required to meet the cost-efficient contribution of RES in H&C is thus around 24 Mtoe (4 + 20 Mtoe), even before taking into account the need to replace existing units reaching the end of their life. This compares to an overall effort required in the electricity sector of c 39 Mtoe (EUCO27), where overall demand will increase over the period.

Cost-efficiently reaching the target will also require a significant change in the energy mix for the heating and cooling sector. Between 2020 and 2030, the H&C will need to see: a high uptake of heat pumps (x2 in final consumption); a high deployment of solar thermal (+50% in consumption at residential level); a reduction in overall biomass consumption in the residential sector (-25%); and an uptake in biogas production (up to +2/3).

Currently most Member States have heating and cooling policies in place, mainly focussed on efficiency. However, the instability of the schemes, the technology lock-in due to the absence of specific RES-targeted support along with the uncertainty of continuation of such policies post-2020 means that the EU will not reap the full potential of heating and cooling in meeting the overall RES target

	cost effectively. **Regarding proportionality and subsidiarity, the Proposal now foresees that Member States shall endeavour to achieve an annual increase of [1]% in the share of renewable energy in heating and cooling supply. Member States will decide how to implement this measure.** **This provision will contribute to reaching cost-effective contribution of the H&C sector (c. 27% RES-H&C share in 2030) towards meeting the overall RES target. Additionally, full flexibility is left to Member States as to the manner by which they will seek to meet this objective.** **It can be noted that, where Member States decide to introduce supplier obligations, related costs can be expected to be limited. The IA addresses the administrative burden associated with obligations - for national administrations the implication is very moderate, particularly when combined with e.g. administration of the Article 7 EED measures. In light of additional information from recent studies, the annual additional costs on fossil fuel sales could be around 0.32 €/MWh, which represents around 0.5% of the price of natural gas for households in 2030[4].** **Furthermore, the provisions on heating and cooling have been carefully aligned across all the legislative texts. The proposed EED and EPBD focus on new and renovated buildings and individual consumer choice, while RED addresses the large thermal suppliers where consumers are unable to make individual choice. The risk of unintended consequences, such as a worsening of air quality due to the use of biomass has been fully assessed through the policy scenario (EUCO27) on the *Environmental impacts* section of chapter 5.2.1. of the IA and found, focusing on the residential sector, that biomass use remains constant (and even decreases in absolute terms) between 2020 and 2030, thanks mostly to energy efficiency and**

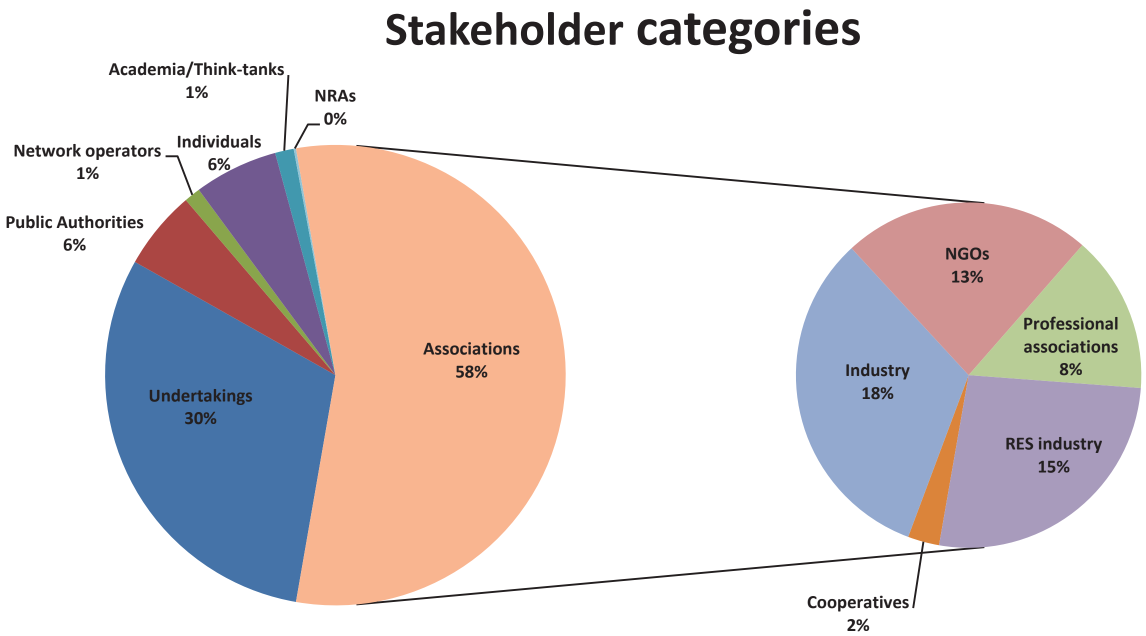
[4] EU average. Draft interim results from Fraunhofer.

	electrification. -
(5) This impact assessment takes a different approach to that which assessed directly the sustainability of other forms of bioenergy in relation to their possible contribution to the Union's 27% target. The revised IA remains primarily focused on how to deliver a particular volume of renewable energy in the transport sector but does not address the sustainability of biofuels directly including the important issue of indirect land use change (and associated greenhouse gas emissions). It is not clear whether food-based biofuels should contribute to the Union's 2030 target. Consideration should be given to an additional policy option that addresses the deficiencies in the current sustainability criteria (i.e. absence of Indirect Land Use Change) and which would apply equally to all biofuels (advanced and food-based).	**Building on the analysis carried out in the IA to the ILUC Directive, this IA analysed further options for mitigating the ILUC impacts of food-based biofuels in the period post-2020. The analysis shows that such impacts can be effectively mitigated by introducing a progressive reduction in the share of food-based biofuels that can count against the 2030 RES target on top of existing sustainability criteria for biofuels. In this way, the Proposal clarifies the role of food-based biofuels in the post-2020 period. Furthermore, the IA analyses options for increasing the GHG savings requirement to ensure optimal climate performance of advanced biofuels.**
(6) The coherence and proportionality of the measures intended under the present initiative and under the energy governance and RES options related to the delivery of the EU's 27% target should be better explained. Assuming the new legal obligations are adopted, and taking into account the commitments under the Effort Sharing Decision, the report needs to demonstrate the need for the linear increasing trajectory for the period 2020-2030 as well as the possible corrective measures under the governance framework	**The Proposal establishes EU-wide measures that are complementary to the proposed Effort Sharing Regulation (ESR). While the ESR establishes binding GHG emission targets for each Member State without defining how to get there, the Proposal establishes EU-wide measures only in certain sectors covered by the ESR (heating and cooling and transport) where the added value of EU action is demonstrated and where subsidiarity and proportionality principles are respected. This approach is similar to other EU-wide measures impacting sectors covered by the ESR, such as CO2 emission standards for new cars and vans, or restrictions on fluorinated industrial gases.** **As part of the investment requirements for the period 2020-2030, a number of trajectories have been examined. The assessment confirms that a clear profile of demand, across all technologies, would result in a consistent stream of investments, allow for industrialisation of the supply chain, continued cost reduction, whilst supporting jobs and growth in the renewables sector. Combined this also has**

	a positive impact on greenhouse gas emission reductions. **As regards trajectories, the Proposal does not establish any binding trajectories on Member States. The Governance Proposal establishes a need to define indicative Member States ambition levels including indicative trajectories that correspond to their national circumstances and preferences. Without being binding on Member States a linear EU-wide trajectory will help track progress towards the achievement of the EU-wide target.** **Should corrective measures be needed to make sure the EU as whole achieves the target this would be done through the Energy Union Governance. Instead, the Proposal defines a set of balanced measures across the different sectors to allow Member States to deliver the target collectively and cost efficiently on the EU level target.**
(D) Procedure and presentation	
While the report is still very long, adding the abstract has improved the presentation of relevant information.	**Acknowledged**

ANNEX 2 - STAKEHOLDER CONSULTATION

This public consultation was launched on 18 November 2015 and remained open until 10 February 2016. The Commission received in total 614 replies. 340 replies were sent by national and EU-wide associations, accounting for 58% of the replies. Out of these, 110 came from industry associations (18% of total replies) and 90 were submitted by the renewable energy industry (15%). Moreover, there were 186 replies directly from undertakings (30%). A total of 19 national governments and 22 regional or local authorities also participated in this consultation. To note the significant participation by individual citizens, energy cooperatives and NGOs.



The detailed assessment of the replies confirms broad consensus amongst respondents on a number of the elements put forward in the public consultation, including *inter alia* the need for a stable and predictable EU legal framework for renewables, the importance of defining complementary measures in the new directive to ensure the achievement of the at least 27 % binding target and the relevance of developing a market fit for renewables. However, stakeholders are divided on other issues, such as on the geographical scope of support schemes and the exposure of renewables to market conditions (*e.g.* priority dispatch and balancing responsibilities).

1. General framework for renewable energy policies

Ensuring stability, transparency and predictability for investors

Respondents from all stakeholder categories stress the need for a robust legal framework that can replace key features of the RES Directive, such as national binding targets which were considered crucial to achieve the 2020 objectives. Likewise, 73% of respondents consider that the current directive has been successful in helping to achieve the EU energy and climate objectives. Nevertheless, more than 90%[5] of respondents believe that the renewable energy potential at local level is still underexploited.

When defining the future legislative framework for the period after 2020, several topics stand out as important for stakeholders, most notably:

- Strategic planning of renewable energy at national level required by the EU, which 95% of respondents from across all stakeholder categories consider as important/very important to improve investor confidence.
- Member States consulting on, and adopting, renewable energy strategies that serve as the agreed reference for national renewable energy policies and projects (93% of respondents consider it as important/very important).
- Yet, this measure should be completed by strong guidance from the EC (78% of respondents qualify it as important or very important) and rely on the best practices identified within the RES Directive (for 87% of respondents).

Stakeholders stress that retroactive changes to support schemes should be prevented. Other elements are identified as important to improve the stability of investments; these include the removal of administrative barriers, further market integration and a reinforced investment protection regime going beyond the Energy Charter Treaty. Several respondents also insist on the necessity to ensure a quick implementation of the 2030 Renewables Directive, well ahead of 2021, in order to give timely policy signals and an outlook to investors.

Regarding national energy and climate plans, more than 80 % of respondents support the different tentative elements suggested to be included in the plans. This includes *inter alia* renewable energy trajectories and policies up to 2050, specific technology relevant trajectories for renewable energy up to 2030 and measures to be taken for increasing flexibility of the energy system and for achieving market coupling and integration.

Complementary measures to achieve the at least 27 % binding EU renewable target

Having a robust legal framework enshrined in the Renewables Directive is considered key to achieving the at least 27% EU renewable energy target by 2030. The majority of respondents favour preventive measures to avoid a gap in target achievement, but also see a need for implementing corrective actions if this happens to be the case. Some stakeholders, such as Energy Regulators, highlight the need to ensure consistency of any complementary measures with national support schemes.

There is wide consensus amongst stakeholders around measures such as EU-level support to research, innovation and industrialisation of innovative renewable energy technologies (for 91 % of respondents[6]) and for EU-level financial support to renewable energy, such as, for instance, a guarantee fund to support renewable projects (80 % of respondents are in favour).

Enhanced EU level regulatory measures are also supported by 72 % of respondents. Member States' respondents further believe that sharing best practices, information and updated guidelines would be useful to improve chances of target achievement.

[5] Amongst those who have an opinion on the question itself
[6] Amongst those who have an opinion on the question itself

Respondents' support for other complementary measures is also high, reaching 67 % for EU-level requirements on market players to include a certain share of renewable energy, and 49 % for EU-level incentives such as an EU-wide or regional auction of renewable energy capacities.

Furthermore, all stakeholders touch on the need for enhanced infrastructure investments and highlight the importance of smart grids and storage systems.

Support schemes

Regarding the geographical scope of support schemes, there is a wide variety of opinions across the stakeholder community. While the preferred option by stakeholders (34 %) is a gradual alignment of national support schemes through common EU rules, there is some willingness (17 %) to move further and consider a progressive opening of national support schemes to energy producers in other Member States under some conditions such as, for instance, obligation of physical delivery of the electricity, or having a bilateral cooperation agreement in place. The reasons given to sustain this position generally lie on the fact that the natural conditions of the location in terms of abundancy of the resource (wind or sun) are only one element to be looked at to minimize the cost of deployment of renewable energy (*e.g.* grid issues, market development). As for Member States, those generally believe that cross-border participation to support schemes should be on a voluntarily basis. Overall, the development of a concrete framework for cross border participation is generally welcomed.

Moving towards even further integration by introducing a EU-wide level support scheme, or a regional support scheme, is supported by 24 % and 12 % of the respondents respectively, while keeping national level support schemes that are only open to national renewable energy producers is the preferred option for 13 % of the respondents. Several respondents highlight some possible risks and political sensitivities associated with schemes entailing further integration, as those could imply citizens in one Member State having to contribute to renewables' development in another Member State.

Respondents largely consider that support mechanisms should encourage greater market responsiveness, resulting in gradually decreasing support levels as technologies become mature. Several respondents regard regional cooperation and consultation as a useful method to reduce differences and facilitate convergence amongst national support schemes.

2. Empowering consumers

Self-consumption

There is a strong support for additional EU action for empowering energy consumers and local authorities. The vast majority of replies (84%) support stronger EU rules guaranteeing that consumers have the possibility to produce and store their own renewable heat and electricity and participate in all relevant energy markets in a non-discriminatory and simple way, including through aggregators. Many respondents support increasing short-term market exposure for self-consumption systems, by valuing surplus electricity injected into the grid at the wholesale market price. However, a number of renewables' generators highlight that market-based support schemes are still needed for small-scale self-consumption systems during the transition towards a reformed market design. Several respondents support facilitated access to finance for local initiatives on renewable energy.

Moreover, the majority supports the introduction of clearer principles for ensuring that network tariffs support the transition to a more prosumer-centric system. While TSOs, DSOs and some Member States support a strong capacity-related element in tariffs as it is considered more cost-reflective, cooperatives believe that volumetric tariffs are, instead, needed.

Information disclosure to consumers

An easily understandable Guarantees of Origin (GO) system is considered an important factor to drive market demand for renewable energy by enabling consumer choice. A large consensus between respondents exists on the fact that the GO system is a key tool of disclosure of energy sources to consumers and, with few exceptions, that it should be strengthened. In addition, there is support for the extension of GOs to all energy generation types (including information on carbon intensity) and its full operation across-borders. Some opposing views between stakeholders exist as regards whether full disclosure should be mandatory or voluntary, and several stakeholders raise the problem of excessive administrative burden.

3. Decarbonising the heating and cooling sector

There is an overwhelming consensus about the need to remove barriers hampering the deployment of renewable heating and cooling. A high number of respondents, including Member States and renewable energy industry regard the absence of a functioning heat market as an important barrier. The vast majority of respondents see the lack of energy strategies and planning at the national and local levels (for 84% of stakeholders), the lack of targeted financial resources and financing instruments (for 80% of stakeholders) and the lack of electricity market design supporting demand response as very important, or important, barriers. Moreover, measures to enhance decentralised energy and self-consumption and thermal storage in buildings and district systems is perceived as an appropriate (78% of respondents consider it important/very important). The majority of respondents is in favour of a mandatory minimum use of energy in nearly zero-energy buildings (67% of respondents consider this important/very important) and a renewable heating and cooling obligation (for 61% of respondents this is important/very important). Various stakeholders mention the need for a strong alignment of the relevant European directives (*i.e.* the Energy Efficiency Directive, the Energy Performance of Buildings Directive and the RES Directive).

4. Adapting market design and removing barriers

Building a market fit for renewables

There is general consensus about the need to evolve towards a market fit for renewables along the lines outlined in the new Energy Market Design Consultative Communication. Most stakeholders support the cross-border integration of short-term markets as a key tool to facilitate renewable energy generators to trade their imbalances. A high number of respondents[7] consider either important or very important to have a fully harmonised gate

[7] Amongst those who have an opinion on the question itself

closure time for intraday markets across the EU (82%), lower thresholds for bid sizes (80 %), shorter trading intervals (77%) or regulatory measures to enable thermal and electrical storage (77%).

In addition, stakeholders identify as crucial to ensure the liquidity in these markets and guarantee the absence of price caps/exposure to market prices. Several stakeholders also highlight the necessity of equally addressing storage markets and demand side response.

Finally, the ETS improvement is a major priority for most of the stakeholders to further drive investments in renewable energy.

Balancing responsibilities, grid connexion and priority dispatch

Stakeholder views diverge with respect to the degree of exposure of renewable energy generation to market conditions.

As regards balancing responsibilities of generators, stakeholders reveal different positions: while 59 % of respondents consider that, in principle, everyone should have full balancing responsibilities, the remaining 41 % state that exemptions are still needed. In the view of the latter, exemptions should remain in place until the maturity of short-term markets can guarantee that renewable energy producers are not being discriminated. An important number of stakeholders also emphasize that small-scale renewable energy installations and early demonstration projects should not be subject to balancing responsibilities.

Stronger EU rules to remove grid regulation and infrastructure barriers are considered instrumental for renewable energy deployment. A high number of respondents[8] consider it either important or very important to have stronger EU rules regarding the treatment of curtailment, including compensation rules (77%), transparent and foreseeable grid development (87%) and predictable and transparent connection procedures (89%), which are identified as even more important than strengthening rules on obligation/priority of connection for renewables.

As regards priority dispatch, 54 % of respondents consider that merit order dispatch is sufficient, while 46 % consider that some exemptions for renewables are still necessary given that markets are not mature. Key stakeholders such as Energy Regulators stress the need to keep priority access for renewables especially in case of network congestions while agreeing that dispatching on the basis of merit order is sufficient.

Administrative barriers

Simplifying administrative permitting procedures are perceived as an untapped potential for reducing costs of renewable energy technology roll-out. Stakeholders identified the creation of a one stop shop (*i.e.* a national single permitting authority) at national level as a centrepiece of simplified administrative procedures (for 79% of stakeholders). Harmonising permitting procedures appears to be less of a priority for stakeholders even if still important. Amongst stakeholders, there is strong consensus that permitting procedures should be managed at national level.

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8 Amongst those who have an opinion on the question itself

As regards EU action on renewable energy training and certification, mutual recognition of certifications between Member States has been identified as the key priority by a majority of stakeholders (83%).

Public acceptance of renewables

The necessity of tabling measures to improve public acceptance of renewables was addressed by key stakeholders. Half of the respondents mention the importance of involving citizens and local communities in the development of renewable energy projects, also through awareness campaigns and public dialogue emphasising the contribution of renewables to achieving climate goals, energy security, and local growth. Involving the general public through investments and co-ownership (*e.g.* cooperatives) is also widely mentioned as a driver to increase public acceptance alongside decreasing costs of renewable energy technology.

5. Increase the renewable energy use in the transport sector

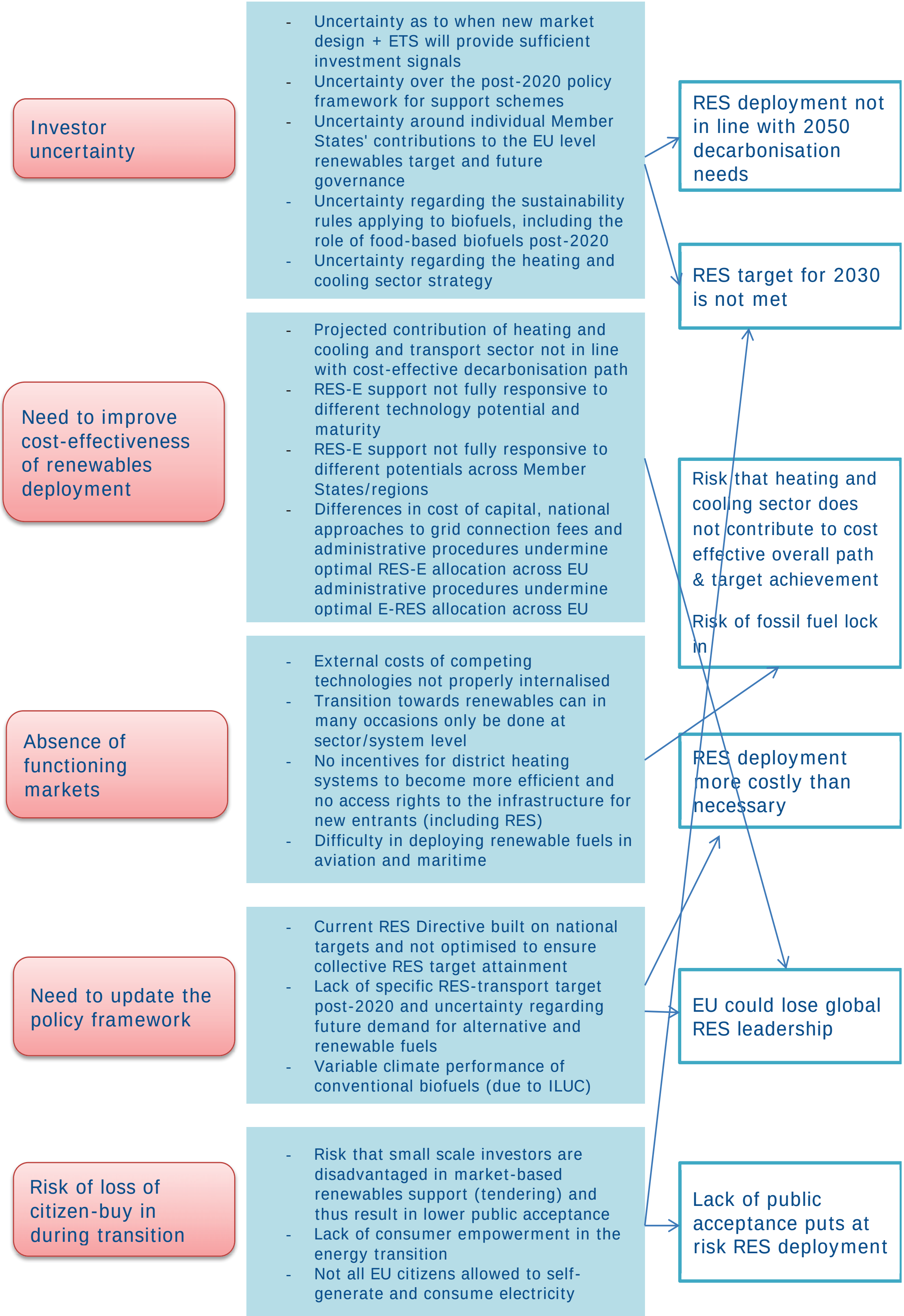
According to many respondents, the main barrier to increasing renewable energy in transport is the lack of a stable policy framework for after 2020, the long debate about biofuels, and the high price of electric vehicles. In order to promote the consumption of sustainable renewable fuels in the EU transport sector and increasing the uptake of electric vehicles, 80% of respondents consider increased incorporation obligations to be effective or very effective.

Further, a large majority regards a higher degree of harmonisation of the support mechanisms, or an obligation at EU level to be effective or very effective (81% and 75% of respondents, respectively). Targeted financial support for the deployment of innovative low-carbon technologies was considered to be effective, or very effective, for 77% of respondents.

Finally, the great majority of stakeholders (87%) show strong support to facilitating access to alternative fuel infrastructure, such as electric-vehicle charging points.

ANNEX 3 - PROBLEM DRIVERS MATRIX

	Electricity	Heating & cooling	Transport	Governance
Reduce investor uncertainty	- Consolidated framework: EU toolkit for support schemes	- Mainstream renewables: obligation on heating and cooling	- Increase renewables: obligation on renewable fuels	- 2020 Baseline - Trajectory towards 2030 target - Avoid and fill delivery gap
Improve cost-effectiveness	- Consolidated framework: tendering design principles - Reducing cost of capital - Administrative simplification	- Facilitate renewables in district heating and cooling: Energy performance		
Create functioning market	- Consolidated support framework: market-based design principles - Consolidated framework: energy communities	- Facilitate renewables in district heating and cooling: Access rights	- Increase renewables: obligation in aviation and maritime	
Update regulatory framework	- Coordinated regional approach		- Increase renewables: phase-out of food based biofuels	- Avoid an ambition gap - Avoid and fill delivery gap
Ensure citizen buy-in	- Empower consumers: self-consumption and storage-consumption - Consolidated support framework: fair tendering for small producers - Disclose information on electricity generation	- Facilitate renewables in district heating and cooling: Consumer rights - Trace origins of renewable fuels in heating and cooling	- Trace origins of renewable fuels in transport	


Investor uncertainty
Need to improve cost-effectiveness of renewables deployment
Absence of functioning markets
Need to update the policy framework
Risk of loss of citizen-buy in during transition
- Uncertainty as to when new market design + ETS will provide sufficient investment signals
- Uncertainty over the post-2020 policy framework for support schemes
- Uncertainty around individual Member States' contributions to the EU level renewables target and future governance
- Uncertainty regarding the sustainability rules applying to biofuels, including the role of food-based biofuels post-2020
- Uncertainty regarding the heating and cooling sector strategy
- Projected contribution of heating and cooling and transport sector not in line with cost-effective decarbonisation path
- RES-E support not fully responsive to different technology potential and maturity
- RES-E support not fully responsive to different potentials across Member States/regions
- Differences in cost of capital, national approaches to grid connection fees and administrative procedures undermine optimal RES-E allocation across EU administrative procedures undermine optimal E-RES allocation across EU
- External costs of competing technologies not properly internalised
- Transition towards renewables can in many occasions only be done at sector/system level
- No incentives for district heating systems to become more efficient and no access rights to the infrastructure for new entrants (including RES)
- Difficulty in deploying renewable fuels in aviation and maritime
- Current RES Directive built on national targets and not optimised to ensure collective RES target attainment
- Lack of specific RES-transport target post-2020 and uncertainty regarding future demand for alternative and renewable fuels
- Variable climate performance of conventional biofuels (due to ILUC)
- Risk that small scale investors are disadvantaged in market-based renewables support (tendering) and thus result in lower public acceptance
- Lack of consumer empowerment in the energy transition
- Not all EU citizens allowed to self-generate and consume electricity
RES deployment not in line with 2050 decarbonisation needs
RES target for 2030 is not met
Risk that heating and cooling sector does not contribute to cost effective overall path & target achievement
Risk of fossil fuel lock in
RES deployment more costly than necessary
EU could lose global RES leadership
Lack of public acceptance puts at risk RES deployment

EUROPEAN
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Brussels, 30.11.2016
SWD(2016) 418 final

PART 3/4

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)

{COM(2016) 767 final}
{SWD(2016) 419 final}

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Contents

Annex 4 - Analytical models and model-based scenarios used in preparing the Impact Assessment

1. Description of analytical models used – PRIMES related suite of models

The model suite used for this impact assessment has a successful record of use in the Commission's energy and climate policy impact assessments – it is the same model suite as used for the 2020 climate and energy package as well as for the 2030 climate and energy policy framework. The models and their linkages are briefly described in the following subsections. Detailed model descriptions can be found on the DG CLIMA website[1]. Assumptions relevant for this impact assessment are described in section 2 on the EU Reference scenario and section 3 on policy scenarios.

The model suite covers:

- **The entire energy system** (energy demand, supply, prices and investments to the future) and all GHG emissions and removals:
- **Time horizon:** 1990 to 2050 (5-year time steps)
- **Geography:** individually all EU Member States, EU candidate countries and, where relevant Norway, Switzerland and Bosnia and Herzegovina
- **Impacts:** on energy, transport and industry (PRIMES and its satellite models on biomass and transport), agriculture (CAPRI), forestry and land use (GLOBIOM-G4M), atmospheric dispersion, health and ecosystems (acidification, eutrophication) (GAINS); macro-economy with multiple sectors, employment and social welfare (E3ME and GEM-E3).

The models are linked with each other in formally-defined ways to ensure consistency in the building of scenarios, as shown graphically in Figure 1. These inter-linkages are necessary to provide the core of the analysis, which are energy, transport and GHG emissions trends.

1 http://ec.europa.eu/clima/policies/strategies/analysis/models/index_en.htm

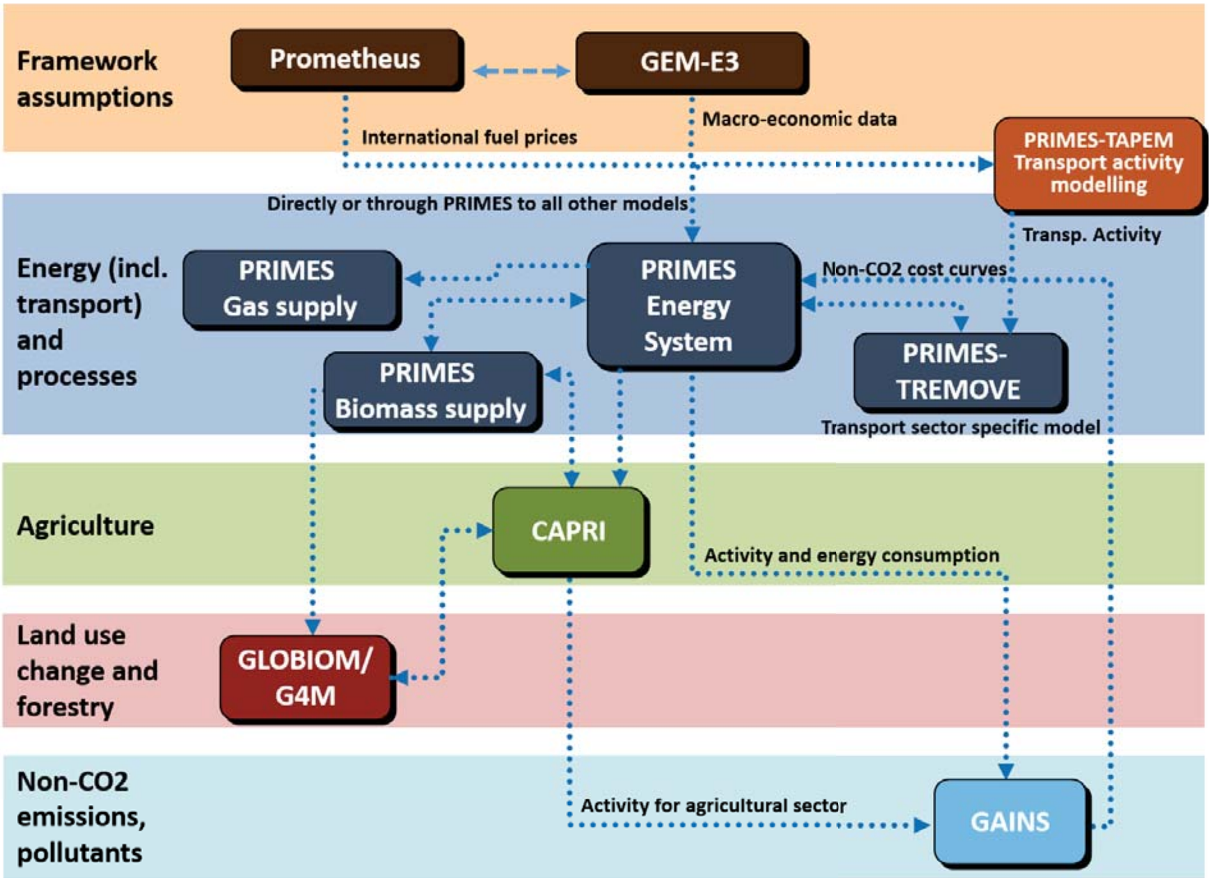

Figure 1: Inter-linkages between models
Source: EU Reference Scenario 2016 publication report

1.1. PRIMES

The PRIMES model is an EU energy system model which simulates energy consumption and the energy supply system. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States. This includes consistent EU carbon price trajectories.

Decision making behaviour is forward looking and grounded in micro-economic theory. The model also represents in an explicit way energy demand, supply and emission abatement technologies, and includes technology vintages.

The core model is complemented by a set of sub-modules, of which the transport sector module and the biomass supply module are described below separately in more detail. Industrial non-energy related CO_2 emissions are covered by a sub-module so that total CO_2 emissions can be projected. The model proceeds in five year steps and is for the years 2000 to 2010 calibrated to Eurostat data.

The PRIMES model is suitable for analysing the impacts of different sets of climate, energy and transport policies on the energy system as a whole, notably on the fuel mix, CO_2 emissions, investment needs and energy purchases as well as overall system costs. It is also suitable for analysing the interaction of policies on combating climate change, promotion of energy efficiency and renewable energies. Through the formalised linkages with GAINS non-CO_2 emission results and cost curves, it also covers total GHG emissions and total ESD sector emissions. It provides details on the Member State level, showing differential impacts across Member States.

The PRIMES model represents energy efficiency by simulating different measures with different techniques. These modelling techniques will affect the context and conditions under which stylized agents per sector, make their decisions on energy consumption.

PRIMES has been used for the analysis underpinning the Commission's proposal on the EU 2020 targets (including energy efficiency), the Low Carbon Economy and Energy 2050 Roadmaps, the 2030 policy framework for climate and energy and the energy efficiency Impact Assessment in 2014.

PRIMES is a private model and has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[2] in the context of a series of research programmes co-financed by the European Commission.

The model has been successfully peer reviewed[3], most recently in 2011[4].

1 .2. PRIMES- TAPEM & PRIMES-*TREMOVE*

PRIMES-TAPEM, operated by ICCS/E3MLab is an econometric model for transport activity projections. It takes GEM-E3 projections (GDP, activity by sector, demographics and bilateral trade by product, and by country) as drivers, to produce transport activity projections to be fed into PRIMES-TREMOVE. The econometric exercise also includes fuel prices coming from PROMETHEUS, as well as transport network infrastructure (length of motorways and rail-ways), as drivers. The PRIMES-TAPEM model provides the transport activity projections for REF2016.

The PRIMES-TREMOVE Transport Model projects the evolution of demand for passengers and freight transport by transport mode and transport mean. It is essentially a dynamic system of multi-agent choices under several constraints, which are not necessarily binding simultaneously. The model consists of two main modules, the transport demand allocation module and the technology choice and equipment operation module. The two modules interact with each other and are solved simultaneously.

The projection includes details for a large number of transport means, technologies and fuels, including conventional and alternative types, and their penetration in various transport market segments. It also includes details about greenhouse gas and air pollution emissions, as well as impacts on external costs of congestion, noise and accidents.

PRIMES-TREMOVE has been used for the 2011 White Paper on Transport, Low Carbon Economy and Energy 2050 Roadmaps as well as the 2030 policy framework for climate and energy.[5]

The PRIMES-TREMOVE is a private model that has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens [6], based on, but extending

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2 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/.

3 http://ec.europa.eu/clima/policies/strategies/analysis/models/docs/primes_model_2013-2014_en.pdf.

4 https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1569_2.pdf'.

5 The model can be run either as a stand-alone tool (*e.g.* for the 2011 White Paper on Transport) or fully integrated in the rest of the PRIMES energy systems model (*e.g.* for the Low Carbon Economy and Energy 2050 Roadmaps, and for the 2030 policy framework for climate and energy). When coupled with PRIMES, interaction with the energy sector is taken into account in an iterative way.

features of the open source TREMOVE model developed by the TREMOVE[7] modelling community. Part of the model (*e.g.* the utility nested tree) was built following the TREMOVE model.[8] Other parts, like the component on fuel consumption and emissions, follow the COPERT model.

In the transport field, PRIMES-TREMOVE is suitable for modelling *soft measures* (*e.g.* eco-driving, deployment of Intelligent Transport Systems, labelling), *economic measures* (*e.g.* subsidies and taxes on fuels, vehicles, emissions; ETS for transport when linked with PRIMES; pricing of congestion and other externalities such as air pollution, accidents and noise; measures supporting R&D), *regulatory measures* (*e.g.* CO_2 emission performance standards for new passenger cars and new light commercial vehicles; EURO standards on road transport vehicles; technology standards for non-road transport technologies), *infrastructure policies for alternative fuels* (*e.g.* deployment of refuelling/recharging infrastructure for electricity, hydrogen, LNG, CNG). Used as a module which contributes to a broader PRIMES scenario, it can show how policies and trends in the field of transport contribute to economy wide trends in energy use and emissions. Using data disaggregated per Member State, it can show differentiated trends across Member States.

1.3. PRIMES Biomass Supply

The biomass system model is linked with the PRIMES energy system model for Europe and can be either solved as a satellite model through a closed-loop process or as a stand-alone model.

It is an economic supply model that computes the optimal use of biomass/waste resources and investment in secondary and final transformation, so as to meet a given demand of final biomass/waste energy products, projected to the future by the rest of the PRIMES model. The biomass supply model determines the consumer prices of the final biomass/waste products used for energy purposes and also the consumption of other energy products in the production, transportation and processing of the biomass/waste products. The model also reflects the sustainability criteria currently in place and can be used for reflecting policies facilitating the use of renewable energy sources. After cross check of input data and draft results, results of the biomass supply model are used to ensure consistency between PRIMES, CAPRI and GLOBIOM bioenergy modelling.

The PRIMES biomass supply model is private and has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[9].

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6 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/

7 http://www.tmleuven.be/methode/tremove/home.htm

8 Several model enhancements were made compared to the standard TREMOVE model, as for example: for the number of vintages (allowing representation of the choice of second-hand cars); for the technology categories which include vehicle types using electricity from the grid and fuel cells. The model also incorporates additional fuel types, such as biofuels (when they differ from standard fossil fuel technologies), LPG and methane fuels. In addition, representation of infrastructure for refuelling and recharging are among the model refinements, influencing fuel choices. A major model enhancement concerns the inclusion of heterogeneity in the distance of stylised trips; the model considers that the trip distances follow a distribution function with different distances and frequencies. The inclusion of heterogeneity was found to be of significant influence in the choice of vehicle-fuels especially for vehicles-fuels with range limitations.

9 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/

1.4. GAINS

The GAINS (Greenhouse gas and Air Pollution Information and Simulation) model is an integrated assessment model of air pollutant and greenhouse gas emissions and their interactions. GAINS brings together data on economic development, the structure, control potential and costs of emission sources and the formation and dispersion of pollutants in the atmosphere.

In addition to the projection and mitigation of greenhouse gas emissions at detailed sub-sectorial level, GAINS assesses air pollution impacts on human health from fine particulate matter and ground-level ozone, vegetation damage caused by ground-level ozone, the acidification of terrestrial and aquatic ecosystems and excess nitrogen deposition of soils.

Model uses include the projection of non-CO_2 GHG emissions and air pollutant emissions for EU Reference scenario and policy scenarios, calibrated to UNFCCC emission data as historical data source. This allows for an assessment, per Member State, of the (technical) options and emission potential for non-CO_2 emissions. Health and environmental co-benefits of climate and energy policies such as energy efficiency can also be assessed.

The GAINS model is accessible for expert users through a model interface[10] and has been developed and is maintained by the International Institute of Applied Systems Analysis[11]. The underlying algorithms are described in publicly available literature. The source code is not disclosed. GAINS and its predecessor RAINS have been peer reviewed multiple times, in 2004, 2009 and 2011.

1.5. GLOBIOM-G4M

The Global Biosphere Management Model (GLOBIOM) is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors. Agricultural and forestry production as well as bioenergy production are modelled in a detailed way accounting for about 20 globally most important crops, a range of livestock production activities, forestry commodities as well as different energy transformation pathways.

GLOBIOM covers 28 (or 50) world regions. The disaggregation of the EU into individual countries has been performed only recently.

Model uses include the projection of emissions from land use, land use change and forestry (LULUCF) for EU Reference scenario and policy scenarios. For the forestry sector, emissions and removals are projected by the Global Forestry Model (G4M), a geographically explicit agent-based model that assesses afforestation-deforestation-forest management decisions. GLOBIOM-G4M is also used in the Impact Assessment for agriculture and LULUCF to assess the options (afforestation, deforestation, forest management, cropland and grassland management) and costs of enhancing the LULUCF sink for each Member State.

10 http://gains.iiasa.ac.at/models/
11 http://www.iiasa.ac.at/

The GLOBIOM-G4M is a private model and has been developed and is maintained by the International Institute of Applied Systems Analysis[12].

1.6. Prometheus

PROMETHEUS is a fully stochastic world energy model used for assessing uncertainties and risks associated with the main energy aggregates including uncertainties associated with economic growth and resource endowment as well as the impact of policy actions. The model projects endogenously the world energy prices, supply, demand and emissions for ten world regions.

World fossil fuel price trajectories are used as import price assumptions for EU Reference scenario and for policy scenario modelling.

The Prometheus model is private and has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[13]

1.7. CAPRI

CAPRI is an open source economic partial equilibrium model developed by European Commission research funds. Operational since more than a decade, it supports decision making related to the Common Agricultural Policy and Environmental policy related to agriculture based on sound scientific quantitative analysis.

CAPRI is only viable due to its pan-European network of researchers which based on an open source approach tender together for projects, develop and maintain the model, apply it for policy impact assessment, write scientific publications and consult clients based on its results. It has been the basis of numerous peer reviewed publications.

The model has been used to provide consistent agricultural activity projections for the EU Reference scenario 2016s. It is also used in the LULUCF impact assessment. The CAPRI model is an open source model which has been developed and is maintained by Eurocare GmbH[14], JRC, and other partners of the CAPRI network.

2. The EU Reference Scenario 2016 – approach and main results

2.1. Scenario design, consultation process and quality assurance

Scenario design and consultation process

Building an EU Reference scenario is a regular exercise by the Commission. It is coordinated by DGs ENER, CLIMA and MOVE in association with the JRC, and the involvement of other services via a specific inter-service group.

REF2016 2016 (REF2016) has been developed building on a modelling framework including as core models PRIMES (PRIMES-TREMOVE for transport), GAINS and GLOBIOM-G4M and as supporting models GEM-E3, PROMETHEUS, PRIMES Biomass supply and CAPRI (see prior section for details).

12 http://www.iiasa.ac.at/
13 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/
14 http://www.eurocare-bonn.de/

For the REF2016, the model was calibrated on energy data up to year 2013 from Eurostat and other sources, and for agriculture and non-CO_2 emission data up to the year 2015.

Member States were consulted throughout the development process through a specific Reference scenario expert group which met three times during the development of REF2016. Member States provided information about adopted national policies via a specific questionnaire, key assumptions have been discussed and in each modelling step, draft Member State specific results were sent for consultation. Comments of Member States were addressed to the extent possible, keeping in mind the need for overall comparability and consistency of the results.

Quality of modelling results was assured by using state of the art modelling tools, detailed checks of assumptions and results by the coordinating Commission services as well as by the country specific comments by Member States.

REF2016 projects EU and Member States energy, transport and GHG emission-related developments up to 2050, given current global and EU market trends and adopted EU and Member States' energy, transport, climate and related relevant policies.

"Adopted policies" refer to those that have been cast in legislation in the EU or in MS (with a cut-off date end of 2014[15]). Therefore the binding 2020 targets are assumed to be reached in the projection. This concerns GHG emission reduction targets (both for the EU ETS as well as ESD sectors) as well as renewables targets, including renewables in transport.

However, policies which are not yet legally implemented, *e.g.* those necessary to implement the 2030 energy and climate framework, are not part of REF2016[16]. On this basis, REF2016 can help identify areas where the current policy framework falls short of reaching the EU's climate and energy objectives[17]. Notably, REF2016 shows that current policy and market conditions will deliver neither the 2030 targets nor the long-term 2050 80-95% GHG emission reduction objective.

REF2016 provides projections, not forecasts. Unlike forecasts, projections do not make predictions about what the future will be. They rather indicate what would happen if the assumptions which underpin the projection actually occur. Still, the scenario allows for a consistent approach in the assessment of energy and climate trends across the EU and its Member States.

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15 In addition, amendments to two Directives only adopted in the beginning of 2015 were also considered. This concerns notably the ILUC amendment to the RES Directive and the Market Stability Reserve Decision amending the ETS Directive.

16 For the period after 2020, policies are included that are part of the EU *acquis*, as well as important investments that are part of Member States' national energy plans. For instance, ETS with the Market Stability Reserve is included in REF16, but not the Commission's proposal for a change in the linear reduction factor post-2020. New near-zero energy buildings after 2020 - as defined in the Energy Performance of Buildings Directive - continue to be built, as well as energy labelling continues. Member States also gave input on planned energy investments, particularly in nuclear energy.

17 Each new update of REF2016 models the projected impact of policy adopted up to the relevant cut-off date. Therefore, differences between two consecutive Reference scenarios, *e.g.* between the one from 2013 and REF2016, can be explained by the implications of policies adopted in the meantime as well as by changed economic and technological trends.

The report "EU Energy, Transport and GHG Emissions Trends to 2050 - Reference Scenario 2016" describes the inputs and results in detail. This section summarises the main messages derived from it, especially those relevant for the Energy Union framework.

Main assumptions

The projections are based on a set of assumptions, including on population growth, macroeconomic and oil price developments, technology improvements, and policies.

Macroeconomic assumptions

In REF2016, the population projections draw on the European Population Projections (EUROPOP 2013) by Eurostat. The key drivers for demographic change are: higher life expectancy, convergence in the fertility rates across Member States in the long term, and inward migration. The EU28 population is expected to grow by 0.2% per year during 2010-2030 (0.1% for 2010-2050), to 516 million in 2030 (522 million by 2050). Elderly people, aged 65 or more, would account for 24% of the total population by 2030 (28% by 2050) as opposed to 18% today.

GDP projections mirror the joint work of DG ECFIN and the Economic Policy Committee, presented in the 2015 Ageing Report[18]. The average EU GDP growth rate is projected to remain relatively low at 1.2% per year for 2010-2020, down from 1.9% per year during 1995-2010. In the medium to long term, higher expected growth rates (1.4% per year for 2020-2030 and 1.5% per year for 2030-2050) are taking account of the catching up potential of countries with relatively low GDP per capita, assuming convergence to a total factor productivity growth rate of 1% in the long run.

Sectorial activity projections are derived in a consistent way from these macroeconomic assumptions, using the macro-economic modelling tool GEM-E3 as well as econometric estimates for global demand for energy intensive industries.

Fossil fuel price assumptions

Oil prices have fallen by more than 60% since mid-2014, to an average of around 40 $/barrel for Brent crude oil in the first four months of 2016. The collapse of oil prices has been driven by low demand and sustained oversupply, due in particular to tight oil from North America and to the decision of the Organization of Petroleum Exporting Countries (OPEC) countries not to cut their output to rebalance the market. REF2016 considers a gradual adjustment process with reduced investments in upstream productive capacities by non-OPEC countries. Quota discipline is assumed to gradually improve among OPEC members. Thus, oil price is projected to reach 87 $/barrel in 2020 (in year 2013-prices). Beyond 2020, as a result of persistent demand growth in non-OECD countries driven by economic growth and the increasing number of passenger cars, oil price would rise to 113 $/barrel by 2030 and 130 $/barrel by 2050. This price trend resulting from PROMETHEUS modelling is in line with other reference sources such as the 2015 IEA World Energy Outlook.

No specific sensitivities were prepared with respect to oil and gas price developments. Still, it can be recalled that lower fossil fuel price assumptions tend to increase energy consumption and CO_2 emissions not covered by the ETS. The magnitude of the change would depend on the price elasticities and on the share of taxation, like excise duties, in

[18] European Commission/ DG-ECFIN (2015) "The 2015 Ageing Report Economic and budgetary projections for the 28 EU Member States (2013-2060)", European Economy 3/2015

consumer prices. For instance, for transport, the changes would be limited (depending on the magnitude of the change in the oil price) due to the high share of excise duties in the consumer prices but they are still expected to lead to some higher energy consumption and CO_2 emissions. They also tend to lead to lower overall energy system costs, as the increase in consumption is more than compensated by lower prices. Conversely, costs for emission mitigation could slightly increase. Different fossil price assumptions are unlikely to lead to significantly different impacts across Member States.

Technoeconomic assumptions

In terms of technological developments, input assumptions are based on a wide range of sources[19], with estimates on technological costs across main types of energy equipment, from power generation to heating systems and appliances. In addition, it should be recalled that the PRIMES model (and other models where relevant) take into account technological progress.

In terms of technological developments relevant to the transport sector, battery costs for electric vehicles and plug-in hybrids are assumed to go down to 320-360 $/kWh by 2030 and 270-295 $/kWh by 2050; further improvements in the efficiency of both spark ignition gasoline and compression ignition diesel are assumed to take place. In addition, the market share of internal combustion engine (ICE) electric hybrids is expected to increase due to their lower fuel consumption compared to conventional ICE vehicles.[20]

For the techno-economic assumptions in the projection of non-CO_2 GHG emissions, see the detailed technical documentation[21]. In general, technological progress in this domain is strongly linked to regulation; hence Reference scenario assumptions are conservative.

Technology assumptions are based on extensive literature review and have been peer-reviewed by the Commission services, notably the Joint Research Centre of the European Commission.

Specific policy assumptions

Following the above described policy modelling approach, the key policies included in the REF2016 are[22]:

- The EU Emissions Trading System (Directive 2003/87/EC and its amendments) is fully reflected in the modelling, including the linear reduction factor of 1.74% for stationary installations and the recently adopted Market Stability Reserve.[23]

19 Those include, among others, the European Commission Joint Research Centre, notably for power generation costs or identification of Best Available Technologies, or MURE, ICARUS or ODYSSEE for the demand sectors.

20 REF2016, by design, assumes the continuation of the current trends and policies without the implementation of additional measures. Hence, due to the absence of further policies, car manufacturers and industry are not expected to devote additional effort in marketing advanced vehicle technologies. The relatively low production of advanced vehicles, in REF2016, is not expected to yield economies of scale which could potentially imply high reduction in battery costs as suggested by other sources. Such assumptions change in a decarbonisation policy scenario context.

21 Höglund-Isaksson, L., W. Winiwarter, P. Purohit, A. Gomez-Sanabria (2016): Non-CO2 greenhouse gas emissions in the EU-28 from 2005 to 2050: GAINS 2016 Reference scenario, International Institute for Applied Systems Analysis (IIASA)

22 For a comprehensive discussion see REF2016 report

23 Decision EU/2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and amending Directive 2003/87/EC

- The Effort Sharing Decision (406/2009/EC) is assumed to be implemented, *i.e.* ESD GHG emission reductions at EU level in 2020 need to reach at least -10% compared to 2005 levels. It turned out that no specific policy incentives in addition to adopted EU and national policies were needed to achieve the EU level target. National ESD targets need not be achieved domestically given the existing flexibilities (*e.g.* transfers between Member States).
- The Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD) are reflected, including Member States' specific obligations as regards energy savings obligation and buildings codes.
- Ecodesign and Energy Labelling Directives and Regulations are also reflected.
- CO_2 standards for cars and vans regulations (Regulation (EC) No 443/2009, amended by Regulation EU No 333/2014 and Regulation (EU) No 510/2011, amended by Regulation EU 253/2014); CO_2 standards for cars are assumed to be 95gCO_2/km as of 2021 and for vans 147gCO_2/km in line with current legislation. Standards are assumed constant after 2020/2021.
- The Renewable Energy Directive (Directive 2009/28/EC) and Fuel Quality Directive (Directive 2009/30/EC) including ILUC amendment (Directive (EU) 2015/1513): achievement of the legally binding renewables target for 2020 (including 10% renewables in transport target) for each MS, taking into account the use of flexibility mechanisms when relevant as well as of the cap on the amount of food or feed based biofuels (7%). Member States' specific renewable energy policies for the heating and cooling sector are also reflected where relevant.
- Directive on the deployment of alternative fuels infrastructure (Directive 2009/30/EC).
- The Waste Management Framework Directive (Directive 2008/98/EC) and in particular the Landfill Directive (Directive 1999/31/EC) which contribute to a significant reduction of emissions from waste.
- The revised F-gas Regulation (Regulation 517/2014) strengthens existing measures and introduces a number of far-reaching changes, notably limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030, and banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available.
- The impacts of the Reforms of the Common Agricultural Policy are taken into account, *e.g.* the milk quota abolition.
- Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) for maritime transport.[24]
- Relevant national policies, for instance on the promotion of renewable energy, on fuel and vehicle taxation or national building codes, are taken into account.

Discount rates

The PRIMES model is based on individual decision making of agents demanding or supplying energy and on price-driven interactions in markets. The modelling framework includes two distinct stages: a) a first stage models decision-making behaviour of agents,

[24] IMO Resolution MEPC.203(62)

hence investment and technology choices; b) a second stage calculates total costs for the entire energy system in order to support comparisons across scenarios.

In the first stage, agents take decisions considering the time dimension of money flows. Private discount factors can be defined as reflecting opportunity costs of raising funds by the actor on a private basis. The opportunity costs of an investment decision also vary with the degree of market distortions and non-market barriers as well as with the degree of risk associated with the decision options. The opportunity costs differ hence by sector and by type of agent.

The aim is to assess policy impacts as close as possible to reality and to avoid under- or over- estimation of the costs, and thus the difficulties, of transformation required to meet targets and transition objectives (*i.e.* transition towards a low carbon economy). Therefore, in line with the impact assessment guidelines the modelling is based on private discount rates[25].

For determining the values of discount rates to be applied, the model follows different approaches by sector. Decisions by firms are based on the weighted average cost of capital (WACC) to determine the discount rates. REF2016 applies different WACC rates by business sector, by type of technology (mature versus emerging), by scale level (*e.g.* industrial or decentralised versus utility scale) and for companies subject to regulation by the state. WACC rates vary between 7.5% and 11%.

Decisions by individuals are modelled based on a subjective discount rate, annualizing investment costs following the equivalent annuity cost method. Literature surveys[26] find high implicit discount rates for households, because of various factors, such as lack of information, uncertainties, different income levels, lack of sufficient funding, agency costs, transaction and hidden costs. By varying the discount rates applied in the model, it is therefore possible to reflect, for instance, the effects of energy efficiency policy instruments, mainly ESCOs, campaigns and labelling programs, by lowering the discount rates when these policies are implemented. Therefore, the EU Reference scenario uses discount rates for individuals reflecting both existing barriers for investment decisions (which have an upward effect on discount rates) and the impact of existing energy efficiency policies, such as energy-labelling, energy performance certificates for buildings, or the promotion of energy service companies (ESCOs), which are reflected by lower discount rates compared to default values. As such, discount rates for investment decisions used in REF2016 are comprised between 9.5% and 12% depending on the consumer good subject that is purchased.

As said above, in a second stage the model analyses the resulting energy system costs. Here, the crucial element is the amount of money that energy consuming agents (households and firms, grouped into the sectors services and industry, transport and agriculture) are required to pay in order to get the energy services they need. Energy services are provided by using energy commodities purchased by end-consumers, which depend on energy efficiency at the consumption level. The PRIMES report aggregates

25 This is different from the perspective of a social planner who optimises the whole system from a societal perspective. In such a perspective social discount rates could play a role for determining normative inter-temporal choices.

26 For instance: Mundaca Luis, Lena Neiz, Ernst Worell and Michael McNeil (2010) "*Evaluating energy efficiency policies with energy*-economy *models*", Ernest Orlando Lawrence Berkeley National Laboratory

capital or investment expenditures (CAPEX) and purchasing costs for fuels and other energy commodities or operational expenditures (OPEX) of end-consumers to show a single total cost figure. OPEX for end-users already incorporates through pricing of energy commodities the CAPEX and OPEX costs incurred by the energy supply and trading sectors (calculated using the above mentioned WACC rates for those sectors). For making costs comparable, the CAPEX figures related to investments by final energy demand consumers also need to be annualised, and a flat discount rate of 10% is used for this purpose, a lower rate than in the past that is more in line with the WACC used for the supply sector. The cost accounting approach adopted in the EU Reference scenario maintains comparability of costs across different scenarios, which is key.

2.2. Summary of main results

Figure 2 below presents the projected evolution of EU Gross Inland Energy Consumption. After the 2005 peak, energy consumption is projected to steadily decline until 2040, where it stabilises. Oil still represents the largest share in the energy mix, mostly because of transport demand. Solid fuels see a significant reduction in their share of the energy mix, while the biggest increase is for renewable energy. Natural gas and nuclear energy keep relatively stable shares in the energy mix.

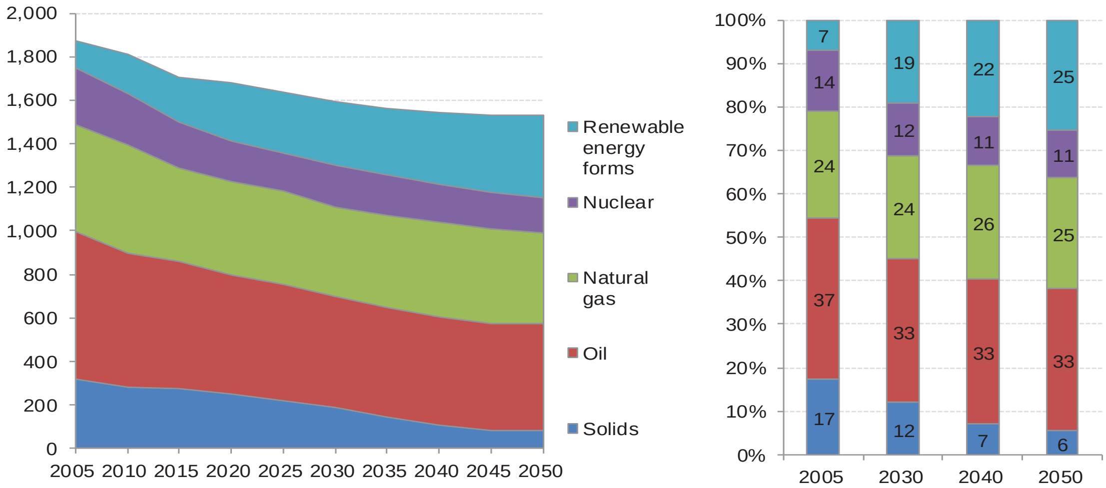

Figure 2: EU28 Gross Inland Consumption (Mtoe, left; shares (%), right)
Source: PRIMES

Energy security

EU energy production (Figure 3) is projected to continue to decrease from around 760 Mtoe in 2015 to around 660 Mtoe in 2050. The projected strong decline in EU domestic production for all fossil fuels (coal, oil and gas) coupled with a limited decline in nuclear energy production is partly compensated by an increase in domestic production of renewables. Biomass and biowaste will continue to dominate the fuel mix of EU domestic renewable production, although the share of solar and wind in the renewable mix will gradually increase from around 17% in 2015 to 36% in 2050.

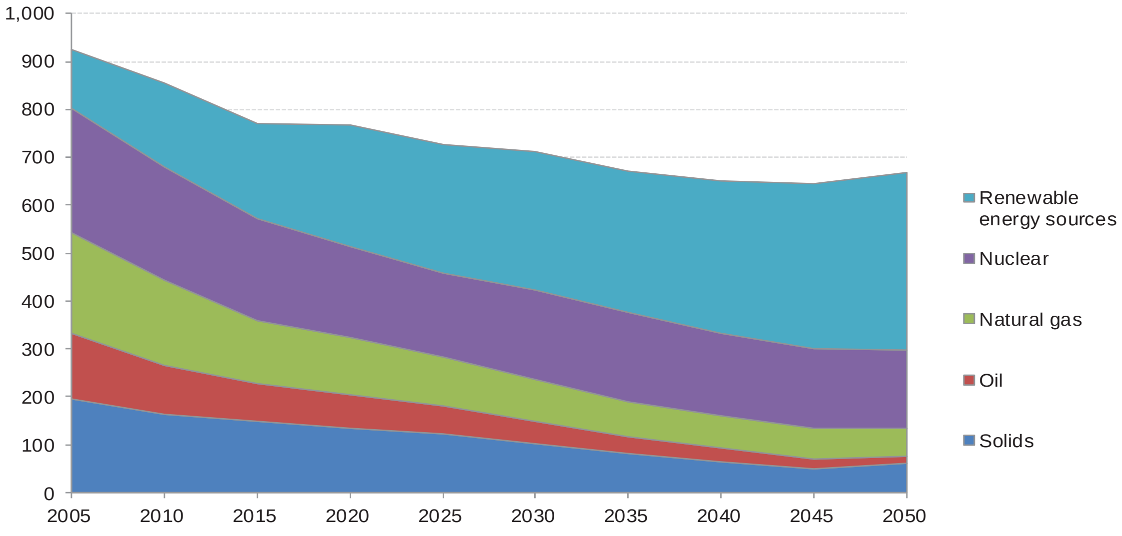

Figure 3: EU28 Energy Production (Mtoe)
Source: PRIMES

EU's import dependency shows a slowly increasing trend over the projected period, from 53% in 2010 to 58% in 2050. Again renewables deployment, energy efficiency improvements and nuclear production (which remains stable) counteracts the strong projected decrease in EU's fossil-fuel production.

Solid imports as well as crude oil and (refinery) feedstock decline throughout the projection period, while oil products imports slightly increase. Natural gas imports increase slightly in the long term reaching approximately 370 bcm[27] net imports in 2050. Biomass remains mostly supplied domestically, although the combination of increased bioenergy demand and limited potential for additional EU domestic supply leads to some increases in biomass imports post-2020 (from 11% of biomass demand in 2020 to about 15% in 2030 and beyond).

Up to 2020, the consumption of gas[28] is expected to remain stable (at around 430bcm in gross inland terms). Net import dependency of natural gas registers an increase as domestic gas production continues its downward trend. Post 2020, a slight decrease in gross inland consumption of gas (412 bcm in 2030) is projected, as well as further reductions in indigenous production of gas. Net import dependency of natural gas registers an increase as domestic gas production continues its downward trend. The imported volumes of gas are projected to increase between 2015 and 2040 and then to stabilise in the long term, 15% above the 2010 net import level (from 309 bcm in 2010 to 369 bcm in 2050).

[27] The conversion rate of 1 Mtoe = 1.11 bcm was used for natural gas, based on the BP conversion calculator.

[28] The imported volumes of gas are projected to increase between 2015 and 2040 and then to stabilise in the long term, 15% above the 2010 net import level (from 309 bcm to 369 bcm - Figure 3).

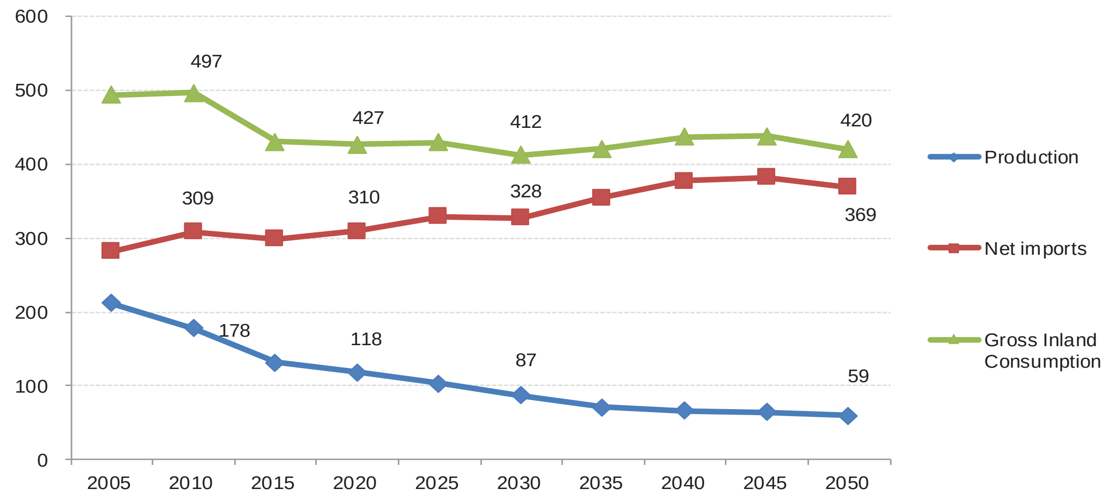

Figure 4: Gas - production, net imports and demand (volumes expressed in bcm)
Source: PRIMES

Internal energy market and investments

The EU power generation mix changes considerably over the projected period in favour of renewables (Figure 5). Before 2020, this occurs to the detriment of gas, as strong renewables policy to meet 2020 targets, very low coal prices compared to gas prices, and low CO_2 prices do not help to replace coal. After 2020, the change is characterised by further renewables deployment, but also a larger coal to gas shift, driven mainly in anticipation of increasing CO_2 prices.

Gas therefore maintains its presence in the power generation mix in 2030 (at slightly higher levels in the long term compared to 2015). The share of solids/coal in power generation significantly declines, but not before 2020, to 15% in 2030.

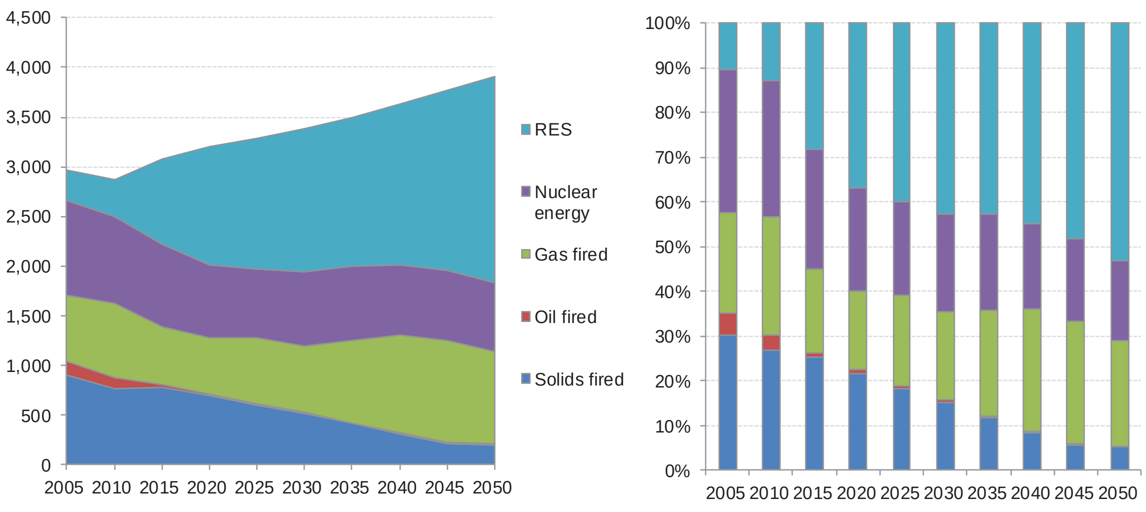

Figure 5: EU power generation (net) by fuel (Mtoe – left, shares – right)
Source: PRIMES

Variable renewables (solar and wind) reach around 19% of total net electricity generation in 2020, 25% in 2030 and 36% in 2050, demonstrating the growing need for flexibility in the power system. Wind onshore is expected to provide the largest contribution. Solar PV and biomass also increase over time. Hydro and geothermal remain roughly constant.

The share of nuclear decreases gradually over the projected period despite some life time extensions and new built, from 27% in 2015 to 22% in 2030.

REF2016 shows increasing volumes of electricity trade over time. The flow between regions increases from 17% in 2015 to 26% in 2020, 29% in 2030 and then stays almost stable for the remainder of the projection period reaching 30% in 2050. Main drivers are intermittent RES power generation and the resulting balancing requirements. Trade is facilitated by the assumed successful development of the ENTSO-E Ten-Year Network Development Plan 2014[29] as well as pan-European market coupling and sharing of reserves and flexibility across Member States.

Average retail electricity prices[30] (Figure 6) steadily increase up to 2030 by about 18% relative to 2010 levels, stabilising around 20% during 2030-2040, after which they start to gradually decrease. The structure of electricity costs changes over time, with the capital cost component (generation and grid costs) increasing significantly in the short term up to 2020, but decreasing afterwards in the longer term. From 2030, the fuel cost component remains stable despite the increase in fuel prices, due to a decreasing share of fossil-fuel combustion. Transmission and distribution costs increase significantly in the longer term, post-2030, partly linked to the need to cater for the increased presence of RES in the power generation mix.

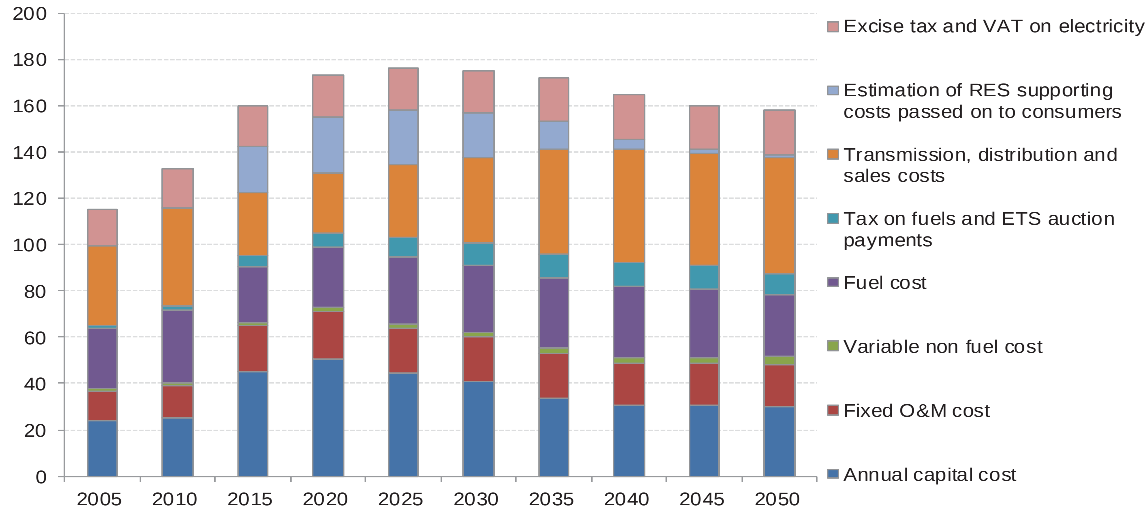

Figure 6: Decomposition of electricity generation costs and prices (€'2013 MWh)
Source: PRIMES

As a result of the modelling, the carbon price is projected to increase (Figure 7), reflecting both the steadily decreasing ETS cap and the stabilising effect of the Market Stability Reserve. However, the increase in electricity prices due to ETS remains limited despite the significant increase in CO_2 price, as the share of carbon-intensive power generation decreases.

29 Source: https://www.entsoe.eu/major-projects/ten-year-network-development-plan/ten%20year%20network%20development%20plan%202016/Pages/default.aspx

30 In the PRIMES model, prices differ per type of end-user.

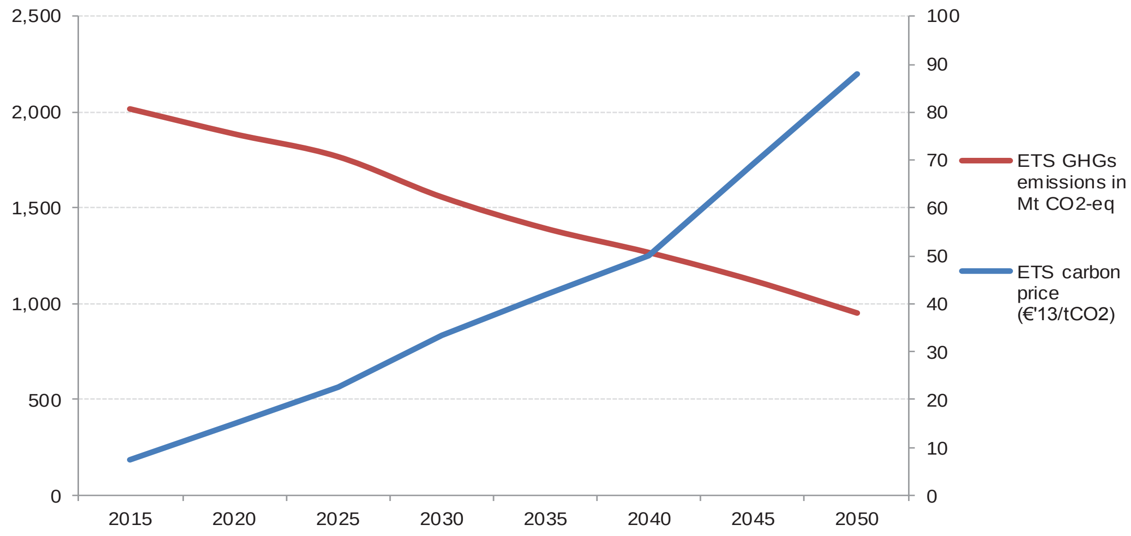

Figure 7: ETS emissions and carbon prices over time
Source: PRIMES, GAINS

Electricity prices for households and services are projected to increase moderately in the medium term and to decrease slightly in the long term. Prices for industry on the contrary are stable or decrease over time as energy intensive industry maintains an electricity demand profile compatible with base-load power generation and bears a small fraction of grid costs and taxes. Taxes apply mainly on prices for households and services.

Investment expenditures for power supply increase substantially until 2020 driven by renewables targets and developments, but slow down thereafter, until 2030, before increasing again from 2030 onwards notably due to increasing ETS carbon prices reflecting a continuously decreasing ETS cap based on the current linear factor. New power plant investment is dominated by renewables, notably solar PV and wind onshore. Nuclear investment mostly takes place via lifetime extensions until 2030 and in the longer term via new built, such as projected in, for instance, the UK, Finland, Sweden, France, Poland, and other Central European Member States. New thermal plant investment is mainly taking place in gas-fired plants.

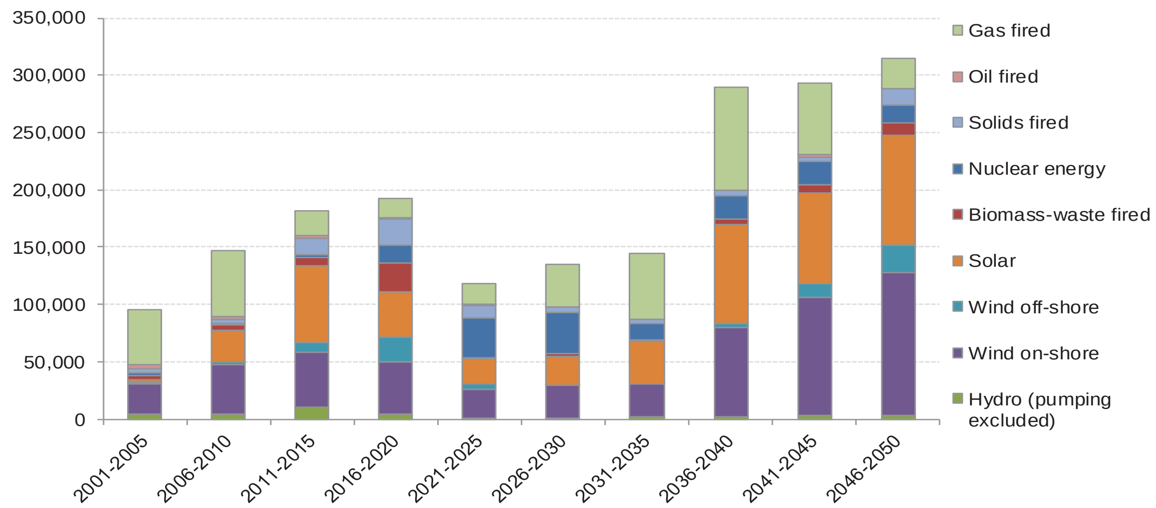

Figure 8: Net power capacity investments by plant type (MWh – for five year period)
Source: PRIMES

Investment expenditures in demand sectors (Figure 9 – left hand side) over the projected period will be higher than in the past. They notably peak in the short term up to 2020, particularly in the residential and tertiary sectors, as a result of energy efficiency polices. Post-2020 they slightly decline until 2030, before increasing again to 2050. On the supply side (Figure 9 – right hand side), investments peak towards 2020, followed by a decrease, notably explained by a decline in power generation investments.

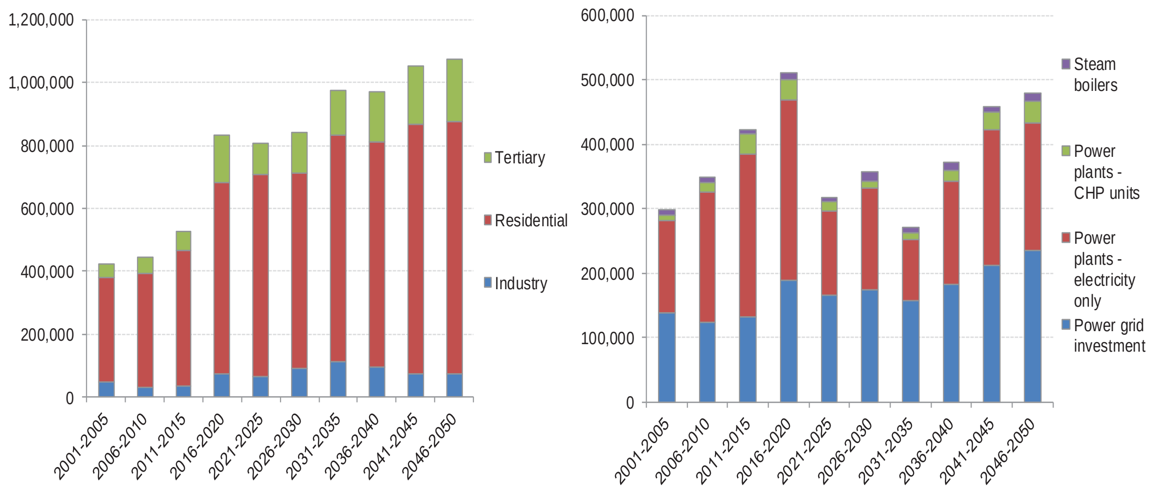

Figure 9: Investment expenditures (5-year period) - demand side, million €'2013 (left, excluding transport) and supply side, million €'2013 (right)
Source: PRIMES

Transport investments (expenditures related to the turnover of rolling stock) steadily increase over time but maintain a relatively stable share of GDP.

The relative weight of energy-related spending in households' expenditure[31] increases in 2020 compared to 2015 (7.5% compared to 6.8%), stabilising until 2030 before decreasing again until 2050 (6.1%).

Moderation of energy demand

In 2020, primary energy consumption decreases by 18.4% (relative to the 2007 baseline, *i.e.* how the energy efficiency target is defined), more than the sum of national Member States' indicative energy efficiency targets but still falling slightly short of the 2020 indicative EU energy efficiency target of 20%. In 2030, energy consumption is projected to decrease (again relative to 2007 baseline projections) by 23.9%. Primary energy demand and GDP continue to decouple (Figure 10), which is consistent with the trends observed since 2005. Energy efficiency improvements are mainly driven by policy up to 2020 and by market/technology trends after 2020.

[31] Share of energy system costs for the residential sector (fuel costs and annualised capital costs of energy related investment expenditures) in total households' consumption

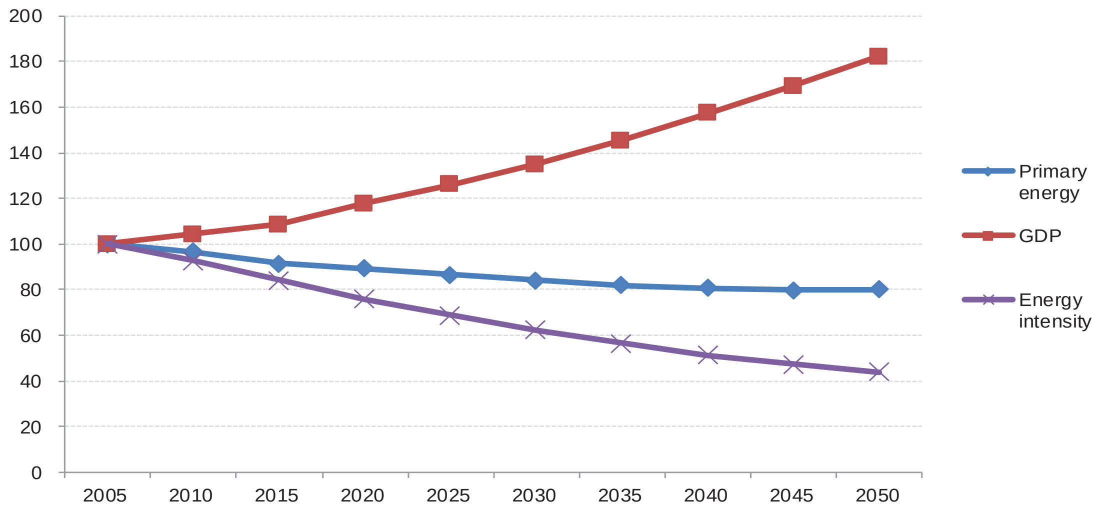

Figure 10: Decoupling of EU energy use and intensity from GDP (2005=100)
Source: Commission calculations based on PRIMES and GEM E3

The distribution of final energy consumption across sectors remains broadly similar to the current picture, all the way to 2050, with transport and the residential sector comprising the lion's share of final energy consumption (32% and 27% of final consumption, respectively, in 2030). Industry sees its share in final energy demand slightly decreasing, from 28% in 2005 to 23% in 2050, mostly due to improved energy efficiency in non-energy intensive industries. The tertiary (services and agriculture) sector keeps a stable share of about 17%.

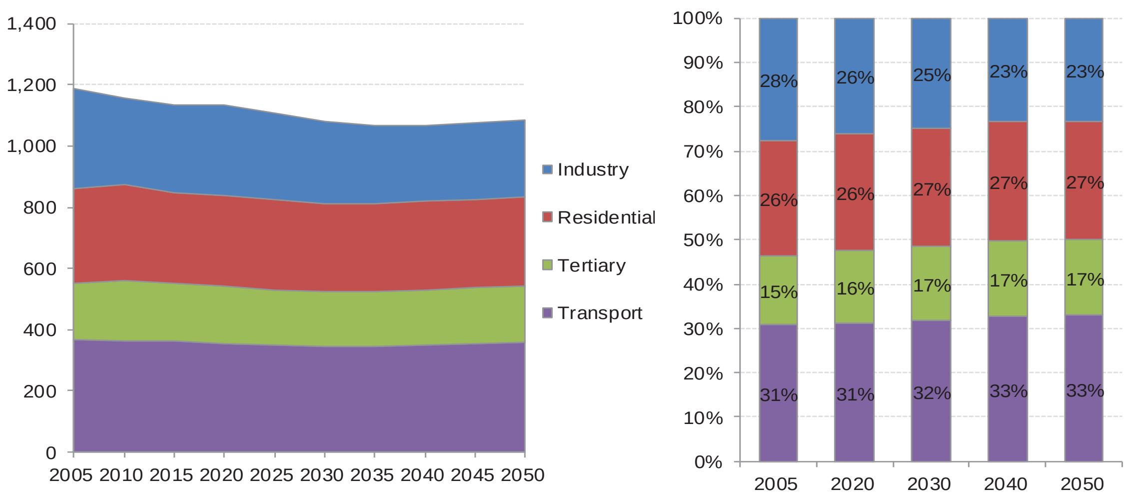

Figure 11: Evolution of final energy demand by sector (Mtoe – left, shares – right)
Source: PRIMES

With regard to the fuel mix in final energy, there is a gradual penetration of electricity (from 22% in total final energy use in 2010 to 28% in 2050). This is because of growing electricity demand as compared to other final energy use and to some electrification of heating (heat pumps) and to a limited extent in the transport sector.

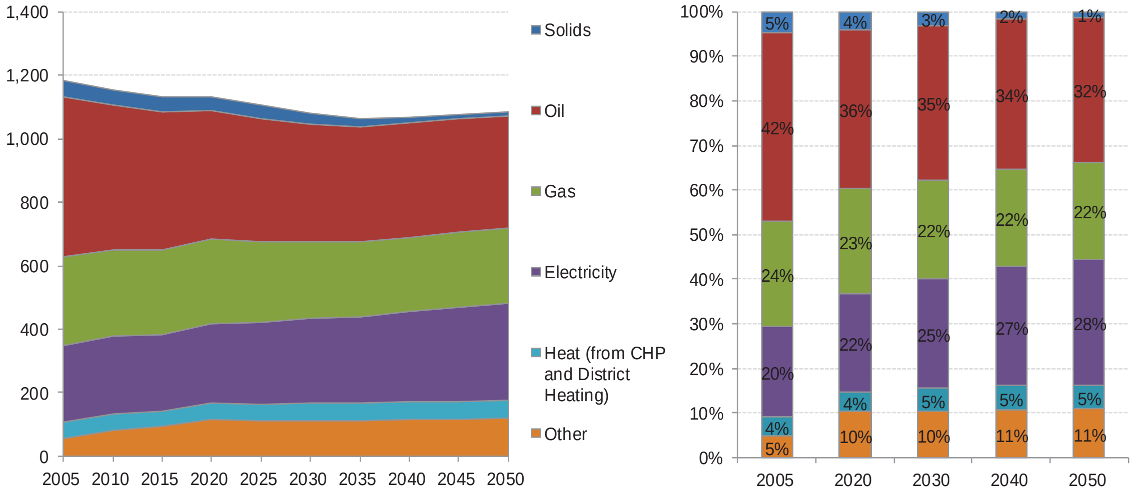

Figure 12: Evolution of final energy demand by fuel (Mtoe – left, shares – right)
Source: PRIMES

Energy intensity of the industrial sectors remains approximately constant in the medium term, as additional energy demand is due to the increase in production activity. In the long term however energy demand decreases, even though activity in terms of value added progresses. This is due to the energy efficiency embedded in the new capital vintages which replace old equipment and structural changes towards higher value added and less energy-intensive production processes, such as in iron and steel or non-ferrous metals.

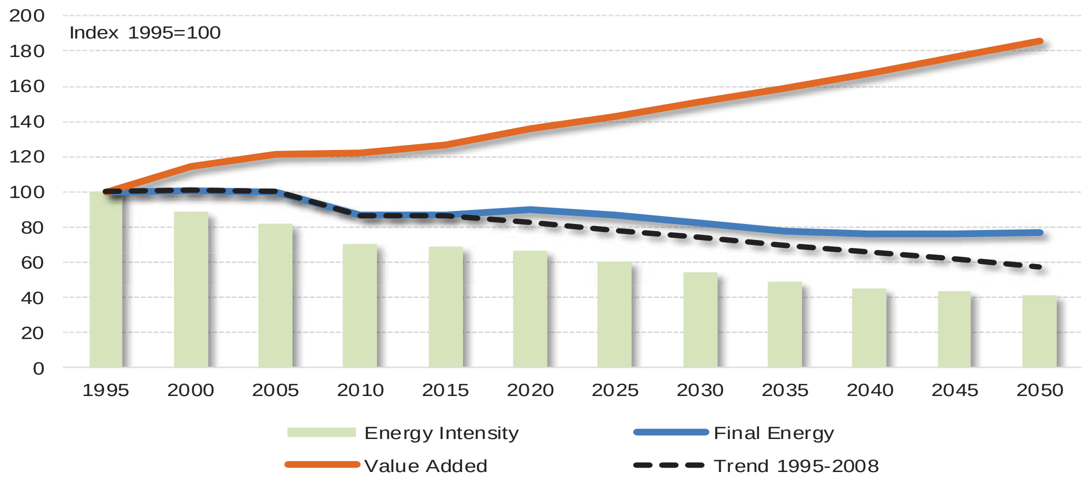

Figure 13: Industrial energy demand versus activity (value added)
Source: PRIMES

In the residential sector, energy demand remains below 2015 levels throughout the projection period. Energy demand decouples from income growth more than would be suggested by extrapolation of trends as the efficiency policies drive energy intensity improvements fast in the medium term; in the long term however the rate of improvements decreases due to the absence of additional policies.

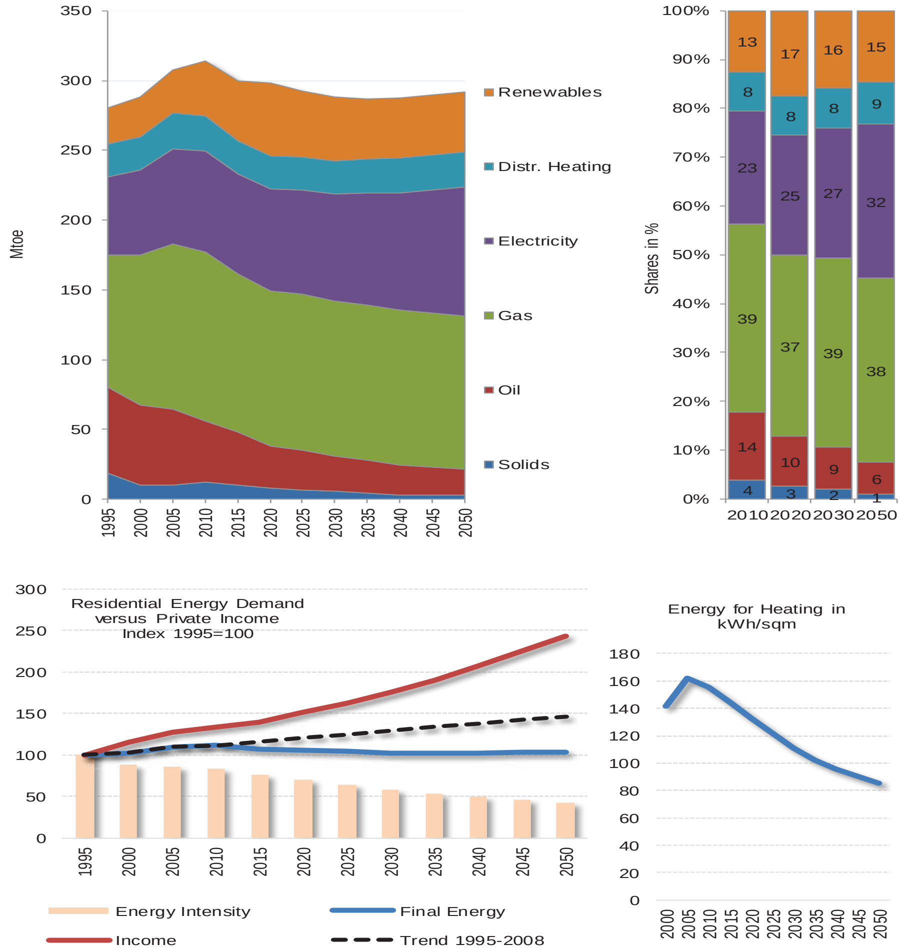

Figure 14: Final energy demand in the residential sector
Source: PRIMES

The activity of the transport sector shows a significant growth (Figure 15), with the highest increase in 2010 to 2030, driven by developments in economic activity. Historically, the growth of final energy demand in the transport sector has shown strong correlation with the evolution of transport activity. However, a decoupling between energy consumption and transport activity has been recorded in the past years. The decoupling between energy consumption and activity is projected to continue and even to intensify in the future.

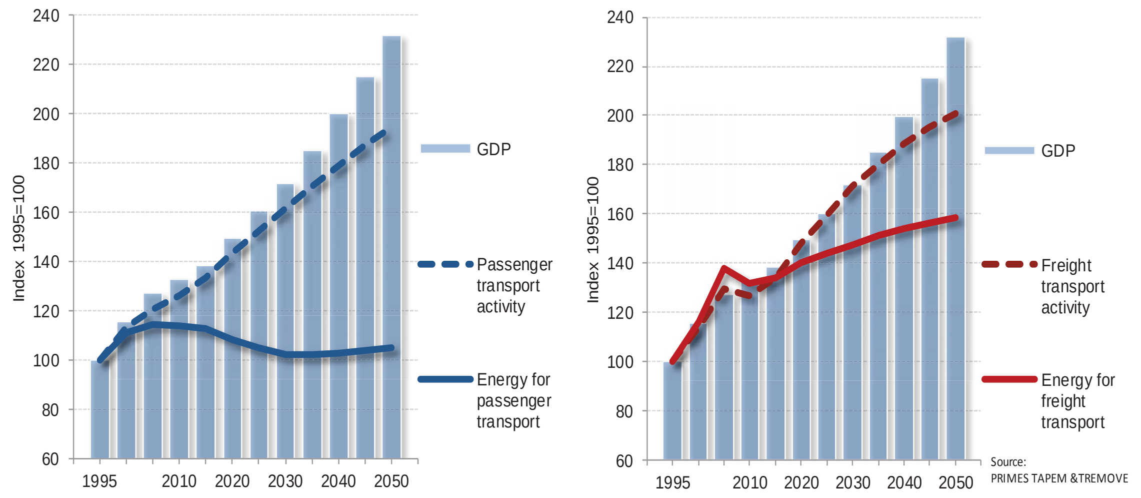

Figure 15: Trends in transport activity and energy consumption

Source: PRIMES and GEM-E3; For aviation, passenger transport activity includes domestic, international intra-EU and international extra-EU aviation

Electricity use in transport is expected to increase steadily as a result of further electrification of rail and the uptake of alternative powertrains in road transport. However, its share is projected to remain limited in REF2016, increasing from 1% currently to 2% in 2030 and 4% in 2050 (Figure 16). The uptake of hydrogen would be facilitated by the increased availability of refuelling infrastructure, but its use would remain low in lack of policies adopted beyond the end of 2014.

Liquefied natural gas becomes a candidate energy carrier for road freight and waterborne transport, especially in the medium to long term, driven by the implementation of the Directive on the deployment of alternative fuels infrastructure and the revised Trans-European Transport Network (TEN-T) guidelines which represent important drivers for the higher penetration of alternative fuels in the transport mix. However, the potential of gas demand developments in the transport sector do not fully materialise in REF2016, suggesting that additional policy incentives would be needed to trigger further fuel switching.

Diesel is projected to maintain its share in total final energy demand in transport by 2030, slowly decreasing its share only during 2030-2050. Consumption of gasoline declines considerably until 2030, continuing the declining trend from 1995 and stabilizes from thereon to 2050. Consumption of jet fuels in aviation increases steadily by 2050 due to the strong growth in transport activity and despite improvements in energy efficiency.

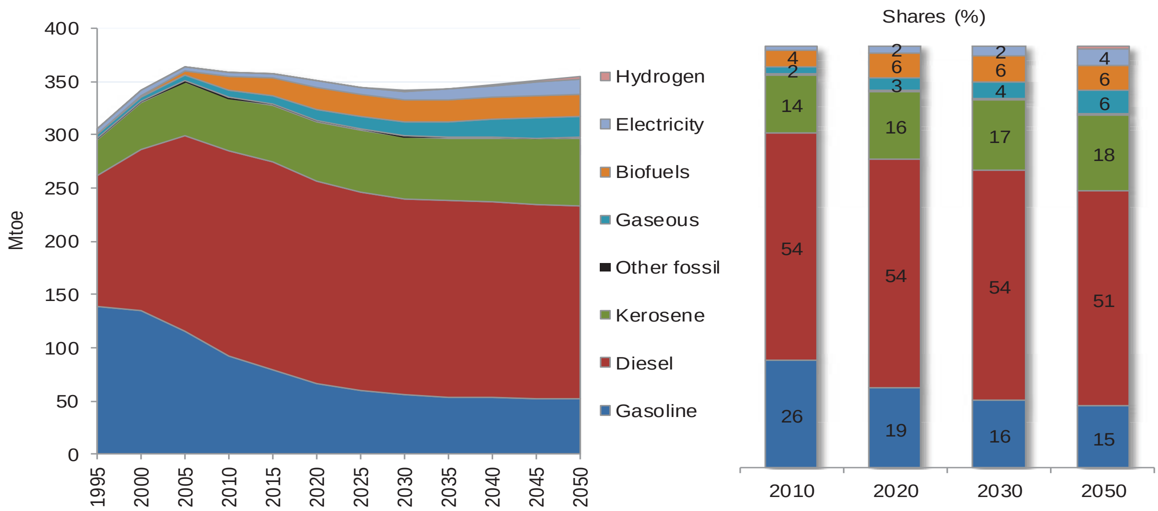

Figure 16: Final energy demand in transport by fuel type

Source: PRIMES-TREMOVE; Biofuels include biomethane used in transport

Oil products would still represent about 90% of the EU transport sector needs (including maritime bunker fuels) in 2030 and 86% in 2050, despite the renewables policies and the deployment of alternative fuels infrastructure which support some substitution effects towards liquid and gaseous biofuels, electricity, hydrogen and natural gas.

Decarbonisation:
CO_2 emission reduction

In REF2016, the binding energy and climate targets for 2020 will be met by assumption. However, current policy and market conditions will not deliver achievement of either the EU 2030 targets or the EU long-term 2050 decarbonisation goal.

Total CO_2 emissions are projected to be 22% below 1990 levels by 2020. In 2030, CO_2 emissions reduce (relative to 1990 levels) by 32%. Most of these emissions are energy related, and this part also determines the overall trends. Non-energy related CO_2 emissions mainly relate to industrial processes, and remain rather stable. Land-use related CO_2 emissions are discussed below in the LULUCF section.

Emission reductions in the ETS sectors are larger than those in sectors covered by the Effort Sharing Decision (ESD) as current legislation implies a continuation of the reduction of the ETS cap with 1.74% per year over the projected period leading to a carbon price driving long term emission reduction. In the ESD sectors there are no further drivers beyond market forces (*e.g.* rising fossil fuel prices) and the continued impact of adopted policies such as CO_2 standards for vehicles or energy performance standards for new building to further reduce energy and consequently emissions.

CO_2 emissions can be decomposed in the components GDP, Energy Intensity of GDP and Carbon Intensity of Energy. The Energy Intensity of GDP component declines due to structural changes in the economy and increasing energy efficiency in all sectors. The decrease of carbon intensity of energy supply becomes an increasingly significant component over the period. This is mainly due to Renewable Energy policies in the short term and the ETS in the medium to long term.

On a sectorial level, CO_2 emissions decrease in all sectors. Figure 17 shows a steep decrease in power generation, whereas emissions in the field of transport decrease at much slower pace between 2010 and 2050, and the transport sector becomes the largest source of CO_2 emissions after 2030. Non-energy and non-land use related CO_2 emissions (*e.g.* industrial processes) reduce only slowly throughout the projection period; however they only represent a small share of total CO_2 emissions.

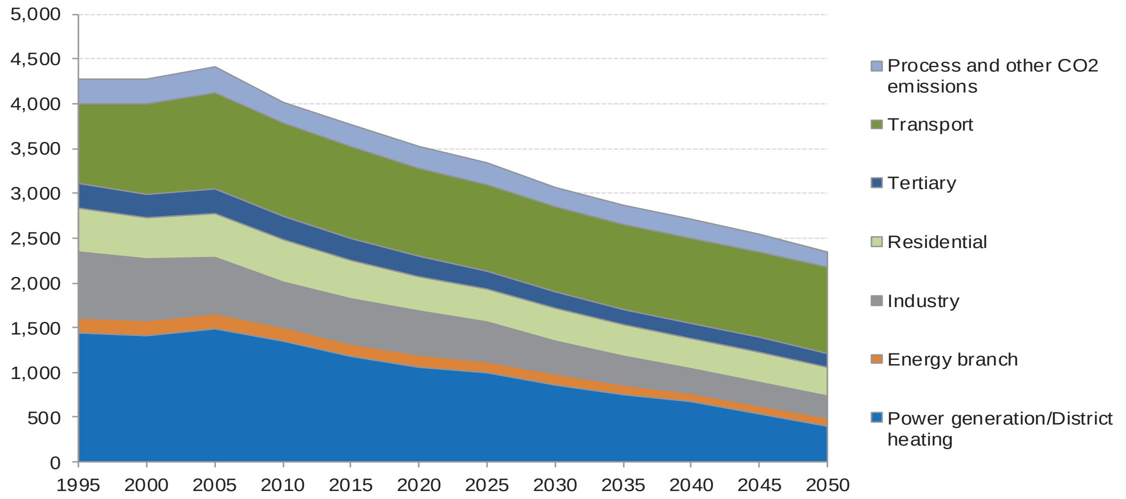

Figure 17: Evolution of CO_2 emissions (Mt) by sector
Source: PRIMES

Renewable Energy

In 2020, the renewables share in gross final energy consumption reaches 21% in 2020, while in 2030, it reaches 24%.

In the short term, the set of EU and national specific policies that promote renewables (notably implementation of supportive financial support such as feed-in-tariffs) drive significant penetration of renewables in power generation. By 2020, renewables in power generation are projected to increase to 35.5% (RES-E indicator[32]) or 37.2% of net electricity generation, of which 52% are projected to be variable renewables – wind and solar. This implies an acceleration compared to observed trends, in particular in those countries that currently facing difficulties to reach their targets. Beyond 2020 support schemes are phased out and further investments in renewables are more limited (reaching 43% in 2030), driven by market forces such as the ETS and the improvement in the techno-economic characteristics of the technologies.

[32] Calculated according to the definitions of the RES Directive used also for the pertinent provisions of Eurostat statistics

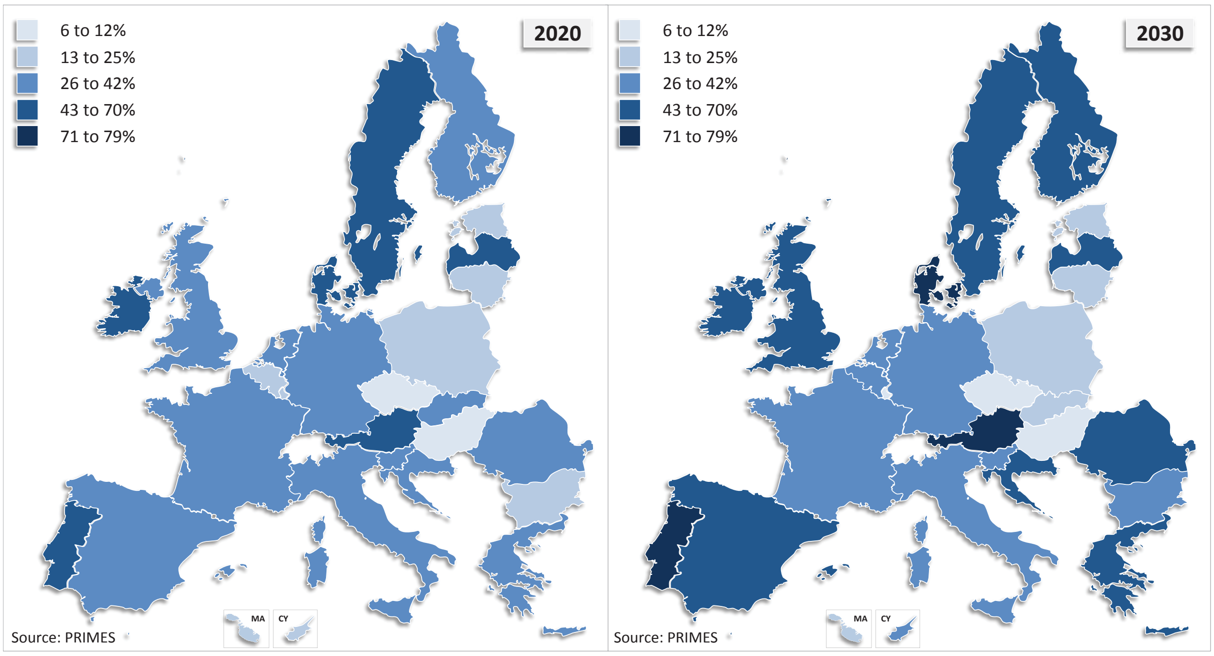

Figure 18: RES-E shares across EU Member States in 2020 and 2030

While renewables provide growing shares in electricity generation (up to 56% in 2050 of net power generation in overall EU28), the contribution of variable renewables (solar, wind as well as tidal/wave in the definition used here) remains significantly lower. These variable renewables reach 19% of total generation in 2020, 25% in 2030 and 36% in 2050. Wind off-shore capacities stagnate, as in the absence of support schemes this technology is not projected to be competitive.

Wind provides the largest contribution from renewables supplying 14.4% of total net electricity generation in 2020, rising to 18% in 2030 and 25% by 2050. A share of 24% of total wind generation is produced from wind off-shore capacities in 2020 (33GW installed capacity), but the share of offshore wind declines thereafter. Total wind capacities increase to 207 GW in 2020, 255 GW in 2030 and 367 GW in 2050, up from 86 GW in 2010. Wind onshore capacity and generation increases because of exploitation of new sites but also because of the progressive replacement of wind turbines with newer taller ones which are assumed to have higher installed capacity and higher load hours.

Generation from PV contributes 4.8% in net generation by 2020. Beyond 2020, PV generation continues to increase up to 7% in 2030 and 11% in 2050. PV capacity is projected to reach 137.5 GW in 2020, up from 30 GW in 2010. Investment is mostly driven by support schemes in the short term and the decreasing costs of solar panels and increasing competitiveness in the long term, in particular where the potential is highest, *i.e.* Southern Europe. PV capacities continue to increase due to the low costs and installed capacity reaches 183GW in 2030 and 299GW in 2050.

The use of biomass and waste combustion for power generation also increases over time, both in pure biomass plants (usually of relatively small size) and in co-firing applications in solid fuel plants. Biomass attains a share in fuel input in thermal power plants of 17.3% in 2020, 22% in 2030 and 31.5% in 2050[33]. Pure biomass/waste plant capacities

[33] Calculated following Eurostat definitions, *i.e.* excluding energy consumed by Industrial sectors and refineries for on-site CHP steam generation

(excluding co-firing) reach 51.6 GW in 2020, up from 21.7 GW in 2010, 53.2GW in 2030 and 57.3 GW in 2050. The share of biomass products in total inputs rises from 68% in 2015 to 79% in 2050, whereas waste products, including industrial waste, represent the remaining quantities.

The relative contribution of hydro generation remains rather constant at 10-11% of total net generation, with small hydro slightly increasing. Net installed capacity increases by 19GW in the time period from 2010 to 2050; 8.5GW are planned investments in hydro-reservoirs between 2010 and 2020. Beyond this period the majority of investments are in small run-of-river plants.

Looking at the decomposition of change of RES-E relative to 2010, it is also important to highlight the negative contribution of electricity demand savings. This means that electricity demand increases over the period, and therefore requires even more RES investments than constant demand would otherwise suggest.

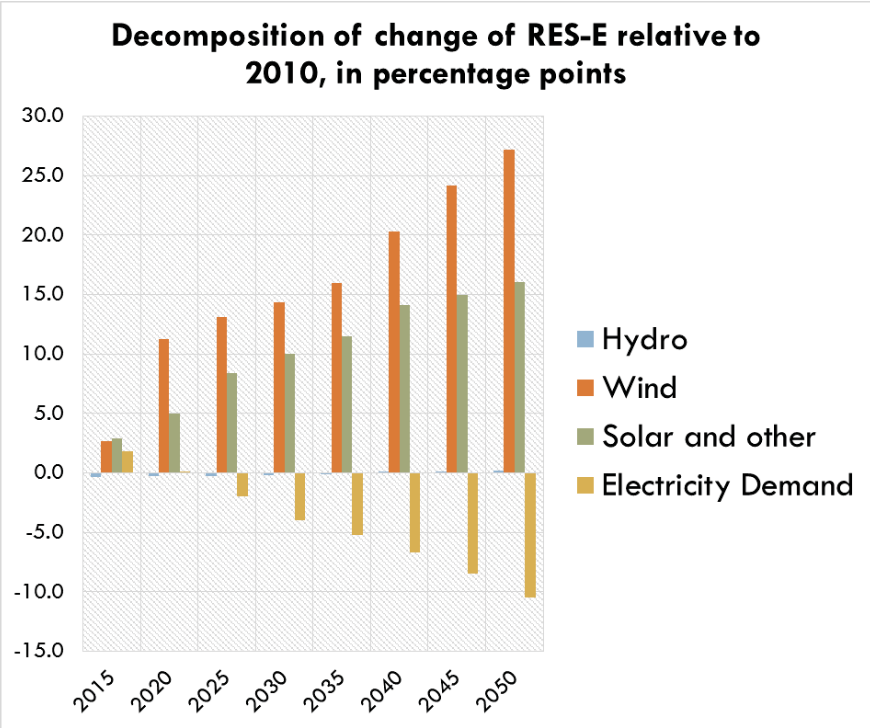

Figure 19: Decomposition of change of RES-E relative to 2010, in % terms
Source: PRIMES

The renewables share in heating and cooling increases from 17% in 2015 to 22% in 2020, reaching 25% in 2030. The use of renewables in final demand for heating and cooling is the main driver of RES-H&C increase in the short term, but its contribution first decreases and then stagnates in the long term. Final consumption of renewable energy in the industrial sector (excluding derived heat) is the second contributor to renewable energy in the heating and cooling sector. In the long-term, renewables in CHP and heat plants (*e.g.* district heating), as well some deployment of heat pumps, drive further increases of the RES-H&C share. In terms of district heating fuel input, the share of solids and oil decreases considerably, as well as the share of gas. Biomass and waste as well as other renewables and electricity in fuel input increase, representing almost 42% of fuel input in 2020 and 88% in 2050 (in comparison to 31% in 2010) – excluding heat from CHP. Energy efficiency, implying lower demand for heat in all sectors, is also an important driver in the medium and long term, as it tends to reduce demand for renewable heating and cooling, all else equal.

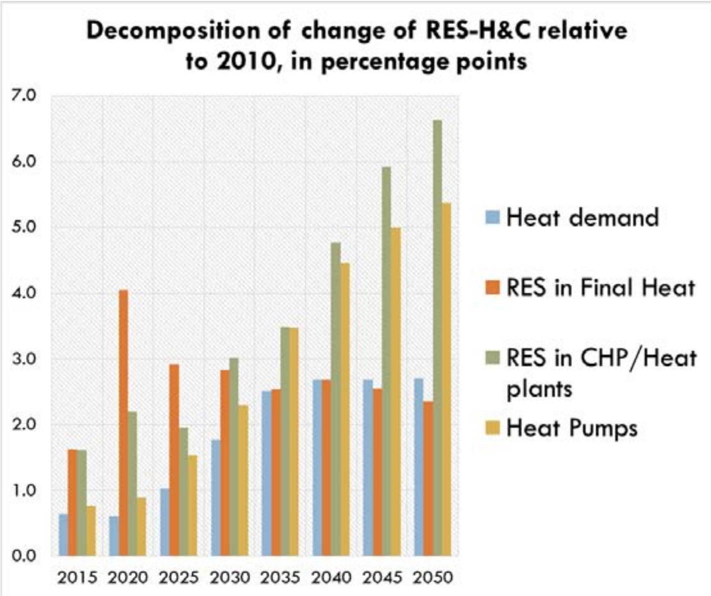

Figure 20: Decomposition of change of RES-H&C relative to 2010, in % terms
Source: PRIMES

The RES-T share reaches 11% in 2020. The development of bio-fuels is the main driver in the short term, but its contribution stagnates in the long term, as the share of biofuels in total fuels used in transport remains stable, around 6%. The biofuel penetration is mainly driven by the legally binding target of 10% renewable energy in the transport sector. Projections also take into consideration specific Member States' mandatory blending obligations and tax incentives, as well as the ILUC Directive. Renewables in electricity, combined with the relative increase of electricity use (albeit modest in share terms), is the main contributor to RES-T in the long term.

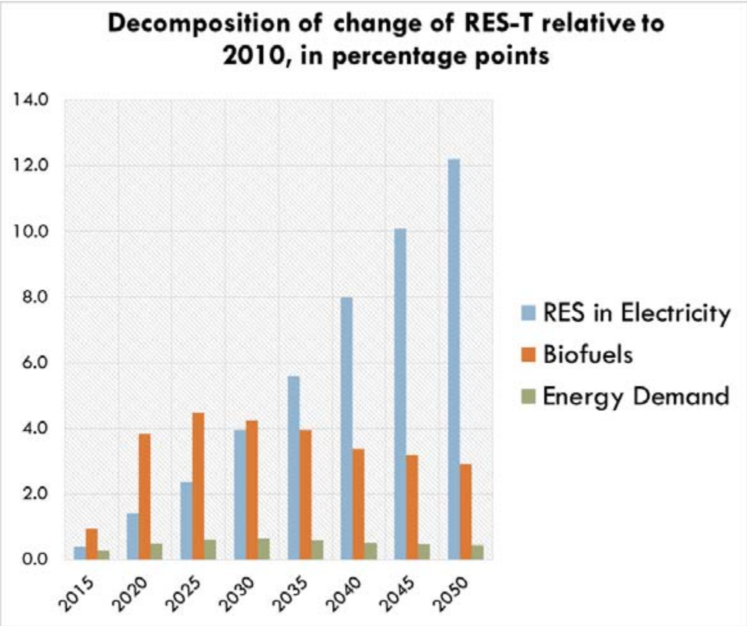

Figure 21: Decomposition of change of RES-T relative to 2010, in % terms
Source: PRIMES

Non-CO_2 emission reduction

Non-CO_2 emissions (CH4, N2O and F-Gases), account currently (2013) for 18% of total EU GHG emissions (excluding LULUCF). They have decreased significantly (32%) between 1990 and 2013. They are expected to further decrease by 29% below 2005 levels in 2030 (-46% compared to 1990 levels), and to stagnate later on. CH_4 emissions – which have the largest share in this aggregate - are projected to decrease above average (33% due to declining trends in fossil fuel production, improvements in gas distribution and waste management) and N_2O emissions fall below average (17%) until 2030, both remaining flat thereafter. F-Gases would reduce by half between 2005 and 2030, largely driven by EU and Member State's policies (*i.e.* the 2014 F-gas regulation and mobile air conditioning directive); F-gases would increase somewhat between 2030 and 2050 in line with economic developments. Except for a very minor fraction from some specific industries, non-CO_2 emissions fall under the ESD.

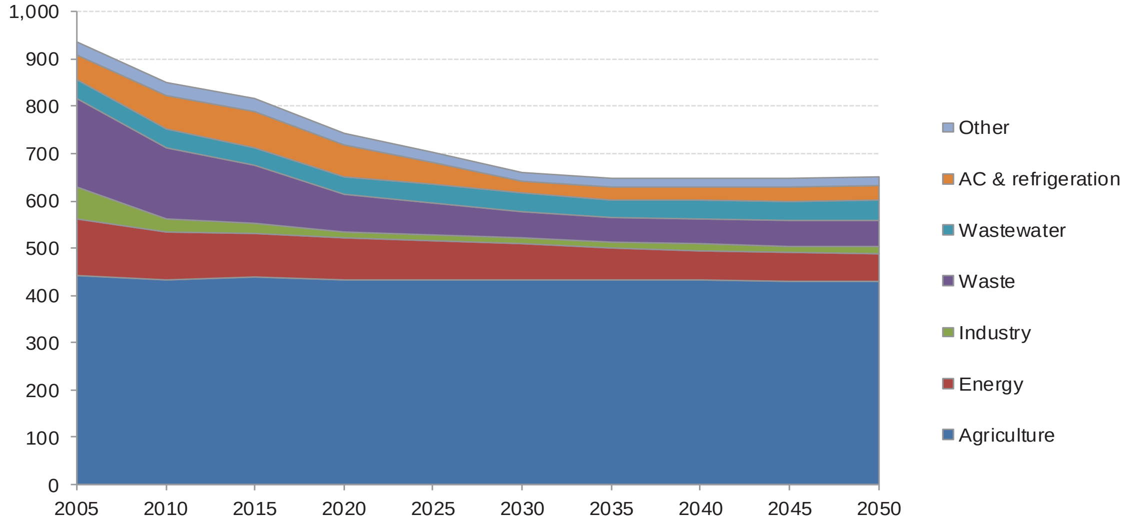

Figure 22: Non CO_2 GHG emissions
Source: GAINS

The non-CO_2 emission trends and their drivers vary by sector.

Agriculture is responsible for about half of all non-CO_2 emissions and is expected to increase its share in total non-CO_2 until 2030. While the agricultural non-CO_2 emissions have reduced by 22% between 1990 and 2013, they are projected to roughly stabilize at current levels as a result of different trends which compensate each other, such as decreasing herd sizes (both of dairy cows and of non-dairy cattle) but increasing milk yields. Slightly reduced use of mineral fertilizer through improved efficiency (2% less in 2030 than in 2005) leads to corresponding reductions in N_2O emissions from soils. Improved manure management (*e.g.* through anaerobic digestion) also delivers minor emission reductions. The Common Agricultural Policy influences, *inter alia*, livestock numbers/intensities and the Nitrogen Directive and the Water Framework Directive impact on the use of fertilizer.

Waste is currently the second most important sector emitting non-CO_2. There, a substantial reduction between 2005 and 2030 is expected (70%), strongly driven by environmental legislation, such as the Landfill directive and improvements in waste management as well as an update in inventory methodology of historic landfills that results in increased historic emissions and subsequent increased reductions of these emissions in the near to mid-term future. Also an increasing amount of CH_4 is recovered and utilised, thereby impacting on these trends towards lower emissions. After 2030, however, a moderate increase is projected, reflecting trends in economic development.

CH_4 and N_2O emissions from the **energy** sector (incl. transport) are expected to decrease by 36% from 2005 to 2030, and further 26% between 2030 and 2050. The main reductions come from less coal-mining and crude oil production in the EU, together with reduced emissions from power generation with fossil fuels. On the other hand, transport is expected to generate an increasing share of energy sector non-CO_2 emissions (N_2O from road transport being the most important contributor), growing from 12% in 2005 to 15% in 2030 and 20% in 2050 within the energy aggregate.

Emissions from **air conditioning and refrigeration** decrease by half from 2005 until 2030, also thanks to existing legislation (*i.e.* the new 2014 F-gas Regulation and the Mobile Air Conditioning systems Directive).

Most of the non-CO_2 emissions from **industry** – overall a minor non-CO_2 sector - are covered by the EU ETS (production of adipic and nitric acid, and of aluminium). The resulting incentive in combination with relatively cheap abatement options and (previous) national legislation cut emissions quite rapidly, to, in 2030, only a fifth of those in 2005. For the period after 2030 slight increases are projected in line with economic trends.

Emissions from the **wastewater** sector and remaining **other sectors** are projected to increase moderately in line with economic development over the whole period covered.

LULUCF emissions and removals

The EU28 Land Use Land Use Change and Forestry (LULUCF) sector is at present a net carbon sink which has been sequestering annually on average more than 300 Mt CO_2 over the past decade according to the UNFCCC inventory data[34]. In REF2016, the LULUCF sink is expected to decline in the future to -288 Mt CO_2 eq in 2030 from -299 Mt CO_2 eq. in 2005 and decreases further after 2030. This decline is the result of changes in different land use activities of which changes in the forest sector are the most important. These changes are driven partly by the increase in timber demand for all uses (including the increase in bioenergy demand that is expected in order to reach the RES targets in 2020). Figure 23 shows the projection of the total EU28 LULUCF sink in REF2016 and the contribution from different land use categories.

At present, the carbon sink in managed forest land (-373 Mt CO_2 eq. in 2010 without applying any accounting rules[35]) is the main component of the LULUCF sink. The managed forest land sink is driven by the balance of forest harvest and forest increment rates (accumulation of carbon in forest biomass as a result of tree growth). Forest harvest is projected to increase over time from 516 million m^3 in 2005 to 565 million m^3 in 2030 due to growing demand for wood for material uses and energy production. Along with the aging of EU forest – which reduces the capacity of forest to sequester carbon – the forest increments are projected to decrease from 751 million m^3 in 2005 to 725 million m^3 in 2030. As a consequence, the rate of accumulation of carbon (*i.e.* the sink) in

34 See: http://unfccc.int

35 The GHG accounting approach for LULUCF differs from other emission sectors. Notably, forest management is not accounted compared to historic emissions, but against a so called Forest Management Reference Level. This means that the accounted removals from the LULUCF sector are much smaller than the reported removals seen by the atmosphere.

managed forest land declines by 32% until 2030. This is partially compensated by a continuation of increasing trend in carbon sink from afforestation and decreasing trend of emissions from deforestation which decline from 63 Mt CO_2 in 2005 to 20 Mt CO_2 eq. in 2030. Carbon sequestration from afforested land increases steadily to 99 Mt CO_2 eq. by 2030, as new forests continue, albeit at slower rate, to be established. In addition, young forests that were established over the last 20 years get into a phase of high biomass production.

Activity in the agricultural sector (on cropland and grassland) has a smaller impact on the total LULUCF sink than the forest sector. Still, net carbon emissions from cropland are projected to decline by some 18% by 2030 compared to 2005 as soils converge towards soil carbon equilibrium over time. In addition, perennial crops (miscanthus, switchgrass and short rotation coppice) that typically sequester additional carbon in soil and biomass contribute to decreasing cropland emissions. By 2030, 0.9 Mha of perennial crops are expected to be cultivated. The grassland sink increases to around -19 Mt CO_2 eq. in 2030 as land continues to be converted to grassland *e.g.* through cropland abandonment while at the same time the total grassland area slightly declines over time due to afforestation and the expansion of settlements.

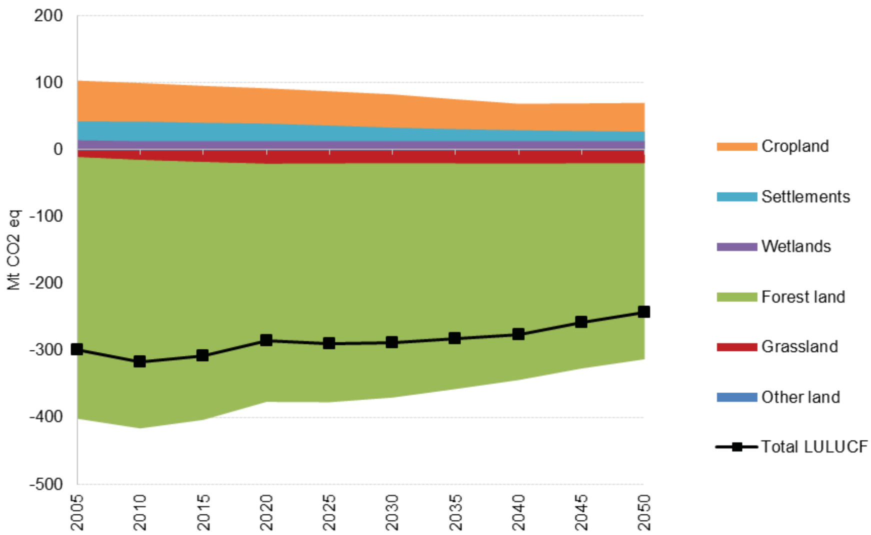

***Figure 23: Development of the EU28 emissions/removals in the LULUCF sector in Mt CO_2 until 2050*[36]**

Source: GLOBIOM-G4M

Research, innovation and competitiveness

Although REF2016 does not deal explicitly with research and innovation, it does tackle directly the penetration of new technologies. The approach is in two steps. First, assumptions are made on techno-economic characteristics and technological learning curves based on latest scientific evidence[37]. Figure 24 presents an illustration of the RES power technologies assumptions used in REF2016. Second, the model endogenously selects the most economically viable technologies at each point in time, leading to further technological cost reduction as technologies are deployed at increasingly larger scales.

[36] Emissions from deforestation and harvested wood products are included in "Forest land" in contrast to UNFCCC inventories

[37] See notably the European Commission's Joint Research Centre ETRI 2014 report, available at: https://setis.ec.europa.eu/publications/jrc-setis-reports/etri-2014

The development of solar photovoltaics (PVs) starts from lower costs than in the previous Reference Scenario and has a positive learning curve throughout the projection period. This translates into significant deployment of solar PVs in REF2016, especially in Southern Europe.

Although wind onshore costs are already competitive with many conventional technologies, the remaining potential for learning is estimated to be small, but costs can decrease due to the size of turbines and their height; very small scale wind is the only exception and still has high learning potential.

There remains large uncertainty about the costs for offshore wind and there have been cost increases due to previously unforeseen difficulties and logistics. Surveys have identified significant potential of cost decrease due to economies of scale and possibilities of improvement in logistics, but these cost decreases are likely to occur only towards 2030. As such, offshore wind developments in REF2016 are more conservative than in past exercises.

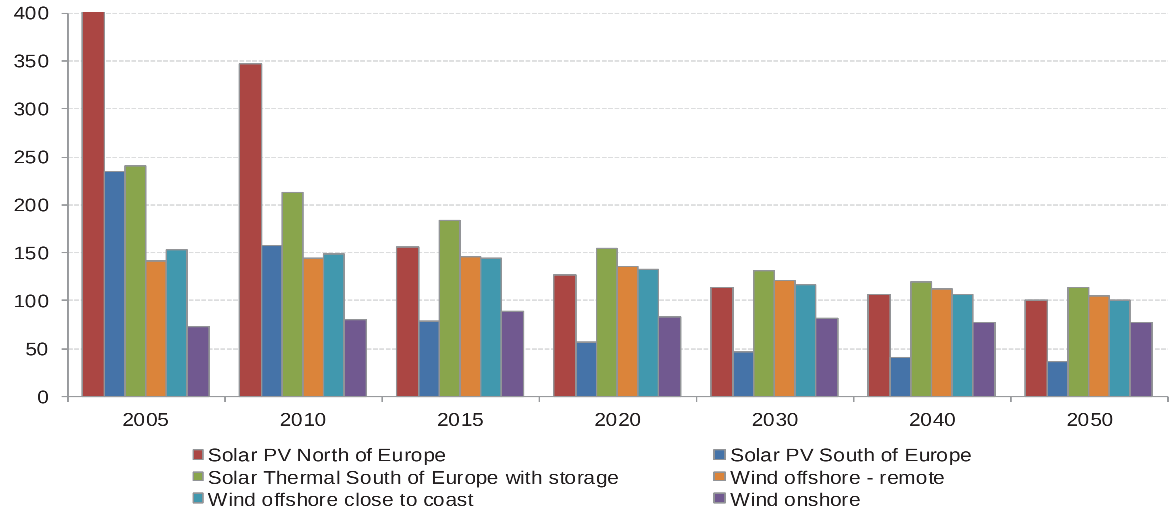

Figure 24: Illustrative levelized cost of electricity for selected RES technologies (expressed in €'2013/MWh-net)
Source: NTUA based on PRIMES

Compared to the previous Reference scenario, the costs of nuclear investment have increased and also the costs for nuclear refurbishments have been revised upwards. Although lifetime extensions of nuclear power plants remain economically viable in most cases, investments in new built plants are lower compared to previous projections.

The construction of power plants equipped with carbon capture and storage (CCS) technologies is developing at a very slow pace, and is dependent on public support (*e.g.* EEPR and NER300). Geological restrictions as well as current political restrictions on storage are also reflected. For these reasons, CCS costs are assumed higher than in previous Reference scenarios. Uptake of carbon capture and storage (CCS) in power and industry beyond supported demonstration plants remains very slow and occurs only towards the end of the projection period, driven by increasing ETS carbon prices.

On the demand side, demand for electric appliances continues to increase. However, there is an uncoupling between appliance stock and energy consumption due to the technological progress facilitated by eco-design regulations.

Car manufacturers are expected to comply with the CO_2 standards by marketing vehicles equipped with hybrid system, which are becoming more appealing to the consumers thanks to lower costs. Electrically chargeable vehicles emerge around 2020 and are kick-started by existing EU and national policies as well as by incentive schemes aiming to boost their penetration. The share of activity of total electric vehicles in the total activity of light duty vehicles reaches 15% in 2050 (Figure 25). Fuel cells would add an additional 2% by 2050. Other energy forms such as liquefied petroleum gas (LPG) and natural gas maintain a rather limited share.

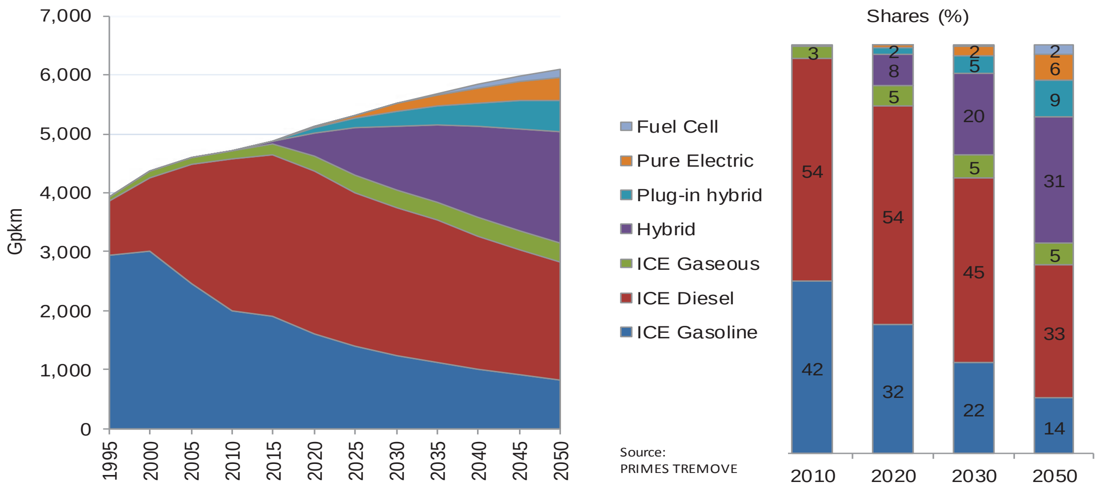

***Figure 25: Evolution of activity of light duty vehicles by type and fuel*[38]**
Source: PRIMES-TREMOVE

Energy system costs (Figure 26) increase up to 2020. Large investments are undertaken driven by current policies and measures (Figure 26). Overall, in 2020 energy system costs constitute 12.3% of the GDP, rising from 11.4% in 2010 and 11.2% in 2015, also driven by projected rising fossil fuel prices[39]. Despite further fossil fuel price increases, between 2020 and 2030 the share remains stable and decreases thereafter, as the system reaps benefits from the investments undertaken in the previous decade (notably via fuel savings). In this period, the share of energy system costs in GDP is gradually decreasing, reaching levels close to 2005 by 2050.

38 Light duty vehicles include passenger cars and light commercial vehicles.

39 Total system costs include total energy system costs, costs related to process-CO_2 abatement and non-CO_2 GHG abatement.

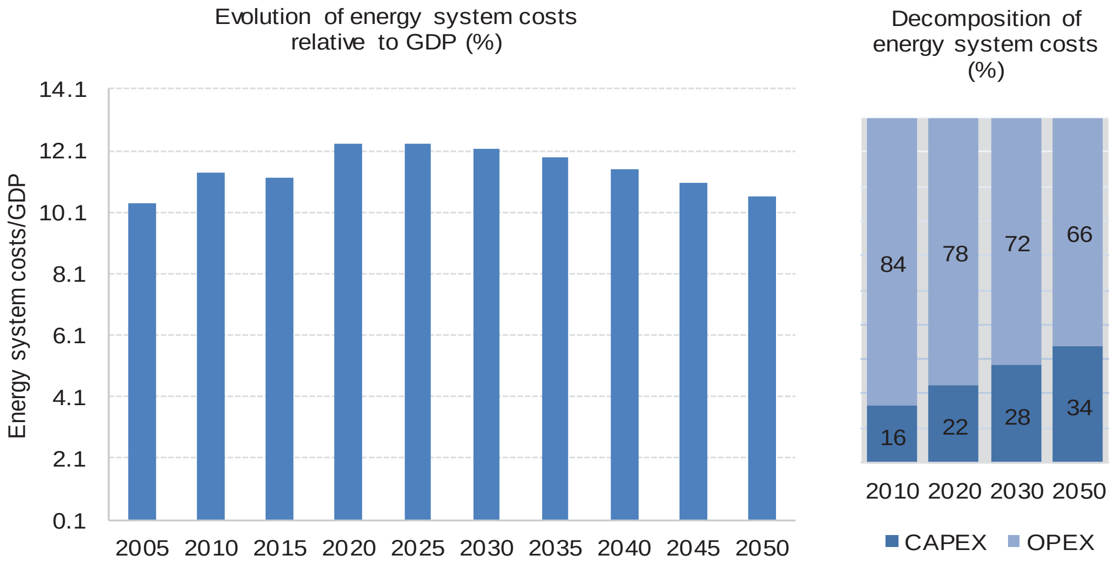

Figure 26: Projected evolution of energy system costs

Source: PRIMES, Energy system costs exclude ETS auction payments, given that they result in corresponding auction revenues.

3. Description of modelling set-up for the policy scenarios developed with PRIMES

Policy scenarios developed in this Impact Assessment rely first on a number of scenarios used in other impact assessments underpinning other 2016 Energy Union policy proposals, notably the Impact Assessments underpinning the Energy Efficiency Directive, the Effort Sharing Regulation, and the proposals on Electricity Market Design. All policy scenarios build on the EU Reference Scenario 2016[40].

In addition, coordination policies are assumed which enable long term decarbonisation of the economy. Coordination policies replace the "enabling conditions" which have been modelled in the 2030 framework Impact Assessment and the 2014 Impact Assessment on 2030 Energy Efficiency targets.

3.1. EUCO27

In October 2014, the European Council decided on the energy and climate 2030 framework.[41] The following was agreed among the Heads of States and Governments:

- Substantial progress has been made towards the attainment of the EU targets for greenhouse gas emission reduction, renewable energy and energy efficiency, which need to be fully met by 2020.
- Binding EU target is set of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990.

40 Full description of the EU Reference Scenario is available above

41 http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf.

- This overall target will be delivered collectively by the EU in the most cost-effective manner possible, with the reductions in the ETS and non-ETS sectors amounting to 43% and 30% by 2030 compared to 2005, respectively.
- A well-functioning, reformed Emissions Trading System (ETS) with an instrument to stabilise the market in line with the Commission proposal will be the main European instrument to achieve this target; the annual factor to reduce the cap on the maximum permitted emissions will be changed from 1.74% to 2.2% from 2021 onwards.
- An EU target of at least 27% is set for the share of renewable energy consumed in the EU in 2030. This target will be binding at EU level.
- An indicative target at the EU level of at least 27% is set for improving energy efficiency in 2030 compared to projections of future energy consumption based on the current criteria. It will be delivered in a cost-effective manner and it will fully respect the effectiveness of the ETS-system in contributing to the overall climate goals. This target will be reviewed by 2020, having in mind an EU level of 30%.
- A reliable and transparent governance system is to be established to help ensure that the EU meets its energy policy goals, with the necessary flexibility for Member States and fully respecting their freedom to determine their energy mix.

These requirements are reflected in the scenario called the European Council (EUCO) scenario with a 27% energy efficiency target for 2030 (EUCO27).

The table below summarises the assumptions on climate, renewable energy and specific energy efficiency policies in the EUCO27 scenario that have been modelled.

Table 1: Policy assumptions in EUCO27 scenario

EUCO27	**This scenario is designed to meet all 2030 targets set by the European Council:** • At least 27% share of renewables in gross final energy consumption • 27% primary energy consumption reduction (*i.e.* achieving 1369 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). • At least 40% GHG reduction (wrt. 1990) • 43% GHG emissions reduction in ETS sectors (wrt 2005) • 30% GHG emissions reduction in Effort Sharing Decision sectors (wrt 2005) **Main policies and incentives additional to Reference:** **Revised EU ETS** • Increase of ETS linear factor to 2.2% for 2021-30 • After 2030 cap trajectory to achieve 90% emission reduction in 2050 in line with Low Carbon Economy Roadmap. **Renewables policies** • Renewables policies necessary to achieve 27% target, reflected by renewables values applied in electricity, heating & cooling and transport sectors. **Residential and services sector** • Increasing energy efficiency of buildings via increasing the rate of renovation and depth of renovation. In this model, better

implementation of EPBD and EED, continuation of Art 7 of EED and dedicated national policies are depicted by the application of energy efficiency values (EEVs).

- Financial instruments and other financing measures on the European level lowering the cost of capital for investment in thermal renovation of buildings. This, together with further labelling policies for heating equipment, is depicted by a reduction of behavioural discount rates for households from 12% to 11.5%.
- More stringent (than in Reference[42]) eco-design standards banning the least efficient technologies.

Industry

- More stringent (than in REF2016) eco-design standards for motors.

Transport

- CO_2 standard for cars: 85g/km in 2025; 75g/km in 2030 and 25 gCO_2/km in 2050[43].
- CO_2 standards for vans: 135g/km in 2025; 120g/km in 2030; 60g/km in 2050[44].
- 1.5% average annual energy efficiency improvements for new conventional and hybrid heavy goods vehicles between 2010 and 2030 and 0.7% between 2030 and 2050.
- Measures on management of transport demand:
  - recently adopted/proposed measures for road freight, railways and inland navigation[45];
  - gradual internalisation of transport local externalities[46] as of 2025 and full internalisation by 2050 on the inter-urban network.

Non-CO_2 policies

- In 2030 carbon values of EUR0.05 applied to non-CO_2 GHG emissio order to trigger cost-effective emission reductions in these sectors inclu in agriculture.
- After 2030, carbon values set equal to EU ETS carbon price level).

3.2. EUCO30 scenario

The table below summarises the assumptions on a specific energy efficiency policy scenario reaching a 30% energy efficiency target. As this scenario built on EUCO27, only the differences that illustrate the increases level of ambition are listed. Assumptions are further explained below the table.

Table 2: Assumptions in EUCO30 scenario

42 REF2016 does not include the revisions of existing ecodesign measures that are required by their implementing regulations or any future measures under this directive which are currently under discussion.

43 On current test-cycle

44 On current test-cycle

45 Directive on Weights & Dimensions, Fourth railway package, NAIADES II package, Ports Package

46 Costs of infrastructure wear & tear, congestion, air pollution and noise

EUCO30	**As EUCO27 except:** • **30% primary energy consumption reduction target is set** (*i.e.* achieving 1321 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a reduction of primary energy consumption of 23% compared to historic 2005 primary energy consumption (1713 Mtoe in 2005). **Main policies and incentives additional to Reference:** **Energy efficiency policies:** **Residential and services sector** • Further increasing of energy efficiency values compared to EUCO27. • More stringent (compared to EUCO27) eco-design standards banning the least efficient technologies. • Policies facilitating uptake of heat pumps **Transport** • CO_2 standard for cars: 80g/km in 2025; 70g/km in 2030 and 25 gCO_2/km in 2050. • CO_2 standards for vans: 130g/km in 2025; 110g/km in 2030; 60g/km in 2050. • Additional measures on management of transport demand - Modulation of infrastructure charges for HDVs according to CO_2 emissions leading to faster fleet renewal. - Eco-driving. - Deployment of Collaborative Intelligent Transport Systems. **Non-CO_2 emissions reduction policies** • No policy incentive until 2030.

3.3. EUCO3030 scenario

This scenario builds on the EUCO30 scenario, but increases the share of renewable energy to 30%, via the use of renewables values mimicking further developments of unspecified policies across Member States and sectors. Other assumptions are kept the same as in EUCO30. The exception is the modelling of ETS and non-ETS: GHG emission reductions are allowed to go beyond the greenhouse gas reduction targets as agreed in the 2030 framework, both in the ETS (in practice the ETS carbon price trajectory was kept the same as in EUCO30) and the non-ETS sectors.

3.4. CRA scenarios and variants

CRA scenario

Building on the EUCO27 scenario, a specific renewable energy baseline policy scenario – reaching the same targets – was developed. Instead of focusing on a cost-effective development of renewable energy across the EU, it assumes the continuation of current support policies by Member State, and further differentiates investment costs assumptions in power generation across Member States and technologies. All other assumptions, notably as regards ETS and electricity market functioning, are kept unchanged. Regarding ETS in particular, the ETS price is an outcome of the modelling work.

The main characteristics of this scenario are described in the table below, with additional details on input assumptions provided afterwards.

Table 3: Assumptions in CRA scenario

CRA	**As EUCO27 except:** • Support schemes in 2020 reflect policy developments under preparation, mostly feed in premium schemes to be granted after auctions. This is different than in REF2016 or the EUCO scenarios, where only policies in place by end of 2014 were reflected, by construction of REF2016. • In contrast to Reference Scenario and EUCO scenarios, a continuation of Member States' support schemes policies for renewable energy in the power generation sector post-2020 is modelled; such policies phase out post-2030. • In contrast to REF2016 and EUCO Scenarios, additional differentiation in risk premium factors is applied to renewables technologies in the power sector (as add-ons) and these are differentiated by technology and by Member State (in REF2016 and EUCO Scenarios, no country-specific risk premiums are introduced). Regarding technologies, less mature technologies (with higher WACCs than onshore wind or solar PV for instance) include tidal, geothermal, offshore wind, biogas, biomass solid and bioliquids. Regarding Member States, differences in WACC reflect the outcome of the DiaCore project[47], but are recalibrated to be in line with the WACCs taken by PRIMES for other investment projects. • Renewables values for the power sector are put to 0 in 2025 and 2030 and replaced by detailed modelling of specific policies in power generation. • No Priority Dispatch as a general rule. Specific exemptions are applied for certain categories, *e.g.* (a) small scale renewables, (b) emerging technologies and (c) industrial CHP. • Grid connexion charges reflect current practices per Member State, which means notably deep costs (and not shallow) for offshore wind • Incentives, absence of them or even effective banning of certain resources from the market like self-generation and small scale generation reflecting current practices. This notably means no net metering allowed beyond what is considered in Reference scenario

CRA_regio

[47] See http://diacore.eu/

This variant builds on the main CRA scenario, but includes the following changes: instead of national support, support to renewables is being regionalised. Specifically, the EU is split into 5 main regions:

- Nordic/Baltic countries: this region includes the following countries: SE, FI, LV, LT, EE
- British Isles: this region includes the following countries: UK, IE
- Central Europe: this region includes the following countries: DK, NL, BE, LU, FR, DE, PL, HU, CZ, SK, SI, AT
- South East Europe: this region includes the following countries: IT, BG, RO, EL, CY, MT, HR
- Iberian Peninsula: this region includes the following countries: ES, PT

Concretely, this means that within each region, support levels are harmonised, per technology. In addition, the WACC assumed for investment decisions is also harmonised. Specifically, an average weighted WACC for the region is calculated, based on initial WACCs per Member State and taking account of the relative share in renewables investments in the CRA scenario for each country in the region. In addition, since a broad market at regional level implies broadening the funding, the procedures and the guarantees, a small reduction of the weighted average WACCs is being applied. The difference from the weighted average does not exceed 0.5pp.

It is also important to note that this variant aims at mirroring, to the extent possible, the overall renewables investment levels of the CRA scenario at EU level and within each region. This is necessary to ensure comparability of the results, and to test implications on deployment of renewables across countries and impacts on overall investment and system costs. As such, support levels necessary to reach the renewables deployment of the CRA scenario and ETS prices are an outcome of the modelling work.

CRA_crossborder

This variant is an intermediate case between the main CRA scenario, and the CRA_regio variant. Specifically, it has been constructed by assuming that it uses in 2030 85% of CRA assumptions (support levels and WACC) and 15% of CRA_regio. The percentages are 90% and 10% respectively in 2025.

CRA_countryspec

This variant builds on the CRA scenario, but assumes that for the Member States with the initially highest WACCs for renewables investment projects, a guarantee scheme is put in place, reducing the cost of debt of the project, and therefore the overall WACC. The assumption is that the WACC decreases by 15% for all technologies in the selected Member States. This scenario also tries to mirror overall renewables investment levels, to ensure comparability of the results, as mentioned above in the case of CRA_regio.

CRA_techspec

This variant focuses on the sector specific risks of renewables investments projects. That is, contrary to CRA_countryspec, the focus is not on specific Member States but rather on specific renewables technologies, namely, tidal, geothermal, offshore wind, biogas, biomass solid and bioliquids. These are the technologies with initially a risk premium in the CRA scenario as compared to more mature renewables technologies. As in

CRA_countryspec, a 15% decrease in the WACC is assumed for these projects, on the basis of the expected benefits of a guarantee of the debt finance of the project.

3.5. Modelling input parameters for the PRIMES scenarios and variants

RES values

Renewables policies necessary to achieve 27% target (in EUCO27 and in EUCO30) and 30% (in EUCO3030) are reflected by renewables values applied in electricity, heating and cooling and transport sectors. Renewables values are used in order to ensure cost-efficient renewables target achievement at European level.

The renewables value is a shadow price, a signal of potential costs per unit of renewable energy not achieved (relative to the target) which is internalized in the optimizing behaviours of actors and thus leads to higher renewables uptake. Renewables values do not describe in detail the renewables supporting policies, but are introduced if needed, in addition to the supporting policies, so as to complement them and reach the renewables target. The renewables value should not be confused with feed-in tariffs or green certificates, because it does not model any sort of power purchasing agreement with the renewables developers and the renewables projects compete on equal economic grounds with other forms of energy.

Renewables values needed to be slightly increased with more ambitious energy efficiency efforts in 2030 to achieve a share of renewables of at least 27%. They needed to be increased even more to reach a share of 30% renewables in the case of EUCO3030. However, as described above, the renewables values are significantly reduced in the CRA scenario, as they are replaced in the power generation sector by concrete policies, differentiated by Member State, and mimicking existing renewable support policies.

The decrease in renewables values for heating and cooling between Reference Scenario and policy scenarios is due to the impacts of additional energy efficiency in those scenarios.

Energy Efficiency values

The EEV, as described above in modelling terms, are used to simulate increasing energy efficiency obligations related to thermal integrity of houses and buildings, implying reduced consumption of fuels and electricity. Currently, such obligations are chiefly driven by the Art 7 of the EED but in addition some Member States have also put in place national policies aiming at renovation of the building stock (notably fiscal policies and financial incentives). As EEV increase step-wise by scenario and in time, they drive a faster pace of investments in renovations (as demonstrated by renovation rates) as well as increasing depth of renovations from an energy perspective (as demonstrated by the increased energy savings of the renovations). Other energy efficiency policies such as eco-design, labelling etc. act in addition to the EEV by influencing the choice of equipment technologies and their turnover over time.

All details on the use of energy efficiency values can be found in the Energy Efficiency Directive Impact Assessment. The table below shows, that significant energy efficiency values are needed to achieve higher energy efficiency levels. To achieve 23.9% of energy reductions in 2030, only EUR5 per toe are necessary. To achieve 27%, an EEV of EUR338 per toe is already needed. This values needs to be increased to EUR713 toe to achieve an energy efficiency level of 30% in 2030. No further changes were performed in the dedicated renewables scenarios, when compared to the EUCO scenario they build upon.

Table 4: Main policy variables

Main policy variables (2030)	**Ref2016**	**CRA**	**CRA_regio**	**CRA_crossborder**	**CRA_countryspec**	**CRA_techspec**	**EUCO27**	**EUCO30**	**EUCO3030**
Carbon price ETS sectors (EUR'13/ t of CO_2)	34	38	41	38	38	29	42	27	27
Carbon value non-ETS sectors (EUR'13/ t of CO_2)	0	0	0	0	0	0	0	0	0
Average Renewables value (EUR/ MWh)	11	4	4	4	4	4	7	16	58
Average Renewables value - Power generation (EUR/ MWh)	0	0	0	0	0	0	6	23	51
Average Renewables value - heating and cooling sector (EUR/MWh)	20	6	6	6	6	6	6	6	62
Average Renewables value - Biofuels support (EUR/MWh)	12	12	12	12	12	12	12	12	16
Energy efficiency value (EUR/ MWh)	5	338	338	338	338	338	338	713	713

Source: PRIMES

Modelling of Eco-design regulations

The Eco-design policy aims at reducing energy consumption of energy-related equipment and appliances by promoting product varieties which embed higher energy efficiency. Depending on implementing measures and voluntary agreements, the eco-design regulations certify specific energy consumption by product variety and eventually provides for mandatory requirements for certain products. The requirements impose a minimum bound on energy performance of products. The bounds are set for the next two to five years. This implies that the menu of technologies for consumer choices in the future is restricted to product varieties which have performances exceeding the minimum threshold value. The menu will still allow selecting technologies which perform above minimum threshold value; the choice will depend on relative costs, perception of technical risks and the policy context. The Eco-design regulations, combined with the labelling directive, are playing an important role to remove uncertainties regarding technical risks and those stemming from lack of information.

PRIMES considers equipment in an aggregated manner, looking at the equipment performance in heating and cooling, water heating, cooking, lighting and (white and black) appliances.

REF2016 is assumed to include the currently adopted eco-design regulations. The effects additional of Eco-design regulations are then simulated to intensify towards the 2030 horizon relative to REF2016 and across the energy efficiency scenarios. Moving from 2030 to 2050, the effects are simulated to intensify further relative to the 2020-2030 period and approach technical potential in the very ambitious cases. The learning effects are modelled to be relatively lower until 2030 than after 2030.

Modelling of transport policies

CO_2 standards for new cars and light commercial vehicles

The tightening of CO_2 standards post-2020 is a key assumption, leading to improvements in energy efficiency and CO_2 emissions reduction in transport. The CO_2 standards assumed in the policy scenarios are provided in Table 5 for cars and in Table 6 for light commercial vehicles.

Table 5: Assumptions on CO_2 standards (gCO_2/km) for new cars across scenarios[48]

Scenario	**CO_2 standards (gCO_2/km) for new cars**		
	2025	**2030**	**2050**
EUCO27	85	75	25
EUCO30	80	70	25

Source: PRIMES

Table 6: Assumptions on CO_2 standards (gCO_2/km) for new light commercial vehicles across scenarios[49]

Scenario	**CO_2 standards (gCO_2/km) for new light commercial vehicles**		
	2025	**2030**	**2050**
EUCO27	135	120	60
EUCO30	130	110	60

Source: PRIMES

Vehicle efficiency of new heavy duty vehicles

The following improvements in specific fuel consumption of new heavy duty vehicles were assumed:

- 1.5% per year on average in all scenarios. EUCO27, EUCO30

48 On current test-cycle
49 On current test-cycle

Recently adopted/proposed measures

Measures adopted after the cut-off date of Reference scenario 2016 (*i.e.* Directive on Weights & Dimensions[50]) and measures already adopted by the Commission and in discussion by co-legislators (*i.e.* Fourth railway package[51], NAIADES II package[52], and the Ports Package[53]) are assumed to apply in all scenarios. The input for modelling draw on the respective Impact Assessments.

Fair and efficient pricing for sustainable transport

Gradual internalisation of the costs of infrastructure wear & tear, congestion, air pollution and noise in the pricing of road transport on the inter-urban network is assumed from 2025 onwards. For rail, internalisation of the costs of air pollution, noise and congestion is assumed from 2030 onwards; for inland waterways internalisation of the costs of air pollution is assumed from 2030 onwards. In scenarios EUCO27 and EUCO30, the levels of the charges are gradually increased from 2025/2030 to 2050, when they become equal to the values of the 2014 Handbook on external costs of transport[54]

Modulation of the infrastructure charges according to CO_2 emissions for heavy goods vehicles (HGVs) is assumed to apply in all scenarios except for EUCO27; it is assumed to apply on the inter-urban network from 2025 onwards. Starting from the average infrastructure charge in each Member State, a linear incremental variation is assumed for HGVs with higher emissions than average; a similar linear variation is assumed for HGVs with lower emissions than average (by HGVs category). The measure is assumed to apply similarly to the Euro class-differentiation of network-wide tolls and implies revenue neutrality.

Collaborative Intelligent Transport Systems (C-ITS)

Deployment of C-ITS in road transport has been assumed in all scenarios except for EUCO27.

1. In scenarios EUCO30, the input assumption for modelling draws on the central scenario of a Cost Benefit Analysis (CBA) study carried out by Ricardo AEA[55]

Eco-driving

Promotion of eco-driving is assumed in all scenarios except for EUCO27; the input assumption used for modelling draw on "EU Transport GHG: Routes to 2050?" project.[56] It is assumed that virtually all drivers would be trained by 2050 (for road and rail). Savings from training decline to 2050 due to technology effects. No variation in the level of intensity of the measure is assumed between scenarios.

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50 SWD(2013)109 final

51 SWD(2013) 10 final

52 SWD(2013) 324 final

53 SWD(2013) 181

54 Source: http://ec.europa.eu/transport/themes/sustainable/internalisation_en.htm

55 Source: http://ec.europa.eu/transport/themes/its/c-its_en.htm

56 "EU Transport GHG: Routes to 2050?" final report is available at: http://www.eutransportghg2050.eu/cms/assets/EU-Transport-GHG-2050-Final-Report-22-06-10.pdf

Coordination policies

In this modelling exercise, all scenarios (except Reference) achieve decarbonisation in 2050 and hence assume an overall policy framework which enables this. Given that concrete policies will most likely have to be proposed in order to fulfil the necessary conditions in infrastructure, technology, market coordination, the elements of this framework which go beyond the drivers and policies specified in the policy scenarios are called coordination policies. Coordination policies replace the "enabling conditions" which have been modelled in the 2030 framework IA (in decarbonisation scenarios) and the 2014 IA on energy efficiency target.

In the past modelling exercises, enabling conditions were present in all decarbonisation scenarios. Enabling conditions meant that because of good anticipation of future GHG emission reduction commitments, all conditions were met in infrastructure, technology learning, public acceptance and market coordination so as to enable the decarbonisation. In other words, enabling conditions enabled to maximize the effectiveness of policy instrument which aim at driving strong GHG emission cuts. These enabling conditions were fully costed in decarbonisation scenarios.

These assumptions have been revisited considering that concrete policies will most likely have to be proposed in order to fulfil the necessary conditions in infrastructure, technology, market coordination, etc. Consequently, enabling conditions are replaced by coordination policies as indicated in the list included in Table 7. These coordination policies will be proposed by the Commission post 2020. Coordination policies are fully costed in the scenarios, as it was the case with enabling conditions. It is important to make a distinction between 2 types:

- coordination policies related to ongoing infrastructure developments that will enable a larger exploitation of cost-effective EE, RES, GHG abatement options after 2020.
- coordination policies related to R&D and public acceptance that are expected to be needed to meet long term decarbonisation objectives, and have effects post 2030

Table 7: Summary of coordination policies assumed

Enabling conditions in the 2030 Impact Assessment	New approach
Intelligent grids and metering (also for EVs)	Coordination policy post 2020 (Partly accomplished in REF2016 2016 - implementation of the 3rd Internal Energy Market package).
Infrastructure to harvest decentralised as well as remote RES for power generation	Coordination policy post 2020
Carbon transportation and storage infrastructure and acceptance	coordination policy post-2030 (CCS is indispensable for decarbonisation towards 2050)
Gas and hydrogen: (technological progress enabling mix of hydrogen and bio-gas in gas supply and possibility to use hydrogen-	coordination policy post-2030 (advanced storage is necessary and in that time perspective)

Enabling conditions in the 2030 Impact Assessment	New approach
based storage for balancing RES power)	
Battery technology development (for electric and plug-in hybrid vehicles) and fuel cells	Reference scenario 2016 has assumptions on battery technology development and fuel cells which are rather conservative, consistent with the logic of a Reference scenario, *i.e.* without additional policies stimulating R&D, infrastructure or purchase. For the decarbonisation scenarios, increased R&D, expectations and learning effects lead to lower technology costs for electrification technology (for electric and plug-in hybrid vehicles) and fuel cells.
Recharging infrastructure	Coordination policy post 2020 (based on the Directive on the deployment of alternative fuels infrastructure)
Market acceptance (of electrification)	Coordination policies post 2020 (supported by the implementing measures following the Directive on the deployment of alternative fuels infrastructure)
Innovation in biofuels	Coordination policy with impacts post 2030 These are biomass related innovation and agriculture policies assumed to develop so as to allow the development of new generation bio-energy feedstock (basically lingo-cellulosic crops) at large scale. As a result, a new industry would emerge ranging from agriculture, industrial-scale collection and pre-treatment, bio-refineries with new conversion technologies, product standardization and commercialisation.
Overcoming some market barriers to Energy Efficiency in Buildings	Part of 2020-2030 policy mix as described in assumptions on policy options.
Heating equipment and appliances technology uptake in the domestic sector	As above
Energy efficiency innovation diffusion in Industry	As above

4. Set-up of modelling scenarios in the various impact assessments underpinning the 2016 energy union policy proposals

This section aims at describing how modelling scenarios were designed, how they can be used to describe a baseline or policy scenario and which questions they try to address in the Impact Assessments (IA) underpinning the various 2016 Energy Union proposals.

Role and use of the EU Reference Scenario 2016

A common starting point to all Impact Assessments is the EU Reference Scenario 2016 ('REF2016'). It projects greenhouse gas emissions, transport and energy trends up to 2050 on the basis of existing adopted policies at national and EU level and the most recent market trends. This scenario was prepared by the European Commission services in consultation with Member States. All other PRIMES scenarios build on results and modelling approach of the REF2016.

Although REF2016 presents a comprehensive overview of the expected developments of the EU energy system on the basis of the current EU and national policies, and could be considered as the natural baseline for all IA, it fails doing so for an important reason. This scenario does not have in place the policies to achieve the 2030 climate and energy targets that are already agreed by Member States in the European Council Conclusions of October 2014. It also does not reflect the European Parliament's position on these targets.

Therefore, although it was important for all initiatives to have a common "context" in order to ensure coherent assessments, each Impact Assessment required the preparation of a specific baseline scenario, which would help assess specific policy options relevant for the given Impact Assessment.

A central policy scenario: EUCO27

Because of the need to take into account the minimum agreed 2030 climate and energy targets (and the 2050 EU's decarbonisation objectives) when assessing policy options for delivery of these targets, a central policy scenario was modelled. This central policy scenario, (called "EUCO27"), reaches by construction the 2030 targets (40% greenhouse gas emissions reductions compared to 1990, a split of 43% and 30% in emissions reduction between the ETS and ESD sectors, compared to 2005, a share of renewables of 27% and an energy efficiency target of 27%).

Concrete specifications on assumptions were made by the Commission in order to reach the relevant targets by using a mix of concrete and yet unspecified policies. A detailed description of the construction of this scenario is presented in Chapter 4 of the EED IA and in its Annex IV.

This scenario is the central scenario for all Impact Assessments. Additional baseline and/or policy scenarios were prepared for each Impact Assessment, addressing the specific issues to be assessed by each initiative, notably which measures or arrangements have to be put in place to reach the 2030 targets, how to overcome market imperfections and uncoordinated action of Member States, etc.

This approach of separating a central policy scenario reaching the 2030 targets in a cost-effective manner and specific scenarios that look into specific issues related to implementation of cost effective policies enables to focus on "one issue at a time" in the respective separate analysis. It enabled to assess in a manageable manner the impacts of several policy options and provide elements of answers to problems specified in the respective 2016 Impact Assessments, without the need to consider the numerous possible combinations of all the options proposed under each respective initiative.

The Impact Assessment accompanying the proposal on an Effort Sharing Regulation (ESR)

The EUCO27 and EUCO30 scenarios were used in the Impact Assessment underpinning the Effort Sharing Regulation Proposal of July 20 2016 to assess the implications for specific Member States of setting national targets to reduce greenhouse gas emissions in the ESR sectors, following the guidance provided by EU leaders to use a methodology that reflects fairness, solidarity and cost-effectiveness.

In this Impact Assessment, the projections in the non ETS sectors of the EUCO27 and EUCO30 scenarios, representing the cost effective implementation of the agreed 2030 climate and energy targets, are compared with 2030 targets defined purely on the basis of GDP per capita criterion only, as well as other important elements such as starting point of the target trajectory and additional flexibilities, to assess any concerns related to cost efficiency, fairness and environmental integrity.

The Impact Assessment accompanying the proposal for the revision of the Energy Efficiency Directive

Regarding the Impact Assessment accompanying the proposal for a revised Energy Efficiency Directive, one central question to be addressed concerned the level of the energy efficiency target for 2030. This reflects the European Council conclusions from October 2014 which leave the issue of 2030 energy efficiency target still open.

In this context, the baseline is a situation where the EU would achieve the minimum commonly agreed target among the three EU Institutions, that is, 27% energy efficiency, or the EUCO27 policy scenario. Additional policy scenarios were then developed leading to higher energy efficiency levels, notably the EUCO30 scenario as well as scenarios achieving energy efficiency savings going up to 40% (30, 33, 35 and 40% respectively). The additional policy scenarios were then compared to EUCO27 baseline in order to identify the impacts of increasing energy efficiency level only.

The Impact Assessment accompanying the proposal for the revision of the Renewable Energy Directive

Regarding the Impact Assessment accompanying the proposal for a revised Renewable Energy Directive, various scenarios are developed, building on the central EUCO27 policy scenario. Each scenario focuses on specific issues to be addressed in each renewable energy sector, namely, electricity, heating and cooling, and transport.

Regarding the electricity sector, a scenario was built focusing on what the continuation of current practices would mean for reaching the overall RES target. In fact, EUCO27 considers harmonised additional incentives to renewable electricity projects as well as the same financing conditions across Member States (but not technologies) for renewable electricity investments over the 2020-2030 period. Contrary to the EUCO27 scenario, the baseline scenario (so-called Current Renewables Arrangement – 'CRA') models continuation of current national specific renewable support schemes, designed at national level, also after 2020, in order to reach the 27% target. A continuation of differences in investment environments and financing conditions for renewable electricity projects across Europe is therefore assumed. Additional details on the construction of the CRA scenario are presented above. Policy scenarios build on this baseline scenario by testing the impacts of various designs and scopes of renewable support schemes, direct financial support or collaboration across borders to develop renewable electricity projects with the aim of establishing which policies can contribute best to further improve cost efficiency related to renewables deployment.

Regarding the heating and cooling sector, the EUCO27 scenario considers a set of yet unspecified policies in the heating and cooling sector, contributing in a cost effective manner to achieving the overall 2030 target. However, given the absence of evidence of concrete policies by Member States post-2020, it is also relevant to consider as a baseline scenario a case where such policies would not materialise. REF2016 was then used as an approximation for such a baseline scenario. Various policy options are then compared to this baseline, with in mind comparing policies that could ensure a deployment of renewables in the heating and cooling sector in line with deployment occurring in the central policy scenario.

Finally, for the transport sector, it is pertinent to consider as baseline the EUCO27 scenario. Under this scenario, Member States, as in REF2016, are assumed to maintain post-2020 biofuels blending obligations, where those exist thus maintaining the 7% cap on food-based bio-fuels. The key policy question to be assessed for this sector concerns the implications of additional policies promoting the use of advanced biofuels and the phase-out of food-based biofuels as well as dedicated measures for maritime and aviation sector. Policy scenarios used to illustrate different choices in these matters build on the EUCO30 scenario in order to keep consistency with scenarios used in Strategy for Low-emission Mobility (see below) and for the reasons specified below. These policy scenarios are, in some cases, more ambitious in terms of the transport sector contribution to the overall 2030 RES target, which would imply smaller role of other sectors.

Staff Working Document accompanying Strategy for Low-emission Mobility

While the SWD does not analyse policy options like an IA would do, it analyses impacts of the EUCO27 and EUCO30 scenarios in transport sector and presents several pathways/scenarios that are even more ambitious options in three fields: low- and zero-emission vehicles; low emission alternative energy for transport; efficiency of the transport system. Those additional, more ambitious pathways/scenarios are built on EUCO30 scenarios in order to combine ambitious energy efficiency with other actions. Two key scenarios on bio-fuels (BIO-A and BIO-B) are common with the transport section of the IA for revision of the Renewable Energy Directive. In addition, the same transport-related measures have been used to define the more ambitious pathways/scenarios in the SWD on Low-emission mobility and the more ambitious policy options in the Energy Efficiency Directive IA; they have been however packaged differently to address their respective purpose.

The Impact Assessment accompanying the Market Design Initiative

Similar to the other 2016 Energy Union initiatives, EUCO27 was chosen as the starting point (*i.e.* context) of the baseline for the Market Design Initiative (so-called "Current Market Arrangements" – CMA). The EUCO27 scenario is the most relevant to the objectives of the initiative, as it provides information on the investments needed and the power generation mix in a scenario in line with the EU's 2030 objectives.

As all analysis focuses on the power sector, all assumptions exogenous to the power sector were taken from the EUCO27 scenario. This also applied for the energy mix, the power generation capacities at each period, the fuel and carbon prices, electricity demand, technology costs etc. The scenario achieves the 2030 targets as in EUCO27.

However and importantly, the CMA scenario differs from the EUCO27 scenario by including existing market distortions, as well as current practices and policies on national and EU level. It assumes implementation of the Network Codes, including the Capacity Allocation and Congestion Management and the Electricity Balancing Guidelines (the latter in their proposed form). CMA does not consider explicitly any type of existing support schemes for power generation plants, neither in the form of RES-E subsidies nor in the form of capacity remuneration mechanisms. A full description of this scenario is included in Annex IV of the Market Design Impact Assessment. Policy scenarios are then prepared to address specific issues covered by the market design initiative, and are compared to the CMA baseline scenario.

Higher energy efficiency levels and the role of the EUCO30 scenario

Because the specific target for energy efficiency in 2030 remains an open question, it was also necessary to take into account in all Impact Assessments the potential impacts of higher energy efficiency levels, notably of 30% target which is explicitly mentioned by the European Council conclusions. The achievement of this 30% energy efficiency target, in combination with other agreed 2030 targets, is illustrated by the 'EUCO30' scenario.

The EUCO30 scenario is one of the policy scenarios investigated in detail in the Energy Efficiency Impact Assessments and one of the central scenarios used in the SWD accompanying the Strategy for Low-emission Mobility. It was also used in the Effort Sharing Regulation Impact Assessment to test the potential implications of higher energy efficiency levels on the cost-effective level of greenhouse gas emissions reductions at Member State level in the non-ETS sector.

The EUCO30 scenario results are also presented in the Renewable Energy Directive Impact Assessment. Regarding the electricity market design, changing the level of energy efficiency has marginal effects on the issues to be addressed in the power generation sector, and therefore this scenario is not used for comparing results of policy options in that sector. Regarding the heating and cooling sector, the implications are, however, more significant, and therefore, this issue is addressed in more detail in the relevant sections of the Impact Assessment.

Likewise, in the transport sector, the policy scenarios presented in the Renewable Energy Directive Impact Assessment build on the results of the EUCO30 scenario. This is because compared to EUCO27 scenario, EUCO30 includes a set of specific energy efficiency policies in the transport sector which have a bearing on policy options directly related to the use of biofuels. For instance, EUCO30 leads to higher market penetration of electric vehicles, which needs to be taken into account before looking at the remaining needs for additional biofuels policies.

5. Description of analytical models used – other models

5.1. Whole-electricity System Investment Model (WESIM)[57]

WESIM is a comprehensive electricity system analysis model simultaneously balancing long-term investment-related decisions against short-term operation-related decisions, across generation, transmission and distribution systems, in an integrated fashion. In this context, WESIM is a holistic model that enables optimal decisions for investing into generation, network and/or storage capacity (both in terms of volume and location), in order to satisfy the real-time supply-demand balance in an economically optimal way, while at the same time ensuring efficient levels of security of supply. A key feature of WESIM is in its capability to simultaneously consider system operation decisions and infrastructure additions to the system, with the ability to quantify trade-offs of using alternative smart mitigation measures, such as DSR, new network technologies and distributed energy storage, for real-time balancing and transmission and distribution network and/or generation reinforcement management. The model also captures potential conflicts and synergies between different applications of distributed resources (*e.g.*

[57] Source: http://www.wholesem.ac.uk/documents/icl-model-summary

demand side response - DSR) in supporting variability management at the national level and reducing necessary reinforcements in the local distribution network.

The objective function of WESIM is to minimise the overall system cost, which consists of cost of investment in generation, network, interconnection and emerging flexible network, storage and DSR technologies and cost of operating the system, which includes generation operating cost and cost of supply interruptions. The problem is subject to power balance constraints, reserve and adequacy constraints, carbon emission constraints, power flow limits in transmission, distribution and interconnection, generation plants' dynamic characteristics, and DSR and storage operational constraints.

WESIM can be used to assess the electricity infrastructure development and system operation within UK or EU. Different network topologies are generally used to balance the complexity and accuracy of modelling. Different levels of market integration can be modelled in WESIM through distinctive levels of energy exchanges cross-border, sharing of security or various operating reserves, *e.g.* country, regional, EU levels. WESIM optimises the generation, storage, and DSR dispatches taking into account diversity of load profiles and renewable energy profiles (hydro, wind, PV, CSP) across Europe, in order to minimise the additional system capacity to meet security requirements.

Regarding the local distribution networks, WESIM uses a set of representative networks that follow the key characteristics of different type of real GB (and EU member states) distribution network. These representative networks are calibrated to match the actual electricity distribution systems. The mismatches in control parameters between the actual GB and representative networks characterised using this process, are less than 0.1%.

Regarding DSR modelling, WESIM broadly distinguishes between the following electricity demand categories: (i) weather-independent demand (ii) heat-driven electricity demand (space heating / cooling and hot water), (iii) transport demand and (iv) smart appliances' demand. Different demand categories are associated with different levels of flexibility. Losses due to temporal shifting of demand are modelled as appropriate. Flexibility parameters associated with various forms of DSR are obtained using detailed bottom-up modelling of the different types of DSR.

5.2. Description of the modelling set-up for the policy options tested with WESIM

Hourly electricity prices are modelled with WESIM for five separate years: 2020, 2025, 2030, 2040 and 2050. The scenarios modelled used a number of common assumptions, as presented in the table below.

Table 8: Common assumptions

Assumption	Description
Price base	Monetary values are in Euros and were converted to 2015 price base.
Modelling Years	2020, 2025, 2030, 2040, 2050
Countries modelled	• All EU Member States (28 countries) • Non-EU countries: Switzerland, Norway, Albania, Serbia, Montenegro, Bosnia, Macedonia.

Hourly demand profiles	Hourly demand was derived using PRIMES annual electricity demand projections in combination with hourly demand profiles taken from ENTSO-E's TYNDP 2016.[58] The following demand profiles were used: • 2020: ENTSO-E's 'Expected 2020' hourly demand profiles by country. • 2025: Apply the average of 2020 and 2030 hourly profiles, *i.e.* if the weighting of hour one in 2020 was 1% and the weighting of hour one in 2030 was 2%, use a weighting of 1.5% for hour one in 2025. • 2030: ENTSO-E's 'Vision 3' hourly demand profiles. • 2040/2050: Assume no change in demand profile after 2030. Peak demand was calculated as the maximum hourly demand (GW) for a given country in a given year.
Fuel prices	Coal, oil and gas prices were taken from PRIMES and converted to constant 2015 prices. Biomass fuel cost forecasts were supplied by Parsons Brinkerhoff and uranium prices from ENTSO-E's TYNDP 2016.
ETS prices	Taken from PRIMES EUCO27 scenario results
Technology costs (RES-E)	Fixed and variable O&M costs: provided by Parsons Brinkerhoff. Capex costs: sourced from PRIMES.
Technology costs (Conventional technologies)	Fixed and variable O&M: provided by Imperial College London. Capex costs: Build on PRIMES
RES-E generation profiles	Country and technology specific generation profiles were used to capture variable renewables generation. These were based on profiles used for the EC's Roadmap 2050 study.
Electricity storage	Assumed only pumped hydro storage. Distribution level storage was not captured, as WESIM does not model distribution networks.

Results from PRIMES scenarios were used to calibrate the deployment mix for both renewable and conventional technologies in EU Member States. Still, due to difference in models, some unavoidable differences remain in the exact power generation mix between the two approaches. The table below summarises the links between the WESIM scenarios and the PRIMES scenarios.

In addition, the same approach was followed to calibrate WESIM for each Member State's annual electricity demand. As an input, WESIM used data on final electricity demand, plus transmission and distribution losses as a measure for annual electricity demand.

58 Malta is not a member of ENTSO-E. However, we received 2015 hourly electricity demand data from the Maltese energy regulator, and following an assessment of the similarities in the load profile between Malta and Cyprus we opted to use the ENTSO-E load profile for Cyprus, as a proxy for Malta's projected load profile.

For non-EU countries, deployment scenarios were developed based on ENTSO-E TYNDP 2016 forecasts where possible, supplemented by forecasts from National Renewable Electricity Action Plans (primarily for the Balkan countries). No change in capacity mix was assumed after 2030 for these countries. Projections from ENTSO-E's TYNDP 2016, Vision 3 were used for electricity demand.

Table 9: PRIMES sources for the different WESIM scenarios

	Scenario	Deployment scenario
1	WESIM27	PRIMES EUCO27
2	WESIM30	PRIMES EUCO30
3	Removal of preferential market rules	PRIMES EUCO27

Interconnection capacity was calibrated in WESIM using ENTSO-E's TYNDP 2016. Assumptions on transmission capacity were equivalent across scenarios/ sensitivities. As part of WESIM's cost minimisation algorithm, WESIM also endogenously adds additional interconnection capacity if it was efficient to do so. The following assumptions:

- 2020: Used ENTSO-E reference interconnection capacities for 2020 as an input into WESIM.
- 2025: Transmission capacity of projects of common interest (PCIs) with a commissioning date on or before 2025 were added to the 2020 capacity values. Capacity and commissioning dates for PCIs were taken from ENTSO-E TYNDP 2016.
- 2030: Used ENTSO-E interconnection capacities for 2030 as an input into WESIM.
- 2040/50: No additional interconnection capacity was assumed to have been installed after 2030. WESIM's optimisation process forecast additions to interconnection capacity.

Demand response is another important assumption for this modelling work. The characterisation of DSR is based on the concept of achievable potential, which describes the total amount of demand resources that could be realistically expected to be deployed if enabling policies are put into practice. In the modelling, a distinction was made between curtailable DSR and shiftable DSR, with the split between the two being 60:40 in terms of overall achievable potential. Differentiation between countries was also performed based on the level of DSR they would likely require in the future given renewables penetration and additional needs for flexibility in the electricity system. The table below shows the level of achievable potential assumed across scenarios/ sensitivities, defined as a % of daily electricity demand.

Table 10: DSR potential

Curtailable DSR potential	Shiftable DSR potential	Total DSR potential
6%	4%	10%

Finally, the last important assumption for this modelling work concerns priority dispatch. Priority dispatch is a market access rule which places an obligation on transmission system operators to schedule and dispatch RES-E generators ahead of all other types of generation. The purpose of priority dispatch is to provide certainty to renewable generators that they will be able to sell electricity into the grid at all times (reducing volume risk) and to enable a more rapid integration of RES-E generators into the power system. Currently, priority dispatch is being combined with other forms of support (*e.g.* FITs & CfDs in UK) that make it profitable to sell electricity on the wholesale market at any price (even below marginal cost). It is implemented for renewable electricity generators, but is relevant only for those with non-zero marginal costs, namely biomass. By default, it is assumed that renewable would continue to receive priority dispatch indefinitely. However, a sensitivity was conducted in which priority dispatch for all renewables was removed from 2020 onwards.

ANNEX 5 - KEY INDICATORS

1. Options to increase renewable energy in the electricity sector (RES-E)

This section presents an overview of the detailed numerical results used in section 5.1. of the Impact Assessment to analyse and compare the different policy options. First, a detailed discussion is included on the potential funding gap that an absence of support schemes for renewable electricity projects would entail. Second, the relevant results of the various PRIMES runs used to assess and compare options are presented.

1.1. Detailed analysis on viability of RES projects and on the need for support schemes in the electricity sector post-2020

This subsection presents in detail the modelling approaches and the results of an analysis of the impacts of the absence of support schemes on the viability of renewables projects over the 2020-2030 period, as summarised under the assessment of policy options in section 5.1 of this Impact Assessment.

Lessons learned from the main PRIMES scenarios

EU Reference Scenario 2016

The EU Reference Scenario 2016 (REF2016) assumes no additional policies post-2020. From a RES perspective, it means no additional policy support beyond the already adopted policies and the assumed additional policies necessary to implement the current EU acquis in the RES area, namely reaching the binding 2020 RES targets.

In this context, by 2020, RES in power generation are projected to increase to 35.5% (RES-E indicator) or 37.2% of net electricity generation, of which 52% are projected to be variable RES (wind and solar). Beyond 2020, support schemes are phased out and further investments in RES are driven by market forces, the ETS and the improvement in the techno-economic characteristics of the technologies.

Still, such additional investments are insufficient to contribute to achieving the 27% RES target. Overall, RES-E reaches 42.5% in 2030 (RES-E indicator), or 42.8% of net electricity generation.

To conclude, no additional policy in any energy or climate field beyond 2020 would lead to a shortfall in RES investments, hampering the achievement of the RES (and of the GHG emission reductions) targets. However and importantly, many initiatives have been or will be implemented in various relevant climate and energy fields, and therefore, REF2016 only very partially answer the question on the need for additional support schemes for renewable energy.

The EUCO27 scenario

As opposed to REF2016, the EUCO27 scenario was constructed with in mind a cost-effective achievement of the 2030 climate and energy targets. A detailed description of this scenario is presented in Annex 4.

This scenario assumes implemented the proposal for a revised ETS post-2020, including a new linear reduction factor. It also models a set of concrete policies in the field of energy efficiency and transport, as well as some additional unspecified policies via the use of energy efficiency values in the residential and tertiary sectors. This scenario also considers improved electricity market functioning and uses RES values to model yet unspecified dedicated policies in the RES sectors to reach the 27% target. In the electricity sector, such RES values are on average equal to 6 €/MWh. Finally, under this scenario, financing conditions are assumed to be the same across Member States (similar WACC) as specific country risks, as in Reference Scenario, are assumed inexistent.

Under this scenario, the RES-E share reaches 47.3% in 2030, or 47.6% of net electricity generation. Installed capacity for RES technologies increases by 34% between 2020 and 2030.

This scenario suggests that under the right framework conditions, namely a reformed ETS, good electricity market functioning, a cost effective set of energy efficiency policies, and equal financing conditions across the EU, it is possible for the majority of RES investments to develop such that they effectively contribute to the overall achievement of the RES target. However, there remains a gap, visible because RES-E values had to be used in the model to trigger the necessary investments to achieve a 27% share of renewable energy by 2030.

The EUCO30 scenario

Similar to the EUCO27 scenario, this scenario aims at reaching 2030 targets (in this case 30% energy efficiency in addition to 40% GHG emissions and 27% RES), in a cost effective manner. Again, in this scenario, RES-values are used to simulate the impact of unspecified policies necessary to reach the 27% RES target. The average renewables value is 16€/MWh, more than in the EUCO27 scenario. This implies that more stringent policies would be needed to reach the 27% RES target in case of a more ambitious energy efficiency target. This result is explained by the higher RES value used in the electricity sector (23€/MWh instead of 6€/MWh), which, in turn, is the result of a lower ETS carbon price in EUCO30 than in EUCO27. In other words, this scenario suggests that the investment gap for RES-E projects would increase in the case of more ambitious energy efficiency policies, as such policies tend to decrease the carbon price needed to reach the ETS target, and therefore make renewable electricity projects relatively less profitable.

The CRA scenario

In contrast to the EUCO27 scenario, the CRA scenario is based on the assumption of the continuation of current Member States policies and practices in the renewable energy field. The description of this scenario is detailed in Annex 4, and has similar assumptions in non-RES-related policy fields than the central policy scenario (EUCO27).

The first assumption that this scenario considers is that Member States continue supporting renewable electricity projects, on a national basis, with no additional provision considered in the Revised RES Directive. Potential provisions would be left entirely to the revised, post-2020 State Aid guidelines. Therefore, a continuation of nationally-based support schemes is assumed, while complying with the current State-Aid guidelines provisions. The second assumption made is that Member States support renewable electricity projects in such a way that the overall 27% RES target is achieved.

The third assumption made for the preparation of this baseline scenario is that current distortions in the financing cost of renewable electricity projects across countries remains until 2030.

Regarding other assumptions, this scenario assumes, as in the central policy scenario (EUCO27) an improved functioning of the ETS, in line with the Commission's proposal for a revised ETS, as well as efficient market functioning. In other words, this scenario differs in its design compared to the EUCO27 scenario via two main features: i/ the cost-effective support reflected by the use of similar RES-E values across Member States in the EUCO27 scenario is replaced by explicit, nationally-based and differentiated support schemes; and ii/ financing conditions for RES projects differ per Member State.

Under this scenario, as under any other PRIMES scenario, the RES investments resulting from the overall policy and economic context as well as incentives have been projected assuming that investors evaluate project specific Internal Rates of Return including the financial incentives and decide upon investing accordingly. The projected RES investments implied directly from the financial incentives are considered as given by the market model which then decides upon the remaining potentially necessary investments (among all power generation technologies) based on pure economic considerations with a view to meeting the RES obligations. In that respect, this scenario does not try to directly answer whether an investment gap would necessarily emerge, but rather that the continuation of current policies and practices would lead to policy support driving more than half of EU investments in renewable electricity projects.

More specifically, one of the results of the CRA scenario is that 59% of RES investments over the 2021-2025 period would be based on public support. This share decreases to 51% for the 2026-2030 period. The following table presents the split by technology and by region. The results show mature RES technologies can be more easily financed without public support, in particular in regions with the highest potential (*e.g.* Southern Europe for solar, Nordic region for wind onshore). Differences also exist in general between regions, as RES projects seem in general less profitable in British Isles and Central Europe than in other regions.

% of GW new investment driven from support schemes (CRA scenario		2021-2025	2026-2030
Nordic region	Wind onshore	16%	21%
Nordic region	Wind offshore		
Nordic region	Solar and other		100%
Nordic region	Biomass solid	0%	0%
Nordic region	**Sum**	**15%**	**19%**
British Isles	Wind onshore	100%	100%
British Isles	Wind offshore	100%	100%
British Isles	Solar and other	100%	100%
British Isles	Biomass solid	100%	100%
British Isles	**Sum**	**100%**	**100%**
Central Europe	Wind onshore	81%	58%
Central Europe	Wind offshore	98%	100%

Central Europe	Solar and other	67%	22%
Central Europe	Biomass solid	93%	91%
Central Europe	**Sum**	**84%**	**61%**
Southern Europe	Wind onshore	0%	0%
Southern Europe	Wind offshore	100%	100%
Southern Europe	Solar and other	1%	4%
Southern Europe	Biomass solid	18%	58%
Southern Europe	**Sum**	**2%**	**2%**
Iberian Peninsula	Wind onshore	15%	1%
Iberian Peninsula	Wind offshore	100%	100%
Iberian Peninsula	Solar and other	20%	26%
Iberian Peninsula	Biomass solid	38%	27%
Iberian Peninsula	**Sum**	**19%**	**20%**
EU28	**Sum**	**59%**	**51%**

Source: PRIMES – description of which countries are included in each region is provided in Annex 4

Lessons learned from electricity market simulation tools

In addition to PRIMES, which is an energy-system model notably looking at interactions across sectors and variables, it is possible to investigate the viability of RES projects using specific analytical tools focusing on electricity market functioning only.

WESIM

The issue of viability of RES investments has first been investigated with the use of the WESIM model. As described in Annex 4, WESIM is a comprehensive electricity system analysis model simultaneously balancing long-term investment-related decisions against short-term operation-related decisions, across generation, transmission and distribution systems, in an integrated fashion.

For the purpose of this analysis, WESIM has been calibrated to mirror investment patterns as projected by PRIMES in the EUCO27 scenario. The focus of the analysis presented below is to assess whether wholesale electricity market revenues would be sufficient, on their own, to finance the necessary RES investments as projected by PRIMES over the 2020-2030 period. However, this analysis does not consider investment profitability issues for conventional power generation technologies, an issue assessed in detail in the market design IA via other tools.

Assuming overall framework conditions similar to the ones used to build the EUCO27 scenario (*e.g.* in terms of interconnection, market functioning, ETS prices[59]), WESIM determines hourly electricity prices and dispatching and uses this to project a stream of revenues for all RES generation technologies. By comparing overall RES investment and

[59] The noticeable exception is that the main scenario developed with WESIM still assumes priority dispatch for biomass generation over the 2020-2030 period.

operational costs to this stream of revenues, it is possible to assess the viability of RES projects.

The difference between total annual investment as projected with PRIMES in the EUCO27 scenario and the ones that are not estimated to be viable with WESIM provides an indication of a potential investment gap. This investment gap corresponds to the share of RES investments estimated to not be able to be financed by wholesale electricity market revenues on their own. The analysis performed with this model concludes that the investment gap will amount to EUR 13 billion in 2020; EUR 12 billion in 2025 and EUR 9 billion in 2030[60]. It is important to note that this does not correspond to the level of public support which would be needed, as only a fraction of the investment cost might need to be supported for the project to become viable.

More specifically, the model results show that only 41% of investments in 2020 could be financed by the market. This share increases to 54% in 2025 and 66% in 2030. Onshore and solar PV become gradually profitable and by 2030, such projects could be financed entirely by the markets, under the specific assumptions considered in this scenario. Conversely, technologies such as offshore wind investments cannot be yet fully financed via electricity market revenues by 2030.

Required annual investment (€ bn)	Biomass	Geothermal	Hydro reservoir	Hydro ROR	Offshore wind	Onshore wind	Solar PV	Tidal	TOTAL
2020	0.48	0.00	0.26	0.04	5.54	7.21	8.09	0.24	**21.88**
2025	0.77	0.00	0.41	0.14	8.74	9.43	5.33	0.37	**25.19**
2030	0.94	0.23	0.09	0.69	9.61	8.93	6.75	0.50	**27.74**
Total investment gap (€bn)	**Biomass**	**Geothermal**	**Hydro reservoir**	**Hydro ROR**	**Offshore wind**	**Onshore wind**	**Solar PV**	**Tidal**	**TOTAL**
2020	0.48	0.00	0.23	0.00	5.54	3.55	2.91	0.24	**12.95**
2025	0.00	0.00	0.34	0.00	8.74	0.00	2.26	0.37	**11.71**
2030	0.00	0.00	0.00	0.00	8.99	0.00	0.00	0.50	**9.49**
Share of investment financed by the market	**Biomass**	**Geothermal**	**Hydro reservoir**	**Hydro ROR**	**Offshore wind**	**Onshore wind**	**Solar PV**	**Tidal**	**TOTAL**
2020	1%		12%	100%	0%	51%	64%	0%	41%
2025	100%		18%	100%	0%	100%	58%	0%	54%
2030	100%	100%	100%	100%	6%	100%	100%	0%	66%

Source: CEPA, central scenario

Two sensitivity analyses were performed. First, the assumption of priority dispatch for biomass was lifted. In this context, biomass units are not forced to operate when their marginal cost is lower than the electricity price in absence of operational support, and therefore, average electricity prices tend to increase. This increases the viability of (other) RES projects and in this context, the share of investments that could be financed

60 For additional details on viability gap of RES-e technology assessed with WESIM methodology, see Annex 4

based on electricity market revenues increases as follows: 52% in 2020, 61% in 2025 and 89% in 2030.

Second, another sensitivity was performed to investigate potential impacts of different expectation regarding ETS prices. This extreme case scenario considers that investors in each year take as given the prevailing ETS price, and assume that it remains constant over the life of their project, and do not expect the price to increase over time. This is obviously a simplification, only aiming at illustrating the impact of extreme boundary conditions on the viability of RES projects. Wholesale market revenues received by RES-E generators were amended to reflect this change of assumption. Given that it is difficult to accurately determine the contribution of carbon costs to the total wholesale price in every hour, a less granular approach was therefore used, using average yearly prices instead. Overall, under this assumption, 35% of investments in 2020 could be financed via these revised (theoretical) market revenues, 48% in 2025 and 54% in 2030.

PRIMES market simulation tools

The issue of whether wholesale electricity market revenues would be sufficient to finance investments in power generation is addressed in detail in the MD Impact Assessment.

First, the MD IA simulates market revenues taking as a constant the level of investments provided by the EUCO27 scenario (PRIMES/IEM). It identifies viable and non-viable power generation technologies based on various electricity market functioning assumptions, from status quo to a scenario removing all existing barriers. Potential revenues on day-ahead, intraday and balancing markets are then calculated, and the net profits or losses, as compared to overall costs of investments, are determined. Second, additional projections are provided, where investment decisions become endogenous (PRIMES/OM). A detailed analysis of the results is provided in the MD IA.

Focusing on the most important results from a RES generators perspective, the analysis shows first that onshore wind across the EU from 2025 and solar PV in the South Europe (excluding small scale) from 2030 make profits on energy-only markets. However, this is not the case of the other RES technologies. The benefits of improving the energy-only market are then assessed in the MDI IA but from a RES generation investment profitability perspective, the results are not significantly amended.

To complement this analysis, it is important to also look at the dynamic behaviour of markets and how markets can also provide investment signals. A different model was used, PRIMES/OM, in the MDI IA. The following table summarises the results for RES technologies. It confirms that mature RES technologies are among the profitable technologies by 2030. Conversely, less mature technologies, such as wind offshore, biomass or solar thermal, remain unprofitable.

	Profit or Loss by plant type in M€'13		
	2020	**2025**	**2030**
Lakes	13 384	15 132	17 435
Run of River	10 382	12 065	13 219
Wind onshore	0.323	6 152	20 231
Wind offshore	-0.205	-3 152	-3 262
Solar PV (large)	-3 207	-0.141	3 644
Solar thermal	-1 786	-2 080	-2 900

Geothermal	0.158	0.242	0 323
Tidal	-2 705	-2 833	-0 320
Biomass	-5 938	-7 432	-6 160
CHP biomass	-2 958	-3 094	-3 075
RES (small)	-9 486	-8 525	-4 126

Source: PRIMES/OM

Conclusions

The various modelling approaches used to analyse the potential viability of RES investments based on market revenues alone, as well as in an overall energy-system context, all converge around the following conclusions:

- Profitability of RES technologies will improve over the 2020-2030 period. The combination of technological progress, improved market functioning, and increasing ETS prices, among other factors, lead to more and more RES investments being projected to be viable without support.
- The situation is contrasted depending on the level of maturity of RES technologies. Even if some less advanced RES technologies would need support to emerge as part of the power generation mix towards 2030, this is likely not the case anymore for most mature technologies, at least towards the end of the 2021-2030 period, such as hydro, wind onshore and solar PV (at least in some parts of Europe).
- Improving electricity market functioning will overall be beneficial to RES investments profitability. This is also true as regards confidence of investors in the evolution of ETS prices. Anticipating on future ETS price increases improve the profitability of RES investment projects.

1.2. Main indicators used to compare results of electricity policy options modelled with PRIMES

This subsection presents tables summarising the main results of the various PRIMES modelling scenarios used for the assessment of policy options in the electricity sector. Detailed explained for these results are included in the main part of the report (section 5.1.).

Electricity indicators (2030)	**Ref2016**	**CRA**	**CRA countryspec**	**CRA techspec**	**CRA regio**	**CRA crossborder**	**EUCO27**	**EUCO30**
Net Electricity Generation (*TWh*)	3390872	3372371	3373067	3374239	3363306	3369539	3396680	3285630
- Renewable share	43%	50%	49%	52%	50%	49%	47%	49%
of which hydro share (%)	11%	11%	11%	11%	11%	11%	11%	11%
of which wind onshore share (%)	14%	15%	15%	15%	15%	15%	17%	17%
of which wind offshore share (%)	4%	8%	8%	11%	6%	8%	4%	4%
of which solar share (%)	7%	9%	9%	8%	11%	9%	9%	9%
of which Biomass &	7%	7%	7%	7%	7%	7%	7%	8%

waste share (%)								
Average Electricity prices	158	166	166	166	168	166	161	157
Average cost of electricity generation	101	108	108	108	109	107	103	100
ETS carbon price	34	38	38	29	38	41	42	27

Source: PRIMES

Energy system costs	**Ref2016**	**CRA**	**CRA countryspec**	**CRA techspec**	**CRA regio**	**CRA crossborder**	**EUCO27**	**EUCO30**
Total System Costs in bn €'13 *(average annual 2021-30)*	1928	1952.5	1951.0	1961	1951.2	1951	1943	1952
change in system costs compared to Ref2016 (in bn €'13)	0	24.3	22.8	32.6	23.0	23.2	14.9	24
Total System Costs as % of GDP *(average annual 2021-30)*	12.28%	12.43%	12.42%	12.48%	12.42%	12.42%	12.37%	12.43%
Total System Costs as % of GDP increase *(average annual 2021-30)* compared to REF16 in % points	0.00%	0.15%	0.14%	0.21%	0.15%	0.15%	0.10%	0.15%
Total System Costs in bn €'13 *(average annual 2021-2050)*	2130	2275	2273	2281	2273	2274	2264	2255
change in system costs compared to Ref2016 (in bn €'13)	0	145	143	151	143	144	134	125
Total System Costs as % of GDP *(average annual 2021-2050)*	11.62%	12.41%	12.41%	12.45%	12.40%	12.41%	12.35%	12.31%
Total System Costs as % of GDP increase *(average annual 2021-2050)* compared to Ref2016 in % points	0.00%	0.79%	0.781%	0.83%	0.78%	0.79%	0.73%	0.68%

Source: PRIMES

Investment indicators (2030)	**Ref2016**	**CRA27**	**CRA countryspec**	**CRA techspec**	**CRA regio**	**CRA crossborder**	**EUCO27**	**EUCO30**
Investment expenditures in power generation (2021-2030 period)	311663	552761	544188	649884	558000	542093	395403	393970
Investment expenditures in renewables (2021-2030 period)	150431	404130	394090	502666	406862	393311	240131	245414
% of RES investments in total investments in power generation	48%	73%	72%	77%	73%	73%	61%	62%
% of total RES investments in wind	62%	70%	70%	77%	54%	69%	59%	58%

% of total RES investments in solar	29%	18%	19%	13%	31%	19%	36%	36%
% of total RES investments in biomass-waste	4%	8%	8%	7%	11%	9%	2%	2%
% of total RES investments in other renewables (hydro, tidal, etc.)	5%	3%	3%	3%	3%	3%	3%	1%
Share of top three MS in overall RES-E investments	54%	67%	63%	74%	58%	65%	47%	44%
Share of bottom ten MS in overall RES-E investments	0.7%	0.6%	0.8%	0.4%	2.0%	0.6%	2.2%	2.8%

Source: PRIMES

Social impacts and affordability issues (2030)	Ref2016	CRA27	CRA countryspec	CRA techspec	CRA regio	CRA crossborder	EUCO27	EUCO30
Electricity price - households (€/MWh)	212	226	224	226	231	225	218	215
RES supporting costs passed on to consumers	19	26	25	31	25	25	19	20
Electricity price - industry (€/MWh)	100	104	104	104	102	103	100	98
Energy related production cost - industry	376363	381358	381293	379351	380087	380917	377935	374087

2. Options to increase renewable energy in the heating and cooling sector (RES-H&C)

2.1. Mainstreaming renewables in heating and cooling supply

Dimension	Indicator	Option 0	Option 1-1	Option 1-2	Option 2-1	Option 2-2	Source
Social	Average share of small-scale companies under HCOS (in energy supply)	N/A	18%	18%	2%	2%	Fraunhofer-own assessmnet
	Maximal share of small-scale companies under HCOS (in energy supply)	N/A	100%	100%	25%	25%	Fraunhofer-own assessmnet
Economic	Standard deviation of additional effort in terms of RES-H&C shares at MS level compared to cost-effective	N/A	2.80%	3.20%	2.80%	3.20%	PRIMES+own calculations
Political	Maximal additional effort asked to a single MS vs. cost-effectiveness	0%	4%	6%	4%	6%	PRIMES+own calculations

2.2. Facilitating the uptake of renewable energy and waste heat in district heating and cooling systems

Dimension	Indicator	Option 0	Option 1	Option 2	Option 3	Source
Social	Consumers empowerement	0	0	+	+++	Öko Institut and EC-own assessment
Economic	Potential impact on district heating operators	0	0	-	-	Öko Institut and EC-own assessment
Environmental	Potential fuel-switching to RES in H&C	0	0	20%	20%	Öko Institut and EC-own assessment
Administrative burden	Potential impacts on administrative costs	0	+	-	-	EC-own assessment

3. Options to increase renewable energy in the transport sector (RES-T)

Dimension	Option 0	Option 1	Option 2 (variant 1)	Option 2 (variant 2)	Option 2 (variant 3)	Option 3	Option 4 (variant 1)	Option 4 (variant 2)	Option 4 (variant 3)
Social	0	+	0/+	+	+	+	+	+	+
Economic	0	-	-	- -	-	-	- -	-	-
Environmental	0	+	++	+++	+++	+	+	+++	+++

4. Options to empower and inform consumers of renewable energy

4.1. Empower consumers to generate, self-consume and store renewable electricity

Dimension	Indicator	Option 0	Option 1	Option 2	Option 3 (variant 1)	Option 3 (variant 2)	Source
Social	Potential level of consumers participation	0	+	+	+++	++	PRIMES, EC own assessment
Economic	Potential impact on grid costs	0	-	-	---	-	EC own assessment
Environmental	Potential contribution of rooftop solar PV to RES-E	0	-	+	+		PRIMES, EC own assessment

4.2. Disclosing information for renewable electricity

Dimension	Indicator	Option 0	Option 1	Option 2	Option 3	Source

Social	Transparency and data reliability	0	+	++	++	EC own assessment
Economic	Data coverage: % of the energy system covered by GOs	0	Natural change – approx. 50% RES	All RES - E	All electricity sources	EC own assessment
	Changes in financial flow	0	No change	Some change	Some change	EC own assessment
	Reduction in administrative cost	0	Marginal impact	Marginal impact	--	EC own assessment
Environmental	Potential for encouraging consumers to switch to RES contracts	0	+	++	+++	EC own assessment
	Consumer data on CO_2 emissions through GOs	0	None	None	+	EC own assessment

4.3. Tracing renewable fuels used in heating and cooling and transport

Dimension	Indicator	Option 0	Option 1	Option 2	Option 3	Source
Social	Increase ability of consumers to choose renewable fuels	0	++	+	+	EC own assessment
Economic	Fraud prevention through better tracking	0	+	+	+++	EC own assessment
	Minimise administrative burden	0	+	+	+	EC own assessment
Environmental	Reduce sustainability concerns of the fuels	0	+	++	+++	EC own assessment

5. Options to ensure the achievement of at least 27% renewable energy in 2030

5.1. Baseline of 2020 targets

Dimension	Indicator	Option 0	Option 1	Source
Social	Impact of consumer groups	0	-	EC own assessment
Economic	Reduced cost of capital	0	+	EC own assessment
Environmental	Reduced GHG emissions	0	+	EC own assessment

5.2. EU Trajectory 2021-2030 for achievement of the EU renewables target

Dimension	Indicator	Option 0	Option 1	Option 2	Source

Social	Consumer impacts through avoiding changes in policy	0	++	+	EC own assessment
Economic	Encouraging long term investment in renewables	0	++	+	EC own assessment
Environmental	Reducing GHG emissions	0	++	+	EC own assessment

5.3. Mechanisms to avoid an "ambition gap" to the EU renewables target

Dimension	Indicator	Option 0	Option 1	Option 2	Option 3	Source
Social	Avoids distributional impact	0	+	+	+	EC own assessment
Economic	Incentivises investment in RES	0	+	++	++	EC own assessment
Environmental	Avoids increase in emissions by correcting any ambition gap	0	+	++	++	EC own assessment

5.4. Mechanisms to avoid and fill a "delivery gap" to the EU renewables target

Dimension	Indicator	Option 0	Option 1	Option 2	Option 3	Option 4	Source
Social	Avoids distributional impact	0	+	+	+	+	EC own assessment
Economic	Incentivises investment in RES	0	+	+	++	++	EC own assessment
Environmental	Avoids increase in emissions by correcting any delivery gap	0	+	+	++	++	EC own assessment

6. Other results of energy-system modelling scenarios, including a sensitivity scenario and a RES decomposition analysis

This section summarises first the energy-system results of various core scenarios used in this Impact Assessment, while also presenting the results of the sensitivity scenario projecting an increase of renewable energy to 30% in 2030 (EUCO3030 scenario).

In a second subsection, a RES decomposition analysis is provided, presenting in detail the contribution of the various subsectors to the achievement of the overall RES target in the various scenarios considered.

6.1. Evolution of energy system indicators and variables in main scenarios used in this Impact Assessment

This section presents the results of REF2016, of the CRA scenario (baseline scenario for assessing electricity policy options), the EUCO27 scenario, the EUCO30 scenario and the EUCO3030 scenario. This last scenario corresponds to a sensitivity analysis performed, looking at the specific impacts of higher ambition level in renewable energy[61]. These scenarios help illustrate the scale of the challenge in each renewable energy sector depending on assumptions as regards overall policy ambition and specific targets in other areas than renewable energy alone.

6.1.1. Energy system indicators

The table below presents the outcome of the various scenarios regarding main energy system indicators. Except in REF2016, the overall renewables share in 2030 is an exogenous input to the scenarios, as scenarios are meant to achieve specific shares of renewable energy. The same logic applies for primary energy consumption, in line with various potential energy efficiency targets.

On the contrary, renewables shares per sector are an outcome of the model. Here, it can be seen that the various scenarios in line with a 27% share in renewable energy do not fundamentally differ, although a scenario with additional energy efficiency (EUCO30) indicates an extra contribution from the electricity and transport sectors, as an overall decrease in heating and cooling demand leads to smaller requirements for renewable energy in that sector. Looking at the variant reaching a 30% share of renewables by 2030, together with 30% energy efficiency, it can be seen that a significant increase in the share of renewable energy in all sectors is projected, and notably in the electricity sector.

Energy System indicators (2030)	Ref2016	CRA	EUCO27	EUCO30	EUCO3030
Overall RES share (% of GFEC)	24%	27%	27%	27%	30%
RES-E share	42%	49%	47%	49%	54%
RES-H&C share	25%	27%	27%	26%	30%
RES-T share	14%	18%	18%	19%	21%
Total RES consumption (Ktoe)	272957	295374	291507	279377	310262
Gross final consumption of RES for heating and cooling	123824	127007	128049	116637	132899
Gross final consumption of electricity from RES	128391	147848	142971	142436	156049
Biofuels consumption	20742	20519	20486	20304	21314
Gross Final Energy Consumption (Ktoe)	1133091	1085207	1086070	1040139	1038151

[61] In this case, a 30% share of renewables by 2030 is assumed, together with 30% energy efficiency levels.

Electricity	302437	299252	302057	292307	287843
Heating and Cooling	485055	455346	453540	422926	424876
Transport	274253	256245	256086	251778	252237
Primary Energy Consumption (Ktoe)	1436069	1358072	1369069	1321337	1306157
Final Energy Demand (Ktoe)	1081368	1031259	1031401	987097	986214

Source: PRIMES

6.1.2. Environmental indicators

The following table illustrates the GHG emission reductions in the various scenarios. By construction, the CRA, EUCO27 and EUCO30 scenarios are meant to achieve the same level of GHG emissions reductions, overall and between ETS and ESD sectors. This is not the case for the EUCO3030 scenario, where emission reductions are not constrained. In this scenario, much more additional GHG emission reductions come from the ETS sector, which is notably explained by the exogenous assumption of keeping constant the ETS price, as compared to EUCO30. The carbon intensity of power generation is also reduced by 15% compared with EUCO30, mostly due to the decrease of gas use. As such, this scenario illustrates potential additional deployment in the renewable electricity sector, although the scenario outcome does not reflect interactions with the ETS carbon market and would not be in line with the current Commission proposal for a reformed ETS.

Higher ambition in energy efficiency leads to additional GHG emission reductions in demand sectors. Conversely, no drastic change is projected between the CRA and the EUCO27 scenario in decarbonisation patterns.

Environmental indicators (2030)	Ref2016	CRA	EUCO27	EUCO30	EUCO3030
Total GHG emissions (% change to 1990)	-35.2%	-40.8%	-40.7%	-40.8%	-43.2%
ETS sectors emissions (% change to 2005)	-37.7%	-43.4%	-43.1%	-43.1%	-48.1%
ESD sectors emissions (% change to 2005)	-23.7%	-30.1%	-30.2%	-30.3%	-30.7%
CO_2 emissions (in kt CO_2) thermal power plants	881933	760720	773423	756853	646027
Carbon intensity power generation (per MWhe+MWhth)	0.202	0.177	0.179	0.182	0.157
Power generation, CHP and district heating GHG emissions (%	*-41%*	*-49%*	*-48%*	*-49%*	*-56%*

change compared to 2005)					
Industry (only energy related) (Mt CO_2 eq), (% change)	*-41%*	*-43%*	*-44%*	*-44%*	*-46%*
Residential GHG emissions (% change compared to 2005)	*-25%*	*-35%*	*-35%*	*-40%*	*-41%*
Tertiary GHG emissions (% change compared to 2005)	*-33%*	*-42%*	*-43%*	*-46%*	*-47%*
Transport GHG emissions (% change compared to 2005)	*-12%*	*-18%*	*-18%*	*-19%*	*-19%*
Power generation, CHP and district heating GHG emissions (Mt of CO_2 eq for REF and % change from REF for other scenarios	*977.5*	*-13%*	*-12%*	*-14%*	*-26%*
Industry (energy + processes) (Mt CO_2 eq), (% change)	*375.8*	*-3%*	*-5%*	*-5%*	*-9%*
Residential (Mt CO_2 eq), (% change)	*360.8*	*-13%*	*-12%*	*-20%*	*-20%*
Tertiary (Mt CO_2 eq), (% change)	*183.2*	*-15%*	*-15%*	*-21%*	*-21%*
Transport (Mt CO_2 eq), (% change)	*946.9*	*-6%*	*-6%*	*-8%*	*-8%*

Source: PRIMES, GAINS

6.1.3. Social impacts indicators

From a social impacts perspective, it can be seen that the CRA scenario lead to a higher increase in electricity prices, as compared to EUCO scenarios, showing signs of lack of efficiency in the continuation of current practices, as opposed to a situation where renewables deployment is more cost-effective. This is even more visible when focusing on the calculated renewables supporting costs passed on to final consumers, which increase significantly in CRA as opposed to EUCO scenarios.

On the demand side, the energy purchases are more affected by energy efficiency requirements than by different renewables pathways, as most significant differences appear when comparing EUCO27 and EUCO30 results.

Social impacts and affordability issues (2030)	Ref2016	CRA	EUCO27	EUCO30	EUCO3030
Avg. electricity price incr. compared to 2010 price (%)	18%	25%	21%	18%	21%

RES supporting costs passed on to consumers	19	26	19	20	21
Energy Purchases in bn EUR'13 (average annual 2021-30)	1448	1422	1415	1388	1391
Industry	272	273	271	269	268
Residential	417	413	410	397	400
Tertiary	249	245	243	235	236
Transport	510	492	491	486	487

Source: PRIMES

6.1.4. Energy security impacts indicators

Deployment of renewables – together with energy efficiency – is expected to contribute to increased energy security, by lowering the needs for non-diversified energy imports. This can be observed by comparing the results of the various EUCO scenarios, where, as energy efficiency and/or renewable energy ambitions increase, the volume and value of imports decrease. Significant savings in terms of fossil fuel import bills are therefore projected, in particular in the case of the EUCO3030 scenario. In this latter scenario, due to the higher rate of renewables deployment, import dependency is the lowest of all scenarios. However, the increasing net import dependency for biomass (energy and non-energy uses, including food) should be taken into account.

Impacts on energy security (2030)	Ref2016	CRA	EUCO27	EUCO30	EUCO3030
Net Energy Imports Volume (2005=100)	93	86	86	82	79
Solid	67	57	57	59	53
Oil	88	80	80	79	78
Gas	116	110	110	97	89
Renewable Energy Forms	796	846	848	804	863
Import Dependency	57%	55%	54%	53%	52%
Gas imports (bcm)	325	306	306	270	248
reduction compared to REF2016 (in bcm)	0	-18	-18	-54	-77
reduction compared to	0%	-6%	-6%	-17%	-24%

REF2016 (% change)					
Value of Fossil Fuel Net Imports (bn EUR'13) ***(average annual 2021-30)***					
Oil	326	309	309	307	306
Gas	111	107	107	102	99
Solid	12	11	11	12	11
Fossil Fuels Import Bill: absolute results for REF2016 and % change compared to REF2016 for other scenarios (bn EUR '13 - cumulative 2021-30)	4494	-4.6%	-4.9%	-6.4%	-7.2%

Source: PRIMES

6.1.5. Total system costs

The table below presents the evolution of overall energy system costs across the scenarios. The most striking feature in the context of this impact assessment is that system costs increase in the CRA scenario as compared to EUCO27, showing the negative overall impacts of the continuation of current practices and policies. This is true for the 2021-2030 period as well as for the whole period up to 2050. As opposed to more energy efficiency or renewable energy scenarios, there are no trade-offs in this case between short and long term costs for the energy system.

The most ambitious scenario, the EUCO3030 scenario, is also the most costly over the 2021-2030 period. The increase in system costs compared to EUCO30 over the 2021-2030 period corresponds to € 4 billion on average annually. Conversely, costs of EUCO3030 are among the lowest over the 2030-2050 period and EUCO3030 system costs fall closer to EUCO30 results when looking at the 2021-2050 period.

Energy system costs	Ref2016	CRA	EUCO27	EUCO30	EUCO3030
Total System Costs in bn EUR'13 ***(average annual 2021-30)***	1 928	1 953	1 943	1 952	1 956
change in system costs compared to Ref2016 (in bn EUR'13)	0	24	15	24	28
Total System Costs as % of GDP (average annual 2021-30)	12.28%	12.43%	12.37%	12.43%	12.46%
Total System Costs in bn EUR'13 ***(average annual 2021-2050)***	2130	2274.7	2264	2255	2257

change in system costs compared to Ref2016 (in bn EUR'13)	0	145	134	125	127
Total System Costs as % of GDP (average annual 2021-2050)	11.62%	12.41%	12.35%	12.31%	12.32%

Source: PRIMES

6.1.6. Macro-economic and employment impacts

Macro-economic impacts (including employment and GDP) have been estimated using the E3ME model and the GEM-E3 model, mirroring the approach used in the Impact Assessment for the revision of the Energy Efficiency Directive. The description of these two models and the methodology used for testing potential macroeconomic impacts are presented in detail in the Energy Efficiency Impact Assessment (see for instance Annexes 4.8 and 4.9 of the EE IA).

Both models use as input energy system and investment developments coming from PRIMES scenarios. In the context of this Impact Assessment, the E3ME and GEM-E3 models were calibrated and run for the CRA and EUCO3030 scenarios. Results developed in the context of the Energy Efficiency Impact Assessment, namely for assessing the macroeconomic impacts of REF2016, EUCO27 and EUCO30 scenarios, are also reported.

In terms of methodology, one important element to highlight concerns the treatment of the CRA scenario. In the CRA scenario, the financing conditions for renewable electricity projects are different than in the other scenarios reported in this section, reflecting different status-quo (and more difficult) access to capital market conditions across EU Member States. As such, as compared to EUCO27 results, investment costs are higher, but not so much due to increased capacity installed but rather due to higher risk premiums assumed for the financing of investments. In the GEM-E3 model this has been modelled by the introduction of inefficient capital (i.e. increasing the cost of capital to deliver the same service without increasing the demand for equipment). In the E3ME model, the different financing costs across Member States were also reflected, mirroring the different access to capital market conditions across Member States.

The following tables present the main results:

Levels (bln €2013) for REF2016 and EUCO27 and % change wrt to EUCO27 for the rest of scenarios	**REF2016**	**EUCO27**	**CRA**	**EUCO30**	**EUCO3030**
	GDP (bln €2013)	GDP (bln €2013)	GDP	GDP	GDP
E3ME					
no crowding out	17,928.1	18,044.9	-0.08%	0.39%	0.53%
partial crowding out	17,928.1	18,044.9	-0.08%	0.39%	0.53%
GEM-E3					
loan based	16,954.6	16,961.7	-0.06%	0.26%	0.13%

self-financed	16,954.6	16,907.4	-0.08%	-0.22%	-0.49%

Source: Cambridge Econometrics E3ME modelling and National Technical University of Athens, E3M-Lab, GEM-E3 modelling

In terms of GDP, the CRA scenario leads to lower GDP levels in 2030 than the EUCO27 scenario. This is a direct consequence of the inefficiencies considered in the financing of renewable energy projects in this scenario. This result is confirmed in both models used and for each variant considered.

The EUCO3030 scenario leads to additional RES investments, compared to EUCO30. In the case of the E3ME model, this leads to additional GDP benefits, with very limited changes between the partial crowding out[62] and no crowding out variants, as investment levels are not sufficient to breach the output growth constraint imposed in the partial crowding out case[63].

In the case of the GEM-E3 model, EUCO3030 results are overall less positive (or more negative) than for the EUCO30 scenario. Additional RES investments tend to shift away investments from other productive sectors in the economy. The increasing share of RES translates into higher average electricity prices and production costs, since additional investments need to be recovered via higher prices and therefore costs for electricity users, hence reducing the initial positive impact resulting from additional RES deployment. Still, overall, GDP effects remain positive in 2030, compared to EUCO27, in the loan-based variant, that is, when increased financial liquidity and the possibility for borrowing is considered[64], as crowding out effects tend to rather materialise post-2030. It can be noted that, under current market conditions, RES investments are financed in majority through borrowing, either from banks or capital markets. When interpreting the scenario results, a key determinant will be the opportunity to finance additional RES – or other energy-related – investments without immediate crowding out on investments in other sectors of the economy.

Levels (mln people)	REF2016	EUCO27	CRA	EUCO30	EUCO3030

62 The "partial crowding out" imposes a constraint on activity expansion by introducing a rule that would set a maximum amount that the sectors benefiting from the energy union target setting would be allowed to increase by, without adversely affecting other economic activities. This rule entails a 15% limit on additional energy-related policy induced output growth by 2030. For more information please see the section on macroeconomic impacts of the 2016 Impact Assessment for the revised Energy Efficiency Directive

63 However, as investment requirements increase with more ambitious renewable and/or energy efficiency levels, this constraint is manifested by limiting the potential output growth in the partial crowding out case versus the no crowding out case. Please see the section on macroeconomic impacts of the 2016 Impact Assessment for the revised Energy Efficiency Directive for more discussion on this

64 In the case of GEM-E3, the two versions are referred to as loan-based finance and self-financing. In the former, businesses and households can borrow in the markets, whereas in the latter no borrowing is possible and economic agents finance the required additional energy investments via firms increasing their prices and households spending less on other items. The self-financing variant corresponds to immediate financial closure in GEM-E3 and thus implies that the model will show full crowding out effects, meaning that any upward deviation from optimal baseline investments requires consumption to be reduced or investments in other parts of the economy to be cancelled. The loan-based variant mitigates such crowding out effects and defers these to later periods via increasing financial liquidity and allowing for borrowing to take place

for REF2016 and EUCO27 and % change wrt to EUCO27 for rest of scenarios	Employment (mln people)	Employment (mln people)	Employment	Employment	Employment
E3ME					
no crowding out	233.1	233.5	-0.03%	0.17%	0.18%
partial crowding out	233.1	233.5	-0.03%	0.17%	0.18%
GEM-E3					
loan based	216.4	216.6	-0.03%	0.20%	0.14%
self-financed	216.4	216.0	-0.03%	-0.18%	-0.29%

Source: Cambridge Econometrics E3ME modelling and National Technical University of Athens, E3M-Lab, GEM-E3 modelling

In terms of employment, the CRA scenario leads to negative impacts compared to EUCO27, due to the inefficiencies discussed above, and in line with GDP developments. Employment impacts for the EUCO3030 scenario are very similar to EUCO30 when considering the E3ME results. Using GEM-E3, employment impacts are more negative or less positive (depending on the variant) than for EUCO30, in line with GDP developments projected by the model and the resulting changes in sectorial labour intensities.

Overall, the results of these macroeconomic simulations are rather intuitive: inefficiencies in renewable electricity investments captured in the energy system impacts of the CRA scenario also lead to inefficiencies, and GDP losses, when looking at the macroeconomic implications. Regarding the scenario leading to a 30% RES share in 2030, its overall macroeconomic impacts very much depend on whether the additional RES investments it entails could be financed and implemented without negatively affecting the potential availability of finance for other sectors, or in other words without constraining the monetary liquidity of the overall economy.

6.2. A decomposition analysis of RES developments in the various policy scenarios modelled with PRIMES

6.2.1. <u>Contribution of each RES sector to overall RES increases</u>

The following figure presents the RES share evolution per sector, between 2010 and 2030, per main scenario. First, it can be seen that the most important contribution is expected to be from the electricity sector, followed by heating and cooling. Contributions from transport and from reduced energy demand are at similar lower levels.

The graph also highlights the fact that the CRA scenario projects an additional contribution from the electricity sector in the total renewables increase as compared to the other scenarios. It also clearly shows that additional energy efficiency translates into a lower contribution from the heating sector, while overall reduction in demand contributes more, by decreasing the denominator used to calculate the share of renewables.

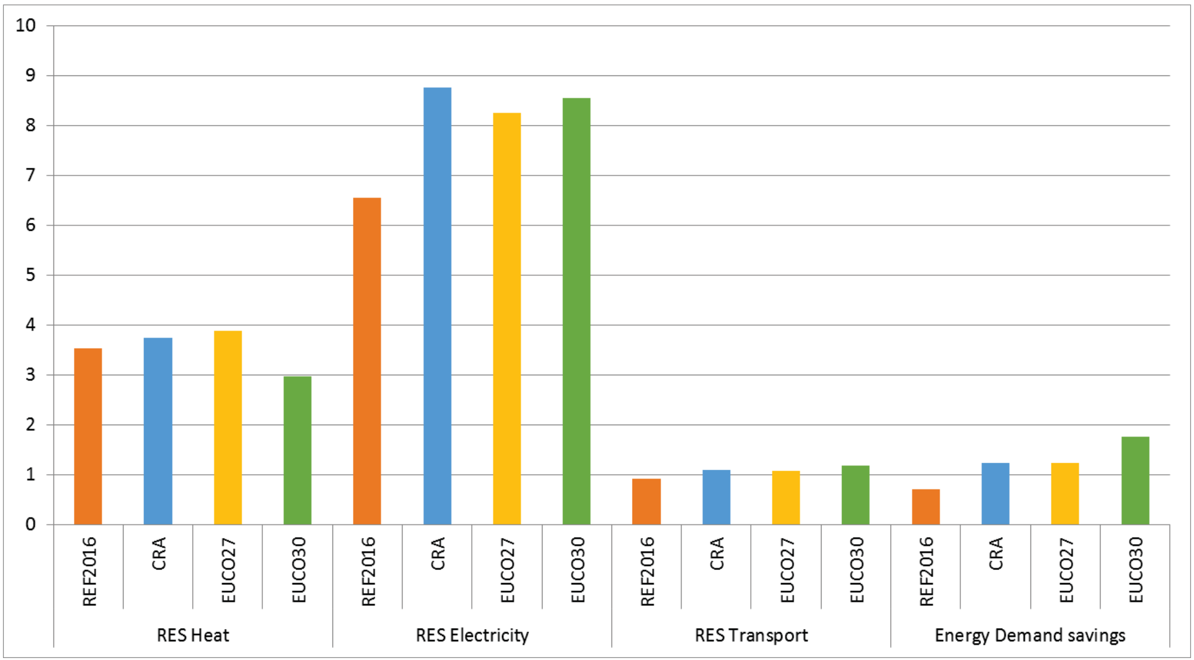

Figure 1: Decomposition of change of overall RES Share in 2030 relative to 2010, in percentage points – Main Scenarios
Source: PRIMES

6.2.2. Decomposition analysis for the renewable electricity sector

The figure below focuses on the evolution within the electricity sector across the main scenarios and variants. In all scenarios, the main contributor to the increase in RES-E share is wind. It influences more the overall increase than all other RES technologies put together.

Within this overall context, there are also important variations in the specific split between wind and other RES technologies. For instance, the CRA scenario leads to much more significant investments in wind, particularly wind offshore, than in solar. This is due to a mix of factors, including more favourable financing conditions in regions more favourable to wind than in regions more favourable to solar. The CRA_regio variant shows in this respect a much more balanced evolution in RES technology developments. This is also the scenario closest to the central policy scenario (EUCO27) in terms of RES deployment across technologies. The other three variants to the CRA scenario show much more limited impacts as compared to the baseline (CRA) scenario.

Finally, electricity demand negatively contributes to the evolution of the RES-E share. This is because electricity demand increases in all scenarios, and therefore this requires even more RES investments to increase the renewable electricity share than under constant electricity demand.

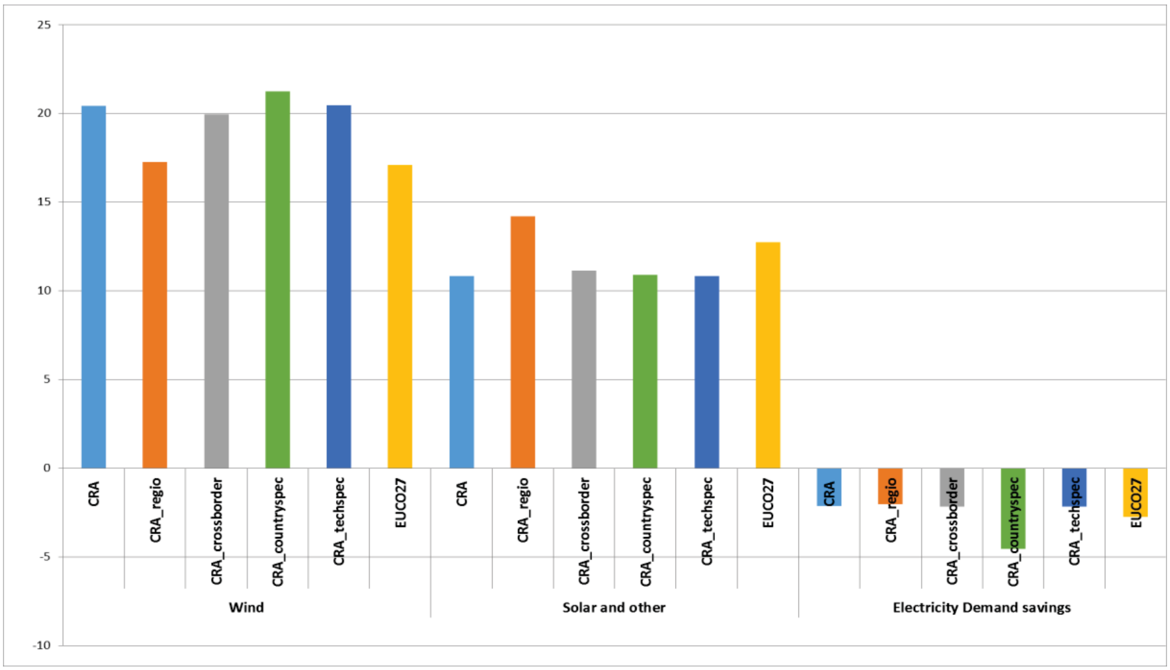

Figure 2: Decomposition of change of RES-E share in 2030 relative to 2010, in percentage points -- various scenarios

Source: PRIMES

6.2.3. <u>Decomposition of RES H&C share</u>

The figure below represents the evolution of the various determinants of RES H&C in 2030, as compared to 2010, across scenarios.

The main determinant of the developments of RES H&C very much depends on the scenario considered. In the case of the Reference and of the EUCO27 scenarios, the main factor is the increase in RES in final heat, followed by heat pumps, RES in CHP and heat demand savings. However, in the case of EUCO30, the main determinant is heat pumps, followed by heat demand savings. This suggests that higher ambition in energy savings lead to, all else being equal, lower needs for additional investments in RES in final heat sector.

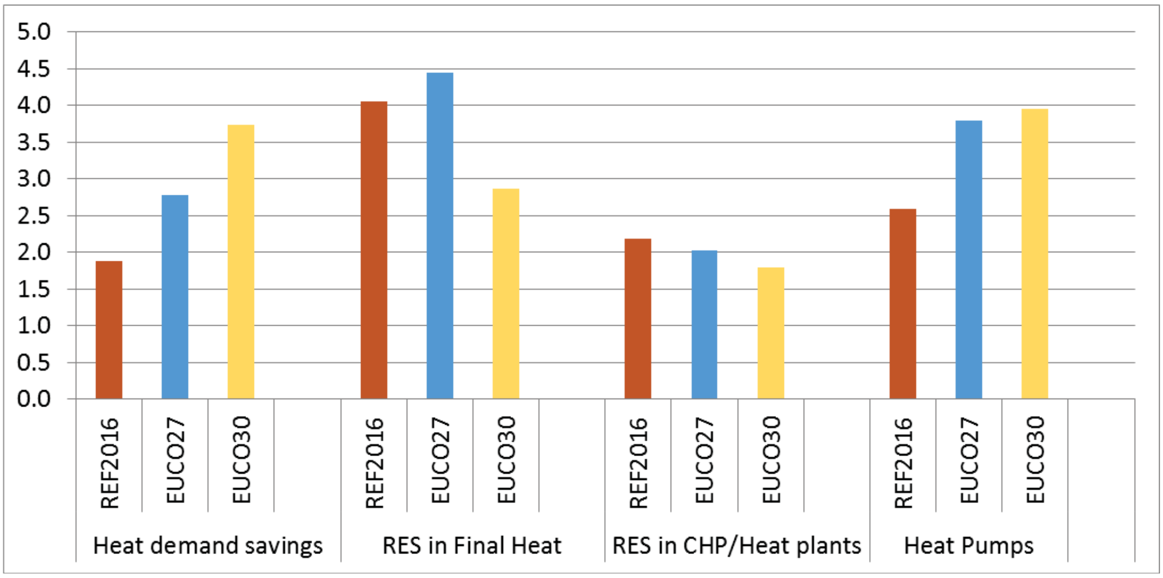

Figure 3: Decomposition of change of RES-H&C share in 2030 relative to 2010, in percentage points -- various scenarios

Source: PRIMES

ANNEX 6 - WHO IS AFFECTED AND HOW

Member States could be affected by the procedure to deliver pledges within their national renewables development path, as well as by the provisions for gap-filling instruments in case of difficulties in reaching the at least 27% target.

Local communities and **municipalities** will also be affected in the effort to coordinate national level and local level renewables planning. This might imply some additional administrative costs for coordination between governmental levels, but also ensure that local authorities are involved from the start so that public resistance issues can be better addressed.

The Revised RES Directive will also impact **non-renewables producers** and **suppliers** with regard to their market share as a consequence of the deployment of more renewables across the EU energy market.

Provisions on permit granting and authorisation could contribute to lower administrative and transaction costs associated with renewables project development, therefore impacting **renewables projects developers** at large and especially SMEs active in the industry.

As per **renewables technology producers** and **renewables installers**, the post 2020 renewables and Energy Union Governance policy framework could foster investment security and increase cross border business opportunities.

The **investors** and the **financial sector** will factor in an increased investment security in the post-2020 renewables provisions.

Businesses in general could benefit from the renewables cost reductions expected from new requirements for support to renewables and administrative procedures.

Transmissions service operators and **distribution service operators** could be affected by provisions to ensure that renewable electricity production and injection into the grids is guaranteed without discrimination *vis-á-vis* non-renewable electricity.

The Revised RES Directive could put in place a regulatory framework to enable consumers to self-produce and self-consume, and sell surplus renewable electricity (which so far only exists in 19 Member States) across the EU. This would enable **energy consumers** to become active market participants.

Energy service providers (ESCOs) and **aggregators** could exploit a new avenue both for entrepreneurs and consumers.

Citizens should be impacted in terms of higher local acceptance of renewables projects and increased utilisation of renewable energy in their energy mix, therefore reaping the ultimate benefit of a lower-carbonisation of the economy at large and related lower degrees of pollution.

ANNEX 7 - OVERVIEW OF BIOFUELS MANDATES IN MEMBER STATES

Table 1 : Biofuel mandates in the EU[65]

EB: Energy basis Vol: vol. basis	Year	Overall mandate	Biodiesel mandate	Bioethanol mandate	Double counting	Comments
Austria	2012	5.75 % EB	6.3 % EB	3.4 % EB	Y	
Belgium			6.0 %vol.	4.0 %vol.	N	
Bulgaria	2012 2015 2018 2019 2020		6 %vol.	 7 %vol. 8 9 10	N N N N N	
Croatia	2014 2015 2016 2017 2018 2019 2020	3.18 %EB 3.88 4.89 5.89 6.92 7.85 8.81			Y Y Y Y Y Y Y	
Czech Republic	2014-2016 2017-2018 2019-2020	5.71 %EB 8.0 10.0			N N N	Min. GHG red. 35 % 50 % 60 %
Denmark	2010 2020	5.75 %EB 10 proposed			N	
Estonia						5 %EB 2016, 10 % 2020 proposal rejected 2015
Finland	2014 2015	6 % EB 8			N N	
EB: Energy basis Vol: vol. basis	**Year**	**Overall mandate**	**Biodiesel mandate**	**Bioethanol mandate**	**Double counting**	**Comments**
France	2010-2013 2014 Future?		7 % EB 7.7 min. 0.35 % double counted 8 %	7 % EB 7 min. 0.25 % double counted	 Y	
Germany	2015 2017 2018 2020	3.5 % GHG red. 4 4 6			N N N N	Min. GHG red. 35 % 50 % 60 % for new plants No co-processing
Hungary	2014-2015		4.9 % EB	4.9 % EB 304 ktoe	Y	

[65] Biofuel Mandates in the EU by Member State. GAIN report GM15015. USDA 7/13/2015

	2020		202 ktoe			
Ireland	2010-2012 2013	4.166 6.383 %vol			N Y	
Italy	2014 2015 2018 2022	5 %EB. 5			Y N	“Adv. Biofuels” mandate 0.6 %EB 1 %
Latvia	2010	5.75 %EB				No later info available
Lithuania						No information available
The Netherlands	2011 2012 2013 2014 2015 2016 2017 2018 2019 2020	4.0 %EB 4.5 5.0 5.5 6.25 7.0 7.75 8.5 9.25 10	Min 3.5 % Min 3.5 % Min 3.5 % Min 3.5 % No longer required as of 2015	Min 3.5 % Min 3.5 % Min 3.5 % Min 3.5 % No longer required as of 2015	Y Y Y Y Y Y Y	Mandates in place since 2007 A certificate system has been introduced in 2015. Renewable fuels accepted since 2015
Poland	2014-2016 2017 2018	7.1 %EB 7.8 8.5			N Y?	The on double counting proposition did not pass parliament as planned in 2015, expected for 2016[66].
Portugal	2014 2015-2016 2017-2018 2019-2020	5.5 %EB 7.5 9 10		 2.5 %EB 2.5 2.5	Y Y Y Y	Ethanol includes also ETBE
Romania	2014-2015 2016		5 %EB 6	4.5 %EB 4.5	? ?	
Slovak republic	2015 2016 2017 2018 2019 2020	5.5 %EB 5.5 5.8 7.2 7.5 8.5	6.8 %EB 7.0 7.0 7.0 7.0 7.0	4.5 %EB 4.6 4.7 5.9 6.2 7.0	N N N N N N	ETBE 3 % in gasoline, 1.41 % bio-ethanol
Slovenia	2010	5 %EB			Y	
EB: Energy basis Vol: vol. basis	**Year**	**Overall mandate**	**Biodiesel mandate**	**Bioethanol mandate**	**Double counting**	**Comments**

66 Poland to postpone double-counting biodiesel ruling to 2017. Platts March 1 2016. https://www.platts.com/latest-news/agriculture/london/poland-to-postpone-double-counting-biodiesel-26383952

Spain	2013-	4.1 %EB	4.1 %	3.9 %	?	
Sweden	2007-				Y	Tax based system eligible for approved renewable fuels. Co-processing accept. Proposal for new system 2017?
UK	2013- 2017 2018	4.75 vol % in overall supply			Y	RTFO system in place > 50 % GHG red. eligible > 60 % GHG red. eligible for new installations New rules on co-processing expected April 2016?

Table 2: Classification of BIO, CCUS, e & Hydrogen transport fuels

Classification of BIO, CCUS, e & Hydrogen Transport Fuels					
	Raw material	**Technology**	**Type of biofuel**	**Status TRL[1]**	**Application**
Conventional	Sugar*	Fermentation	Ethanol	Commercial	Gasoline blend, E10, E85, E95,
Conventional	Starch*	Fermentation	Ethanol	Commercial	Gasoline blend, E10, E85, E95,
Conventional	Vegetable oils*	Esterification or transesterification	FAME/Biodiesel	Commercial	Diesel blend, B7, B10, B30, 100%
Conventional	Fats	Esterification or transesterification	FAME/Biodiesel	Commercial	Diesel blend, B7, B10, B30, 100%
Conventional	Food crops	Biogas production & removal of CO_2	Biomethane	Commercial	100% in heavy duty transport, captive fleets, injected in the gas grid
	Waste streams of oils & fats	Esterification or transesterification	FAME/Biodiesel	Commercial	Diesel blend, B7, B10, B30, 100%
	MSW[2], sewage sludge, animal manures, agricultural residues, energy crops	Biogas or landfill production & removal of CO_2	Biomethane	Commercial	100% in heavy duty transport, captive fleets, injected in the gas grid
	Vegetable oils*, fats, used cooking oils, liquid waste streams & effluents[7]	Hydrotreatment	Hydrogenated	Commercial	Diesel drop-in or 100%, bio-kerosene

Advanced	Lignocellulosics, MSW, *solid* industrial waste streams/residues[3]	Enzymatic hydrolysis + fermentation	Ethanol	TRL 8-9	Gasoline blend, E10, E85, E95, upgrade to biokerosene
			Other alcohols	TRL 6-7	
		Gasification + fermentation	Ethanol	TRL 6-7	
	Lignocellulosics, MSW, *liquid* industrial waste streams & effluents[5] or intermediate energy carriers[6]	Gasification + catalytic synthesis	Synthetic[4]	TRL 6-7	Depends on fuel type; can be used for blends with diesel, gasoline, kerosene, bunker fuel , drop-in
	Algal oils[8] and other non-food oils	Hydrotreatment	Hydrogenated	TRL 5-6	Diesel drop-in or 100%, bio-kerosene
		Esterification	FAME/Biodiesel	TRL 5-6	Diesel blend, B7, B10, B30, 100%
	Pyrolysis oils from lignocellulosics, MSW, waste streams	Hydrotreatment	Hydrotreated	TRL 4-5	Diesel drop-in or 100%
		Co-processing in existing petroleum refineries[9]	Ethanol, diesel, kerosene	TRL 5-6	All of the above
	Non-lignocellulosic biomass, (algae, non-food biomass)[10]	Various as above	Ethanol, diesel, hydrogenated	TRL 5-6	Various as above
	Sugars [11] (cellulosic, non-food)	Microbial	Ethanol, diesel	TRL 5-6	Diesel drop-in or 100%, bio-kerosene
	Supply of waste/byproduct gases	**Technology**	**Type of biofuel**	**Status**	**Application**
CCUS	Steel & Chemical Industry	Fermentation	Ethanol	TRL 6-7	Gasoline blend, E10, E85, E95,
		Upgrading & Catalysis	Methanol	TRL 5-6	Shipping, blends with gasoline
			Methane	TRL 5-6	100% in

					heavy duty transport, captive fleets, injected in the gas grid
	Waste polymers, plastics, non-biodegradable fraction of MSW	Gasification + catalytic synthesis	Synthetic[4]	TRL 6-7	Depends on fuel type; can be used for blends with diesel, gasoline, kerosene, drop-in
	CO_2 from RES systems	Reaction with RES H_2	Synthetic[4]	TRL 6-7	Depends on fuel type; can be used for blends with diesel, gasoline, kerosene, drop-in
e-Fuels	**Supply of H2**	**Technology**	**Type of biofuel**	**Status**	**Application**
	RES electricity	Catalysis	Methanol	TRL 6-7	Shipping, blends with gasoline
	RES electricity		Methane	TRL 7-8	100% in heavy duty transport, captive fleets, injected in the gas grid
	RES electricity		Synthetic[2]	TRL 5-6	Depends on fuel type; can be used for blends with diesel, gasoline, kerosene, drop-in

RES H2	Source	Technology	Type of Biofuel	Status	Application
	RES electricity	Electrolysis	H_2	TRL 5-8	Fuel cells, H2 engines, natural gas grid
	Ethanol or Methanol[12]	Reforming (on vehicle)	H2		
	Methane[12]	Reforming	H2		

ANNEX 8 - MODELLING METHODOLOGY FOR THE GHG EMISSION REDUCTION OPTIONS

ICCT assessment tool for option 4

The model used to estimate potential alternative fuel volumes, greenhouse gas impacts, costs and jobs for the various scenarios presented in this memo was developed by Dr. Stephanie Searle and Dr. Chris Malins at the International Council on Clean Transportation. The model is private and has not undergone peer review or been discussed with external experts. The model was developed specifically for understanding the impacts of various potential alternative fuel policies in the EU in the year 2030.

The model structure is linear. The amount of alternative fuel supplied in each scenario is multiplied by its carbon intensity value and then compared to the carbon intensity of diesel or petrol in order to calculate greenhouse gas savings. Alternative fuel amounts are multiplied by projected fuel prices for each type and compared to the projected price of diesel or petrol to calculate total cost of each fuel type in each scenario. The number of permanent jobs that would be directly supported by the production of each type of fuel was estimated on a per ton oil equivalent basis, and this was multiplied by alternative fuel volumes to calculate total jobs that would be supported by each fuel type in each scenario. Maximum volumes of advanced fuel technologies that have not yet been widely commercialized (cellulosic ethanol and synthetic diesel from pyrolysis or Fischer Tropsch processes) were calculated by estimating the number of facilities that could plausibly be constructed in each year from the present to 2030 with strong policy support. The estimated maximum volume of these advanced fuel technologies was not directly input into any of the scenarios presented in this memo, but was used as a comparison point to contextualize whether particular scenarios were likely achievable or not. The volumes of each type of alternative fuel in each scenario were largely determined by (a) the GHG reduction target in each scenario, and (b) the amounts of biodiesel and ethanol that could be consumed with current blend limits in diesel and petrol. REF2016 used in this modelling exercise was provided by the European Commission; volumes of specific fuel types was inferred from the given material using the information available.

Because the model projects future conditions, there is inherent and unavoidable uncertainty in the results. The maximum potential volumes of each type of fuel in 2030 will depend heavily on a number of factors, including but not limited to: the perceived strength of policy support, technology development, diesel and petrol prices, financial markets, and local policies and regulations throughout the EU. This model relies on inputs from several other sources that each carry uncertainty – for example, the fuel price projections taken from the UK Transport Energy Task Force report have uncertainty associated with them, and actual fuel prices in 2030 will depend on a variety of factors, including technology development and petroleum prices. There is uncertainty in the estimates of indirect land use change emissions used in this model, and to a lesser extent, in our assumptions on direct production emissions for alternative fuels in 2030. The number of permanent agricultural jobs that would be directly supported by the production of each type of alternative fuel was estimated in a simple approach by looking at the EU agricultural sector as a whole, and this estimation could be refined. The estimates of jobs both in feedstock production and in facility operation were made considering current conditions, but the number of jobs in alternative fuel production could change to 2030 depending on technology development. Uncertainty in this model has been minimized by focusing on the factors that most strongly influence the policy conclusions. For example, assumptions about ILUC emissions greatly affect the results about the net GHG impacts of each scenario; we therefore present results using two sets of ILUC emission estimates that were produced for the European Commission (the IFPRI study and the GLOBIOM study). The quality of the results from this model were otherwise assured by relying on published studies for the assumptions when such information was available.

Modelling assumptions for GHG mandate

GHG savings: It is assumed that the 60% GHG reduction requirement for direct lifecycle emissions under the RED sustainability criteria will continue to apply, and that some operators will achieve higher GHG savings. Food-based biodiesel is assumed to have an average direct GHG savings of 65% and food-based ethanol of 70%. All non-food based fuels are assumed to have higher GHG savings. For all scenarios, it is assumed that ILUC accounting will not apply towards eligibility or reportable GHG savings. In estimating real GHG savings including ILUC, ILUC results from the 2011 IFPRI study are used (Laborde, 2011). The composition of food-based biodiesel and ethanol by crop was taken from the 2020 EU crop mix in Valin et al. (2015).

Potential volumes: A 7% blendwall is assumed to apply for biodiesel blended in diesel and a 10% blendwall for ethanol blended petrol. 20% of the gasoline pool was assumed to be E85 (51-83% ethanol blended in gasoline, at an average blending rate of 75%) for scenarios B1, B2, and B3, and 5% of the gasoline pool was assumed to be E85 for all other scenarios under Options B, C, and D. While E85 availability may increase in the EU, the experience from the US, where corn ethanol consumption is strongly supported by the Renewable Fuel Standard, shows that biofuel mandates are an inadequate driver for increased use of higher biofuel blends, as the high cost of infrastructure changes presents a significant barrier (*e.g.* see EPA, 2016). The blendwall does not apply to drop in fuels, such as hydrogenated vegetable oil (HVO) or pyrolysis synthetic diesel. For the purpose of estimating volumes under the blendwall, diesel and gasoline projections are taken from REF2016 provided by the European Commission. Volumes of second generation fuels, such as cellulosic ethanol or cellulosic synthetic diesel, are estimated based on a deployment model, and are assumed to have preferential access under the blendwall when it applies. The use of electricity in vehicles follows Lutsey (2015). A category for “Other Annex IX fuels” is intended to include alternative fuels from glycerine and other sources for which individual projections are not possible at this time. A category for “Other advanced fuels” is intended to include non-biological fuels from waste, and other, unforeseen, types of low carbon, alternative fuels. The blendwall is not assumed to apply to “Other Annex IX fuels” and “Other advanced fuels.”

Cost: Cost estimates from the UK’s Transport Energy Task Force report are used for the cost of different types of fuel, including diesel, petrol, waste and crop-based biodiesel, and crop-based and cellulosic ethanol in the year 2030.[67] The cost of pyrolysis and Fischer Tropsch synthetic diesel and other advanced fuels are assumed to be the same as for cellulosic ethanol in 2030. Other Annex IX fuels are assumed to be slightly less expensive to produce. HVO is assumed to be slightly more expensive than crop-based biodiesel. The cost to obligated parties of electricity used in vehicles is assumed to be related to charger installation costs, which were estimated for level 2 home chargers in the year 2030 from EPA (2012). Only a portion of this cost is included in this analysis because other policies such as efficiency standards and purchase and tax incentives for

[67] "Data and outputs spreadsheet": http://www.lowcvp.org.uk/projects/transport-energy-task-force.htm

electric vehicles contribute to electric vehicle deployment and thus petroleum displacement by electric vehicles; this cost therefore cannot be attributed solely to a low carbon fuel policy.

Employment: Only direct, permanent jobs were estimated; construction jobs and indirect employment impacts were not assessed here. For second generation ethanol, pyrolysis diesel, and Fischer Tropsch diesel, feedstock collection jobs were derived from Turley et al. (2013), using values for straw collection. For other advanced fuels and other Annex IX fuels, it was assumed that a portion of fuel would be waste-based with fewer feedstock collection jobs. For food-based crops, feedstock production jobs were estimated as the average number of agricultural jobs per harvested hectare in the EU in 2010, using employment data from Eurostat[68] and crop production data from FAOSTAT.[69] The fraction of additional crop demand from food-based biofuel that would be met with increased agricultural production in the EU was taken from the recent GLOBIOM study (Valin et al., 2015). It is assumed that second generation fuel production (*e.g.* cellulosic ethanol from wheat straw) would result in 100% new feedstock collection in the EU. Biofuel facility jobs for second generation fuels was taken from a review in Pavlenko et al., (2016). Facility jobs for first generation biofuels was assumed to be half of this, per unit fuel on an energy equivalent basis, because second generation biofuel facilities tend to be more complicated than first generation facilities. The number of jobs created by electricity used in vehicles was estimated as labour required to install electric chargers (assuming 8 hours per charger, following costs from EPA (2012)); a portion of the employment created in charger installation was considered attributable to the low carbon fuel policy. Waste collection jobs were not included.

[68] http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_census_2010_-_main_results#Agricultural_labour_force. It was assumed that half of total agricultural jobs are in crop production, as opposed to livestock or other types of jobs.

[69] http://faostat.fao.org/

ANNEX 9 - REFIT EVALUATION

The REFIT evaluation concluded that the objective of sustainably increasing the share of renewable energy in the EU final energy consumption has been successful. The binding national targets, the National Renewable Energy Action Plans and the biennial monitoring[70] provided for by the RES Directive have been particularly effective for promoting transparency for investors and other economic operators, and have ensured high quality information on renewable energy markets and policies in the Member States. This is illustrated by the rapid deployment increase after the date of adoption of the Directive, passing from 10.4% share of renewables in 2007 to 17% in 2015[71].

These legal provisions, together with additional national policies and other non-regulatory measures, have contributed to the overall achievement of EU's energy and climate policy goals, resulting in greenhouse gas emission saving, increased security of energy supply, innovation leadership, employment creation, public acceptance and regional development. They have proved their relevance, coherence, efficiency, effectiveness and added value for the overall EU energy and climate change objectives. Renewable energy is, currently, the only decarbonisation option in the power sector deployed at a rate that is close to what is required under long-term IEA scenarios to limit global temperature rise to 2°C above pre-industrial levels[72].

However, even if the EU and all but one Member States are currently on track towards its overall renewable energy 20% target for 2020, target achievement by 2020 will only be secured if Member States continue to meet their increasingly steep trajectories. Furthermore, further efforts are necessary to increase the current progress rate of renewables deployment in transport to ensure the sectorial 10% target is met. The regulatory uncertainty caused by the long political discussion on ILUC, the late adoption of the amendments on ILUC to the RES Directive and the lack of a post-2020 policy for transport, together with the lack of commercial availability of alternative fuels and advanced biofuels at the needed scale and pace, have had a negative impact in the deployment of renewables in the transport sector.

In addition, the effectiveness of the national targets, based on a flat-rate/GDP approach (as opposed to an approach based on national potential, which would have been more cost effective, but considered less equitable[73]) was, however, compromised by the fact that flexibility and trading options were not utilised by the Member States as expected during the reference period. However, intergovernmental negotiations that were held in 2015 and 2016 amongst several potential "selling" and "buying" Member States, demonstrate increasing mobilisation of efforts towards concluding the first renewable energy cooperation agreements.

Another issue which requires follow-up is the level of investments in renewable energy. Their decline after 2011 due to undermined inverstor confidence and some external factors highlights the need to reflect on how investors' legitimate interests can be better

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70 National Renewable Energy Action plans and biennial national renewable energy progress reports are legal requirements set out in Art. 4 and Art.22 of the Renewable Energy Directive

71 EUROSTAT

72 IEA, 2015

73 "Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020", 2008, SEC(2008) 85

protected.The REFIT evaluation of the RES Directive also pointed to a number of shortcomings in the Renewable Energy Directive:

- *National renewable energy action plans*: While the national renewable energy action plans provided transparency and information for investors on Member States' plans for renewable energy development, they eventually became outdated as the RES Directive does not require their regular updating to adjust them to policy and global economic changes. This shortcoming was largely compensated by biennial national RES progress reports that provided regular updates on national regulatory and financial measures in the renewable energy space. In the context of the new 2030 Climate and Energy Framework and Energy Union Governance process, the current legal provisions on the planning and reporting will need to be revised for post 2020 period.

- *Cooperation mechanisms*: The cooperation mechanisms set out in the RES Directive have not yet been used to any significant extent by Member States, with exception of the joint Swedish-Norwegian support scheme. In the RES Directive, the use of cooperation mechanisms is voluntary and Member States have so far, for various reasons, preferred to use national renewable energy sources for target achievement. The opportunity given by the RES Directive to share the efforts to achieve the renewable energy target cost-effectively has, therefore, been rather underused. However, as national interim trajectories become steeper after 2015, a number of Member States are currently in active phase of negotiations aiming to conclude such cooperation mechanisms, in the form of a partial opening of national support schemes, or statistical transfers. .

- *Renewable energy support schemes:* Pursuant to Article 3(3) of Directive 2009/28/EC, support schemes are but one instrument - amongst others - that can be chosen by Member States to achieve the binding national renewable targets. The majority of the Member States though used them as part of their renewable policies. In the absence of clear principles established in the RES Directive, Member States had wide discretion in their decisions on the design and scope of renewable energy support schemes. As the cost of renewable energy technologies fell, several national support schemes were unable to be adapted rapidly enough. As a result, technology bubbles were encouraged, resulting in market distortion and fragmentation.

- *Administrative procedures*: Administrative and planning systems are very diverse across the EU Member States and progress in simplifying them has been hampered due to the large margin of discretion left in the legal provisions of Article 13(1). Clear and transparent rules are not yet in place in all Member States and at all necessary levels. The absence of clear legal requirements to establish one administrative entity (one-stop shop) for the permit granting procedures and the absence of maximum time-limits for permit granting in Member States are still perceived as major administrative obstacles and an additional cost burden to project developers. In view of tackling investment bottlenecks and lengthy project approval procedures, further reinforcement of these provisions might need to be considered for the amended post 2020 legislation[74].

[74] Building on the previous rather general requirement set out in Directive 2001/77/EC for Member States to take action to reduce and simplify administrative procedures, the impact assessment

- *Renewable energy in heating and cooling supply and in buildings:* The RES Directive recommended Member States to promote and integrate renewable energy in the urban and local environment (*e.g.* newly developed areas, district heating and cooling systems), and to mandate renewable energy use through buildings codes for new buildings as of 2015, while leaving full discretion to the Member States as regards implementation modes. Despite the long term decarbonisation goal in the heating and cooling sector and in buildings, the existing framework did not provide sufficient incentives for fuel switching from fossil to renewable energy in the heat supply and buildings. Further reinforcement of these provisions might need to be considered in the revision of the Directive for post-2020.

- *Grid access rules*: Certain provisions of the RES Directive are not specific enough (*e.g.* providing deadlines for their implementation) for the purpose of enabling better monitoring and enforcement. The Directive also leaves discretion to Member States on whether shallow or deep grid charging is applied, which considerably changes the risk and thus the cost for new renewable installations across Member States. In view of the intended wider electricity market reform, some of the current legal provisions on RES electricity integration might need further streamlining and integration with the electricity market legislation.

- *Self-consumption*: The RES Directive does not contain specific provisions on self-consumption of renewable electricity, which has given Member States a wide discretion to regulate this type of emerging trend of consumers' empowerment. This has led to a wide range of policies across the EU, some of them hampering the cost-effective development of self-consumption. The benefits of introducing a EU framework enabling cost-effectives self-consumption (in line with the Energy Union's objective of empowering consumers) could be assessed in the revision of the legislative framework for post-2020.

- *Guarantees of origin (GO)*: The regulatory framework in the RES Directive has not provided sufficient clarity and suitable provisions for the creation of a comprehensive, liquid and harmonised GO system for all energy sources throughout the EU. It enables the provision of "green" supply contracts which are dissociated from the physical delivery of renewable electricity. The revision of this provision in the context of the legislative work for the post-2020 energy framework could look at improving the consistency in the application of the system by Member States as well as extending their use.

- *Bioenergy sustainability*: Indirect land use effects were not included from the very beginning in the EU mandatory sustainability criteria for biofuels and bioliquids. The related policy debate and regulatory amendments have created investors uncertainty and, in turn, a serious slowdown in investments, including in advanced biofuels. Different national implementation modes of the EU sustainability criteria, including a lack of mutual recognition of national

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accompanying the proposal for the RES Directive considered a reinforced "national action" approach without specific EU guidance as the most appropriate way forward. However, the REFIT evaluation concluded that even the reinforced provisions of Article 13(1) of the RES Directive have not substantially improved the situation and the public consultation for the present Impact Assessment demonstrated clear support for a more stringent approach and harmonised EU minimum rules in the post-2020 period.

certification schemes, have led to some market fragmentation. The lack of EU sustainability framework for biomass and biogas used in heating/cooling and electricity has also resulted in a growing debate, which in turn has prompt the introduction of national scheme, with possible market distortion.

In a post-2020 scenario consideration should be given to the opportunity of extending the sustainability criteria to account, not only for biofuels and bioliquids as it is already the case, but also for solid and gaseous biomass, in a cost-efficient way. Furthermore, the future framework should give consideration to effective and pragmatic ways to enhance renewables deployment, notably advanced biofuels, in the transport sector. This should build on the experience gained by many Member States with the implementation of national incorporation mandates for biofuels/renewable energy. Improved information and tracking systems are also needed to prevent fraud and abuse.

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SWD(2016) 418 final

PART 4/4

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Sustainability of Bioenergy

Accompanying the document

Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)

{COM(2016) 767 final}
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Table of Contents

GLOSSARY

Bioenergy	All energy produced from biomass sources
Biofuels	Liquid or gaseous fuel for transport produced from biomass
Biogenic emissions (and removals)	Greenhouse gas emissions and removals from various biological pools. In the case of bioenergy this includes emissions/removals from plant growth, combustion, decay, etc.
Biomass	The biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste
Black liquor	By-product from the chemical process of digesting pulpwood into pulp. It is used for energy in the pulp industry.
Carbon sink	Removal of CO2 from the atmosphere by vegetation and soil.
Carbon stock	The amount of carbon contained in the vegetation and soil of an area of forest or agricultural land
Co-firing	The combustion of two different types of materials at the same time. In the biomass context, co-firing generally means the partial replacement of coal by wood in existing coal-fired power plants
Feedstock	Biomass raw material which can be directly used as fuel or converted to another form of energy. Examples of biomass feedstocks include forest residues, straw, roundwood, short rotation coppice, maize, etc.
Forest residues	Biomass usually left in the forest after the harvest, such as tree tops, branches, bark, coarse dead wood, stumps and roots
Industrial residues (industrial by-products)	By-products or residues from the wood-processing industry (for example sawdust, shavings, trimmings and bark) and from the pulp and paper industry (black liquor)
Lifecycle emissions	Emissions generated by a product over its lifetime, from its creation until its disposal. In the case of biomass, the term refers to the emissions from the time the biomass material is initially cultivated or collected (in the case of wastes and residual biomass), until the final commodity is produced (being it energy, fuel or other materials).
Particleboard	Panel manufactured from small pieces of wood. These include for example low- and medium-density fibre boards, particle boards and oriented strandboard (OSB)

Pellets	Biomass for energy which has been dried and compressed in the form of pellets, with high energy density and low moisture content. Pellets can be made e.g. from wood or agricultural material. Pellets are produced for households and industrial market. They are traded commodities with standardized properties.
Pulpwood	Roundwood (excluding tops and branches) not satisfying the quality and/or dimensional requirements for the sawmill, veneer or plywood industries, but of sufficient size and industrial quality to be usable for the panels and pulp production.
(Industrial) Roundwood	Stemwood of industrial quality (i.e. sawlog or small industrial roundwood e.g. pulpwood)
Sawlog	Large diameter roundwood of sufficient length, straightness and other qualities, which can be used by the sawmilling industry
Short rotation coppice	Tree plantations established and managed under an intensive, short-rotation regime, typically on agricultural land. They can be established with quickly growing species such as willow.
Solid biomass	Biomass in solid form (currently mostly made from wood), by opposition to biomass in gaseous (biogas) or liquid (biofuels and bioliquids) form
Stemwood	Tree stems (excluding stumps, roots, tops and branches)
Thinnings	Trees removed during thinning operations, the purpose of which is to enhance the properties (composition, stability, quality, growth) of the residual stand through the selective removal of trees. It (temporarily) reduces stand density (volume), but can increase the increment of the remaining stand and reduce future losses due to mortality. This also includes trees removed to reduce fire hazard
Supply-chain emissions	Greenhouse gas emissions associated with the production of the bioenergy commodity. They include emissions from fossil sources used throughout the life cycle of the biomass, including cultivation, processing and transport. They also include emissions from direct land use change (according to methodology in Directive 2009/28/EC and COM(2010)11). They exclude biogenic CO2 emissions and removals.
Wood chips	Wood that has been reduced to small pieces (typically several centimetres across) and can be used for material production (pulp/panels) or as fuel.

ACRONYMS

CHP	Combined Heat and Power
ETS	Emissions Trading Scheme
GHG	Greenhouse gas
INDC	Intended Nationally Determined Contribution
IPCC	Inter-governmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
LCA	Life Cycle Analysis
LULUCF	Land Use, Land Use Change and Forestry
REDD	Reducing emissions from deforestation and forest degradation
NGOs	Non-Governmental Organizations
UNFCCC	United Nations Framework Convention on Climate Change

1. CONTEXT OF THE INITIATIVE

The 2009 Climate and Energy Package introduced a legislative framework to deliver a number of climate and energy objectives by 2020, namely a 20 % reduction in greenhouse gas (GHG) emissions, a 20 % share of renewable energy of all energy consumed in the EU and a 20 % reduction in energy consumption. The Directive 2009/29/EC on renewable energy sources (RES) was a key element of the 2009 package. It aims, in particular, to promote renewable energy sources, including bioenergy, and to deliver greenhouse gas emissions reductions as part of the EU's policy to tackle climate change.

The RES Directive established two objectives: (i) a 20 % target for renewable energy as a proportion of the total energy consumed in the EU; and (ii) a 10 % target for renewable energy as a share of energy used in the transport sector. This latter target has been implemented by Member States through various measures, including subsidies or obligations to blend biofuels into conventional petrol and diesel transport fuels.

The 2009 Climate and Energy Package also added a requirement to reduce the greenhouse gas intensity of the EU fuel mix by at least 6 % by 2020 compared to a 2010 baseline into the Fuel Quality Directive. Biofuels are expected to deliver most of this reduction.

Both, the Renewable Energy Directive and the Fuel Quality Directive contain binding sustainability requirements for biofuels that are accounted towards the above targets.

In January 2014, the Commission set out its views on a new policy framework on climate and energy for 2030, which was broadly endorsed by the European Council. The Commission indicated that it would not propose new targets for the share of renewable energy in the transport sector or for the decarbonisation of transport fuels. The European Council subsequently agreed three new targets for 2030: (i) a target to reduce the EU greenhouse gas emissions by 40 % relative to emissions in 1990, (ii) a renewable energy target of at least 27 % at Union level; and (iii) an indicative target for energy efficiency of at least 27 % at Union level. The implementation of these targets will be supported through the actions described in the Energy Union Framework Strategy in pursuit of its key objective — to provide households and businesses in the EU with secure, sustainable, competitive and affordable energy.

The EU has also an objective to decarbonise its economy by 2050 with an 80-95 % reduction of GHG emissions compared to 1990.[1] The Paris Agreement[2] established the goal to limit global warming to well below 2 °C relative to the pre-industrial level. In addition, the Agreement has an aspirational goal to pursue efforts to limit the temperature increase to 1.5 °C.

This initiative is closely related to several others:

– The Commission has adopted a legislative proposal on the distribution of effort between Member States in reducing national emissions of greenhouse gases outside

[1] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/119175.pdf
[2] http://unfccc.int/paris_agreement/items/9485.php.

sectors covered by the EU's emissions trading system.[3] The use of bioenergy is one of the tools available to Member States to meet those objectives.

– The Commission has adopted a legislative proposal on reducing emissions of greenhouse gases in the EU's emissions trading system (ETS).[4] The use of bioenergy is one of the tools available to ETS installations to comply with their obligations.

– The Commission has also adopted a proposal for a regulation on emissions in the land use, land use change and forestry (LULUCF) sector[5] which ensures that emissions from this sector are fully included in the EU's 2030 climate commitments, and makes the link between the use of wood for energy and forestry carbon stocks[6] in the EU.

– The Commission is preparing in parallel an initiative to promote sources of renewable energy in relation to the EU's target of 27 % of renewable energy by 2030. The current initiative can affect the use of bioenergy in the renewable energy mix, on the one hand by setting out sustainability restrictions, and on the other hand by giving more certainty to operators and acceptance to the public.

– The European strategy for low-emission mobility[7] provides analysis and scenarios regarding the use of bioenergy in the transport sector in the coming decades.

– The initiative on the future design of electricity markets, in conjunction with the reviewed renewables directive, will address the generation of electricity with the aim of reforming the markets in order to maximise the revenues and reduce the need for public intervention.

– The Commission has adopted an action plan for the circular economy, which encourages resource and energy efficiency, including through the cascading use of bio-based materials, such as wood.

This impact assessment therefore examines the need and options for a policy on the sustainability of bioenergy in the context of these other policy proposals.

[3] COM(2016)482.
[4] Revision of the ETS Directive :2015/148 (COD)
[5] COM(2016)479
[6] In national inventories, greenhouse gas emissions from wood combustion are accounted as zero in the energy sector because these emissions are accounted in the LULUCF sector – see more explanations in section 0.
[7] COM(2016)501

2. WHAT IS THE PROBLEM AND WHY IS IT A PROBLEM?

Bioenergy represents a significant part in the renewable energy mix in Europe. Traditionally, it has been used mostly for heat, but its use for transport and electricity production increased in the early 2000s, following the adoption of the 2001 Renewable Electricity Directive and the 2003 Biofuels Directive[8]. This increase was further driven by the adoption of the 2009 Renewable Energy Directive[9], which sets out national renewable energy targets for each Member State. Each Member States has prepared a National Renewable Energy Action Plan presenting how they intend to reach their national target, and in particular the planned mix of renewable energy technologies, including biomass. For renewables in transport, the policy was further complemented by the revised Fuel Quality Directive[10] requiring a reduction in the greenhouse gas intensity of the EU fuel mix by at least 6% by 2020. Public support in different forms, including subsidies, has then been put in place to implement these plans.

Although the recent development of bioenergy is mostly due to targeted policies implemented through public support, in some cases it has also been market driven. Although a precise quantification is difficult, model projections[11] for the period 2016-2020 show for example an increased capacity for biomass electricity in that period of 21 GW due to support schemes, and 5 GW market driven.

In 2014, bioenergy represented 60% of the final renewable energy consumed in the EU[12] and about 10% of the gross final energy consumed. Bioenergy is used mostly for heat, followed by electricity generation, and transport. It provided in 2014 88% of renewable energy in heating, and 19% of renewable electricity. Most of the bioenergy is used in solid form; biogas and liquid biofuels represent smaller shares (see Figure 1). Annex 5 provides more information and quantitative data about the production, use, and trade of bioenergy in the EU.

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[8] Directive 2003/30/EC
[9] Directive 2009/28/EC
[10] Directive 2009/30/EC
[11] Projections by PRIMES, see description of the modelling framework in section 0
[12] Bioenergy represented 103.6 Mtoe out of 174.5 Mtoe for renewable energy

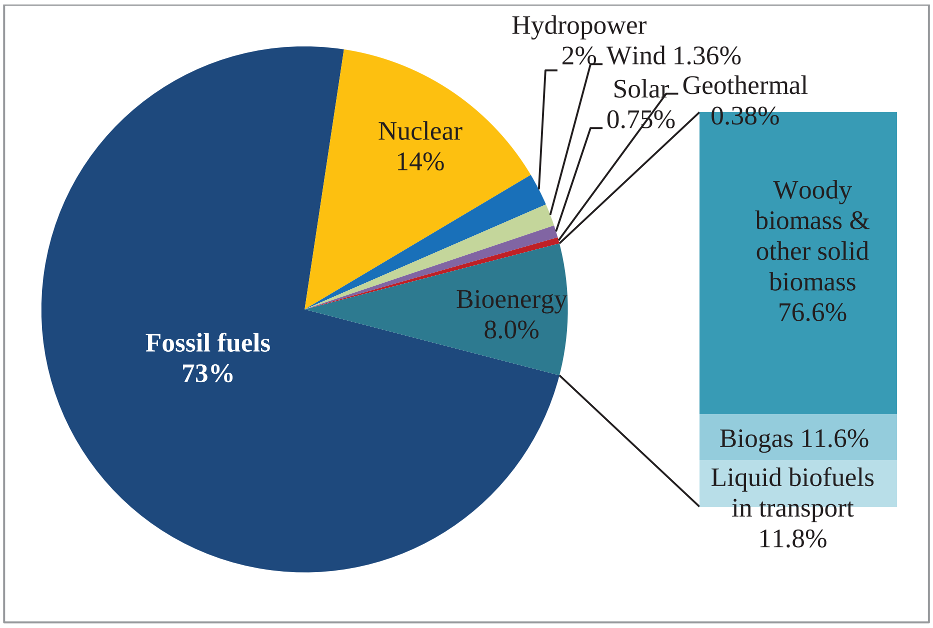

Figure 1: Gross inland energy consumption, EU 28, 2014 *(source: Eurostat)*

The use of bioenergy varies widely across Member States, as shown in Figure 2. In absolute terms, Germany, France, Sweden and Italy have the highest consumption of biomass for energy, whereas in relative terms, the highest share of bioenergy compared to other energy sources is found in Latvia, Finland and Sweden (in these three countries, bioenergy represents more than 30% of final energy consumption).

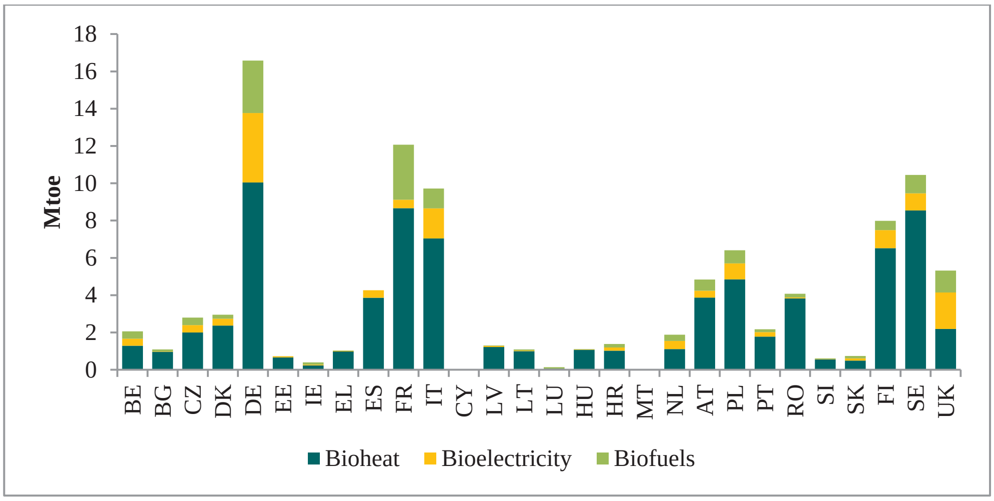

Figure 2- Final energy consumption of bioenergy in 2014 (Mtoe) per Member State in 2014[13]

The analytical modelling undertaken to support the 2030 climate and energy framework[14] projects an increasing role for bioenergy by 2020 and 2030 in order to meet the EU's climate and energy targets, as well as in the longer term to meet the 2050 climate objectives. Figure 3

[13] [13] Source: Eurostat/ JRC NREAPs Data Portal

[14] Projections for future use of bioenergy in the EU have been made in the context of the modelling work carried out in preparation of the 2030 climate and energy policy package, using the PRIMES model (see Annex 4).

shows the model projections for bioenergy use with the full implementation of the 2030 climate and energy targets, including a target for energy efficiency of 27% (EUCO27) or 30% (EUCO30).

The model projects that the use of bioenergy would grow steeply between 2015 and 2020 (increase of 27%), as a result of the implementation of EU and national binding renewable targets for 2020 by EU Member States. Between 2020 and 2030, bioenergy use would level off, due on the one hand to energy efficiency measures (reducing in particular demand in the heating sector), and on the other hand to a drop in the cost of other sources of renewable electricity. If the EU achieves a 27% energy efficiency target by 2030, bioenergy use would increase by 4% between 2020 and 2030. With a 30% energy efficiency target, bioenergy use would decrease by 2%.

The modelling also shows that there could be an increase in the post-2030 period in particular in the transport sector (advanced biofuels), driven by the 2050 objective of -80 % greenhouse gas emissions.[15]

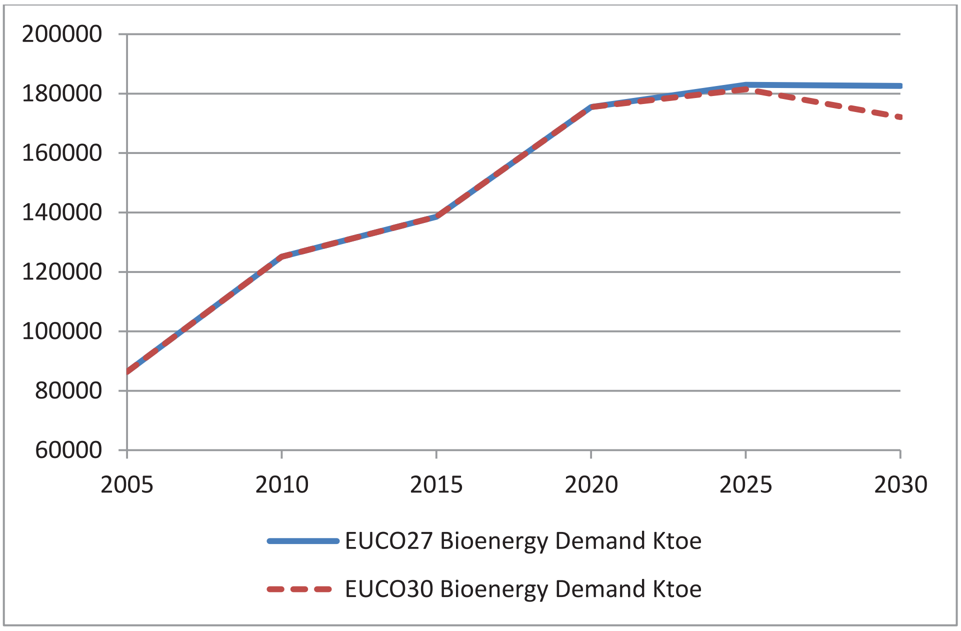

Figure 3: Historical and projected EU bioenergy demand as modelled by PRIMES

Figure 4 shows that the share of bioenergy in total energy demand is also projected to increase, up to 12-13% by 2030. This increase is driven both by the increase in total bioenergy use, and by a reduction in total energy demand as a result of energy efficiency measures.

[15] Source: PRIMES modelling. To be noted that overall the modelling projections for the post-2030 period are subject to higher uncertainty than for the period 2020-2030.

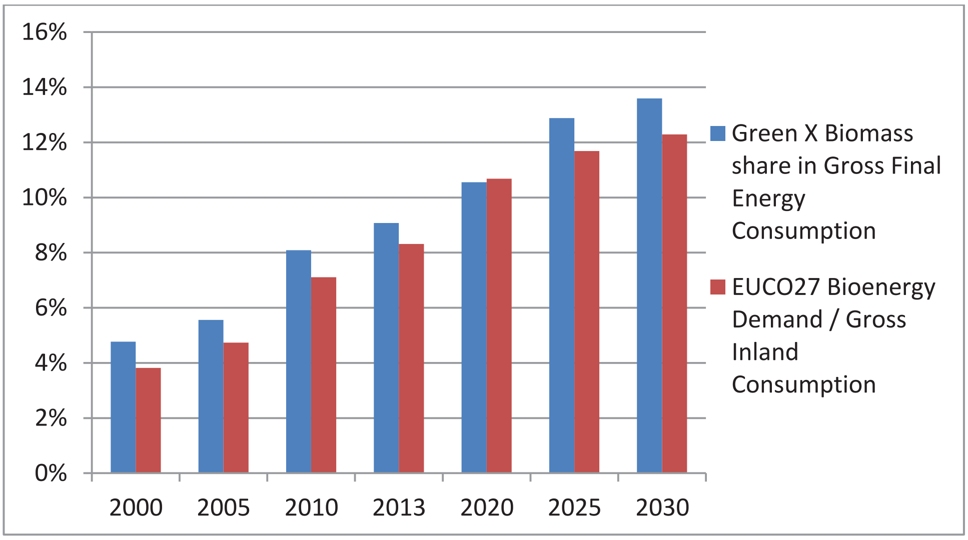

Figure 4: Share of bioenergy in total energy demand (Source: PRIMES/Green-X modelling)

Bioenergy therefore plays a key role towards delivering the EU climate and energy objectives, and this role will continue in the future. At the same time, a number of sustainability risks are linked to its increasing use. The public consultation carried out in preparation for this Impact Assessment has also clearly illustrated that the public opinion about benefits and risks of bioenergy is mixed. This can undermine investments in this particular sector, notably in the absence of a sound public policy framework.

With regards to biofuels used in transport and bioliquids, sustainability criteria have been established in the EU Renewable Energy Directive and Fuel Quality Directive. In 2015, amendments to these two directives have been included with the aim to address the specific issue of indirect land use change through a cap on the use of food-based biofuels. Indirect land use change impacts linked to the future policy framework on biofuels are examined in the Impact Assessment on the revised Renewable Energy Directive[16], as it concerns mainly the future of the cap on food-based biofuels and the enabling framework for advanced biofuels, which are both closely interlinked with the overall targets for renewable energy. The present Impact Assessment also examines whether existing sustainability criteria for biofuels need to be modified (see section 5.2).

The present Impact Assessment mostly examines sustainability issues related to **solid and gaseous biomass used for heat and power**.

On the basis of stakeholder inputs, studies and other scientific evidence, the Commission has identified four key problems or potential risks as follows:

1. ***The climate performance of bioenergy varies, and in particular biogenic CO_2 emissions associated with an increased demand for forest-based biomass may lead to minimal or even negative greenhouse gas savings compared with fossil fuels.***

2. ***The production and use of biomass for energy can lead to adverse environmental impacts on biodiversity, soil and air quality.***

[16] SWD(2016)418

3. ***The increasing combustion of large volumes of biomass in low-efficiency installations, driven by public support, can create additional pressure on resources, in particular in the case of electricity only plants.***

4. ***Increased administrative burden and related costs for operators induced by differing binding sustainability requirements across EU Member States.***

2.1. Climate impacts of bioenergy[17]

In the public consultation undertaken for the preparation of this initiative (see Annex 2), a vast majority of respondents supported climate change mitigation as the most important objective of the policy on the sustainability of bioenergy. However, their analysis of how to reach this objective varied: many of the respondents considered bioenergy as a risk to the climate, while many others considered it as an important contribution to climate change mitigation.

The impacts on climate change of solid and gaseous biomass used for heat and electricity are complex and can vary significantly (from very positive to very negative impacts, i.e. reducing or increasing emissions compared to fossil fuels). However, a growing body of scientific evidence is available to understand these impacts. A recent study[18] carried out for the European Commission has for example shown that, taken as a whole, bioenergy can make a significant contribution to greenhouse gas emission reductions, but that the level of this contribution depends on the scale and type of bioenergy considered: more specifically an increase in forest feedstock can result in net greenhouse gas emissions (as detailed in section 2.1.2).

The greenhouse gas performance of bioenergy from a lifecycle perspective depends on the **emissions from the supply chain** of bioenergy (which include emissions from direct land use change, cultivation, transport, processing[19]), as well as on **biogenic CO_2 emissions,** which include the emissions from combustion of the biomass source and the CO2 absorbed due to plant regrowth.

For agricultural biomass, supply chain emissions provide a good proxy for the lifecycle emissions[20] (excluding indirect land use change). For forest biomass, on the other hand, biogenic CO_2 emissions and removals — i.e. emissions and removals from the biological pools — need to be taken into account, and can have a critical role in the overall climate performance. Annexes 7, 8 and 9 give more in-depth information on biogenic carbon from forest biomass.

2.1.1. Greenhouse gas emissions from the supply chain

Emissions from the supply chain form a part of bioenergy's net greenhouse gas performance. In the case of biofuels for transport and of bioliquids, a specific requirement is set out as part of the existing sustainability criteria[21] in order to discourage the worst performing biofuels pathways in terms of supply chain emissions. This current requirement includes a

[17] This section does not include climate impacts due to indirect land use change
[18] Described in section 2.1.2 and Annex 8
[19] E.g. transformation into wood pellets
[20] Given that plant regrowth takes place over a short period.
[21] Included in the Renewable Energy Directive and the Fuel Quality Directive

methodology for calculating supply chain emissions as well as a binding minimum threshold for supply chain emission reduction compared to fossil fuels. Additional criteria were set to avoid the conversion of high carbon stock areas for biofuels cultivation.

A similar methodology (although non-binding) was developed by the Commission for solid and gaseous biomass used for heating and electricity production.[22] Supply chain emissions are compared against reference values for greenhouse gas emissions of fossil fuels (including both supply chain and combustion emissions) used for electricity and heating. The performance of different pathways is presented in Annex 6.

Supply chain emissions vary significantly for agricultural feedstocks[23], from a small fraction of fossil greenhouse gas emissions to much larger share, or even in a few cases higher emissions than those of the fossil comparator. Hence, **in some cases involving suboptimal technologies (**such as biogas produced from energy crops with an open digestate storage)**, the greenhouse gas savings associated with the production of bioenergy from agricultural feedstocks are small or negative**.

For forest-based feedstocks, supply chain emissions are usually low compared to the fossil fuel emissions, for most of the pathways commonly used today (including imports of pellets from third countries).

The supply chain emissions associated with bioenergy are generally[24] accounted for in national greenhouse gas inventories, primarily in the non-ETS sector (e.g. emissions from transport or cultivation).

Drivers

For solid biomass (including forest-based and short rotation coppice feedstocks), the main factors influencing greenhouse gas emissions from the supply chain are conversion efficiency, processing (technology and efficiency), the use of fertilisers, and (to a lesser degree) the distance and mode of transport.

For biogas, emissions vary significantly depending on the feedstock (e.g. emissions of biogas from energy crops are similar or even slightly higher than fossil fuels) and, mainly, the conversion technology (with methane leakage – both structural and accidental - playing an important role). Biogas production from animal manure on the other hand can reduce methane emissions which would otherwise be emitted into the atmosphere, provided that appropriate technological solutions are used (e.g. use of a gas-tight tank for the storage of the residual digestate).[25]

2.1.2 Biogenic greenhouse gas CO2 associated with forest-based biomass for energy

The assessment of the greenhouse gas performance over the entire lifecycle of bioenergy sources often only include emissions linked to the supply chain (described in the previous

[22] See in particular COM(2010)11 final and SWD(2014)259.
[23] Agricultural feedstocks include short rotation coppice
[24] To the extent they occur domestically and do not involve international maritime transport.
[25] Manure management is responsible for significant greenhouse emissions in the livestock sector. Anaerobic digestion and collection of the produced methane can reduce these emissions substantially.

section) and do not include the CO_2 released by the combustion of biomass. This is because it is assumed that the CO_2 emitted will be compensated by the CO_2 captured during plant regrowth.

However, compared to crops which regrow over short periods, forest biomass is part of a much longer carbon cycle. A forest stand typically takes between decades and a century to reach maturity. Recent studies have found that when greenhouse gas emissions and removals from combustion, decay and plant growth (so-called biogenic emissions from various biological pools) are also taken into account, the use of certain forest biomass feedstocks for energy purposes can lead to substantially reduced or even negative greenhouse gas savings compared to the use of fossil fuels in a given time period (e.g. 20 to 50 years or even up to centuries)[26]

Currently, the majority of the solid biomass used for energy purposes in the EU can be considered to deliver substantial greenhouse gas benefits even when taking into account biogenic emissions. This is because the forest biomass that is used consists mostly of industrial residues[27] as well as harvest residues (branches, tree tops) and traditional fuel wood. Studies show that these feedstocks generally deliver a beneficial greenhouse gas performance when compared to fossil fuels.[28]

However, this may change in the future if the demand for forest biomass continues to grow. In particular, the availability of industrial residues in the EU is limited and there is currently little spare capacity. There are also uncertainties over the types, amount and geographical origin of forest feedstocks which will be supplied in response to increased demand, but these could increasingly come from additional harvesting, rather than forest residue removal, and include feedstocks or forest management practices which are more risky in terms of their biogenic emissions, such as an increased use of small industrial roundwood[29] or stumps.[30] Hence, and as shown by a recent study[31] (detailed in ANNEX 8), **an increase in use of forest biomass for energy may lead to limited greenhouse gas savings or to an increase in emissions**.

The issue of biogenic carbon from forest biomass is one the most debated among stakeholders. The industry and forest owners generally see forest biomass overall as supporting climate change mitigation, whereas NGOs point to biogenic carbon emissions as one of the main risks from using forest biomass for energy.

Drivers

The contribution of biogenic carbon to greenhouse gas emissions of forest bioenergy is sensitive to the **scale of consumption**: a significant increase in forest biomass use is more likely to generate high biogenic emissions[32] (as discussed in ANNEX 7). Biogenic emissions could therefore be higher by 2030 and 2050, if a significant amount of forest biomass is used

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[26] See in particular JRC, 2014 'Carbon accounting of forest bioenergy' and Forest research, 2014 ‘Review of literature on biogenic carbon and life cycle assessment of forest bioenergy’.
[27] More than half of solid biomass use in the EU in 2013.
[28] See Annex 7
[29] E.g. roundwood of pulpwood quality
[30] See Annex 7
[31] ‘Carbon impacts of biomass consumed in the EU: quantitative assessment’ – Forest Research, 2015.
[32] Forest research, 2014 ‘Review of literature on biogenic carbon and life cycle assessment of forest bioenergy’. and Forest Research, 2015 'Carbon impacts of biomass consumed in the EU: quantitative assessment'

to meet the EU's climate targets. The scale of use of forest biomass will also depend on how other, non-forest feedstocks are used for bioenergy (e.g. agricultural residues, short rotation coppice, etc.) as well as on the overall bioenergy demand.

Uncertainties exist on the market response to an increased demand of wood for energy, which in turn can have an effect on its climate impacts. This concerns in particular the behaviour of forest owners: indeed, an increase in the demand for forest biomass for energy and the resulting increase in wood price can result in a higher harvesting intensity (leading to a decreased carbon stock in the forest), but also in better preservation of carbon stocks through avoided deforestation or increased investments in the forest (in order to secure future revenues)[33]. The responses are also subject to site-specific conditions and may be different for EU and non-EU forests. There is a lack of empirical data today that would allow for a more accurate assessment and quantification of these phenomena.

ANNEX 8 also discusses other issues related to the climate impacts of forest bioenergy, such as long-term impacts and non-greenhouse gas climate forcers.

Sustainable forest management practices (e.g. implemented through national legislation or in the context of certification schemes) play a role in mitigating the risk of overharvesting of forests. As such, they cannot guarantee that an increase in forest biomass for energy will deliver greenhouse gas savings,[34] but they can avoid excessive wood removals which would result in a decrease in carbon sinks.

Box: Forest biomass for energy and the accounting of GHG emissions in the land use, land use change and forestry (LULUCF) sector

Under international guidance[35] for the preparation of national greenhouse gas inventories, CO_2 emissions from biomass combustion are not reported in the energy sector ('**zero rating**'). This is to avoid double counting, because it is assumed that these emissions are accounted as part of the emissions from the land use, land use change and forestry (LULUCF) sector[36] in the same national inventory.[37] This zero rating has often been misinterpreted as meaning that biomass combustion emissions are always compensated by regrowth ('**carbon neutrality**').

The proposed EU 2030 climate framework mirrors international rules: biomass combustion counts as zero emissions under the EU ETS and the Effort Sharing Regulation because, to the extent they lead to carbon stock changes on land, emissions would be accounted for under the LULUCF sector.[38] Most of the domestic forest biomass harvest will come from the 'managed forest land' category, where emissions and sinks are accounted for by comparison to a projected reference level. Because the LULUCF sector is included in the EU's economy-wide objectives for greenhouse gas reduction by 2030, if emissions occur in the LULUCF sector

[33] Biomass for energy is generally a lower value product for forest owners, at the same time it can generate additional revenue and influence investment and/or harvest decisions.
[34] As shown in Forest research, 2015, where all scenarios examined assume that the level of forest harvest is less than the annual forest growth.
[35] From the Intergovernmental Panel on Climate Change (IPCC)
[36] For annual crops, the IPCC Guidelines assume that biomass carbon stock lost through harvest and mortality equal biomass carbon stock gained through regrowth in that same year and so there are no net CO_2 emissions or removals from biomass carbon stock changes. See also http://www.ipcc-nggip.iges.or.jp/faq/faq.html
[37] They are accounted as occurring instantaneously at the moment of harvest of the wood.
[38] COM(2016)479

from biomass used for energy, they would have to be compensated by emission reductions elsewhere in the economy.

Hence, after 2020 biogenic emissions from the use of EU-produced forest-based feedstocks for energy will be accounted by Member States in their national LULUCF inventories and towards their 2030 commitments, while supply chain emissions occurring in the EU (cultivation, transport etc.) will be accounted under the EU ETS and the Effort Sharing sectors.

This would also be the case for non-EU countries that have included the LULUCF sector in their overall GHG reduction objectives and account for these emissions towards their internationally agreed commitments.

2.2. Impacts on biodiversity, water, soil and air quality

The production and use of biomass for energy can cause harmful environmental impacts in certain cases. These concern mainly biodiversity, soil, and air quality.

The production of agricultural biomass can result in negative impacts on soils (e.g. loss of nutrients and soil organic matter, erosion, peatland drainage), water availability (in particular in water scarce areas[39]) and biodiversity[40]. A 2013 study[41] concluded that '*considerable potential risks to sustainability from biofuel cultivation exist, particularly risks to soils and to water quality and water availability*'.[42] The use of agricultural residues (such as straw) can also cause negative impacts on soils (fertility and structure) and on biodiversity if extracted in excessive amounts. On the other hand, the use of waste (for example manure) to produce biogas can significantly reduce methane and other emissions.
In the EU, the rules of cross-compliance under the Common Agricultural Policy ensure the implementation of existing environmental requirements and the requirement of maintaining land in good agricultural and environmental condition.

An increased production and use of forest biomass for energy can also cause negative environmental impacts.[43] For example, an excessive removal of harvest residues, or the removal of stumps, can harm soil productivity, biodiversity, and water flows.[44] If done sustainably, additional mobilisation of forest biomass can also have positive impacts (e.g. removal of early thinnings beneficial to biodiversity, improvement of forest structure, prevention of fires, pests and diseases, afforestation on eroded land, etc.). Often, such practices incur barriers (such as higher costs) compared to traditional forest management.

[39] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC102696/jrc102696%20online.pdf
[40] Study on Impacts on Resource Efficiency of Future EU Demand for Bioenergy, 2016, task 2: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/bioenergy/Task%202.pdf .
[41] https://ec.europa.eu/energy/sites/ener/files/documents/2013_tasks3and4_requirements_soil_air_water.pdf .
[42] The same study also states: '*It is evident that the soil, water and air risks from feedstock cultivation for biofuel are on the whole the same as the risks from any kind of agricultural expansion. However, the study has found that in many situations, biofuel markets bring additional pressure on the areas under existing agricultural use and have acted as an important driver in the intensification and expansion of intensive agriculture into areas with challenging soil conditions in particular.*'
[43] Study on Impacts on Resource Efficiency of Future EU Demand for Bioenergy, 2016, task 2: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/bioenergy/Task%202.pdf
[44] Deadwood and in particular coarse deadwood has an important role in preserving biodiversity in forests.

In the EU, sustainable forest management (SFM) is actively promoted in the context of the EU Forest Strategy[45] and in the Forest Europe process.[46] Most Member States have in place legislation and other measures to promote sustainable forest management practices.[47] There are however no EU-wide binding standards ensuring an equal and high level of sustainable forest management practices across the EU Member States, and such standards don't necessarily exist in non-EU countries that supply biomass to the European market.

Deforestation or other land use change (for example conversion of land with high biodiversity to cropland) is also a risk linked to biomass production[48]. It can happen directly or indirectly as a result of a higher demand for bioenergy. With regards more specifically to wood used for energy, it has been shown that an increase in demand and prices can lead to an increase in harvesting intensity, but at the same time to a reduction in deforestation due to the higher value of the standing forest.[49]

In the EU, the risk of deforestation is low given existing national legislation on forests. Restrictions for the conversion of grassland also exist (with variations among EU Member States). However these can take place outside of the EU, as a direct or indirect effect of EU bioenergy demand.

Finally, biomass combustion is a source of air pollution.[50] According to the World Health Organisation, residential heating with solid fuels (coal or wood) is an important source of particulate matters and carcinogenic compounds in particular in Central Europe.[51] Increasing the use of solid biomass for energy, in particular in domestic combustion and small and medium-sized installations, can therefore compromise air quality locally or regionally, particularly given the fact that most residential heating systems used today are relatively inefficient.

In the EU, Ecodesign requirements will enter into force in 2020 for solid fuel boilers and local space heaters[52] and ensure the efficiency of new devices. In addition, existing EU legislation on air pollution includes requirements on medium[53] and large combustion plants.[54]

The importance of risks to biodiversity and air quality from the use of biomass for energy has been highlighted by about one third of the respondents to the public consultation. These views

[45] COM(2013)659.
[46] http://www.foresteurope.org/
[47] http://ec.europa.eu/agriculture/forest/publications/pdf/sfcci-report_en.pdf _and Forest Europe – State of Europe's Forests 2015
[48] The existing sustainability criteria for biofuels forbid the conversion of land with high carbon stock (such as wetlands or forests) for biofuels production, as well as the cultivation of biofuels feedstocks on land with high biodiversity such as primary forest or highly biodiverse grassland. No such criteria exist for biomass used for heat and electricity.
[49] http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/bioenergy/Task%204.pdf
[50] For all air impacts, see the impact assessment on air policy (2013):
http://ec.europa.eu/environment/archives/air/pdf/Impact_assessment_en.pdf
and the impact assessment for solid fuel boilers and room heaters ecodesign regulation (2015):
http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2015/swd_2015_0092_en.pdf
[51] http://www.euro.who.int/__data/assets/pdf_file/0009/271836/ResidentialHeatingWoodCoalHealthImpacts.pdf
According to this report, each year 61 000 premature deaths are attributable to ambient air pollution from residential heating with wood and coal in Europe.
[52] Commission Regulation (EU) 2015/1189 and 2015/1185.
[53] Directive (EU) 2015/2193.
[54] Directive 2010/75/EU.

were present across the stakeholder spectrum, but were particularly frequent among civil society organizations, followed by public authorities and academic institutions.

Drivers

Environmental risks from the production of biomass for energy are driven by the fact that the increased demand for this biomass comes in addition to land and biomass needs for other uses, thus bringing additional pressure on resources.

With regards to air pollution, the increased use of solid biomass for heating in urban areas is a key driver, combined with the fact that most of the existing stock of domestic boilers and stoves is inefficient and polluting.[55] Ecodesign requirements will improve the situation, but the replacement of the existing stock will take time given the lifetime of such devices. More generally, the scale and location of biomass combustion also strongly influences its impacts on air pollution.

2.3. Efficiency of biomass conversion[56] and increasing competition for the resource

The efficiency of conversion of solid biomass to energy varies significantly depending on the type of conversion (i.e. to deliver electricity, heat, or combined heat and power) and the inherent efficiency of the plant. [57] The efficiency is generally in the range of 15-40 % to produce electricity only, 60 % and more in plant that combines heat and electricity production (combined heat and power – CHP), and up to 90-95 % in recent efficient CHP and heat only biomass boilers.

Burning biomass in an installation with a lower efficiency means that more feedstock is needed for a given energy output. Given that a number of sustainability risks linked to biomass production are sensitive to the scale of demand, a lower efficiency of conversion to energy will tend to accentuate these impacts; it also leads to higher air pollution. This issue has been raised by the NGOs and civil society, also pointing out its inconsistency with the goal of using resources efficiently.

In the EU, half of the EU Member States produced more than 80% of their bioelectricity in CHP plants in 2014. Nonetheless, approximately 40% of all the electricity generated from biomass is produced without making use of the heat[58], which corresponds to around 2% of total electricity production in the EU.

In the EU, a number of policies and measures exist to promote a more efficient energy production. In particular, the Energy Efficiency Directive encourages Member States to introduce measures promoting higher energy efficiency in energy production, including cogeneration of heat and power.

[55] For example, almost half of EU buildings have boilers installed before 1992, with an efficiency rate below 60% - see COM(2016) 51 final.
[56] This section looks at the efficiency of combustion facilities for biomass transformed into heat and power, but does not cover lifecycle efficiencies in bioenergy pathways, such as production and use of biofuels in combustion engines nor the efficiency of transmission of various energy types (electricity, heat) to final consumers.
[57] The same applies to the combustion of other solid fuels such as coal
[58] AEBIOM statistical report 2016

The efficiency of conversion of biomass to energy has also been raised in the context of the competition for the use of feedstocks, and wood in particular. The wood industry (including pulp and paper and wood panels producers) have expressed concerns around the development of large plants burning wood with low efficiency, and therefore requiring significant amounts of feedstock. Because these plants receive public support, this increases their capacity to pay for wood, which could cause market distortion (including an increase in wood prices) as industries do not receive such support. This applies particularly to sawmill residues (i.e. sawdust, used for panels), waste wood, and small industrial roundwood.[59] These concerns have also been expressed for certain non-EU countries exporting wood pellets to the EU.[60]

Currently there is no clear trend of wood price increase: global pulpwood prices have been falling, and overall in the EU pulpwood prices have been stable in the last few years, although this hides regional and local differences (such as substantial local price increases and even shortages of supply)[61]. In general, stakeholders from the above-mentioned industries do not observe major economic difficulties at the moment, however they see a risk if the demand for biomass continues to grow significantly. Stakeholders have also raised concerns linked to the emergence of competition for the use of wood already today at local or regional level, as well as in some non-EU countries[62].

Drivers

An important driver for the development of low efficiency conversion of biomass to energy is the fact that replacing coal by wood in existing coal-based power plants is an easy way to increase the use of renewable energy at national level without major additional investments or changes to the existing infrastructure. The national policies are in turn driven by the legally binding requirement to reach the 2020 targets. A number of Member States have therefore followed this path and given public support to such practices. Large-scale electricity-only biomass plants often receive state aid in order to be economically viable, as well as other advantages such as priority dispatch[63].

A recent study[64] found that subsidies to the use of wood for energy increase the purchasing capacity for energy use of feedstocks, and thereby can exacerbate competition between the energy sector and the panel and paper sectors. This concerns particularly the use of industrial residues (i.e. sawdust) and waste wood. Competition for pulpwood can happen when a pulp mill or a wood panel plant and a bioenergy plant are geographically close to each other so that their raw material catchment areas overlap. The same study points out that the impacts of subsidy regimes can vary depending on specific situations, in particular due to the subsidy scheme design, aid intensity, duration, etc. In 2014, the amount of subsidies for electricity produced from biomass was equal to approximately a fifth of all subsidies received by renewable energy in the EU. See more information on the level of subsidy in Annex 5.

[59] Sawnwood is generally not used for energy due to its higher price.
[60] See for example COWI, 2016: Environmental Implications of Increased Reliance of the EU on Biomass from the South East US - http://bookshop.europa.eu/en/environmental-implications-of-increased-reliance-of-the-eu-on-biomass-from-the-south-east-us-pbKH0116687/?CatalogCategoryID=DSoKABstDacAAAEjA5EY4e5L
[61] Modelling results show that there could be an increase in prices for harvested wood and semi-finished forestry products by 2030 (see Recebio, task 3 fig 8: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/bioenergy/Task%203.pdf)

[63] i.e. priority access to the electricity grid independently of the marginal cost of producing this electricity
[64] Vis M., U. Mantau, B. Allen (Eds.) (2016) Study on the optimised cascading use of wood

In addition, for installations covered by the EU Emissions Trading Scheme, burning biomass is counted as zero greenhouse gas emissions (because emissions would be accounted for in the land-use and forestry sector[65]) – in itself, this does not constitute an incentive for an efficient combustion of biomass.

Another factor relevant for the competition between different uses of feedstocks is the challenge to increase wood biomass supply in response to increased demand. A number of measures to increase wood biomass supply in the EU have long lead time (e.g. afforestation), require upfront investment (e.g. the cost of land and planting) or face other difficulties such as fragmented forest ownership structures or forest owners' lack of interest in harvesting, which slow down the response of the sector to market signals.

2.4. Fragmentation of the internal market

Most of the biomass in the EU is currently consumed within its country of origin,[66] because the bulkiness and relative low energy density and low value of the feedstocks makes it costly to transport over large distances.[67] Pellets, the most easily transportable and hence tradable form of solid biomass currently represent only 6 % of the biomass consumed for energy in the EU. Projections however show that the level of import of solid biomass from non-EU countries, mostly in the form of pellets, could rise from around 3 % of solid biomass today to 10-20 % in 2030,[68] although significant uncertainties remain over this level.

The 2014 report on the state of play of sustainability of solid and gaseous biomass notes that barriers to trade of biomass in and to the EU seem limited today, and there is no evidence that such barriers occur to a significant degree. However concerns related to the fragmentation of the internal market have been voiced by some stakeholders, in view of the fact that differing national schemes for the sustainability of solid biomass used for energy might impede intra-EU and/or international trade in biomass in the future. Currently, there is indeed no harmonised sustainability scheme at EU level for solid and gaseous biomass.

In 2010, the Commission issued a recommendation on sustainability criteria for solid and gaseous biomass, leaving Member States free to implement it. On that basis, several Member States who import large volumes of biomass from non-EU countries, such as the United Kingdom, the Netherlands, and Belgium have put in place mandatory sustainability requirements for solid and gaseous biomass used for electricity and heat. In Denmark, a voluntary sustainability scheme has been established in cooperation between industry and NGOs. The establishment of these schemes has been motivated by the need for these national governments to address public concerns about environmental impacts of the biomass originating from non-EU countries, particularly in the absence of an EU-wide scheme.

[65] see more explanations in the box in section 0

[66] In 2013, the biomass traded across borders (both within the EU and imports from non-EU countries) represented less than 7% of the total solid biomass consumed. Source: AEBIOM statistical report 2015.

[67] For example, according to a research by the Finnish forest research institute in 2013, the average procurement distance of woodfuels for heating plants in Finland was as follows: 2MW heating plant: 30km radius, 5MW heating plant: 60km radius, 20MW heating plant: 100km radius.
http://www.metla.fi/julkaisut/workingpapers/2013/mwp267.pdf.

[68] Source: modelling results from PRIMES, GLOBIOM and Green-X – see section 5.

In order to face these potential barriers, a number of large bioenergy companies have developed a voluntary, industry-led sustainability certification scheme (the Sustainable Biomass Partnership). The scheme is designed with the aim to ensure compliance with the differing national schemes that are in place. It is already recognised in UK and Denmark and has applied to be recognised in the Netherlands. Following the setting up of the scheme in 2015, 50 organisations have been certified by September 2016.[69]

Whilst projections show that the level of import of solid biomass from non-EU countries, mostly in the form of pellets, could increase substantially between now and 2030,[70] this increase in imports would mostly go to a small number of Member States, which in general already have a sustainability scheme in place[71]. It is also unlikely that Member States that mostly depend on domestic sources of biomass would develop such schemes, as for those Member States national policies on sustainable forest management are the main instrument to address sustainability risks.

Considering the proactive action taken by the industry, prospects for future imports and reliance on national forest management policies by most of the EU Member States, it is rather unlikely that the risk of fragmentation of the internal market, leading in turn to increased administrative burden for bioenergy operators, will materialise in the future.

[69] http://www.sustainablebiomasspartnership.org/ .
[70] Source: modelling results from PRIMES, GLOBIOM and Green-X – see section 5.
[71] In PRIMES projections, most of the increase in imports of solid biomass go to the UK

3. SUBSIDIARITY: WHY SHOULD THE EU ACT?

3.1. Legal basis

The Treaty on the Functioning of the European Union provides legal bases to act in the field of energy (art. 194), environment (art. 191) and the internal market (Article 114).

3.2. Necessity test: Can the Member States solve the problems on their own?

The EU renewable and climate change targets are set at EU level, and in particular the EU renewable energy target has been driving the significant increase in biomass consumption for energy in the EU over the past decade. It is therefore also necessary to ensure at EU level that the use of bioenergy to fulfil renewable energy targets is supporting the overall climate objective.

Some of the sustainability risks linked to the development of bioenergy have a cross border dimension and hence can be more efficiently addressed at EU level. This is in particular the case for environmental impacts such as climate change, biodiversity or air pollution. Market-mediated effects can also occur across borders, as is the case for example for indirect land use change and competition issues for biomass feedstocks.

Although cross border trade of solid biomass for energy is currently limited, it is expected to grow to some extent in the future. Hence internal market considerations are also relevant.

Member States can set their own sustainability schemes for solid and gaseous biomass to address the issues identified in Section 2. So far, only a minority of Member States have set up such schemes (mostly Member States which import biomass from non-EU countries).

On the other hand, all EU Member States have developed national policies on sustainable forest management, which are also relevant for sustainability of forest-based bioenergy.

3.3. EU added value: What would be the added value of action at EU level?

Action at EU level would:

- reinforce consistency with the different policies mentioned in Section 1 in the area of climate and energy, and in particular with the objective of climate change mitigation, as well as with other policy areas such as the Circular Economy ;

- provide a minimum assurance of sustainability for biomass used in all Member States and thereby provide reassurance to the EU operators, public authorities and the wider public;

- provide legal certainty to investors and operators.

In addition, it could prevent a possible fragmentation of the internal market.

At the same time, subsidiarity considerations will need to be adequately taken into account, in particular with respect to:

- the Member States' freedom to determine their energy mix as guaranteed by the Treaty on the Functioning of the European Union (Article 194);

- the clear wish of EU Member States to keep their national prerogatives to determine their policies for forest management.

4. OBJECTIVES: WHAT SHOULD BE ACHIEVED?

The development of bioenergy needs to be seen in the wider context of a number of Energy Union priorities, including the ambition for the EU to become the world leader in renewable energy, to lead the fight against global warming, to ensure security of supply and integrated and efficient energy markets, as well as other objectives such as to reinforce Europe's industrial base, stimulate research and innovation and promote competitiveness and job creation, including in rural areas. The commitment of the EU to meeting the 2030 Sustainable Development Goals should also be taken into account, as well as the compatibility with the circular economy. It is likely that the policy will require certain trade-offs; the policy options will therefore need to be carefully assessed against the various objectives presented below.

4.1. General objectives:

- Promote the prudent and rational utilisation of biomass as a natural resource
- Ensure bioenergy's positive contribution to reducing greenhouse gas emissions in the economy in the context of objectives set by the EU for 2030 and 2050
- Avoid or limit harmful impacts of bioenergy on the environment
- Ensure a stable legislative framework based on a functioning single market, security of energy supply in the EU and promote new and renewable sources of energy supply.

4.2. Specific objectives

For problem 1 (climate change impacts)

- Ensure that bioenergy use in the EU delivers a significant contribution to climate change mitigation, taking into account the full lifecycle emissions including biogenic carbon

For problem 2 (impacts on biodiversity, soil, water and air)

- Discourage practices that lead to harmful impacts on the environment, in particular on biodiversity and ecosystems, air emissions, soil fertility, and water. Promote practices with positive impacts thereon.

For problem 3 (inefficient use of biomass resources)

- Promote efficient uses of biomass for energy, including in the process of conversion to energy, taking into account competition and/or synergies between the energy and non-energy uses of biomass, as well as the potential for innovation;

Other

- Ensure coherence with other EU policies, in particular on climate, energy and agriculture, as well as environment and circular economy, and compatibility with international trade rules.
- Avoid disproportionate administrative burden, in particular for small economic operators

In the public consultation, respondents were asked to rank policy objectives for this policy in order of importance. The contribution of bioenergy to climate change objectives was by far the most important objective for all stakeholder categories. Other objectives that were seen as particularly important by stakeholders included long-term certainty for operators, the efficient use of biomass (including efficient energy conversion), the avoidance of environmental impacts, and the promotion of energy security.

5. POLICY OPTIONS

5.1. Baseline (option 1)

Under the baseline, no additional safeguard is set out at EU level on the sustainability of bioenergy for the heat and power sectors. Existing policies remain in place; however the baseline includes also a number of other elements of the 2030 Climate and Energy framework relevant for bioenergy sustainability. In addition, the existing policies remain in place.

In addition, a number of developments not included in the baseline will take place in other policy areas which are likely to have an effect on the way biomass is produced and used and hence on associated sustainability risks (although the outcome of these cannot be pre-judged). These include the review of the Regional Development Policy, as well as the Common Agricultural Policy. Public support schemes will also have an impact on bioenergy development; these would have to comply with the Environment and Energy State Aid Guidelines, which will be reviewed for the period after 2020.

The baseline scenario also includes relevant national policies (in particular national schemes for the sustainability of biomass for heat and power as well as national policies on sustainable forest management) and industry-led sustainability certification schemes for bioenergy or forest management.

Box: relevant policies included in the baseline (option 1)

Existing EU policies

- The legality of wood-based biomass placed on the EU market continues to be subject to the Timber Regulation and the Forest Law Enforcement, Governance and Trade action plan (FLEGT)

- Ecodesign rules for small solid fuel boilers (<0,5 MW) are implemented as of 2020 (2022 for solid fuel local space heaters)

- Existing EU legislation on environmental protection continues to apply (including on air emissions, biodiversity, and water protection)

- The EU Rural Development policy continues to apply and in particular the possibilities to support wood mobilisation under the European Agricultural Fund for Rural Development (EAFRD)[72]

New EU policies as part of the Energy Union Strategy and the 2030 Climate and Energy Framework

- the revised Renewable Energy Directive

- the new framework on the internal market for electricity,

[72] In particular through the sub-measure "Investments in forestry technologies and in processing, mobilising and marketing of forest products." For the new 2014-2020 programming period more than 80 Rural Development Programmes (out of 118) have included this sub-measure.

- the revised Energy Efficiency Directive

- the regulation on the governance of the Energy Union

- the regulation on emissions from Land Use, Land Use Change and Forestry

- Bioenergy will also continue to benefit from a zero rating under the Commission proposals reviewing the EU Emission Trading Scheme and the Effort Sharing Regulation.

Member States policies

- Member States can continue to set their own sustainability requirements for biomass used for heat and power.

- Member States continue to apply national rules and legislations on sustainable forest management

International agreements

- The Paris Agreement on climate change is implemented by the EU and by non-EU countries that are parties to it.

In the public consultation, 35% of stakeholders responding to the public consultation considered the current policy framework to be sufficient for addressing these risks. The bulk of replies going in this direction came from private and public enterprises and from public authorities. To be noted that within the sub-group of public and private enterprises, about two-thirds of forestry enterprises considered the current framework as sufficient and only one third called for a new policy. Inversely, only one-third of energy enterprises were content with the current rules and two-thirds demanded a new policy. SMEs were more often supporting the current framework, whilst two thirds of large enterprises were in favour of a new policy. Professional association representing European forest owners supported the status quo, as well as several forest-rich Member States.

5.1.1. Modelling framework

In preparation for this impact assessment, three complementary modelling exercises have been performed, in order to understand the impacts of the baseline scenario as well as of the policy options (the modelling tools are described in more detail in Annex 4):

- **The overarching PRIMES modelling** carried out in preparation of the implementation of the 2030 climate and energy framework (including projections for supply and demand of bioenergy). The baseline is represented by the EUCO 27 scenario, which achieves by 2030 the 40% target for the reduction of greenhouse gas, a 27 % share of renewable energy, and 27 % energy efficiency improvements (a scenario with 30% energy efficiency improvement is also modelled). These projections reflect a cost-effective achievement of the various targets and in particular a technology-neutral way to achieve the share of renewable energy, taking into account existing policies.

- **A modelling exercise with GLOBIOM (global economic land use model) and G4M (forestry sector model)**, which uses the total bioenergy demand and production results projected by the PRIMES biomass module for the above-mentioned EUCO 27 scenario as an input. Nevertheless GLOBIOM provides its own detailed projections in term of the material and energy use of woody feedstocks (roundwood, industrial by-products, pellets imports, etc.[73]) and gives projections on commodity prices, land impacts, and greenhouse gas emissions from the land use, land use change and forestry sector.

- **A modelling exercise with Green-X (EU renewable energy model), combined with ArcGIS Network (geospatial model for biomass transport chains) and MULTIREG (input-output model)**, which models the breakdown of renewable energy sources and bioenergy feedstocks as well as greenhouse gas emissions from the energy sector, and economic and social impacts such as gross value added, investment, and jobs.

In the case of PRIMES and GLOBIOM, the results presented include projections to 2030 as well as trends for the period from 2030 to 2050 (for 2050, a greenhouse gas target of -80% is applied in PRIMES). The modelling results are presented in this impact assessment, but it is important to note that the period post-2030 is subject to significantly higher uncertainties.

5.1.2. EU Biomass demand and supply in the baseline

The projections presented on this section are based on the modelling exercises presented in section 5.1.1.

Overall demand and supply of bioenergy

By 2030, the demand for bioenergy is driven by the targets for greenhouse gas emissions reductions and renewable energy. The target on renewable energy by 2030 is set out at EU level, with each Member State delivering a national contribution. Public support will likely be based on the national plans and the choice of Member States for their renewable energy mix; however the modelling only considers the most cost-effective way to reach the target at EU level[74].

PRIMES finds that the steepest increase is projected to take place between 2015 and 2020, in order to meet the 2020 renewable energy target (+27 % increase in bioenergy use in the period). After 2020, bioenergy increase levels off (+4 % for the period), particularly between 2025 and 2030 where no increase is observed. If energy efficiency reaches 30%, the total demand of bioenergy would decrease slightly (decrease of 2% between 2020 and 2030).

Green-X finds a somewhat different trajectory whereby total bioenergy demand is lower than projected by PRIMES in 2020, and would still increase by 17 % between 2020 and 2025, and then no longer increase until 2030.

The overall supply in 2030 is very similar for both models, although the growth in the period is higher for Green-X due to a lower level in 2020. Another notable difference is the level of domestic forestry use, which is significantly higher in Green-X.

[73] The level of use of short rotation coppice is taken directly from the PRIMES projections
[74] However in the modelling investments financed up to 2020 based on support schemes still benefit from these support schemes after 2020

The share of bioenergy vs other renewable energy sources is found to decrease slightly over the period both by Green-X (53.7 % in 2020 to 50.4 % in 2030) and by PRIMES (61 % in 2020 to 54 % in 2030).

By 2050, the objective of reducing greenhouse gas emissions by 80% further drives an increase in bioenergy use. For the period 2030-2050, PRIMES results show a steep increase of bioenergy demand (+46 % increase), driven by the transport sector[75] and the share of bioenergy in renewable energy decreases further (50 % in 2050).

Both PRIMES and Green-X find little variation in absolute levels of biofuels consumption between 2015 and 2030. The share in 2030 is around 12-13 % of total bioenergy use.

After 2030, PRIMES projects the share of biofuels to increase significantly (constituted mostly of advanced biofuels) to reflect the need to decarbonise the transport sector, including the aviation sector. On the other hand, the growth in the use of solid and gaseous biomass needed for electricity and heating is limited in particular by improvements in energy efficiency in the residential sector (for heating), and by the stronger development of other renewable energy sources such as wind and solar (for electricity). Hence, PRIMES projects that the demand for solid biomass for heating and electricity would stay stable between 2030 and 2050.

Feedstocks and geographical origins for solid and gaseous biomass

Regarding biomass produced in the EU, Green-X projects a rise between 2020 and 2030 mostly driven by an increase in agricultural residues (doubling over the period) and forestry products (including forest and industrial residues). GLOBIOM/PRIMES find a less marked increase in agricultural residues, but a substantial increase in industrial residues use for energy.[76] GLOBIOM also finds a doubling of domestic roundwood use for energy over the period, but this feedstock remains under 1 % of total bioenergy demand.

The models also project different levels of imports of solid biomass from non-EU countries: up to 20 % in 2030 for PRIMES, 8 % for both Green-X and GLOBIOM. PRIMES and Green-X find that most of the increase in imports would take place between 2015 and 2020 while GLOBIOM still foresees an increase of 60 % in imported pellets between 2020 and 2030. Future levels of imports of solid biomass are particularly difficult to estimate given that the development of the wood pellets market is very recent, and that the future demand for biomass in non-EU countries is difficult to predict.

Green-X also projects an increase in intra-EU trade, which by 2030 is at a level comparable to imports from third countries.

5.1.3. Evolution of the problems under the baseline

Climate impacts

[75] There is a high uncertainty after 2030 on the cost and availability of technologies for such a development of advanced biofuels as well as on land availability, hence these findings must be taken with precaution.
[76] Due to the increase in demand for sawnwood, as well as an increase in their profitability. This rise is modelled by GLOBIOM, whereas the share of agricultural residues is projected by PRIMES.

In the baseline scenario, no specific measures are taken to address greenhouse gas emissions from the supply chain for biomass used for power and heat, nor on biogenic emissions from forest bioenergy. In the EU, these emissions are accounted for in national inventories and will be included in the EU 2030 targets with specific tools (supply chain under the Emission Trading Scheme/Effort Sharing and biogenic under the LULUCF sector), which however does not guarantee that pathways with a higher greenhouse gas performance will be promoted.

The evolution of these emissions will depend on the magnitude of the demand for bioenergy and the type of biomass feedstocks that will be used to fulfil this demand.

Supply chain emissions have been calculated by Green-X for the year 2030 by projecting the difference between the Fossil Fuel Comparator and supply chain emissions from biomass used for heat and power ("Savings" - according to the methodology developed by the Commission and described in ANNEX 6). The same has been done for other renewable energy. The results are presented below, in absolute terms, and by unit of energy.

	Savings from supply chain in 2030[77] (MtCO2)	Total demand (Mtoe)	Savings from supply chain per unit of energy (tCO2 /toe)
Biomass for heat and electricity	501.2	127.7	3.92
Other renewables for heat and electricity	1 005.8	144.4	6.97
Total renewables for heat and electricity	1 507	272.2	5.54

Table 1: Greenhouse gas savings from biomass supply chain and other renewable energy sources compared with fossil fuels *(this doesn't include biogenic CO_2 emissions from forest biomass)*

Biogenic emissions from forest feedstocks are examined in the BioImpact study.[78] The study results are described in ANNEX 8; they show that in a scenario corresponding to the baseline (i.e. increase in bioenergy demand but no safeguards in place), an increase in the use of forest feedstocks for energy would result in either little or no additional greenhouse gas emission reduction or in an increase in greenhouse gas emissions by 2030, due to biogenic carbon emissions.

By 2050, if this increase in demand for forest feedstocks continues, it would result either a small or large increase in greenhouse gas emissions. All scenarios examined in the study assume a level of harvest lower than the annual forest growth — if that isn't the case, the associated biogenic emissions would be higher.

Uncertainties exist over the level of these biogenic emissions. These include in particular the level of supply from different bioenergy sources, as well as trade patterns. For example, if a higher amount of agricultural residues or short rotation coppice is used, less biomass from

[77] Calculated as the difference between a fossil fuel comparator and supply chain emissions from renewable energy sources
[78] 'Carbon impacts of biomass consumed in the EU: quantitative assessment' – Forest Research, 2015.

forests would be used and biogenic impacts from forest feedstocks would diminish.[79] A sensitivity analysis was run for a scenario where the development of short rotation coppice is significantly faster than in the baseline using the GLOBIOM/G4M model, this resulted in a decrease in total emissions from land use and forests compared to the baseline (the results are described in section 6.3.1.2).

Other uncertainties exist due to the limitations of the modelling and the assumptions used (see ANNEX 8).

In the baseline scenario, these biogenic emissions would be accounted for in the national greenhouse gas inventories of the country where the harvest took place, as emissions from the LULUCF sector. This will be the case for harvest both in the EU as well as in non-EU countries which account for these emissions in the context of economy-wide greenhouse gas reduction targets post-2020 (this is likely to include all of our current main trading partners, but might not be the case if trade develops with other non-EU countries). This means that where forest biomass is used for energy, the related changes in forest sink would have to be compensated by emission reductions elsewhere (in the land use and forestry or other sectors). Overall, therefore, the country in question would still meet their greenhouse gas target, though it may be at a higher cost.

Accounting for biogenic emissions in the LULUCF sector could reduce the incentives for harvesting certain types of forest biomass for energy that would reduce the forest sink. This phenomenon is difficult to assess, as it will largely depend on the degree to which the negative impact of the harvest on national greenhouse gas inventories will be passed on to operators, and how these would counterbalance positive incentives (e.g. the additional income from the sale of biomass for energy). In some cases, split incentives could occur between different operators (such as the zero rating for an ETS operator vs LULUCF accounting for a national government, or production in a country and consumption in a different one).

In conclusion, under the baseline scenario there is a risk that biogenic emissions would increase as a result of a rise in forest biomass use for energy. This increase in emissions could negate the benefits of a higher use of forest biomass to substitute fossil energy, but the degree to which this would happen is uncertain.

Environmental impacts

In the baseline scenario, Member States would still be able to introduce sustainability criteria for solid and gaseous biomass at national level. Other EU and national policies related to environmental protection would stay in place, as well as the EU Timber Regulation to reduce the risk of using illegally harvested forest biomass for energy in the EU. At the same time, legality checks do not automatically ensure safeguards on biodiversity or land use.

The GLOBIOM/G4M modelling projections show an intensification in the use of forests in the EU in the baseline scenario, both due to material and energy use. An increased use of imports of forest biomass could also lead to intensification of forest harvesting in non-EU countries and/or conversion of unused forests to used forests. Increased imports can also be a

[79] The total demand for domestic and imported primary biomass (excluding waste and black liquor) in the BioImpact study is higher in 2030 than the amounts modelled by PRIMES, but for 2050 the total for PRIMES falls in the same range as the BioImpact scenarios.

positive driver to support the economic value of forests in third countries and thus help reduce deforestation for other uses such as urbanization.

Efficiency of conversion

In the baseline scenario, electricity from biomass can be produced either from combined heat and power plants (CHP) or from less efficient, 'electricity-only' plants. The latter also includes co-firing, i.e. the partial replacement of coal by wood in existing coal-fired power plants.

EU-wide policies on renewable energy and market design introduced as part of the 2030 climate and energy framework should have an impact on the degree to which biomass electricity without CHP is produced.

In particular, the proposal on market design includes a removal of priority dispatch (i.e. the practice of giving priority access to the grid to certain technologies, including electricity from biomass, independently of their marginal cost). Since electricity from biomass without CHP will typically be more costly than other renewable electricity (including electricity produced from biomass with CHP), this could significantly reduce the amount of biomass used for electricity, and lead to cheaper feedstocks (such as waste streams) being used rather than wood. In addition, biomass for electricity could be used more as a flexible dispatchable generation, rather than subsidised baseload. This has been modelled in the Impact Assessment on the internal market for electricity. [80]

This impact can however be cancelled if subsidies in the form of operating aid are continued to be given to biomass electricity-only plants, thus de facto reducing their marginal cost of production.

The PRIMES projections are based on a cost-effective achievement of the renewable energy target, and as such don't include elements on priority dispatch. They however show that the total use of solid biomass in ‘electricity only’ plants (including co-firing and biomass-only plants) would increase by approximately 5.4 Mtoe (from 2010 to 2020 the increase in solid biomass use for electricity without CHP was 4.2 Mtoe). This increase takes place mostly between 2020 and 2025; as a result the production of electricity without CHP from biomass represents on average 10 % of solid biomass consumption for energy in 2025-2030 (up from around 3% in 2015 and 6% in 2020). To be noted that, according to the model projections, this increase takes place mostly in one Member State (United Kingdom).

[80] SWD(2016)410

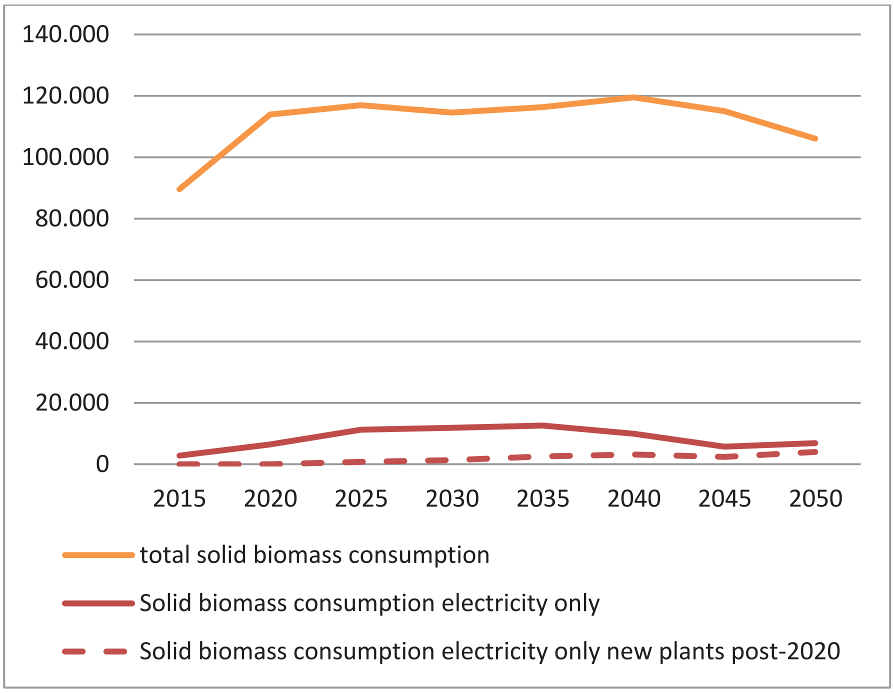
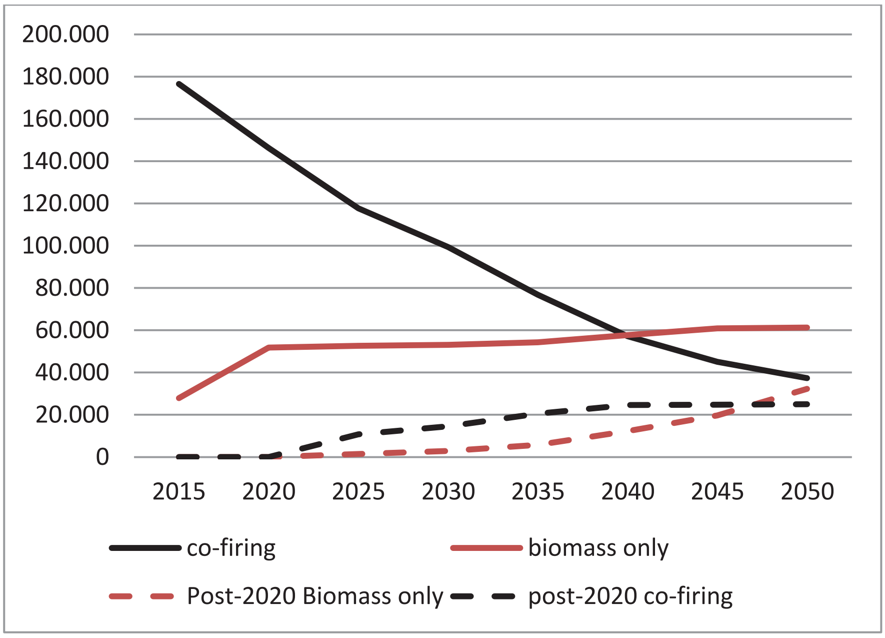


Figure 5: Solid biomass consumption in ktoe (total and electricity only) — Source: PRIMES modelling

This increase in production of electricity without CHP corresponds however to a situation where the total installed capacity for co-firing with coal drops, and the capacity for biomass-only plants stabilises after 2020. Hence, the increase mostly takes place via a more intensive use of already existing installations (for example, an increase in the share of wood burned alongside with coal in existing co-firing plants), while the number of new installations is very limited (approximated to only 1 % of the total solid biomass consumption[81]).



[81] Projections carried out with PRIMES assume for the period after 2020 no support for new installations and a gradual phase out of support for existing installations

Figure 6: Capacity (MW) for solid biomass electricity plants — Source: PRIMES modelling

Competition for biomass resources

In the baseline, the increase in wood consumption for energy has impact on the price of wood and wood products, as shown by the GLOBIOM model[82]:

- EU prices for sawlogs and pulplogs increase more as a result of bioenergy consumption, as well as the price of particleboards. The increase is particularly sharp for pulpwood (+15 % in 2030 and +37 % in 2050). However in the same period the increase of price of sawnwood is less marked (-3 to 6 % compared to a scenario with constant bioenergy), as a result of the increase in the price that sawmills can sell the industrial residues (due to increased demand for these from the energy sector);

- the increases in prices for sawlogs and pulpwood would however not occur or be significantly lower in a scenario where imports of wood for energy from non-EU countries would increase significantly[83] compared to the projected estimates for the baseline.

5.2. Policy options

Based on existing studies, on the inputs from stakeholders and on internal analysis, a range of policy options were screened to respond to the problems identified in the problem definition. Five policy options (including the baseline) were further developed. The common denominator for all the options except the baseline is that compliance with the requirements set out for bioenergy would be a condition for bioenergy to be accounted towards the 2030 renewable energy target or national targets or to receive public support (including the zero accounting for emissions under the EU ETS). More far-reaching policy options, such limiting biomass use for energy or removing all public support for bioenergy, were not considered as i) it was considered disproportionate to the magnitude of the identified risks and ii) it would go against the principle of leaving primary responsibility to Member States on the choice of instruments to reduce emissions.

Each policy option contains elements that respond to some or all of the problems identified in Section 2. Table 2 summarises how each policy option addresses the problems.

Among the policy options that were screened at the beginning of the process, a number were examined but discarded at an early stage. This was mainly linked to concerns regarding their implementability at the EU level, as well as issues with proportionality and effectiveness. Further explanation on the main discarded options is presented in the box below and information on additional discarded options is presented in Annex 10.

Regarding biofuels, it was examined whether the existing sustainability criteria should be modified. Based on the results of the recent REFIT evaluation and of the stakeholders' consultation, it was concluded that improvements are needed that facilitate the

[82] http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/bioenergy/Task%203.pdf – in line with baseline scenario

[83] Imports of pellets increase by 2.4 times in 2030 and more than 4 times in 2050 compared to the baseline scenario.

implementation of the criteria avoiding duplication and overlaps with other policies, but that the level of environment protection should not be changed in substance (more details in the box below). Further, the competences of the Commission with regard to the supervision of voluntary schemes should be strengthened in order to ensure a harmonised implementation of the sustainability framework with a low administrative burden.

Box: Main discarded options — overview

- Modifying the sustainability criteria for biofuels *(problems 1 and 3)*

The sustainability criteria for biofuels have been introduced in 2009 and updated in 2015. The REFIT evaluation[84] of the Renewable Energy Directive finds that these criteria have effectively reduced direct environmental impacts of the biofuels used in most of the EU, but also point to the associated administrative burden for putting in place verification systems and ex-post monitoring tools.

In the public consultation, stakeholders pointed to three issues related to biofuels. The first one concerns indirect land use change (problem 2). Stakeholders were also of the view that sustainability criteria haven't adequately addressed the protection of soil and water (see discarded option on introducing requirements on soil and water quality in Annex 10).

Finally, many industry stakeholders pointed to the administrative burden of the existing sustainability criteria, particularly concerning the implementation of the criteria at national level (e.g. mutual recognition of the schemes between Member States or risk of fraud), but also regarding the design of certain criteria. The content of the criteria as such was not put into question. Therefore, it is not deemed necessary to substantially reopen the biofuels criteria, although improvements in the definitions and verification systems in particular will be explored[85].

- Capping the overall amount of bioenergy

This option is supported in particular by environmental NGOs, who point to the fact that sustainability issues for bioenergy are sensitive to scale. However, this option would indiscriminately cap all bioenergy feedstocks and origins, without distinguishing between the feedstocks which deliver benefits and the ones that don't. It doesn't seem justified to cap feedstocks that are clearly beneficial for climate mitigation and the environment. Therefore this option is discarded, and instead a partial cap on specific feedstocks (roundwood and stumps) is explored in option 5.

- Introducing biogenic carbon emissions in the methodology on lifecycle emissions from solid biomass

This option would ensure that biogenic CO2 emissions are included in the lifecycle greenhouse gas performance of forest biomass, on top of supply-chain emissions. This would allow for a full picture of climate impacts from these feedstocks. This is in line with the agreement in the scientific community that adequate account of biogenic CO2 emissions is needed.

As described in the problem definition, biogenic emissions and removals are often not accounted in standard lifecycle analysis (LCA) because it is implicitly assumed that the plant regrowth will compensate them. However, because of the time lag between emissions and regrowth, a number of studies have started to include both biogenic emissions and removals in the LCA analysis. The findings[86] show a wide variation of greenhouse gas impacts (from very positive to very negative), depending on a number of factors, as well as on the time horizon considered. Studies also stress that it is very difficult to attribute a greenhouse gas performance to a specific consignment of forest biomass. While the combustion emissions are easy to calculate, the benefits accruing to biomass production are difficult and uncertain to estimate, and certain feedstocks can have positive or negative impacts, depending in particular on the counterfactual scenario (i.e. what would otherwise have happened with the wood and with the land).

Hence, while an assessment of the overall greenhouse gas impact of an increase of demand in forest biomass is possible and has been modelled (with the inherent limitations to any prospective modelling exercise), a reliable assessment of lifecycle biogenic emissions of specific consignments or pathways of forest biomass would be extremely difficult, notably because it would have to be based on subjective choices. In addition, it would pose difficulties linked to verification. Therefore, this option is discarded.

- Applying requirements on sustainable forest management to all forest biomass, regardless of its origin

For forest biomass, the land criteria would be replaced by a criterion on Sustainable Forest management in order to demonstrate that forest biomass is sourced through sustainable forest management practices and this should be demonstrated by means of certification.

The option was discarded due to its proportionality (high increase of costs for forest owners) and subsidiarity concerns. The requirement to certify all the forest will be a heavy burden for the number of private forest owners, in particular for small forest owners. The strict requirements of the sustainable forest management criteria are less consistent with the subsidiarity principle and do not respect the competence of EU Member States on forests. In addition, transposition of such requirements will also be burdensome for public administration

Details on the reasons for discarding other policy options is given in Annex 10, they include:

- introducing requirements on soil and water protection for agricultural feedstocks;
- removing the requirement for a minimum greenhouse gas performance on supply chain emissions for biofuels;
- requirements on the level of harvest of forest residues;
- mandatory requirements for the cascading use of wood (i.e. prioritisation to the material use of wood before its conversion to energy)
- requirements for air pollution;
- application of sustainability requirements to all biomass users, including residential.

[86] See in particular 'Carbon accounting of forest bioenergy' JRC, 2014 and Forest research, 2014 'Review of literature on biogenic carbon and life cycle assessment of forest bioenergy'.

Problem/Option	Option 1 (Baseline): no additional EU action	Option 2: extensions of the biofuels sustainability criteria	Option 3: risk-based approach for forest feedstocks + LULUCF requirements	Option 4: minimum energy efficiency requirements	Option 5: cap on roundwood and stumps for energy
Supply chain greenhouse gas emissions	National schemes + emissions accounted in national inventories (ETS and non-ETS sectors)	Minimum requirements for supply chain emissions	As per option 2	As per option 2	As per option 2
Conversion of land with high carbon stock	Legality of wood under EU Timber Regulation (EUTR)[87]	Establishment of 'No-go areas'	Risk-based approach for forest feedstocks (protection of high carbon stock areas), as per option 2 for agricultural feedstocks	As per option 2 or 3	As per option 2 or 3
Biogenic greenhouse gas emissions	National schemes + emissions accounted in national inventories (LULUCF)	As in baseline	Risk-based approach with minimum requirements for sustainable forest management + minimum requirements on LULUCF emissions	As per option 2 or 3	As per option 2 or 3 + cap on the use of roundwood and stumps
Impacts on biodiversity	EU and national policies	'No-go areas'	Risk-based approach: minimum requirements for sustainable forest management for forest feedstocks + protection of high biodiversity areas; as per option 2 for agricultural feedstocks	As per option 2 or 3	As per option 2 or 3 + cap on the use of roundwood and stumps
Impacts on soil, water and air	EU and national legislation	As in baseline*	As in baseline*	As in baseline*	Cap on use of stumps
Efficiency of conversion	Eco-design rules for small boilers, enabling policies on energy efficiency (EU and national)	Efficiency of conversion taken into account in supply chain emissions methodology	As per option 2	Minimum level of conversion efficiency	As per option 2
Competition for different uses	National policies, guidance at EU level on the cascading use of biomass	As in baseline	As in baseline	Minimum level of conversion efficiency, thus freeing up resources for other uses	Cap on the use of roundwood

Table 2: Intervention logics: how the problems identified in the problem definition are reflected in the policy options **** see also Annex 10 with discarded options***

[87] The EU Timber regulation requires any timber or timber product placed on the EU market to be legally sourced.

Option 2: Extend existing sustainability criteria for biofuels to solid and gaseous biomass for heat and electricity

Under option 2, the sustainability criteria for biofuels are extended to solid and gaseous biomass used for heat and power. In particular:

- Existing provisions for biofuels restricting the production of feedstocks from certain areas[88] would be applied to all biomass used for heat and electricity (e.g. no biomass from conversion of wetlands or from deforestation)

- A requirement for minimum performance in terms of greenhouse gas supply chain emissions would be introduced for biomass used for heat and electricity. Impacts of several levels of this minimum performance have been modelled (60%, 70 % and 75% compared to lifecycle fossil fuel emissions). and the possibility of higher levels is also assessed in the impacts section.

In the consultation, many stakeholders have asked for consistency of treatment when imposing measures that concern specific feedstocks, regardless of their final use: this means for example that the rules should be the same for agricultural biomass that is used for producing biofuels or for biogas for heat and power. This option would respond to these concerns.

Option 3: Option 2 + risk-based approach for forest feedstocks (replacing land-based criteria) + requirements on LULUCF emissions

Option 3 would build on option 2, but the land-based criteria for forest biomass included in option 2 would be replaced by requirements on forest management, for which compliance would follow a so-called 'risk-based approach': it could be demonstrated at national level through relevant legislation (low-risk areas), or at the level of the forest holding. Compared to option 2, this would alleviate the administrative burden on operators in case of biomass sourced in areas with existing relevant legislation on forest management.

In addition, option 3 would include requirements on the inclusion of LULUCF emissions in national accounting systems and climate policies in the producing country, in order to ensure that the zero rating of biomass in the energy sector in the EU is justified. This feature could also be implemented on its own, but for the purpose of this impact assessment it was assessed as a complement to the risk-based approach for forest management.

A risk-based approach is currently being used several Member States (United Kingdom, Denmark and the Netherlands). A similar approach is also used by the industry-led Sustainable Biomass Partnership (SBP).

<u>Risk-based approach for sustainable forest management</u>

The risk-based approach works on two levels of evidence (national/regional and forest holding level). The operator gathers the evidence firstly at national level. Only if additional evidence is required, is it to be gathered at forest holding level, with the possibility to use certification or other third party verified schemes as means of proof.

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[88] No production from primary forest or highly biodiverse grassland; no production from protected areas unless evidence is provided that the production of the raw material did not interfere with the nature protection purposes; no conversion/drainage of land with high carbon stock i.e. wetland, peatlands, forested areas.

Under the proposed option, biomass can be obtained from a country which meets the following criteria:

a) Legislation is in place at national or regional level covering in particular the following aspects of sustainable forest management:
    - regeneration (i.e. reestablishment of a forest stand after the removal of the previous stand, either due to harvest or to natural causes);
    - protected areas including also protection of peatlands and wetlands;
    - harvesting (harvest authorisation i.e. obligation of obtaining logging/harvesting permits)

b) The country is a signatory to international processes dealing with issues of highest political and social relevance related to forests, such as Forest Europe process or similar regional process, and regularly reports on it

For countries/regions that do not meet the above-mentioned criteria, operators would need to provide additional information on forest holding level, showing:

- Evidence of the following practices:
    - regeneration where harvesting takes place;
    - best management practices to preserve areas of high carbon and high biodiversity (including peatlands and wetlands)
- documentation allowing harvesting, i.e. harvesting / logging license;

Evidence could either be provided by the operator or by a third party (certification or other third party verified schemes, as for the EU Timber Regulation).

Sustainability criteria	**National/regional level**	**Forest holding level**	
		Certification	Gathering evidence
Regeneration	Legislation and assurance of compliance	Certification or other third party verified schemes	Regeneration is ensured
Protection			Best management practices are used
Harvesting			Permit is obtained
Following international agreements	Evidence of signatory to processes and reporting	Certification or other third party verified schemes as proxy	NA

Table 3: Summary of the risk-based approach for sustainable forest management

<u>Requirements on LULUCF emissions</u>

Forest biomass used for energy would comply with this criterion only if it comes from countries (EU or non-EU) which meet the following conditions:

- the country of origin of the wood biomass is a Party to the Paris Agreement;[89]
- the country has submitted and is implementing a national climate pledge (INDC/NDC[90]), which either includes either an economy-wide[91] emissions reduction

[89] http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

target, or explicitly includes LULUCF or REDD+[92] policies and measures reducing emissions and/or enhancing removals.

Option 3 is supported by a number of EU bioenergy producers and users, as well as by a few Member States. In the view of these stakeholders, the main benefit of the option lies with low administrative burden for areas fulfilling the requirement It was also supported in a recent opinion of the Standing Forestry Committee,as the most appropriate way to demonstrate sustainability, should such policy requirement be needed .[93]

Option 4: option 2 or 3 + energy efficiency requirement for heat and power installations

In addition to the features in option 2 or 3, this option would include a requirement for a minimum level in efficiency of conversion of biomass to heat and electricity. This minimum level would be fixed at 60 % efficiency[94]. This requirement would apply only to new plants conversion of existing plants, in order to protect existing investments. This means in particular that electricity without CHP produced from biomass in new installations would not fulfil the sustainability requirements.

This approach is based on resource efficiency considerations, since biomass is a finite and limited resource, although it is renewable. It would aim at reducing the overall amount of biomass needed for a given amount of energy produced.

On the grounds of the above argument, stakeholders that support taking into account conversion efficiency in sustainability requirements include mainly environmental NGOs and the wood-processing industries.

Option 5: Option 2 or 3 + cap on certain feedstocks for solid biomass

Under option 5, the sustainability requirements under option 2 or 3 would be complemented by a cap fixed at national level on the use of roundwood and stumps for energy[95]. Regarding roundwood, the cap would grandfather existing volumes in the period 2015-2020[96]. Salvage logging[97] would not be included in the cap. Only roundwood over a certain diameter would be targeted by this cap; this diameter would be chosen at Member State level in order to reflect the diversity of national situations regarding wood use and forestry, the objective being to cap the use for energy of roundwood of industrial quality. The cap would also apply to imports. Regarding stumps, the cap would be fixed at zero.

This option aims at limiting the most risky feedstocks in terms of biogenic carbon emissions, according to recent studies (see section 0 and ANNEX 7), as well as, in the case of roundwood, feedstocks that present a risk in terms of competition with other uses. In the case of stumps, this would also aim at reducing biodiversity impacts. Grandfathering existing

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[90] http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx.
[91] Economy wide includes the LULUCF sector
[92] http://unfccc.int/land_use_and_climate_change/redd/items/7377.php
[93] http://ec.europa.eu/agriculture/forest/standing-committee/opinions_en.htm
[94] Other levels could be envisaged, however the main relevant factor for choosing such a level would be the distinction between electricity only and heat/CHP, with the former being below 40% efficiency and the latter generally above 60%.
[95] Either used directly for energy or first transformed e.g. into pellets.
[96] On the basis of average annual volumes for that period
[97] I.e. wood from storms, pests and diseases.

amounts would aim at protecting existing investments, while limiting future growth for these feedstocks. The use of these feedstocks for energy over the level of the cap would still be possible but wouldn't count towards a renewable energy target or be granted public support. This option can be viewed as similar in design to the cap applied on food-based biofuels in the ILUC directive[98]

Environmental NGOs that support an overall cap on bioenergy point out to the use of roundwood of industrial quality (e.g. pulpwood) for energy as particularly problematic and therefore are expected to also support this option. Several Member States have already put in place schemes that include similar requirements or are considering it.[99]

Minimum size of plants to comply with the requirements for solid biomass used in heat and power generation (as part of options 2 and 3)

For the purpose of implementing option 2 and 3 (and of the options built on top of these), it is examined what should be the minimum size of the plants that would have to comply with the sustainability requirements.

The solid biomass sector is relatively fragmented and heterogeneous, with on the one hand small scale heating systems used in households, and on the other hand installations of more than 20 or 50 MW. Currently, half of the solid biomass used in the EU is used for household heating[100]. On the other hand, around 75 % of the wood burned in commercial or industrial installations (in the form of wood chips or pellets) for energy is consumed in installations over 20 MW. In addition, the increase in demand for solid biomass up to 2030 is expected to come mostly from these larger plants.[101]In defining the options for the minimum size of plants to be covered by the requirements set out in options 2 and 3 in particular, a balance must be found between minimising administrative burden and ensuring a good coverage of the biomass consumed in the EU.

The sub-options retained for the application of the sustainability requirements in options 2 and 3 are the following:

– application to installations above 1 MW;

– application to installations above 5 or 10 MW;

– application to installations above 20 MW.

An option of applying the requirements to all biomass users, including the residential sector, is discarded (see Annex 10).

This set of sub-options does not apply to biogas given that typical size of a biogas plant is around 0.5MW and great majority of installations are below 1 MW.

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[98] Directive (EU)2015/1513
[99] Belgium (Flanders), Poland, Netherlands, Italy, France.
[100] With variations across Member States
[101] Source: PRIMES modelling.

6. What are the impacts of the policy options and who will be affected?

6.1. Modelling of the options

The impacts of the policy options have been modelled using the tools described in section 5.1.1 and ANNEX 4. Because of the respective characteristics of the modelling suites, each of them was able to model a subset of the options and of their features, as well as of the impacts:

- Green-X gave information regarding greenhouse gas emissions from the supply chain, as well as economic impacts and impacts on jobs;

- GLOBIOM/G4M gave results focussed on land-use, biogenic carbon, as well as price and production levels for wood products (e.g. wood panels)

- For option 2 (extension of the biofuels criteria), Green-X modelled the impacts of the minimum requirement on greenhouse gas emissions from the supply chain, while GLOBIOM/G4M focussed on the land-based criteria.

- Option 3 (risk-based approach for forest biomass) was particularly complex to model given the uncertainties regarding which countries or regions would be considered "low risk". As a proxy, Green-X considered reduced biomass supply availability for non-EU countries (equivalent to a decrease of 65% in availability), whereas GLOBIOM/G4M increased the cost of imports (with three scenarios: +5 %, +10 %, +15 % compared to the baseline[102]).

- Option 4 (minimum efficiency of conversion) was modelled by Green-X, but not by GLOBIOM/G4M. This is because GLOBIOM/G4M is primarily a land-use and economic model, hence not able to distinguish between efficient or inefficient plants in the conversion of biomass to energy.

- In order to model option 5 (cap on certain feedstocks), Green-X used as a proxy an increase in the price of roundwood after 2020, whereas GLOBIOM/G4M directly modelled a cap on the total amount of roundwood used for energy. In modelling this cap, different assumptions were tested regarding the share of roundwood in imported pellets.[103]

As described in section 5.2, options 4 and 5 can be implemented based on the features of option 2 or 3. In the modelling exercises, they have been considered to be built on top of option 2.

Modelling projections are presented for 2030; for GLOBIOM/G4M trends for 2050 are also available, but are subject to a higher level of uncertainty.

[102] This is based on available data showing that the premium for certified wood vs non-certified wood would be in this range, although in some cases it could be higher or lower. Sources for these figures include https://www.unece.org/fileadmin/DAM/timber/publications/Final_FPAMR2009.pdf and http://www.cefcoproject.org/fileadmin/cefco/pdf/6-Analysis_of_market_demand_of_FSC_products-EN.pdf

[103] With a central assumption of 75% of roundwood in imported pellets, and a sensitivity analysis around that number.

6.2. Impacts of the policy options on the supply and demand of biomass for energy

The policy options set constraints on bioenergy production and use, and thereby can result in:

- a change in overall bioenergy demand (if demand for bioenergy decreases, then demand for other renewable energy sources would increase in order to meet the 27% target);

- a change in the types or geographical origin of feedstocks used for bioenergy.

Table 4 shows the model projections regarding the impacts of policy options on total bioenergy demand, trade patterns and the relative use of feedstocks and end uses compared with the baseline. As noted before, GLOBIOM/G4M considers a fixed amount of biomass demand for energy, derived from PRIMES modelling.

	Change in total demand of biomass for energy by 2030 (Green-X)	**Change in feedstocks and uses by 2030 (Green-X)**	**Change in trade by 2030 (Green-X)**	**Change in feedstocks (GLOBIOM/G4)M**	**Change in trade (GLOBIOM/G4M)**
Option 2	-0.4 %	Small decrease in biogas (-5 %)	Limited	2030: small increase in domestic roundwood for energy in 2030 (+6 %), larger in 2050 (+23 %)	Decrease in imports: -7 % in 2030, -22 % in 2050
Option 3	-3.3 %	Small decrease in heat (-4.8 %); decline in imports partly compensated by increased use of domestic supply in agriculture and forestry	Decrease in imports: -45 % by 2030 (linked to decrease in supply potential described in section 6.1)	Increase in domestic roundwood for energy (+5% to +37%[104] by 2030 depending on scenario, less impact in 2050); almost no effect on industrial by products	Decrease in imports between -4% and -19% in 2030 depending on the scenario, in 2050 trade effects are similar to 2030
Option 4 (built on top of option 2)	-0.7 %	Decline in bioelectricity (-5.1 %) only partly compensated by increase in heat	Limited	NA	NA
Option 5 (built on top of option 2)	-2.7 %	Stronger decrease in heat (-3.7 %)	Decrease in imports: -7 % by 2030	No more domestic roundwood used in the EU (-100 %);[105] significant increase in the use of industrial by-products (+18 % in	Decrease in imports: -23 % by 2030, -51 % by 2050[106]

[104] In absolute term the use of domestic rounwood for energy stays relatively small even after a 37% increase (representing 7% instead of 5% of the total biomass used for energy).

[105] (imported pellets made from roundwood are still used)

[106] This assumes that imported pellets contain 75% of roundwood, and hence are impacted by the cap proportionally. A sensitivity analysis has shown that, as expected, if the share of round wood in imported pellets increases or decreases, the impact on imports would vary in the opposite direction.

				2030, +51 % in 2050)	

Table 4: Impacts on total demand, trade and feedstocks of the policy options compared to the baseline, according to Green-X and GLOBIOM/G4M modelling

The modelling projections show that all policy options considered would result in a small or negligible decrease in total bioenergy demand, compensated by an increase in other renewable energy sources. The smallest effect concerns option 4: this is because this option only applies to newly built plants, and very little new capacity is projected for power only after 2020 (for example, PRIMES finds that new capacity for power only would represent around 1% of total solid biomass consumption between 2020 and 2030). This means that overall, option 4 would only have minimal impacts.

The effect on feedstocks and end-use of bioenergy is also relatively small, except for option 5 where GLOBIOM finds a significant increase in the use of industrial by-products (partly diverted from their use for the panel industry), and a complete disappearance of the use of EU-produced roundwood for energy (which was used at relatively low levels in the baseline) as the level of the cap is met exclusively with imported pellets.

The most significant effect seems to be a decrease of imports from non-EU countries for options 2, 3 and 5, but the two models find somehow different magnitudes for this decrease. To be noted in the case of option 3 that the very significant decrease in imports projected by Green-X is largely influenced by the assumption on biomass supply from non-EU countries (-65%, as described in section 6.1).

6.3. Environmental impacts

6.3.1. Greenhouse gas emissions

6.3.1.1. Greenhouse gas emissions from the supply chain

All the policy options examined include a requirement for a maximum level of greenhouse gas emissions from the supply chain, calculated based on the methodology described in previous Commission documents and on the values calculated by the Commission's Joint Research Centre and described in ANNEX **6**. Impacts of several levels have been further modelled, in particular corresponding to a 60%, 70% or 75% reduction in greenhouse gas emissions if compared with the full lifecycle emissions of fossil fuels. Further in-depth analysis of supply chain emissions is also presented in SWD(2014)259.

As described in ANNEX 6, the performance of different pathways[107] for biomass for heat and power in terms of greenhouse gas emissions from their supply chain is as follows:

- For forest feedstocks, all of the commonly used pathways are compatible with a threshold for their supply chain emissions equivalent to 70 % less than the reference emissions from fossil fuels. The two pathways leading to higher supply chain emissions (drying of wood with natural gas and transporting feedstocks over 10,000

[107] A pathway is defined as the chain of processes that constitute the supply chain, including the choice of feedstocks, the type of process, etc.

km), are extremely rare in practice. In order to comply with a high threshold (75% or above) pathways will have to employ more efficient technologies, such as the use of wood-fuelled CHPs in pellet mills, and higher final conversion efficiency or co-generation of power and useful heat.

- For agricultural feedstocks, certain pathways using intensely cultivated short rotation coppice feedstocks (e.g. eucalyptus plantations from South America) would be incompatible with threshold of 60% or above. Other pathways based on less intensely cultivated, domestic species (e.g. poplar) would generally pass a 75% threshold, especially for pathways with high efficiencies and best practices for pellet mills. Other excluded pathways would be the ones based on agricultural residues transported over long distances (which is very unlikely to happen), as well as certain biogas pathways (in particular those using exclusively of maize crops).

- If a more ambitious requirement is set out (80 or 85% threshold), then more pathways would be affected. In particular, many feedstocks would be restricted to regional production (less than 2500 km distance) and/or to cogeneration of power and heat or heat use (vs electricity-only plants). Pellets would be more affected than wood chips as more processing energy is needed for their production; with a 85% threshold most pellets produced with current technology would not qualify. However, pellets produced using a renewable energy and utilized in co-generating plants would still be able to pass even the highest threshold.

Therefore, in the case of forest-based bioenergy, almost all of the biomass used would comply with a minimum threshold of 70%, and only a few pathways would be excluded if that threshold was raised to 75%. In the case of agriculture-based feedstocks, the worst performing pathways would be excluded. A higher threshold would have more significant impacts on installations in Member States that are most dependent on imports from outside the EU and/or produce electricity-only rather than heat or CHP from biomass. Installations in Member States that are rich in forestry resources or import from short distances, and favour heat or co-generation production, would in principle not be affected. A higher threshold could also favour the upgrade of supply chains to apply more efficient pellet mills using only renewable resources.

Projections of supply-chain emissions from the Green-X model show in all options a combination of two effects:

- An effect on bioenergy emissions due to the establishment of the threshold,

- A (modest) shift from bioenergy to other renewable energy sources, resulting in an increase in greenhouse gas savings

Regarding the first effect, Green-X examines several sensitivity analyses concerning the level of the threshold (60%, 70% or 75%) combined with different minimum sizes of installations (1 MW or 5 MW). However, in all cases the results show that the effects of the minimum requirement in terms of greenhouse gas savings per unit of bioenergy used in heat and power are negligible.

When examining the savings in emissions from the supply chain for all renewable energy sources (hence including the effect of the shift to other types of renewable energy), all options show an improvement, which is in general very small (less than 0.5% compared to the baseline), except for option 3 and 5 (respectively 1.1% and 1.5%).

Hence, it can be concluded that there seems to be almost no benefit of a minimum greenhouse gas performance criterion for supply chain emissions of biomass as long as it is set at the level of 75% or lower. This confirms the findings that almost all forest feedstocks would comply with such a criterion. For agricultural feedstocks, this criterion could still act as a safeguard to avoid worst performing pathways. The threshold would have a constraining effect when set at a level of 80% or higher.

6.3.1.2. Biogenic CO_2 emissions and impact on forest carbon sinks

Modelling by GLOBIOM/G4M gives indications on the impact on emissions and carbon sink in the land use and forestry sector for options 2, 3 and 5. These include biogenic emissions directly linked to biomass production and use, but also market-mediated effects (e.g. change in production and consumption linked to a change in wood prices, and impacting the carbon sink).

The projections show an increase in the net global[108] carbon sink in the land use and forest sector for all the modelled options by 2030 (and most options by 2050) compared to the baseline, as detailed in table 5. This net increase in sink is the aggregated result of:

- a reduction of the carbon sink in managed forests[109] within the EU, as the domestic harvest of wood from forests increase to compensate for reduced imports;

- a increase in the carbon sink in harvested wood products within the EU as their consumption increases;

- a slight increase of emissions from deforestation in the rest of the world[110];

- reduced emissions from greenhouse gases in the rest of the world from cropland and increase in the carbon sink in managed forests, which together more than compensate the increased emissions from deforestation

The results are shown below as global cumulative net emissions/sink for the period 2020-2030 and 2030-2050, both total and annualised:

Cumulative total emissions from the LULUCF sector, worldwide (MtCO2 eq)	**Baseline**	**Option 2 change vs baseline**	**Option 3 change vs baseline**	**Option 5 change vs baseline**
2021-2030	17 250	-199	-8 to -34	-213
2031-2050	34 717	-469	-10 to +17	-530

108 In this section, global emissions are presented rather than EU emissions since greenhouse gas emissions have the same effect on climate change regardless of where they occur
109 Forest land remaining forest land
110 Linked to the decrease of imports, which leads to a lower value of the wood and the forests

Annualised cumulative emissions from the LULUCF sector (MtCO2 eq/year)	**Baseline**	**Option 2 change vs baseline**	**Option 3 change vs baseline**	**Option 5 change vs baseline**
2021-2030	1 725	-20	-1 to -3	-21
2031-2050	1 839	-23	0 to 1	-26

Table 5: Cumulative global LULUCF emissions for the baseline scenario and comparison with options 2, 3 and 5 *(negative numbers indicate that the option results in an increase sink/reduced emissions vs the baseline)*

In addition, the order of magnitude of the impacts (considered in annualised emissions) don't change significantly before and after 2030.

Option 2 presents a significant impact on the LULUCF sink, due in particular to the protection of high carbon stock areas. However, the model applies restrictions on high carbon stock land and high biodiversity land to all wood harvest, including for material, therefore the results in terms of net sink are overestimated.

Option 3 has very little additional impact on the LULUCF sink. This is because the reduction of imports to the EU leads on the one hand to an increased pressure on EU forests, and on the other hand to a slightly higher deforestation in non-EU countries. On the other hand, the reduction of imports in wood for energy leads to a reduced pressure on non-EU forests. These effects counterbalance each other, leading to an overall small effect on the carbon sink..

Option 5 has a positive but very limited additional impact compared to option 2, on which it is built. The cap on the use of roundwood for energy is compensated by an increase in roundwood use in the material sector (to substitute for by-products diverted to energy use), therefore the overall effect on the level of wood harvest from this cap is relatively small.[111]

A sensitivity analysis was carried out to examine the effects of an earlier development of biomass feedstocks from short rotation coppice.[112] It shows that this would reduce by - 6 MtCO2eq/year in 2030 the annualised cumulative emissions for the period 2021-2030. Under this sensitivity analysis, model projections also show almost no use of domestic roundwood for energy, and a decrease in imports of solid biomass of 40% in 2030 compared to the baseline.

6.3.2. Land use and biodiversity

GLOBIOM/G4M modelling explores land use and biodiversity effects for options 2 and 5 compared with the baseline[113]. In both cases, the modelling projects a reduction in imports as described above, which results in an increased reliance on EU domestic biomass sources. As a

[111] Impacts on greenhouse gas emissions from material substitution effects are not taken into account in the modelling

[112] This sensitivity analysis considers that the level of short rotation coppice used for bioenergy feedstock in 2030 would be 50% of the level projected by PRIMES for 2040 (i.e. 11% of total bioenergy instead of 6%).

[113] Biodiversity impacts of option 3 were not modelled because it was not possible to specifically model the impacts of the requirements on sustainable forest management with GLOBIOM/G4M.

result, projections show that the conversion of unused forests to used forests[114] in the EU could increase. However this increase would not be very significant in comparison with the baseline (around 0.5 Mha in 2030, up to a maximum of 4.5 Mha in 2050 for option 5). In non-EU countries, the protection of high biodiversity area would be beneficial for biodiversity.

Option 3 is likely to show similar patterns as option 2 concerning the protection of high biodiversity areas and land use change, although to a lesser degree as countries with existing forest legislation would not be subject to further constraints. On the other hand, in countries where such legislation doesn't exist (more likely to be non-EU countries), the requirements on forest management would positively impact on biodiversity.

Option 4 would reduce the overall amount of biomass for energy compared with the baseline, which could indirectly reduce negative impacts on land use and biodiversity; however this effect is likely to be limited as shown in the modelling results. In option 5, the cap would apply on roundwood but also on stumps, the use of which has been shown to be detrimental to biodiversity (see problem definition), thus mitigating such impacts (this is not included in the model results).

In addition, as is done for biofuels, all options could include possible compliance through voluntary schemes (in particular for option 3). Such schemes often include criteria in particular on biodiversity: by promoting the use of these schemes, they would indirectly contribute to further positive effects compared to the baseline.

6.3.3. Summary of environmental impacts

Table 6 summarises the environmental impacts of the policy options compared to the baseline (option 1). For options 4 and 5, only their specific feature (energy efficiency requirement and cap respectively) is assessed (i.e. the impacts due to the fact that these options are built on top of option 2 are not considered). This table shows that overall the environmental impacts of the policy options are very limited compared to the baseline

Impact in 2030	Option 2	Option 3	Option 4 (energy efficiency criterion only)	5 (cap only)
Supply chain GHG	no impact	no impact	no impact	no impact
Biogenic carbon	positive but uncertain	Positive, but very small	not quantified but likely to be very small	Positive, but very small
Land use and biodiversity	positive but uncertain	positive but uncertain	not quantified but likely to be very small	Positive, but very small

Table 6: Environmental impacts in 2030 of policy options 2-5 compared to the baseline (option 1)

[114] In the modelling, 'unused forests' are forests which currently do not contribute to wood supply, based on economic factors. 'Used forests' are forests managed for production of woody biomass.

6.4. Economic impacts

Overall, the economic impacts of policy options will be affected by the volume of bioenergy used for each option.

As described above, models shows that the reduction of total bioenergy demand due to the effects of policy options should be very small. Where such reductions occur, they will lead to compensation with other renewable energy sources in order to meet the renewable energy targets, with effects on gross added value, investment costs and employment. The effect observed in general is that a small decrease in bioenergy accompanied with a small increase in other renewable energy sources leads to an increase in gross added value and employment. This would not necessarily be the case if the shift from bioenergy to other renewable energy was higher in magnitude[115].

Creating a sustainability framework would also provide more certainty to investors and increased acceptance of the use of bioenergy to the general public — two issues that were pointed out by economic operators in their response to the public consultation when asking for the development of an EU-wide framework. The degree to which these two effects will result in an increase in biomass use for energy is very difficult to ascertain, however it is likely that it will be a factor for further developments.

To be noted that in the modelling carried out using Green X/MULTIREG, the impacts on non-energy sectors are not included. The effect on the sectors using wood for materials is described through GLOBIOM/G4M.

6.4.1. Contribution to gross added value[116]

In the baseline scenario, the deployment of renewable energy sources is projected to generate a total value added of almost €122 billion as an annual average. Bioenergy deployment accounts for almost half of that total value added (48%), with the other half related to other renewable technologies.

The results of the Green-X/MULTIREG modelling show that the (modest) shift between bioenergy and other renewables in the policy option brings a net, small positive effect to the gross added value to the EU economy, as displayed in Table 7. This effect is the highest for option 5, followed by option 3, but remains overall very modest.

This positive impact on gross added value is a combination of:

- a positive "deployment effect": the increase in other renewable energy sources leads to more investments and therefore a larger positive impact in the economy as a whole

- a positive "income effect": the additional jobs created by this shift leads to additional income for households, which is spent in consumption

- a negative "indirect effect": other renewable energy sources require higher level of public support, either directly through subsidies, or through feed-in tariffs. This can impact

[115] As shown for example in the results of the BioImpact study – see Annex 8
[116] Gross added value is the measure of the value of goods and services produced in the economy.

consumers, if the feed-in tariffs is directly passed on to them through an increase in energy prices, or if the subsidies are financed through an increase in taxation: in both cases, household consumption would go down. Increased support for other renewables can also be made available by giving less public support to other sectors, which will also have a negative economic impact.

However, this negative effect is more than compensated by the deployment effect and the income effect in all options.

The assessment doesn't take into account the administrative cost for administrations and economic operators, which would reduce the benefit in terms of gross added value.

(M€)	Option 2	Option 3	Option 4	Option 5
Change in gross value added / baseline (absolute and in %)	+330 M€ (+0.3%)	+1 380 M€ (+1.1%)	+900 M€ (+0.75%)	+2 070 M€ (+1.7%)

Table 7: Change in gross value added for the policy options

6.4.2. Costs for economic operators (including capital investment costs)

In the baseline scenario, Green-X finds a moderate uptake of renewable energy by 2030, and a decrease in investments volumes compared to 2020 levels, which is partly explained by the reduction in the costs of renewable energy. In the period 2021-2030, bioenergy represents about 40% of the capital expenditure on renewable energy, and about 75% of the operational expenditures, which reflects its cost structure compared to other renewable energy sources.

The change in capital and operational expenditure for operators under the policy options is mainly reflecting the small shift from bioenergy to other renewable sources, as shown by the Green-X modelling results (see Table 8): capital investment for biomass decreases slightly while total capital investment for renewable energy production increases by 2 to 5.5 % in options 3 to 5 (with almost no change in option 2). Operational costs are largely unaffected.

	Option 2	Option 3	Option 4	Option 5
Change in CAPEX / baseline for biomass installations	Negligible (less than 0.5 %)	-3.9 %	Negligible (less than 0.5 %)	-3.9 %
Change in CAPEX / baseline for total RES installations	Negligible (less than 0.5 %)	+5.5 %	+2.1 %	+4.4 %

Change in OPEX / baseline for biomass installations	Negligible (less than 0.5 %)	Negligible (less than 0.5 %)	-1 %	Negligible (less than 0.5 %)
Change in OPEX/baseline for total RES installations	Negligible (less than 0.5 %)	Negligible (less than 0.5 %)	Negligible (less than 0.5 %)	+1 %

Table 8: Change in capital expenditures (for new installations) and operating expenditures (for all installations) of biomass and other renewable energy sources (solar, wind, etc.) installations period 2021 to 2030, for each policy option — Source: Green-X

6.4.3. Effects on EU industry of wood for materials

The effects of the policy options on the price and production levels of different wood products were examined by GLOBIOM/G4M in options 2 and 5.

In the two options, the price of sawlogs increase slightly after 2030, concomitantly with a higher production level for sawnood. This effect is larger for option 5. Almost no change in price is visible in 2030; the price of other wood products is not significantly affected. Annex 11 gives more detailed results for the price of each wood product.

Impacts on volume of wood uses in materials are shown in Table 9. In option 5, the decrease in the use of roundwood for energy – both domestic and imported – is accompanied by a rise in the use of industrial by-products for energy. This leads to two effects for EU material production: on the one hand, more pulpwood is used for material (in order to replace the by-products diverted from the wood industry); on the other hand the use of sawnwood rises moderately as a consequence of the increase in the use (and hence price) of by-products.

		Sawlogs	Pulpwood	By-products
Option 2	2030	1%	0%	0%
	2050	4%	1%	-1%
Option 5	2030	2%	7%	-13%
	2050	10%	23%	-36%

Table 9: changes in the material use of wood under options 2 and 5 compared with the baseline – source: GLOBIOM/G4M

Other policy options are likely to also have a negligible effect on the price and production level of wood.

6.4.4. Costs for public administration

The BioSustain study assessed the cost for public administration using the standard cost model in line with the better regulation guidelines.

It foresees limited administrative costs for national authorities linked to implementation of the legislation and the respective reporting, monitoring and verification tasks. These costs include one-off costs in the range of 60.000 to 200.000 € as well as recurring yearly costs between 400.000 and 1 M€. The range is similar in all options.

6.4.5. Administrative costs for economic operators

Additional administrative costs would occur for producers of agricultural biomass, forest owners and the wood value chain, and bioenergy plants as a consequence of new legal requirements, in policy options 2-5.

Based on the standard costs model and on data from existing certification schemes for agricultural and forest products (including wood for electricity and heat), the BioSustain study provides estimates suggesting that the overall level of administrative costs for economic operator is rather sizeable for policy options 2-5 as shown in Table 10.

M€	Option 2	Option 3	Option 4	Option 5
One-off costs	109	63	121	114
Recurring costs (per year)	47	30	52	51

Table 10 - Administrative costs for economic operators

The major difference, according to this assessment, concerns the level of impact of the various options on forest owners. While in options 2 they are expected to bear the costs of certification (which is expected to be carried out at least partly through grouped certification); the obligation under option 3 to prove that forest biomass is sourced in a ‘low-risk’ region can be done at the level of a country or region. The study suggests an associated difference in costs. Overall, forest owners would bear the highest cost in all options built on option 2 (particularly for one-off costs linked to certification), whereas in option 3 the costs would be lower for this category of operators and borne by the agricultural sector and bioenergy plants. To be noted that for option 3, it was assumed that only a small number of forest operators would be subject to the requirements for "high risk" areas (46 operators out of a total of nearly 1400). This is linked to the fact that in the Biosustain study, imports would decline significantly under option 3.

Administrative costs for options 4 and 5 must be compared to option 2, on top of which they are built. The estimates suggest that the additional features from these options would increase the administrative costs by 5 to 10%.

6.4.6. Impacts on SMEs

SMEs and micro-firms are widely represented in bioenergy production and use chain through, in particular, small forest owners and small bioenergy installations. In the baseline, SMEs in the forestry sector might be affected by national schemes. It is unlikely however that those SMEs would have to comply with several national schemes given their likely range of operations.

Options 2-5 will affect SMEs through the requirements set along the supply-chain, but to a different extent. Regarding small bioenergy installations, the main factor determining the impact of policy options will be the minimum size of installations submitted to sustainability requirements (see section 6.5.3). SMEs would typically operate installations below 5 MW, therefore could be affected if the minimum size chosen is 1 MW. The energy efficiency criterion in option 4 would have very little impact on SMEs as most plants producing electricity without CHP (and thus with a lower efficiency) are above 5 MW.

Other SMEs along the value chain would be impacted more under option 2 and options building on option 2 than under option 3 and options building on option 3. This is because under option 2 operators would have to demonstrate their compliance with the sustainability criteria for all consignments of biomass used for energy, thus requiring information along the supply chain, including from SMEs (e.g. small forest owners). Under option 3, forest owners operating in "low risk" countries (i.e. countries that have relevant legislation in place) would be exempted from such requirements, but forest owners in other countries would be subject to stricter criteria than in option 2 (certification requirements).

Option 5, requiring monitoring of the harvests of roundwood by national authorities would only have limited or no impacts on small forest owners or harvesters, as this information is normally part of the logging permit that is required in national legislation. However, it could have an impact on the cost for forest owners to e.g. differentiate between roundwood of different diameters, which are harvested at the same time.

Section 6.5.1 also shows that all the policy options would have a small net positive effect on employment in SMEs, due to the small shift from biomass to other renewable energy sources.

6.4.7. Impacts on rural development

Positive impacts on rural development can occur in cases where additional bioenergy demand incentivises more intensive harvesting of EU forests and use of EU agricultural feedstocks (rather than e.g. increasing imports or diverting industrial residues from other uses). This will be mostly driven by the market and/or by relevant subsidy schemes[117] in each region. It can also be influenced at EU level by e.g. support to wood mobilisation under the Rural Development Programmes. However none of the policy options examined in the scope of this report are likely to have a significant impact on this issue, since the options result in a very small decrease in biomass use. The administrative burden on small farmers or forest owners is also relevant in this context and is described under ‘impacts on SMEs’.

Concerning option 5, forest owners would be limited in their possibility to sell roundwood for energy, which could be a problem in periods where roundwood demand for material is lower. However the GLOBIOM/G4M modelling shows that the decrease in demand for domestic roundwood for energy in option 5 would be accompanied by an increase of higher magnitude in the demand for domestic roundwood for materials[118]. In addition, the demand for domestic roundwood for energy under the baseline scenario is expected to grow between 2020 and 2030 but remaining at very low levels. Hence this effect is not likely to be significant, even if positive.

[117] National support schemes being subject to EU State Aid rules, the revision of the Energy and Environment State Aid guidelines for the period after 2020 is also relevant.

[118] This is due to the higher use of industrial by-products – e.g. sawdust - for energy shown by the model for this option, which would be diverted from material uses.

6.4.8. Impacts on the internal market and intra-EU trade

Policy options 2 and 3 would have certain benefits in terms of replacing national sustainability schemes by a harmonised EU scheme, although as discussed previously the barriers to intra-EU trade are limited. However, as the option 3 is based on a risk-assessment undertaken by operators, it may happen that different operators come to different results regarding sustainability of biomass in one region. This may create additional barriers to intra-EU trade.

The combustion efficiency requirement under option 4 would not have any impact on trading with the biomass resources. The "cap" feature of option 5 would be implemented at the national level through supervision on harvested feedstocks and therefore it would not have any further effect on circulation of these feedstocks in the market.

6.4.9. Impacts on external trade

As shown previously, in the baseline scenario imports from non-EU countries are projected to increase by 2020, and stabilise between 2020 and 2030. The policy options could impact the level of imports, in particular for option 3 and option 5. However, the degree to which this would happen is very uncertain.

For example, under option 3, biomass from countries or regions that don't have legal requirements for sustainable forest management would need to demonstrate sustainability at a forest holding level. It is unlikely that the affected forest owners would undertake certification only in relation to the energy market. Therefore, the costs of such requirement could discourage the imports of biomass from countries or regions that do not have certified forests. At the same time, many operators from non-EU countries already comply with requirements from individual EU Member States.[119] Given the fact that imports are not projected to increase significantly between 2020 and 2030, option 3 would affect mostly existing operators that already face these compliance costs. To be noted that it would be particularly important to develop option 3 in a way that is compatible with international trade rules and avoid that it is perceived as discriminatory.

Option 5 would limit the use of roundwood for energy to levels used between 2015 and 2020. The impact on import levels would depend on the availability of wood pellets made from other sources than roundwood, in particular from industrial residues. This is subject to uncertainty: the BioSustain study suggests that a significant potential for industrial residues to be used for wood pellets exists e.g. in the United States while a study examining specifically the US South-East market[120] (where most of the pellets exported to the EU are currently produced) found on the contrary that the availability of industrial residues for energy was very limited.

6.4.10. Energy security

The impacts on energy security in the baseline scenario (option 1) would depend on the relative contribution of bioenergy to electricity and heating on the one hand, and to the

[119] Such requirements exist in the Member States that import the most solid biomass in the EU.

[120] COWI, 2016: Environmental Implications of Increased Reliance of the EU on Biomass from the South East US; http://bookshop.europa.eu/en/environmental-implications-of-increased-reliance-of-the-eu-on-biomass-from-the-south-east-us-pbKH0116687/?CatalogCategoryID=DSoKABstDacAAAEjA5EY4e5L

geographical location of the increase in biomass. Indeed, there are alternative ways to produce electricity from renewable sources whereas options in the heating sector are less numerous. In addition, energy security in countries that are particularly reliant on imported gas or coal for heating (e.g. Eastern Europe) would benefit particularly from an increase of biomass of EU origin in the heating sector.

In this light, none of options 2-4 is likely to have any significant impacts compared to the baseline on energy security, as they either put very limited constraints on biomass use for energy (option 2) or would mostly affect imports (option 3) and large power generation installations which are mostly based in Western European Member States (option 4). Option 5 could have a negative impact on Eastern European Member States wishing to increase their use of roundwood for energy, although this use is not projected to be significant by 2030. This increase would still be possible but could not be linked to public support or the achievement of renewable energy targets.

6.4.11. Innovation and research

While bioenergy has an important innovation angle (for example with regards to advanced biofuels for transport), the policy options are unlikely to make a fundamental difference to innovation and research since the sustainability requirements would only have an impact on well-established technologies (i.e. the use of solid and gaseous biomass for heat and power).

6.4.12. Summary of economic impacts

Overall, the economic impacts by 2030 of policy options 2-5 are modest compared to the baseline (option 1).

The most significant impacts include:

- impact on wood use for materials from option 5

- administrative costs for operators, for all options (lowest costs for option 3)

- decrease in imports from third countries for all options, in particular options 3 and 5

- possible risk in perceived trade discrimination for option 3

6.5. Social impacts

6.5.1. Employment

Employment in the bioenergy economy is most significant in the solid biomass sector, where 306 800 Europeans had a job in 2014. In addition, 110 350 people were employed in the biofuels sector, 66 200 in the biogas sector and 8 410 in the renewable urban waste sector.[121]

In the baseline scenario, the Green-X/MULTIREG modelling projects that the development of renewable energy sources would support 1.4 million jobs, including direct and indirect jobs,

[121] 15th EurObserv'ER Report on State of Renewable Energies in Europe. Both direct and indirect jobs are captured in the statistics. .

in the period 2021-2030 (out of which almost 1 million for SMEs). Bioenergy deployment would represent 60% of these jobs.

The direct impacts of the policy options on employment in the energy sector compared with the baseline should be marginal, as they would mostly depend on additional job opportunities in the certification industry and the additional jobs created by operators in order to cope with the additional requirements. Small negative employment effects could arise for forest owners or farmers linked to additional certification costs. This would be the case in particular for option 2 and the options building on option 2. Option 3 and options building on options 3 would minimise the employment effect on forest owners by adopting a risk-based approach for forest feedstocks.

Employment impacts will also arise as a result of the small shift from bioenergy to other renewable energy in the policy options, due to a higher labour-intensity of other renewable energy sources.[122]

Green-X/MULTIREG results (Table 11) show that the net impact in the energy sector is projected to be small and positive and that most of the jobs created would be in SMEs. Option 5 results in the largest jobs creation as it provides the highest economic impulse, but the amounts still remain modest at the EU scale.

	Option 2	Option 3	Option 4	Option 5
Change in employment / baseline (change of employment in SMEs)	4 420 (3 500)	7 060 (5 160)	2 930 (2 230)	19 980 (12 940)

Table 11: Employment effect of the policy options in the energy sector by 2030

The modelling results shown above do not include employment impacts in non-energy sector, such as the wood material industry. A recent study carried out for the Commission on the cascading use of biomass[123] finds that the use of solid biomass for heat and power creates less jobs than the wood industry per m3 of wood (544 employees/m3 for energy vs on average 884 for the semi-finished wood industry, i.e. sawmills, panels and pulp and paper).

6.5.2. Social impacts in third countries

In the baseline (option 1), imports of solid biomass to the EU could lead to pressure on forests in the exporting regions/countries, with risks of negative impacts on local communities, particularly in rural areas. On the other hand, these imports can create economic activities and jobs in the producing regions.

With option 2 to 5, the pressure would be reduced by excluding certain areas that are high carbon or high biodiversity (options 2 and options built on option 2) or establishing

[122] Solid biomass creates on average 3.7 jobs per ktoe (including direct and indirect jobs creation), which is less than capturing energy from sun (18 jobs/ktoe), wind (16.3), through biogas (9.7) or biofuels (6.6) - Number of jobs reported for 2014 compared with the energy output as reported in the 2015 Renewable Energy Progress report.

[123] Vis M., U. Mantau, B. Allen (Eds.) (2016) Study on the optimised cascading use of wood.

requirements on forest management (including through the use of forest certification) (option 3 and options built on option 3). The policy options would also have an impact on the level of imports, with a potential significant decrease in particular for options 3 and 5 (although this impact is subject to significant uncertainties).

As shown in the case of biofuels, the recognition of voluntary schemes may also have indirect positive social effects by promoting a wider use of these schemes, some of which also include social features such as protection of workers..

6.5.3. Summary of social impacts

Overall, the social impacts of the policy options are very modest. Indirect benefits in third countries could occur through the wider development of voluntary schemes including social features as a means of certification for compliance with the sustainability requirements.

6.6. Impact of the criterion regarding the minimum size of installations submitted to sustainability requirements

While half of the solid biomass for energy is consumed by households, the consumption of solid biomass by commercial and industrial installations is more concentrated in larger plants. The consumption of wood for energy in different size classes of installations over 1 MW is described in Table 12. In particular, around 75% of the wood is consumed in installations larger than 20 MW, while 25% is consumed in smaller installations.

Plant size class	total
1-5 MW	8%
5-10 MW	8%
10-20 MW	9%
more than 20 MW	75%

Table 12 - Consumption of wood biomass for energy (including wood chips and pellets) by plant size class *(source: AEBIOM/BASIS project)*

The requirements in policy options 2-4[124] would only apply to installations over a minimum size (capacity). Operators in smaller installations would be exempt from the requirements. The choice of the minimum size will have environmental and economic impacts.

From an environmental perspective, the minimisation of impacts would be more effective if a larger share of biomass for heat and power is covered. In this respect, the lowest minimum threshold (i.e. 1 MW) would have the highest impact. Setting a higher threshold could allow biomass that doesn’t meet the sustainability requirements to be used in smaller installations, while biomass meeting the requirements would be reserved for larger installations (‘leakage effect’). This is true in any case for biomass used in households, but it has been established that submitting them to sustainability requirements would be disproportionate and pose problems of implementation (see Annex 10).

[124] For option 5, the cap on certain feedstocks would apply at national level; however if option 5 is built on top of option 2 or option 3, the corresponding requirements would also apply above a minimum size of installations (capacity).

From an economic perspective, and in particular in terms of administrative burden for economic operators, setting a higher threshold would be more beneficial, as less installations would have to comply with the sustainability requirements. In particular, there are a high number of small installations using biomass for energy – for wood chips, over half of the installations are below 5 MW[125]. A higher minimum threshold would also imply less impacts on other actors in the supply chain, although to a lesser degree as the impact would be proportional to the volume of biomass concerned (rather than to the number of bioenergy installations). Finally, the level of the threshold would also impact SMEs: a threshold set at a level of 5 MW or above would exempt most SMEs in the energy sector.

As mentioned in section 5.2, the minimum threshold would not apply to biogas installations, as most of them are below 1 MW.

[125] Source: BASIS project

7. COMPARING THE OPTIONS

The Commission Services have not identified a preferred policy option, as all of the policy approaches, including the baseline scenario, could be valid for addressing the problems identified to various extents. The main reason that does not allow for a straightforward identification of the best policy approach is as follows:

- On the one hand, many stakeholders involved in the bioenergy sector claim that its future development, which is important for combating climate change, is hampered by public doubts about the environmental benefits of bioenergy;
- On the other hand, it is clear from the scientific evidence that the overall impacts of using biomass for energy on greenhouse gas emissions and on biodiversity are based on too many variables and cannot therefore be assessed or ensured with general prescriptions, but rather should be examined on a case by case and site-specific basis.

None of the policy options is therefore able to meet the main expectation of citizens and stakeholders on this initiative, in particular to reliably distinguish between 'sustainable' and 'unsustainable' sources of bioenergy for the heat and power sectors and set out this distinction in legislation, as was done for biofuels used in transport. The policy options are however able to address or mitigate some of the problems and risks as identified in this document, as described below.

7.1. How effective are the policy options in addressing the identified problems?

The impact assessment identified **three main sustainability risks** (climate impacts, other environmental impacts, and efficiency of conversion/competition with other uses of wood) which are all linked to the increasing use of in particular forest biomass for energy. In addition, some aspects concerning the production of heat and power from agricultural biomass are also covered in the following section.

A) Under the Baseline Scenario (option 1), the three risks can be addressed through other elements of the 2030 climate and energy framework and existing policies as follows:

i. The 2030 climate and energy framework includes proposed policies that would result in moderating the increase in biomass demand for energy after 2020. This includes in particular energy efficiency, the removal of priority dispatch under the Market Design proposal, and the discontinuation of binding renewable energy targets at national level. Since the increase in biomass demand is a major driver of the sustainability risks identified, this moderation in demand could help mitigate these risks.

ii. Regarding the climate risks, the accounting of biogenic emissions from forest biomass towards the EU's economy-wide climate target through the proposed LULUCF regulation[126] can reduce incentives to harvest certain types of forest biomass for energy that would reduce the LULUCF sink, and could guarantee that a decrease of the EU forest sink would be compensated by emission reductions elsewhere in the

[126] COM/2016/479

economy. Emissions related to changes in land use in non-EU countries exporting to the EU are likely to be accounted for by many countries implementing the Paris Agreement (in particular the largest emitters), but not necessarily by all countries.

iii. Other environmental impacts related to biodiversity, and soil and water quality can be partly addressed through policies promoting sustainable forest management in the EU and beyond. These include EU policy on biodiversity (and particularly the Birds and Habitats Directives[127]), as well as Member States' policies on sustainable forest management. EU action towards developing countries, including the FLEGT action plan, has a potential to encourage sustainable forest management in developing countries.[128]

iv. A more efficient conversion of biomass to energy in households will be promoted through the new Ecodesign measures for domestic boilers, effective as of 2020, and will also be encouraged under the revised Energy Efficiency Directive and Renewable Energy Directive. The conversion of biomass to energy in electricity-only plants is also likely to be discouraged through the disappearance of priority dispatch to the grid for renewables, as proposed in the Market Design Initiative[129].

v. In addition, strengthened monitoring of both supply side and demand for bioenergy in the context of the proposed Regulation on the Governance of the Energy Union would allow to follow biomass developments relevant for the three risks identified.

B) Under option 2 (extension of existing sustainability criteria for biofuels to biomass used for heat and power), additional safeguards would be put in place as follows:

i. This option sets minimum greenhouse gas performance for supply chain emissions only (not including biogenic carbon). The analysis carried out for the impact assessment shows that such a requirement would not drive emission reductions overall (unless the threshold is set above 75% compared to fossil fuels). For forest-based feedstocks, this would prevent the most extreme practices (such as drying of wood in pellet mills with natural gas and their transportation over very long distances). Nonetheless, these are not common pathways used in the EU today and are not likely to develop in the future. Furthermore, the option does not address the impacts of biogenic CO_2 emissions. It would therefore have at best very marginal impact in guaranteeing on climate change mitigation from forest bioenergy, unless a higher threshold is considered. For agricultural feedstocks, it would prevent some practices already existing (e.g. use of energy crops for biogas) or which could develop in future. The option would also prevent the conversion of high carbon stock land for biomass production, a practice which is not currently common, but would be detrimental if it occurred.

ii. The option would provide some minimum safeguards regarding the production of biomass in certain high biodiversity areas. It does not provide additional constraints regarding other environmental issues, such as air, soil and water quality.

[127] Council Directive 92/43/EEC and Directive 2009/147/EC

[128] In its Conclusions from 28 June 2016, the Council called on the Commission to 'examine options to tackle the drivers of deforestation and forest degradation in the world and examine how the EU FLEGT Action Plan can continue to contribute to address these challenges.

[129] Reference to the Market Design initiative

iii. The option would not deliver significant additional effects to the efficient conversion of biomass to energy. Although conversion efficiency is reflected indirectly to some degree in the calculation of GHG emissions from the supply chain, this does not significantly affect the ability of the respective biomass pathways to pass the proposed minimum greenhouse gas performance, unless this threshold is set at 75% savings or above.

C) Under option 3 (risk-based approach for forest management and requirements on LULUCF emissions), the three risks would be addressed as follows (in addition to the baseline scenario and the effects of a threshold for supply chain emissions as described in option 2):

i. The risk of adverse climate effects would be further mitigated by ensuring that all biomass producing countries supplying the EU account for their LULUCF emissions towards an economy-wide target, and also through the effect of this policy on volumes of biomass sourced in areas where there is lack of assurance regarding sustainable forest management.

ii. The same reasoning applies to other environmental impacts. While biodiversity protection will be improved to some degree, there would be no additional effects of this policy option to air, water and soil quality.

iii. There would be no direct effects of this policy on efficiency of conversion, but depending on the impacts on the level of imports,[130] there may be a negative effect on competition for resources in the EU if the use of domestic feedstocks increases.

D) Under option 4 (minimum energy efficiency for new installations), the modelling projections show very little effect due to the low projected new capacity. However in principle, the option would have the following effect on the three risks:

i. If the option results in lower volumes of biomass required to produce a given amount of energy, this would result in lowering to some extent the risk of adverse climate effects, as well as the risks on biodiversity, soil and water quality. It would also lower air pollution through more efficient combustion.

ii. This option would partly mitigate the issues of competition for raw material by ensuring that no public support is given to new inefficient installations; however, it would not impact existing plants which already benefit from support and use inefficient conversion technologies.

E) Under option 5 (cap on the use of certain biomass feedstocks) the three risks would be further addressed as follows:

i. This policy option would in principle provide the most direct safeguard regarding climate impacts of bioenergy, by putting a constraint on the biomass feedstocks whose use entails higher risks of limited GHG savings compared to fossil fuels. However, the modelling has shown that this effect could be compensated by market effects in the material sector.

[130] The impact of option 3 on the level of imports is uncertain, as shown by the differing results from the modelling.

ii. The impact on biodiversity would be as in option 2 or 3 on which it builds, with additional impacts through the limitation of the use of stumps and the possible lower increase in demand for biomass for heat and power. This could lead to reducing pressure on air, water and soil quality.

iii. There could be indirect effects on competition with other wood-using industries under this policy option, in particular by increasing competition for industrial by-products in the EU, at the same time as reducing competition for roundwood, including pulpwood.

7.2. Are the policy options proportionate in addressing the problems?

The four regulatory policy options involve a certain level of administrative cost. This cost is comparable for the four options with regards to public authorities and operators of bioenergy plants; for forest owners these costs are significantly lower for option 3[131] compared to options 2 and the options that build on it. In addition, all regulatory options result in a small shift from bioenergy to other renewable energy sources, leading to a higher level of public support.

By comparison, option 1 (baseline) does not entail any additional cost for Member States or operators.

As discussed previously, options 2 to 5 seem to have a limited effect under the conditions projected by the models. This is notably due to the fact that other elements of the 2030 climate and energy framework will already play a role in moderating the increase in biomass demand (a main driver for sustainability risks), as well as to the difficulty of adequately addressing the issue of biogenic carbon. Indirect market effects triggered by the policy options also play a role in minimising their impact (for example in option 5).

In this light, policy option 1 (baseline scenario) appears as the most efficient policy option in terms of balance between results and the administrative burden (Option 1).

On the other hand, options 2 to 5 would act as additional "safeguards" in case practices that exacerbate the problems develop more strongly than identified in the modelling work. This is relevant in view of the level of uncertainty on future biomass development, including trade patterns and feedstock choice.

In this scenario, option 2 would be the most direct safeguard against the risks of production of biomass in high biodiversity areas or through deforestation.

An ambitious minimum performance requirement for supply chain emissions (75% or higher) would be the most effective way to prevent inefficient practices.

Option 3 would be the most effective safeguard against the risks of increased biomass sourcing through unsustainable forest management or from countries that do not have in place accounting systems for emissions from land use, land-use change and forestry.

Option 4 would be the most straightforward precautionary measure against the risk of further deployment of new installations combusting biomass with low efficiency.

[131] Assuming that option 3 results in a significant decrease in imports of biomass from third countries

Option 5 would provide the most effective safeguard against a risk of increased use of roundwood and stumps for bioenergy, which are the most risky feedstocks in terms of climate impacts.

7.3. How are the policy options coherent with the wider policy agenda of the College?

On top of the policy objectives linked to climate action, environmental protection, resource efficiency and a functioning internal market as discussed above, the Commission has also defined more overarching objectives that may be affected by the future deployment of bioenergy. These include in particular i) growth, jobs and investment and 2) the ambition for the EU to become the world leader in renewable energies.

As follows from the section on economic and social impacts, renewable technologies such as those that capture energy from wind and sun require larger investment input, but at the same time provide more jobs per unit of energy compared to bioenergy, which is in many cases a less costly source of renewable energy. The actual net-jobs benefit is therefore diminished in the analysis by the so-called 'budget effect' (loss of jobs in other parts of the economy, driven by higher consumer spending on energy), which will last as long as the cost of electricity from particularly solar and wind technologies remains higher than the cost of bioelectricity.

The impact assessment on the Renewable Energy Directive[132] suggests that by 2030, the EU is likely to attain the level of 24 % renewable energy in absence of new policies. It will therefore make a difference in terms of the amount of investments in the sector, as well as the number of jobs created, whether the additional 3 % is achieved through encouraging bioenergy or other RES technologies.

While bioenergy is crucial for attaining the above-mentioned binding objective, a marginally higher share of bioenergy versus other renewable sources will result in a marginally lower incentive for emerging technologies. The policy options that establish constraints for bioenergy use (2, 3, 4 and 5) will therefore indirectly stimulate focus of the energy sector on other renewable energy sources.

In order to ensure coherence within the EU *acquis*, the four policy options were designed as a complement to the already existing policies and new initiatives, where these cannot fully address the defined problems.

[132] SWD(2016)418

8. HOW WILL MONITORING AND EVALUATION BE ORGANISED?

Monitoring and evaluation of progress towards the policy objectives can be done partly using monitoring tools under existing instruments or existing Eurostat data, and partly through other means, including the new Energy Union governance framework.

In particular, monitoring of the overall quantities of biomass used for energy as well as the type of biomass, type of feedstocks, geographical origin and final use will be important. Reporting requirements already exist under the Renewable Energy Directive and will be streamlined through the Energy Union governance framework. In the context of this framework, the contribution of biomass use to the climate and energy targets as well as on its efficient use will be monitored through the national plans and measured against the 2030 objectives set for greenhouse gas emissions, renewable energy and energy efficiency.

Regarding the specific policy objectives, the monitoring should take place as follows:

- Objective: contribution of bioenergy to climate change mitigation
    - Reporting under the EU regulation on Land use, Land use change and forestry greenhouse gas emissions[133] and in particular under the provisions for forest management
    - Disaggregated reporting on the type of feedstocks used for bioenergy and their geographical origin

- Objective: reduce impacts on biodiversity, soil, water and air
    - Reporting under existing EU environmental legislation in particular concerning biodiversity and air pollution
    - Reporting on forest management practices in the EU through the Forest Europe process
    - (In the case of option 3 or options building on option 3): reporting on how the requirements concerning sustainable forest management under the risk-based approach are implemented (in EU and non-EU countries)

- Objective: promote efficient uses of biomass for energy
    - Reporting on final use of solid and gaseous biomass (electricity only, electricity with CHP, heating and cooling)
    - Monitoring of prices of wood raw materials in the EU

[133] COM/2016/479

ANNEX 1. PROCEDURAL INFORMATION CONCERNING THE PROCESS TO PREPARE THE IMPACT ASSESSMENT REPORT

The interservice group (ISG) on sustainability of bioenergy was set up on 1 July 2015, as a sub-group of the ISG preparing the review of the Directive on renewable energy sources. Its objective is to prepare, with the participation of all interested services, an impact assessment and a legislative proposal and/or other instruments as appropriate. The ISG is chaired by the Secretariat-General, who also acts as the leading service on this file. Five DGs (AGRI, CLIMA ENER, ENV, GROW) act as associated services in order to support SG in preparing the work of the ISG and the JRC has provided scientific advice and support all along the process.

In the Agenda Planning, the initiative on sustainability of bioenergy is considered as one of the issues within the Renewable Energy Package (2016/ENER/025). As such, it also features in the Commission Work Programme for 2016 as part of the Energy Union Package (action No 7).

The ISG met six times for the purpose of preparing and discussing this impact assessment. As a follow-up to the first meeting, services were in particular invited to provide information on all evidence, studies, and processes relevant for the work of this ISG. The ISG also discussed specific sections of the impact assessment as well as the preparation of the stakeholder consultation.

The five associated DGs and the JRC made substantial contributions to the preparation of this impact assessment throughout the process, including by providing quantified input through dedicated modelling and studies (more details below).

Consultation of the RSB:

The draft IA was submitted to the Regulatory Scrutiny Board (RSB) on 27 July and wasdiscussed at the RSB hearing on 14 September 2016, following which the RSB gave a positive opinion.
The issues raised by the RSB, with the relevant actions undertaken on the text of the Impact Assessment, are summarised in the following table.

Revised Impact Assessment on sustainability of bioenergy	
Issues Raised	**Changes introduced in the revised version**
Issues cross cutting to other impact assessments	
***Support schemes* have played an important role in promoting bioenergy and are key drivers of the future sustainability of bioenergy. The problem definition and baseline should assess and integrate the influence of existing and future support schemes for renewable energy. The report**	The issue has been addressed in further details in sections 2 (problem definition) and particularly 5.1.3 (baseline) where more details have been given on the way changes to the Renewable Energy Directive and Market Design will affect bioenergy demand. The modelling work examines post-2020 a least cost approach at EU level, while taking into account the

should integrate how changes to the Renewables Directive and the market design initiative will affect the demand for bioenergy. Given the importance of support schemes in driving the demand for bioenergy, the IA should explore the need for policy options explicitly covering the design of support schemes.	discontinuation of national binding targets for renewable energy.
***Biofuels:* This IA assesses sustainability requirements for bioenergy, but it explicitly excludes biofuels included in the IA on renewable energy. Given that the issues for biofuels are not different from the issues for other sources of bioenergy, the reference to the impact assessment on renewables should demonstrate the coherence or the possible differences in policy approach.**	Section 2 now explains more clearly the way biofuels are examined in the Impact Assessment on renewable energy (addressing notably indirect land use change, the cap on food-based biofuels and the development of advanced biofuels) and in the present Impact Assessment. (addressing the current sustainability criteria for biofuels).
Issues specific to the present impact assessment	
The IA addresses all forms of bioenergy, but the analysed options mostly concern solid biomass. The IA should explain and justify this focus better. In addition, the report characterises some issues as problems without much support from evidence, including stakeholder views. One such example is fragmentation of the internal market. While the report should explain the issues it considers, it should only retain the most relevant ones throughout the analysis (objectives, options and impacts).	Section 2 now explains the treatment of biomass vs biofuels more clearly. The issue of fragmentation of the internal market has been substantially reworked in the problem definition (section 2.4) as well as in the impacts (section 6.4.8); this issue has also been removed from the specific objectives, as the evidence does not indeed point it out as a major risk.
The IA should explain better its choices regarding examined and discarded policy options. It should explain whether other policy options (like more restrictive support schemes) could have been considered.	The section on policy options (section 5.2) now goes more into depth into discarded options, complemented by Annex 10. It also explain why more far-reaching options were not considered.
The report does not explicitly present a preferred option. While this is not obligatory,	The section on the comparison of the options and the way they are fit for the purpose (section 7.2) has been reworked to

doing so would enhance the usefulness of the IA in the subsequent decision making process. At least, the report should reduce the number of potential "preferred options" to a few realistic ones.	explain more clearly why there is no clearly preferrable option that could be identified by Commission services purely on the basis of evidence.
Main recommendations for improvements	
<u>**Problem analysis and baseline**</u> **The report should better structure the problem analysis and explain the links with other initiatives, such as the revision of the Renewables Directive and the future design of electricity markets. In this context, the baseline should reveal the role played by renewable energy targets, dispatch priority and support schemes for bioenergy in the likely evolution of bioenergy use and its impact on emissions. Moreover, the report should clarify whether it deals with bioenergy in general (as currently in the problems analysis) or rather focusses on solid biomass (as in the policy options; although biofuels appear in the discarded options). Finally, the report should re-examine in how far internal market aspects (mentioned by some stakeholders) constitute a relevant problem to be addressed in the context of this initiative (as biomass is mainly locally consumed).**	The problem definition has been substantially reworked and includes more elements on the link with other initiatives. The baseline (section 5.1.3) has been developed to include more specific elements in particular on the removal of priority dispatch and on elements linked to support schemes. The section on policy options now explains why it was chosen not to reopen the biofuels sustainability criteria on substance, but rather to improve the way they are implemented. Elements on the internal market have been reworked both in the problem definition (section 2.4) and in the impacts (section 6.4.8)
<u>**Policy options**</u> **The report should clarify on the basis of which criteria a number of policy options have been discarded (in particular when some of them could tackle administrative burden concerns) while others have been kept for further examination. Given that the overall impacts of the policy options are found to be rather limited, the report should explain why it has not considered more far-reaching policy options (e.g. moderating the demand for biomass). Moreover, in light of the consideration of support schemes in the problem analysis (see above), the report should reflect why policy options to reform or ban such support schemes have not been examined.**	Section 5.2 on policy options now gives more details on the most important policy options that were discarded at an early stage. This is further complemented by Annex 10 with explanations for discards of a number of other potential policy approaches; the report now also looks into the possible effects of a more stringent threshold for supply chain emissions. Finally, it also gives further explanations on why some more far-reaching policy options are not examined.
<u>**Impact analysis**</u> **The report should clearly set out the most**	In section 6, a summary has been

significant impacts and separate limited from uncertain impacts. The report currently does not identify a preferred policy option; however, as section 7.2 indicates that the policy options have only limited impacts, the report should evaluate, taking into account the analytical uncertainties, whether the baseline is itself a viable policy option. In the absence of a preferred policy option, the report should clearly present how the different options compare, including stakeholders' views when available and at least reduce the number of potential "preferred options" to the most credible ones.	introduced for each category of impacts (environmental, economic, social), summarising the impacts and identifying the ones that could be significant. Section 7 and in particular 7.2 (proportionality) have been reworked to better explain how the baseline is a viable policy option. The account of stakeholder preferences regarding various options was further streamlined in the sections describing the policy options. The section 7.2 now also compares the options in terms of the effectiveness with which they address the identified risks.
Procedure and presentation	
The report needs to be more reader-friendly. Non-expert readers should easily be able to discern the main policy trade-offs. The issues and the examined policy options should be easy to recognise and understand. Policy makers should have straightforward access to the main arguments in a way that allows them to rank the various policy options. The report should be shorter and better structured, with minimal use of jargon and acronyms.	The various sections of the report have been significantly redrafted for clarity, while at the same time introducing the additional elements requested. Also the glossary has been expanded and a list of acronyms has been introduced. Section 7 in particular (comparing the options) has been reworked to make the conclusions clearer. At the same time, conciseness was sought across the whole report so that its length is not significantly affected even after introduction of all the requested additional analysis.

Studies

The European Commission contracted several studies, in order to gather further evidence on the main risks and opportunities linked to bioenergy. Work on these studies was in most cases carried out in parallel with the impact assessment process. Nevertheless, either the final versions of these studies or at least their final drafts were available to Commission services before the submission of the draft IA to the Regulatory Scrutiny Board. In particular:

1. *Sustainable and optimal use of biomass for energy in the EU beyond 2020*. By a consortium led by PricewaterhouseCoopers. The draft final report was made available to Commission services on 29 June 2016.
2. *Carbon impacts of biomass consumed in the EU: quantitative assessment*. By a consortium led by The Research Agency of the Forestry Commission (United Kingdom). The final study was delivered in December 2015.

3. *Study on impacts on resource efficiency on future EU demand for bioenergy*. By a consortium led by the International Institute for Applied Systems Analysis (Austria). The final study was delivered in May 2016.
4. *Environmental Implications of Increased Reliance of the EU on Biomass from the South East US.* By a consortium led by COWI (Denmark). Published in July 2016.

As the above studies examined the bioenergy sustainability issues from different angles. The first three studies provided a range of analytical outcomes that were not, in some cases, consistent across the three studies, while they were at the same time based on slightly different baseline scenarios or assumption inputs.

In order to make sure that the underlying assumptions, the modelling results, as well as the strengths and limitations of the models used are well understood by policy makers when reading the results of these studies, the Joint Research Centre organised a conference addressing this challenge with the three *consortia*, researchers from European universities and think-tanks and the Commission services. The event took place in Ispra, Italy, on 21-22 April 2016. Further detail on the underlying modelling exercise is then available in the Annex 4.

In addition, Commission services were informed by other studies that have been conducted in the course of other policy work streams, but with high relevance for sustainability of bioenergy:

1. *Climate benefits of material substitution by forest biomass and harvested wood products: perspective 2030.* Consortium led by Thünen Institute of Wood Research (Germany). The revised draft of the Final Report was made available to Commission services in March 2016.
2. *Study on the optimised cascading use of wood.* Vis M., U. Mantau, B. Allen (Eds.) 2016
3. *Study on the wood raw material supply and demand for the EU wood-processing industries.* 2013.
4. *Study on Renewable Energy and Research and Innovation Capacity of Sub-Saharan Africa: Theme report — Biomass.* By a consortium led by Ecorys. The final report was delivered in April 2015.

The interservice group also profited from the scientific input by the Joint Research Centre, in particular through the following reports:

1. *Biomass study 2015/2016.* By the Joint Research Centre, pursuant to the mandate on the provision of data and analysis on a long-term basis on biomass supply and demand. The Interim Report has been made available in December 2015.
2. *Solid and gaseous bioenergy pathways: input values and GHG emissions*. Giuntoli et al. Version 1a available to Commission services as of xx. 2015.
3. *Carbon accounting of forest bioenergy*. Agostini et al. 2014.

Apart from its direct inputs through its studies, the Joint Research Centre played a key role in verifying the robustness of the studies provided to the Commission by external experts.

There are indeed a number of other recent studies addressing the challenges related to bioenergy, notably its climate impacts. These have been thoroughly mapped through two literature reviews (one by Joint Research Centre (JRC) study on carbon accounting, the other in the Study on Carbon Impacts) that are summarised in ANNEX 7.

ANNEX 2. STAKEHOLDER CONSULTATION

Since launching the impact assessment process in July 2015, Secretariat-General as the leading service on the file participated in a broad stakeholder outreach. This has been taken forward at three levels:

i) Bilateral meetings with stakeholders in order to discuss bioenergy sustainability from their specific point of view. This was particularly pertinent for gathering the evidence for the problem definition.

ii) An online public consultation allowing a broad range of stakeholders to express their views and suggestions on all elements of the impact assessment process, in particular risks and benefits of bioenergy, policy objectives to be pursued, the ability of existing legal framework to cope with the challenges and the possible policy approaches.

iii) A stakeholder conference providing for an exchange of views between representatives of civil society, professional organisations, businesses, public authorities, scientists and researchers. The particular added value of this event was that stakeholders from the full spectre of interests discussed questions and challenges from the expert audience in the conference plenary.

In addition, as of the end of April 2016 the Commission has received over 58 000 emails as part of a campaign. These emails originate predominantly from US citizens, with a small fraction of these messages also from EU Citizens. With a few exceptions, these messages were coordinated through a communication campaign lead by US-based environmental NGOs Natural Resources Defence Council, National Wildlife Federation and Dogwood Alliance

The campaign focused on the impact of EU bioenergy demand on US forests. Concerns were expressed that the increase in pellet productions in the US, driven by EU demand, was leading to unsustainable practices with impacts in particular on climate change and biodiversity. The campaigners ask the EU to take action to remedy these concerns.

I) Bilateral meetings

In the period between July 2015 and June 2016, Secretariat-General met with a wide range of stakeholders at their request. Other services (in particular the five associated DGs) also met with a wide array of stakeholders.

II) Online consultation

II.1. Introduction

The online public consultation was open for 12 weeks, from 10 February until 10 May 2016. During this period, the Commission received in total 971 replies, with a few belated responses arriving after the deadline.[134]

Through the online consultation, the Commission meant to gather the views of all interested stakeholders and citizens, across the European Union and beyond, as well as across public,

[134] Whilst all contributions were fully considered in Commission's analysis, the statistical data in this Annex only reflect the 971 contributions received within the deadline.

private, academic and NGO sectors. The aim of the consultation was to inform the policy making process on the future bioenergy sustainability policy and contribute to the underlying analysis.

The following sections present the main features of the consultation as well as some of the key results. A detailed analysis of the EU Survey has been carried out by VITO NV.[135]

II.2. Organisation of the questionnaire

The questionnaire was designed in the way that allowed reaching out to a wide range of interested stakeholders, including individuals, while at the same time giving space for in-depth analytical input by stakeholders with significant expertise/experience in the field. The web tool also provided for a possibility to upload position papers or other material.

The online consultation was composed of 28 questions, including open and closed ones. 11 questions were aimed at gathering information about respondents, i.e. whom they represent, their sector of activity, size (where appropriate), country of residence etc. This allowed drawing more detailed analysis from the responses on the substantial questions.

The next group of questions focused on broad perceptions of bioenergy and assessment of the related risks and opportunities. In particular, participants were asked to rate the contribution of bioenergy to a range of benefits as well as the significance and relevance of a number of risks that have been raised concerning bioenergy production and use.

The following set of questions asked stakeholders to appreciate the environmental and administrative effectiveness of the existing EU sustainability scheme for biofuels and bioliquids, its role in promoting market uptake of advanced biofuels and the obstacles to faster development of innovative technologies. Similarly, respondents were also invited to review the effectiveness of the existing policy framework in addressing the risks linked with solid and gaseous biomass used for heat and power.

Finally, the questionnaire asked respondents to rank nine policy objectives for the future policy. Building on responses to the previous questions, stakeholders were then asked about the need for additional EU policy on bioenergy sustainability, either for biofuels and bioliquids, for solid and gaseous biomass, or for both, and their views on what this policy should entail.

II.3. Respondents

Out of the 971 replies:

- The largest contribution came from individuals (278 respondents). The background of these respondents in a number of cases overlap with some of the other stakeholder groups below, as they often involve researchers in think-tanks and universities, employees in private and public enterprises or retired practitioners.
- 207 replies were sent by private enterprises and 55 by public enterprises. The energy and forestry sectors were the most represented in these answers (110 and 78 answers respectively). 39 % of the respondents in this category defined themselves as large enterprises, 25 % as micro-enterprises, 21 % as small enterprises and 14 % as medium-sized enterprises.
- Moreover, there were 155 replies from professional organisations representing stakeholders in one or more sectors. The sectors that were most often listed in the scope activity were energy (83 respondents), forestry (54 respondents), agriculture (42),

[135] Insert reference to the report, once finalised.

followed by food (19), biotechnology (18), woodworking industry (16), pulp and paper (13).

- a total of 73 public authorities participated in the consultation — these included national, regional and local authorities.
- there were also 110 civil society organisations, mostly active in the area of environmental protection, 51 academic/research institutions and 22 'international organisations'[136] who contributed to the survey.

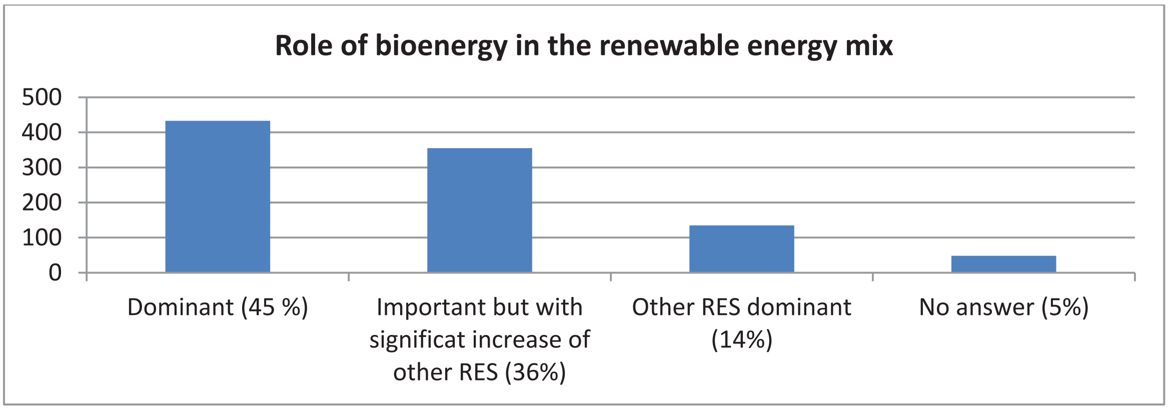
II.4. Representativeness of the online consultation

The level of response to the online consultation is considered satisfactory, as well as the representation of a wide range of stakeholders and citizens from a range of sectors and geographical origins in the responses. It has to be noted however that certain geographical areas were over-represented in the number of responses, while on the other hand some countries are less represented. In particular almost half of all responses (46 %) came from Germany and Austria. A large number of contributions (at least 20) were received from Sweden, Finland, Belgium, the Netherlands, United Kingdom, Spain and France. At the same time, the Commission received only 67 replies from the EU12 countries combined.

A significant number of stakeholders answered open questions as well as the closed ones, providing more detailed comments. For instance, more than half of respondents provided views regarding the content of the future EU policy framework on sustainability of bioenergy. About a third of all respondents answered question 9 which allowed for other specific views that could not be expressed in the context of the replies to the previous questions.

II.5. Bioenergy and its future role in the EU's Renewable energy mix

The survey started with an inquiry about general perceptions of bioenergy and the various forms its takes. Firstly, stakeholders were asked whether bioenergy should i) continue to play a dominant role as it does today (over 60 % of share in RES), ii) continue to play an important role in the renewable energy mix, but the share of other renewable energy sources (such as solar, wind, hydro and geothermal) should increase significantly, or iii) play an important role in the renewable energy mix, but with other renewable energy sources becoming dominant.



These results can be interpreted in two principal ways. On the one hand, there are more than 80 % of respondents who underline the importance of bioenergy in the future energy mix. At

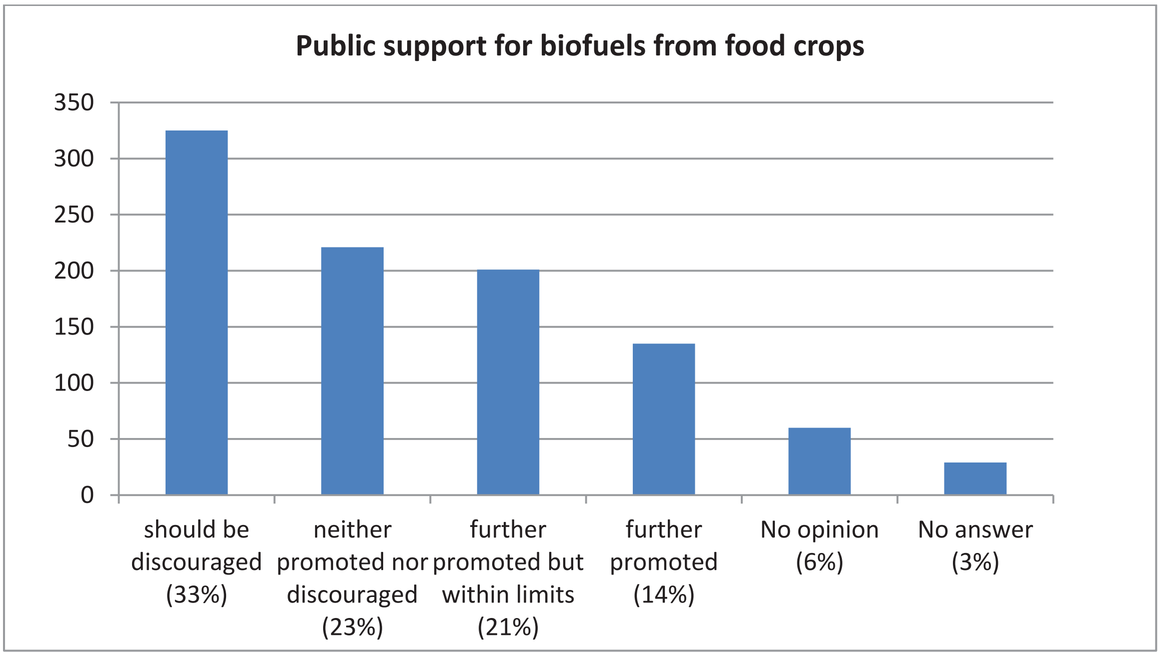
[136] The subsequent analysis showed that respondents who defined themselves as international organizations are in majority of cases professional associations acting at the international level.

the same time, about one half of respondents consider that future deployment of renewable technologies should be driven by other renewable energy sources that bioenergy. The support for dominance of bioenergy was mostly driven by private enterprises, professional organisations and individuals. On the other hand, the call for dominance by other technologies came primarily from civil society organisations. The middle way between the two was most often preferred by public authorities, public enterprises and academic/research institutions.

II.6. Public support for bioenergy

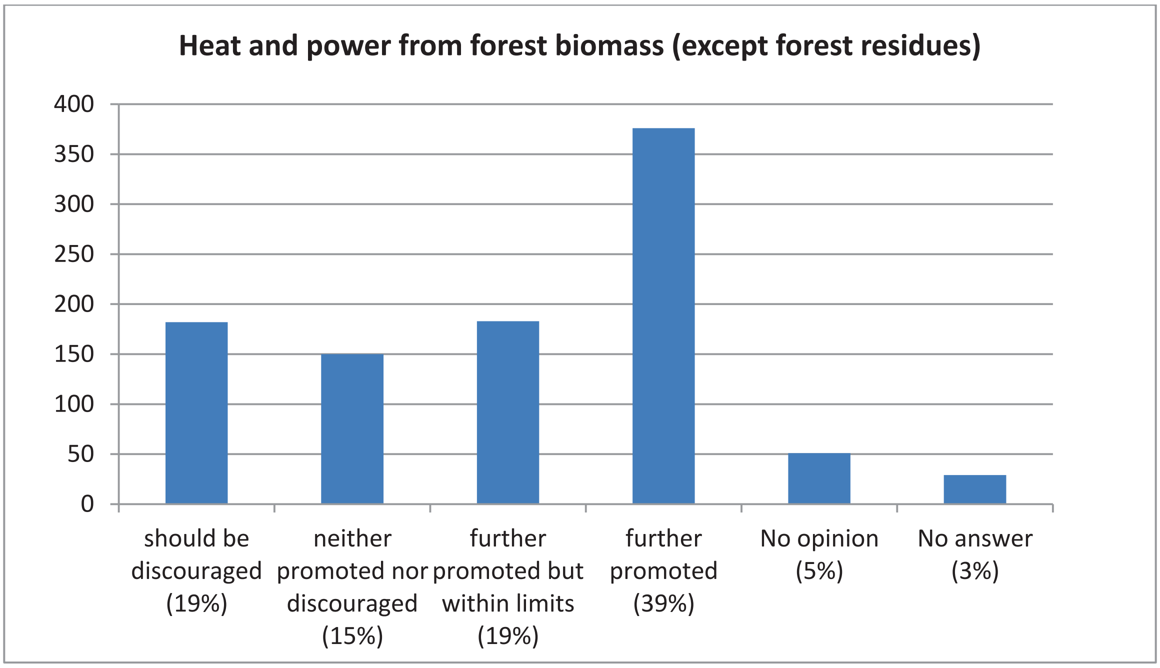
The bulk of bioenergy in nowadays based on the use of food crops for production of biofuels and the use of forest biomass for heat and power generation. In this regard, stakeholders were asked about the role of public policy in promoting or discouraging this practice.

On food based biofuels, approximately one third of respondents considered that this should be discouraged by public policy, while a similar amount of replies suggested continuation of public support for this practice, albeit a majority within this respondent group considering that there had to be some limits to such support. While the continuation of public policy support was mostly favoured by private companies and professional associations, the discouragement of such biofuel production pathway or a neutral policy approach was emphasised across all stakeholder groups to various extents, with civil society organisations indeed in the lead among those calling for discouragement.



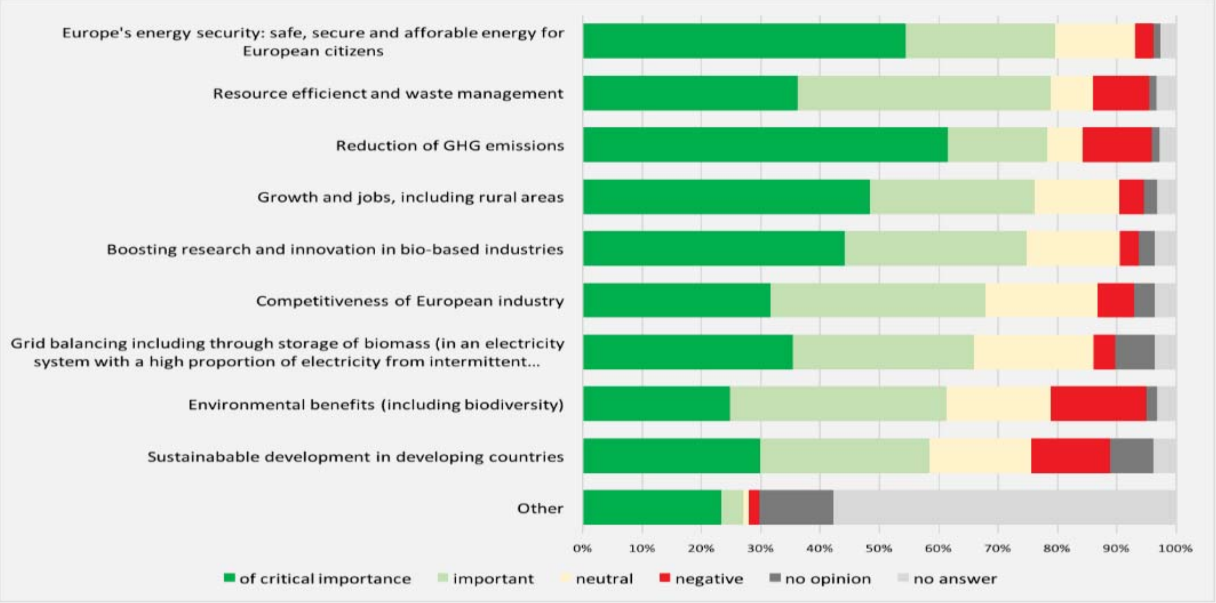
Regarding the use of forest biomass for heat and power, the replies received were more strongly in favour of further promotion by public policy. Almost 70% of the replies went in this direction and only a minority within this sub-group was calling for support within certain limits. The support for these options was mostly driven by private and public enterprises and professional organisations. More than half of replies from public authorities and academic organisations did also support this point of view

The call for discouragement came mostly from civil society organisations, while the support for the mid-way option of 'neutral' policy treatment was voiced across all stakeholder groups in a rather equal manner.

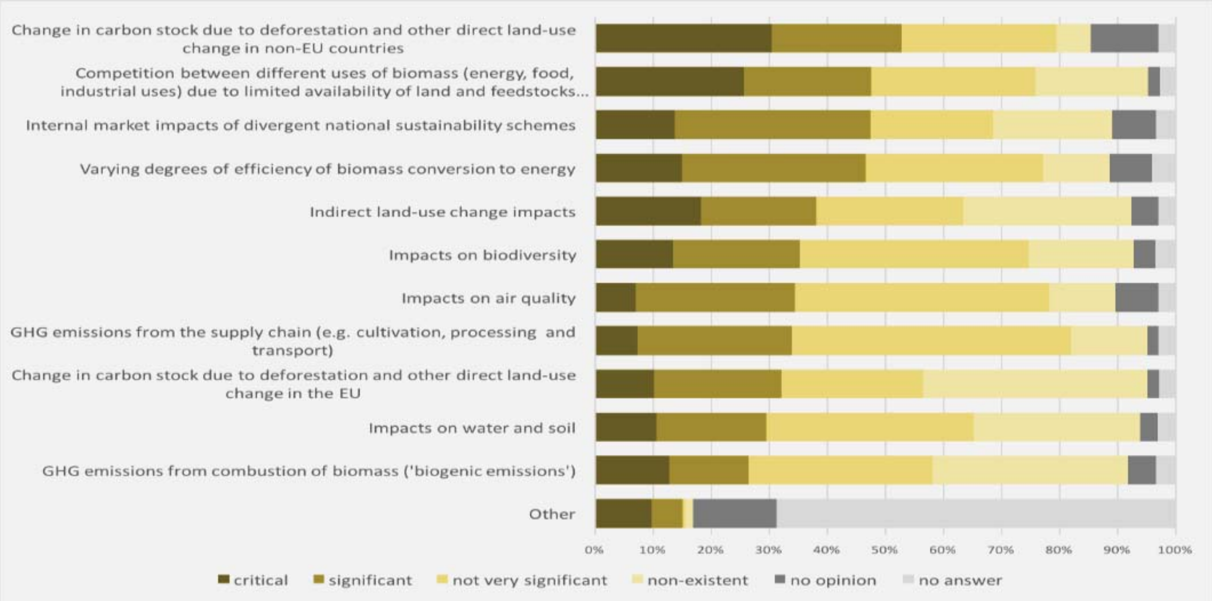


II.7. Risks and benefits of bioenergy

When asked about benefits of bioenergy, all of the options suggested to stakeholders scored relatively high — between 58 % and 79 % cumulatively for importance and critical importance of the mentioned benefits. The reduction of GHG emissions scored the highest in terms of critical importance, but reached similar levels to a number of other benefits when both critical importance and importance are considered.

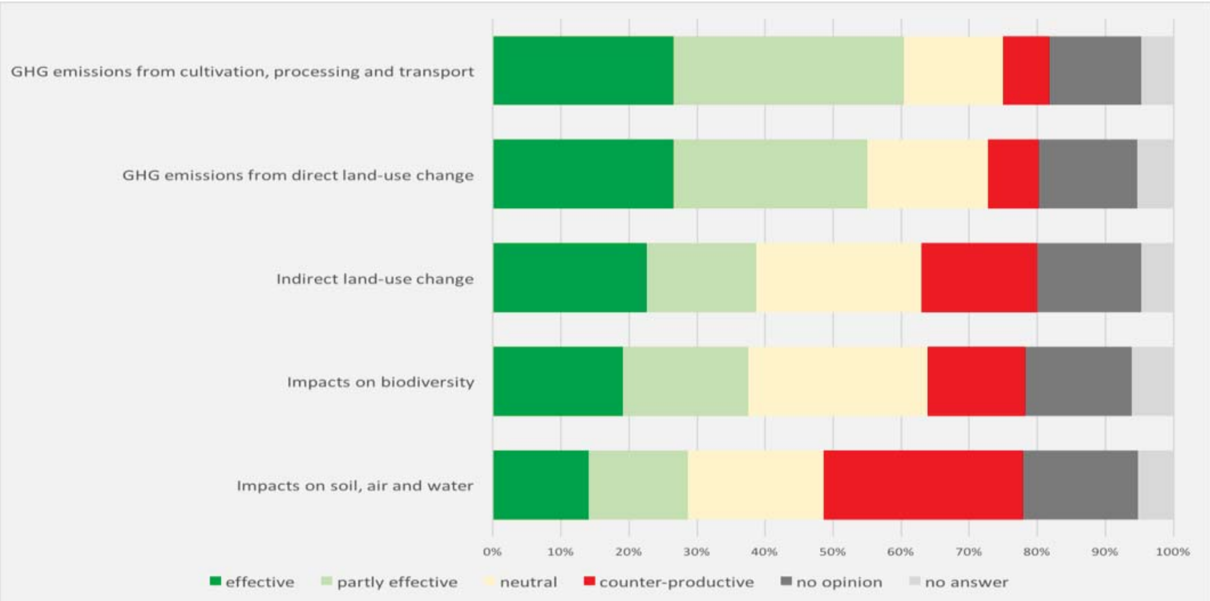


On the other hand, similar elements have at the same time been considered as posing significant or critical risks, although the negative impact on climate change through deforestation was mostly pointed to when it comes to third countries.

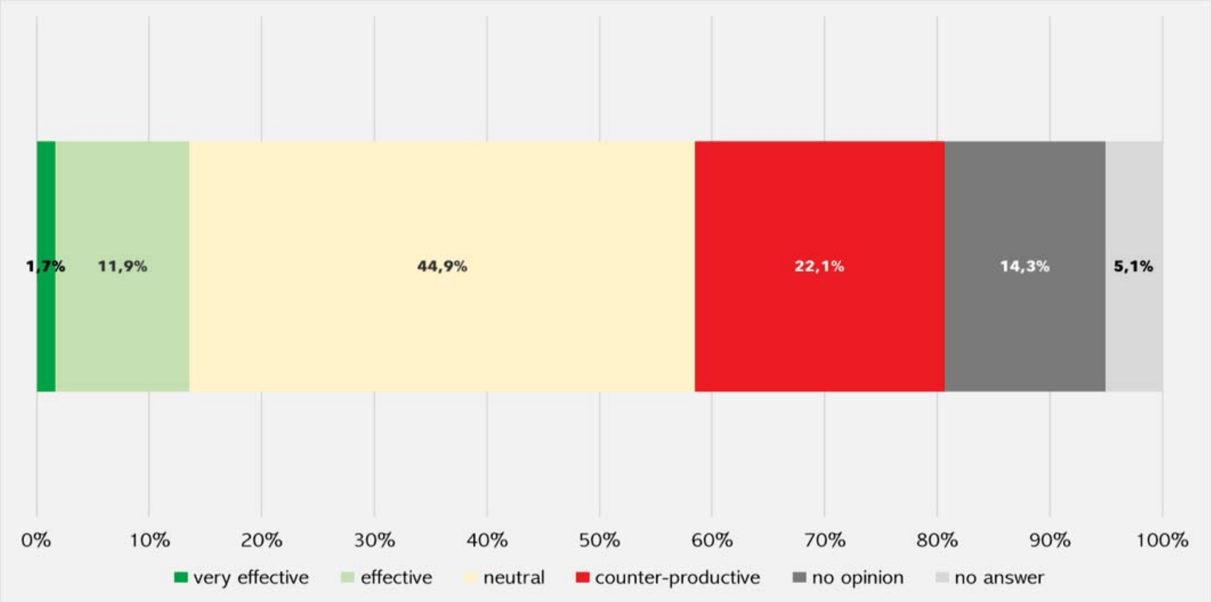


II.8. Efficiency of the current policy framework

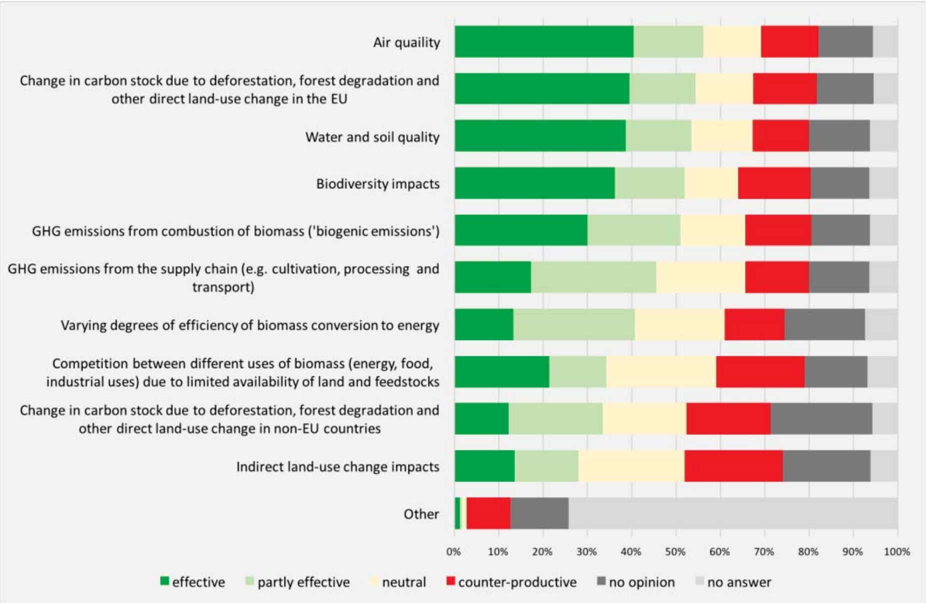
Stakeholders were asked about the effectiveness of the current EU sustainability scheme for biofuels and bioliquids. While the mitigation of GHG emissions from the supply chain and land use was considered rather satisfactory, it was less so for the remaining environmental impacts.



The following figure shows how effective, in views of the stakeholders, is the current policy framework on biofuels effective in driving the development of advance biofuels. While the most frequent answer was 'neutral', more than 20 % of the respondents considered the framework as counter-productive, which is double compared to those who viewed it as effective or very effective.



The final table under this section illustrates how stakeholders perceive the effectiveness of existing EU and national policies on sustainability of solid biomass. There is an obvious correlation between the worst scoring areas in this table and the most critical/important risks identified before (see the figure in chapter II.7), such as indirect land use change impacts, deforestation in third countries and competition between uses of biomass.



II.9. Prioritisation of policy objectives

Stakeholders were asked to establish an order of priority for the list of nine policy objectives that may be pursued through the bioenergy sustainability policy. By ranking the policy objectives according to the number of times they featured among the top three objectives,[137] there are three levels of priority that come out of the consultation.

1) Contribution to climate change featured among top 3 objectives in 765 replies

2) promotion of efficient use of the biomass resource scored top 3 in 473 replies;
3) avoiding environmental impacts follows third with 443 replies;
4) the next in line is long-term certainty for operators with 426 respondents;
5) closely followed by promotion of energy security featuring in top 3 in 423 replies;

6) 294 respondents prioritised promotion of EUs industrial competitiveness;
7) 277 replies put mitigation of indirect land use change impacts among top 3;
8) minimising administrative burden was of top importance for 263 stakeholders;
9) promotion of free trade and competition in the EU was a priority to 192 replies.

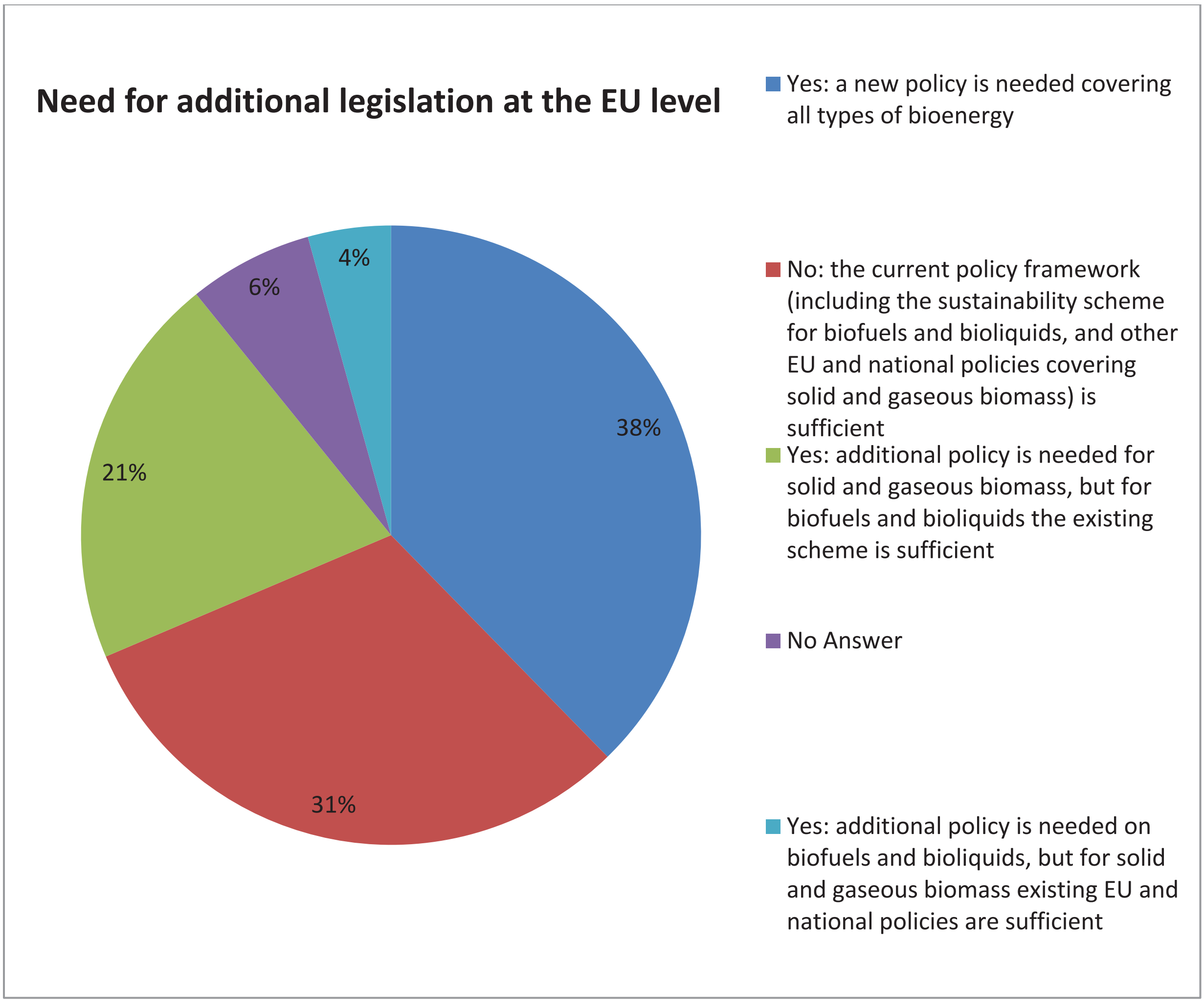
An overwhelming majority of respondents to the public consultation considered fighting climate change to be the highest policy priority in the context of this file. However — and this shows the complexity and differing views about this file — views were divided on how to achieve this objective. A large share of the same respondents considered that the best way to support climate mitigation is to further encourage bioenergy and make sure it keeps its dominance in the renewable energy mix. Another large number of respondents suggested on the other hand that the climate policy objective would best be achieved through relying less on bioenergy and meeting the renewable target predominantly with other technologies such as solar, hydro and wind.

II.10. Need for an additional policy at the EU level

While approximately one third of respondents considered that the current policy framework at the EU and national levels are sufficient to address the risks and opportunities of bioenergy, 59 % of the replies suggested that a new sustainability policy is needed for solid and gaseous biomass and 42 % called for an additional policy biofuels and bioliquids.

The drive for new legislation came mostly from private enterprises, civil society organisations, professional organisations, academia and individuals, while satisfaction with the legislative status quo was particularly visible among the replies by public authorities and public enterprises.

[137] To be noted that use of other weighing methodologies for measuring the relative importance of policy objectives do not bring any major difference to the final ranking of the options.



III) The stakeholder conference

The stakeholder conference on "A sustainable bioenergy policy for the period after 2020" took place on 12 May 2016 in Brussels. It consisted of 4 panels, each focusing on different risks and benefits linked to bioenergy. 110 participating stakeholders represented the bioenergy industry (both biofuels and biomass for heat and power), forest owners, agricultural sector, wood-working industries including pulp and paper, researchers, academia, civil society organizations, representatives of EU Member States, representatives of several third countries and Commission services.

- The first panel examined forest biomass as a resource for energy and other uses, based on presentations by AEBIOM (European biomass Association), CEI-Bois (European Confederation of Woodworking Industries), CEPF (Confederation of European Private Forest owners) and CEPI (Confederation of European Paper Industries).

  Issues touched upon in this panel included competition for raw materials, where views differed between the biomass industry/forest producers on the one hand, which didn't see it as an issue, whereas the paper and woodworking industry argued that lower availability of raw material could be observed in certain regions or sectors and were concerned by public subsidies for bioenergy (although these would not be an issue if focused on encouraging further mobilization of the resource, rather than shifting the use of the already harvested raw material). In the ensuing discussion, stakeholders with business interests in bioenergy highlighted the opportunities of the increased use of bioenergy for the whole supply chain (opportunities for forest owners, saw mills, etc.), whilst civil society organizations pointed out negative impacts of bioenergy on climate and biodiversity.

- The second panel examined impacts of bioenergy on climate. All speakers on the panel (representatives of the Joint Research Centre, UK Forest Research and University of Wageningen) recognised that biogenic emissions from combustion of wood were an important factor to be taken into account in policy making. At the same time, though with different nuances, all the three scientists considered that the carbon neutrality of forest bioenergy depends on a number of variables and cannot therefore be automatically assumed in all cases.

  In the ensuing discussion, a number of civil society organizations underlined the in their view false assumption of carbon neutrality and saw this as a reason for addressing biogenic carbon emissions in the future policy initiative. At the same time, the complexity of the assessment of biogenic carbon emissions and hence the difficulty to address it through a policy based on robust carbon accounting also emerged from the debate.

- The third panel assessed the contribution of the agricultural sector and in particular the perspectives for advanced biofuels and biogas. In the panel, Copa-Cogeca (representing agricultural producers) outlined the potential of the agricultural sector and called for encouragement for all bioenergy sources, including food-based biofuels, advanced biofuels, biogas and heat and power from forestry biomass. The European Biogas Association outlined the opportunities of biogas, as it can serve multiple uses (heat, power, transport) and can be easily transported and stored. Representative of St1 Nordic Oy (on behalf of the Leaders of Sustainable Biofuels) underlined the essential role of advanced biofuels in decarbonisation of transport and called for a blending mandate in order to create a stable market for this technology.

  The following discussion confirmed the controversial nature of biofuels, where in particular civil society organizations are very critical about food-based biofuels and call for caution regarding the advanced ones, whilst stakeholders representing business interests pointed out the economic benefits and synergies between biofuels production and other agricultural economic streams. An extensive debate also took place on modelling tools used to quantify the effects of indirect land-use change.

- In the final panel, the speakers were invited to examine possible streams for the future EU policy on sustainable energy in the post-2020 period. The representative of the US Forest Service emphasized the consequences of imposing unnecessary administrative burden on US forest owners, and pointed that the demand for wood products, in particular wood pellets for export to Europe, did help to promote the economic value of forests in the South-East US and to prevent conversion of these forests due to urbanization. Birdlife Europe outlined a number of negative aspects of bioenergy and suggested an overall cap on its use in the EU, coupled with restrictions on specific categories of biomass (such as roundwood and stumps) as well as on final uses (through a minimum conversion efficiency). A representative of Swedish Government outlined a national consensus (including Swedish NGOs) over bioenergy and its role in decarbonising energy and transport systems. He advocated the use of a risk-based approach, which would provide the necessary sustainability guarantees for the bioenergy sector, without undue administrative burden. A Representative of Sustainable Biomass Partnership (SBP) certification scheme explained how their scheme complemented the existing standards for wood based products (FCS, PEFC). This Framework is primarily based on regional risk assessments and was particularly designed to meet regulatory requirements in several EU Member States (UK, NL, DK and BE).

The brief discussion that followed was particularly dominated by a controversial exchange of views about the overall benefits of bioenergy in transformation of the economy from one based on fossil-fuels into a low-carbon one.

ANNEX 3. WHO IS AFFECTED BY THE INITIATIVE AND HOW

If a new legislation is adopted, it will affect economic actors such as solid biomass producers from agriculture, forest biomass producers and operators of medium and/or large bioenergy plants, depending on the 'de minimis' threshold for the size of installation, and users of wood biomass in other sectors. This will be notably linked to conducting activities necessary to pursue a certification in order to show compliance with sustainability requirements.

In addition, public authorities would have to conduct administrative efforts linked to implementation of the sustainability requirements in their national legislation and the subsequent monitoring and enforcement of the compliance and the reporting to the European Commission.

ANNEX 4. ANALYTICAL MODELS USED IN PREPARING THE IMPACT ASSESSMENT

PRIMES

The PRIMES model is an EU energy system model which simulates energy consumption and the energy supply system. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States. This includes consistent EU carbon price trajectories.

Decision making behaviour is forward looking and grounded in micro economictheory. The model also represents in explicit and detailed way energy demand, supply and emission abatement technologies, and includes technology vintages.

The core model is complemented by a set of sub-modules, of which the biomass supply module is described below.

PRIMES has been used for the analysis underpinning the Commission's proposal on the EU 2020 targets (including energy efficiency), the Low Carbon Economy and Energy 2050 Roadmaps as well as the 2030 policy framework for climate and energy.

PRIMES is a private model and has been developed and is maintained by E3M Lab/ICCS of National Technical University of Athens[138] in the context of a series of research programmes co-financed by the European Commission.

The model has been successfully peer reviewed,[139] most recently in 2011[140]

PRIMES Biomass Supply

The PRIMES biomass model is a modelling tool aimed at contributing to the energy system projections for the EU Member States and the impact assessment of policies promoting renewable energy sources and addressing climate change mitigation. The detailed numerical model simulates the economics of supply of biomass and waste for energy purposes through a network of processes, current and future, which are represented at a certain level of engineering detail for which a very detailed database of biomass and waste processing technologies and primary resources has been developed.

The model transforms biomass feedstock — primary energy — into bioenergy commodities — secondary or final form — which undergo further transformation in the energy system, e.g. as input into power plants, heating boilers or as fuels for transportation.

The model calculates the inputs in terms of primary feedstock of biomass and waste to satisfy a given demand for bioenergy commodities. The model further estimates the land use and the imports necessary and provides quantification of the amount of production capacity required. Furthermore, all the costs resulting from the production of bioenergy commodities and the resulting prices of the commodities are quantified.

[138] http://www.e3mlab.National Technical University of Athens.gr/e3mlab/ .
[139] http://ec.europa.eu/clima/policies/strategies/analysis/models/docs/primes_model_2013-2014_en.pdf.
[140] https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1569_2.pdf .

The model covers all EU28 Member States individually and covers the entire time period from 2000 to 2050 in five year periods. It is calibrated to Eurostat statistics wherever possible, data from Eurostat is complemented by other statistical sources to fill in the database necessary for the model to function.

The model can operate as a standalone model provided that the demand for bioenergy commodities is given exogenously, but is more often used together with the PRIMES Energy System Model as a closed loop system.

EUCO scenarios

Two central policy scenarios reflecting the 2030 targets and main elements of the 2030 climate and energy framework agreed by the European Council in 2014[141] have been developed, EUCO 27 and EUCO 30. This recognises that for the energy efficiency target a review will still be undertaken to set the level of ambition. These scenarios also aim to provide consistency across a number of impact assessments underpinning 2016 Energy Union policy proposals. Using two central scenarios increases the robustness of policy conclusions.

Both scenarios start from the EU reference scenario 2016 and add the targets and policies described in detail below. In addition, coordination policies are assumed which enable long-term decarbonisation of the economy. Coordination policies replace the 'enabling conditions' which have been modelled in 2030 framework IA and the 2014 IA on 2030 EE targets.

Coordination policies relate to ongoing infrastructure developments that will enable a larger exploitation of cost-effective options after 2020, such as grid developments, and relate to R&D and public acceptance that are expected to be needed to meet long-term decarbonisation objectives.

The table below summarises the assumptions on climate, renewable energy and specific energy efficiency policies in the EUCO 27 scenario that have been modelled.

EUCO 27	This scenarios is designed to meet all 2030 targets set by the European Council: • at least 40 % GHG reduction (wrt 1990); • 43 % GHG emissions reduction in ETS sectors (wrt 2005); • 30 % GHG emissions reduction in Effort Sharing Decision sectors (wrt 2005); • At least 27 % share of RES in final energy consumption • **27 % primary energy consumption reduction** (i.e. achieving 1 369 Mtoe in 2030) compared to PRIMES 2007 baseline (1 887 Mtoe in 2030). This equals a reduction of primary energy consumption of 20 % compared to historic 2005 primary energy consumption (1 713 Mtoe in 2005). Main policies and incentives additional to Reference: Revised EU ETS • increase of ETS linear factor to 2.2 % for 2021-2030;

[141] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf. .

	• after 2030 cap trajectory to achieve -90 % emission reduction in 2050 in line with Low Carbon Economy Roadmap. Renewables policies • renewables policies necessary to achieve 27 % target, reflected by RES values applied in electricity, heating and cooling and transport sectors. Energy efficiency policies: Residential and services sector • increasing energy efficiency of buildings via increasing the rate of renovation and depth of renovation. In this model, better implementation of EPBD and EED, continuation of Art 7 of EED and dedicated national policies are depicted by the application of energy efficiency values. • financial instruments and other financing measures on the European level facilitating access to capital for investment in thermal renovation of buildings. This, together with further labelling policies for heating equipment, is depicted by a reduction of behavioural discount rates for households from 12 % to 11.5 %. • more stringent (than in Reference) eco-design standards banning the least efficient technologies. Industry • more stringent (than in Reference) eco-design standards for motors. Transport • CO_2 standard for cars: 85 g/km in 2025; 75 g/km in 2030 and 25 gCO_2/km in 2050;[142] • CO_2 standards for vans: 135 g/km in 2025; 120 g/km in 2030; 60 g/km in 2050;[143] • 1.5 % average annual energy efficiency improvements for new conventional and hybrid heavy duty vehicles between 2010-2030 and -0.7 % between 2030-2050; • measures on management of transport demand: - recently adopted/proposed measures for road freight, railways and inland navigation;[144] gradual internalisation of transport local externalities[145] as of 2025 and full internalisation by 2050 on the inter-urban network. Non-CO_2 policies • in 2030 carbon values of €0.05 applied to non-CO_2 GHG emissions in order to trigger cost-effective emissions reductions in these sectors

[142] On NEDC test-cycle.
[143] On NEDC test-cycle.
[144] Directive on Weights & Dimensions, Fourth railway package, NAIADES II package, Ports Package.
[145] Costs of infrastructure wear & tear, congestion, air pollution and noise.

	including in agriculture; • after 2030 carbon values set at EU ETS carbon price level.

In the EUCO 27 scenario, energy efficiency delivers a large part of GHG emissions reduction in the ESD/ESR sectors. This reduction is complemented by cost-effective reductions in non-CO_2 emissions — mostly in agriculture.

GLOBIOM-G4M

The GLOBIOM-G4M is a private model and has been developed and is maintained by the International Institute of Applied Systems Analysis.[146]

In the analysis performed in support to this impact assessment, an economic land use model GLOBIOM[147] is utilized together with a detailed forestry sector model G4M[148]. GLOBIOM is an economic model that jointly covers the forest, agricultural, livestock, and bioenergy sectors, allowing it to consider a range of direct and indirect causes of biomass use. The wood demand estimated by GLOBIOM is used as input in G4M, a detailed agent-based forestry model that models the impact of wood demand in terms of forestry activities (afforestation, deforestation, and forest management) and the resulting biomass and carbon stocks. In essence, G4M is a geographically explicit model which in combination with GLOBIOM helps to evaluate changes in national silvicultural forest practices related to changing demand and price information. GLOBIOM-G4M is also used in the impact assessment for agriculture and LULUCF to assess the options (afforestation, deforestation, forest management, cropland and grassland management) and costs of enhancing the LULUCF sink for each Member State.

GLOBIOM is a global model of the forest and agricultural sectors, where the supply side of the model is built-up from the bottom (land cover, land use, management systems) to the top (production/markets). The GLOBIOM model has a long history of publication[149] and has previously been used in several European assessments[150]. The model computes market equilibrium for agricultural and forest products by allocating land use among production activities to maximise the sum of producer and consumer surplus, subject to resource, technological and policy constraints. The level of production in a given area is determined by the agricultural or forestry productivity in that area (dependent on suitability and management), by market prices (reflecting the level of supply and demand), and by the conditions and cost associated to conversion of the land, to expansion of the production and, when relevant, to international market access. Trade flows are computed endogenously in GLOBIOM, following a spatial equilibrium approach so that bilateral trade flows between individual regions can be traced for the whole range of the traded commodities.

[146] http://www.iiasa.ac.at/ .
[147]. See also: www.iiasa.ac.at./GLOBIOM
[148]. See also: www.iiasa.ac.at/G4M
[149]. See Havlík, P., Valin, H., Herrero, M., Obersteiner, M., Schmid, E., Rufino, M.C., Mosnier, A., Thornton, P.K., Böttcher, H., Conant, R.T., Frank, S., Fritz, S., Fuss, S., Kraxner, F., Notenbaert, A., 2014. Climate change mitigation through livestock system transitions. Proc. Natl. Acad. Sci. 111, 3709–3714.
[150]. See EC, (2013). EU Energy, Transport and GHG Emissions Trends to 2050: Reference Scenario 2013. European Commission Directorate-General for Energy, DG Climate Action and DG Mobility and Transport., Brussels, p. 168. and EC, (2014). A policy framework for climate and energy in the period from 2020 to 2030. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European Commission, Brussels, p. 18.

The following modelling features are reflected in the GLOBIOM integrated framework used for this assessment:

- All bioenergy demand projections are exogenously defined. They stem from PRIMES and POLES modelling results developed for previous Commission work. GLOBIOM uses these bioenergy demand projections as exogenous inputs, they always have to be fulfilled, even if it reduces the availability of biomass resources for other purposes.
- There is no feedback from price signals of feedstocks upon total bioenergy demand i.e. increases in bioenergy use may well push up prices for feedstocks, however, this will not feedback to reduce demand for bioenergy (over other energy technologies). The demand of food and feed commodities is on the other hand price elastic and therefore changes depending on consumers' willingness to pay. The same applies to material production, which is also price elastic and hence varies depending on the changes in the total demand.
- During the modelling, change in GHG emissions and removals due to increased or reduced biomass demand linked to land use and land use change (LULUCF) is not accounted for in the efforts needed for reaching an overall EU GHG emission reduction target for each scenario. Therefore, there is no feedback loop from increasing or decreasing forest carbon stocks in relation to the forest management levels to bioenergy demand. GHG consequences are, however, analysed as outputs of the study.
- The starting year of the modelling is that of the year 2000, and the potential impact of bioenergy demand is being assessed for years 2010–2050. Bioenergy demand and model outcome are presented on a ten-year basis.
- Material and energy substitution effects are not assessed in this work. The emissions and removals from the LULUCF sector that are reported covers the Harvest Wood Products (HWP) carbon pool development, but does not cover change in emissions and removal related to a decrease or increase in the production and consumption of materials substituted by woody products.
- The availability of recovered wood for the production of wood based panels and/or energy production is fixed over time and a change in availability of recovered wood from an increase or decrease in consumption of woody products are not accounted for in the framework. Therefore, there is no feedback loop from a change in the consumption of HWP commodities and the future availability of recovered wood for material and/or energy purposes.
- In terms of Common Agriculture Policies (CAP) within the EU, the following is assumed for this study. It is assumes that direct payments under the CAP stay constant throughout the modelling timeframe. The Ecological Focus Areas (EFA) policy is assumed to have no further impacts on EU agricultural production and the level of set-aside land is here considered to remain constant.
- As compared to EU LULUCF and Agriculture GHG projections, it should be noted that a number of project specific updates of the GLOBIOM and G4M models has been done for this project and not the same input data is being used as for the earlier projection published with the European Commission Trends to 2050 Report that describes the EU Reference scenario projection 2013.

For the forestry sector, emissions and removals as well as biomass supply are projected by the Global Forestry Model (G4M), a geographically explicit model that assesses afforestation-deforestation-forest management decisions. Forest area change and associated emissions and removals from afforestation, deforestation and forest management are reported based on estimated by the G4M model. By comparing the income of managed forest (difference of wood price and harvesting costs plus income by storing carbon in forests) with income by alternative land use on the same place, a decision of afforestation or deforestation is made. The G4M model receives information from GLOBIOM on the development of land use, wood demand, wood prices and land prices, and is initially is calibrated to historic data reported by Member States on afforestation and deforestation rates and therefore includes policies on these activities.

By comparing the income of managed forest (difference of wood price and harvesting costs) with income by alternative land use on the same place, a decision of afforestation or deforestation is made by G4M. Land and wood prices that G4M receives from GLOBIOM are used for the decision concernign land use change through contrasting the Net Present Value (NPV) generated by land use activities toward forestry with the NPV generated by alternative land use activities. The increased value of forests driven by an increase in wood prices thereby reduces deforestation activities and increases afforestation activitites. An increase in NPV of agriculture activites acts in the opposite direction and induces land use change through increased deforestation activities and reduced afforestation activitites.

The following modelling features are reflected in the G4M are used for this assessment:

- The afforestation and deforestation rates in G4M have been calibrated to forest area changes for the period of 2000 to 2010 based on data provided by FAO FRA 2010. Historical harvest removals from 1960 onwards taken from FAOSTAT data have been considered in the calculation of the harvested wood sink and the forest area was set to match the reported forest area in 2000 according to FAO FRA 2010.

GREEN-X

The Green-X model is a specialized energy system model, geographically bounded to the European Union and its neighbours, that has been used in several impact assessments and research studies related to RES. The core strengths of this tool are its detailed representation of renewable resources and technologies, and its comprehensive incorporation of energy policy instruments, including also sustainability criteria for bioenergy. This allows various policy design options to be assessed with respect to resulting costs, expenditures and benefits, as well as environmental impacts.

Identified potentials for bioenergy supply (incl. domestic and imported supply) combined with trends concerning biomass demand for material use as discussed above serve as basis for the modelling works as well as information on related costs. For the incorporation of biomass trade in the Green-X database and the subsequent model-based analysis, a well-established linkage between the Green-X model / database and Utrecht University’s geospatial network model is used. The extended database includes for example feedstock specific costs and GHG emissions for cultivation, pre-treatment (for instance, chipping, pelletisation) and country-to-country specific transport chains.

Brief characterisation of the Green-X model

The model Green-X has been developed by the Energy Economics Group (EEG) at TU Wien under the EU research project “Green-X–Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market" (Contract No. ENG2-CT-2002-

00607). Initially focussed on the electricity sector, this modelling tool, and its database on renewable energy (RES) potentials and costs, has been extended to incorporate renewable energy technologies within all energy sectors. The model is privately owned (by TU Wien) but a public demo version is available to allow for a simplified use and to a better understanding of the functionality.

Green-X covers geographically the EU-28, the Contracting Parties of the Energy Community (West Balkans, Ukraine, Moldova) and selected other EU neighbours (Turkey, North African countries). It allows for detailed assessments of demand and supply of RES as well as of accompanying cost (including capital expenditures, additional generation cost of RES compared to conventional options, consumer expenditures due to applied supporting policies) and benefits (for instance, avoidance of fossil fuels and corresponding carbon emission savings). Results are calculated at both a country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2050. The Green-X model develops nationally specific dynamic cost-resource curves for all key RES technologies within all energy sectors. Besides the formal description of RES potentials and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying (combinations of) different energy policy instruments (for instance, quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, impact of emission trading on reference energy prices) at both country or European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.

Within the Green-X model, the allocation of biomass feedstock to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as available to a possible investor under the conditioned, scenario-specific energy policy framework that may change on a yearly basis. Recently, a module for intra-European trade of biomass feedstock has been added to Green-X that operates on the same principle as outlined above but at a European rather than at a purely national level. Moreover, Green-X was extended throughout 2011 to allow an endogenous modelling of sustainability regulations for the energetic use of biomass. This comprises specifically the application of GHG constraints that exclude technology/feedstock combinations not complying with conditioned thresholds.

The Green-X database on potentials and cost for renewable energy sources

The input database of the Green-X model offers a detailed depiction of the achieved and feasible future demand and supply of the individual RES technologies, initially constraint to the European Union (EU28) but within the course of recent projects extended to the EU's neighbouring countries / regions (i.e. Western Balkans, North Africa and Turkey). This comprises in particular information on costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the modelling of future RES deployment. Note that several expert reviews and validation processes of this comprehensive data set used in Green-X have been undertaken throughout past years.

The use and validation of the Green-X model

Since its initial development the Green-X model has been widely used within various studies and research activities both at national and European level. For example Green-X has been successfully applied for the European Commission within several tenders and research projects to assess the feasibility of “20% RES by 2020” and for assessments of RES developments beyond that time horizon (up to 2050). The studies performed comprised generally expert reviews and validation processes of both input data as well as of outcomes derived.

Below a brief list of selected reference projects is provided:

- EmployRES II: Employment and growth impacts of renewable energies in the EU - Support Activities for RES modelling post 2020 (client: EC, DG Energy; duration: 2013-2014)
- Beyond2020: Design and impact of a harmonised policy for renewable electricity in Europe (client: EC, Intelligent Energy Europe; duration: 2011-2013)
- Refinancing: Financing renewable energy in the European energy market (client: EC, DG Energy and Transport; duration: 2010)

Use of Green-X in the BioSustain project

With BioSustain modelling of future demand and supply of bioenergy and other renewables in the energy sector has been done by using the Green-X model. In this context, Green-X provides a broad set of results concerning environmental (avoidance of fossil fuels and of GHG emissions following a supply chain approach) and economic impacts (CAPEX, OPEX, support expenditures).

<u>Development of baseline scenarios for bioenergy demand</u>
Within the project Green-X is used to quantitatively model bioenergy demand scenarios up to 2030, key among them is the following baseline scenario: a *RES policy scenario* in accordance with the Council agreement on 2030 energy and climate targets, aiming at 40% GHG reduction and (at least) 27% RES and energy efficiency by 2030. This case is subsequently named as *Green-X euco27* scenario and is used throughout this study as benchmark for analysing the impacts of policy options to safeguard sustainability of bioenergy supply and use. The underlying policy concept for incentivising RES can be characterised as a least-cost approach, enhancing an efficient use of bioenergy and other RES for meeting the 2030 RES target in a cost-effective manner. Specifically for biofuels in transport a continuation of current policy practices is however envisaged post 2020, in accordance with the calculation done by the PRIMES model in related works.

<u>Key input parameter</u>
In order to ensure maximum consistency with existing EU scenarios and projections the key input parameters of the scenarios presented in this report are derived from PRIMES modelling and from the Green-X database with respect to the potentials and cost of RES technologies. Table 13 shows which parameters are based on PRIMES, on the Green-X database and which have been defined for this study. The PRIMES scenarios used for this assessment are the latest *reference scenario* (European Commission, 2016) and climate mitigation scenarios that

building on an enhanced use of energy efficiency and renewables in accordance with the Council agreements taken for 2030 (PRIMES euco27 and euco30 scenario).

Table 13 Main input sources for scenario parameters

Based on PRIMES	Based on Green-X database	Defined for this assessment
Primary energy prices	Renewable energy technology cost (investment, fuel, O&M)	Renewable energy policy framework
Conventional supply portfolio and conversion efficiencies	Renewable energy potentials	Reference electricity prices
CO_2 intensity of sectors	Biomass trade specification	
Energy demand by sector	Technology diffusion / Non-economic barriers	
	Learning rates	
	Market values for variable renewables	

ANNEX 5. DEMAND AND SUPPLY OF BIOENERGY

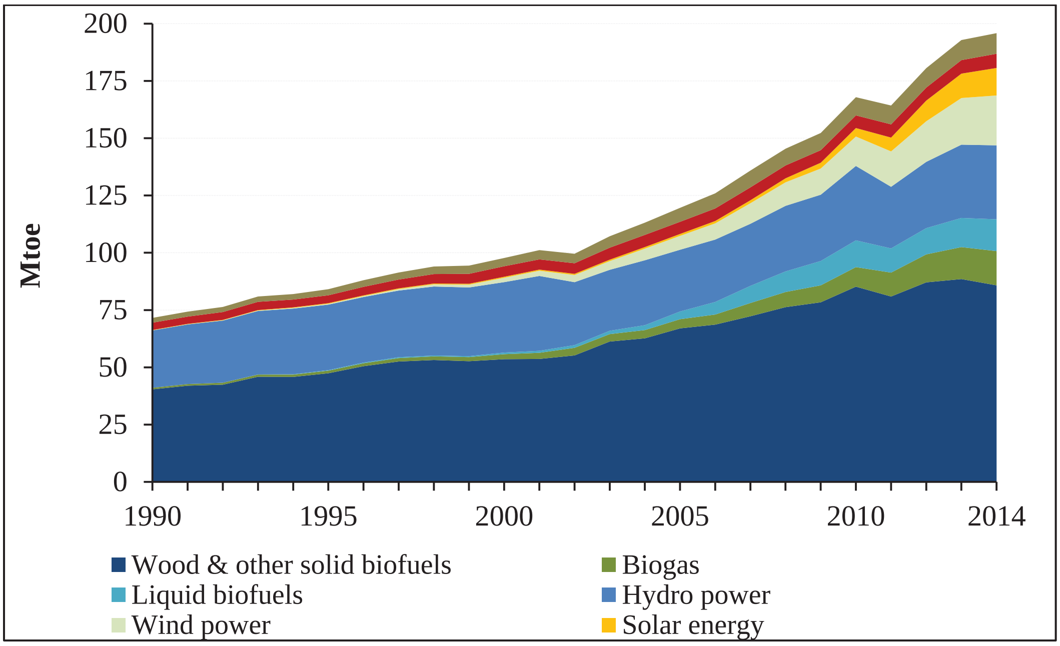
1. Current use of bioenergy in the EU

In 2014, the use of bioenergy represented 60 % of the overall final renewable energy consumption[151] and almost 10 % of total energy consumption. A wide variation occurs among Member States, with a contribution of biomass to total renewable energy from 30 to over 90 %, and a contribution to total energy use that goes from almost 1 % to over 30 % depending on the Member State considered.[152]

The role of bioenergy is most important in the heating and cooling sector, which alone is responsible for almost half of final energy consumption in the EU. In this sector, bioenergy provides almost 90 % of the renewable energy (in total, renewable energy represents 18 % of heating and cooling in 2014[153]), with other technologies such as geothermal, solar thermal and heat pumps contributing marginally. More than half of the heat produced from biomass is used in the residential sector[153]. In three Member States (Sweden, Latvia and Finland), biomass provided more than half of the total heating and cooling consumption in 2014[154].

The situation is different in the power sector, where renewable sources are more diverse. Currently, 27 % of electricity is generated from renewable sources, which then is divided between hydropower (39.6 %), onshore and offshore wind (29.6 %), solid biomass and biogas (18 %) and solar (11.5 %).

Finally, in the transport sector a 5.9 % share of RES was observed in 2014, predominantly based on first generation biofuels.



[151] Unless mentioned otherwise, all numerical data in this section are sourced from the Renewable Energy progress report COM (2015) 293.
[152] Source: Eurostat/JRC NREAPs Data portal.
[153] Source: JRC NREAPs Data portal
[154] AEBIOM 2016 statistical report

Figure 7: Primary production of renewable energy by sources in the EU (source: Eurostat)

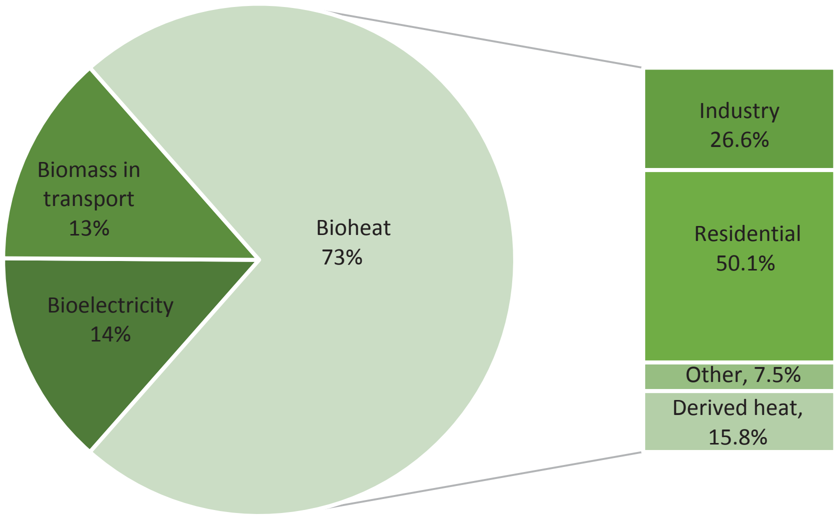


Figure 8 — Gross final energy consumption of biomass in heat, electricity and transport in 2014 (ktoe) (Source: AEBIOM 2016 Statistical report)

2. Supply of bioenergy for EU consumption

Bioenergy for electricity and heating is mostly based on solid biomass (more than 90 % in 2014), whereas biogas provides a small share (8.7 % in 2014).

Solid biomass

Currently, the main sources of solid biomass used in electricity, heating and cooling are EU produced forestry-based feedstocks such as fuelwood, industrial residues (e.g. residues from sawmills or from the paper industry), and forest harvesting residues (such as branches or tree tops) (see box).

Box: EU feedstocks for woody-based biomass

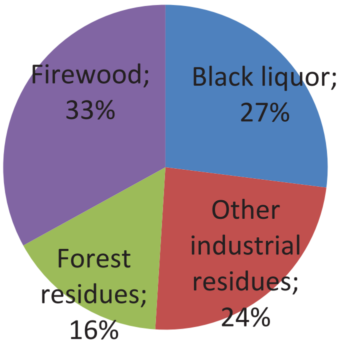
The main feedstocks for EU woody-based biomass used for energy in heating and electricity are the following:

- Industrial residues (sawdust and other residues from the wood-processing industry, black liquor from the processing of pulp and paper): these represent together around half of the woody-based biomass consumed in the EU;

- Forest residues (e.g. branches, tree tops or stumps): their exact share is more difficult to estimate, but they represent around 15-20 % of the use;

- Fuel wood: this small wood not suitable for industrial use represents the most traditional use of woody biomass, in particular for household heating, and can be estimated to around a third of EU consumption;

Dedicated harvest of stemwood (for example pulpwood) for bioenergy plays a marginal role in EU produced feedstocks.



Woody biomass used for energy — estimates for EU produced feedstocks (*Source: Recebio study)*

Imports of solid biomass from third countries represent 3.84 % of total primary bioenergy (4.92 Mtoe), an increase of 2.5 times between 2009 and 2013. These imports are mostly constituted of pellets, which have low moisture content and are easy to store and transport. They originate mainly from North America, and are made from pulp-grade and low-grade stemwood as well as wood-processing residues. Imports from EU neighbouring countries also take place.

Straw and other agricultural residues can also be used for combustion, but no EU statistics exist, and the volumes are still limited. It is unlikely, at least in the short to medium term, that agricultural residues will be imported from third countries into the EU for technical and economic reasons.

Future additional sources of solid biomass can include both EU-based and imported biomass (although the supply of EU industrial residues for energy is not expected to increase further significantly, as most of the existing residues are already used).[155] Some of the options to increase solid biomass production in the EU however face barriers, including costs. For example, the use of forest residues for bioenergy could be increased, but their cost of collection and transport is significant. Hence, at current and projected prices of wood, this cost would be a barrier to their mobilisation. Short rotation forestry and short rotation coppice for bioenergy entail significant upfront investment costs as well as barriers linked to land availability, and are not currently developing. On the other hand, bioenergy can provide an outlet for wood in cases of e.g. wood logged from areas that have suffered from natural disturbances (such as storms) or for overgrown coppice where a more active management would be required.

As indicated in the model projections presented in section 5.1.1, a rise of pellets imports can take place as a response to an increase in demand of bioenergy. The feedstock for these pellets is likely to be mainly stemwood (pulp-grade roundwood or other low-grade quality

[155] For energy or for other industrial uses such as the production of wood panels. Source: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/bioenergy/Task%201.pdf

stemwood[156]), and industrial residues. Currently, pellet imports are mostly used for large electricity plants, but are starting to be used also in smaller installations such as district heating. In the event of a significant increase in bioenergy demand, and in the absence of additional mobilisation of domestic biomass, imports of pellets might play an increasing role in the EU.

Therefore, there are a number of uncertainties as to which forest feedstocks would develop in response to an increase in demand. Factors such as the magnitude of EU demand as well as of the demand from third countries, the design of support schemes in the energy and forest sectors in particular, the availability of recycled wood, the development of woody biomass produced on agricultural land (short rotation coppice), will play a role in shaping the market response.

The level of **public subsidies for production of bioelectricity** differs significantly among EU Member States. Whilst in some countries it has been close to zero (such as in Finland, Sweden and Denmark), it has been rather high in Austria, Belgium, Netherlands, Germany, Italy, Estonia, Poland, Portugal and Romania (in the range of 60-90 EUR per MWh, which was above the EU average of 60 EUR per MWh). The low levels of required subsidy in the mentioned countries can be explained by high efficiency in their bioelectricity production (virtually all of the bioelectricity being produced in CHP installations), as well as good availability of the raw material.

This should be seen in the contrast with public subsidies for other technologies, which were significantly lower for coal (13 EUR per MWh) and gas (15 EUR per MWh), where the costs are, just like for bioelectricity, mainly driven by high operational expenses on fuel.

When compared to other renewable technologies, whose costs are mostly driven by capital investments, the lowest level of public subsidy has been reported for hydroelectricity (10 EUR per MWh). Whilst the support for on shore wind has been slightly lower than the one for bioelectricity (50 EUR per MWh), it has been significantly higher for offshore wind (120 EUR per MWh) and solar electricity (220 EUR per MWh).

All the above data refer to the levels of public support in 2012, as per the report by the European Commission on Subsidies and Costs of EU Energy published in 2014.[157] This report is subject to an update in the course of 2016.

Biogas

While biogas has been produced mainly from annual energy crops (e.g. maize), there is a large potential in producing biogas from agricultural waste, residues, by-products (e.g. manure), sewage sludge, separated household waste, as well as industrial household waste.

Biofuels

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[156] COWI 2016, Environmental implications of increased reliance of the EU on biomass from the South East US - http://bookshop.europa.eu/en/environmental-implications-of-increased-reliance-of-the-eu-on-biomass-from-the-south-east-us-pbKH0116687/?CatalogCategoryID=DSoKABstDacAAAEjA5EY4e5L

[157] https://ec.europa.eu/energy/sites/ener/files/documents/DESNL14583%20Final%20report%20annexes%201-3%2011%20Nov.pdf

Currently, biofuels are mostly produced from agricultural crops. In 2015, an amount equivalent to 61 % of domestic oilseed production, and 3.7 % of domestic cereal production were used for the production of biofuels; in the case of sugar beet an amount equivalent to 13% of domestic sugar beet production went to the production of ethanol, of which virtually all was used for biofuels[158]

The existing sustainability framework on biofuels provides some incentives and constraints for the production and use of biofuels up to 2020. In particular, biofuels made from food crops are limited to 7 % in terms of their contribution to the 2020 target of renewable energy in transport (although the 7 % cap does not apply to the target on the greenhouse gas intensity of fuels set in the Fuel Quality Directive[159] and to state aid or other forms of support). In addition, biofuels made from waste and advanced biofuels count twice towards the 10 % target. This has mostly encouraged the use of certain waste sources such as used cooking oil for biofuels.

For the **future production of biofuels**, the state of development of technologies to produce biofuels from lignocellulosic sources[160] will be an important factor. For the moment, lignocellulosic ethanol is at advanced stage of demonstration phase with several industrial scale plants operating in Europe and the US, while second generation biodiesel is developing very slowly. Therefore, and in particular given the high need for diesel substitutes, there are uncertainties regarding the level of contribution of second generation biofuels up to 2030. It is also important to note that second generation biofuels will use not only feedstocks from agricultural sources (such as agricultural residues) but also from forestry (i.e. wood, forest residues). The development of biofuels from waste and residues could play an important role in the future biofuels supply, in particular for diesel substitutes using waste oils.

Third generation biofuels (algae, micro-organisms) are still at a very early stage of research and development and their production cost is still very high.

The production of biofuels feedstocks (e.g. food crops) on marginal land faces the same difficulties as short rotation coppice in terms of fragmentation of the land and lower yields. It is currently not taking place and is unlikely to develop unless a dedicated supportive framework is put in place.

158 MTO 2915, DG AGRI
159 Directive 98/70/EC
160 Often referred to as 'second-generation' biofuels.

ANNEX 6. GREENHOUSE GAS EMISSIONS FROM THE SUPPLY CHAIN

To estimate the performance of different biomass pathways in terms of their supply chain emissions, the Joint Research Centre (JRC) carried out an attributional Life Cycle Assessment (LCA) analysis of the most common biomass feedstock, following the EU harmonised methodology contained in the 2010 Biomass Report and in SWD(2014)259 final.[161] This methodology doesn't take into account biogenic carbon, therefore the CO_2 emissions due to biomass combustion are considered as zero in the calculation.

The figures below show the comparison of these supply chain emissions to a representative set of lifecycle emissions of fossil fuels for the most commonly used pathways. This methodology considers the greenhouse gas emissions from the cultivation of raw materials, harvesting, processing and transport of the biomass feedstocks. Emissions from carbon stock changes caused by direct land use change (if they occurred) should also be taken into account.

The supply chain greenhouse gas emissions are calculated on the basis of final energy (i.e. MJ of electricity or of heat); a standard efficiency of conversion has been applied (25 % electrical efficiency and 85 % thermal efficiency). In order to obtain the comparison of greenhouse gas performance, supply chain emissions from bioenergy pathways are assessed against the emissions of a reference value (Fossil Fuel Comparator), which represent a marginal mix of present and perspective EU fossil power production technologies and feedstocks. The FFCs considered for power and heat production are respectively 186 gCO2 /MJ and 80 gCO2 /MJ. The logic behind the conceptual and numerical choice for the Fossil Fuel Comparator is explained in the related Commission documents (COM(2010) 11 and SWD(2014) 259). It is worth remembering, though, that these values are simply reference numbers used to benchmark the various bioenergy pathways against each other and exclude, through a GHG savings threshold criterion, the worst performing pathways in terms of resource efficiency and GHG emissions. The GHG savings calculated with this methodology do not reflect actual climate change mitigation obtained by the use of bioenergy. For a full description of the possible misinterpretations of these results see Plevin et al., 2014[162] and the other Annexes in the Impact Assessment.

Figure 9 shows supply chain greenhouse gas emission compared to the lifecycle emissions of the fossil fuels replaced for the most representative forest-based solid biomass pathways. It can be concluded from the figure that most of the forest biomass pathways deliver high levels of supply-chain greenhouse gas emissions savings compared to the Fossil Fuel Comparator, with the exception of some pathways using feedstock imported from distances above 10 000 km and using natural gas to dry the wood in pellet mills.

Figure 10 illustrates greenhouse gas savings for the most representative biogas and biomethane pathways, from manure and an energy crop (silage maize). The figure shows that

[161] All the results are available in the 2015 report 'Solid and gaseous bioenergy pathways: input values and GHG emissions' - https://ec.europa.eu/energy/sites/ener/files/documents/Solid%20and%20gaseous%20bioenergy%20pathways.pdf
[162] Plevin, RJ., et al., *Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation Benefits Misleads Policy Makers.* J Ind Ecol, 2014. **18**(1): p. 73-83

the use of a gas-tight tank for the storage of the residual digestate is needed to obtain higher greenhouse gas savings for all pathways. Manure-based pathways have always better greenhouse gas performances than energy crops-based pathways. This is mainly due to the emissions credits for the avoided GHG emissions linked to the management of raw manure as organic fertilizer; this can lead to GHG savings higher than 100%. Therefore manure digestion or its co-digestion in high shares with energy crops, is the most efficient way to reduce greenhouse gas emissions.

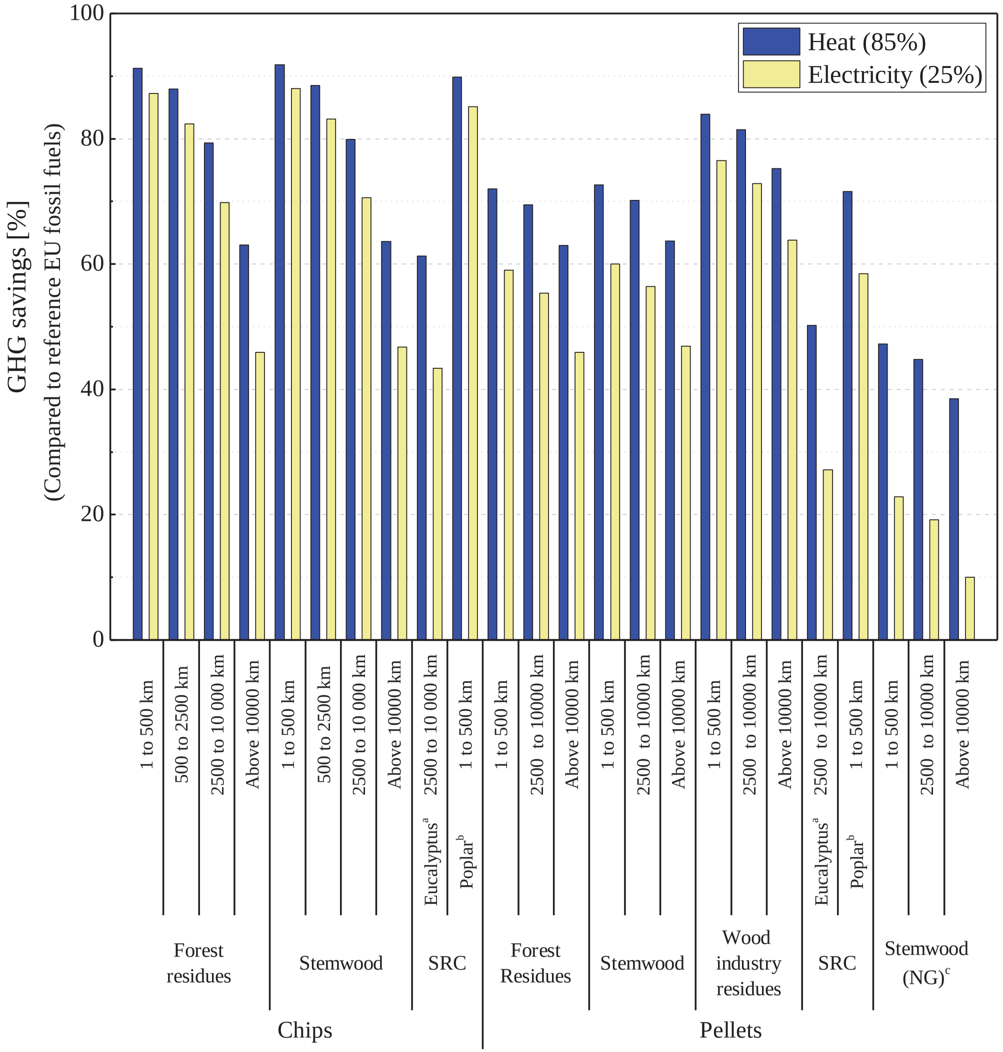

Figure 9: Illustration of greenhouse gas supply chain emissions compared to reference fossil fuel emissions (excluding combustion and all emissions and removals of biogenic carbon in the supply chain, except methane) for the most representative forest based solid biomass pathways. Calculations are based on the methodology described in Commission document COM(2010) 11 and SWD(2014) 259 and further details can be found in JRC report EUR27215. SRC = Short Rotation Coppice.

[a]) The calculations are based on greenhouse gas data from eucalyptus cultivation in tropical areas. [b]) Data are based on poplar cultivated in EU without any synthetic fertilization. [c]) Stemwood (NG) = pellets produced using natural gas as process fuel, all the other pathways are based on wood as process fuel

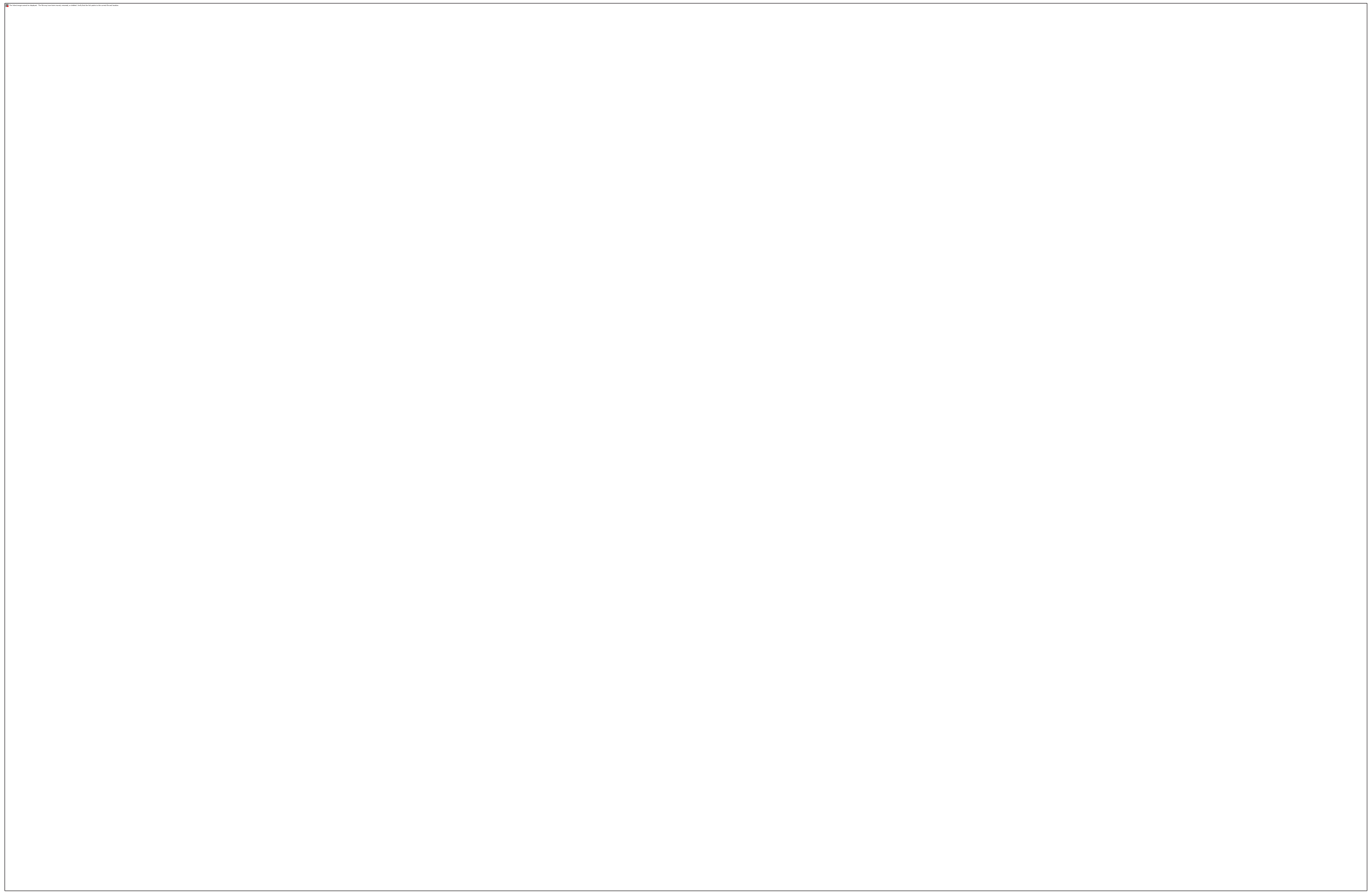

Figure 10: Illustration of greenhouse gas supply chain emissions (excluding combustion and all emissions and removals of biogenic carbon in the supply chain, except methane) compared to reference fossil fuel emissions for the most representative biogas and biomethane pathways. Calculations are based on the methodology described in Commission document COM(2010) 11 and SWD(2014) 259 and further details can be found in JRC report EUR27215. Values higher than 100% represent systems in which credits from improved agricultural management more than offset any supply chain emission. Values lower than 0% indicate systems which emit larger amounts of greenhouse gas than the fossil fuel comparator. For illustrative purposes, values obtained for the co-digestion of a mixture of 70% (wet mass) manure and 30% (wet mass) maize are also included.

ANNEX 7. BIOGENIC CARBON — FINDINGS FROM REVIEWS OF SCIENTIFIC LITERATURE

Two literature reviews on biogenic carbon from forest biomass used for energy have been carried out for the Commission.[163] Their main findings are the following:

- **The assumption of 'carbon neutrality' of bioenergy is not generally valid when considering forest biomass used for energy**

Lifecycle assessments of greenhouse gas emissions from bioenergy often consider the emissions of biomass combustion as zero and considers supply chain emissions as equal to (or a proxy of) the total CO_2 impact of bioenergy. This assumes that the CO_2 emitted by the production and use of bioenergy (combustion emissions, soil C loss, etc.) is fully and immediately compensated by the land use benefits (regrowth of the plant).

Both literature reviews find that this assumption is not generally valid in the case of forest biomass and that biogenic emissions must be considered in the assessment of climate impacts of forest.

This conclusion is also backed for example by the US EPA[164] and the European Environmental Agency Scientific Committee.[165] The IPCC also supports the view that biomass used for energy is not automatically carbon neutral.[166][167]

The combustion of woody biomass releases, in most cases, more CO_2 in the atmosphere, per unit of delivered energy, than the fossil fuels they replace. This is mostly because biomass normally has less energy per kg of carbon and also lower conversion efficiency. Therefore, the bulk of the scientific literature suggests that all together these phenomena create an emission of biogenic-CO_2 from forest bioenergy which may be higher than the emissions from a reference fossil system in the short term. If the forest productivity increases because of the bioenergy production, the continuous substitution of fossil fuels may, in time, recover the additional emissions of bioenergy production.

- **In assessing lifecycle GHG emissions from forest biomass used for energy, the best approach is a consequential lifecycle analysis including all carbon pools**

Assessing the potential of bioenergy technologies to mitigate climate change is a complex task. Bioenergy systems can influence directly and indirectly, local and global climate through a complex interaction of perturbations, including:

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[163] JRC, 2014, 'Carbon accounting of forest bioenergy' and Forest research, 2014 'Review of literature on biogenic carbon and life cycle assessment of forest bioenergy'.

[164] https://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html.

[165] Opinion of the EEA Scientific Committee on Greenhouse Gas Accounting in Relation to Bioenergy, September 2011.

[166] http://www.ipcc-nggip.iges.or.jp/faq/faq.html - q2-10.

[167] Under international climate change guidelines for the preparation of national GHG emission inventories, CO_2 emissions from biomass combustion are not accounted in the energy sector (e.g. they are zero rated). This is to avoid double counting, because it is assumed that these emissions are accounted as part of the emissions from the land use, land use sector and forestry (LULUCF) sector in the same national inventory.

- emissions of CO_2 and other long and short-lived climate forcers from biomass combustion;
- alteration of biophysical properties of the land surface;
- influence on land use and land management;
- substitution of other energy sources (including fossil fuels) with biomass and other commodities (such as food crops and wood products).

Life Cycle Assessment (LCA) has emerged as the main tool used to inform policy makers about potential environmental impacts of products and policies, and has been applied also to bioenergy pathways. Two approaches for LCA can be defined:

- attributional LCA (A-LCA), which is used to quantify and allocate impacts among existing products and activities. It is related to 'micro-level decision support'[168] (i.e. typically for questions related to specific products).
- consequential LCA (C-LCA) which is instead appropriate for 'Meso/macro-level decision support'[169] (i.e. for a strategic level with consequences for example on the production capacity).

A-LCA is static and descriptive, while C-LCA is dynamic and predictive.

Both reviews find that traditional attributional LCAs focusing on supply chain emissions and assuming carbon neutrality of biomass, have been unable to capture the above-mentioned complexities of bioenergy climate impacts, in particular as they relate to impacts on land use, land-based products and their substitution. LCA studies have recently started to include explicitly biogenic-C flows and the use of biomass and land in the baseline[170] system so that the climate change mitigation potential of bioenergy is better captured.

Nonetheless, both reviews find that when the goal of the assessment is to assess the consequences of a policy, then impacts caused by various policy choices against one (or multiple) baselines (biomass alternative uses to bioenergy) should be investigated through consequential LCA. This assessment usually involves the use of integrated assessment models and ideally it should:

- assess impacts at a **global geographic scale**;
- assess impacts on **all market sectors** of the economy;

[168]. 'Micro-level decisions' are assumed to have limited and no structural consequences outside the decision-context, i.e. they are supposed not to change available production capacity.
[169] Life cycle based decision support at a strategic level (e.g. raw materials strategies, technology scenarios, policy options). 'Meso/macro-level decisions' are assumed to have structural consequences outside the decision-context, i.e. they are supposed to change available production capacity.
[170] A baseline or counterfactual is defined in this context as 'the hypothetical situation without the studied product system' (Soimakallio et al., 2015).

- assess impacts on **all relevant carbon pools,** including biogenic carbon emissions and removals;[171]

- **The contribution of biogenic carbon to emissions from forest bioenergy is very variable, going from negligible to very significant levels, and the variation is systematic rather than due to uncertainty**

Both reviews find that biogenic carbon can make a very variable contribution to greenhouse gas emissions from forest biomass used for energy, depending on a number of factors (see below). While these emissions vary a lot, the net outcome of a certain combination of factors is predictable to a great extent. As the results depend on assumptions for the counterfactual scenarios (see below), they can be difficult to verify.

- **Biogenic emissions are sensitive to the scale of consumption**

The review by Forest Research finds that the contribution of biogenic carbon to GHG emissions of forest bioenergy is likely to be more important if the demand is higher. This is because the scale of demand is expected to affect the forest management regimes and the type of feedstocks used for bioenergy production

- **The variation of net biogenic emissions depends on a number of factors**:

The two reviews find that the level of net biogenic emissions depends on a certain number of factors and in particular:

  - the type of feedstock (e.g. forest residues, stemwood/roundwood, etc.) (see more details below);

  - the type and change in forest management.

Forest research for example finds that increased harvesting involves reductions in forest carbon stocks on the short term (few years to decades), but in some cases can be consistent with increased forest carbon stocks (e.g. in the case of extension of the length of rotations or enrichment of degraded or relatively unproductive forests).

  - market-mediated effects.

JRC finds that market-mediated effects can play a role in the level of biogenic CO_2 emissions. These include for example the displacement of wood from products to bioenergy. It also includes the impact that an increased demand and price for wood would have on the use of the land. The forest management is also relevant, either by adding pressure on forests, or on the other hand by incentivising more investments in the forest. Market-mediated effects can also occur through competition between different sources of energy. The evidence available to adequately understand and quantify such market-mediated impacts is currently limited.

[171] Examples of this type of assessment include the studies Recebio and BioImpact performed for the Commission.

- counterfactual for land use and biomass use.

Both reviews find that biogenic emissions vary depending on what would be the alternative fate of the land (in particular what type of forest management would occur and whether the land would remain forest), and also what would be the alternative use of the wood (e.g. left standing in the forest, decay, burned, used for materials,…). This is strongly linked to market-mediated effects.

- counterfactual for energy.

Although this is not directly related to the absolute level of biogenic emissions but rather to the climate performance of forest bioenergy, both reviews find that the GHG performance of forest biomass for energy is sensitive to the assumption on which type of energy it replaces (e.g. coal, natural gas, other renewables), and the rate of substitution.

- **Biogenic emissions from forest bioenergy vary depending on the time horizon considered**

Both reviews find that biogenic emissions vary over time and different results are obtained for GHG emissions depending on the time horizon considered. An immediate increase in GHG emissions compared to using fossil fuels is almost inevitable, as combustion emissions of biomass are higher than those of fossil alternatives, eventually leading to reductions in GHG emissions. The initial period of increased GHG emissions can vary from less than one year to hundreds of years (or even to infinity in the worst cases, if no savings can be realised), depending on the type of forest bioenergy pathway.

- **The same feedstock used for energy can result in low or high biogenic emissions, depending on other factors**

Both reviews find that while the type of feedstock used plays an important role in the amount of biogenic emissions, in many cases it is not a sufficient predictor of biogenic emissions, as these emissions can be small or large depending on other factors (e.g. the alternative fate of the biomass and/or forest, which, in turn, can change with the scale in demand) This is particularly true with small roundwood (including pulpwood), but also for certain other feedstocks.

- **While the results vary, certain trends can be observed for specific feedstocks or practices**

The reviews find that in general:

- biogenic emissions are low for forest residues (except for stumps/coarse dead wood), waste wood, industrial residues (as long as they are not diverted from use as material), salvage wood (i.e. from pest/storm, to the extent they are not suitable for industrial use), pre-commercial thinnings, wood from afforestation;
- biogenic emissions remain high (higher than emissions from fossil fuels) beyond a policy-relevant timeframe for sawnwood, stumps, coarse dead wood;

   - biogenic emissions vary depending on situations (they can be low or high) for small stemwood including pulpwood.

- **Certain forest management practices can enhance the carbon sink, but ensuring that the harvest level stays below the growth rate of the forest is not sufficient to ensure climate change mitigations**

Forest Research finds that increased harvest and removals typically involve a reduction in carbon stocks. In some specific cases interventions to increase biomass production may involve increased forest carbon stocks. Examples of relevant activities include extension of rotations or afforestation (avoiding organic soils and risks of indirect land use change) and the ‘enrichment’ of the growing stock of existing forest areas.

The JRC literature review also highlighted that, even if with sustainable forest management practices forest removals are lower or equal to the net annual increment of the forest, and carbon stocks are preserved or increasing in time in absolute terms, the total carbon stored in the forest will be in any case lower than the reference scenario of the unmanaged forest and the resulting difference translates into increased net emissions.

ANNEX 8. SUMMARY OF THE RESULTS OF THE STUDY 'CARBON IMPACTS OF BIOMASS CONSUMED IN THE EU' (BIOIMPACT) [172]

Background

The study was carried out for the Commission (DG ENER), by a consortium led by Forest Research[173].

The objectives of the study were to carry out a qualitative and quantitative assessment of the GHG emissions associated to different uses of solid biomass for electricity and heating/cooling in the EU, under a number of defined scenarios focusing on the period to 2030 and to 2050. The assessment aims to quantify the GHG emissions at global level including all relevant sources of emissions, in particular covering the effects of:

- Carbon stock/sequestration changes;
- Indirect Land Use Change (iLUC)[174];
- Impacts of using land for energy crops;
- Indirect impacts of diverting woody biomass to energy;
- The full biomass/bioenergy life cycle and key GHGs;
- Specified time horizons, notably 2030 and 2050.

Policy scenarios were compared to a reference scenario considering no additional policy targets after 2020.

The project therefore considered impacts on global GHG emissions due to consumption of bioenergy in the EU, i.e. not only the GHG emissions occurring in the EU regions, or reported by Member States.

The modelling tools used for this project are described more in details in Annex 4.

Baseline and policy scenarios assessed

The project assessed six scenarios for the supply and consumption of biomass for energy within the EU:

- Reference (or baseline) **scenario A**, considering existing 2020 policy targets for energy consumption and reductions in GHG emissions and no further policies after 2020.
- Five decarbonisation scenarios, which consider the EU climate and energy targets for 2030. The following scenarios were defined:
    - **Scenario B** "Carry on/unconstrained use": highest use of biomass for energy, from all sources, no constraints;

[172] The report and its appendixes can be found here: https://ec.europa.eu/energy/sites/ener/files/documents/EU%20Carbon%20Impacts%20of%20Biomass%20Consumed%20in%20the%20EU%20final.pdf and https://ec.europa.eu/energy/sites/ener/files/documents/EU%20Carbon%20Impacts%20of%20Biomass%20Consumed%20in%20the%20EU%20Appendices%20final.pdf

[173] Project partners included members of three different research institutes, namely: North Energy Associates (UK); Alterra (Netherlands) and VTT (Finland).

[174] By setting constraints to avoid that feedstocks causing indirect land use change are used in the scenarios

- **<u>Scenario C1</u>** “Carry on/import wood”: emphasises (relatively unconstrained) imported forest bioenergy;
- **<u>Scenario C2</u>** “Carry on/domestic crops”: emphasises energy crops/agricultural biomass in the EU region;
- **<u>Scenario C3</u>** “Carry on/domestic wood”: emphasises forest bioenergy supplied from the EU region;
- **<u>Scenario D</u>** “Back off”: ambitious climate and energy targets for 2030, but reduced bioenergy use for meeting these targets post 2020.

The details for each scenario are reported in **Error! Reference source not found.**

Table 14: Summary of key assumptions and criteria in the various Scenarios defined in the project.

Assumption/ criterion	**Scenario**		
	Reference (A)	**Carry on (B-C)**	**Back off (D)**
Underlying PRIMES scenario	Reference	EEMRES30	
Renewable energy target 2020/2030	20%/20%	20%/30%	
GHG reduction target/level 2020/2030/2050[175]	20%/~30%/-	20%/40%/80%	
GHG savings criteria[176]	60% for biofuels	60% for all solid and gaseous biomass pathways as well as biofuels	
Scenario storyline details	No further developments beyond existing 2020 policies.	Measures to stimulate bioenergy demand and production.	Reduced contribution from bioenergy after 2020, so that the contribution of bioenergy is lower than in the Reference scenario after 2020.
Other constraints	No further developments beyond existing	All biomass of agricultural origin consumed for heat and/or power generation in the EU region would also be produced in the EU region.	

[175] These are GHG emissions reduction targets or levels, relative to 1990 levels, assumed in the PRIMES scenario referred to in constructing each scenario. The GHG emissions reduction level has a strong influence on the selection of renewable energy technologies (including bioenergy) in the modelling of scenarios.

[176] In constructing each scenario, it was assumed that contributions to GHG emissions from bioenergy due to biogenic carbon were zero. The contributions to GHG emissions due to biogenic carbon were then assessed for all scenarios, along with other contributions to GHG emissions. This has been a fundamental research issue addressed by this project.

	2020 policies.	All scenarios apart from Scenario B: Strict GHG emissions mitigation criteria (e.g. see earlier), also Encouragement of energy crops whilst avoiding iLUC Application of sustainability criteria to forest biomass.

Sensitivity: Forest management approaches

It was considered important to look at a range of possible forest management approaches and responses to bioenergy demand to investigate their influence on overall GHG balances. For this reason, two possible approaches were defined in the project: a "Precautionary" and a "Synergistic" approach[177].

The ‘Precautionary’ approach about forest biomass supply for use as energy in the EU did not favour either particularly ‘good’ or particularly ‘bad’ types of forest or wood feedstocks, covering all possible types that might be involved in such supply, according to their potentials, but it excluded extreme cases such as the use of sawnwood or of wood from deforestation for bioenergy. The 'Precautionary' approach also assumes that the level of harvest is below the growth rate of the forest in all supplying regions.

In essence, the strategies assumed under the ‘Precautionary’ approach included:

- The introduction of management for production (involving felling and possibly thinning) in forest areas not previously managed for production. This also involved an element of increased salvage logging.
- The increased extraction of harvest residues, and changes in patterns of wood use (e.g. increased use of early small thinnings for bioenergy), in a proportion of forest areas managed for production.

The ‘Synergistic’ approach was designed to represent a situation in which additional policies or measures may be taken that actively support the production of forest bioenergy with negative, relatively low or moderate risks of significant associated GHG emissions.

The additional positive changes to forest management assumed under the ‘Synergistic’ approach included:

- Avoiding the introduction of additional harvesting in forest areas with very low growth rates, to protect against slow recovery of carbon stocks after harvesting In the EU27 region only, enhanced rates of afforestation post 2015, deprioritising creation of forest areas with very low growth rates or on organic soils.
- Where feasible, conservation and enhancement of forest carbon stocks alongside increased harvesting to produce forest bioenergy and materials, through adjustments to existing rotations applied to forest areas managed for production.

[177] Chapter 4.8.3 of the report

- Additionally under the ‘Synergistic’ approach, in forest areas where management for production was introduced, much greater emphasis was placed on co-production of material wood products alongside production of forest bioenergy when compared with the ‘Precautionary’ approach

Results

All scenarios achieve reduction in GHG emissions compared to reference Scenario A

> **Key conclusion #1**
> **A significant increase in bioenergy use in the EU, considered as a whole, is likely to lead to a net decrease in GHG emissions being contributed by this particular type of energy source.**
> However, the trend in the trajectory of total annual GHG emissions for a ‘Back off’ scenario where bioenergy use is reduced (Scenario D) is also consistently and significantly downwards.
> The study concludes that *"In the context of future development of EU energy policy, the ‘bioenergy option’ may be viewed as neither a ‘show-stopper’ nor a ‘must-have’ from the simple perspective of total annual GHG emissions alone" (Section 6.5.1 p221)*

The first finding of the study is that **all decarbonisation scenarios achieve GHG emissions reductions compared to the reference Scenario A.** Emissions reductions are mainly driven by displacement of (reductions in) fossil energy emissions. These reductions are *partly* due to increased bioenergy use, but also to other renewable energy sources, nuclear and CCS. At the same time, other contributions to GHG emissions, notably the ones due to biogenic carbon associated with bioenergy, increase. However, the net impact is an overall reduction in GHG emissions compared with Reference Scenario A.

Figure 11 illustrates the trajectories of GHG emissions up to 2050 for all the scenarios considered. With the slight exception of Scenarios B and C1, the trajectories for low-carbon scenarios are closely bunched in by 2030. The trajectories diverge after 2030, notably by 2050 and **the main reason is the projected increase in level of deployment of forest bioenergy for the different carry-on scenarios** (see section 6.6.1 of the final report).

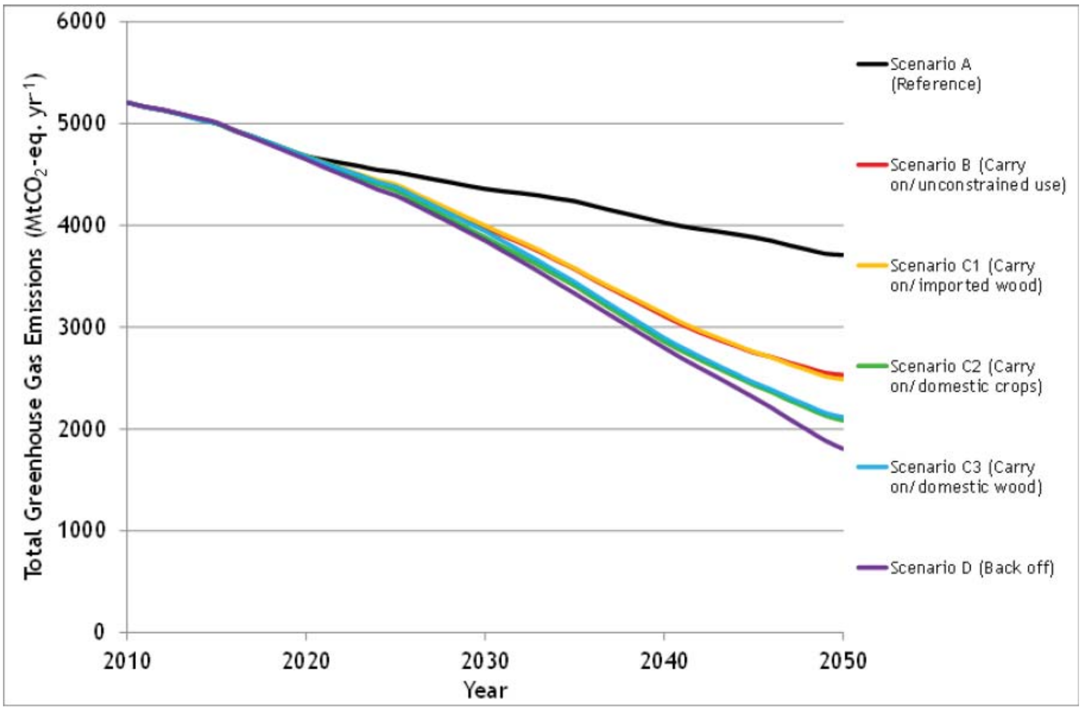

Figure 11: Trajectories of total GHG emissions over time for all scenarios, based on average emissions factors and referring to the 'Precautionary' approach to forest management and wood use.

Box 1: Observations on the modelling framework

The bioenergy penetration and deployment strategy in the energy mix is driven by the VTT-TIAM model which focuses on the cost-minimization of the system based on a **carbon-neutrality assumption** of bioenergy. If a feedback was applied to the energy system model so that indirect GHG emissions and biogenic-C emissions from biomass were included (and priced) in the model, the model would likely produce a different energy mix. This would potentially affect not only the overall quantity of bioenergy deployed, but also the type of feedstocks and the timing of deployment (due to the dynamics linked to carbon sinks).

Box 2 - Observations on the 'Back off' scenario (D)

The results for Scenario D suggest that de-prioritising biomass consumption for energy in the EU post-2020, whilst also trying to achieve significant reductions in GHG emissions would involve:

- The increased use of **other renewable energy sources** (particularly solar and wind power);
- More concerted efforts towards **energy efficiency** in the EU region, notably in the residential and transport sectors;
- Increased use of **nuclear power**;
- Some increased deployment of **carbon capture and storage** technologies.

This would also involve increased reliance on natural gas, nuclear fuels and electricity **imported** into the EU region from elsewhere. The study finds that Scenario D 'Back off' stands out as significantly more expensive, in terms of cost performance, compared with all of the 'Carry on' Scenarios. However, these results for cost performance require very careful interpretation, since **the assessment of costs is for the energy system only and hence does not include costs in other sectors**.

It must also be appreciated that there are logistical challenges associated with the high-bioenergy 'Carry on' Scenarios as well as the 'Back off' Scenario D.

The higher costs of Scenario D are associated generally with challenges involved in meeting the targets set for levels of renewable energy consumption and GHG emissions reductions, whilst also de-prioritising the consumption of bioenergy. This leads the model to choose, for instance, large deployment of nuclear installations and wind power installations in low-wind areas, with higher costs associated.

The cost of the energy systems modelled is lower when bioenergy is included in the mix.

Key conclusion #2
Future energy demand and decarbonization targets can be met reducing bioenergy use, but most likely at much higher cost for the energy system and with significant logistical challenges (Section 7.1.4 p 297)

Table 15: Cost performance of bioenergy scenarios in 2030-2050 (% GDP, €/tCO_2)

Scenario	Marginal energy system cost (% of GDP) for year		Average GHG reduction cost 2010-2050 (€/tCO_2)
	2030	2050	
B ('Carry on/ unconstrained use')	0.18%	0.90%	122
C1 ('Carry on/ imported wood')	0.19%	0.89%	125
C2 ('Carry on/ domestic crops')	0.18%	0.91%	96
C3 ('Carry on/ domestic wood')	0.20%	0.91%	100
D ('Back off')	0.63%	1.59%	183

Table 15 illustrates the resulting costs of the energy system in each of the scenarios and the average cost for the reduction of each tonne of CO_2.

From these results **it follows that future energy demands can be met reducing bioenergy use, but most likely at much higher cost for the energy system and with significant logistical challenges** (see Box 2). However, it is important to note that the assessment of costs associated with the scenarios developed in this project, whilst consistent, is not comprehensive. For example, cost impacts in the wider wood industries (either positive or negative), due to changes in the use of forest biomass for energy, have not been assessed.

It is also worth mentioning that the positive activities modelled in the project (e.g. on forest management, wood use and increased mobilization), the ones that allow delivering the negative GHG emissions for forest bioenergy sources (see discussion in following sections and last row of Table 17) were not included in the costs. The costs for certain positive outcomes for forest bioenergy are thus underestimated.

The GHG benefits achieved depend on the type of bioenergy used and on the scale of deployment

The results presented in **Figure 12**require careful interpretation and they do not allow an understanding of the role that bioenergy plays in overall GHG savings, i.e. whether GHG benefits are obtained **thanks** to bioenergy or **despite** bioenergy. Table 16 and Figure 14 help to understand this issue.

The answer to this question differ significantly between 2030 and 2050. The scenarios consider an ambitious decarbonisation target for 2050 (85% GHG emissions in the energy sector compared to 1990[178]. After 2030, thus, the energy system model (VTT-TIAM) **relies very heavily on bioenergy to comply with the GHG target and the differences between the scenarios in terms of bioenergy strategies and types**, **become more evident**.

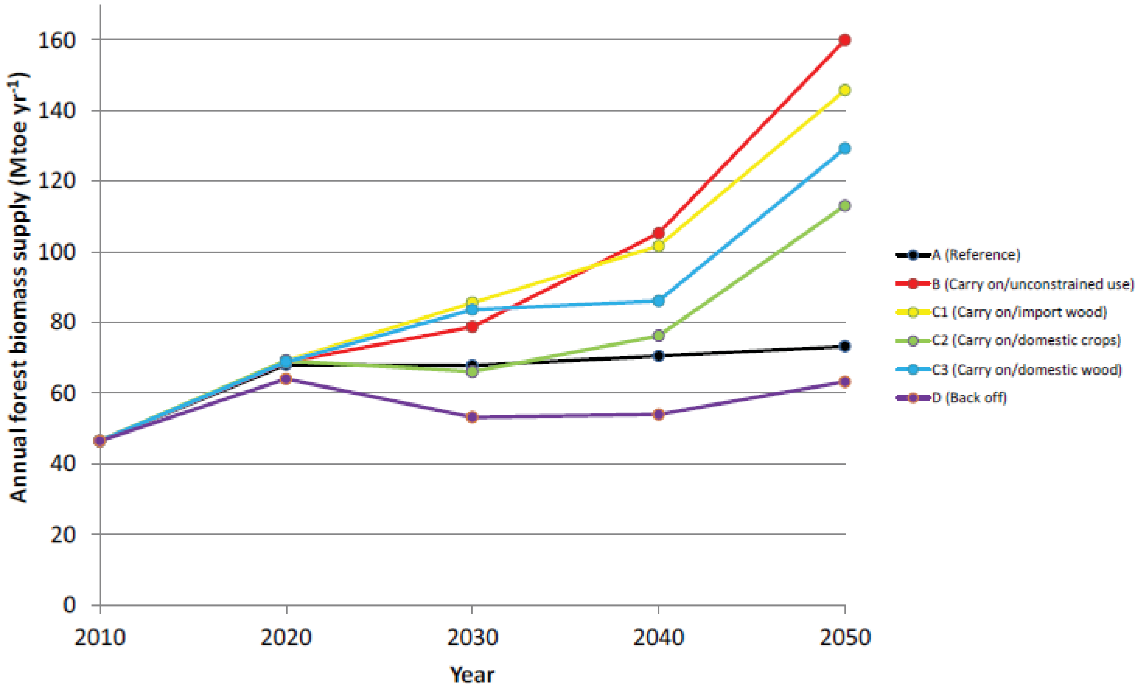

Figure 12: Total quantity of forest bioenergy supplied (i.e. total primary forest bioenergy supplied internally and externally) to the EU region for all scenarios.

Figure 12 highlights the increasing reliance on forest biomass supply in all the scenarios except for scenario D. In order to quantify the sustainability of the harvest levels predicted by the model, the removals in EU27 forests under different scenarios have been compared to the maximum theoretical long-term potential (details in section 4.10.4 of the project report), see Figure 13. It is assumed that a safe threshold for sustainable-yield production of industrial and fuel wood is equal to 70% of the theoretical potential shown

[178] Consistent with the 80% reduction economy-wide target

in Figure 13. Removals in EU27 forests approach the sustainable-yield level by 2030, any additional demand to 2050 would go beyond this theoretical limit, even more so in the Synergistic approach which focuses on co-production of wood products and energy[179].

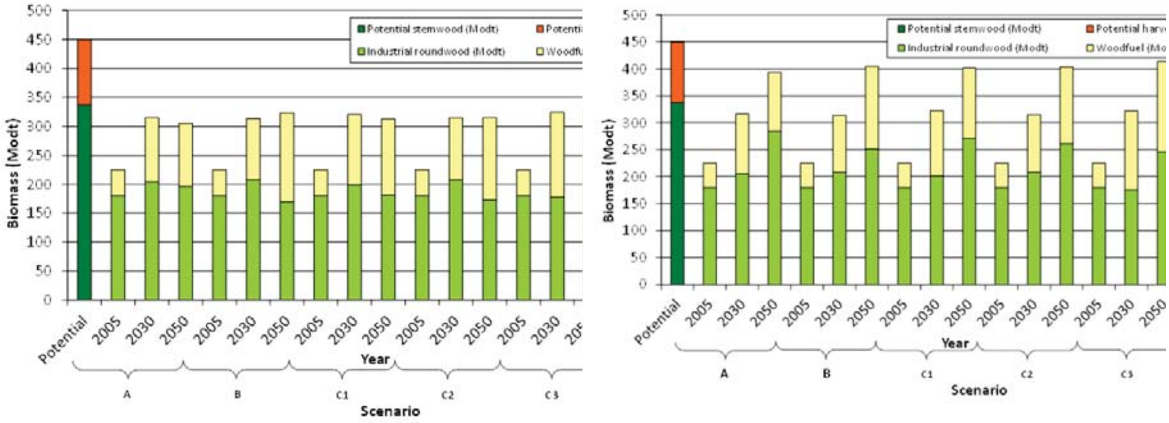

Figure 13: Comparison of reported and projected estimates of biomass production from domestic EU27 forests with estimates of theoretical maximum potential production, for all scenarios. Including both industrial roundwood and wood extracted for energy purposes. a) Based on the 'Precautionary' approach to forest management and patterns of wood use; b) Based on the 'Synergistic' approach to forest management and patterns of wood use.

Based on the evidence given by modelling, the study concludes that, "*any targets for future scale and rates of increase in forest bioenergy supply need to be set with care, with particular regard to potentials for sustainable-yield supply and time-dependent impacts on biogenic carbon emissions*" *(section 6.6.2, p 223).*

Key conclusion #3
According to the study, the projected levels of forest bioenergy supply under the 'Carry on' Scenarios approach an upper limit for sustainable-yield supply from 2030, particularly in the EU region. (Section 6.6.2, p 223)

Table 16 (for 2030) and Figure 14 (for 2050) disaggregate the GHG contributions from different sectors for each policy scenario compared to Scenario A. In 2030, **bioenergy specifically, can generate significant GHG savings (positive numbers) which are, though, partially compensated by the additional emissions caused by it (negative numbers).** Both emissions and removals consider not only biogenic-C but also other carbon pools (HWP) and substitution, albeit the effects of these contributions on the overall results are marginal.

Table 16: Changes in GHG emissions compared to Scenario A by 2030.

[179] Because this scenario implies an increase in wood harvest for materials

Results refer to the "Precautionary" approach and represent contributions to additional GHG emissions savings achieved under each policy scenario relative to Reference Scenario A. Positive numbers indicate that a net reduction or saving is being contributed by the source; negative numbers indicate that a net increase is being contributed.

Source	**Contribution by scenario ($MtCO_2$-eq. a^{-1})**				
	B	**C1**	**C2**	**C3**	**D**
CCS	24	24	24	24	42
Energy efficiency	89	37	85	56	-72
Nuclear	100	135	65	86	280
Other renewables	3	74	31	73	290
Bioenergy (avoided[180][181]	*262*	*223*	*277*	*247*	*-133*
Bioenergy (emissions)[182]	*-101*	*-133*	*-4*	*-71*	*101*
Bioenergy (net)	161	90	273	176	-32
Total	378	360	478	415	508

[180] Bioenergy consists of contributions due to biomass, bioliquids, biogas and biowastes

[181] Results for Bioenergy (avoided) represent GHG emissions of counterfactual energy sources displaced by bioenergy

[182] Results for Bioenergy (emissions) represent biogenic CO_2 emissions and indirect GHG emissions of bioenergy, including impacts on GHG emissions related to changes in the use of material wood products and their counterfactuals.

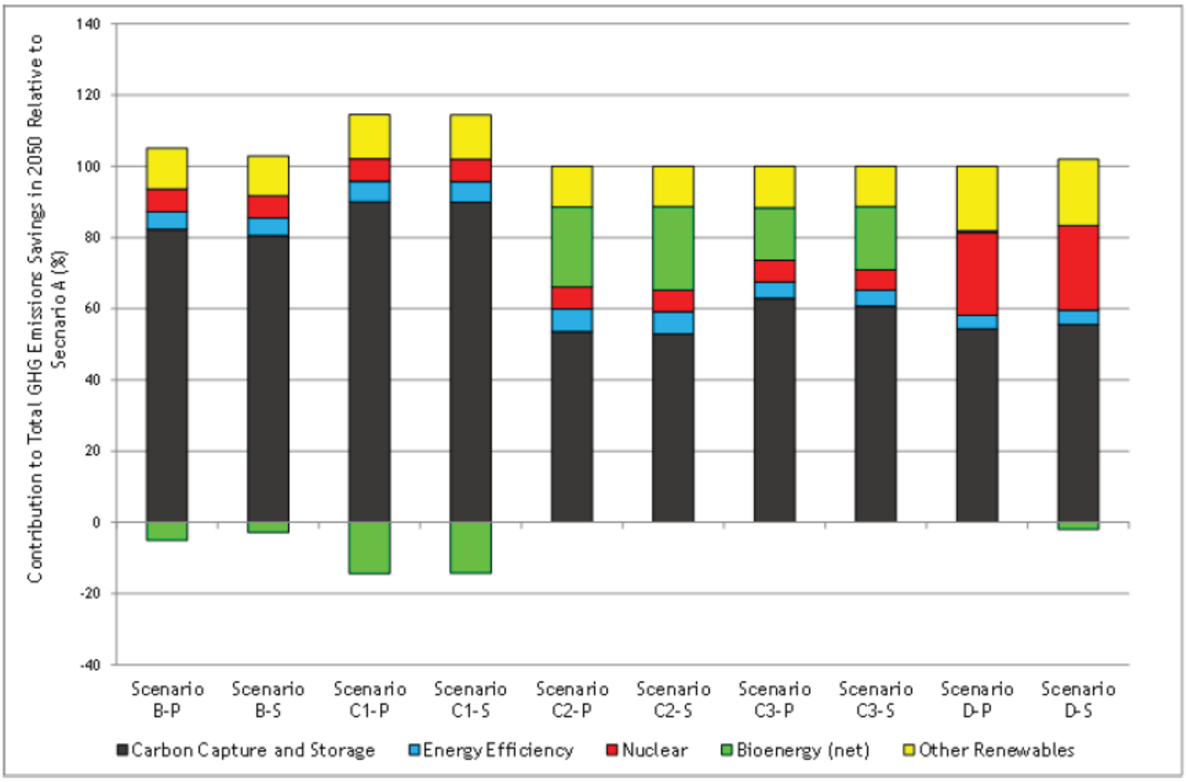

Figure 14: Contributions to total GHG emissions reductions in the European Union in 2050 relative to Reference Scenario A. Numbers are calculated as in Table 16 but for 2050.

When looking at the results for **2050** (Figure 14), though, it appears that total GHG emissions due to (all types of) bioenergy use, **exceed the avoided GHG emissions due to the displacement of fossil fuels by bioenergy in scenarios B and C1**, or in other terms that for these scenarios **bioenergy supply is generating more GHG emissions than the fossil fuels it replaces**. Scenario B and C1 all **reflect substantial increases in the use of forest bioenergy** (see Figure 12), with high level of imports from forests outside the EU27 region. However, the study highlights that this outcome is not linked to specific issues with imported forest bioenergy resources but rather to factors relating to types of forest, approaches to forest management and patterns of wood use involved in forest bioenergy supply.

The increase in net GHG emissions is more than compensated by the penetration of CCS technology which causes the net GHG emission reduction compared to the reference Scenario A.

The study then looks more closely at the impact of forest feedstocks on the overall GHG balance in different scenarios.

Figure 15 and the assessment in Table 17 show that the increase in forest bioenergy actually contributes only slightly to the decarbonisation efforts by 2030 compared to the reference scenario, and never by 2050.

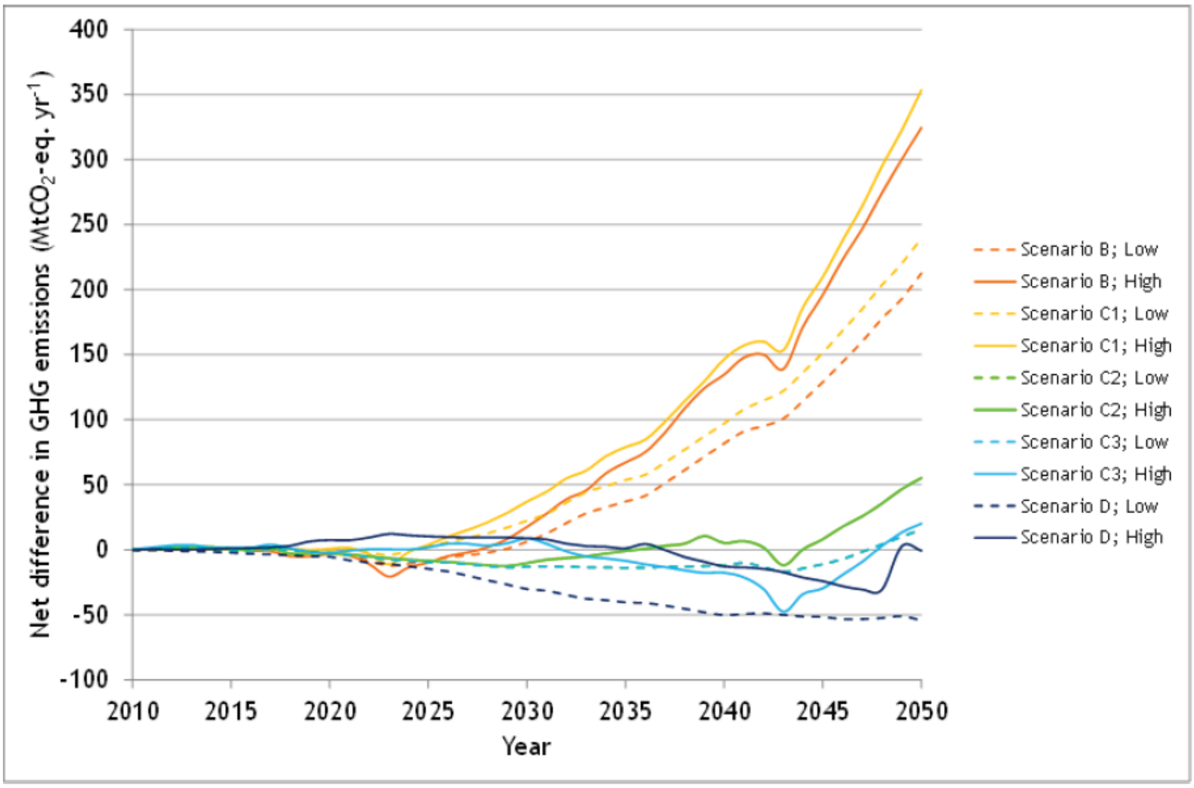

Figure 15: Ranges of annual net differences in GHG emissions due to forest bioenergy consumption in the EU, for the decarbonisation scenarios, relative to Reference Scenarios A-Precautionary and A-Synergistic, as appropriate.

Table 17: Assessment of the contribution of increased forest bioenergy to the overall decarbonisation efforts compared to Scenario A.
Evaluation considers cumulative emissions from 2015 up to the specified time horizon. This 'traffic-light' system assessment is based on the code defined in a supplement to the BioImpact final report and it evaluates both overall GHG emissions from forest bioenergy (major decrease/minor decrease/minor increase/major increase) as well as the relative certainty of the result (low/medium/high).

	2030	**2050**
B ('Carry on/ unconstrained use')	☺☹ (Caution)	☹ (Avoid)
C1 ('Carry on/ imported wood')	☹ (Avoid)	☹ (Avoid)
C2 ('Carry on/ domestic crops')	☺ (Prefer)	☺☹ (Caution)
C3 ('Carry on/ domestic wood')	☺☹ (Caution)	☺☹ (Caution)
D ('Back off')	☺☹ (Caution)	☺☹ (Caution)
All scenarios (considering positive approaches to forest management and	☺ (Prefer)	☺ (Prefer)

wood use)		

Key conclusion #4

The GHG benefits achieved depend on the type of bioenergy used and on the scale of deployment.

The detailed contributions of individual feedstocks to the GHG balance are variable, depending on the scenario and thus on the types of bioenergy. In particular, the contribution of bioenergy towards GHG emissions savings is higher for scenarios emphasising bioenergy supply from domestic sources and lower for scenarios emphasising consumption of imported forest bioenergy and/or the relatively unconstrained use of bioenergy sources.

The study concludes that "*in order to reduce risks of **net increases in GHG emissions associated with forest bioenergy use**, the increases in levels of consumption of forest bioenergy after 2030 should be avoided, unless **additional supporting measures** can be applied to ensure that increased production of forest bioenergy leads to overall positive impacts on GHG emissions*". *(section 6.9.4, p278)*

Sensitivity to forest management practices to achieve GHG benefits

The study shows differences in GHG savings between the two forest management approaches considered ("precautionary" and "synergistic"). The main differences are in the lower impact of forest C-stocks changes both in EU and in exporting countries in the synergistic approach (see final row of **Table 17**). Hence, **forest management choices and strategies have a very important role in mitigating bioenergy GHG impacts, but this suggests going beyond conventionally accepted measures for robust forestry practice such as achieving sustainable-yield wood production** (which are already reflected in the 'precautionary' approach).

The study concludes that: *"The assessment highlights the importance of additional measures to support positive forest management and wood use in terms of GHG emissions. Such measures can reduce risks of high GHG emissions and underpin and/or enhance the positive impacts on GHG emissions associated with forest bioenergy use. As part of any such additional supporting measures, it is important to address potential interactions with the production and consumption of material wood products. For example, this could involve favouring the co-production of forest bioenergy in conjunction with additional material wood products, targeting the displacement of GHG-intensive counterfactual products, and encouraging the disposal of wood products at end of life with low impacts on GHG emissions." (Section 6.9.4, p278)*

Key conclusion #5

Forest management choices and strategies have a very important role in mitigating bioenergy GHG impacts, but this suggests going beyond conventionally accepted measures for robust forestry practice such as: ensuring the conservation and enhancement of forest carbon stocks (and sequestration) as a complement to additional forest bioenergy supply and favouring co-production of material wood products in conjunction with additional forest bioenergy supply (Section 6.9.4, p 278)

ANNEX 9. CLIMATE CHANGE IMPACTS OF FOREST BIOENERGY — TIME HORIZON AND NON-GREENHOUSE GAS CLIMATE FORCERS

This annex focuses on discussing two important factors affecting the climate change mitigation potential of bioenergy from forest biomass resources: the time-horizon and biophysical (non-GHG) forcers. These aspects are treated separately from the sections dealing with biogenic carbon emissions and supply-chain GHG emissions because they are currently not quantified in the studies forming the basis for this IA. These phenomena are still the subject of scientific research and uncertainties are higher; however, since they are generally linked to an overall worsening of climate change, should be taken into account when defining bioenergy sustainability criteria.

Time horizon

Forest systems inertia

Studies based on partial and general equilibrium models tend to assess GHG emission temporal development and economic interactions up to 2030 or 2050. This represents the timeframe for current EU climate policies and it is also in line with the timeframe by which, according to the IPCC AR5 Representative Concentration Pathways (RCP) models, the global peak of GHG emissions should be achieved to have higher probability of maintaining the temperature anomaly below 2°C.

It is important to point out that the frameworks used in modelling studies, including recent projects mandated from the Commission (BioImpact[183], ReceBio[184]), are based on macro and micro economic drivers; this implies that any result of simulations spanning very long timeframes (e.g. 2100 and beyond) would be characterized by a high level of uncertainty (e.g. over the long-term extrapolation of meaningful price-elasticities, macro-economic drivers, technical and economical biomass potentials etc.), which makes difficult to draw any policy conclusion.

Nonetheless, changes in forest management and structure caused in the short/medium-term will have an inertia effect on forests carbon stocks and sinks because of the long time horizons involved in forest management. This means that even for policies carried out until 2030, the changes in forest management will cause changes in forest sinks that will reverberate for many years after the policy target. Those effects, which should be considered as independent from future management changes, should also be attributed to the policy choices examined. This is not usually done in modelling exercises.

Moreover, while the modelling studies underpinning this IA attempt to simulate the management effects on the GHG balance of the land system (LULUCF), the RCP models underpinning the long-term trajectories and targets assume that the residual terrestrial carbon sink (dominated by forests remaining forest) is driven primarily by biophysical factors (CO_2 fertilisation and climate change) and not by management. Therefore, harvest-driven reductions in the net forest sink can create discrepancies with the airborne

[183] https://ec.europa.eu/energy/sites/ener/files/documents/EU%20Carbon%20Impacts%20of%20Biomass%20Consumed%20in%20the%20EU%20final.pdf

[184] http://ec.europa.eu/environment/enveco/resource_efficiency/index.htm#bioenergy

fraction of CO_2 assumed by the RCP models, and thus with the assumed warming impact of CO_2 in general (incl. from fossil sources). Better reflecting management effects should be a priority in the development of the new generation of global climate scenarios, in particular for scenarios assuming a high uptake of bioenergy.

Long-term vs short term impacts on climate of forest bioenergy

Recent literature has shown that some climate change mitigation strategies based on the use of bioenergy contribute to climate change mitigation only in the long term, while causing a climate change worsening in the short term when compared to alternatives that do not rely on large amount of bioenergy[185].

This effect becomes apparent when evaluating single pathways/commodities through a Life Cycle Assessment which is properly designed to include biogenic carbon emissions and reabsorption [186] and that considers a baseline for the non-energy use of the biomass or of the land[187].

Table: Qualitative evaluation of the CO_2 emission reduction efficiency of various forest biomass feedstocks at different temporal horizons.

Source: Agostini et al., Carbon accounting of forest bioenergy, JRC report EUR 27354, 2014

Biomass source	CO_2 emission reduction efficiency					
	Short term (10 years)		Medium term (50 years)		Long term (centuries)	
	coal	natural gas	coal	natural gas	coal	natural gas
Temperate stemwood energy dedicated harvest	---	---	+/-	-	++	+
Boreal stemwood energy dedicated harvest	---	---	-	- -	+	+

185 See for instance JRC, 2014 "Carbon accounting of forest bioenergy" , available at http://publications.jrc.ec.europa.eu/repository/bitstream/JRC70663/eur25354en_online.pdf

186 Feedback through the terrestrial carbon cycle that react on different timescales than above ground biomass.

187 See a review on this topic in JRC, 2014 "Carbon accounting of forest bioenergy" and recent works on residues in "Giuntoli, J., et al., *Climate change impacts of power generation from residual biomass.* Biomass and Bioenergy, 2016. **89**: p. 146 – 158" and "Giuntoli, J., et al., *Domestic heating from forest logging residues: environmental risks and benefits.* Journal of Cleaner Production, 2015. **99**: p. 206-216." or on roundwood in "Holtsmark, B., *A comparison of the global warming effects of wood fuels and fossil fuels taking albedo into account.* GCB Bioenergy, 2015. **7**(5): p. 984-997" and "Cherubini, F., R.M. Bright, and A.H. Strømman, *Site-specific global warming potentials of biogenic CO2 for bioenergy: Contributions from carbon fluxes and albedo dynamics.* Environmental Research Letters, 2012. **7**(4)."

Harvest residues*	+/-	+/-	+	+	++	++
Thinning wood*	+/-	+/-	+	+	++	++
Landscape care wood*	+/-	+/-	+	+	++	++
Salvage logging wood*	+/-	+/-	+	+	++	++
New afforestation on marginal agricultural land (if not causing iLUC)	+++	+++	+++	+++	+++	+++
Forest substitution with fast growth plantation	-	-	++	+	+++	+++
Indirect wood (industrial residues, waste wood etc.) If not diverted from other uses	+++	+++	+++	+++	+++	+++

+/-: the GHG emissions of bioenergy and fossil are comparable; which one is lower depends on specific pathways,

-; --; ---: *the bioenergy system emits more CO_2 eq than the reference fossil system*

+; ++; +++-: *the bioenergy system emits less CO_2 eq than the reference fossil system*

**For residues, thinning & salvage logging the result depends on alternative use (e.g. roadside combustion) and decay rate.*

However, it is important to remember that analyses based on the evaluation of GHG emissions and carbon flows between pools (e.g. biosphere v atmosphere) are only quantifying a *pressure* on the environment, in this case the climate.

Emissions of GHG to the atmosphere cause an increase in atmospheric concentration of these gases, which in turn results in an increase in radiative forcing, which is an imbalance in the energy budget of the planet. This results in a variety of response, including an overall increase in the surface temperature. Responses are regionally heterogeneous and may also lead to impacts such as changes in occurrence of extreme weather events. Other impacts such as sea level rise are mostly driven by the cumulative amount of additional energy trapped in the planet. The rate of climate change also has an impact on the capacity of species to adapt and thus overall on biodiversity losses.[188] Thus, for strategies characterised by a time lag between an initial increase in carbon emissions and the long-term benefits, the impacts on climate for the time period in which the concentration of CO_2 in the atmosphere has increased, will not be negligible.

[188] http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf .

Therefore, the impact of biogenic carbon emissions and removals on the temperature increase depends on the trajectory of emissions and not only on the total cumulative emissions over a given timeframe.[189] Hence the type of biomass feedstock used, the rate, and the timing at which bioenergy technologies are deployed, all influence the overall climate impact of various mitigation strategies: the same long-term target on GHG emissions can be achieved with different trajectories and types of bioenergy penetration but the impact on climate change magnitude and rate will be different.

Biogeophysical climate forcers

International and EU climate targets cover GHG emissions, but not other important climate forcers which can influence global temperature change. Some of these forcers - the biophysical forcers - are particularly relevant for forest management and provision of bioenergy by forests. This is because the change in land management (i.e. harvest) and land cover (i.e. deforestation) influences global and local climate through surface albedo change, as well as through modifications in evapotranspiration, surface roughness, latent heat flux etc[190].

The result of the interaction between all these forcing mechanisms is still not fully understood[191], but recent studies[192] indicate that:

- in boreal regions, the overall effect of permanent land cover change is close to zero, (because changes in surface albedo compensate the warming due to decreased evapotranspiration)

- in other climatic zones, permanent land cover change results in a warming effect

- a temporary change during harvest and regrowth of forest stands (clearfelling) could also result in a warming response in temperate regions, while in boreal regions the effect is still neutral

Therefore, in temperate areas the effect of including biophysical forcers could cause a relatively strong warming response in the case of clearfelling or deforestation, which materializes mostly on local/regional scales. This would come in addition to effects from greenhouse gas emissions, which have a more global reach.

- Emissions and deposition of black carbon on ice and snow-covered land is another important source of increased warming.

Increased emissions of black carbon increases warming by reducing the albedo (in particular on ice and snow) and greatly increase the melting of icesheets.

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[189] Cherubini, F., et al., *Linearity between temperature peak and bioenergy CO_2 emission rates.* Nature Climate Change, 2014. **4**(11): p. 983-987.

[190] Luyssaert, S., et al., *Land management and land-cover change have impacts of similar magnitude on surface temperature.* Nature Clim. Change, 2014. **4**(5): p. 389-393

[191] Stocker, T.F., et al., *Technical Summary, in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* 2013, Cambridge University Press: Cambridge, United Kingdom

[192] In particular Alkama, R. and A. Cescatti, *Climate change: Biophysical climate impacts of recent changes in global forest cover.* Science, 2016. **351**(6273): p. 600-604

Biomass burning is an important source of black carbon, whether this is in wildfires, open air combustion of agricultural residues or the use as traditional or modern bioenergy. An increased bioenergy demand could have positive consequences by promoting the substitution of inefficient wood stoves with modern pellet stoves. On the other hand the combustion of solid biomass will inevitably cause higher emissions of particulate matter, and consequently of black carbon, than other renewable technologies such as solar and wind.

ANNEX 10. DISCARDED OPTIONS

Introducing requirements on soil and water protection for agricultural feedstocks

In the sustainability criteria for biofuels and bioliquids, no requirement was set out concerning soil and water protection. This is because such requirements would mostly consist of good agricultural practices, which can vary depending on a number of factors including geographical circumstances, making it difficult to define, apply and enforce mandatory criteria. At EU level, it is more efficient to approach such risks through agricultural policy. For non-EU countries, there are no mandatory requirements, but many of the voluntary certification schemes which have been recognised by the Commission for demonstrating compliance with the sustainability criteria require farmers to apply good agricultural practices.

In addition, the future use of agricultural feedstocks for heat and power is expected to mostly consist of:

- agricultural residues (e.g. straw): these cannot be transported over long distances hence they will come mostly from within the EU territory, where they are covered by cross-compliance requirements under EU agricultural policy;

- perennial crops (e.g. grasses or short rotation coppice): these have generally a positive impact on soil and water compared to annual crops.

For biofuels, the use of food crops is expected to decrease and be gradually replaced by other sources, including agricultural residues and perennial crops.

Hence, it is not proposed to introduce specific requirements for the protection of soil and water for agricultural feedstocks for heat and power.

Removing the supply chain greenhouse gas methodology and threshold for biofuels, and not introduce one for other agricultural feedstocks for heat and power

Supply chain greenhouse gas emissions for biofuels are accounted for in national inventories (for example in the EU, cultivation emissions and transport emissions are accounted in the non-ETS sector, and processing emissions either in the non-ETS or ETS sector depending on the size of the installation). Hence, it could be envisaged to remove altogether the lifecycle calculation and minimum performance standards for supply chain emissions that exist for biofuels. However, this would go against the objective of ensuring a contribution to greenhouse gas reductions from bioenergy by allowing biofuels with poor or negative direct lifecycle savings (for example where coal is used in the transformation process) to be considered sustainable.

Introducing requirements concerning the level of harvest of residues in forest (to protect biodiversity and soil fertility)

A specific issue related to forest feedstocks and biodiversity concerns the harvesting of forest residues: as described in the problem definition, excessive harvesting of forest residues, and in particular coarse dead wood and stumps, can have negative effects for biodiversity as these residues provide habitat for different species. In addition, such excessive harvesting could also damage soil fertility. It could therefore be envisaged to limit the amount of forest residues harvested for a given area. However, this would be very difficult to put in place given the fact that the local conditions and the amount of residues necessary for ensuring biodiversity and soil fertility vary a lot depending on the geographical conditions. In addition, in some regions prone to forest fires, removing residues is beneficial to avoid the propagation of fires. Forest residues are also normally not traded over a long distance and are not turned into pellets. Therefore, this option is not pursued further.

Mandatory cascading use of wood

A cascading use of wood refers to a more efficient use of resources by giving priority to the material use of wood before it is transformed to energy, e.g. making energy recovery the last step in the use of wood after it has been used once or several times as a product.

Promoting a cascading use of wood has also been proposed as a way to promote a resource efficient use of biomass. However, given the widely differing situation across Member States and regions, a single, biding approach at EU level wouldn't be proportionate or effective. However, as announced in the Circular Economy Action Plan[193], the Commission will present a non-binding guidance on the cascading use of wood by 2018.

Requirements for air pollution

As described in the problem definition, air pollution is addressed through a number of legal measures at EU level. These include Directive 2004/107/EC aimed to reduce concentrations of pollutants in ambient air, Directive 2008/50/EC on ambient air quality, as well as the Large Combustion Plants Directive (2001/80/EC).

Air pollution specifically related to biomass is particularly linked to the stock of old boilers used in particular in households, as well as by the scale of use in certain populated areas. Replacing the stock of existing boilers could be incentivised through e.g. scrappage schemes but this goes beyond the scope of this impact assessment.

Regarding large combustion plants, specific standards are set for air emissions in the context of the Directive on large combustion plants.[194]

Given the fact that air pollution from biomass is specifically addressed through other EU measures and regulations, it is not considered appropriate to set specific requirements in the context of this policy initiative.

Application of sustainability requirements to all biomass users (including residential)

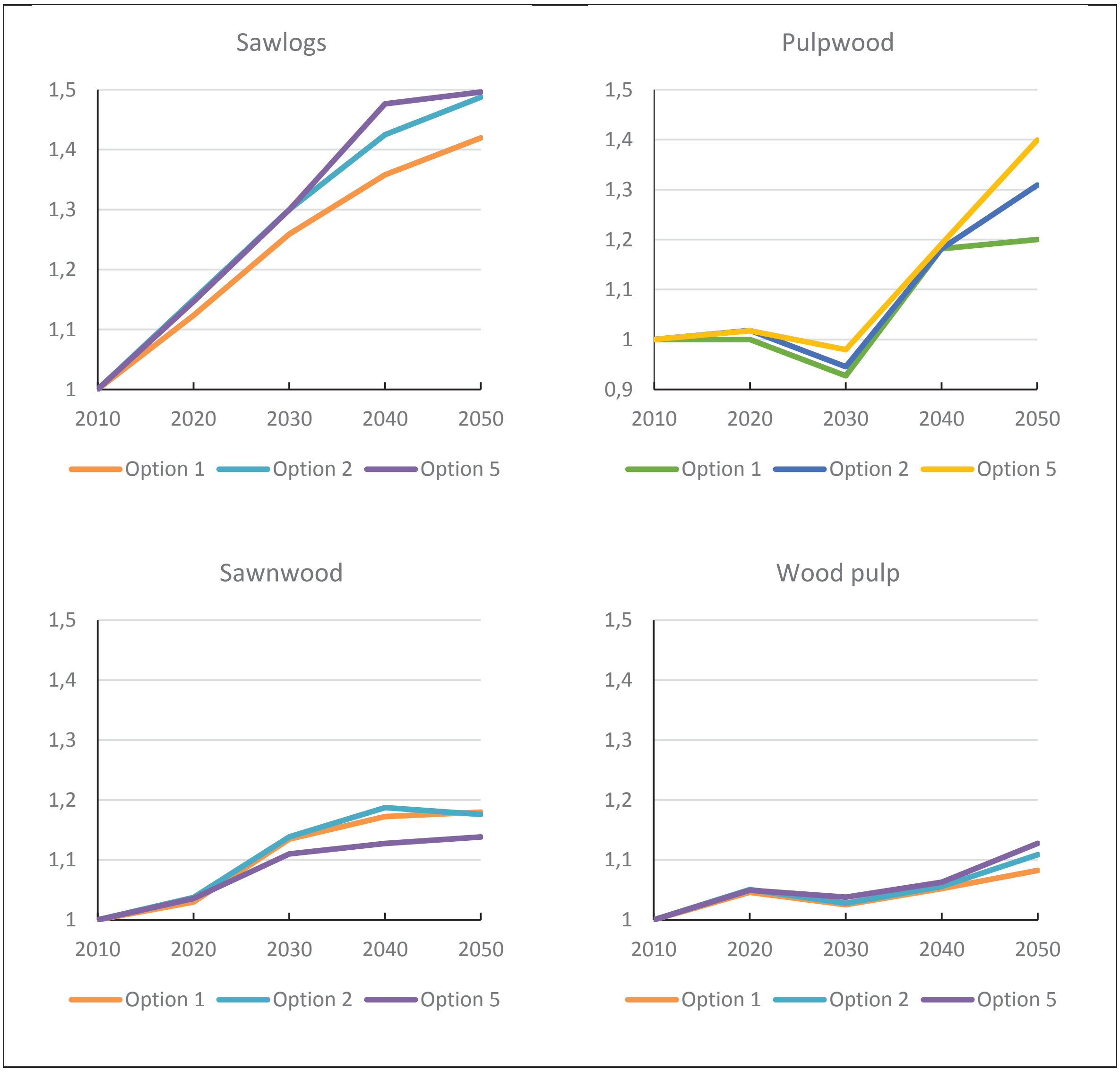
This option aims at avoiding that only part of the biomass consumed in the EU is subject to sustainability rules. In addition, it would prevent that biomass is directed towards certain uses at the expense of others. However, monitoring compliance for residential

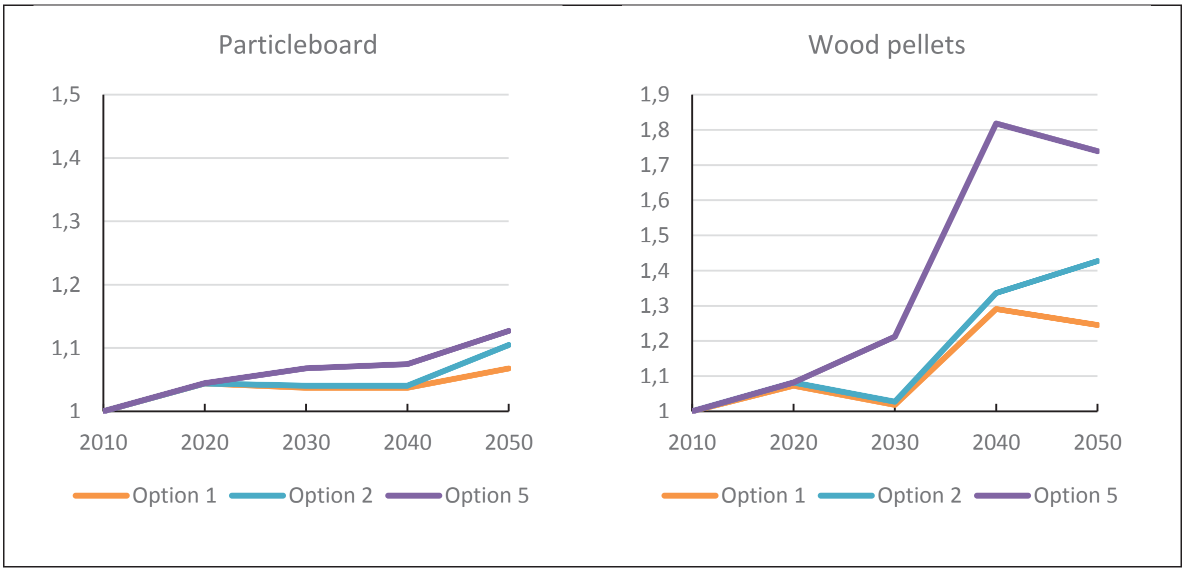
[193] COM/2015/0614 final
[194] Directive 2001/80/EC

heating installation would be particularly challenging, particularly in those Member States that have significant auto-consumption of biomass for heating which is not registered in the commercial markets. It should be recalled that biomass use in the residential market is accounted by Member States towards their renewable energy target by means of statistical surveys. Making all bioenergy installations (including residential ones) subject to an EU-wide sustainability scheme would imply additional administrative burden on Member States to verify the compliance of a high number of small scale installations.

ANNEX 11. IMPACT OF POLICY OPTIONS ON PRICE OF WOOD-BASED MATERIALS

Price developments of various woody feedstocks under option 2 and option 5, as modelled by GLOBIOM/G4M, relative to price in year 2010





Sawlogs: Large diameter roundwood of sufficient length, straightness and other qualities, which can be used by the sawmilling industry

Sawnwood: Wood product produced from sawlogs (planks, beams, etc)

Pulpwood: Roundwood (excluding tops and branches) not satisfying the quality and/or dimensional requirements for the sawmill, veneer or plywood industries, but of sufficient size and industrial quality to be usable for the panels and pulp production.

Wood pulp: Pulp produced from wood