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Accompanying document to the

Proposal for a

COUNCIL REGULATION

setting up the Fuel Cells and Hydrogen Joint Undertaking

IMPACT ASSESSMENT

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EXECUTIVE SUMMARY

The purpose of the present document is to consider alternative policy options, including a Joint Technology Initiative, for the implementation of fuel cell and hydrogen RTD and demonstration actions under the 7th Framework Programme (FP7) and make a comparative assessment of their potential impact.

New energy technologies of conversion and use can make important contributions to the improvement of energy security, the mitigation of climate change, sustainable development, and the competitiveness of the EU. Faced with the rapid growth of energy demand and the approaching decline in oil and gas production, new energy sources must be developed and they will need novel methods of clean and efficient energy conversion, transport and use.

Although significant public funds have been directed to research, fuel cell and hydrogen technology is unlikely to be commercially available as quickly as is desirable. Technology breakthroughs are needed to improve performance and durability and reduce system costs. The energy market has insufficient pricing mechanism adequately to reward advantages to the environment and security of supply and there are technical and infrastructure barriers to entry. The absence of a long-term, integrated RTD and market strategy leads to a fragmented research coverage and discourages industry and the research community from committing more of their own resources. The fledgling fuel cell and hydrogen industry in Europe is facing competition not only from global competitors in the same sector mostly in North America and Japan, but also from other well-established energy sectors as well as fast-developing energy alternatives. The industry includes innovative SME technology developers and new divisions of large enterprises who are the potential users of the new technologies.

Responding to the challenge, the European Commission (EC) in collaboration with the Hydrogen and Fuel Cells Technology Platform (HFP) is proposing a Joint Technology Initiative (JTI) for research, technological development and demonstration (RTD&D) of fuel cells and hydrogen. This JTI would carry out pre-competitive RTD&D, in particular based on the Implementation Plan developed by the HFP through the establishment of a Joint Undertaking on the basis of Article 171 of the EC Treaty. The JTI would strengthen the European Research Area (ERA) throughout the EU-27 and associated countries by gathering together stakeholders from the energy and transport industries, public institutions of the EU and Member States and regions, regulators, and user groups in a joint effort to develop a range of fuel cell and hydrogen technology demonstrators.

This new kind of research cooperation has a number of clear advantages over the Business-as-Usual FP7 with national and regional RTD alternative:

- time to market shorter by between 2 and 5 years - the importance of being first in a new market cannot be over-emphasised, and pays off in reducing the cumulative investment, bringing forward the break-even point, and strengthening the competitive position of the early market entrants, of which many could be SMEs;

- long-term commitment and a clear-cut budget encourage confidence in public and private investors;

- additionality: the Joint Undertaking will leverage at least 600 M€ more than Business-as-Usual, corresponding to almost two and a half times as much private research investment;

- making correspondingly earlier gains on improving energy efficiency and security of supply and reducing greenhouse gases and pollution.

SECTION 1: PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

The purpose of this document is to consider research policy options for implementing fuel cell and hydrogen Research and Technological Development (RTD), including a Joint Technology Initiative[1] on Fuel Cells and Hydrogen[2] (JTI FCH).

The concept of the JTI was included in the Council Decision[3] on the 7th Framework Programme (FP7)[4] which also identified Fuel Cells and Hydrogen as one of the first six candidates for a JTI. This was recently confirmed by the Competitiveness Council[5] . JTIs should pursue activities that are of common European interest and their establishment should contribute to the achievement of the Lisbon competitiveness objective[6] and the Barcelona targets for research spending[7]. Article 171 of the EC treaty states that 'the Community may set up joint undertakings or any other structure necessary for the efficient execution of Community research, technological development and demonstration programmes'. The Council will adopt the provisions after receiving the opinion of the European Parliament.

In the preparation of its proposals for setting up Joint Technology Initiatives, the Commission took into account the views expressed by many stakeholders from the research community and industry in a broad consultation involving the Member States and the European Parliament. The European Parliament in its Written Declaration[8] adopted in May 2007 called upon the EU Institutions to improve energy efficiency and support a higher market penetration for clean and renewable energies through the use of hydrogen fuel cell storage technologies for portable, stationary, and transport applications through a partnership with committed regions and cities, SMEs and civil society organisations. The Commission also consulted the European Hydrogen and Fuel Cell Technology Platform (HFP)[9] which produced the *Strategic Research Agenda*, the *Deployment Strategy*, and the *Implementation Plan 2006*, which is the main reference document and which outlines the "Snapshot 2020" technical and market objectives for fuel cells and hydrogen technologies. The Implementation Plan sets out priorities for a comprehensive, integrated programme of

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1 *Science and technology, the key to Europe's future – Guidelines for future European Union policy to support research* - COM(2004) 353.

2 European Commission, 2005 *Report on European Technology Platforms and Joint Technology Initiatives: Fostering Public-Private R&D Partnerships to Boost Europe's Industrial competitiveness* - SEC(2005) 800.

3 Decision No 1982/2006/EC of the European Parliament and of the Council of 18 December 2006 on FP7.

4 Council Decision No 971/2006/EC of 19 December 2006 on the Specific Programme "Cooperation" implementing the Seventh Framework Programme (2007-2013) of the European Community for research, technological development and demonstration activities.

5 Council press release 15717/06 on the Competitiveness Council meeting on 4-5 December 2006.

6 Lisbon objectives - see http://ec.europa.eu/growthandjobs/pdf/lisbon_en.pdf.

7 More Research and Innovation - Investing for Growth and Employment :A Common Approach Impact Assessment - COM(2005) 488.

8 *Written Declaration pursuant to Rule 116 of the Rules of Procedure on establishing a green hydrogen economy and a third industrial revolution in Europe through a partnership with committed regions and cities, SMEs and civil society organisations*, European Parliament 0016/2007, May 2007.

9 European Hydrogen and Fuel Cell Technology Platform – *Strategic Research Agenda, the Development Strategy Implementation Plan*; see https://www.hfpeurope.org/hfp/keydocs.

RTD and Demonstration (RTD&D), with timelines and recommended budget allocations over seven years to accelerate commercialisation of the new technologies. The HFP Member States Mirror Group was also consulted at all stages of the process. In addition to the HFP bodies, information has been widely disseminated through the HFP web-site and newsletters, enabling all stakeholders to contribute to the debate. Stakeholders included Original Equipment Manufacturers (OEMs), fuel cell and energy equipment companies including many SMEs[10], utilities, industrial gas companies, energy companies, universities and research centres. Other stakeholders not benefiting directly from the policy option (e.g. NGOs, Regions, etc) were also represented in the HFP and consulted during the process.

The three-year consultation process has involved several hundred stakeholders, public internet consultation on the above-mentioned platform documents, contributions from EC research projects, and studies on the wide-ranging socio-economic and environmental impacts of hydrogen and fuel cell technologies and the economic feasibility of their deployment. The main sources of supporting data have been EU funded projects under FP6, particularly "*HyWays*" (contract N° 502596) and, to a lesser extent, '*Roads2Hycom*' (contract N° 019723), WETO-H2 (contract N° 501669) and '*HyLights*' (contract N° 019990). Reference to them is made in the footnotes of this document when applicable. The Commission also organised four major conference events (three General Assemblies and the Technical Review Days), and workshops for regions and the research community.

Towards the end of the process, a Peer Review Group of four internationally-acknowledged, independent experts was engaged to help finalise this Impact Assessment[11]. An inter-service steering group was also established in May 2007 involving the following DGs: ADMIN, BUDG, COMP, ECFIN, EAC, ENTR, ENV, IAS, JRC, RTD (with several Directorates), SG and TREN, which reviewed and provided comments to the Impact Assessment and to the text of the Regulation proposal.

SECTION 2: AN INTRODUCTION TO FUEL CELLS AND HYDROGEN

Fuel Cells

Fuel cells are very quiet, highly efficient, energy converters capable of delivering substantial cumulative greenhouse gases (GHG) and pollutant reductions. They convert fuel and oxygen directly to electricity, heat and water in an electrochemical process. Unlike conventional combustion engines whose efficiency is limited by the Carnot efficiency limit of thermal processes, they do not burn the fuel and they do not have reciprocating or rotating masses , and hence have low vibration and noise, lower efficiency losses, and low emissions. Their mechanical simplicity also leads to low maintenance requirements. Fuel cells offer flexibility to the energy mix as they can be operated on fuels other than hydrogen, such as natural gas, ethanol and methanol depending on their particular operating

10 Micro, small and medium-sized enterprises or SMEs are defined by the European Commission as: enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding 50 M€, and/or have an annual balance sheet total less than 43 M€.

11 This panel was chaired by Professor Luigi Paganetto, University "Tor Vergata" of Rome and president of ENEA (Ente per le Nuove tecnologie, l'Energia e l'Ambiente) and was also composed of Mrs. Michèle Pappalardo, president of ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie, France); Professor, Peter Lund, Helsinki University of Technology, former Chair of the FP6 Advisory Group for Energy (AGE); and Professor Nigel LUCAS (formerly Imperial College and international energy policy adviser, UK).

principles. Fuel cells using hydrogen are intrinsically clean energy converters because the only exhaust product is steam, while other types using natural gas and other fossil fuels also reduce emissions because they use less fuel owing to their higher efficiency. They have higher energy storage densities than batteries and can even store hydrogen from excess electricity production.

Fuel cells are as yet too expensive for commercial introduction except in premium sectors such as space and military applications and back-up power generation. Some fuel cell technologies have already advanced to the stage where they have been demonstrated for thousands of hours and workable systems could be mass-produced. Nevertheless, the long-term durability and reliability of the majority of fuel cell types as well as their fuel processors and other items of 'balance of plant' must still be proven.

Applications of fuel cells

Fuel cells have the potential to have a major impact on economic competitiveness in a wide range of energy-consuming applications, including portable electronic and electrical devices, small and large combined heat and power (CHP) and tri-generation systems, as well as road, rail, sea and air transport applications. Energy utilities, industrial gas companies, the transport propulsion industry, consumer goods industry, power generation and equipment manufacturers will be affected – as will the associated supply chains. Their use is mostly foreseen in three kinds of applications, portable, stationary and transport:

Portable fuel cells

The increased use of portable electronic and electrical equipment such as mobile phones, mp3s, laptop computers and cordless power tools could open up a wide range of different applications. Consumers' biggest complaint about portable devices is the short battery life and the need to recharge or replace batteries, so the ability to out-perform the capacity of batteries in this respect could open the market to fuel cells in the short to medium term, in the first instance in premium applications. Such fuel cells will normally use methanol or ethanol. There remains great scope for innovation in this area, particularly to reduce costs to make portable fuel cells more competitive with Li-polymer batteries.

Stationary fuel cells

Large numbers of stationary fuel cells are already being tested in field trials and demonstrations in larger installations such as hospitals. Projections for power generation and energy conversion indicate a multi-billion euro market. This sector is likely to see commercial units available in the medium term, where they may displace distributed fossil-fuelled generator sets, or small internal-combustion engine (ICE) power units, which can generate disproportionate levels of pollution. Stationary fuel cells can deliver a higher ratio of electricity to heat than conventional combined heat and power plants, but for the moment the costs are too high to be competitive with conventional systems in most applications. Stationary fuel cells come in a wide range of sizes and types, are constructed using different materials, and operate at temperatures from 60°C to 1,000°C. They can run directly on natural gas, as well as biogas and hydrogen. Gasified biomass (via fermentation or gasification) is a possible choice of fuel, as high-temperature fuel cells can convert methane and carbon monoxide either directly or via internal reforming of hydrogen from gas.

Transport fuel cells

Mainstream road transport is the application where fuel cells could have the greatest net environmental effect. Fuel cell (FC) vehicles have a greater range than battery vehicles, and their autonomy is now approaching that of conventional vehicles running on gasoline or diesel. The DG TREN 'CUTE'[12] buses have already demonstrated the durability needed for vehicles with systems operating for longer than 5,000 hours. Note that FC vehicles use no energy whilst stationary in congested traffic, other than for on-board electrical auxiliaries, and combining this effect with regenerative braking can reduce CO_2 emissions by between 10 and 50 g/km[13] depending on the fuel pathway. Fuel cell-based auxiliary power units (APU) can also provide more efficient on-board electrical power for air-conditioning, refrigeration, potable water or electrical equipment in other kinds of transport including aircraft, submarines, and ships where problems of emissions and noise are also significant.

Hydrogen

The introduction of hydrogen as a flexible energy carrier can contribute positively to energy security and stabilise energy prices as it can be produced from any primary energy source. It can be used in fuel cells or it can be burned either to provide heat or to drive turbines or internal combustion engines for motive and electrical power. And because the exhaust product is heat and steam, the emissions and the associated externalities are far lower than other alternatives, especially for transport applications. Hydrogen can also be used as a means of storing energy. For instance, when renewable electricity production is higher than demand, the excess energy could be used to produce hydrogen by electrolysis, thereby facilitating the integration of renewable electricity into the energy market.

It is one of the ways to introduce diversity into the transport mix, which is currently 98% dependent on oil. Other alternatives for transport include electricity (batteries), natural gas, and liquid and gaseous bio-fuels, which may also be used for other energy services such as residential and process heat and mechanical drives. Each has its merits and capacity limitations.

SECTION 3: PROBLEM DEFINITION

The energy challenge for the EU

Energy is fundamental to modern society and to sustainable development. Most energy supply to Europe is imported. Security of energy supply in the EU will worsen as dependency on energy imports is likely to rise from 50% to 70%. Any energy shortage or insecurity would have serious implications for individuals, communities and business, both immediately and in their planning for the future. Recent disruptions and future uncertainties in the supply of oil and gas and the resulting price volatility dampen economic growth and raise inflation and unemployment and depress the value of financial and other assets. Oil and gas resources are depleting and, in the view of some experts, peak production will soon

12 DG TREN CUTE demonstration project – see http://www.fuel-cell-bus-club.com/
13 'HyWays' DG RTD FP6 Energy project – see http://www.hyways.de/

be reached[14]; what is certain is that the remaining resources are increasingly concentrated in a few countries to which political access is constrained, and security of supply will be an important problem for most industrialized countries and especially the EU. In the context of competitive and gradually integrating global transport and energy markets, energy demand is growing rapidly in large emerging countries. Globally, we face the major issue of climate change with levels of greenhouse gases rising. There are many uncertainties, but leading scientific opinion is agreed that large reductions in greenhouse gas emissions are needed urgently and must be sustained over a long time[15].

New forms of energy for transport and new patterns of energy production, transmission, distribution and consumption must be developed. For transport, which is currently 98% dependent on oil, the EU has set a binding minimum target to replace 10% of its road transport fuels by biofuels by the year 2020. In addition to biofuels, natural gas and hydrogen can also help to reduce the dependence on oil.

The fuel cell and hydrogen sectors

The present structure of the industry in Europe is unsatisfactory and leads to concerns as to its ability to compete. Although the EU has some world-class research facilities and for instance leads the world in fuel cells for large submarines and fuel cell membranes, the industry is in general immature and large-scale manufacturing processes, infrastructure deployment for refuelling, and support services such as trained personnel are not yet available. The fuel cell industry worldwide is characterised by very large corporate companies and very small, highly innovative SMEs. Europe has many of the latter, and it is crucial that their innovation potential is realised as these companies can form the future backbone of an EU component supply chain.

The fuel cell and hydrogen industries are strongly inter-related, but not wholly inter-dependent. The nature and degree of competition in the two industries is highly complex. The use of bulk hydrogen in process industries is long-standing and well-established and industrial enterprises see the prospect of new markets in energy and transport opening up through the wider adoption of fuel cell technologies on the one hand and hydrogen combustion engines on the other. At the same time, fuel cell manufacturers, who are very much at the start-up stage, are not wholly reliant on hydrogen because some fuel cells can use alternative fuels including natural gas, methanol and ethanol.

Market entrants employing fuel cell and hydrogen technologies face barriers to entry related to large economic investments locked into industries and physical infrastructures under threat from a change to the energy mix. Market entry is also made more difficult by the lack of a pricing mechanism to reward internalisation of externalities[16] (e.g. carbon value); the long-term investment needed to change over to a new generation of products and build up infrastructure for fuel cells and hydrogen; and the difficulties of establishing common regulations, codes and standards to facilitate global market development. There is

[14] *Stern review on the economics of climate change*, HM Treasury, 2006; http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

[15] Working Group III contribution to the Intergovernmental Panel on Climate Change. Fourth Assessment Report. *Climate Change 2007: Mitigation of Climate Change.* Approved at the 9th Session of Working Group III of the IPCC, Bangkok, Thailand, 30 April – 4 May 2007.

[16] *ExternE – Externalities of Energy* DG RTD JOU LE project; see http://www.externe.info/

a clear need to coordinate at European level the integration of R&D results with the "classical" standardisation approach and methodology of the international organisations (e.g. ISO, IEC). An integrated strategy is also required to maximise the benefits of transition technologies with fuel cells using natural gas, biogas, methanol and ethanol, if possible combined with carbon capture and storage (CCS) in the pathway and exploiting strategic niche markets in a planned and optimised framework.

<u>International competition in fuel cells and hydrogen</u>

The annual world turnover of the fuel cell industry in 2005 amounted to about 300 M€, with market shares of 52% for North America, 14% for Japan, 12% for Europe and 22% distributed around the rest of the world. There are relatively fewer OEMs in Europe compared to North America and Japan developing their own fuel cell stack and component technology – especially for road transport. Private RTD investment is estimated at about 700 M€ per year, of which 78% is made in North America and only 10% in Europe. A survey[17] of 23 of the most significant independent fuel cell and hydrogen development companies shows that the North American companies collectively have raised 3,600 M$ of capital investment from the private sector whilst the European companies raised only 130 M$, or 30 times less. European industry needs additional stimulation to invest in these technologies to become more competitive. The commercial and environmental rewards, not only within the EU but also on a world level, would be great for those who could be first to the market with breakthrough technologies, while the losses would be correspondingly high for those who lag behind.

Major competitors are pressing ahead with ambitious programmes of integrated research and development designed to bring products to market and establish *de facto* standards which latecomers will be obliged to follow. An EC study[18] estimates that the EU is 5 years behind Japan and North America on the demonstration of fuel cell vehicles. The US and Japanese programmes are strategically managed in close co-operation with the respective industries. The US DoE has developed a 'Hydrogen Posture Plan'[19] - the result of extensive consultation with the main stakeholders. The Ministry of Economy, Trade and Industry (METI) in Japan provides targeted support for basic research. In addition, Japan supports the development of hydrogen production and distribution infrastructure - with 12 fuelling station sites testing a range of hydrogen production options already commissioned or planned for Phase II of their 'Fuel Cell Commercialisation Conference of Japan' (FCCJ)[20]. Japan also has an ambitious programme for demonstrating some 800 small domestic CHP fuel cell systems. Both US and Japanese programmes have well-developed processes for managing technology validation, which is difficult to achieve comprehensively in the nationally-dispersed EU research environment.

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17 EC DG RTD FP6 project 'Roads2HyCom' CoreTech study

18 'HyLights' project DG TREN – see http://www.hylights.org/

19 *Hydrogen Posture Plan – An integrated research development and demonstration plan*; US Department of Energy and US Department of Transportation; December 2006 (update 2004 plan); see: http://www.hydrogen.energy.gov/pdfs/hydrogen_posture_plan_dec06.pdf.

20 FCCJ – Fuel Cell Commercialisation Conference of Japan; see : http://fccj.jp/index_e.html.

The challenges for fuel cells

Between all the potential application areas for fuel cells – portable, stationary and transport - the greatest investment will be in the change-over to a new generation of private cars. Their cost will be far higher than the cost of the new infrastructure. The use of hydrogen-fuelled transport will thus depend on consumer purchase of the fuel cell vehicles themselves as well as public and private investment in a widespread refuelling infrastructure conforming to internationally-agreed standards of compatibility. Before that, fleet vehicle fuelling stations for niche markets such as light-duty vehicles and buses and water- or rail-based applications would be introduced, particularly in environmentally-sensitive areas. Forms of transport systems will also evolve over the same long-term period, with the introduction of clean urban transport such as neighbourhood vehicles, scooters and three-wheelers, for which hydrogen-powered fuel cells may be ideally suited. The European Commission is currently drafting a Regulation[21] relating to the type-approval of hydrogen-powered motor vehicles, to allow their free circulation on public roads within the EU.

The experience currently being gained on the development and mass-production of hybrid electric vehicle drivetrains can be fed forward to lower the costs of the equivalent components required for fuel cell vehicles. A detailed value analysis[22] has provided projections for costs for volume production indicating lower overall vehicle cost because of the trade-offs on parts counts and systems simplification, and these now need to be proven. A breakthrough in battery technology could open a way to fuel cell/electric hybrid vehicles enabling downsizing of the fuel cell and allowing it to operate at a more constant load, thereby increasing its lifetime.

Figure 1 uses data from the EUCAR/CONCAWE/JRC study[23] to show that on a well-to-wheel basis, a hydrogen fuel cell is more energy-efficient than a fossil-fuelled or hydrogen internal combustion engine. Nevertheless, hydrogen combustion engines in vehicles may provide an important early route to market - the HyICE[24] project has just demonstrated a hydrogen internal combustion vehicle with 45% peak efficiency. The net environmental impact on GHG and pollution will heavily depend on the hydrogen production pathways[25]. So using wind-generated electricity to electrolyse water and produce hydrogen, the production plant might still use grid electricity comprising a mix of fossil, nuclear and renewables.

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21 Regulation of the European Parliament and of the Council relating to the type-approval of hydrogen powered motor vehicles, draft 2007.

22 TIAX study - see http://www.tiaxllc.com/aboutus/pdfs/nrel_fnlrpt_093005.pdf

23 EUCAR/CONCAWE/JRC study, May 2006. Example for a typical EU energy mix, for a medium-sized car, using compressed gas hydrogen storage for the fuel cell versions. (Primary energy source shown in brackets).

24 HyICE project, DG RTD FP6 Transport programme – see http://ec.europa.eu/research/transport/news/article_5199_en.html

25 The term 'pathway' refers to the whole value chain associated with production, distribution, storage and use of hydrogen

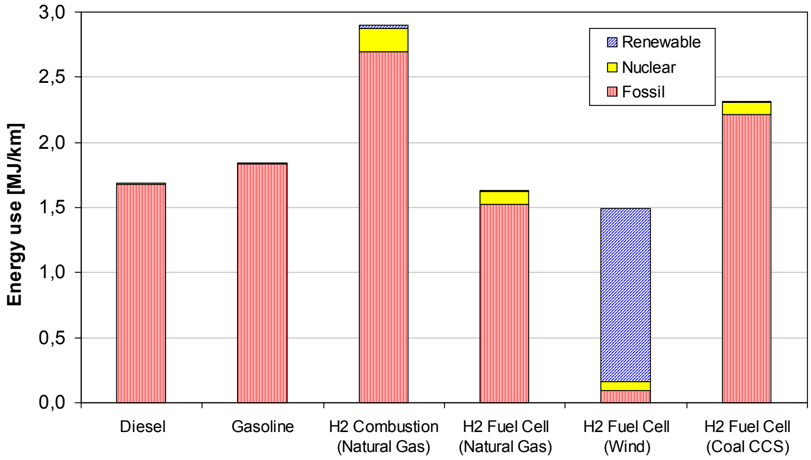

Figure 1: Comparison of Well-to-Wheel Energy Efficiency for fuel cell vehicles and alternatives.

In Figure 2, from the DG RTD FP6 'HyWays' project[26], CO_2 emissions per passenger-km for vehicles using hydrogen from different production pathways are plotted against hydrogen cost and compared to diesel and gasoline alternatives. Comparing with untaxed traditional gasoline or diesel cars, and with an oil price of 50 €/barrel, fuel cell cars using hydrogen from natural gas, or biomass gasification, or coal with a carbon capture and storage (CCS) cost of up to 30 €/tonne are predicted to become commercially viable by 2030, when technological progress and learning effects are taken into account. If externalities are considered, then fuel cell vehicles using hydrogen from wind would also be commercially viable. All hydrogen pathways lead to a decisive reduction of GHG emissions.

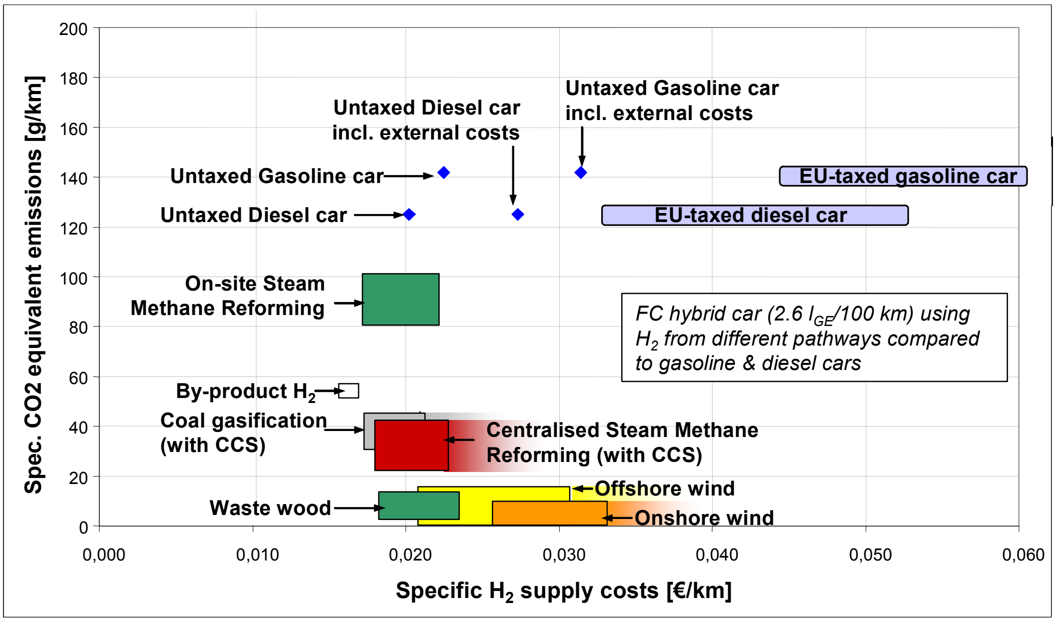

Figure 2: CO_2 emissions per passenger-km for different well-to-wheel H2 pathways (2030)[27]

[26] 'HyWays' DG RTD FP6 Energy project summary, 8 May 2007 – see http://www.hyways.de/
[27] 'HyWays' DG RTD FP6 Energy project summary, 8 May 2007 – see http://www.hyways.de/

The challenges for hydrogen

Current hydrogen production is mostly at a large scale for process industries, using well-established safety procedures. These procedures would have to be adapted for consumer use. Research is going on to complement this with hydrogen production from various forms of biomass, solar and nuclear energy and small-scale production technologies, including electrolysers and stationary and on-board reformers, which extract hydrogen from gaseous and liquid fuels. Some of these involve established industrial processes and can be introduced immediately while others are still at the laboratory stage and need considerable research and development.

Greenhouse gases are released in the various stages of processing compressed and liquid hydrogen from fossil fuels. Greenhouse gas emissions associated with hydrogen produced from renewable primary sources are generally very low, but not necessarily zero. They include elements of greenhouse gas emissions associated with energy consumption from conventional sources for example in hydrogen compression, liquefaction, distribution or storage. If fuels other than hydrogen are used for portable or transport applications, or if on-board reforming is employed, greenhouse gases and other pollutants are still released. Centralised production of hydrogen from fossil fuels opens the possibility to use CCS, although this adds to the cost and reduces overall system efficiency.

A technological breakthrough in hydrogen storage energy density and packaging is needed to achieve comparable autonomy to today's diesel car, although the latest fuel cell demonstration vehicles already have a range of more than 500 km. There is also the question of loss of efficiency at each stage of the pathway from the original energy source to the final application, though of course this is unavoidable in all forms of energy conversion. Too circuitous a route, with too many transformations and intermediate storage steps could lead to too low an overall system efficiency.

The general public needs to be informed about the advantages to the environment and the greater public good, and to reply to any concerns which they might have about hydrogen safety.

Market failure

Fuel cells and hydrogen offer advantages to society over conventional technologies through the avoidance of negative externalities caused by greenhouse gas emissions and local air pollutants and through enhanced security of energy supply and price stability. At present, market prices of current energy and transport systems do not reflect these advantages to society at large and this holds back their adoption in the short to medium term.

Funding of R&D is generally impeded by the market failure associated with public goods. Knowledge eventually becomes shared among many actors and for the market to fund its acquisition, the developers must see a possibility of a financial return, normally assured by exclusive intellectual property rights (IPR) for a period. This generic market failure is exacerbated in the fuel cells and hydrogen case by the long time to market and the high degree of coordination required. The long time to market weakens the ability of companies to secure returns on their investment; the high degree of coordination and the creation of a joint strategy require sharing of knowledge again weakens the possibility to secure returns. Public support is justified therefore to stimulate the acquisition of knowledge in these circumstances and to foster the necessary long-term vision and coordination.

Standards can arise from market practices, but in modern economies it is normally a consequence of the intervention of public bodies. The pre-normative research to be conducted by the JTI may also be seen as a correction of the public goods market failure that hinders cooperation between companies on pre-normative work in a competitive structure.

Technological lock-in can arise from sunk costs or from market dominance. The former is not a market failure but the second is, and it definitely exists in this sector with its many vested interests in existing technologies that may be threatened by fuel cells and hydrogen.

Recognition of the problem at EU level

The importance of energy in general and fuel cell and hydrogen technologies in particular have been recognised at European level, as witnessed by the above-mentioned Written Declaration of the European Parliament. As one of the initiatives launched in January 2007 in the communication 'Energy for a Changing World - An Energy Policy for Europe'[28], the European Commission is currently developing a European Strategic Energy Technology Plan (SET Plan)[29] to guide the course of energy technology innovation over the coming decades, deliver efficient and low-carbon technologies including fuel cells and hydrogen, and arrive at a more sustainable energy system. The consultation phase of the SET Plan is under way and the Commission will make a proposal in early 2008. The strategic plan would consist of a framework for technology development and validation that assures sustainability as the long-term goal, supported by evolving regulations, codes and standards, safety screening and larger-scale deployment, possibly supported through the Risk-Sharing Finance Facility (RSFF)[30], and with commercialisation goals firmly in view. Such a system is unlikely to emerge without public intervention.

Summary of the problems for fuel cells and hydrogen RTD

Although significant EU public funds have already been directed to research, and fuel cells and hydrogen are already included in the FP7 energy and transport research portfolio as an important component of RTD strategy, the technologies are unlikely to be commercially available as quickly as is desirable. There is a danger of fuel cell and hydrogen industrial development stagnating and falling further behind global competitors. Contributing factors include:

- the research needed is often so complex that no single fuel cell company or public research institution can perform it alone;
- the absence of an agreed long-term budget plan and strategic technical and market objectives to encourage industry and the research community to commit more of their own resources;
- the sub-optimal application of funds leaving gaps and overlaps in a fragmented research coverage;

28 *"Energy for a Changing World - An Energy Policy for Europe* - COM(2007) 1, 10.1.2007.
29 *Towards a European Strategic Energy Technology Plan* - COM(2006) 847, 10.1.2007.
30 Risk Sharing Finance Facility - a joint initiative of the European Investment Bank (EIB) and the European Commission to improve access to EIB debt financing for participants in large-scale European RTD projects.

- an insufficient volume of funds for an integrated programme from fundamental research through to large-scale EU-level demonstrations;
- the European fuel cell sector is dispersed across different countries and activity areas (academia, new industrial companies, high-tech SMEs) which restricts the exchange and pooling of knowledge and experience;
- and technical breakthroughs are needed to improve performance, materials, reliability and durability and reduce system costs to meet the expectations of potential customers.

Conclusions

The conclusion that might reasonably be drawn from the foregoing discussion is that there is a need for a new kind of joint European-level RTD to allow companies, including those in the new Member States, to collaborate between themselves and with other stakeholders, working towards shared short, medium and long-term objectives in the different application areas, as in the HFP 'Snapshot 2020' (see Section 4). Without public and private RTD investment at European level in a focused and coherent industrial RTD programme accompanied by longer-term research taking account of industrial development priorities, efforts addressing the research bottlenecks and the search for technological breakthroughs will continue in a scattered and unstructured manner. EU and national RTD currently lags behind our main competitors and funding needs to be spent more efficiently if we are to catch up. One possible answer is the Joint Technology Initiative, which can be implemented through a Joint Undertaking based on Article 171 of the Treaty establishing the European Community.

The subsidiarity principle applies since the proposal does not fall under the exclusive competence of the European Community. The objectives of the proposal cannot be sufficiently achieved by the Member States because the scale of the challenge exceeds the capacity of any Member State to act alone. The pooling and coordination of research and development efforts at EU level stand a better chance of success, given the trans-national nature of the infrastructure and technologies to be developed, and also the need to achieve a sufficient mass of resources. The intervention of the European Community will help to rationalise research programmes and ensure inter-operability of the developed systems not only through common pre-normative research to support the preparation of standards but also through the *de facto* standardisation which will arise from the close research cooperation and the trans-national demonstration projects. This standardisation will open a wider market and promote competition. The scope of the proposal should encourage the Member States to pursue complementary initiatives at national level, in the spirit of reinforcing the European Research Area - indeed the very intention of the JTI is to leverage these national and regional programmes to make best use of the combined efforts.

SECTION 4: OBJECTIVES

The overall objective is to establish an EU-level policy framework to stimulate an integrated research, technological development and demonstration effort in fuel cell and hydrogen technologies of sufficient critical mass to contribute significantly to European public policy objectives for:

- security of energy supply;
- new, cleaner forms of energy to mitigate against greenhouse gases and air pollution;
- energy efficiency and saving;
- sustainable development and sustainable transport;
- and industrial competitiveness.

The specific objectives are:

- to enable the market breakthrough of fuel cell and hydrogen technologies, enabling commercial market forces to drive the substantial public benefits;
- to place Europe at the forefront of fuel cell and hydrogen technologies worldwide;
- to reach the critical mass of research effort to give confidence to industry, public and private investors, decision-makers and other stakeholders to embark on a long-term programme;
- to leverage further industrial, national and regional RTD investment;
- to build the European Research Area through close cooperation with research carried out at national and regional levels - whilst respecting subsidiarity;
- to integrate research, development and demonstration, and focus on achieving long-term sustainability and industrial competitive targets for cost, performance and durability and overcome critical technology bottlenecks;
- to stimulate innovation and the emergence of new value chains including SMEs;
- to facilitate the interaction between industry, universities and research centres on basic research;
- to encourage the participation of the new Member States and candidate countries;
- to perform broadly-conceived socio-techno-economic research to assess and monitor technological progress and non-technical barriers to market entry;
- to perform research to support the development of new, and review existing regulations and standards to eliminate artificial barriers to market entry and support

interchangeability, inter-operability, cross-border hydrogen trading, and export markets whilst ensuring safe operation and not inhibiting innovation.

- to provide reliable information to the general public on hydrogen safety, and the benefits from the new technologies to the environment, security of supply, energy costs, and employment.

The HFP has developed the 'Snapshot 2020' set of specific objectives. ‘Snapshot 2020’ assumes that policy support and long-term industrial investment is maintained at the appropriate level to develop the technologies beyond the end of the RTD programme. These aim to: reduce fuel cell costs and enhance the performance and durability of fuel cell systems, particularly through advances in materials; develop mass production technologies for fuel cell stacks and systems; reduce hydrogen production and distribution costs; research into future large-scale production of hydrogen from renewable and carbon-free energy sources; and pursue novel hydrogen storage materials and principles in order to achieve energy densities consistent with vehicle operating range and packaging requirements. The probability of reaching the targets is discussed in Section 6 ‘Analysis of impacts’.

'Snapshot 2020' Fuel cell & hydrogen applications in 2020[31]

	Portable FCs for handheld electronic devices	**Portable Generators & Early Markets**	**Stationary FCs** for Combined Heat and Power (CHP)	**Road Transport**
EU H_2/ FC units sold per year projection 2020	~ 250 million	~ 100,000 per year (~ 1 GW_e)	100,000 to 200,000 per year (2-4 GW_e)	0.4 million to 1.8 million
EU cumulative sales to 2020	n.a.	~ 600,000 (~ 6 GW_e)	400,000 to 800,000 (8-16 GW_e)	1-5 million
EU Expected 2020 Market Status	Established	Established	Growth	Mass market roll-out
Average power FC system	15 W	10 kW	<100 kW (Micro HP) >100 kW (industrial CHP)	80 kW
FC system cost target	1-2 €/W	500 €/kW	2.000 €/kW (Micro) 1.000-1.500 €/kW (industrial CHP)	< 100 €/kW (for 150.000 units per year)

31 European Hydrogen and Fuel Cell Technology Platform – Implementation Plan; see https://www.hfpeurope.org/hfp/keydocs

SECTION 5: POLICY OPTIONS

The 'no EU action' option to discontinue RTD funding at European level, leaving only national and regional programmes is discounted, given that RTD into fuel cells and hydrogen is included in FP7 as an integral part of the effort to develop key technologies for future sustainable energy and transport systems. This action is appropriate where technologies are sufficiently mature to enter the market or are unlikely to have sufficient Europe-wide impact. There would be a danger of too narrow focus, and the risk of developing incompatible standards and technologies and products that could not be commercialised on a European or global scale.

The other options are considered in turn:

<u>Inter-governmental programme of research established under Article 169</u>

An inter-governmental approach can tackle dispersion and fragmentation and promote cohesion at the level of research centres and academia, and can be a successful approach for highly-focussed specific research projects. The Commission consulted stakeholders on the possibility of initiating cooperation under Article 169, but this was not the preferred option of member states or industry. The main arguments of industry against the inter-governmental option were that decision-making would be slower because of the need for long consultations and annual budgetary formalities in each member state. There is also the potential for problems with synchronising contributions of different MS who may also request a "just return" on their investments. Moreover, the nature of the "bottom up" process would make it difficult to implement an industry-led strategy. Industry's aim is to confront the issues that cause market failure at European level and to lead a programme that is focused on solving technical problems and reducing time to market in the most cost-effective way. The long-term strategy for fuel cells and hydrogen is on a very different scale and calls for a pan-EU approach, to which this kind of action is not well suited. Lack of industrial stakeholder support for an inter-governmental approach due to the above-mentioned reasons precludes its further consideration.

<u>Business-as-usual (B-A-U): Seventh Framework Programme plus national and regional effort, supported by a Technology Platform to provide strategic direction</u>

This option has to be considered very seriously as it has served the community well for more than 20 years. The RTD would be implemented through the standard EU funding schemes and, separately, through national and regional programmes including some inter-governmental cooperation. Arguments in favour of maintaining the *status quo* include: the RTD Framework Programme is well-established and well-understood by industry and the research community and its worth has been proven over time; it is efficient and well-managed with clear objectives and expected impacts; a traditional emphasis on scientific quality and innovation; tried and tested financing structures and rules for participation; a mature approach to technical and financial auditing; open and transparent procedures and a respected peer review process. HFP could provide strategic inputs to work-programmes and stimulate proposals that reflect industrial priorities, and has in fact performed this function in the latter stages of FP6 and at the beginning of FP7.

On the other hand, effort is fragmented across a number of different FP7 themes which are overseen by different programme committees, each with different priorities, giving rise to operational difficulties in co-ordinating calls and difficulties in feeding back results from demonstration actions to re-focus research priorities. In FP6, hydrogen and fuel cell RTD was given 314 M€ over four years under ten different programme priorities: Energy medium-long term (57%), short-medium term (18%), Transport and Aeronautics (14%), Materials (5%), Environment, SMEs, NEST, ERA-NET, Marie Curie, INCO (all around 1% each)[32]. In FP7, Work Programmes and topics in each Theme are decided each year and it is not possible to map out a multi-annual strategic RTD programme for a specific sector. There are also other EU actions relevant to various aspects of fuel cells and hydrogen RTD which are outside of FP7, such as the Competitiveness and Innovation Programme's (CIP) Intelligent Energy for Europe action and the European Institute of Technology.

A variation on the B-A-U option would be to bring together all the fuel cells and hydrogen RTD actions across FP7 under the control of a single directorate or agency. This would allow a more strategic, coordinated approach centred on the needs of the sector but industry would no longer be at the heart of the action and the expected funding additionality and leverage effects would not be assured. The administrative costs for the EC would also be higher than in the JTI, because the costs would not be shared 50/50 with the Industry Grouping.

Different surveys of annual public funding on fuel cells and hydrogen RTD, which is similarly dispersed across different actions at national level by EU countries, give EU totals of 133 M€[33] and 278 M€[34]. The wide variations reflect the difficulties in establishing accurate figures and factors such as double-counting of Framework Programme and national funds, and cross-cutting projects in other technologies. The average annual figure is 205 M€. Adding the average annual FP6 funding gives a total EU FP and national funding of about 286 M€ per year, which compares with a funding of about 260 M€[35] in the Japanese METI programme and about 235 M$[36] in the US DoE and DoT programmes in the last three years. However looking further back, the cumulative EU funding lags well behind the longer-established and more closely-coordinated programmes of the USA and Japan. One of the aims of the present initiative is to ensure that the total RTD effort within the EU reaches the critical mass to make up this deficit.

A lack of continuity and strategic technical and policy focus can give rise to knowledge gaps and overlapping effort, an inconsistent approach, and an over-emphasis on new, untested technologies. Even with support from a Technology Platform, the research portfolio might leave critical technologies under-funded or unaddressed. A major issue for industry is the unpredictability of funding levels, which is critical for long-term investment planning. A mature industry can organise itself effectively around the FP7 structure, but fuel cells and consumer hydrogen are embryonic industries facing large entry barriers to mature markets. They need well-defined strategic goals and a sustained, stable funding regime to raise confidence in private sector investors.

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32 An overview of Commission funded research projects on fuel cells and hydrogen in the Sixth Framework Programme can be downloaded at: http://ec.europa.eu/research/energy/pdf/hydrogen_synopses_en.pdf

33 HyCo DG RTD ERA-NET project survey 2005

34 IEA *Prospects for Hydrogen and Fuel Cells* - http://www.iea.org/textbase/npsum/Hydrogen2005SUM.pdf

35 FCCJ – Fuel Cell Commercialisation Conference of Japan; see : http://fccj.jp/index_e.html.

36 *Hydrogen Posture Plan – An integrated research development and demonstration plan*; US Department of Energy and US Department of Transportation; December 2006 (update 2004 plan); see: http://www.hydrogen.energy.gov/pdfs/hydrogen_posture_plan_dec06.pdf.

Establish a Joint Technology Initiative as a Joint Undertaking under Article 171

After extensive consultation with a working group set up under the HFP, this approach emerged as the option preferred by the stakeholders collectively, though it is not without its drawbacks. Industry prefers an action with a strategically-managed route from research through development and demonstration to market deployment and it also favours a pre-defined budget as this allows industry to make long-term investment plans and manage its cash flows. This would also encourage confidence in industry to engage in the necessary longer-term projects in cooperation with basic research organisations. Under the present concept for JTI governance, industry, in consultation with the research community and the European Commission, would take the lead role in defining the programme priorities and timelines, set against commercialisation targets for cost and performance – with milestones to aid strategic decisions. Although the JTI would apply the general principles of FP7 regarding equal treatment, openness and transparency, there is scope for more dynamic and efficient implementation.

The JTI would be established as a Joint Undertaking with a single management structure to mobilise in one and the same legal entity all the funds assigned from the public and private sectors. The Joint Undertaking would be a community body involving a public-private partnership based on the principles of the European Communities Financial Regulations. The founding members would be the EC and an 'Industry Grouping' of stakeholders from the fuel cell and hydrogen industries. The EC and the Industry Grouping would contribute equally to the budget for the JTI, with the EC share coming from the 7th Framework Programme (FP7) Energy, Transport, Materials, and Environment Themes. The Joint Undertaking would conclude the contracts to develop the key hydrogen and fuel cell technologies through research, technological development and demonstration actions.

The JTI would implement a programme of pre-competitive research, development, and demonstration without entering into market development, which is the responsibility of industry itself. RTD priorities would, for example, include improvement of fuel cell materials, membranes, and catalysts; balance of plant; environmental impact; hydrogen ICE integration; hydrogen storage and grid development; drive train integration and production engineering; renewables and hydrogen; electrolysis; and integration with CCS. The HFP Implementation Plan may serve as the basis, being structured around smart (specific, measurable, accepted, realistic, and time-dependent) objectives. It puts forward four priority Innovation and Deployment Actions (IDAs):

- Fuel Cells for early markets
- Fuel Cells for Combined Heat and Power (CHP)
- Sustainable hydrogen production and supply
- Hydrogen vehicles and refuelling infrastructure

These would be complemented by a comprehensive programme of technology validation, life cycle analysis, pre-normative research in support of the development of standards, and integrated technical, social and economic assessments, for instance to analyse the effect on the workforce and society in general of the development of new industries related to fuel cells and hydrogen. To build critical mass in the European Research Area, the JTI would openly encourage participation from organisations in the new Member States and candidate countries and there would be close cooperation with other EU-level initiatives such as Intelligent Energy for Europe[37], the EIB financing of sustainable energy and low carbon solutions in developing countries[38], and the European Institute of Technology[39], as well as with national and regional-level actions. In a two-factor learning approach, the strategic coordination from fundamental research through to deployment projects would allow new findings to be fed back and forth between research and deployment. The key deliverables would be a new generation of fuel cell prototypes and demonstrators for testing and validation in transport, stationary and portable applications.

The industry participants in the HFP compiled an 'Industry Submission to the Impact Assessment of the Joint Technology Initiative on Fuel Cells and Hydrogen'[40], describing the 'key success factors' for the JTI, in terms of market failure, governance, and additionality.

Governance

The JTI would be established as an independent legal entity, a Joint Undertaking created under Article 171 of the EC Treaty. The Joint Undertaking would have a Governing Board and an Executive Director assisted by the staff of the Programme Office. The Governing Board would be composed of six members from the Board of the JTI Industry Grouping[41], and six representatives of the European Commission. The research community may also be represented in the board in the future, depending on the form and contribution these stakeholders may propose. The Programme Office would be responsible for issuing calls for proposals, as well as knowledge management and education, public outreach and dissemination activities. A Member States Group and a Scientific Committee would oversee the work of the JTI and ensure co-ordination between the JTI and other EC activities, and national and regional actions and transparency of its activities towards all stakeholders. The EC would maintain a right of veto concerning the use of its contribution to the Joint Undertaking.

Additionality

The JTI should lead to increased private investment in the research areas covered by the JTI, over and above existing investment. At the HFP General Assembly in October 2006[42], 48 industrial stakeholders from all over Europe issued a joint declaration stating their readiness to invest 5,000 M€ in hydrogen and fuel cell technologies over the next ten years. In their Declaration of Commitment of 18th June 2007[43], the members of the JTI Industry Grouping undertook to make their best efforts to achieve the goal of at least 3,200 M€ of

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37 Intelligent Energy for Europe – see http://ec.europa.eu/energy/intelligent/index_en.html.

38 EIB Energy Review – see www.eib.europa.eu/Attachments/thematic/energy_review_2006_en.pdf.

39 European Institute of Technology – see http://ec.europa.eu/education/policies/educ/eit/index_en.html.

40 HFP *Industry Submission to the Impact Assessment of the Joint Technology Initiative on Fuel Cells and Hydrogen*, February 2007.

41 JRC Institute for Energy *Report on the Hearing of the Hydrogen and Fuel Cells European Technology Platform*, 29 March 2007.

42 JTI – industry declaration; see https://www.hfpeurope.org/uploads/1857/HFP_GA06_PressRelease_05OCT2006.pdf

43 JTI Industry Grouping members - Declaration of commitment to the process of creating a Joint Technology Initative on Hydrogen and Fuel Cells, letter to the European Commission, 18th June 2007.

private investment during FP7, compared to 2,600 M€ without the JTI, representing an additionality of 600 M€ for the JTI period. In the industry submission to the Impact Assessment, the industry estimated that the JTI would accelerate market breakthrough by between 2 and 5 years.[44] The JTI would also have a crowding-in effect on nationally-funded programmes and private research investment, even to the extent of encouraging multi-national enterprises to maintain RTD efforts in the EU rather than move them elsewhere and promote inward investment from outside of the EU.

SECTION 6: ANALYSIS OF IMPACTS

Given the global scale of the challenge, the 'No EU action' and the 'Inter-governmental approach' have been discarded. The short-listed options are:

- the Joint Technology Initiative, and
- the Business-as-Usual FP7 plus national and regional effort, supported by a Technology Platform.

The comparison of impacts between Business-As-Usual and JTI which follows in this section is based on information gathered from the FP6 RTD Energy projects *HyWays*, *Roads2Hycom* and *WETOH*$_2$ and the HFP Technology Platform's Implementation Plan 2006 and the Industry Submission to the Impact Assessment of the Joint Technology Initiative, combined with the analysis contributed by the Peer Review Group. The quantification of impacts relies on applying the econometric and energy system models to specific scenarios, based on extensive stakeholder consultation and agreed projections for parameters such as population growth, GDP, oil price, transport demand, progress in technology learning, etc.

Modelling approach.

The analysis of economic, environmental and social impacts of fuel cells and hydrogen is largely based on the results of a number of EU funded projects.

WETO-H2 studies[45]

The WETO-H2 project studied the ***world*** energy outlook using the POLES energy model, returning projections for the world energy system, including prospects for hydrogen, out to 2050. POLES includes projections (differentiated by world regions) for growth in population, GDP, sectoral energy demand, energy price dynamics, resource constraints, technology prospectives. WETO-H2 explored three scenarios: 1) base case – continuation of current trends with "minimum" climate constraints; 2) carbon constrained case – increasingly aggressive policies designed to mitigate climate change, modelled by imposing escalating carbon value; 3) hydrogen case – resulting from technology breakthroughs that render hydrogen and fuel cells more competitive.

[44] p.21, *Industry Submission to the Impact Assessment of the Joint Technology Initiative on Fuel Cells and Hydrogen*, HFP, 31 January 2007.

[45] EUR 22038 — World Energy Technology Outlook - 2050 - WETO H2; Luxembourg: Office for Official Publications of the European Communities;2007;16 pp. ISBN 92-79-01636-9;ISSN 1018-5593.

HyWays Studies[46]

The HyWays project applied scenario analysis to explore future perspectives for hydrogen in the ***European*** energy system – again with a 2050 horizon. Whilst HyWays considered stationary and residential combined heat and power, the main emphasis was on hydrogen for transport. HyWays returned results for 10 European member states, covering 81% of land area and 71% of the population. The fundamental assumptions used for the energy system model (Markal) were based on "official" EU scenarios e.g. realisation of energy policy targets (eg renewables targets), oil reserves-to-production ratios, energy price evolution according to Energy Trends 2030, and WETO-H2 energy price updates. HyWays returned values for a least-cost mix of primary energy sources for hydrogen production – as well as estimates for economic, environmental and social impacts.

The scenarios investigated in HyWays were developed following extensive stakeholder consultation and 50 workshops in the 10 participating countries. Four scenarios were developed based on some combinations of modest, high, and very high policy support for hydrogen technologies with either modest or fast technology learning. These resulted in differentiated penetration rates for stationary and transport hydrogen fuel cell systems. The various stakeholder workshops identified a number of time-differentiated hydrogen production and distribution pathways – based on demand – and included in the earlier stages decentralised hydrogen production from fossil and renewables leading later on to large-scale hydrogen production from fossil sources with CCS, from renewable sources (especially wind and bio-mass) and nuclear. The scenario building included energy agencies from the participating countries, thereby enabling the application of appropriate constraints to the energy system model consistent with the foreseeable evolution from current national energy policies. Sensitivity analysis was carried out - applying different targets for carbon constraints and variations in oil and gas prices.

Calculations of the environmental impacts follow from the "optimum" mix of hydrogen primary sources returned by Markal. This enables estimates of avoided CO_2 and pollutant emissions for the four scenarios. The impact on air pollution is calculated using the COPERT model. For transport, only passenger cars and light duty vehicles were considered as there are lower expectations of using hydrogen for truck propulsion, though there are likely to be applications for Auxiliary Power Units. The calculations of CO_2 and pollutant emissions are on a well-to-wheel basis and taken from the E3 database, consistent with the widely accepted EUCAR/Concawe/JRC studies.

The results of the Markal energy system model for the four HyWays scenarios are adapted as inputs for macro and meso- level economic models – PACE-T and ISIS. This enabled development of corresponding scenarios for GDP Growth and employment creation / loss.

46 A full set of HyWays project deliverables, covering modelling approach, scenario analysis, and results is available at: http://www.hyways.de/.

Stakeholder survey on accelerative effect of JTI.

A strictly confidential survey of industrial stakeholders was carried out by the Technology Platform Secretariat in December 2006. The analysis was performed only for hydrogen fuel cell vehicles, as insufficient data was available on stationary applications of fuel cells.

The industrial questionnaires provided estimates for additional RTD investments that would result from the JTI[47]. Based on 65 responses to the survey, companies reported an average planned increase of 50% in their RTD expenditure over the seven year period of FP7. Conversely, some 60% of the respondents noted that they would decrease their planned RTD spend by 40% on average if there were no JTI. Aggregated over all respondents, the net additionality of the JTI would correspond to an RTD budget increase of 20%.

Companies also returned their views on whether the JTI would have a positive effect in bringing forward market breakthrough. Responses varied from 2 to 10 years with an average of 4.9 years, and thus it is reasonable to conclude that market breakthrough might be accelerated by between 2 and 5 years.

These data were introduced into the two-factor learning method, as developed in the Sapientia[48] project and implemented in Roads2Hycom, in order to simulate the overall economic impact of the JTI v no JTI.

Review of impacts

If appropriately structured, the JTI can leverage public funding at national level. It is envisaged to establish the JTI with as open a structure as possible – for linking national and regional initiatives where this is of mutual interest and benefit. Relevant areas would include safety, technology validation and sharing of results on a mutually agreed basis. In certain situations it could be envisaged that an EU-funded project could receive 'top-up' funding from a member state – to research or demonstrate technology that is complementary to an EU action. This could be relevant in the case of developing research infrastructure with shared access – e.g. safety testing facilities.

Major advantages would come from bringing all the RTD and demonstration effort under a common programme management. This would at once ensure a consistency of approach. It would avoid disjointed actions resulting from funding decisions that reflect different programme priorities. It also allows the pace of calls for proposals to be matched with the pace of development in the specific sectors and appropriate phasing of RTD with demonstration – allowing currently successful research to be incorporated into the next phase of demonstration. In addition, demonstrations can be planned with subsequent exploitation in mind and results can be fed back to ongoing research actions. Industry can

[47] Without the formal establishment of a JTI it is clearly not possible to establish financial commitments from potential partners to determine a really reliable figure for increased R&D investment. The data returned for increased R&D expenditure in the industry surveys are therefore indicative only.

[48] EC DG RTD Project ENK6-CT-2002-00615 'Sapientia' Systems Analysis for Progress and Innovation in Energy Technologies for Integrated Assessment see page 21 of http://ec.europa.eu/research/environment/pdf/socio_ec_projects_en.pdf.

also go to the Risk-Sharing Finance Facility (RSFF)[49] to seek loans for major deployment actions such as 'Lighthouse Projects'. On the other hand, there are risks of a loss of transparency and also of conflicts of interest for the industrial participants when selecting applicants for funding and when making choices between supporting near-market demonstrations and long-term, fundamental research.

The HFP Implementation Plan 2006 'Snapshot 2020'[50] foresees established markets by 2020 for portable and hand-held fuel cell powered devices, a growth market for stationary fuel cell systems and market roll-out for hydrogen fuelled light duty vehicles. The projections in 'Snapshot 2020' indicate a combined market value of fuel cells and hydrogen in 2020 of 20 to 45B€, depending on the range of market prices and market penetration.[51] The impact on reductions in CO_2 and pollutant emissions will depend heavily on energy pathway choice but there is strong potential, especially from the road transport sector. Portable and hand-held fuel cell powered devices will normally have a relatively small impact – even though very large numbers of units are projected and significant amounts of hydrogen will be required – estimated at 0.7 to 1M tonnes in 2020 to meet the 'Snapshot 2020' projections. Based on extensive consultation of energy utilities, energy companies, industrial gas companies, and the automotive and supplier industries, fuel cells and hydrogen will begin to have an impact on CO_2 from around 2020, saving about two or three years' worth of cumulative emissions by 2030. In urban environments, the effect on air pollutants such as CO, NOx and Particulate Matter (PM) would be more significant. The effect on employment could be up to half a million jobs gained or lost to the EU, depending on how much of the new market is taken by EU industry.

<u>Risk analysis</u>

Considering that the technology is at an early stage of development and the outcome of the research is uncertain, public and private investors look for some assurance that the benefits generated by the initiative are likely to offset the costs of the RTD phase. As an example, the Peer Review Group has assessed[52] for the transport sector i) the likelihood of reaching the 'Snapshot 2020' targets and ii) the economic viability of the JTI.

i) Using data from the HyWays project, a probabilistic model has been built to assess the potential impact of the JTI on market penetration, emission reductions and energy costs at time horizons between 2020 and 2050. The analysis takes into account the following sources of uncertainty: the degree of policy support, fuel cell system cost, and the prices of hydrogen and oil at the pump. The results give some confidence in the feasibility of reaching the 'Snapshot 2020' targets. The analysis predicts that the most likely outcome in the year 2020 will be an EU transport fuel cells market worth about 8.6 B€ (corresponding to 1.5% of the total fleet and to a reduction of CO_2 emissions worth 0.5 B€). The analysis also emphasizes the importance of strongly involving Member States during the JTI in

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49 Risk Sharing Finance Facility - a joint initiative of the European Investment Bank (EIB) and the European Commission to improve access to EIB debt financing for participants in large-scale European RTD projects.

50 European Hydrogen and Fuel Cell Technology Platform – Implementation Plan; see https://www.hfpeurope.org/hfp/keydocs;

51 Combined data from 'HyWays' DG RTD FP6 Energy project – http://www.hyways.de/ and HFP Implementation Plan https://www.hfpeurope.org/hfp/keydocs

52 *Risk and Real Options Analysis of the Innovation and Deployment Action 1 on Road Transport in the HFP Implementation Plan.* Prof. L. Paganetto & Dr. S. Stefanoni, Univ. Roma "Tor Vergata", June 2007.

order to strength their commitment in view of the deployment phase beyond 2020. With appropriate policy support, the market value could reach 118 B€ by 2050 (corresponding to 70% of the total fleet and CO_2 emission reductions worth 33B€).

ii) Like all long-term RTD&D programmes, the outcome of the JTI is subject to a high level of uncertainty. Its economic viability has therefore been evaluated using Real Options Analysis (ROA), which is able to factor in the uncertainties in the RTD&D phase. Two scenarios were considered, one where the JTI would bring forward the market introduction by five years, and one in which the timing would not be affected. In both cases, the JTI would be economically viable, in terms of its benefits to society, with an expanded net present value[53] (ENPV) of the order of 20 to 35[54] B€ depending on the timing of market entry. These results indicate that the benefits generated by the initiative would more than offset the investment costs.

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53 Expanded Net Present Value (ENPV) gives the discounted value of the investment taking into account all the options related to the project. Committing resources to the JTI in FC and Hydrogen today will give EU industry the option to deploy the new technology in the future.

54 The data are for the transport sector alone.

The following table compares Business-as-Usual with the JTI in terms of their relative impact on inputs to RTD&D management and short and long-term economic, environmental and social impacts[55]:

Impacts	Business-As-Usual	JTI
Impacts on the management and implementation of the RTD&D		
Governance	Management responsibility split between different FP7 themes, with annual Work Programmes. Fragmentation of RTD across a number of different national and regional schemes and different FP7 themes, each with different priorities - separate schemes and uncoordinated calls for training, energy, transport, materials and environment. Lack of strategic focus on the specific sector. Industry not involved in management of the overall RTD action. Limited coordination with national and regional actions.	JTI governance gives industry the lead role in defining priorities and timelines, in consultation with the research community and the European Commission. This will include a mechanism for carrying through a programme of fundamental research to take advantage of research capacities in universities and research centres. Single management structure to mobilise in a single legal entity all the funds assigned to the programme from the public and the private sectors: consistency of approach from research through to deployment. Multi-annual sector-specific integrated research, development, & demonstration, strategically managed by industry and the EC. Coordination between EC, national and regional programmes.
Additionality	Uncoordinated private research investment of 2,600 M€ during the period of FP7.	An increase of private research investment from 2,600 M€ to more than 3,200 M€ - an additionality of about 600 M€ for the JTI period[56,] with more effective, coordinated public research investment. The co-financing principle will leverage additional private research investment and crowding-in of new industrial investors. Its size and visibility should promote inward investment and encourage multi-nationals to maintain RTD effort in the EU. The JTI should make investment in these technologies more attractive to venture capitalists.

[55] *Impact Matrix of JTI compared to Business as usual: FP7 with national and regional actions*, N. Lucas, 2007.

[56] JTI Industry Grouping members - Declaration of commitment to the process of creating a Joint Technology Initative on Hydrogen and Fuel Cells, letter to the European Commission, 18th June 2007.

Industrial involvement	HFP can continue to provide advice on topics for annual work-programmes and stimulate proposals that reflect industrial priorities, as in latter stages of FP6 and beginning of FP7.	The Industry Grouping strategically manages the JTI, with a mechanism to allow new industry partners, including SMEs, to join the Industry Grouping.
Funding budget	No ring-fenced funding for a specific technology. Work programme topics decided annually, leading to uncertainty as industry cannot plan RTD investment more than one year ahead.	Pre-defined budget of sufficient critical mass and 6-year time horizon raises confidence in private sector investors and allows industry to make long-term investment plans and manage its cash flows. Ring-fenced budget reduces opportunities for re-allocation of funds to other areas of FP7.
Administrative costs	The administrative costs for the Commission pertaining to Framework Programme RTD projects are limited to 6 % of the research budget.	In the FCH Joint Undertaking the selection, award, follow-up etc. of the research activities will be performed by the Programme Office within the Joint Undertaking. The costs are estimated to be limited to 4 – 4.5 % of the project funding. These running costs are furthermore shared with the Industry Grouping on a 50/50 basis. In addition to the costs in the Joint Undertaking very limited resources are taken from within the Commission amounting to 2-3 FTE AD/AST officials, mainly for internal auditing and coordination of the Commission's responsibility in the Governing Board.
SMEs		13 companies out of the 45 founding members of the Industry Grouping were SMEs. The Industry Grouping is open to new members and the Industry Grouping is actively encouraging more SMEs to become members by giving a lower membership fee for SMEs; One seat in the Governing Board of the Joint Undertaking is reserved for SMEs; SME participants in JTI research activities are planned to be funded at higher percentage rate than large industrial participants.

Implementation	Bottom-up implementation by project participants, monitored by the EC. Limited flexibility in funding schemes.	Scope for more dynamic and efficient implementation as the JTI implements the strategy it has itself designed, making for more efficient, lean, flexible management and control. The pre-competitive RTD&D programme goes from fundamental research through to large-scale demonstration, including socio-economic research and pre-normative research in support of the development of standards essential to strong & effective competition and wide market potential.
Two-factor learning[57]	Limited possibilities to feed back results from demonstration actions to re-focus research priorities and vice versa since the projects are under separate EC management and budgets.	RTD and demonstration projects integrated under common management, enabling two-factor learning where the coordinated RTD&D programme allows new findings to be fed back and forth between research and demonstration, accelerating the pace of learning and moving faster along the experience curve.
Track record	The RTD Framework Programme is well-established and well-understood by industry and the research community and its worth has been proven over time.	New, unproven concept. An exit strategy and a means of re-adjusting interim targets and implementation plans will be foreseen in case the JTI wholly or partly fails to meet its strategic objectives.
Procedures	Openness and transparency of RTD Framework Programme. Perceived heavy administrative burden associated with proposal preparation, contract negotiation and reporting.	JTI would also apply FP7 principles of openness and transparency and respect the provisions of the Financial Regulation, but the approval circuit would be shorter and involve fewer decision-makers, allowing for streamlined procedures and faster project selection, contract negotiation and follow-up.
Project selection	Respected peer review process. Proposal selection based on open competition between technologies. Emphasis on scientific quality and technical excellence more than realisation of a strategic portfolio according to industrial priorities, hence a risk of technology gaps. Best adapted to evolutionary development of mature technologies or, conversely, stimulation of technology breakthroughs.	JTI governance will be designed to control decision-making when selecting projects to be funded to avoid conflicts of interest in industry, for instance between short-term commercial gains & the longer-term public good. Difficulty in striking correct balance between top-down and bottom-up strategy – can inhibit innovation and result in lock-in to unpromising technology.

57 FP6 DG RTD Energy project 'Roads2HyCom'.

Intellectual property rights	Well-established IPR regime.	The IPR rules should accommodate the interests of a wide range of stakeholders from large enterprises to SMEs to researchers in different application sectors.
Accountability	Budget was approved through FP7 decision. Calls approved by Programme Committee set up under Comitology.	The application of FP7 principles and the Financial Regulations will ensure accountability.
Support to European Research Area	ERA not yet realised between EC and national and regional RTD programmes – fragmentation, duplication of effort, and poor knowledge exchange prevail.	Strengthening the European Research Area (ERA) through an open structure ensuring effective coordination between the JTI, other EC initiatives, and national and regional actions. Greater scope and flexibility to associate projects in member states and regions. Coordination with other relevant European initiatives including the Technology Platform on Carbon Capture and Storage, the EIT European Institute of Technology, & Intelligent Energy for Europe.
RSFF Risk-sharing Finance Facility		Planned 'lighthouse projects' with debt financing (RSFF) leveraging additional private funding.
New Member States	Level of participation depends on success of proposals in Calls for Proposals.	Focussed efforts to encourage the participation of companies from New (EU-12) Member States in the Industry Grouping, as well as in Calls for Proposals.

Longer-term economic impact

The longer-term effects would eventually be seen with the JTI and Business-As-Usual but with a time delay as mentioned in the introduction to this section. The JTI should also reduce the risk of not achieving these objectives. Achievement of the goals is also dependent on other factors and policies beyond the scope and control of RTD policy decisions.

Overall economic benefit to society		The overall economic benefits to society would potentially be of the order of tens of billions of euros over the period 2025 to 2050.

Competitiveness, investment & consumers	Shorter time to market by 2 to 5 years[58], with cumulative investment costs reduced by about 20-30%, bringing forward the break-even point, bringing down unit costs, and strengthening the competitive position of early market entrants. The JTI would encourage private investors by showing leadership & the confidence of the EC & industry in the technology.
Energy imports & security of energy supply	Earlier reduction in oil imports for transport, since hydrogen can be produced from a wide range of primary energy sources, also giving greater price stability.
Relations with third countries & international cooperation	The higher visibility of the JTI provides a focus for promoting relationships and international cooperation with North America, Japan, Russia, China, Asia and also with developing regions. Greater assurance that international standards will be put in place to promote competition and facilitate exports to and imports from global markets. Cleaner, more sustainable energy solutions can be made available for developing countries, for instance through EIB financing of sustainable energy and low carbon solutions in developing countries.

Longer-term environmental impact

The longer-term effects would eventually be seen with the JTI and Business-As-Usual but with the aforementioned time delay. The JTI should also reduce the risk of not achieving these objectives. Achievement of the goals is also dependent on other factors and policies beyond the scope and control of RTD policy decisions.

Climate change and air quality	Saving about two to three years' worth of cumulative greenhouse gas emissions and air pollutants by 2030 through the substitution of fossil fuels by renewables in the production and end-use pathways, higher efficiencies and hence reduced fuel consumption. Maximum benefits would be achieved with the parallel introduction of carbon capture and storage (CCS). Atmospheric concentration of hydrogen would increase with large scale

58 p.21, *Industry Submission to the Impact Assessment of the Joint Technology Initiative on Fuel Cells and Hydrogen*, HFP, 31 January 2007 and two-factor learning approach.

deployment of hydrogen as a consumer fuel; hydrogen networks will suffer leakage and evaporative losses; hydrogen is known to affect greenhouse gas burden; studies show negative effects of hydrogen as a GHG, but modelling indicates these effects are small compared to the benefits[59];

Water vapour is a significant combustion product of conventional systems so fuel cells should not significantly disturb the water vapour cycle[60]; increases in local relative humidity can have affects on local and regional climate; releases of water vapour at high altitude (e.g. if aircraft were fuelled by hydrogen) may affect global warming;

More in-depth technology assessment recommended as part of JTI and to monitor and stimulate progress to sustainable hydrogen systems;

Potential major positive impact on air quality, because of higher efficiency of fuel cells and electro-chemical conversion as opposed to combustion, leading to reduced NOx, benzene, VOCs and pm; depending on relative concentration of these species this could lead to a transient increase in ground level ozone, but a long term decrease;

Some pathways could lead to negative impacts; e.g. hydrogen produced by electricity from coal without clean-up technologies could lead to significant increases in NOx and SOx, with consequential impacts on acidification and eutrophication; the JTI must analyse and monitor options in greater depth;

Emissions from large centralised hydrogen production processes are easier to control than individual (ageing) vehicles or domestic heating systems;

Hydrogen vehicles are zero (pollutant) emission vehicles, emitting only water vapour at point of use – positive impact especially on urban air quality; may be

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59 Riso Energy Report 3;"Hydrogen and its competitors" Ed H Larsen, R Feidenhans and L Sonderberg Petersen; ISBN 87-550-3349-0

60 see "Hydrogen Cars and water vapour" Letter *Science* 21 November 2003: Vol. 302. no. 5649, p. 1329, at http://www.sciencemag.org/cgi/content/full/302/5649/1329b?ck=nck

	especially significant for reducing pollution from 2-wheelers.
Mobility (transport modes) and the use of energy	First effects would be seen earlier in niche markets such as fleets of light-duty vehicles. Mass market penetration is dependent on other policies, consumer choice, and investment in infrastructure.
Water quality and resources	Potential positive impact resulting from reduced use of fossil fuels in road transport – resulting in less polluted rain-water run-off and consequential groundwater pollution; reduced transhipments of crude oil reduces risk of major sea-water pollution incidents; Significant hydrogen production by electrolysis will place large demands on water resources, implying major installations will need access to large water resources – e.g. for seawater de-salination, energy is required for electrolysis but energy consumption is small in relation to the energy content of the hydrogen produced.
Soil quality and resources	Little appears to be known about soil uptake of hydrogen or its effect on soil quality and further study is needed; No foreseeable impact on soil resources.
Renewable or non-renewable resources	Hydrogen, being a secondary carrier, should be developed in complement to RES – including solar, wind, ocean; electricity will be the preferred carrier under circumstances where a robust grid connection is possible; Europe has very substantial RES capacity much of which is remote, or isolated (e.g. wind, ocean); Hydrogen is one of the few options to introduce RES into the transport energy chain;

	Only one carrier (hydrogen) infrastructure need be developed to accommodate a mix of both RES and non-renewable sources[61]; The opportunity to distribute hydrogen mixed with natural gas in local natural gas networks can partly offset the added cost of a separate hydrogen distribution infrastructure, though there are safety and gas quality implications[62].
Biodiversity, flora, fauna, and landscapes	No direct impact foreseeable, though the effect of hydrogen uptake in soil seems not well understood; Indirect impact depends on hydrogen production routes and the extent of land used for biomass production or wind or solar farms; Similar indirect effect on landscapes or seascapes in the case of off-shore wind hydrogen.
Land-use	Indirect effect, depending on the choices for hydrogen production pathways; massive production from bio-mass leads to essentially similar and competing demands on land-use as for bio-fuels and materials produced from bio-mass; Massive on-shore wind farms / solar thermal energy collection can substantially increase productivity of otherwise marginal land.
Waste production/ generation/recycling	Again dependent on hydrogen production/ pathway choices; Massive centralised hydrogen production from fossil primary energy with CCS leads to the need for disposal of massive quantities of carbon dioxide; there are varying views on capacity and security for sequestering CO_2 in geological structures such as depleted gas/oil wells, saline aquifers, deep ocean;

61 HyWays project stakeholder consensus on evolution of the hydrogen primary energy source mix for 10 EU member states for 2050.

62 Currently under investigation in the EU funded contract NATURALHy – see http://www.naturalhy.net/start.htm.

	Mineralisation of CO_2 could lead to major disposal problems; Similarly hydrogen production from nuclear energy (thermal or electrical) may allow optimal, steady-state plant operation - hydrogen being produced during periods of reduced electricity demand - but would clearly generate additional radio-active waste, and demands for waste processing; Recycling will be an important element of recovery of precious metal catalysts from fuel cells and hydrogen fuel processors; this is essential to maintain precious metal prices at affordable levels.
Likelihood and scale of environmental risks	The IPCC[63] has demonstrated the potentially catastrophic consequences associated with climate change; it is no longer avoidable; effort must be concentrated on damage limitation – i.e. mitigation and adaptation; mitigation strategies need to be developed which provide the most cost-effective routes to achieving environmental and economic targets; being secondary carriers, hydrogen and electricity increase the flexibility to continuously adapt and maintain secure supply and stable energy prices; Large impact on mitigation is foreseeable but only in the medium to long term – at which point hydrogen from various sources will have to help make up the shortfall beyond peak oil and peak gas production –especially in transport.
Environmental consequences of firms' activities	Impact will be largely confined to consumption of energy and benefits / drawbacks described above apply to firms' energy consumption.
Animal and plant health, food and feed safety	Positive health impacts should arise from improved air quality and reduced water pollution; No perceived effect on safety of food and feed.

63 IPCC – Intergovernmental Panel on Climate Change.

Longer-term social impact

The longer-term effects would eventually be seen with the JTI and Business-As-Usual but with the aforementioned time delay. The JTI should also reduce the risk of not achieving these objectives. Achievement of the goals is also dependent on other factors and policies beyond the scope and control of RTD policy decisions.

Consumers and households	Greater choice for householder regarding more efficient and more sustainable home heating, electricity, air-conditioning and personal transport; Long-term benefits to consumers and society alike in terms of enhanced energy sustainability; Hand-held and portable fuel cell and hydrogen-powered energy systems will normally offer significantly enhanced autonomy and more convenient refuelling compared to advanced batteries and re-charging; however advanced (especially lithium) batteries are likely to maintain significant market share in small, price sensitive applications.
Employment and labour markets	The JTI would create the conditions for a strong EU industry to be first to market with new products with high export potential, able to compete on the world stage. This should result in earlier growth & a net gain of up to half a million jobs, but if the EU fails to acquire this technology and has to import it, these jobs could be lost[64]; Significant new education and re-training will be needed as some traditional skills associated with design, manufacture, installation, repair and maintenance of equipment, infrastructure and safe operation will be replaced by different requirements; No perceived effect on the functioning of the labour market

64 Results from HYWAYs socio-economic model.

Specific regions and sectors	All regions and sectors are likely to be affected to a greater or lesser extent; Main sectors affected will be energy producers, utilities, industrial gas companies, OEMs in the auto, Light Duty Vehicles, bus and two-wheeler sectors, small and large energy equipment manufacturers, auxiliary power units, portable and hand held devices, and to a lesser extent, trucks, guided rail vehicles, ships and aircraft (though these may be an important premium market); Other sectors include more "niche" applications fork lifts, neighbourhood vehicles, wheelchairs, pleasure craft, golf-carts; Transport, industrial and domestic end-users of energy; Regions most affected will be those that host the above manufacturing industries or their suppliers – they have to adapt or compete with new fuel cell technologies; Regions with conventional or alternative energy resources and capacities will be affected – hydrogen being a secondary carrier creates opportunity for cleaner conventional energy sources and renewable energy- this in an era when limitations on peak energy production may threaten energy security.
Public authorities	No direct budgetary or structural consequences for public authorities; A recent survey indicates significant interest amongst city and regional authorities throughout Europe to establish fuel cell and hydrogen projects to demonstrate their potential to improve energy utilisation and reduce pollution; these regional initiatives reflect specific regional capacities (e.g. renewable energy sources) and competencies[65]

65 The Roads2HyCom project has registered 117 expressions of interest relating to "hydrogen communities" of which 67% are existing projects; 33% planned; 88% of these involve government offices or regional/local authorities; see "Report on first results from communities registration" at http://www.roads2hy.com/pub_download.asp.

The macro-economic environment	Econometric modelling indicates the potential for a significant increase in economic growth – in the order of +0.5%GDP by 2030 ~= 0.5t€ for EU25[66]; the effect is likely to be more as the model does not take account of stationary natural gas-fuelled fuel cell systems; The economic losses that could arise from disruptions to energy supply and climate change are potentially several trillions of euros[67] – the results of inability to plan, resource, and build sufficient alternative energy capacity, natural disasters, desertification, civil unrest and even resource wars; hydrogen and fuel cells are part of the portfolio of technologies that will be needed to combat these most serious threats
Standards and rights related to job quality	Survey of operation of hydrogen fuel cell bus fleets shows positive impact on motivation and interest at all levels of employment, due to perceived high-tech image, coupled with positive environmental impact; this is probably only a fairly short term "early adopter" effect; Substantial obligations to acquire new knowledge, new skills; Safety risks different to conventional technology, but considered manageable, especially in a well-controlled work environment; there would need to be EU safety standards for the work environment; Should facilitate structural changes due to creation of attractive high tech jobs.

[66] Results from MATISSE project based on assumption that EU maintains same external balance of trade in hydrogen and fuel cell technologies as it currently has for conventional technologies; HyWAYs project shows a 0.2% increase in GDP for EU10 in 2050 – both compared to the reference case of no hydrogen vehicles; stationary hydrogen fuelled fuel cell systems are not predicted to make a big impact; model does not take into account potential of natural gas fuel cell systems.

[67] Stern review on the economics of climate change, HM Treasury, 2006; http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

Social inclusion and protection of particular groups	No specific issues not covered under other impacts
Equality of treatment and opportunities, non-discrimination	Potential for some social inequality as technology likely to be more expensive for early adopters; policy measures such as discriminatory road pricing for lower polluting vehicles may lead to life cycle cost advantage denied to those unable to afford first cost.
Private and family life, personal data	No foreseeable effects
Private and family life, personal data	No foreseeable effects
Public health and safety	Positive impacts on health, longevity and overall security resulting from positive contributions to improving air quality and mitigation of climate change; Modest reduction in road transport noise through quieter, near silent propulsion; Operational safety of vehicles and equipment leads to safety risks of a distinctly different nature compared to conventional combustion technologies; Public perception of safety of hydrogen is poor and surveys show that the public has a poor understanding of risks – making incorrect associations with the hydrogen bomb; in fact hydrogen is in some ways safer and in some ways more dangerous than conventional energy carriers, all of which carry risk; merchant hydrogen is routinely handled in massive quantities in the petro-chemical, fertilizer, and space industry and has an excellent safety record; There are safety risks and these need to be managed; the JTI will place considerable emphasis on analysis and monitoring safety associated with all aspects of the hydrogen value chain; International regulation and safety standards are required for stationary, transport

	and portable applications of hydrogen and fuel cells – the JTI will co-ordinate European pre-normative research efforts and participation in international standards-making.
Crime, terrorism and security	All large energy production facilities and distribution systems are potential targets; Hydrogen when produced from sustainable sources and used in fuel cells is likely to lead to a more distributed generation reducing to some extent the security threat – both in terms of direct casulties and through disruption to energy supply

Potential obstacles to the market breakthrough of fuel cells and hydrogen

The potential impact of fuel cells and hydrogen cannot be realised through RTD effort alone - public policies in the fields of energy, transport, the environment, and standards and private sector support for a long-term industrial strategy will need to follow compatible aims. Whilst workable solutions have been demonstrated, significant technological breakthroughs to overcome current problems of cost, durability and performance would substantially improve the market prospects for these technologies and the EU market share; overcoming these is the very reason for the JTI. Modest policies to internalise at least some of the external costs will ease market introduction. For instance, sensitivity analysis in the HyWays project indicates that for transport applications, the cost of the fuel cell drivetrain is far more critical to market penetration than factors such as oil and gas prices or carbon pricing; a tax break on fuel cell vehicles to take account of avoided externalities would have a strongly positive effect on early market entry. Existing industrial structures and value-chains need to adapt and new industries need to be established and grow, entailing education and re-training of the workforce. Public acceptability has to be achieved through information and dissemination of knowledge, for instance over safety and welfare concerns. To this end, a new safety and regulatory environment is currently being developed. International standards have to be agreed to support fair competition in a global market. Large investments from the public and private sectors will need to be made to adapt infrastructure to the new technology.

SECTION 7: COMPARING THE OPTIONS

In making the comparison, it is assumed that the budget devoted to fuel cells and hydrogen from FP7 will be broadly similar, whichever option is chosen. The key difference being that with a JTI, the budget would be pre-defined and set aside for the specific purpose and under the control of a single body, the Joint Undertaking. Going ahead with the JTI option would show decisiveness on the part of the EU and demonstrate leadership and determination to take the development of fuel cells and hydrogen seriously, engendering the confidence of the research community and industry and encouraging private investment into the sector. The table of impacts for JTI and B-A-U in the previous section points to the significant advantages of a JTI over the usual Framework Programme, national and regional programme approach.

The stable funding regime, critical mass, and a focused, target-driven multi-annual research programme, evolved through extensive stakeholder consultation in the HFP, is more attractive to industry and the research community. The two-factor learning effect is unique to the JTI: on the one hand, knowledge gained from deployment experience is fed back to research and on the other hand, new research findings are fast-forwarded for trials in demonstration projects. The additionality effect would provide significantly higher funds to the RTD&D programme and would feed through to more rapid technology development, earlier achievement of technological and cost targets, faster time to market and lower cumulative development costs. The focus provided by the JTI will attract industrial commitment and investment, build a critical mass of researchers and give confidence to the financial community. The public-private partnership structure should act as a catalyst to Europe's emerging equipment industry and energy supply chains to develop technology for fuel cells and hydrogen. A light, efficient governance structure should direct JTI operations covering the entire spectrum of activities from fundamental research through to demonstrations. The JTI should also enhance opportunities for international collaboration, for example by acting as a European focal point.

Conclusion:

The Joint Technology Initiative has a number of clear advantages over the Business-as-Usual FP7 alternative:

- time to market shorter by between 2 and 5 years - the importance of being first in a new market cannot be over-emphasised, and pays off in reducing the cumulative investment, bringing forward the break-even point, and strengthening the competitive position of the early market entrants, of which many could be SMEs;

- long-term commitment and a clear-cut budget encourage confidence in public and private investors;

- additionality: the co-financing principle will leverage at least 600 M€ more than Business-as-Usual, corresponding to almost two and a half times as much private research investment;

- making correspondingly earlier gains on improving energy efficiency and security of supply and reducing greenhouse gases and pollution.

An increase in R&D expenditures as induced by the JTI compared to Business-as-Usual has the potential to reduce the time to reach the break-even point by 2–5 years and reduce the cumulative costs by about 20-30%. The positive effects on EU competitiveness in the short, medium and long term would, as indicated by model simulations, be accompanied by an order of magnitude of tens of billions of euros of benefits to the public good in reductions of greenhouse gases and pollution, improved security of energy supply, more sustainable transport, and higher efficiency and cleaner energy production and end-use over the period 2025 to 2050.

The challenges are greater but the potential benefits correspondingly higher, and this is why the Fuel Cells and Hydrogen activity has been selected as one of the first energy and transport technologies to be proposed for a Joint Technology Initiative.

SECTION 8: MONITORING AND EVALUATION

The Financial Regulation and its Implementing Rules require the Commission to carry out an 'ex-ante evaluation' for all programmes and activities entailing significant spending. This impact assessment has been performed with the objective to address *i.a.* the provisions of Article 21(1) of the Implementing Rules of the Community Financial Regulation within the Impact Assessment, thus providing an ex-ante evaluation for the FCH JTI. In particular cost-effectiveness, risks and monitoring have been addressed.

A set of quantitative and qualitative performance indicators will be established to follow the implementation of the FCH JTI. These performance indicators will measure the impact of the JTI on EU competitiveness and the research environment for fuel cells and hydrogen. The quantitative indicators will be measured on a large scale in a comparative and systematic manner, while the qualitative approach will include case studies and technical audits. The indicators should be assessed against the baseline of the state of affairs in the years prior to the start of the JTI to help assess additionality effects during its lifetime.

The progress and efficiency of the JTI will be closely monitored at different levels. Besides an ongoing, internal monitoring by the executive management, the Commission will present to the European Council an annual implementation report including a report on the state of progress of the JTI and on its financial position. In support of the European Research Area objective, a series of peer review conferences open to the whole research and industrial community could be established to encourage exchange of information and help coordinate activities between the JTI, other EC initiatives, and national and regional and private actions. In particular, the Executive Director will monitor public and private financing and will have the responsibility to take corrective action to maintain the 50/50 funding balance.

The progress of the JTI will be continuously monitored against a set of Objectively Verifiable Indicators (OVI) including:

- monitoring of public (EC and other) and private funding
- estimation of additionality;
- selection of projects and allocation of funding;
- technical monitoring against well-defined specific programme milestones;
- adherence to time schedule;
- quantified monitoring of market penetration in target sectors;
- level of SME participation and benefits;
- level of participation from the newer Member States;
- sustainability indicators;
- safety screening;
- development of codes of good practice.

In addition, qualitative monitoring will be carried out on other important aspects such as:

- openness and transparency of procedures;
- coordination between JTI, other EU initiatives, and national and regional actions;
- avoidance of conflict of interest;
- financial auditing;
- monitoring of good governance.

At mid-term, the JTI will be evaluated by independent experts on behalf of the Commission. This evaluation will cover the quality and efficiency of the Joint Undertaking and its progress towards its objectives and make recommendations for any necessary re-adjustment of the programme and if applicable, consideration of an exit strategy. The Commission will communicate the conclusions of the evaluation to the Council. At the end of 2017, the

Commission will conduct a final evaluation of the Joint Undertaking and the results will be presented to the European Parliament and the Council.

Review by the Impact Assessment Board

The Commission's Impact Assessment Board received the Impact Assessment on 4 July 2007 and provided its opinion on 27 July 2007.

The Impact Assessment Board also provided a number of useful recommendations for improvements. In particular more details were added to the economic, social and environmental impact section and the main text was completed with some key results of the external studies and projects that contributed to the work. As to the option of intergovernmental research programme some elements to clarify its consequences were added. A number of clarifications pertaining to the risk analysis and additionality were also introduced in the final version together with some additional details on the administrative costs.

As to the procedural issue it has also explicitly been stated that this Impact Assessment is to be considered as a complete ex-ante evaluation as provided for in the Implementing Rules of the Community Financial Regulation.