EUROPEAN
COMMISSION

Strasbourg, 18.10.2022
SWD(2022) 341 final

COMMISSION STAFF WORKING DOCUMENT

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Digitalising the energy system - EU action plan

{COM(2022) 552 final}

1 Contents

1. Digital and green transformation of the energy system

1.1 Digitalisation in the energy system

Digitalisation is developing at an exponential rate, internet traffic has tripled in only the past 5 years and around 90% of the data in the world today were only created in the last 2 years.[1] The increase ICT sector's use of energy also follows this trend – it currently accounts for approximately 7% of global electricity consumption and this is forecast to rise to 13% by 2030.[2] Digitalisation is not new to the energy sector, however: the energy sector was one of the early adopters of digitalised solutions, many of which have already been in service for decades. The early developments took place mainly in a few areas of the value chains (e.g. large power plants or electricity transmission networks), while the more recent ones span across the whole spectrum. Since the 1970s, digital pioneers have been using emerging technologies to facilitate grid management and operations and or to improve decision making for exploration and production assets. The planning and operation of wind and photovoltaic (PV) installations uses geo-information systems and advanced weather models. Sensors help to maintain power plants. Modelling tools optimise the planning of wind farms or predict the re-charging needs of the growing number of electric cars. The digital transformation is accelerating, widening and deepening. More computing power, improved connectivity, as well as better sensors and algorithms.

Main characteristics of digitalisation

Apart from the move away from analogue solutions, access to ever more information and the rapid rate of innovation in computer and communication tools, the main characteristics of digitalisation are as follows.

Access:	Falling costs for measuring and sharing information have made data a valuable private and public resource.
Algorithms:	Combining information faster and smartly enhances forecasting and leads to better decision-making
Automation	A growing number of tasks can be delegated and executed without humans – for example, virtual assistants and self-driving cars.

Source: Hafner, Manfred / Luciani, (2022), The Palgrave Handbook of International Energy Economics Cham, Switzerland

The decentralisation of energy generation and millions of connected smart appliances, heat pumps and electric cars transform the last meters in the distribution grids into the first, and operators have to invest in monitoring and control capabilities. Improving the performance of wind turbines depends on digital technologies, for example by equipping wind blades with

[1] International Energy Agency, Digitalization and Energy, 2017, https://iea.blob.core.windows.net/assets/b1e6600c-4e40-4d9c-809d-1d1724c763d5/DigitalizationandEnergy3.pdf

[2] Bertoldi, P. ; Avgerinou, M.; Castellazzi, L. (2017) "*Trends in data centre energy consumption under the European Code of Conduct for Data Centre Energy Efficiency*", EUR 28874 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-76445-5, doi:10.2760/358256, JRC108354

sensors to gather more precise data on their performance and improve (predictive) maintenance that will reduce outage times. Building detailed digital models of energy assets based on detailed sensoring and large data-sets to model performance under various circumstances, also known as digital twins, can improve performance of these energy assets or reduce the costs of research and experiments through virtualisation. High-Performance Computing is already contributing to the energy transition, for example by improving wind plant performance, by improving the understanding of the physics of solid-state batteries, or by better hydrological modelling that is key in reservoir management for hydropower production.[3]

Smart Computer for the Energy Transition

In Northern Germany large quantities of wind power are fed in to the grid: at peak times, this is often more than can be transported via power lines to the south and west of the country, where many large consumers are located. German TSO TenneT and experts from the Jülich Supercomputing Centre (JSC) have developed a special computer system that enables to perform numerous calculations in parallel for the optimal adaptation of the grid and design of new lines: with this system computer simulations of the power flows were accelerated more than 30 times.

Source: Smart Computer for the Energy Transition (fz-juelich.de), press release 31 July 2018: https://www.fz-juelich.de/en/news/archive/press-release/2018/2018-07-31-tennet

In the upcoming years, the digitalisation process will evolve into service-oriented architectures and moving beyond today's cloud computing ecosystems. Artificial intelligence can help to optimise the management and operation of the energy grids or to optimise the room temperature in smart buildings. With the rise of the platform economy and personal data becoming a valuable commodity, new opportunities and challenges for the governance appear. Uncertainties, if connected appliances that offer more comfort might also open the door to espionage and cyber-crime, could hinder the digital transformation if left unchecked. Also, the increasing energy consumption of the IT sector – improvements in energy efficiency are outrun by the increase in use of IT – poses a challenge to policy makers.

1.2 Towards a decentralised, decarbonised and flexible energy system

To meet the Green Deal objectives in the most cost-efficient way requires an energy system that is much smarter and more interactive than it is today. Increased grids' observability and controllability, improved forecasting of energy production from distributed energy resources, and seamless integration across different operators in actively managing their systems are all examples of new needs and challenges that require innovative digital solutions. Decarbonisation, electrification and decentralisation of the energy system require digitalisation to make it work. The Green Deal and the Digital Agenda need to go hand-in-hand as a twin transition.

[3] January 2022, Exascale, a great opportunity for Clean Energy Transition in Europe, European Energy Research Alliance and Energy-oriented Center of Excellence, Brussels: https://www.eera-set.eu/component/attachments/?task=download&id=771, page 10-12

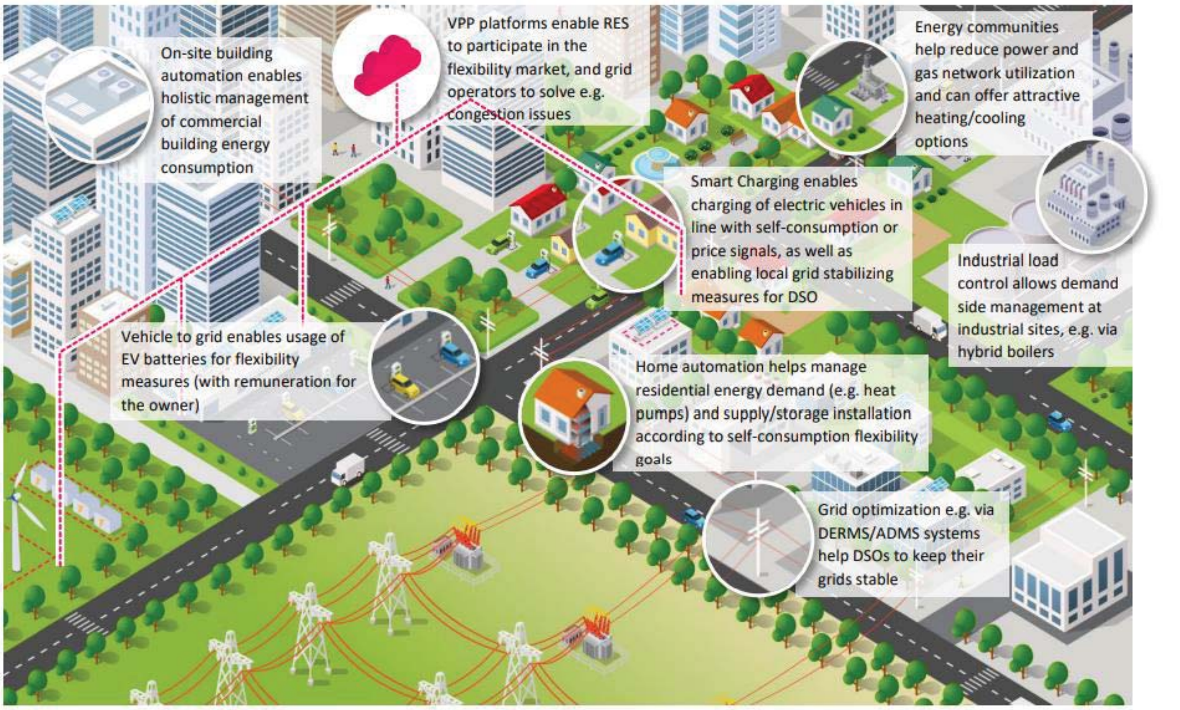
The value of flexibility in the energy system

Most renewable energy sources generate fluctuating amounts of energy, because they rely on the availability of sun, wind or water. This fluctuation creates a significant mismatch between generation and demand. Balancing the system requires adding flexibility through an array of solutions on four different levels:

- flexible energy generation (including biomass and geothermal)
- storing energy and releasing it later through batteries or other options
- markets linking the supply and demand of flexibility

Digitalisation interconnect all the relevant parts of the energy system and enabling end consumers to access markets directly. Most renewable energy sources are of a variable nature. The availability of sun, wind, or water varies from seconds to seasons. This variability creates a potential mismatch between generation and demand. Balancing the energy system depends on adding flexibility, on both supply and demand sides. This flexibility ideally connects locally and system-wide, through an array of solutions that can address the fluctuations inherent in renewable energy sources. Such flexibility will be particularly important for short-term fluctuations, whereas it is unlikely to be an efficient or sufficiently scalable solution for seasonal fluctuations that require long-term energy storage. This 'smartness', in turn, will avoid additional capital expenditures for enhancing the existing grid infrastructure, and allow a faster deployment of electric cars, decentralised renewables, and other technologies - due to reuse of existing infrastructure.

Figure 1: Flexibility in the Energy System



Source: Energy Transition Expertise Centre (2021) Digitalisation of Energy Flexibility, p. 12

The need to integrate an increasing amount of renewable energies while maintaining the security of energy supply, the decentralisation of energy generation and advent of prosumers, and the flurry of Internet of Things (IoT) devices connected to the grid require novel solutions and energy services to facilitate/incentivise flexible energy consumption and demand side management. All these services and the new actors emerging on the energy markets, ranging from aggregators and providers of flexibility to prosumers, are relying on readily available energy data.

More specifically, realising such a smart system requires access to data, the ability to operate smooth and transparent data exchanges, and an effective management of data use and reuse. Operating the modern energy systems and accommodating the variety of new technologies, products, as well as new business models and market players to enhance the flexibility require bi-directional communication capabilities, data exchanges and data sharing. Not only the energy, but also data must flow freely in the system4.

In its turn, the quantity of data that is generated and used has been increasing at an exponential scale over the past several years while opening opportunities for data-driven innovation and new investment models. Thus, ensuring a coherent and coordinated European framework for data sharing and (re-)use, based on common approaches that ensure interoperable solutions becomes an overall objective sought by numerous stakeholders.

Despite the digitalisation of energy is already happening there is still a significant gap to come to a smart and flexible energy system. One essential element where more is needed, is to create suitable electricity infrastructure as well as digital-ready regulatory frameworks. Smarter grids

[4] JRC Science for policy report - Digital Transformation in Transport, Construction, Energy, Government and Public Administration, 2019

are the backbone of the digitalisation of the energy system. It is therefore essential to foster investments in smart grids development and related enabling digital solutions.

Smart charging in Stromnetz Hamburg

The decentralisation of energy generation and millions of connected smart appliances, heat pumps and electric cars transform the last meters in the distribution grids into the first, and operators have to invest in monitoring and control capabilities. An assessment for Hamburg (Germany) indicated the cost savings potential: EUR 2 million investments in smart charging to decrease simultaneous demand can prevent EUR 20 million costs for the necessary reinforcement of the grid to cater for a share of 9% of electric vehicles in the city.

Source: Stromnetz Hamburg (2018), Elektromobilität – Netzausbaustrategie und Restriktionen im Hamburger Verteilnetz https://www.hamburg.de/contentblob/10993526/1f90214d9b07e4de6323c078ff779d9d/data/d-anlage-13-pra%CC%88sentation-snh-20180504-energienetzbeirat-snh.pdf

Example: IElectrix

IElectrix is an EU-funded project that aims at developing innovative technical solutions and economical business models to facilitate the implementation of Local Energy Communities. This is also a way to speed up the integration of Renewable Energy Sources in Smart Grids and to increase the grid resilience and thereby the security of supply.

The IElectrix project consists in implementing different smart grids demonstrators to experiment a set of functionalities required to keep up with the current energy sector transformation: renewable intermittent energies, digitalisation, decentralisation, and consumer’s implication.

Source: IElectrix - Integrated local energy systems (Energy islands) (ielectrix-h2020.eu) ; Website: Indian and European Local Energy Communities for Renewable Integration and the Energy Transition. | IELECTRIX Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)

1.3 The benefits for citizens and consumers

It may seem contradictory to address the need for investments in grids at a time where the EU is experiencing particularly high energy prices and fears shortages of energy for the coming winter, due to Russia’s war of aggression against Ukraine. These high energy prices had a particular impact on the energy poor and the more vulnerable households, for whom energy already represented a higher portion of their average expenditure. Increased renewables production and increased energy efficiency could help mitigate the impact of such episodes and reduce the EU dependence on energy imports (as stated in the REPowerEU Communication). But, in addition to other measures, this requires a smart energy system that empowers citizens through better and more innovative energy services and digital tools.

For example, it is essential that consumers have the option to access their energy data, and ensure that they have the appropriate knowledge of how to use it for them to be able to adopt more energy-efficient consumption patterns and reap further benefits of energy-efficient behaviour. For instance, such was the goal of the EU-funded ECO2 (Energy Conscious Consumers) project[5], which created thee-learning Act4eco.eu platform, which provides 22 e-learning modules that consumers can use to learn how to plan and improve their energy efficiency.

Many Member States now make it possible for households to equip their homes with smart meters to follow their energy consumption on a day-to-day, or even real-time basis. This information and insight into their energy use can help them take control of their energy consumption, make informed choices on when and how to consume and opt for the most suitable pricing contract. Moreover having the appropriate information, consumers will be able to improve their energy habits for making savings, and manage their energy behaviour to reduce their bills, which is especially important in the current high and volatile price context .[6] Smart meters can also support a wider-range of tariffs that encourage consumers to shift their energy usage to off-peak cheaper times. This helps consumer save money and it would reduce the pressure on the energy system to activate fossil fuel capacity, including gas, at peak times.

Furthermore, digitalisation allows to automate the reaction to price-signals or other incentives: consumers can use their electric vehicles and other small and easy-to-mobilise assets (i.e. batteries and heat pumps which can provide energy storage and enable bidirectional recharging) to increase grid efficiency and help the system operators to avoid costly network reinforcements thus lowering the use of system charges. This can also be the best response when too much renewable electricity is produced (digital tools can provide information in real time on the renewable electricity and of GHG emissions share in the grid, so that consumers can use clean electricity to charge their electric vehicles).

Digital tools such as smart meters have helped to empower consumers in recent years. Simplicity is crucial: tools and services must be easy to understand and use so that users do not revert back to their old consumption patterns, lose interest and even disengage. Users may find it difficult to understand and apply concepts such as energy flexibility. It is therefore of crucial importance to increase their trust in demand-side management and associated innovative energy services so that they can fully exploit the potential of digital tools. Overall, new business models and actors should be encouraged in the market, as they will facilitate the introduction of innovative products and make it easier for consumers to recognize the benefits and subscribe into new energy services.

To fully unlock the potential of the opportunities of digitalisation and facilitate end-users' participation in the system, awareness and learning must support the twin transitions. Consumers must be able to operate these new innovative tools so that new vulnerabilities are not created and no one is left behind. Successful green and digital transitions require significant changes in organisational culture, leadership profiles, mind-set and skillsets.

Matching technological innovation with innovation in social practices and relations (both individually and collectively) is crucial for the success of the twin green and digital transitions. Digital innovation and social innovation reinforce each other. Disparities between different consumer groups (e.g., different levels of digital skills or different levels of willingness to participate in the energy markets) mean that the design of digital tools and solutions must adapt

---

5 http://eco2project.eu/

6 For instance, without smart metres consumers have no control over their bills when suppliers adjust prices.

to differing needs. Different consumer groups (e.g. on the basis of consumers' principal motivations and/or their willingness to engage) have been proposed[7] .Digitalisation provides an additional opportunity for consumers to engage in the energy market, because the inherent flexibility of digital tools makes it possible to adapt designs to each consumers' specificities and preferences.

1.4 Enabling cooperation and collective action

Communities as well as individuals can participate in the energy market. Since the 1970s in Denmark and Germany, some communities and local groups have come together to invest in shared renewable production assets, share the resulting benefits and exchange information and best practices on supporting the energy system. More recently, social innovation and digital innovation have reinforced each other. Energy communities (as defined by the Clean Energy for All Europeans Package,[8]) are important drivers of innovation due to the disruptive and decentralised nature of their activities (community networks, energy sharing, self-consumption), and they have more recently enjoyed increasing attention and popularity.[9]

Energy communities are a testing ground for real-life experimentation with new technologies and the social arrangements needed for an inclusive and just transition, and they are some of the drivers of such forms of citizen's empowerment.[10] These innovative activities can often be facilitated or optimised using digital tools. For example, remote rural energy systems that suffer from high transport costs and insecure supply due to weak and unstable and/or remote connection to the medium-voltage grid can use digital tools to reduce their dependence on the main electricity grid by pooling their own consumption of individually produced electricity.[11] Benefits of digitalisation are also evident for urban energy systems which are characterised by

7 See for instance https://www.ceer.eu/documents/104400/-/-/44055630-31dc-d3da-386a-a6edfec24eb1

8 In order to provide a homogenous institutional framework for energy communities while still encompassing the diversity of such forms of organisation, Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II) and Directive (EU) 2019/944 on common rules for the internal market for electricity (the IEMD) introduce the notions of renewable energy communities (RECs) and citizens' energy communities (CECs). The two notions differ in several respects (type of production assets, geographical scope, participation requirements etc.), and Member States have substantial flexibility in transposing the relevant provisions of these directives, but the overall objective is to ensure that all Member States have an enabling framework for energy communities that features a standard set of conditions and associated rights (particularly in terms of licensing and permitting procedures, and applicable charges, levies and taxes).

9 Communities in the EU are a buoyant and even booming sector, with thousands of associations run by members of the public to develop local energy solutions. The European Federation of Energy Cooperatives (REScoop.eu) alone claims that it has a growing network of 1 900 cooperatives operating across the EU and that it represents more than 1.25 million members of the public. For further examples see https://op.europa.eu/en/publication-detail/-/publication/e421aa35-fe0e-11ea-b44f-01aa75ed71a1/language-en/format-PDF/source-search.

10 This means empowerment not only in terms of access to services and goods that help communities to overcome their problems, but also in terms of capacity-building so that they can manage for themselves and own the means to secure their own well-being.

11 For an example of using digital tools to optimise collective electricity self-consumption and reduce dependence on the main electricity grid, see Pilot site Luče – Compile Project (compile-project.eu). This also concerns not only the development of smart micro-grids (currently partly enabled by EU legislation on community networks and closed distribution networks without an islanding option), but also energy management systems (decentralised or centralised control systems; action-based or automated systems etc.).

a complex energy infrastructure that is designed to supply energy to multiple energy users and from an increasing number of players (including members of the general public) acting not only as consumers but also as suppliers or otherwise adding flexibility to the system.[12] A recent report published by CINEA emphasises that the digitalisation of energy systems has multiple specific benefits in urban contexts. These benefits also extend to mobility, infrastructure, and buildings. The same report examines different scenarios for 2025, 2030 and 2040, and formulates policy recommendations to foster these evolutions and lift remaining barriers.[13]

Digital tools for energy communities

Many digital tools make it possible for communities of consumers to scale up and diversify their positive impact on the electricity system.

- For instance, digitalisation makes it possible to develop business cases to provide flexibility1 services through aggregation. Digital tools make a seamless exchange of electricity between grid operators and the community possible. This can in turn make it possible to use digital tools and interfaces to set up dynamic pricing tools and share price signals with the community's members. The Belgian energy community Ecopower is focusing on developing such models. The Delta-EE Whitepaper on Residential demand response shows that residential sector has huge untapped potential with over 200GW of installed assets of which HVAC and hot water heaters account for 97%. Lastly, an EU-funded project, FLEXCoop, is developing digital tools to enable energy cooperatives to act as an aggregator and build up the flexibility potential of their members.
- Communities' digital tools can be used to manage congestion (e.g. the EnerGent project partially resolved power-poverty issues by controlling inverters of households' photovoltaic panels to support the grid).

One of the most interesting developments of the past decade has been the development and implementation of tools that enable the peer-to-peer ('P2P') trading of electricity. A recent study from the German Institute for Ecological Economy Research (IÖW)[14] evidenced the enormous potential for energy sharing: more than 90% of all households in Germany could benefit from electricity from citizens-owned power plants, thereby mitigating current high European energy prices.

Evidence also shows that P2P trading of electricity increases the added-value citizens[15] (that is to say both self-producers and consumers) can gain from engaging in electricity trading, which in turn may drive increased levels of private investment in renewable energy generation assets.

---

12 This was the case in the *Partagélec* energy sharing project in Brittany, which was directly initiated by the municipality of Pénestin and the CAP Atlantique community of municipalities along with an energy syndicate. See Verde, S. F. and Rossetto, N., *The Future of renewable energy communities in the EU: an investigation at the time of the clean energy package,* available at https://op.europa.eu/en/publication-detail/-/publication/e421aa35-fe0e-11ea-b44f-01aa75ed71a1/language-en/format-PDF/source-search.

13 See https://cinea.ec.europa.eu/publications/digitalization-urban-energy-systems_en

14 See https://www.ioew.de/en/news/article/energy-sharing-how-citizens-can-accelerate-the-energy-transition

15 The H2020-funded project SocialRES' 'Report on new business models for cooperation among cooperatives, crowdfunding platforms and aggregators in the energy market of the future' describe how autonomy was identified as an 'active' social value in the context of a Portuguese P2P energy-sharing demonstration and was seen by users as a social value that was reinforced by the P2P energy-sharing activities (Adams et al., 2021).

Peer-2-peer trading

- Several companies and projects – both in the EU and elsewhere – use peer-2-peer trading: The Brooklyn microgrid (BMG) project in the US has enabled 40 prosumers and 200 consumers to sell the electricity they produce on their own premises at a price they are free to set for a period of 12 months.
- The RENeW Nexus Project in Australia has enabled 22 residential prosumers and 26 residential consumers living in the same area to trade their surplus energy production through a blockchain-based platform.
- The Dutch SchoonSchip pilot project has interconnected a floating neighbourhood of 46 households and enabled them to engage in P2P residential energy sharing while at the same time helping the operator of the distribution system to avoid congestion. The project was set up under a Dutch national experimentation scheme. Through the application of demand response, energy storage, conversion and electrification, the Schoonschip smart grid has become almost fully autonomous, requiring only a minimal backup connexion with the rest of the national grid: the 46 homes with a combined capacity of approximately 900 kVA are connected to the public grid with a single connection of only 160 kVA.
- Ogarniamgrad.pl is a Polish energy trading platform that makes it possible to buy and sell electricity at real-time auctions. It has saved more than USD 970 000 for its users.
- The EU project PARITY aims at delivering a transactive flexibility framework that will increase durability and efficiency of the electrical grid, while simultaneously enabling the adoption of more RES through enhanced real-time control of DER Flexibility combined with novel active network management functionalities. PARITY goes beyond the traditional "top-down" grid management practices by enabling the functioning of a local flexibility market platform making use of IoT, as well as blockchain technologies for P2P energy trading. The examples elaborated in the PARITY project tend to evidence that the major share of the cost savings enabled by consumer participation in the energy system result from local (P2P) energy trading, but hybrid market models (energy trading + flexibility provision) are also able to generate additional smaller revenues from flexibility provision.
- The EU-funded Energy Community Cooperatives (ECCO project) has created a digital platform to provide users with all the necessary resources for community energy projects. These include: (i) a community space which connects users and provides space for communication, (ii) a resources page with links to relevant resources to assist community energy groups' progress, and (iii) custom-built tools designed to measure the progress of community energy projects, including: a) a greenhouse gas calculator that calculates the annual carbon dioxide savings that can be achieved by consuming different forms of renewable energy, b) a self-assessment tool to help community energy groups see what stage of development their projects have reached, c) a technology decision plan that suggests the best renewable energy option for a given user based on the resources available in their local community and d) a timeline tool that gives an in-depth view of each step in the ECCO timeline.

1.5 Cooperation to share knowledge

The evidence from policy trends, stakeholders' feedback and insights into research and innovation projects that were analysed as input for this action plan underlined the importance to understand and steer the digital transformation of the energy system.[16] The potential to accelerate the EU Green and Digital Transition and the implementation of the REPowerEU

Knowledge and knowledge sharing

- As we gradually progress to a green energy system, **new knowledge** which is **currently lacking** will have to be built up, at both EU and national levels. Technology, market functioning and legal frameworks are all closely connected to each other. Knowledge needs to be shared across different policy areas and levels.

- A lot of research and innovation is taking place in the EU on relevant topics, producing a lot of new knowledge, but this **knowledge is sometimes fragmented**. Collective learning and knowledge sharing should be improved (BRIDGE is active in this area). Knowledge should be shared between **all stakeholders (including policymakers and regulators in Member States, market stakeholders and the general public**). **Sharing knowledge** will make it possible to develop a common vision and strategy, making it easier to create the conditions for success.

- As the transformation towards a green and digital energy system progresses, new knowledge which is currently missing will have to be built up, both on an EU and on a national level. Technology, market functioning and legal frameworks are strongly intertwined, and its corresponding knowledge should be shared across the different structures and at all levels.

- Knowledge coming out of research and innovation activities is sometimes fragmented. Many respondents ask for extended collective knowledge sharing, organised at EU level, among policy makers and regulators in MS, stakeholders, and last but not least, European citizens.

Upscaling from innovations

- A significant number of EU research and innovation projects **have not upscaled** their results into new business operations. The main reasons given were interoperability issues and inconsistencies between the Member States' legal frameworks.

Organisation and governance structures

- In the step towards new business operations, coordinate action at EU and MS level is asked to ensure governance, market design, business models, standardisation and interoperability facilitate scale-up.

[16] 65 projects have been analysed for these lessons learnt, identified through Horizon Europe and a stakeholder survey.

Plan requires a closer cooperation in the EU, with likeminded countries and international organisation, and between energy and digital players across the entire energy value chain.

2 Developing an EU framework for sharing data to support innovative energy services

2.1 Context

Strategic and regulatory EU frameworks are starting to lay down measures to ensure coherent approaches and interoperable solutions. Thus, the EU Strategy for Energy System Integration[17] stresses the importance of data availability and interoperability for the functioning, development and further integration of the energy system, and for realising the full potential of prosumers and grid flexibility. Additionally, several legal acts already in force or recent legal proposals for the energy sector include provisions regarding the exchange of energy-related data.

- The Electricity Market Directive[18] and Regulation[19] include provisions on the access to, and interoperability of data[20] from (smart) meters, as well as requirements for transmission and distribution system operators with regard to data access and data management.
- The Commission's proposal for a revision of the Renewables Directive[21] lays down requirements on access to data to enable smart and bidirectional charging of electric vehicles. It also requires making available information on the share of renewable electricity and the greenhouse gas emissions content of the electricity supplied in the Member States.
- The Commission's proposal for a revision of the Energy Performance of Buildings Directive[22] defines rules for access to, and exchange and interoperability of data from (smart) buildings. This will enable the rollout of new smart building services and will support renovation actions.

In addition, recent legal proposals and strategic documents cover general topics regarding the exchanges of data. They are highly relevant for numerous economic sectors, including the energy sector.

---

[17] COM(2020) 299 final.

[18] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU, OJ L 158, 14.6.2019, p. 125.

[19] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, OJ L 158, 14.6.2019, p. 54.

[20] The term 'data', according to article 23(1) of the Electricity Directive, refers to metering and consumption data, as well as data required for customer switching, demand response and other services.

[21] COM(2021) 557 final.

[22] COM(2021) 802 final.

- The Commission's proposal for a Data Governance Act[23] aims to foster the availability of data for use by increasing trust in data intermediaries and by strengthening data-sharing mechanisms across the EU. It also establishes the European Data Innovation Board, a new expert group that would support the Commission on enhancing cross-sectoral data sharing and (re-)use.
- The Commission's proposal for a Regulation on harmonised rules on fair access to and use of data (Data Act[24]) defines generic data-sharing requirements, based on consumers' requests, for non-personal data generated by physical, connected objects.
- The Commission's proposal for a Regulation on alternative fuels infrastructure[25] aims to support the availability and accessibility of data from publicly accessible recharging points, ensuring a suitable functioning and offering of services.
- The European Data Strategy[26] published in 2020 announced the establishment of common European data spaces in nine sectors, including energy. The energy data space will reinforce the availability and cross-sector sharing of data, in a customer-centric, secure and trustworthy manner. This will facilitate innovative solutions and support the decarbonisation of the energy system.
- The Statement of the Members of the European Council of 25 March 2021[27] calls for progress in establishing the sectoral data spaces announced in the European Data Strategy.
- Building on the European Data Strategy, the Commission's 2022 Staff Working Document on Common European Data Spaces[28] stresses the point that the energy data space will help the further integration of renewables, increase the energy system efficiency, and ensure a smooth and competitive transition towards the electrification of sectors such as heating and transport.
- The European Interoperability Framework lays down guiding principles and recommendations[29] that could drive the seamless exchanges of data within and across various sectoral data spaces.

Several key actions will therefore be implemented with the aim of making the best use of data in the energy sector, and helping to build, scale up and maintain interoperable solutions for a strong European energy system.

The actions proposed have the electricity system at their core, as an accelerated integration of renewables and electrification are now driving the pace of its transformation. However, the proposed framework is designed not only to closely interact with and gradually include other energy carriers (e.g., decarbonised gases and hydrogen), but also to interconnect with other sectors such as transport and finance.

Furthermore, it should be noted that the actions do not directly address matters related to the ownership of data or intellectual property rights that may apply. Nor do they directly address data confidentiality, privacy and personal data protection. These very important cross-policy

23 COM(2020) 767 final.
24 COM(2022) 68 final.
25 COM(2021) 559 final.
26 COM(2020) 66 final.
27 https://www.consilium.europa.eu/media/48976/250321-vtc-euco-statement-en.pdf.
28 SWD(2022) 45 final.
29 https://joinup.ec.europa.eu/collection/nifo-national-interoperability-framework-observatory/3-interoperability-layers.

aspects are all considered to have a general applicability, which is governed by separate frameworks[30]. The focus is kept on data sharing arrangements and processes that are needed to improve the functioning of existing energy services, and on developing new ones in order to increase the share of renewables in the energy system and to strengthen the system efficiency and the overall security of supply. In this approach, it is considered that the relevant actors (e.g. prosumers) have an interest in sharing their energy-related data. The relevant stakeholders therefore express their consent for sharing their energy-related data when subscribing to new services that bring them direct benefits, e.g. through the monetisation of their flexibility, by lowering the energy bills through charging their electric vehicles (EVs) in a smart way, by improving the self-consumption of the energy produced by their PVs or by any other means. Additionally, data sharing is envisaged to be conducted among eligible and trusted parties.

Finally, the data sharing arrangements that need to be built in a coordinated way aim primarily to further develop several areas of the energy value chains, and innovative energy services and products that are key to deliver on the Green Deal and REPowerEU objectives. The policy areas that require easy and seamless data exchanges include: establishing new flexibility products and services that help the integration of increasing shares of renewables and strengthen the liquidity and resilience of the energy markets; facilitating the rollout of smart EV charging and vehicle-to-grid services; supporting smart energy buildings as a source of renewable energy production and flexibility in the energy system, and making the data from buildings available to define business cases for renovation and improving the buildings' overall efficiency. The data exchanges among the grid operators (i.e. transmission and distribution system operators), which are required for the functioning and stability of the grids, are not directly addressed here, but the strong synergies will be closely observed and factored in[31]. In other words, the main aim will be to coordinate action at the edge of the grids and at the interface with the electricity markets, by bringing together the views of a large variety of stakeholders that would otherwise find very hard to coordinate among themselves.

2.2 Evidence, projects and best practice[32]

Numerous stakeholders have pointed out the need to strengthen EU cooperation and coordination on the exchange of data for energy. Their views indicate several key areas of action and the main priorities to be addressed.

The Commission conducted an online public consultation[33] between October 2021 and January 2022 to collect the views of citizens, businesses and national authorities on the main priorities

[30] For instance, by the General Data Protection Regulation (EU) 2016/679 (https://eur-lex.europa.eu/eli/reg/2016/679/oj), Regulation (EC) No 223/2009 on European statistics (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009R0223) or by the cybersecurity measures described in the area of the Action plan dedicated to them.

[31] Additionally, a specific action under this Action plan will support enhanced data exchanges between TSOs and DSOs. See 'Support the development of a Digital Twin of the EU electricity grid' for more details.

[32] Selective country and project examples are presented throughout the text. However, these are not intended to cover exhaustively the whole of the EU, nor are the result of a prioritization exercise. The examples are solely for providing insights into specific arrangements for exchanging data in the energy sector, without prejudice to the numerous other valuable actions that are undertaken throughout the EU.

[33] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13141-Digitalising-the-energy-sector-EU-action-plan/public-consultation_en

for digitalising energy. The answers received stressed the point that insufficient cooperation, at various levels, is a barrier to unlocking the full potential of the data. Legal uncertainties due to different national rules on accessing energy data across Member States, and the lack of appropriate infrastructures for such data access prove to be currently quite problematic. The national organisations should therefore cooperate and harmonise their approaches whenever possible. Additionally, any legal uncertainties regarding their mandates should be resolved and the responsibilities of the actors involved should be clarified.

Interoperability aspects were also a major area of concern for the stakeholders consulted. The lack of interoperability for accessing data and exchanging it between devices and/or organisations was seen as the main barrier at operational level.

Country example: Austria

Nation-wide standardized data exchanges on energy started in 2012, with the implementation of an automated digital process for consumers to switch their energy supplier. The data exchange framework underwent multiple developments over time, driven by the needs of smart grid stakeholders that established working groups. Today, a decentralized, scalable, and highly standardized framework covers many additional use cases, including customer billing and customer management processes, access to metering and consumption data, processes linked to energy communities etc. The principles observed ensure that data always stays as close to the source as possible and is only exchanged based on customer consent or in the context of well-defined business processes observing clear legal requirements. Consumers and energy market players get a unified and secure interface to interact with the smart grid services. All data exchanges are conducted with securely signed and encrypted market messages. Customers can give and revoke their consent to sharing data and/or participating in an energy community.

Each new market process is developed on the basis of public consultations and it subsequently becomes mandatory for all market actors. The management of the technical infrastructure for the energy-related data exchanges (EDA) was initially ensured by a working group without a legal personality. In 2020 this was transformed into a limited liability company (EDA GmbH), which now acts as a solution provider.

Additional information: https://eda.at; https://ebutilities.at.

Concluding, the top three actions recommended by stakeholders to be taken at the EU level were: (1) to define roles and responsibilities and to clarify the legal framework for data exchanges in energy; (2) to address interoperability; and (3) to create a governance structure for access to and sharing of data.

The Commission followed up its online public consultation by organising a series of six workshops[34] in February and March 2022 to collect additional inputs. Hundreds of participants attended and shared valuable views and ideas. One of the key conclusions drawn[35] referred to the opportunity to establish an EU expert group on data for energy. This would bring together several main categories of stakeholders, including Member State authorities and regulators,

34 https://ec.europa.eu/info/events/workshops-digitalisation-energy-system-2022-feb-16_en

35 Workshop conclusions – 'Priorities in the energy transition that require enhanced data exchanges at EU level':https://ec.europa.eu/info/sites/default/files/energy_climate_change_environment/conclusions_2302_data_exchange_priorities.pdf.

grid operators and energy market players, research and innovation experts, technology providers and equipment manufacturers, standardisation representatives, and organisations representing consumers/prosumers. Additionally, a governance for the upcoming energy data space should be built and interoperable building blocks should be established for developing the data space in a robust and scalable way[36].

> **Country example: The Netherlands**
>
> All Dutch electricity grid operators joined forces in 2007 and embarked, via the NEDU association, on exchanging energy data with market stakeholders. The scope covers data for supplying energy, consumers switching their energy suppliers, and exchanging metering data. In 2018 it became apparent that the energy transition would require data exchange between more parties within the energy sector, and with other sectors such as transport, buildings, and the financial sector. A national initiative was launched and resulted in a legal entity (BAS, the data exchange framework administrator) and an association (MFF, the market facilitating forum, which replaced NEDU). Both became operational in April 2022. BAS is an independent legal entity that has the Dutch TSO and DSOs as its shareholders. BAS is expected to handle all energy data exchanges. In the MFF meetings all relevant energy and cross-sectoral stakeholders, which require access to energy-related data, meet and agree on standard data formats and data exchange processes that should be used. Once agreed, BAS will implement those solutions, and monitor and report on their correct usage.
>
> Additional use cases for data exchanges are being actively developed as needed. Thus, data that is instrumental for operating the electricity system is currently exchanged between market stakeholders and grid operators. This is done via the GOPACS platform, which coordinates the procurement by grid operators of market-based flexibility services that are used to mitigate grid congestion. Furthermore, frameworks start to be developed for accommodating smart EV charging, and for supporting social housing associations to renovate the homes of their tenants for improving their energy efficiency.
>
> Additional information: https://www.mffbas.nl/; https://en.gopacs.eu/.

Challenges regarding interoperability and access to data that might hamper the large-scale deployment of demand side solutions for flexibility were also identified in an expert report published by the Smart Grids Task Force (SGTF)[37]. The report recommended several key actions, which included: ensuring stakeholder coordination at EU level to promote data access and interoperability, jointly developing guidelines, defining standard capabilities and requirements for smart appliances, defining an EU framework and associated building blocks for data access, and working with the Member States for establishing customised national implementations of those building blocks. A separate SGTF report[38] laid the ground for more detailed work on data access in the electricity and gas sectors. It recommended engaging all relevant stakeholders and agreeing on several key interoperability features. Building upon this

[36] Workshop conclusions – 'Best practices for energy data sharing', https://ec.europa.eu/info/sites/default/files/energy_climate_change_environment/conclusions_1602_best_practices_for_data_exchange.pdf.

[37] European Smart Grids Task Force, Expert Group 3 – Final Report: Demand Side Flexibility - Perceived barriers and proposed recommendations, April 2019.

[38] SGTF, Expert Group 1 - Towards Interoperability within the EU for Electricity and Gas Data Access and Exchange, March 2019.

work, the SGTF experts further proposed[39] a set of interoperability rules to be considered at

Country example: Estonia

Estfeed is the first Estonian secure platform and protocol for managing distributed exchanges of metering and consumption data between data providers and data users. The transfer of metering data requires the owner's consent. The platform is designed and operated by Elering AS, the Estonian TSO, as a flexible and scalable system to share consumer energy data with any energy services that can use it for deploying value-added services. A dedicated API (Application Programming Interface) allows access to the platform services through standard interfaces.

The initial use cases that drove the design of the platform referred to supporting and coordinating the energy supply processes. As such, the main users have been energy suppliers, balance responsible parties and grid operators. Recently, aggregators, as providers of flexibility services to the electricity system, were also granted access. Furthermore, any consumer/prosumer can grant access to its data to any third party, while remaining the owner of that data and being able to fully supervise its use.

Estfeed is built on the X-Road software-based national solution, which manages data exchanges and is the backbone of e-Estonia. X-Road allows various public and private sector e-service information systems to link up and function in harmony.

Additional information: https://elering.ee/en/developments-related-energy-companies; https://e-estonia.com/solutions/interoperability-services/x-road/.

EU level for access to electricity metering and consumption data.

Valuable work for improving data exchanges in energy and advancing interoperability is being carried out by the Bridge[40] Initiative of the European Commission. The Data Management working group regularly publishes reports based on the findings and lessons learnt from research and innovation projects. Their reports focus on analysing frameworks and technical matters that underpin the exchange of data in a secure and interoperable manner. Ensuring interoperability is identified as a key prerequisite for a successful energy transition and solutions are being sought. Therefore, a common European reference architecture for data exchanges[41] and a repository of use cases[42] are being developed and proposed to be used by the energy actors and research projects, and a methodology[43] was developed for analysing the system implementation of flexibility-related use cases. These products are being further refined and developed. Further joint work by key stakeholders will be needed in order to ensure their

[39] SGTF, Expert Group 1 - EG1 advice on the implementing acts on data access and interoperability – metering and consumption data, March 2022.

[40] The BRIDGE initiative brings together Horizon 2020 and Horizon Europe projects that are active in the areas of smart grids, energy storage, islands, and digitalisation. It aims to foster the exchange of information, experience, knowledge, and best practices among its members. It was launched in 2016, comprises 93 projects (out of which 58 are ongoing) that bring together almost 1000 partner organisations from 40 countries and have a total value of over 1 billion euros. For more information visit https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/.

[41] Bridge, Data Management Working Group - European energy data exchange reference architecture, April 2021.

[42] Bridge, Data Management Working Group – Use case repository, April 2021.

[43] Bridge, Data Management Working Group – Interoperability of flexibility assets, April 2021.

use on a wide scale. This technical perspective is naturally complemented by the regular reports published by the other Bridge working groups[44], which focus on regulatory models, business models, and consumer and citizens' engagement, respectively.

With regard to the main priorities that would warrant enhanced data exchanges and require extensive stakeholder coordination, the feedback collected during the preparatory phase of this action plan converged by indicating several areas. The vast majority of respondents in the online public consultation indicated that balancing electricity supply and demand by using flexibility solutions should be the top priority. The stakeholder workshops went into more detail and stressed that priority should be given to the areas that are rapidly developing from strategic, legal, technical and organisational perspectives. These areas include aggregation, demand response and flexibility services for the grids, smart and bidirectional EV charging, and reinforcing the role of smart buildings as key players for improved energy efficiency and innovative energy services.

The OneNet project

OneNet is co-financed by Horizon Europe with EUR 22 million and has a total value of EUR 28 million. Over 70 partners from 22 European countries, including two major associations of electricity grid operators (ENTSO-E and E.DSO) are part of a unique consortium with an ambitious goal. They aim to provide a seamless near real time integration of all the actors in the electricity networks across Europe for the optimization of the overall system and the promotion of an open and fair market structure. More specifically, during its three-year implementation schedule lasting until September 2023 the project undertakes to: define standardised products and key parameters for grid services that aim at the coordination of all actors, from grid operators to customers; define a common IT architecture and common IT interfaces that enable open interactions among the existing platforms for all energy products and services envisaged; and implement and showcase scalable solutions grouped in large-scale demonstrators covering major regions in Europe.

OneNet therefore works to develop an open and flexible architecture to transform the actual European electricity system, tackling country- or zonal fragmentation, and building a pan-European smarter and more efficient coordination. The vision is to coordinate market and network technical operations among them and across different countries, while maximizing the consumer capabilities to participate in an open market structure. The general use case of the OneNet system describes, among others, the main steps to enable a cross-platform energy data exchange using the OneNet middleware. Such a data exchange will allow building multiple cross-platform services for market-based management of flexibility in the electricity system. Open mechanisms will allow the OneNet participants (including platforms, applications or services that act as Data Providers or Data Consumers) to interact with each other by using the OneNet Middleware.

Additional information: https://onenet-project.eu/; https://op.europa.eu/en/publication-detail/-/publication/abf32809-143e-11ec-b4fe-01aa75ed71a1/language-en.

---

44 https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/download

Similar priorities were identified by a recent study completed by the Energy Transition Expertise Centre (EnTEC)[45].

The RENAISSANCE project

RENAISSANCE is a Horizon Europe project that ends its 36-month implementation schedule in the second half of 2022. The project has a total value of EUR 6.9 million, out of which EUR 5.9 million represent the EU co-financing. Fifteen organisations from 7 European countries are partnering for a successful delivery of the project objectives.

RENAISSANCE aimed at demonstrating highly replicable design and management approaches for integrated local energy systems, that achieve high participation of local consumers (15-20%), exceed at local level the EU targets for renewable energy sources (37-80%) while decreasing the energy price for community members (10-15% below current market prices). The methodology and each of the four pilots (in Belgium, Greece, Spain and the Netherlands) covered key energy vectors (like electricity and heat), and involved different actors (e.g. households, SMEs, institutions) to valorise flexibility services within and between communities, and with DSOs. Local data exchanges for each pilot site, as well as between pilots, were instrumental for putting the design into practice, lowering the local GHG emissions and bringing value to the local energy communities of prosumers. The secure, interoperable and scalable RENAISSANCE platform interconnects all energy vectors of the demonstration sites into a unique decentralized multi-vector energy services market where consumers/prosumers can interact and perform financial actions defined by smart contracts.

Additional information: https://www.renaissance-h2020.eu/;
https://op.europa.eu/en/publication-detail/-/publication/abf32809-143e-11ec-b4fe-01aa75ed71a1/language-en.

45 EnTEC - Digitalisation of Energy Flexibility, February 2022, https://op.europa.eu/en/publication-detail/-/publication/c230dd32-a5a2-11ec-83e1-01aa75ed71a1/language-en.

The InterConnect project

The Interconnect project funded by the Horizon 2020 programme gathers 50 European organisations from 11 countries to bring efficient energy management solutions within the reach of end-users. The four-year project will operate until 2023 and has a value of EUR 35.8 million, receiving an EU contribution of EUR 35.8 million.

InterConnect will implement interoperable solutions connecting smart homes, smart buildings and smart grids. It will demonstrate, among others, the benefits of enabling smart homes and buildings to become active energy players. Seven large-scale pilots in the participating countries are deploying and testing innovative digital solutions that are interoperable and provide flexibility services to the electricity grids. These pilots make it possible to reduce grids investment and operational costs, and will benefit consumers. Facilitating seamless exchanges of interoperable data will also make it possible to extend these benefits beyond R&I pilots.

Additional information: https://interconnectproject.eu/; https://op.europa.eu/en/publication-detail/-/publication/abf32809-143e-11ec-b4fe-01aa75ed71a1/language-en.

2.3 Key actions

Against this backdrop, the Commission will take concrete steps to establish a common European energy data space for improving the access to, exchange of, and (re-)use of data. The goal is to broaden the availability of data, and to make smooth and transparent data exchanges possible for the benefit of different players and different use-cases throughout the entire value chain. They include: system operators, suppliers, aggregators, providers of storage and/or demand response services, energy service companies, building managers, financial institutions, consumers and prosumers, manufacturers of electric vehicles, smart equipment and appliances (including SMEs), operators of charging points for EVs. The best use of already available data must be ensured, including data from smart meters, to serve the interests of consumers and the energy system as a whole. The actions will also enhance the interoperability of energy assets and services, will facilitate the comparability of solutions, promote standardisation, enhance grids flexibility and responsiveness, and will ultimately contribute to the overall energy security and reliability of the energy system.

Along the road towards deploying a common European data space for energy, several underlying principles will be observed.

- Access to non-personal and/or anonymised energy data needs to be made available to all relevant parties, based on the consent of the data owners and while observing technical data protection needs and confidentiality requirements. Data monopolies need to be avoided.
- Cybersecurity and personal data protection are an intrinsic part of the approach.
- Consumer acceptance and empowerment are key, being the starting point for accessing and using data coming from individuals[46] and businesses.

46 Chapter 4 presents additional details.

- EU data sovereignty principles are duly observed, with data being able to flow within the EU and across sectors.
- The rules for access to, and use of data are fair, practical and clear, and there are clear and trustworthy data governance mechanisms in place; there is an open, but assertive approach to international data flows, based on European values[47].
- Open-source solutions, including software modules, open standards and data models will be considered whenever possible, as enablers of innovation and generating economies of scale. The use of open application programme interfaces (APIs) should nonetheless be the norm, facilitating the exchanges of real-time data.
- Data that are to be shared (and widely exchanged) should be focused and should contain only the elements that are really needed for establishing and managing innovative energy services. Additionally, non-essential data should be stored and processed locally.
- The construction of the energy data space will be closely coordinated with the development of other sectoral data spaces, so that interoperable cross-sectoral solutions and services could be rolled-out.

The logic of the actions envisaged will cover several key dimensions.

- The actions will ensure that energy data is actually made available and shared with the relevant partners and market players (subject to the consent expressed by the owners of that data). Access to relevant energy data is instrumental for bringing innovative services to the market and creating value along the value chains.
- They will coordinate the EU and Member States efforts and relevant initiatives, and will ensure that the European arrangements build on the national ones, and facilitate pan-European or cross-border transactions. National models and arrangements for data exchanges should be coordinated at EU level with a view to furthering the integration of the energy markets.
- They will bring all relevant parties together to develop coherent business models and grid services that are deployed at scale and in an interoperable manner. Stakeholders should therefore coordinate their work when developing relevant energy services that fully respond to the key enablers laid down in the energy regulatory framework. Economies of scale and faster deployment could be reached this way.
- They will capitalise on the solutions that are readily available and, where necessary, accelerate their development and ensure their full market uptake. These key inputs equally include relevant legal instruments and arrangements (such as interoperability requirements for metering data), market and stakeholders coordination results (for instance a code of conduct for smart appliances), and key results achieved by research and innovation activities (for instance, recommendations on data exchanges and interoperability put forward by the Bridge initiative).
- They will mobilise the resources and interoperable building blocks developed as described above in order to roll out a common European energy data space. Coordination arrangements will contribute to the future governance of the data space, while the various interoperability building blocks will facilitate effective data exchanges across the EU energy markets and value chains.

The key actions that will be pursued are grouped into three main dimensions, bringing together in a complementary way top-down coordination initiatives, with bottom-up targeted actions,

47 According to the vision established by the European Data Strategy.

all benefitting of support from the latest developments in research, innovation and digitalisation actions and programmes.

A ‘one size fits all’ solution would not be optimal for this area of action, which is very complex in terms of legal, operational and technical requirements, entailing numerous processes and involving a variety of actors. Therefore, a development of customised approaches based on use cases will be pursued.

A first category of actions will define the strategic approach, aiming to ensure convergent and coherent EU action. Thus, a key action is to strengthen the coordination at EU level regarding data exchanges in the energy sector. The Commission will set up the ‘Data for Energy’ (D4E) expert working group to coordinate the views and actions of the relevant stakeholders with regard to sharing and (re-)using energy data. The working group will foster the exchange of experiences and best practices, and will assist the Commission in the preparation of policy initiatives and regulatory frameworks. Notably, its advice will play a key role in the preparation and rollout of a common European data space for energy, and in setting up its governance. A set of priorities will guide from the outset the activity of this expert group, and those are based on areas of energy markets and services that are in rapid development and undergo profound transformations.

The D4E group will be integrated, as a permanent working group, within the current ‘Smart Grids Task Force’ (SGTF). The SGTF will be formally re-established, expanded and reconfigured to achieve its revised objectives, which will include specific competences regarding data exchanges. This overhaul will include broadening its membership and further developing its internal organisation and working procedures. Member States’ representatives will work together with energy system operators, technology and service providers, manufacturers, research and innovation organisations, academia, financial institutions, technical standardisation experts and NGO representatives to strengthen coordinated data sharing across Europe, to improve interoperability and to reduce market fragmentation.

The participation of Member States in D4E is key, as data exchange is defined by energy market and data rules and principles agreed at EU level, but it also requires national data exchange frameworks for its practical implementation. Additionally, ensuring EU-wide interoperability among the various national frameworks will be needed for successfully building a genuine common European energy data space. Some of the text boxes above give examples of data exchange governance in Member States, and of EU-wide projects that achieve consistency and interoperability across borders. Facilitating and promoting the exchange of best-practices and experiences between policy makers in Member States, while learning from EU-wide projects and making best use of their results, will be an important added value of D4E.

D4E will undertake the development of a portfolio of European high-level use cases for data exchanges in energy. These use cases represent the main priorities that need to be analysed and developed. The coordination at EU level will aim to ensure that, on the one hand they evolve into the main elements of a future common European energy data space and, on the other hand they build on the work already carried out either in the Member States or through various EU initiatives.

The high-level use cases that will be addressed from the outset by D4E are:

1. ‘Flexibility in energy systems’ – aims to further develop and roll out flexibility products for the energy markets, including demand response services for the integration of

renewable energy sources and to limit grid congestion, including facilitating the aggregation of flexibility potential based on access to data from devices behind-the-meter;
2. 'Smart and bidirectional EV charging' – refers to integrating smart EV charging into power grids and promoting bidirectional vehicle-to-grid (V2G) services;
3. 'Smart and energy-efficient buildings' – develops mechanisms for capitalising on data from smart buildings for promoting and financing energy-efficient building renovations.

It should be noted that although the second priority mentioned above could also be analysed as part of the wider flexibility approach of the first high-level use case, it is nonetheless defined as a priority in its own right because of the distinctive characteristics, prominent uses, and cross-sectoral application. Other high-level use cases[48] might be considered later on, depending on the development priorities of EU energy grids and markets.

D4E will develop these priorities to detail the use case-specific needs and objectives for data exchanges. This will prepare the ground and building blocks for establishing a common European energy data space. In doing so, D4E will make the best use of the relevant inputs and building blocks developed by various initiatives or new legal instruments, and will closely interact with existing initiatives to explore synergies. These include: the upcoming Network code on demand side flexibility[49] (in particular for the 1st high-level use case above), the work of the Sustainable Transport Forum (STF)[50] (for the 2nd high-level use case), and that of the Expert group on European financial data space[51], the Energy Efficiency Financial Institutions Group[52], and the Smart Readiness Indicator and its platform[53] (for the 3rd high-level use case). This work also aims to establish EU-wide interoperability principles both inside the energy data space, and between energy and other European data spaces (e.g. for transport or for financial services). Interoperability will be analysed and worked on in all its different dimensions, be it coherent business and functional approaches based on common use cases, or technical interoperability ensured by common data models and communication protocols. A close cooperation with the upcoming European Data Innovation Board is envisaged to that end.

As an example of ensuring cross-sectoral interoperability and data sharing, D4E will jointly work with the Data group[54] of STF for developing in detail the high-level use case on smart and bi-directional EV charging, and with the Expert group on the financial data space for

---

48 Additional examples of priorities that could be addressed in the future include: data coming from the operation of renewable energy generation assets (as discussed with stakeholders in a webinar in February 2022: https://ec.europa.eu/info/sites/default/files/energy_climate_change_environment/conclusions_2402_data_exchange_res.pdf), data enabling enhanced forecasts and predictive maintenance for optimised energy production, or data needed for unlocking sustainable private financing of the energy transition.

49 https://www.acer.europa.eu/sites/default/files/documents/Media/News/Documents/2022%2006%2001%20FG%20Request%20to%20ACER_final.pdf

50 https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/sustainable-transport-forum-stf_en

51 https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?lang=en&groupID=3763

52 https://eefig.ec.europa.eu/index_en

53 https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator_en

54 Working group 'A Common Data Approach for Electromobility and other Alternative Fuels' (STF on Data), https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/sustainable-transport-forum-stf/active-sub-groups/sub-group-common-data-approach-electromobility-and-other-alternative-fuels_en.

developing the details on green mortgages and funding green renovations under the use case on energy efficient buildings. Ensuring stronger linkages between the energy and transport sectors could contribute to the overall optimisation of the energy system as a whole. The integration of electric vehicles into the energy system offers a clear opportunity to provide flexibility to the electricity system, facilitating the incorporation of renewable energy and supporting the development of an energy-efficient charging infrastructure. D4E and the Data group of STF will pursue an effective expert collaboration for outlining the requirements and key actions to develop effective and interoperable European data-sharing arrangements for the energy system, capitalising on and complementing the provisions for governance and data sharing of electric vehicle charging infrastructure. To that end, the two working groups will define a joint work programme with the aim to issue recommendations on common principles and best practices for supporting the EU-wide uptake of smart and bidirectional charging solutions. They will also work to define the key elements for a data exchange framework between grid operators, aggregators and relevant charging infrastructure stakeholders that supports a successful integration of electric vehicles into the energy system. Limiting grid congestion and enabling vehicle-to-grid (V2G) services will be key objectives. Furthermore, seamless data exchanges between the energy and the financial data spaces could help unlocking additional private financing to support the energy transition.

As a general approach, the activity of D4E will cover two main phases of development.

- In the first phase, the precise scope of the EU action in all the three high-level use cases will be further developed by building on, and complementing various national initiatives. The roles and responsibilities of the main actors that exchange data will be clarified and the data flows and their various components will be defined. Horizontal requirements will be established, including the legal, operational, functional and technical components that underpin those data exchanges. The identified processes and principles will constitute the main building blocks of the future energy data space.
  The work of the first phase, envisaged to take around 24 months, will use the immediate inputs that will be made available by the second and third categories of actions described below. The continuous development of the energy data space and ensuring its subsequent improvements and expansions will remain a key task of D4E on long term;
- In the second phase, after the main building blocks will be defined and agreed upon, D4E will assist the European Commission in deploying the common European energy data space, and will play an active role in establishing its governance. This will be done in close coordination with the governance of the other European data spaces, to ensure consistent approaches and to embed interoperable processes. Overall support, coordination and guidance to ensure a coherent development of the various sectoral data spaces, and interoperability among them, will be provided by the European Data Innovation Board and the Data Spaces Support Centre[55].

A second category comprises immediate actions, which will feed into the strategic coordination and will provide the first deliverables for enhancing data exchanges and underpinning the work of the upcoming D4E expert group. These actions represent targeted initiatives, for which preparatory work is being carried out, and will provide immediate results.

[55] The Data Spaces Support Centre is set up with the support of the Digital Europe Programme (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/digital-2021-cloud-ai-01-suppcentre).

Their outcomes will benefit the work that the D4E will undertake for developing the high-level use cases.

An implementing act on interoperability requirements and procedures for access to metering and consumption data is being developed and will be submitted by the Commission for adoption through the comitology procedure. Subsequently, the Commission will start the preparation of one or more implementing acts on interoperability requirements and procedures for access to data required for demand response and customer switching. The Commission was empowered to adopt these acts by the Electricity Market Directive[56]. These implementing acts will lay down the rules regarding the interoperability requirements and non-discriminatory and transparent procedures for access to, and management and exchange of data generated by the (smart) meters, aiming to support the interoperability of energy services throughout the EU.

The Commission will also promote a code of conduct for energy smart appliances to boost participation in demand response schemes. This action will build on the work started under the Ecodesign framework[57]. Through this action there will be defined sets of (functional and interoperability) requirements for energy smart appliances. These requirements would demonstrate a specific ‘energy-smart’ behaviour of products, meaning that they are able to participate in demand response schemes and they could do so in an interoperable way. The code of conduct will be offered for adherence to the manufacturers that place equipment on the EU internal market. A mass adoption of this Code of Conduct will mean that heat pumps, smart EV chargers, PV inverters, smart washing machines and other smart home appliances would be able to easily communicate with each other and aggregate efforts to provide flexibility to the grid. This level of interoperability is expected to greatly facilitate both the participation of consumers/prosumers in demand response schemes, and the efforts of aggregators to access significant numbers of assets and installed flexibility capacities.

Thirdly, research and innovation actions will, together with pilot deployments of data exchange frameworks and solutions, support the development and implementation of the actions detailed above and the deployment of the common European energy data space.

Substantial funding will continue to be made available through Horizon Europe and Digital Europe programmes for research and innovation, and to bringing digital transformation towards market deployment. European projects will be invited to develop and upscale the high-level use cases, and to bridge the identified market gaps. They will also start to prepare and demonstrate the building blocks of the upcoming energy data space. In particular, the Digital Europe Programme will include a specific call in 2024 for supporting the deployment of the common European data space for energy. This will capitalise on the results that will be achieved by five projects funded by Horizon Europe, which aim to establish the ground for a common European data space for energy[58].

As an important step forward for enhancing interoperability on a European scale, mechanisms for building interoperable solutions will be embedded from the outset in the future research and innovation projects. The Bridge[59] initiative, which groups together all the Horizon 2020

---

[56] As per the provisions of Article 24.
[57] Additional details are available at https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances.
[58] Horizon Europe 2021 Work Programme, Call for projects ‘Sustainable, secure and competitive energy supply (HORIZON-CL5-2021-D3-01)’ with a budget of EUR 32 million, https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-2021-d3-01-01.
[59] https://www.h2020-bridge.eu/

and Horizon Europe projects that are active in the areas of smart grids, energy storage and digitalisation, will take concrete steps in that direction. Key building blocks are being developed and will be proposed for use by all the future European projects. These interoperability blocks include a repository of common use cases, agreement on reference architectures to be widely used, and the use of a set of harmonised role models for the energy actors. Other building blocks could be developed in the future, based on the needs that are identified by the projects. Complementing these technical products, coordination activities will ensure that the widespread use of these technical products will be embedded in the work plans of Bridge and its various working groups. This will boost the interoperability and scalability of the solutions developed by the research projects, and thus prepare them better for their large-scale adoption in real-life operation. A subsequent step will be to feed these results into the work of D4E, because they could be used for the development of the high-level use cases envisaged.

3 Details on actions to promote investments in a smart electricity grid

As highlighted in the introduction, to digitalise the energy system and be able to fully exploit the opportunities it brings, investments in smart grids development and related enabling digital solutions are instrumental. Currently the pace at which these investments are taking place is not high enough. It is therefore necessary to speed up investments in smart and digital electricity grids in order to make the network and the energy system as a whole more intelligent (ref. Expert Workshop held on 25 May 2022[60]). This was also highlighted during the open public consultation conducted as part of the consultative process on which this Action Plan is built upon.

Many of these investment projects are innovative, so a regulatory framework that further supports innovation is crucial.

[60] https://ec.europa.eu/info/events/workshops-digitalisation-energy-system-2022-feb-16_en

Net2DG Horizon 2020 Project

The Net2DG Horizon 2020 Project has led to the development of an ICT-Gateway that enables a digital twin of the low voltage distribution grid. On top of this digital twin, some applications for Grid Monitoring, Loss Calculation, Outage Detection and Diagnostic have been developed. Overall, this architecture leads to a fully digital process for operation and planning of the low voltage grid.

The system has been deployed in two field environments in Germany and Denmark and field trials in the low-voltage grid have allowed to highlight the following benefits of using this system:

1. Outage detection and diagnosis time could be reduced to few minutes
2. Grid losses could be reduced by 11% via voltage management applied in combination with continuous voltage monitoring; when applying a variant of the reactive power coordination of inverters, a reduction by 20% was possible.
3. The hosting capacity of the field trial example grid was increased by 30% through an enhanced planning process using the digital grid status, and an additional 50% increase was achievable through the coordinated reactive power management of the inverters.

Source: Net2DG Horizon 2020 Project, http://www.net2dg.eu/wafx_res/Files/Net2DG_D5.3_25.06.2021.pdf

In many Member States, the regulatory frameworks appear to set barriers to innovation on electricity infrastructure. It may be the case that there are no specific provisions related to innovation or that these set out a bias towards capital expenditure (CAPEX) based solutions instead of operational expenditures (OPEX) solutions. In general, innovative solutions that are usually of lower (total) costs and more operational expenditure (OPEX) intensive are not as attractive to invest in as they should be[61].

Investments in digitalisation of the grid by Fluvius

In its 2022-2032 investment planning, Fluvius, the Flemish distribution system operator (DSO), has added EUR 4 billion in planned grid investments to the EUR 7 billion already planned to achieve the energy transition. Fluvius evaluates that an additional EUR 2 billion in hardware (e.g., cables, etc.) investments would be needed if the investments are not 'smart' (i.e. if they do not include, for example, the roll-out of flexibility services, smart meters and capacity tariffs).

Source: Investeringsplan 2023-2032, versie 8 juni 2022 (versie voor publieke consultatie): over.fluvius.be/publicatie/investeringsplan-2023-2032

[61] ACER position on incentivising smart investment to improve the efficient use of electricity transmission assets, November 2021

3.1 Support the development of a Digital Twin of the EU Electricity Grid

In order to establish a long-term strategy for innovation, promote investment in a smarter, greener, safer and more resilient electricity network, and reduce the associated investment risk, an EU "digitalisation of energy" flagship initiative, in the form of a Digital Twin of the EU electricity grid, aims to ensure structured cooperation on investments and data exchange between network operators. Holistic DSO and TSO cooperation in network planning and operation is a prerequisite for a smart electricity grid. The EU DSO Entity and ENTSO-E play a key role in line with the tasks set for them under the Electricity Regulation, whilst considering the required flexibilities at national level, and cooperation to create a Digital Twin of the grid can further facilitate such cooperation.

> A Digital Twin of the EU electricity grid will not only help optimise operations management and network development planning, but also streamline renewable integration analysis, synchronise data from various sources across the value chain, and generally strengthen the visibility and controllability of the grid. It will also make it possible to investigate and assess how the electricity grid responds to stimuli or shocks (e.g. renewable energy sources integration, demand response and cyberattacks) using forecasting and long-term modelling, and thus contributing to a more resilient electricity grid. It is also vital to test the application of science and innovation in the energy sector (e.g. testing the combination of high performance computing, big data, AI and cloud computing).

The aim of the Digital Twin will be to enhance the efficiency and smartness of the grid in order to make the networks and the entire energy system more intelligent. The creation of the Digital Twin will be a stepwise process take place step by step and will be achieved through coordinated investment in five areas:

- i) observability and controllability
- ii) efficient infrastructure and network planning
- iii) operations and simulations for a more resilient grid
- iv) active system management and forecasting to support flexibility and demand response data exchange
- v) interaction between TSOs and DSOs.

Subject to approval by the Member States, the Commission will support the creation of a Digital Twin with Horizon Europe.

Implementation of a digital twin by a TSO

The Finnish transmission system operator, Fingrid, implemented a digital twin to help manage its assets and operations, and plan its infrastructure investment.

This digital solution allowed Fingrid to reduce data collection workload and focus on data analysis.

The model provided by the digital twin allows Fingrid to plan investment up to 25 years in advance. The digital twin is used to develop several investment scenarios that take different policy frameworks into account. This enables Fingrid to save costs and use its time more efficiently. Fingrid is currently investing more than EUR 1 billion in developing clean power sources and integrating them into the grids. This investment is based on projects developed by the digital twin.

Fingrid had already decided to digitalise the grid at an early stage. This allowed it to exploit the opportunities provided by the digital twin, because a smart grid is a prerequisite for an accurate digital grid model.

Source: Digital Twin Fingrid | 2018 | Siemens Global: Digital Twin Fingrid | 2018 | Siemens Global

3.2 Support the definition of common smart grid indicators

In addition to the concrete cooperation initiative of the Digital Twin, it is essential that the regulatory framework fully supports innovative investments in the smartness of the grid. To that end, a structured interaction between national regulatory authorities (NRAs) and network operators in defining (common) network key performance indicators (in addition to tailored ones) to measure the smartness of the electricity network (and in the longer term the impact of such investments) is key to setting targets and monitoring developing trends, opportunities and challenges.

The Commission will support and cooperate with the European Union Agency for the Cooperation of Energy Regulators (ACER) and the NRAs to define common smart grid indicators. If useful, objectives for these indicators may be set. These common smart grid indicators will be defined in the five areas listed above and will allow NRAs to monitor smart and digital investment in the electricity grid annually as of 2023, as required by Article 59.1(l) of the Electricity Market Directive. Such common indicators will also provide guidance on the implementation of that article.

These common indicators will help to speed up investment in smart and digital electricity grids because they will ensure cooperation and the exchange of best practices between NRAs for defining efficient investment in digitalisation and innovation at a time when the need to invest in networks is high. The role of NRAs will at the same time ensure that investments are efficient and that the quality of service to grid users improves. Key performance indicators will also help network operators identify the most effective ways to invest in smartness and digitalisation.

The common smart grid indicators should include a limited set of output indicators, supported by input indicators.

- Output indicators reflect the benefits/impacts of the smart and digital electricity grid for grid users. They therefore measure whether system operators fulfil their activities in an efficient manner.
- Input indicators, by contrast, reflect the level of readiness and uptake of specific digital solutions by system operators (SO), and help guide the transition progress by assessing whether SOs have sufficient tools/instruments to deliver on the output indicators.

Both actions are intrinsically linked and both **require TSO-DSO cooperation in smartening the electricity grid.** The Digital Twin of the grid provides a concrete **collaboration framework for integrating the smart grid indicators,** helping to monitor progress made in digitalising the grid. Smarter and more digitalised grids will generate more data as a basis for optimised and interactive grid management to promote flexibility, including smart charging and the integration of more renewables and greater energy efficiency.

4 Details on actions to empower consumers

4.1 Digital tools for energy communities and other collective action initiatives

The Energy Communities Repository[62] will help policy makers, regulators and local communities to better understand how to set up and support business models that require ICT and data-driven solutions (such as community electricity trading). This could increase the financial viability of energy community projects and incentivise convergent and consistent energy legislation across the EU. To the extent that these tools are activity-related, they could also help inform other types of collective action initiatives.

Finally, the Energy Communities Repository could help identify and shortlist digital tools to provide ready-to-use building blocks for emerging energy communities, thus boosting the digital literacy of their members and their ability to become active and dynamic energy consumers. The Commission will also provide funding to support communities at the set-up stage and to support system integration projects through the LIFE Energy Communities Facility.

4.2 Peer-to-peer trading

As mentioned above, P2P electricity trading would allow both individuals and companies (both self-producers and consumers) to gain more from their engagement in the energy system. This

62 https://energy-communities-repository.ec.europa.eu/index_en

may in turn encourage private investment in renewable electricity-generation assets[63]. It is also in keeping with the aspiration of more and more members of the public to contribute to the green transition from the bottom-up, by reducing their consumption, producing and using energy locally, and reducing their overall reliance on the electricity grid (thus helping to mitigate grid congestion and reduce network losses). Finally, by allowing local individuals to trade electricity locally (thereby increasing consumer participation in local energy markets and promoting investment in decentralised generation assets), P2P electricity trading could become the first emerging component of local energy markets. The development of this tool will be funded under the Horizon Europe programme through a dedicated call with the aim of creating a model project in terms of customer-centric design[64], community ownership, replicability, easy open-source access to deliverables and ease of maintenance of the resulting tools.

This will be accompanied by a study to help:

(i) identify and explore multiple business models that could be relevant for Energy Sharing and P2P trading;
(ii) define the requirements for ICT platforms that are relevant for the identified business models;
(iii) engage with ICT platform solution providers to identify the requirements and build an overview of the solutions currently available on the market for these business models;
(iv) describe how these solutions would fulfil the requirements in force;
(v) identify the legal, technical and operational prerequisites for a successful implementation.

The Commission will also, together with the Joint Research Centre (JRC) Living Lab, **develop an experimentation platform to test simulated energy communities.** This will incentivise consumers and other stakeholders to create, develop and support, new energy communities, join existing energy communities and/or improve their practices. It will also provide a testbed for innovative activities such as blockchain-based energy trading to optimise processes and operations, and will help identify potential legal, regulatory, fiscal and technical barriers.

---

63 Local P2P electricity trading is listed among the 18 types of social innovation in energy described in D2.1 *Collective Action Initiatives. Some theoretical perspectives and a working definition of the H2020-funded SONNET project*.

64 Digitalisation also makes it possible to develop more consumer-centric market designs by enabling the use of tools designed to adapt to the needs and preferences of different categories of market participants – thereby maximising consumer adoption and ensuring that different consumers have their needs met. For instance, the 'Exchange of Energy Blocks' ('EoEB') concept presented by the Elia group in Belgium makes it possible for consumers to react to real-time price changes, while also allowing them to opt into additional private or embedded metering to reinforce trust. See https://www.eliagroup.eu/-/media/project/elia/shared/documents/elia-group/publications/studies-and-reports/20210618_ELIA_CCMD-white-paper_EN.pdf

4.3 Support upskilling and reskilling of the workforce for the digitalisation of the energy value chain

We will in the future need digitally empowered and capable members of the public, a digitally skilled workforce and digital experts. The twin green and digital transitions require new and emerging green and digital skills to be integrated into existing jobs and professionals to be enabled to acquire new and specialised skills so that they can adapt to the fast-changing data-driven service market. Innovative technology solutions rely on there being enough skilled workers and trained professionals to apply them on a wide scale in our daily lives. The European Green Deal made this very clear, acknowledging the urgent need for proactive upskilling and reskilling schemes at all levels[65].

The results of the public consultation[66], have led the Commission to conclude that shortcomings in skills development and the lack of a properly trained workforce are the most significant barriers to the uptake of digital technologies. In the context of REPowerEU, such barriers can hamper the application of clean energy technologies. Clear responses are therefore needed in order to successfully close existing skills gaps and mismatches that hinder the growth of the sector.

Revising vocational and educational training strategies, and changing the curricula[67] in energy education are key ways of properly responding to the dynamic context of high renewable penetration and digitalisation of the energy sector, because these require specific knowledge and skills as well as new ways of using new technologies. Well-informed and qualified professionals will have a key role to play in encouraging and stimulating the development and implementation of digital tools for the benefit of consumers.

65 The Erasmus+ funded project EDDIE (Education for the Digitalisation of Energy) conducted a survey of the industry (60 respondents) on the importance of green skills and adding green components to existing skills. Most respondents replied that they have to adapt to climate-driven goals and policies, and engage in activities that require green skills. A significant number also indicated that new green skills are emerging, and that new components have to be added to existing skills. Analysis performed by EDDIE‘s partners has shown that there are similar skill gaps for different staff categories indicating that skills must be developed at various levels. The report “Current and future skill needs in the Energy sector” (https://www.eddie-erasmus.eu/wp-content/uploads/2022/03/D2.2%20Current%20and%20future%20skill%20needs%20in%20the%20Energy%20Sector_v3.0.pdf) identifies some of the most significant skill gaps identified in the process, and the degree at which each staff category is expected to be qualified. The results are drawn from a survey in which 60 organisations throughout the EU participated. The results were confirmed in a new survey of 49 stakeholders.

66 The summary report of the stakeholder consultation process is available on the Have your say portal https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13141-Digitalising-the-energy-sector-EU-action-plan/feedback_en?p_id=26009595. Moreover, in the survey conducted by the European Commission on February 2022 to 28 EU-funded and national projects, six reported that energy communities identify missing knowledge and skills, in facing complexity, as a barrier impacting their market readiness, and access to the market and capital (RESCOOP, PARITY,REDDREAM, INTERFACE,PLATONE, ACCEPT)

67 University-level upskilling programmes can boost the emergence of new and highly skilled occupations such as energy auditing and energy consulting, while also promoting the upgrading of professional skills required by existing occupations such as building facilities management, architecture and engineering (source: ILO, *Skills for a Greener Future*, 2019. https://www.ilo.org/skills/pubs/WCMS_732214/lang--en/index.htm Table ES 1. Changes in skills required, by skill level of occupation).

Building on the 2020 Skills Agenda, Council recommendation on Ensuring a fair transition towards climate neutrality [68] and the Blueprint Strategy for the Digitalisation of the Energy Value Chain (BSDE)[69], the Commission will address these issues by supporting the establishment of a large-scale partnership within the framework of the Pact for Skills[70]. Key national, non-governmental and industrial stakeholders, system operators, academia and research institutions will cooperate in promoting concrete investment in reskilling and upskilling opportunities so that the EU's workforce can adapt and prepare for the future digitalisation of energy-related jobs. Synergies and cooperation with other relevant sectorial alliances[71] and large-scale partnerships will be identified and exploited.

This action will complement the target for basic digital skills established by the European Pillar of Social Rights action plan[72] and the targets of the Digital Decade[73]. The Commission encourages Member States to boost skills by making full use of the European Social Fund+ and the Just Transition Fund. The European Climate Pact and the upcoming Erasmus+ Alliances for Innovation[74] will also play a role in developing forward-looking skills and university-level partnerships for cooperation on skills. The Recovery and Resilience Facility (RRF) can also help promote local and regional upskilling and reskilling schemes.

4.4 Dedicated structures supporting upskilling and reskilling for digitalisation of energy value chain

> Plans and strategies with a specific focus on green jobs and skills tend to be improvised by organisations in sectors badly hit by the greening of employment. There tends to be a weak connection between organisations involved in national policymaking on environmental topics and those involved in labour markets and skills policy, including skills anticipation. Furthermore, the monitoring and anticipation of green jobs and skills tend to take place not through permanent mechanisms dedicated to the green economy, green jobs or green skills – but instead as part of an overall skills anticipation structure (with some notable exceptions such as France's National Observatory for Jobs and Occupations in the Green Economy).

Skills gaps vary depending on the industries, specialisations and demographics of each region. Local actors have a deep understanding of the challenges and needs faced by the local

---

68 (2022/C 243/04), in particular Articles 4 (a) and 5 (c), which detail the need to promote digital skills investment in the context of the energy transition.

69 The blueprint for sectoral cooperation on skills will develop a sectoral strategy for the development of skills relevant to the labour market – including the development of relevant EU vocational core curricula and roll-out training. This could frame strategic cooperation between key stakeholders in a particular economic sector in order to address skills needs which could affect the overall growth of that sector. This will be a feature of the BSDE and will be demonstrated and validated in a pilot environment.

70 https://ec.europa.eu/social/main.jsp?catId=1517&langId=en

71 For example: cybersecurity, onshore renewables (see EU Solar Energy Strategy, COM/20222/221 final), blockchain.

72 https://ec.europa.eu/info/strategy/priorities-2019-2024/economy-works-people/jobs-growth-and-investment/european-pillar-social-rights/european-pillar-social-rights-action-plan_en

73 https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade

74 The Erasmus+ Innovation Alliances foster the EU's innovation capacity through cooperation and the flow of knowledge between higher education, vocational education and training (both initial and ongoing) and the broader socioeconomic environment.

population and can ensure that local skills strategies address them all. In the context of the '**Creating an "EU Digital Energy" platform to support innovation ecosystems**' action,[75] the Large-Scale Partnership on Skills for the Digitalisation of the Energy Value Chain will support the creation of a common vision; promote the sharing of best practices, knowledge and skills throughous the value chain; and contribute to the regional roll-out of the sectorial alliance strategy within the European Digital Innovation Hubs (EDIHs) devoted to the energy sector.[76] EDIHs will be structures dedicated to boosting digital energy skills, deploying strategies for creating demand for such skills and sharing best practices.

5 Cybersecurity and resilience

5.1 Context

Cybersecurity is essential for the security and reliability of the increasingly digitalised energy system. All other sectors depend on energy-critical infrastructures. A cyber-attack that create an outage in a part of the energy system might trigger an immediate and far-reaching cascade consequences. For example, cloud infrastructures for hosting and processing data, transport (through the Vehicle to Grid and smart charging technologies) and building automation, are highly dependent on reliable energy systems.

In 2019, the Commission provided guidance[77] to network operators and technology suppliers on the energy sector's main cybersecurity challenges, notably:

1) real-time requirements
2) the cascade effect,
3) the combination of legacy and state-of-the-art technologies.

There are a number of other key requirements and challenges in this area:

1. Clear and robust cybersecurity governance structures between public and private actors. This includes, for example, the TSOs, the DSOs, vendors, national regulatory bodies from different sectors and EU structures such as the Computer Security Incident Response Team (CSIRT)[78] and the Cyber Crisis Liaison Organisation (CyCLONe)[79] networks
2. Harmonised rules for assessing cybersecurity risks and security measures
3. Agreed procedures for collective responses to cybersecurity incidents
4. Low levels of capacity-capacity building and knowledge sharing in the Member States

75 See https://ec.europa.eu/info/sites/default/files/conclusions_2502_edihs.pdf
76 See https://digital-strategy.ec.europa.eu/en/activities/edihs
77 C(2019) 2400 final Commission Recommendation of 3 April2019 on cybersecurity in the energy sector and Staff Working Document Accompanying the document Commission Recommendation on cybersecurity in the energy sector {C(2019) 2400 final}
78 CISRIT network
79 The CyCLONe network was established in 2020 for rapid cyber crisis management coordination in case of a large-scale, cross-border cyber incident or crisis in the EU. The European Network Information and Security Agency provides its secretariat, infrastructure and tools.

5. Increasing digitalisation and connectivity of energy infrastructure. These make the new decentralised models of production and consumption possible. These models require additional exchanges of data for operations, maintenance and trading, creating data security risks.

Different instruments are being developed to achieve these objectives. For example:

1) forthcoming Network Code on Cybersecurity of Cross-Border Electricity Flows stems from the Electricity Regulation and, will lay down sector-specific rules for cybersecurity of cross-border electricity flows, including rules on common minimum requirements, planning, monitoring, reporting and crisis management. Other energy sectors, such as gas or hydrogen, might require similar rules.
2) The EU funding programmes that will be managed through **the European Competence Centre and the Network of Coordination Centres**[80] will contribute to cybersecurity capacity building. Some of those programmes aim to increase and enhance knowledge sharing between Member States.
3) While cybersecurity is essential, it should not hamper fair competition and market access to for new or competing products and services. To that end, the legislative proposal on the Cyber Resilience Act in 2022[81] will lay down harmonised rules for the placing on the market of products with digital elements in the Union and duty of care for the whole lifecycle of these products, as well as corresponding rules on market monitoring and surveillance. This should help to establish common rules while improving the security of products with digital elements.

To address the challenges and implement the instruments mentioned above, the EU is developing an approach to strengthening the cybersecurity of energy systems. This will build on the EU cross-sectoral cybersecurity framework.

At strategic policy level, the cybersecurity in the action plan is aligned with the Commission priority 'A Europe fit for the Digital Age' and the 'EU Cybersecurity Strategy for the Digital Decade' [82].

At operational level, the Commission (particularly DG ENER) pays utmost attention to cooperation with the Member States and their cybersecurity bodies. Policy work in the area of cybersecurity for energy is carried out in close collaboration with other entities such as the **European Network Information Security Agency** (ENISA)[83] and the Computer Emergency Response Team for the EU bodies and agencies (CERT-EU)[84]. Further collaboration will be sought with other bodies and organisations, such as the CSIRT Network[85], the **Cyber Crisis**

[80] The European Cybersecurity Competence Centre and Network is now ready to take off | Shaping Europe's digital future (europa.eu)
[81] General information on the Cyber Resilience Act initiative at Cyber resilience act – new cybersecurity rules for digital products and ancillary services (europa.eu)
[82] Joint Communication to the European Parliament and the Council: The EU's Cybersecurity Strategy for the Digital Decade (JOIN(2020)18)
[83] ENISA (europa.eu)
[84] CERT-EU News Monitor (europa.eu)
[85] CSIRTs Network

Liaison Organisation Network (CyCLONE)[86], the **Joint Cybersecurity Unit**[87], **European Cybersecurity Competence Centre and the Network[88] of National Coordination Centres.**

In terms of policy instruments, the main legislative text for cybersecurity is the **Directive on Security of Network and Information Systems** concerning measures for a high common level of security of network and information systems across the Union (the NIS 1 Directive [89]). The Commission proposed to revise this Directive through, so called, the NIS2 Directive[90] version and it responds to the increasing degree of digitalisation and connectivity in society. The Directive defines the energy sector (including electricity, district heating and cooling, oil, gas and hydrogen) as a sector of high criticality.

Specific cybersecurity legislation in the energy sector will bring the sector into line with, and complement the revised **Directive on Security of Network and Information Systems** and the Risk Preparedness Regulation[91].

Cybersecurity has become a more important requirement for resilient energy systems because of digitalisation. The cybersecurity attacks on the operational technologies (OTs) can have consequences that go beyond IT systems, such damages to the wider energy infrastructure.

5.2 Evidence, projects and best practices

Digitalisation makes new energy systems possible and cybersecurity is a prerequisite for digitalisation. The Commission's public consultation on the digitalisation of the energy system action plan revealed that a majority of stakeholders see high and medium risks related to digital components and services, on both at the demand and supply sides. There is, however, no clear consensus as to who is best placed to manage these risks.

86 CyCLONe: "Cyber Crisis Liaison Organisation Network », established in 2020 for rapid cyber crisis management coordination in case of a large-scale, cross-border cyber incident or crisis in the EU. ENISA provides the Secretariat, infrastructures and tools.

87 Joint Cyber Unit | Shaping Europe's digital future (europa.eu)

88 https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-competence-centre

89 Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

90 Proposal COM 2020/823 for a Directive of the European Parliament and of the Council on measures for a high common level of cybersecurity across the Union, repealing Directive (EU) 2016/1148.

91 Regulation (EU) 2019/941 on risk preparedness in the electricity sector and repealing Directive 2005/85/EC

Examples of real cases of cyberattacks that show the consequences and impacts:

- Recent attacks to the satellite communication networks used for monitoring of windfarms in Northern Europe. More than 5000 wind turbines lost connection for remote management.
- The Colonial pipeline ransomware attack in May 2021. It halted operations for several days due to unavailability of their IT support systems. Several Federal States had shortage of gasoline and other oil and gas products impacting hundreds of thousands of citizens and companies.
- The Solar Winds compromise of its software supply chain embedding malicious code in its Orion software and replicating it in the end customer's installations.
- The power grid attack in Ukraine in 2015 that resulted in power outages lasting several hours.

In addition to the public consultation, the Commission has also reviewed a number of projects co-funded by the Horizon 2020 Framework Programme in the field of cybersecurity (see the Annex for an overview). In the reviewed sample of projects, the consortia and project coordinators perceive a strong role for cybersecurity and physical security for their infrastructure.

A number of the main lessons have been learned from projects:

1) Lack of interoperability of ICT protocols and solutions: different communication protocols impeding a common cybersecurity framework in the energy sector.
2) There are number of organisational barriers (e.g. perceived insufficient cooperation between the stakeholders involved in regulation, operations, research, production, testing and implementation of cybersecurity solutions).
3) The roles and responsibilities of the parties involved in the prevention, detection and resolution of cybersecurity incidents should be better defined and implemented so that they can effectively support crisis operations.
4) Research and innovation of digital products should include the concept of Cybersecurity by design.
5) Certification schemes for products and services are still lacking.
6) Sector specific information sharing networks are proving very useful for to timely reaction to security threats.. This should also be the case for energy equipment manufacturers and technology vendors.
7) The so-called smart technology makes new services and products possible but brings new cybersecurity risks. For example, secure gateways for smart meters, provide services in addition to measuring electricity consumption. They enable data exchanges that will most probably allow for the creation of new services. Similarly, to other sectors such as telecommunications, these new services and applications will need to be very reliable.

The upcoming policy work should address these and other challenges. Close cooperation between regulatory authorities, public administrations, the private sector and the general public will be necessary in order to ensure that on one side the energy system remains reliable in the new digital age and that it contributes to the wellbeing of the population.

6 Energy consumption of the ICT sector

6.1 Context

This action plan illustrates the potentially very significant economic, environmental and social benefits of digitalisation in the energy sector. Many other sectors and use cases, ranging from teleworking and e-learning platforms to digital tools for the monitoring of climate change, show that digitalisation is very useful from many different perspectives.

These benefits are mainly thought of in socio-economic terms, but are also of an environmental nature: in 2022, the European Commission launched the European Green Digital Coalition (EGDC)[92] which currently includes 34 signatories committed to working together with experts and academia on science-based methods to measure the net environmental impact of digital solutions across priority sectors, including the energy and power sectors. The Commission has also financed a European Parliament Pilot Project to assist with this. By the end of 2022, 18 real-life case studies[93] will be examined to help validate and refine the iterative development of the net environmental impact methodology across sectors. The first calculations of environmental effects of green digital solutions for energy systems, as well as draft guidelines for deployment of digitalisation with enabling effects, will be available within 2023.

The many beneficial use cases unlocked by digitalisation should not, however, obscure the fact that the ICT sector also requires energy to operate and is not climate-neutral. Indeed, the amount of energy consumed by the ICT sector is constantly increasing as the need for and use of digital tools, internet traffic and the number of connected devices rise. This immediately raises the question of the energy consumption of the ICT sector, its energy efficiency and its climate impact. This section aims to provide a framework and show concrete ways to address increasing energy consumption of the ICT sector.

Firstly, it should be stressed that digitalisation affects all areas of society (households, private companies, public administrations, infrastructures, etc.) as well as almost all sectors (the most frequently mentioned for comparison during the Commission's open public consultation were financial services, mobility, building, healthcare and advertising).

This transformation has proceeded very quickly in recent decades, requiring significant corporate investment in communication networks and computation power, as well as household investment in telecommunication equipment, computers and other electronic devices. This investment has gone hand-in-hand with a very steep increase in global internet traffic. It is estimated that internet traffic increased 12-fold between 2010 and 2020 (with an average annual growth rate of 30%)[94]. It is further expected that the internet traffic will continue to increase at

92 https://www.greendigitalcoalition.eu/
93 https://www.greendigitalcoalition.eu/case-studies/
94 Data Centres and Data Transmission Networks, IEA, Paris – November 2021. https://www.iea.org/reports/data-centres-and-data-transmission-networks#resources

a very fast rate of over 40% per year in coming years. This naturally has consequences in terms of energy consumption and the use of natural resources.

Some remarkable energy-efficiency gains notwithstanding, the ICT sector‘s energy consumption has grown very large. It is estimated that the sector accounts for approximately 7% of global electricity consumption and that this share is forecast to rise to 13% by 2030[95]. This is between 3 and 5% of global carbon emissions, which is on a par with the aviation industry's emissions from fuel[96]. More recent analysis based on lifecycle analysis methodologies suggests that at the global level, ICT systems represented 4.2% of primary energy consumption, 5.5% of electricity consumption and 3.8% of greenhouse gas emissions. These three metrics are rising very fast and are expected to have roughly tripled between 2010 and 2025.[97] Finally, a recent meta-study[98] concluded that 'published estimates all systematically underestimate the carbon footprint of ICT, possibly by as much as 25%, by failing to account for all of ICT's supply chains and full lifecycle (i.e. emissions scopes 1, 2 and fully inclusive 3).' The metastudy also deplores the lack of publicly available data underpinning many of these estimates. The fact that published estimates (particularly reports by companies on their ICT-related energy consumption) tend to underestimate the actual level of energy consumption attributable to the ICT sector is widely documented[99]. Several converging indications therefore suggest that (i) current estimates of the ICT sector's energy consumption are significant, (ii) this energy consumption is growing (albeit at a much slower pace than, for example, worldwide internet traffic), and (iii) current estimates of this energy consumption are likely to underestimate its actual magnitude.

Secondly, energy consumption is certainly not the only relevant issue within the broader topic of the environmental footprint of ICT technologies. For instance, the use of natural resources such as water and rare earths, and the environmental impact of their extraction (which largely takes place outside the EU) is another impact of ICT technologies that some of the measures described below will affect. Nonetheless, this section focuses mainly[100] on the ICT sector's energy consumption. In particular, it does not for several reasons contain a detailed analysis of the carbon emissions generated by this energy consumption. The main reasons for this are the following:

- At the macro level, in order to match total energy demand with renewables/low carbon sources of energy, we need to increase the production of renewables/energy with a low carbon footprint while keeping overall energy demand at a reasonable level (and ideally decreasing it). The relevant metric to be considered from the demand side therefore appears to be energy consumption. This is also the approach taken by the Commission in the energy labelling framework (under which appliances are labelled according to

95 Bertoldi, P., Avgerinou, M. and Castellazzi, L. '*Trends in data centre energy consumption under the European Code of Conduct for Data Centre Energy Efficiency'*, 2017, EUR 28874 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-76445-5, doi:10.2760/358256, JRC108354

96 Nicolas Jones, "How to stop data centres from gobbling up the world's electricity". See https://www.nature.com/articles/d41586-018-06610-y

97 See https://www.greenit.fr/wp-content/uploads/2019/11/GREENIT_EENM_etude_EN_accessible.pdf

98 See "*The climate impact of ICT: A review of estimates, trends and regulations*": https://arxiv.org/ftp/arxiv/papers/2102/2102.02622.pdf

99 Klaaßen, L., Stoll, C. "*Harmonizing corporate carbon footprints*." Nat Commun 12, 6149 (2021). See https://www.nature.com/articles/s41467-021-26349-x

100 Though not only – for instance non-energy-related environmental impacts linked to the manufacture of ICT devices and the extraction and production of the necessary materials (in particular rare earths) will be discussed in the sub-section on the production of ICT equipment.

their energy consumption, rather than their carbon-intensity), as well as in the Commission's energy efficiency first principle[101].

- The carbon footprint of a given technology depends largely on the carbon intensity of electricity in a given country. However, significant variations in the carbon intensity of different electricity mixes in different EU Member States confuse the issue.
- This section is a sub-area of the overall action plan. As such, the digitalisation of the energy sector is likely to entail increased use of data centres and network equipment (through an increase in data exchange). By comparison, the use of small portable devices (e.g. mobile phones) is likely to be relatively unaffected by this action plan. Since the embodied carbon footprint and environmental impact of devices is proportionately greater for small devices (due to their lower energy consumption and shorter life span) than for larger devices and network equipment, energy consumption is one of the environmental aspects of ICT most likely to be negatively impacted by the digitalisation of the energy sector. It therefore seemed natural to address this aspect as a priority.

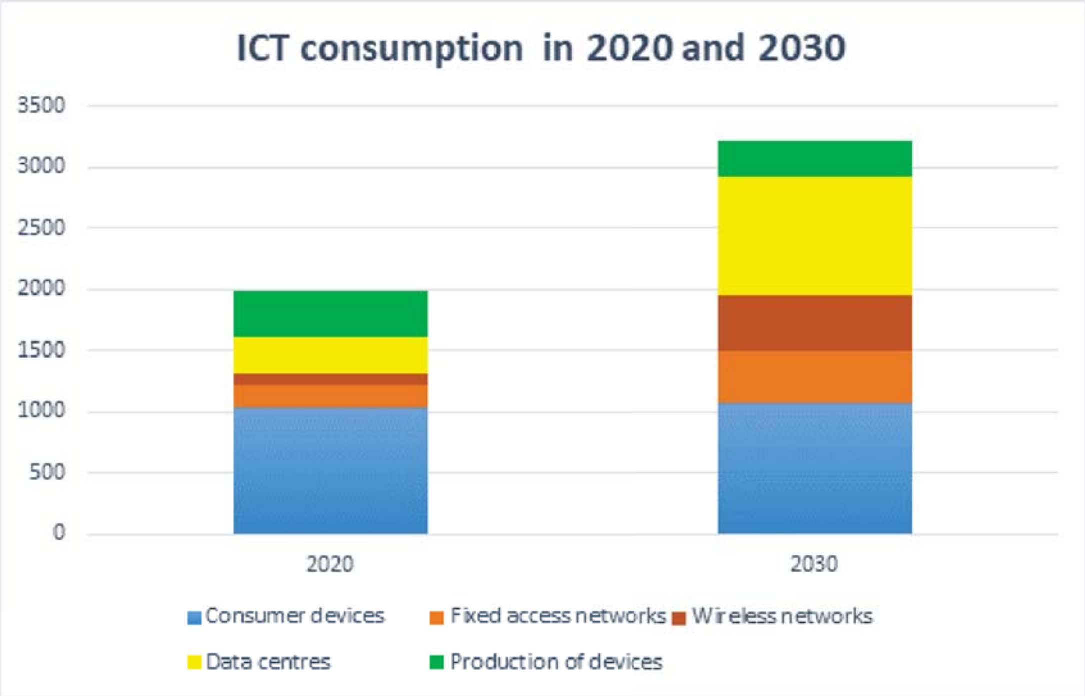
Thirdly, this section considers the ICT sector's energy consumption and environmental impact throughout the entire value chain. This value chain is traditionally broken down, for the purposes of analysing the ICT system's energy consumption into: (i) energy consumption during the manufacture of ICT devices, (ii) the energy consumption of consumers' devices, (iii) the energy consumption of networks, and (iv) the energy consumption of data centres. Most recent analysis suggests that the energy consumption of consumers' devices accounted for roughly 50% of the overall energy consumption of ICT technologies in 2020. The next two most significant contributors were the production of ICT devices (~20%) and data centres (~15%). This is expected to change drastically by 2030, however, as the overall energy consumption of ICT technologies is expected to increase by 50% during the 2020s. The top three contributors in 2030 would then be consumers' devices (33% of the overall energy consumption of ICT technologies), data centres (30%) and networks (27%). In particular, while the energy consumption of consumer devices will decrease (due to a progressive switch to smaller terminals), the electricity demand of data centres (currently close to 0.8% of global final electricity demand[102]) is expected to grow between three and five times by 2030, to as much as 974 TWh worldwide (3.9% of global final electricity demand) with a best-case scenario of 366 TWh (1.5%). Similarly, the energy consumption of fixed and mobile networks is expected to grow three fold by 2030[103]. An overview of these developments is provided in Figure 2 below.

Figure 2: overview of the different components of the energy consumption of the ICT sector in 2020 and 2030 (projected) according to Andrae, A.S.G. (worldwide, in TWh)

[101] See https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-first-principle_en

[102] The International Energy Agency estimated to be 200 TWh in 2019. Andrae and others estimated it to be~300TWh in 2020.

[103] See Andrae, A.S.G. (2020a) *'New perspectives on internet electricity use in 2030'*. Engineering and Applied Science Letters DOI: 10.30538/psrp-easl2020.0038



Source: Andrae, A.S.G. (2020a) "New perspectives on internet electricity use in 2030". Engineering and Applied Science Letters DOI: 10.30538/psrp-easl2020.0038

The International Telecommunication Union (ITU) has also published estimates for the current energy consumption of the different segments of the ICT value chain in 2020, as well as so-called "trajectories" for 2030.[104] While these figures are more or less in line with the ones presented above for 2020,[105] the recommended trajectories for 2030 appear substantially lower.[106] An overview of these figures (corrected for the difference in scopes mentioned in Footnote 105) is presented in Figure 3 below.

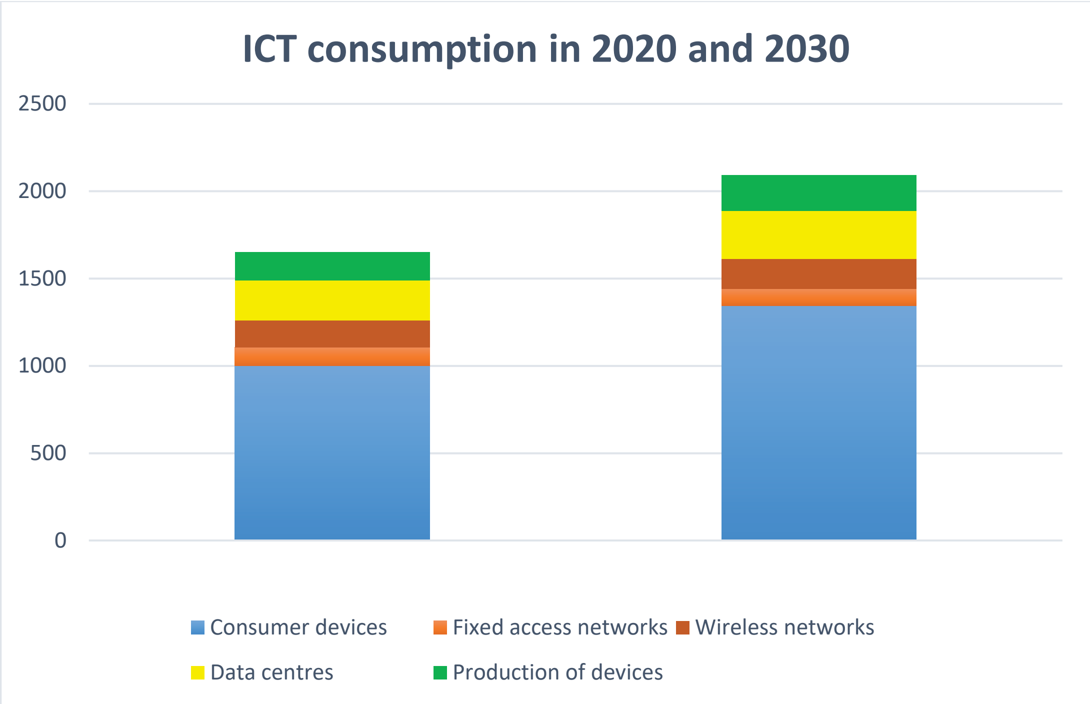
Figure 3: overview of the different components of the energy consumption of the ICT sector in 2020 and 2030 (recommended) according to the ITU (worldwide, in TWh)

---

[104] See *"Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement"*, available at https://www.itu.int/rec/T-REC-L.1470-202001-I/en. It should be noted that ITU provides in this document a set of "normative trajectories" in line with different climate objectives. As such the exercise is somewhat different from a forecasting exercise, as performed by Andrae, A.S.G.

[105] The difference observed for the energy consumption of devices in operation is due to the fact that TVs are not accounted for in the ITU figures. When correcting for the different scopes, the figure of ~1 000 TWh for the energy consumption of devices (including TVs) in operation in 2020 appears consistent across both publications.

[106] To the extent that it is relevant to compare projections with recommended trajectories. See Footnote 104 above.



Source: ITU: "Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement", available at https://www.itu.int/rec/T-REC-L.1470-202001-I/en.

Any projections (or trajectories) are indeed accompanied by several major uncertainties. On the demand side, it is difficult to predict the actual form and main drivers of ICT services' demand in the 2020s. This demand could be influenced by the uptake of new solutions, technologies and business models (e.g. AI, autonomous vehicles, advanced/virtual reality, edge computing, cryptocurrency mining and IoT technologies). The uncertainties are equally significant on the supply-side, where the main driver of ICT energy-efficiency over the past few decades has been the miniaturisation of electronic circuits, which is currently slowing down. Future performance gains might be based more on the parallelisation of computational power, which may nonetheless lead to increasing energy consumption. Major breakthroughs in computing technologies and the subsequent rate of technology adoption are evidently hard to predict. The opportunities provided by quantum computing could lead to a radical decrease in energy consumption by some very energy-intensive applications.

6.2 Key actions

Production of ICT devices

ICT devices are mostly manufactured outside the EU. Ways to reduce energy consumption in this area include (i) imposing tougher sustainability standards for these products (e.g. in terms of the use of recycled or recyclable materials, reparability or recyclability), (ii) making them last longer[107] and (iii) promoting their reuse[108] (e.g. by developing a secondary market for smartphones).

The recently proposed Ecodesign for Sustainable Products Regulation (ESPR)[109] will be the cornerstone of the EU's circular economy action plan. It will in particular amend the Ecodesign Directive and introduce new measures to increase the sustainability of products placed on the EU market. It will establish sustainability principles and specific requirements linked to environmental and, where appropriate, social aspects. It will also contain the changes to the EU legal framework that are needed to achieve the objectives set out in the 2020 circular economy action plan[110].

The ESPR will in particular address a selection of product groups, including electronic and ICT products.

It will:

- establish overarching product sustainability principles;
- require producers to provide more circular products and intervene before products become waste (e.g. providing products as a service, providing repair services, and ensuring that spare parts are available);
- set requirements for mandatory sustainability labelling and/or the disclosure of information to market actors along value chains in the form of a digital product passport;
- set minimum sustainability requirements for the public procurement of products;
- impose measures on production processes (e.g. to facilitate recycling and/or remanufacturing);
- ban the destruction of unsold durable goods.

Energy consumption of ICT devices in operation

Energy consumption by consumers' devices is the only component of overall ICT energy consumption that is expected to decrease by the end of the current decade according to Andrae, A.S.G., because of a progressive switch to smaller terminals[111]. However, the fact remains that electricity consumption by our terminals currently represents over 50% of the ICT sector's energy consumption and is expected to still represent 33% of its energy consumption by 2030 (still over 50% in 2030 according to the ITU trajectories).

---

107 Provided that this is not counter-productive (e.g. when more energy-efficient products come onto the market). This would depend in particular on the balance between the in-built carbon footprint (resulting from the product's manufacture) and the carbon footprint related to the use of the product. As mentioned above, the in-built carbon footprint and environmental impact of devices is in general disproportionately larger for small devices. See in particular Malmodin, J. and Lundén, D., 'The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010-2015', *Sustainability*, 2018, 10, 3027.

108 Subject to the same caveats as above.

109 https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en

110 https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

111 The size of the screen has a crucial impact on the overall energy consumption of many types of electronic devices.

The Commission's ecodesign framework

The Commission has in recent years enacted product-specific ecodesign regulations that apply to a range of products, including several types of electronic products[112]. These ecodesign regulations have led to a remarkable improvement in the energy efficiency of electronic products sold in the EU, generating considerable energy savings[113]. The Commission has also introduced an energy labelling obligation for a more restricted range of products (electronic displays are the only electronic products currently subject to this energy labelling obligation).

Computers account for a significant portion of the energy consumption attributed to consumer electronic devices, because both companies and private households have many such devices and because a laptop computer consumes over 10 times more energy than a smartphone during its operational life (and 5-6 times more energy than a tablet) – while a desktop computer consumes 5-6 times more energy than a laptop computer (i.e. 25-35 times more than a tablet and more than 50-60 times more than a smartphone) during its operational life[114]. It is therefore crucial to address computers' energy consumption[115].

While some existing labels provide information on the idle-state energy consumption of computers (e.g. the US-EPA voluntary Energy Star logo), no label provides information on the energy efficiency of an actively working computer. Idle-state labels are also now considered outdated – despite the recent tightening of some of their requirements – because of the significant progress made in limiting the idle-state energy consumption of computers. As a result, consumers and businesses currently have no indicators that they can use to make an informed choice and to compare the energy efficiency of different computers when they are in operational mode.

Computers are very versatile and are used for very different purposes. This makes it very hard to formulate a proposal on energy labelling for computers. Depending on its hardware and design characteristics, a computer could be very energy-efficient when performing ordinary office activities (e.g. editing text, videoconferencing and e-mail management), but very energy-inefficient when used for intense gaming with very high speed and graphics resolution. This energy labelling proposal will therefore use a set of worklets to assess computers' energy

---

112 These product-specific ecodesign regulations apply to electronic displays, set-top boxes, computers, video game consoles, external power supplies, imaging equipment, servers and data storage products. They also apply to the standby-mode energy consumption of an even wider range of electronic products (e.g. imaging equipment, small appliances, complex set-top boxes, wireless audio speakers and radios) and products not falling within the traditional definition of electronic products (e.g. electric ovens).

113 See 'Ecodesign impact accounting annual report 2020': https://op.europa.eu/en/publication-detail/-/publication/568cac02-5191-11ec-91ac-01aa75ed71a1/language-en.

114 See Malmodin, J.; Lundén, D. (2018), 'The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010-2015', *Sustainability 2018*, 10, 3027. Part of the reason for the differences is the reference lifespan chosen for these devices. This is taken to be 5 years for a desktop computer, 4 years for a laptop computer or a tablet and 3 years for a smartphone. However, this is clearly not the main reason for the very significant differences outlined here.

115 As mentioned above, an existing EU energy labelling scheme already targets electronic displays – the other category of electronic devices identified in the above-mentioned report as being significant energy consumers (and the only ones with an energy consumption higher than desktop and laptop computers). An energy labelling scheme for computers therefore appears to be the logical next step for addressing the energy consumption of electronic devices within the energy labelling context.

consumption in different situations (i.e. (i) office work, (ii) gaming and (iii) graphic design and video editing), with a view to setting three different ratings that are best suited to the purchaser's precise needs.

Finally, such energy labelling may pave the way for new and ambitious ecodesign regulations for other complex electronic devices (e.g. smartphones and tablets).

Network's energy consumption

As mentioned above, both fixed and mobile networks' energy consumption is expected to more than triple between 2020 and 2030 according to Andrae, A.S.G. This is hardly surprising because, with a current compound annual growth rate (CAGR) of over 40%, global internet traffic is set to increase by almost 30 times over that period. The difference between these two figures highlights the remarkable progress made (and still expected to be made in the coming years) in terms of network components' energy efficiency. The roll-out of fibre networks (requiring much less energy to operate by unit of data transported) and 5G technology (also more energy-efficient) are the main reasons for these rather optimistic predictions. The energy consumption of networks is nevertheless set to become a major component of the ICT sector's overall energy consumption by 2030. The main components of global internet traffic nowadays are – by far – video streaming (over 60% of total traffic), online gaming and social networking[116]. There are indications that online gaming and downloading video games could become an even more significant contributor to the mix – due in part to the increase in the size of downloads and the importance of latency[117].

The Commission has addressed this topic in its energy-efficiency approaches by funding research projects aimed at improving the energy consumption and efficiency of network components, protocols and architectures. The One5G research project[118] brought together telecommunications operators, component and infrastructure vendors, universities and research centres from across the EU with the aim of boosting mobile networks' capacity, improving their energy efficiency and making possible a variety of new vertical use cases in both dense urban areas and rural environments. Other research projects have targeted the emerging and fast-growing transmission of IoT data. For example, the SerIoT project[119] developed energy-aware data-flow routing in IoT networks – thus minimising energy consumption while guaranteeing optimal quality of service and security through software defined network (SDN) routing.

In addition, the revision of the Broadband Cost Reduction Directive, will have both direct and indirect benefits for the energy efficiency of electronic communication networks. These benefits stem from promoting the deployment of more energy-efficient fibre and 5G technologies. The new instrument will also strive to promote synergies with the renovation wave for energy efficiency purposes to equip buildings at the same time with advanced in-building connectivity physical infrastructure and wiring.

Conversely, some regulators have (basing themselves on the idea that reversing or merely halting the current upward trend in internet traffic could help reduce the energy consumption

[116] https://www.sandvine.com/covid-internet-spotlight-report and https://www.sandvine.com/hubfs/Sandvine_Redesign_2019/Downloads/Internet%20Phenomena/Internet%20Phenomena%20Report%20Q32019%2020190910.pdf.

[117] https://www.de-cix.net/en/about-de-cix/news/cloud-gaming-as-driver-for-the-internet-traffic-of-the-future.

[118] https://one5g.eu/

[119] https://seriot-project.eu/

of networks – including by postponing the need for new investment in response to increased traffic) introduced legal measures to give individuals a better idea of how much energy they are actually consuming through their online activities. It is believed that raising individuals' awareness of this would prompt them to reduce their consumption as and when possible, and would ultimately make it possible to reduce (or limit an increase in) the amount of data passing through the networks. Raising individuals' awareness of their energy consumption during their day-to-day digital activity (e.g. video streaming, sending an e-mail with a large attachment, playing online videogames and listening to music online) is a prerequisite for more data-frugal and responsible behaviour and could produce positive results without the need for coercive measures.

France is a particular case in point. It adopted a law on 15 November 2021 to reduce the environmental footprint of digital technologies[120]. The law contains several provisions to provide consumers with better information on the real energy consumption (and equivalent CO_2 emissions) of their online streaming activities.

Encouraging data frugality – the example of France

France has passed one of the most ambitious laws on the energy consumption of ICT technologies, notably from the digital frugality perspective. Article 23 of the law introduces, as of 1 January 2023, an obligation for the French audiovisual regulator to publish a recommendation for television and on-demand video services and video-sharing platforms to inform consumers of their energy consumption and equivalent CO_2 emissions. Article 26 states that this information should take account of how content is accessed as well as the display resolution.

The Commission has adopted a similar approach. In 2019, the communication *Shaping Europe's digital future* mentioned the opportunity to introduce 'transparency measures for telecoms operators on their environmental footprint' at EU level[121]. More recently, the Declaration on European Digital Rights and Principles published on 26 January 2022 emphasised in Chapter VI that 'everyone should have access to accurate, easy-to-understand information on the environmental impact and energy consumption of digital products and services, allowing them to make responsible choices.'[122]

To make individuals more aware of the impact of their digital services consumption, the Commission will also fund a study to quantify in detail the energy consumption of a number

[120] LOI n° 2021-1485 du 15 novembre 2021 visant à réduire l'empreinte environnementale du numérique en France (Law No 2021-1485 of 15 November 2021 aimed at reducing France's digital carbon footprint): https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044327272. France had already introduced a transparency obligation for telecommunications operators to inform consumers in their bills of the energy consumption and equivalent CO_2 emissions associated with their data consumption. The French energy agency ADEME published the methodology for establishing these figures on 14 December 2021: https://www.ademe.fr/expertises/consommer-autrement/passer-a-laction/reconnaitre-produit-plus-respectueux-lenvironnement/dossier/laffichage-environnemental/affichage-environnemental-secteur-numerique.

[121] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/shaping-europe-digital-future_en

[122] https://digital-strategy.ec.europa.eu/en/library/declaration-european-digital-rights-and-principles#Declaration

of representative day-to-day digital behaviours. This will provide reliable and simple estimates for use in a communication and awareness-raising campaign.

Energy consumption of data centres

Data centres are a core infrastructure element of ICT systems. As mentioned above, the energy consumption of data centres is expected to more than triple between 2020 and 2030[123] due to increased demand for decentralised services and the huge increase expected in internet traffic[124]. Data centres could thus become a major contributor to ICT energy consumption by 2030. In absolute terms, the energy consumption of data centres in the EU was 76.8 TWh in 2018. This is expected to rise to 98.5 TWh by 2030 – a 28% increase. In relative terms, data centres accounted for 2.7% of the EU's electricity demand in 2018; this will reach 3.2% by 2030 if current trends continue[125]. Moreover, unlike consumer devices and networks, the energy consumption of data centres is very unevenly distributed from a geographical point of view. This can cause concern in local communities and even introduce constraints in the electricity grids at local level. In the most extreme case in the EU – Ireland – data centres consume 14.5% of electricity nationally, but this is much higher in some areas[126]. It is expected that data centres will account for 24% of national electricity consumption in Ireland by 2030.[127] In other Member States such as Sweden, the relocation of cryptocurrency mining activities following their prohibition by China in May 2021 placed a significant extra burden on the electricity network and fuelled the public's concerns about the sustainability of such activities.

The Commission long ago identified data centres' energy consumption as a key topic and put in place its first policy tools.

The Code of Conduct for data centres and its application in different policy tools

The Code of Conduct for data centres was adopted in 2008. It is a voluntary tool to inform and encourage data centre operators and owners to reduce their energy consumption in a cost-effective manner (without hampering the key function of data centres) by improving understanding of energy demand within the data centre, raising awareness of their energy consumption and possible ways to decrease it, and recommending energy-efficient best practices and targets. The Commission published green public procurement criteria in 2020. These provide Member States with guidelines for building/purchasing data centres, server rooms and cloud services. They frequently refer to participation in the Code of Conduct as a key criterion for the selection of data processing, cloud services or hosting services in public tenders[128]. The Code of Conduct underwent a major revision in 2022. This included (i) an expansion of its scope to include non-energy-related environmental indicators (e.g. water

---

123 According to Andrae, A.S.G. ITU trajectories foresee a more modest 20% increase over the same period.

124 The share of cloud data centres accounted for 10% of data centres' energy consumption in 2010. It increased to 35% in 2018 and is expected to increase to 60% in 2025. https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=71330.

125 https://digital-strategy.ec.europa.eu/en/library/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market

126 Data centres' energy consumption is also a cause of public concern and social tension in the Netherlands, where a large data centre planned by Meta/Facebook in Zeewolde is expected to use the same amount of energy annually as the city of Amsterdam.

127 Source: BloombergNEF study on the grid integration of data centres.

128 https://ec.europa.eu/environment/gpp/pdf/20032020_EU_GPP_criteria_for_data_centres_server_rooms_and_cloud_services_SWD_(2020)_55_final.pdf

consumption), (ii) the inclusion of new indicators on the share of renewable energy use and (iii) the inclusion of new indicators on the share of energy reuse.

Studies

The Commission has commissioned several studies to inform its policymaking. These include the 2020 study on '*Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market*'[129] and the 2022 study '*Greening Cloud Computing and Electronic Communications Services and Networks: towards climate neutrality by 2050*'[130].

The topic of the interaction between data centres and the electricity grid was the focus of several European research projects which didn't reach commercial stage in the Commission's Seventh Framework Programme[131]. This topic however appears relatively unexplored in literature to date, with the exception of a few studies, notably by CERRE [132]. In 2022, the Commission will initiate a study on the integration of data centres within the energy network. This study will serve the aim of answering multiple questions related to the interaction between data centres and the grid, such as:

- To what extent and how can data centres contribute to the stability of the electricity grid?
- Can backup energy supply/uninterruptible power supply (UPS) be used and, if so, how?
- How would the introduction of a more granular system for guarantees of origin affect the green electricity supply claims of data centre operators and how to address this?
- Can data centres engage in demand-response[133]; if so, can one quantify the potential for demand response from data centres in the EU? How could this work for colocation data centres, which represent a significant share of all the installed data centres in the EU?
- Would better-informed choices about the geographical location of data centres enable better integration of them into the energy system (for instance, by contributing to heating networks/district heating)?[134]
- How can data centres offset the potential destabilising effects they have on local electricity networks?[135]
- Do data centres consume all available renewable electricity in order to satisfy the additional electricity demand that they generate (to the detriment of the overall carbon footprint of the EU's electricity systems) – or do they have a positive overall 'stirring' effect on the development of new renewables projects by creating security of income and reducing risk for project holders (with a beneficial long-term effect)?

---

[129] Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market | Shaping Europe's digital future (europa.eu)

[130] https://www.ideaconsult.be/en/projects/study-on-greening-cloud-computing-and-electronic-communications-services-and-networks-towards-climate-neutrality-by-2050

[131] https://www.smartcitiescluster.eu/projects

[132] To the exception of the study *"Data centres & the grid – Greening ICT in Europe"* by Catherine Banet, Michael Pollitt, Andrei Covatariu and Daniel Duma, produced by CERRE – see https://cerre.eu/wp-content/uploads/2021/10/211013_CERRE_Report_Data-Centres-Greening-ICT_FINAL.pdf

[133] See for instance https://blog.google/inside-google/infrastructure/data-centers-work-harder-sun-shines-wind-blows/.

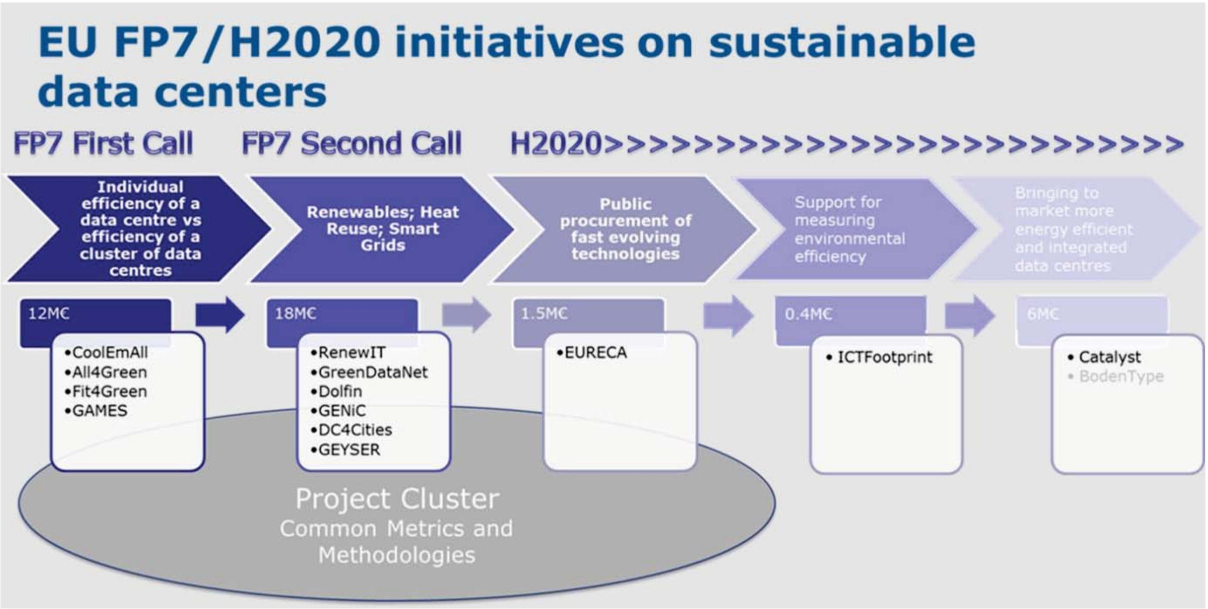
[134] It is debatable whether data centres have much choice in choosing their location in the first place, given all the constraints regarding the availability of connectivity, energy supply and free constructible space, growing public concerns, and local authorities' reluctance to have data centres locate in certain areas. See, for instance, https://www.datacenterdynamics.com/en/news/dutch-government-halts-hyperscale-data-centers-pending-new-rules/.

[135] https://www.iea.org/commentaries/data-centres-and-energy-from-global-headlines-to-local-headaches

Research projects and pilots

The Commission has also funded a number of research projects and pilots on data centres' energy consumption and energy efficiency. In doing so, it followed a very focused and methodical approach in order to launch several successive waves of thematic projects to build on previous projects. An overview of these successive waves and the name of the relevant projects is provided in Figure 4 below.

Figure 4: overview of EC research projects aimed at improving the energy efficiency of data centres



Boden-type data centres
One of the most recently completed projects was the Boden-type data centre project, which sought to design the most efficient data centre in the world and achieved an astonishingly low power use effectiveness (PUE) of 1,015 in northern Sweden by exploring: • the possibility of synchronising server cooling with building cooling; • the possibility of cooling components with colder air (while at the same time allowing the central processing unit (CPU) temperature to remain higher than is usually allowed)

Catalyst and Eco-Qube: two examples of ongoing EU-funded projects
• The Catalyst project seeks to convert data centres into energy-flexible assets by turning existing/new data centres into flexible multi-energy hubs that can support investment in renewable energy sources and energy efficiency by offering mutualised flexibility services to smart energy grids (both electricity and heat grids).

- The Eco-Qube project seeks to improve the energy efficiency of small data centres' instant cooling systems by developing an AI-enhanced holistic management system for data centres that connects cooling systems, IT loads and electrical infrastructure.

Data centres usually produce waste heat in summer and/or when it is hot outside. This means that a significant share of data centres' waste heat is produced when nobody needs it (at least for domestic heating purposes). The Commission intends to propose in the context of the 2023-2024 Horizon Europe work programme to fund a project to explore the possibility of using seasonal heat storage for the waste heat produced by data centres.

Regulation (EU) 2019/424 on the ecodesign of servers and data storage products

Servers and data storage products are a critical component of data centres. The individual energy efficiency of the servers and data storage products they contain can therefore have a drastic impact on a data centre's energy consumption.

Regulation (EU) 2019/424 on the ecodesign of servers and data storage products[136] sets requirements for the energy efficiency (e.g. the minimum efficiency of the internal power supply unit or minimum active-state efficiency for servers) and material efficiency (e.g. the extent to which certain components can be disassembled) of servers and data storage products. It also sets information requirements on the operating conditions class/temperature. The review of this Regulation will help assess various potential improvements in order to tighten its requirements, in particular:

- operating conditions for servers and data storage products (particularly in terms of maximum temperatures, which could have a positive impact on the energy consumption of cooling systems);
- product-specific requirements for the standby-readiness of servers;
- product-specific requirements for servers' DC (direct current) power supply;
- product-specific requirements for liquid cooling systems and solutions;
- product-specific requirements for waste heat recovery systems and solutions;
- product-specific requirements for information on core chip temperature and the possibility of externally overriding internal fan speed control (the Boden-type data centre project demonstrated the relevance of this).

The review is also assessing the technical and economic feasibility and relevance of introducing an energy label requirement for servers and data storage products (perhaps in the form of a label comprising targeted indicators for the different possible uses of the product – e.g. as webserver, disk server, database server or file/disk server).

Such labelling may be an excellent opportunity to promote the best performing products, especially in the context of public tendering and procurement, or the Green Taxonomy. Moreover, the fact that the performance data declared and used in the context of an energy labelling scheme is formally declared and potentially verifiable by authorities avoids the need

[136] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0424

for very burdensome verification of performance claims by the tendering body – reducing the cost of processing offers and the time needed to select the supplier and award the contract.

Corporate sustainability reporting directive

On 21 June 2022, the Council and European Parliament reached a provisional political agreement on the corporate sustainability reporting directive (CSRD), initially proposed by the Commission on 21 April 2021. The CSRD amends the existing reporting requirements of the Non-Financial Reporting Directive that currently apply to large public-interest companies with more than 500 employees, and extends the scope to all large and all listed companies in the EU, as well as non-EU companies with activities in the EU above a certain threshold. This CSRD mandates the adoption of EU sustainability reporting standards. The Commission has instructed the European Financial Reporting Advisory Group (EFRAG) to propose a set of draft standards to this effect.

The Commission will consider, depending on the technical advice it receives from EFRAG, including an obligation for companies to separately report on significant indirect GHG emissions from the procurement of cloud computing and data centre services under the 'upstream purchasing' category of their "Scope 3" emissions.[137] Such an obligation would raise the awareness, reflection and information gathering of data centre operators and their clients with respect to the issue of GHG emissions.

The EU Taxonomy

The EU Taxonomy for Sustainable Finance also includes criteria for data centres. It lists compliance with the EC Code of Conduct for Energy Efficiency in Data Centres as a necessary prerequisite under the criteria on how to substantially contribute to climate mitigation through "data processing, hosting and related activities".

The European Chips Act

Chips are the building block of servers and data storage products. They are therefore a crucial component of data centres and have a decisive impact on their energy consumption. One of the main purposes of the European Chips Act[138], adopted on 8 February 2022, is to build and strengthen the EU's capacity to innovate in the design, manufacturing and packaging of advanced, energy-efficient and secure chips. It also sets out certification procedures for energy-efficient and trusted chips to guarantee quality and security for critical applications. More than EUR 43 billion of policy-driven investment will support this initiative until 2030. This will be broadly matched by long-term private investment.

Revision of the Energy Efficiency Directive

[137] The widely used framework designed by the GHG Protocol to report on a given company's GHG emissions distinguishes three types of emissions: Scope 1 refers to direct emissions from owned or controlled sources, Scope 2 refers to emissions from the generation of purchased electricity, and Scope 3 refers to all other indirect emissions from up- and downstream activities along the value chain.

[138] https://digital-strategy.ec.europa.eu/en/policies/european-chips-act#:~:text=The%20European%20Chips%20Act%20will%20reinforce%20the%20semiconductor,its%20global%20market%20share%20in%20semiconductors%20to%2020%25.

The Energy Efficiency Directive (EED) is being revised with the aim of further promoting and strengthening the EU's energy efficiency policies. The EED revision will address the question of data centres' energy consumption by proposing a range of new requirements:

- an obligation to assess the economic feasibility of increasing the energy efficiency of heat supply for data centres exceeding a certain threshold (Article 23(4) of the Commission's proposal);
- green procurement criteria for the purchasing by public bodies of data centres, server rooms and cloud services (Annex IV);
- a monitoring and reporting requirement for data centres' energy consumption (Article 11(10)).

The monitoring and reporting requirement will help build knowledge of the sector, which is currently lacking, by identifying the data centres in the EU and providing a better understanding of their distribution and main characteristics. In the longer term, it will also be used for the purpose of establishing an energy and environmental labelling scheme for data centres. This will create more transparency in the sector and serve as a selling point for top-performing companies (colocation data centres will be able to advertise their performance to their corporate customers and business data centres will be able to advertise their performance to their customers and shareholders)[139]. This labelling scheme will probably transform the entire EU data centre industry, because it will make the energy and environmental performance of data centres more visible and make it a key factor in consumer choice and industry planning.

Energy consumption of cryptocurrencies

In addition to the elements examined above (i.e. the manufacture of ICT devices, the energy consumption of devices in operation, the energy consumption of networks and the energy consumption of data centres), some first generation cryptocurrencies have raised, in the course of the past decade, issues related to their environmental sustainability. They are widely seen as ICT-related consumers of energy and related physical resources such as semiconductors. Bitcoin is by far the most energy-consuming,[140] because it relies on the relatively outdated "Proof-of-Work" consensus mechanism. Various sources[141] agree that bitcoin's monthly energy consumption has increased tenfold over the past 5 years and has more or less doubled in the last 2 years, reaching a peak of 10.67 TWh in May 2022 (roughly 140 TWh annualised), before dropping to 9.68 TWh in June 2022 (84.87 TWh annualised), as a direct consequence of a decrease in bitcoin's value, which has reduced incentives to "mine" bitcoin.[142] The energy consumption of bitcoin mining[143] has therefore attracted considerable public attention in recent

[139] As is already the case when a company invests in a very and efficient data centre infrastructure – see for instance https://www.euronext.com/en/technology/euronext-data-centre.

[140] It is estimated that bitcoin alone represents over two third of the energy consumption of all cryptocurrencies, the second largest cryptocurrency in terms of energy consumption being Ethereum, accounting for merely ~10% of the total. See Ulrich Gallersdörfer Lena Klaaßen and Christian Stoll, *"Energy Consumption of Cryptocurrencies Beyond Bitcoin"* available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7402366/

[141] See for instance https://www.bloomberg.com/professional/blog/why-bitcoins-energy-problem-is-so-hard-to-fix-quicktake/#:~:text=1.,which%20keeps%20a%20running%20estimate.

[142] See Cambridge Bitcoin Electricity Consumption Index: https://ccaf.io/cbeci/index

[143] Throughout this section, mining will have the meaning of competing for the solution of a computationally demanding and – as a result – energy-intensive, cryptographic puzzle, for the purposes of transaction verification and creation of new units of cryptocurrency.

years, and become a subject of public policy thinking and action. A few elements should be noted in order to describe this issue from an EU policy making perspective.

First, the Cambridge Bitcoin Electricity Consumption Index (CBCEI),[144] states that the vast majority of electricity consumption for bitcoin takes place outside the EU, especially in the USA and Kazakhstan (following the Chinese ban on crypto mining in spring 2021). The CBCEI also suggests that ~10% of global bitcoin mining takes place in the EU (mainly in Ireland and Germany[145]). These elements evidence that there is a clear case for international cooperation to tackle the issue, in addition to policy measures at EU level.

Second, China was the leading country in terms of bitcoin-mining-related energy consumption before spring 2021. However, its ban on cryptocurrency mining in spring 2021 had only a temporary impact on the global energy consumption of bitcoin mining, which returned to pre-ban levels within only a few months. Chinese miners relocated their activities to other countries (to Kazakhstan in particular – with a significant negative impact on Kazakhstan's national electricity system[146]) by physically moving servers and other IT equipment across borders. This suggests that the crypto-mining industry can relocate extremely fast and further confirms that, in the same way that greenhouse emissions are a global issue, policy makers would ideally need to take a global perspective in this domain in addition to potential policy measures at national/regional level.

Third, the energy efficiency of the chips and hardware used for Proof of Work mining purposes has greatly improved in recent years. Energy consumption has gone from around 0.1 MH/J (million hashes per joule) to around 10 000 MH/J as bitcoin mining shifted from CPU-based technologies to Graphic Processing Units (GPU) and finally to Application Specific Integrated Circuit (ASIC) technologies. However, these efficiency gains have been more than offset by an increase in the calculation intensity needed to mine the same amount of bitcoin. This suggests that measures focused on energy efficiency are bound to fail due to very significant rebound effects (particularly in the case of very energy-intensive Proof of Work consensus mechanisms such as the one used for bitcoin[147]). As demonstrated by the report 'Blockchain Energy Consumption – an Exploratory Study'[148], the ratio between the price of bitcoin and electricity prices is the only limit on the energy consumption of bitcoin mining at economic equilibrium and the energy efficiency of the technology in use is irrelevant. This conclusion also seems to be supported by the visible (but not proportional) decrease in electricity consumption of the bitcoin network following the recent crypto crash, which led to a nearly fourfold drop in the price of bitcoin from a high of 68,789 USD in November 2021 to a low of 17,593 USD in mid-June.

---

144 CBECI - https://ccaf.io/cbeci/mining_map

145 With a strong caveat however for both countries mentioning that "*there is little evidence of large mining operations in Germany/Ireland that would justify this figure. Germany's/Ireland's share is likely significantly inflated due to redirected IP addresses via the use of VPN or proxy services*"

146 Analysis of the relocation of bitcoin miners from China to Kazakhstan after the Chinese mining ban suggests that this move actually increased the overall carbon footprint of bitcoin mining (because Kazakhstan has fewer renewable energy sources than China and is therefore more reliant on coal) and had a negative impact on Kazakhstan's electricity system: https://www.euronews.com/next/2022/02/26/bitcoin-mining-was-actually-worse-for-the-environment-since-china-banned-it-a-new-study-sa.

147 Any improvement in the energy consumption per unit of calculation is bound to be offset by a similar increase in the absolute number of calculations performed – with the result that overall energy consumption will not change (or will continue to increase) in absolute terms.

148 https://www.aramis.admin.ch/Default?DocumentID=68053&Load=true

Fourth, there has been a growing uptake on the market for various other, more modern blockchain technologies (e.g. those using consensus mechanisms such as "Proof-of-Authority", "Proof-of-Stake", "Delegated Proof-of-Stake" or "Byzantine Fault Tolerance" instead of "Proof-of-Work") that require much less energy to operate than Proof-of-Work . Such technologies are already being used and could be used even more widely in the future as the building blocks for more energy-efficient cryptocurrencies, and for other blockchain applications in energy, mobility, supply chains, manufacturing and capital markets. In the energy sector, blockchain technologies could be used to ensure trust and reliability in local P2P electricity trading. Blockchain technologies could also support Energy Attribute Certificates (EACs) which attest that a given unit of energy is generated from clean energy sources and act as a market-based instrument to incentivise clean energy roll-out. Other use cases that could contribute to sustainability include monitoring assets through their life cycle in a verifiable way, and tracking sustainability efforts along supply chains. For example, the second largest blockchain ecosystem, Ethereum, has pledged to switch its consensus mechanism to Proof-of-Stake, which would allow energy savings in the order of a factor of 1000 (at the time of writing, this switch had not occurred). The governance of bitcoin is much different from and less structured than Ethereum, however, and replicating such a voluntary switch in bitcoin would depend on first convincing a majority of worldwide bitcoin miners to 'hard fork' the bitcoin protocol and switch from Proof-of-Work to Proof-of-Stake (similar to what Ethereum pledged to do), which appears extremely unlikely at this stage.

All things considered, high energy consumption is not a characteristic feature of all blockchain technologies. Rather, it is related to the use of the Proof-of-Work consensus mechanism. The European Blockchain Observatory and Forum (EUBOF), an academic think tank for sharing knowledge on blockchain, has recently explored the energy efficiency of blockchain technologies. It concluded[149] that mining is not a prerequisite for blockchain and that it is possible to base blockchain technologies on consensus mechanisms that consume far less energy than Proof-of-Work because they do not involve a mining process. The EUBOF also made a set of recommendations in line with its findings on the energy efficiency, scalability and performance of blockchain-based solutions, the use of renewable energy and the deployment of specific energy efficiency evaluation criteria[150]. The Commission is reviewing EUBOF's recommendations for additional actionable points.

The Commission has recently gathered information, set up reflection processes and launched initiatives on how to better address this growing policy challenge. The EU's blockchain pre-commercial procurement has in particular procured research and development aimed at bringing more energy-friendly blockchain solutions to the market for the European Blockchain Services Infrastructure (EBSI) and for the public sector[151]. The EBSI is an initiative by the European Blockchain Partnership (EBP) to use blockchain to create cross-border services for public administrations and their ecosystems to verify information and make services trustworthy[152].

149 See https://www.eublockchainforum.eu/sites/default/files/reports/Energy%20Efficiency%20of%20Blockchain%20Technologies_1_0.pdf.

150 See Ibidem, section 6: Policy Recommendations.

151 https://digital-strategy.ec.europa.eu/en/news/european-blockchain-pre-commercial-procurement

152 For more background information on the European Commission's policy with regard to blockchain technologies, see: https://digital-strategy.ec.europa.eu/en/policies/blockchain-strategy.

The next steps to address this topic can be put into three categories.

- First, since many cryptocurrencies are being mined and/or delivered over the cloud, all existing steps to evaluate and address energy consumption from the expansion of cloud computing services in the EU (see the previous section on the energy consumption of data centres) are relevant for curbing the energy consumption of crypto mining. A recent study[153] highlighted the relevance of using existing instruments (in particular the EU Code of Conduct on Energy Efficiency in Data Centres, the revision of the Ecodesign Regulation on servers and data storage products, and the Energy Efficiency Directive) to address this issue. In addition, CO_2 emissions from the power production system (including electricity production for data centres and IT services in general) are regulated by the EU Emissions Trading System that is progressively reducing the emissions cap. This will have an impact on EU-based cryptocurrency mining.
- Second, the Council presidency and the European Parliament reached in June 2022 a provisional agreement on a Regulation of Markets in crypto assets (MiCA). This proposal would establish a regulatory framework to help regulate cryptoassets that fall outside the scope of current regulation and their service providers in the EU, and would provide a single licensing system throughout the EU by 2024. The Commission did not propose that the MiCA Regulation address energy consumption concerns about Proof of Work, but the European Parliament decided to include several points in this regard in its mandate for negotiations with the Council. The MiCA regulation will require actors in the crypto-asset market to disclose information on their environmental and climate footprint. ESMA will develop draft regulatory technical standards on the content, methodologies and presentation of information regarding principal adverse environmental and climate-related impacts[154]. In addition, the Commission will develop a report including a description on the environmental and climate impact of new technologies in the crypto-asset market. The report will also include an assessment of potential policy options that could be warranted to mitigate adverse impacts on the climate of technologies used in the crypto-asset market, in particular in relation to consensus mechanisms. This would be a first attempt worldwide to decrease the attractiveness of bitcoin investments and curb the price of bitcoin (which, as mentioned above, has been evidenced as being the only relevant factor, along with the price of electricity, acting as a limit to bitcoin mining's worldwide energy consumption at economic equilibrium).
- Third, as already mentioned, Chapter VI of the Declaration on European Digital Rights and Principles emphasises that 'Everyone should have access to accurate, easy-to-understand information on the environmental impact and energy consumption of digital products and services, allowing them to make responsible choices.'[155] As cryptocurrencies are typically used by their owners as a speculative investment asset or as a payment system, this principle should also apply to cryptocurrencies, and could subsequently act as a deterrent for members of the public considering investing in less environmentally friendly cryptocurrencies and crypto assets. This transparency principle is also reflected in the environmental disclosure requirements in the final MiCA text.

---

153 Study on efficient cloud computing technologies and policies: https://ec.europa.eu/digital-single-market/en/news/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market.

154 The final MiCA text was agreed by co-legislators on 30.06.2022.

155 https://digital-strategy.ec.europa.eu/en/library/declaration-european-digital-rights-and-principles#Declaration

- Fourth, it appears necessary to develop technical tools to assess the electricity consumption and carbon footprint of crypto mining at international level. International cooperation with standardisation bodies could provide the technical expertise needed to develop energy-efficient labelling for blockchains. International collaboration with standardisation bodies would put the EU at the forefront of any future global initiative to encourage sustainable blockchain technologies. This incentive should encourage the use of the more environmentally friendly consensus mechanisms and applications of blockchain technology, taking due account of other relevant aspects such as cybersecurity and financial and social impacts. This would need to be accompanied by awareness-raising measures in relevant settings (e.g. the Social Impact and Sustainability Working Group of the International Association of Trusted Blockchain Applications (INATBA)[156]).

[156] https://inatba.org/social-impact-working-group/

7 Annex: Summary of the sample of projects co-funded by Horizon 2020 programme with cybersecurity components

Project reference (CORDIS database, Horizon 2020 projects)	**Participation of the EU Member States and affiliated countries**	**Main fields of work**	**Main technological solutions and protocols/type of cybersecurity measures**
PHOENIX	DE EL ES FR IT NL RO SI FI + Norway	Monitoring, detection, mitigation and recovery from threats and attacks related to vulnerabilities in existing supervisory control and data acquisition (SCADA) and information and communication systems	PHOENIX platform and EPES threat notification, and distribution mechanisms and countermeasures
SDNmSENSE	BG EL ES SE + Norway	ility assessment of industrial and IoT protocols on software defined networking, AI-based detection, mitigation and correlation mechanisms, community sharing of incidents	Security information and event management (SIEM) system, MISP system Focusing on Modbus, DNP3, IEC 60870-5-104, IEC 61850, GOOS and MQTT protocols
ENERGY SHIELDS	BG DE EL IE IT LU RO SE + Iceland and the United Kingdom	Vulnerability assessment at systems/process and component levels	1.SIEM system using standard formats (IDMS) for incident reporting 2. Tools for anomaly detection, distributed mitigation and security behaviour analysis. Seamless reporting to EU CERT and EPES operators
ELECTRON	EL ES RO SE + Norway and Ukraine	Development of frameworks: 1. risk assessment and cyber security certification 2. intrusion detection and correlating mechanisms 3. prevention and mitigation measures 4. training of staff	Cooperation with the European Network Information and Security Agency (ENISA)
CYBERSEAS	IT SI HR FI EE	1. Protecting data and detecting breaches in the cloud. 2. Assigning digital assets to an immutable digital twin.	MIDAS application