European Commission

Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe

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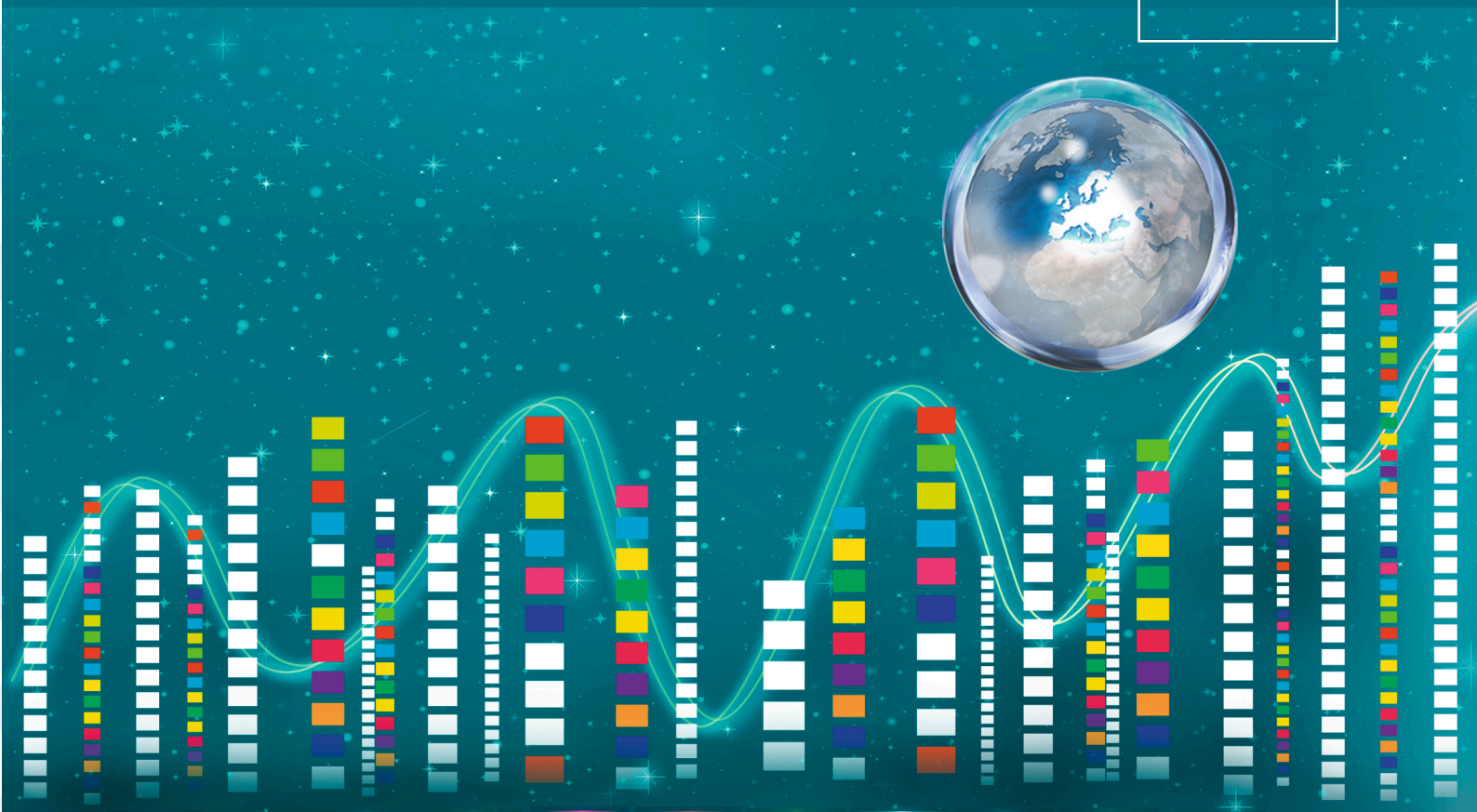
Report



Research and Innovation

Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe

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EUROPEAN COMMISSION

Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe

In collaboration with

2020 Directorate-General for Research and Innovation EN

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Introduction

This Impact Assessment Study had the primary objective to support and provide input to the impact assessments of the first set of 13 European Institutionalised Partnerships based on Articles 185 and 187 of the Treaty on the Functioning of the EU (TFEU) that are envisaged to be funded under the new Framework Programme for Research and Innovation, Horizon Europe.

In addition, the Impact Assessment Study team contributed to future European policymaking on the overall European Partnership landscape by means of a horizontal analysis of the coherence and efficiency in the implementation of European partnerships. The purpose of this analysis was to draw the lessons learned from the implementation of the impact assessment methodology developed for this study and to formulate recommendations for the refinement and operational design of the criteria for the selection, implementation, monitoring, evaluation and phasing-out for the three types of European Partnerships. Finally, an impact modelling exercise was conducted in order to estimate the potential for longer-term future impacts of the candidate Institutionalised European partnerships in the economic and environmental sustainability spheres.

Technopolis Group was responsible for the overall coordination of the 13 specific impact assessment studies, the development of the common methodological framework, and the delivery of the horizontal analysis. It also conducted specific analyses that were common to all studies, acting as a 'horizontal' team, in collaboration with CEPS, IPM, Nomisma, and Optimat Ltd. For the implementation of the individual impact assessment studies, Technopolis Group collaborated with organisations that are key experts in specific fields covered by the candidate Institutionalised European Partnerships. These partner organisations were Aecom, Idate, Steer, Think, and Trinomics. Cambridge Econometrics took charge of the impact modelling exercise.

The Impact Assessment Study was conducted between July 2019 and January 2020. The 13 Impact Assessment Studies were conducted simultaneously, based upon a common methodological framework in order to maximise consistency and efficiency. The meta-framework reflected the Better Regulation Guidelines and operationalised the selection criteria for European Partnerships set out in the Horizon Europe Regulation. The 'Horizontal analysis of efficiency and coherence of implementation' was conducted in the same time period, building upon the information available on the 44 envisaged European Partnerships landscape as in May 2019, complemented with information on five envisaged European Partnerships as decided by the European Commission in October and November 2019.

This final report contains the reports of all individual impact assessment studies and the 'horizontal' analyses. It is structured in two parts, reflecting the two strands of analysis:

PART I. Impact Assessment Studies for the Candidate Institutionalised European Partnerships

1. Overarching context to the impact assessment studies

This report sets out the overall policy context and methodological framework underlying the impact assessment studies for the candidate Institutionalised European Partnerships. It describes the changes in approach to the public-private and public-public partnerships under Horizon Europe compared to the previous EU Framework Programmes. An example is the requirement that all envisaged European Partnerships be implemented as either co-programmed, co-funded or institutionalised. The impact assessment studies will consider these three scenarios as the different options to be assessed, in compliance with the Better Regulation guidelines and against the functionalities that the candidate partnerships are expected to fulfil. The report describes the common methodological framework to assess the envisaged initiatives accordingly. The report also presents the landscape of European Partnerships at the level of Horizon Europe Pillar 2 clusters, which lay the grounds for all

of the impact assessment studies except the candidate Institutionalised European Partnership for Innovative SMEs.

2. EU-Africa Global Health Candidate Institutionalised European Partnership

This initiative focuses on research and innovation in the area of infectious diseases, with a particular focus on sub-Saharan Africa. It will address the challenges of a sustained high burden of infectious diseases in Africa, as well as the (re)emergence of infectious diseases worldwide. Its objectives will thus be to contribute to a reduction of the burden of infectious diseases in sub-Saharan Africa and to the control of (re)emerging infectious diseases globally. It will do so through investments in relevant research and innovation actions, as well as by supporting the further development of essential research capacity in Africa. The study concluded that an Institutionalised Partnership under Art. 187 of the TFEU is the preferred option for the implementation of this initiative.

3. Candidate Institutionalised European Partnership on Innovative Health

This initiative focuses on supporting innovation for health and care within the EU. It will address the EU-wide challenges raised by inefficient translation of scientific knowledge for use in health and care, insufficient innovative products reaching health and care services and threats to the competitiveness of the health industry. Its main objectives are to create an EU-wide health R&I ecosystem that facilitates translation of scientific knowledge into innovations; foster the development of safe, effective, patient-centred and cost-effective innovations that respond to strategic unmet public health needs currently not served by industry; and drive cross-sectoral health innovation for a globally competitive European health industry. The study concluded that an Institutionalised Partnership based on Article 187 of the Treaty on the Functioning of the EU (TFEU) is the preferred option for the implementation of this initiative.

4. Candidate Institutionalised European Partnership in High Performance Computing

The initiative focuses on coordinating efforts and resources in order to deploy a European HPC infrastructure together with a competitive innovation ecosystem in terms of technologies, applications, and skills. It will address the challenges raised by underinvestment, the lack of coordination between the EU and MS, fragmentation of instruments, technological dependency on non-EU suppliers, unmet scientific demand, and weaknesses in the endogenous HPC supply chain. The initiative has as its main objectives to enhance EU research in terms of HPC and related applications, continued support for the competitiveness EU HPC industry, and fostering digital autonomy in order to ensure long-term support for the European HPC ecosystem as a whole. The study concluded that an Institutionalised Partnership is the preferred option for the implementation of this initiative as it maximises benefits in comparison to the other available policy options.

5. Candidate Institutionalised European Partnership in Key Digital Technologies

This initiative focusses on enhancing the research, innovation and business value creation of European electronics value chains in key strategic market segments in a sustainable manner to achieve technological sovereignty and ultimately make European businesses and citizens best equipped for the digital age. It will address the risks of Europe losing the lead in critical industries and services and emerging KDTs. It will also tackle Europe's limited control over digital technologies that are critical for EU industry and citizens. It has as main objectives to strengthen KDTs which are critical for the competitive position of key European industries in the global markets, to establish European leadership in emerging technologies with high socioeconomic potential and to secure Europe's technological sovereignty to maintain a strong and globally competitive presence in KDTs. The study concluded that the Institutionalised Partnership is the preferred option for the implementation of this initiative.

6. Candidate Institutionalised European Partnership in Smart Networks and Services

This initiative focuses on the development of future networks infrastructure and the associated services. This includes bringing communication networks beyond 5G and toward 6G capabilities, but also the development of the Internet of Things and Edge Computing technologies. It will address the challenges raised by Europe delay in the deployment of network infrastructure and failure to fully benefit from the full potential of digitalisation. It has as main objective to ensure European technological sovereignty in future smart networks and digital services, to strengthen the uptake of digital solutions, and to foster the development of digital innovation that answers to European needs and that are well aligned with societal needs. The study concluded that an institutionalised partnership under article 187 is the preferred option for the implementation of this initiative.

7. Candidate Institutionalised European Partnership in Metrology

This initiative focuses on metrology - that is the science of measurement and the provision of the technical infrastructure that underpins accurate and robust measurements throughout society; measurements that underpin all domains of science and technology and enable fair and open trade and support innovations and the design and implementation of policy and regulations. It will address challenges in the fragmentation of national metrology systems across Europe and the need to meet ever-increasing demands on metrology infrastructure to support the measurement needs of emerging technologies and important policy domains in climate, environment, energy and health. The main objective of the initiative is to establish a sustainable coordinated world-class metrology system in Europe that will increase and accelerate the development and deployment of innovations and contribute to the design and implementation of policy, regulation and standards. The study concluded that an A185 Institutionalised Partnership is the preferred option for the implementation of this initiative.

8. Candidate Institutionalised European Partnership on Transforming Europe's Rail System

This initiative focuses on the development of a pan-European approach to research and innovation in the rail sector. It will address the challenges raised by the lack of alignment of research and innovation with the needs of a competitive rail transport industry and the consequent failure of the European rail network to make its full contribution to European societal objectives. It will also strengthen the competitiveness of the European rail supply industry in global markets. Accordingly, the objectives of the initiative are to ensure a more market-focused approach to research and innovation, improving the competitiveness and modal share of the rail industry and enhancing its contribution to environmental sustainability as well as economic and social development across the European Union. The study concluded that an institutionalised partnership under article 187 is the preferred option for the implementation of this initiative.

9. Candidate Institutionalised European Partnership for Integrated Air Traffic Management

This initiative focuses on the modernisation of the Air Traffic Management in Europe - an essential enabler of safe and efficient air transport and a cornerstone of the European Union's society and economy. The proposed initiative will address the challenges raised by an outdated Air Traffic Management system with a non-optimised performance. The current system needs to be transformed to enable exploitation of emerging digital technologies and to accommodate new forms of air vehicle including drones. The objective is therefore to harmonise European Air Traffic Management system based on high levels of digitalisation, automation and connectivity whilst strengthening air transport, drone and ATM markets competitiveness and achieving environmental, performance and mobility goals. This would create €1,800b benefits to the EU economy if the current initiative can

be built on and accelerated. The study concluded that an Institutionalised Partnership under Art. 187 TFEU is the preferred option for the implementation of this initiative.

10. Candidate Institutionalised European Partnership on Clean Aviation

This imitative focuses on further aeronautical research and innovation to improve technology leading to more environmentally efficient aviation equipment. It will address the challenges raised by the growing ecological footprint of aviation and the challenges and barriers faced by the aviation industry towards climate neutrality. It will also strengthen the competitiveness of the European aeronautical industry in global markets. Accordingly, the objectives of the initiative are to ensure that aviation reaches climate neutrality and that other environmental impacts are reduced significantly by 2050, maintain the leadership and competitiveness of the European aeronautics industry and ensure safe, secure and efficient air transport of passengers and goods. The Impact Assessment study assessed the options for implementation that would allow for an optimal attainment of these objectives. The study concluded that an institutionalised partnership under Art. 187 TFEU is the preferred option for the implementation of this initiative.

11. Candidate Institutionalised European Partnership on Clean Hydrogen

The report assesses the impact of potential initiatives to support, through research and innovation, the growth and development of clean hydrogen, among which an Institutionalised European Partnership is one of the options assessed. The existing challenges for clean hydrogen include the limited high-level scientific capacity and fragmented research activities, the insufficient deployment of hydrogen applications, and consequently weaker EU scientific and industrial value chains. Environmental, health and mobility pressures are also driving the need for cleaner hydrogen generation, deployment and use. An initiative for clean hydrogen must have as a main objective the strengthening and integration of EU scientific capacities, to support the creation, capitalisation and sharing of knowledge. This is necessary to accelerate the development and improvement of advanced clean hydrogen applications, the market entry of innovative competitive clean solutions, to strengthen the competitiveness of the EU clean hydrogen value chains (and notably the SMEs within them), and to develop the hydrogen-based solutions necessary to reach climate neutrality in the EU by 2050. The study concluded that an Institutionalised Partnership under Art. 187 TFEU is the preferred option for the implementation of this initiative.

12. Candidate Institutionalised European Partnership on Safe and Automated Road Transport

This initiative focuses on Connected, Cooperative and Automated Mobility: the use of connected and automated vehicles to create more user-centred, all-inclusive mobility, while also increasing safety, reducing congestion and contributing to decarbonisation. With current road traffic collisions and negative local and global environmental impacts not reducing quickly enough, it will address the challenges raised by the current fragmentation of research across the field, and the threat to European competitiveness if the research agenda does not advance quickly enough. The initiative will focus on strengthening EU scientific capacity and economic competitiveness in the field of CCAM, whilst contributing to wider societal benefits including improved road safety, less environmental impact, and improved accessibility to mobility. The study concluded that a co-programmed partnership is the preferred option for the implementation of this initiative.

13. Candidate Institutionalised European Partnership for a Circular Bio-based Europe

This initiative focuses on intensifying research and innovation allowing to replace, where possible, non-renewable fossil and mineral resources with biomass and waste for the production of renewable products and nutrients, in order to drive forward sustainable and climate-neutral solutions that accelerate the transition to a healthy planet and respect

planetary boundaries. It will address the challenges raised by the fact that the EU economy does not operate within planetary boundaries, is not sufficiently circular and is predominantly fossil based. It will also address the insufficient research and innovation (R&I) capacity and cross-sectoral transfer of knowledge and bio-based solutions, as well as risks posed to the European bio-based industry's global competitiveness. The study concluded that Institutionalised European Partnership based upon Article 187 TFEU is the preferred option for the implementation of this initiative.

14. Candidate Institutionalised European Partnership for Innovative SMEs

The initiative is envisaged as a continuation of the Eurostars 2 programme which is managed by the Eureka network. The initiative focuses on international collaborative R&D of innovative companies, facilitated through a network of national funding organisations as included in the Eureka network. The funded projects are bottom-up and involve small numbers of project partners. The candidate partnership addresses a niche issue namely limited opportunities for international bottom-up collaboration. The partnership provides thus an opportunity for SMEs for international R&D collaboration but does not address specific technological, social, or environmental challenges. Its main objective is to improve the competitiveness of European SMEs through collaborative funding. The study concluded that a co-funded partnership is the preferred option for the implementation of this initiative.

PART II. Horizontal studies

1. Horizontal Analysis of Efficiency and Coherence in Implementation

The focus of this report is on the coherence and efficiency in the current European Partnership landscape under Horizon Europe and the potential to enhance efficiency in the European Partnerships' implementation.

European Partnerships are geared towards playing a pivotal role in tackling the complex economic and societal challenges that constitute the R&I priorities of the Horizon Europe Pillar II and are in a unique position to address transformational failures. Multiple potential interconnections and synergies exist between the candidate European Partnerships within the clusters, but few are visible across the clusters.

As for the improvement of the efficiency in implementation of institutionalised partnerships under Art. 187, potential efficiency and effectiveness gains could be achieved with enhanced collaboration. An option for a common back-office sharing operational implementation activities is worth exploring further through a detailed feasibility study in order to assess whether efficiency gains can be made. Ideally this would be co-designed as a common Partnership approach, leading to a win-win situation for all partners.

2. Impact Modelling of the Candidate Institutionalised European Partnerships

This report presents the results of the use of a macroeconomic model to assess the economic and environmental impacts of the preferred options identified in the individual 13 impact assessment studies. The model used is E3ME. It includes explicit representation for each EU Member State with a detailed sectoral disaggregation.

The impact modelling estimated the impacts of the envisaged initiatives at an aggregated as well as individual level. In total, 14 macroeconomic models have been run, one per reviewed initiative with a time horizon of 2035 and one that combines all initiatives with a time horizon of 2050. The results of each of these models were compared with those of a baseline scenario, which corresponds to a situation where the initiatives would be funded through regular Horizon Europe calls rather than European Partnerships.

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Part I. Impact Assessment Studies for the Candidate Institutionalised European Partnerships

1. Overarching Context to the Impact Assessment Studies

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Introduction

This report sets out the overall policy context of the impact assessment studies for the candidate Institutionalised European Partnerships and the methodological framework that was developed for the impact assessment studies.

It describes the changes in approach to the public-private and public-public partnerships under Horizon Europe compared to the previous EU Framework Programmes. An example is the requirement that all envisaged European Partnerships be implemented as either co-programmed, co-funded or institutionalised. The impact assessment studies will consider these three scenarios as the different options to be assessed, in compliance with the Better Regulation guidelines and against the functionalities that the candidate partnerships are expected to fulfil. The report describes the common methodological framework to assess the envisaged initiatives accordingly.

The report also presents the landscape of European Partnerships at the level of Horizon Europe Pillar 2 clusters, which lay the grounds for all of the impact assessment studies except the candidate Institutionalised European Partnership for Innovative SMEs. This analysis is presented in more depth in the report on the 'Horizontal analysis of efficiency and coherence of implementation' in Part II of the Impact Assessment Study report.

The report is structured around two main headings:

- Chapter 1: Background and context to European Partnerships in Horizon Europe and focus of the impact assessment– What is decided
- Chapter 2: The Candidate European Partnerships under Horizon Europe – What needs to be decided

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1 Background and context to European Partnerships in Horizon Europe and focus of the impact assessment– What is decided

1.1 The political and legal context

1.1.1 Shift in EU priorities and Horizon Europe objectives

Horizon Europe is to be set in the broader context of the pronounced **systemic and holistic approach** taken to the design of the new Framework Programme and the overarching Multi-annual Financial Framework (MFF) 2021-27.

The future long-term budget will be a budget for the Union's priorities. In her Political Guidelines for the next European Commission 2019 – 2024, the new President of the European Commission put forward six overarching priorities for the next five years, which reach well beyond 2024 in scope: A European Green Deal; An economy that works for people; A Europe fit for the Digital Age; Protecting our European way of life; A stronger Europe in the world; and A new push for European democracy. These priorities build upon A New Strategic Agenda for 2019–2024, adopted by the European Council on 20 June 2019, which targets similar overarching objectives. Together with the United Nations Sustainable Development Goals (SDGs), they will shape future EU policy responses to the challenges Europe faces and will steer the ongoing transitions in the European economy and society,

The MFF 2021-27 strives to provide a framework that will ensure a more coherent, focused and transparent response to Europe's challenges. A stronger focus on European added value, a more streamlined and transparent budget, more flexibility in order to respond quickly and effectively to unforeseen demands, and above all, an effective and efficient implementation are among the key principles of the MFF. The objective is to strengthen the alignment with Union policies and priorities and to simplify and reform the system in order to "unlock the full potential of the EU budget" and "turn ambitions into reality". Investment from multiple programmes is intended to combine in order to address key crosscutting priorities such as the digital economy, sustainability, security, migration, human capital and skills, as well as support for small businesses and innovation.[1]

These principles underlying the MFF 2021-27 are translated in the intent for Horizon Europe "to play a vital role, in combination with other interventions, for creating new solutions and fostering innovation, both incremental and disruptive." [2] The new Framework Programme finds its rationale in the daunting challenges that Europe is facing, which call for "a radical new approach to developing and deploying new technologies and innovative solutions for citizens and the planet on a scale and at a speed never achieved before, and to adapting our policy and economic framework to turn global threats into new opportunities for our society and economy, citizens and businesses."

In the Orientations towards the first Strategic Plan for Horizon Europe, the need strategically to prioritise and "direct a substantial part of the funds towards the areas where we believe they will matter the most" is emphasised. The Orientations specify, "Actions under Pillar II of Horizon Europe will target only selected themes of especially high impact that significantly contribute to delivering on the political priorities of the Union."

Figure 1, below, which gives an indicative overview of how the EU political priorities are supported under Horizon Europe, shows the major emphasis placed on contributing to the priority 'A European Green Deal', aimed at making Europe the first climate-neutral

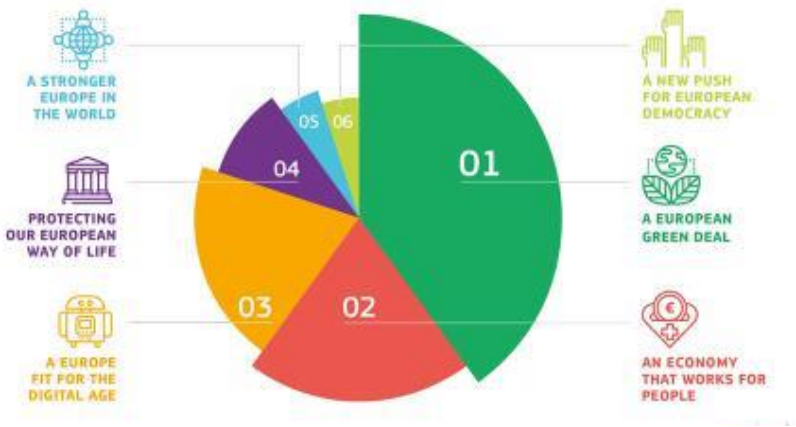
[1] EC (2018) *A Modern Budget for a Union that Protects, Empowers and Defends. The Multiannual Financial Framework for 2021-2027*. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2018) 321 final

[2] EC (2019), *Orientations towards the first Strategic Plan for Horizon Europe*.

continent in the world. At least 35 % of the expenditure from actions under the Horizon Europe Programme will address the Sustainable Development Goal 13: Climate Action.

Especially the R&I activities funded under Pillar II, including seven Partnership Areas (see below), are expected to contribute to the attainment of these objectives in an interconnected manner.

Figure 1: Targeted impacts under Horizon Europe by priority



Note: Preliminary, as described in the General orientations towards the first Strategic Plan implementing Horizon Europe.
Source: European Commission (2019) Orientations towards the first Strategic Plan for Horizon Europe, December 2019.

1.1.2 Renewed ambition for European Partnerships

Reflecting its pronounced systemic nature aimed at 'transformation' of the European R&I system, Horizon Europe intends to make a more effective use of these partnerships with an **ambitious approach** that is impact oriented and ensures complementarity with the Framework Programme. The **rationalisation** of the partnership landscape, both in terms of number of partnership forms and individual initiatives, constituted a first step in the direction of the strategic role that these policy initiatives are expected to play in the context of Horizon Europe. Future partnerships are expected to "provide mechanisms to consistently aggregate research and innovation efforts into more effective responses to the policy needs of the Union".[3] The expectation is that they will act as **dynamic change agents**, strengthening linkages within their respective ecosystems and with other related ecosystems as well as pooling resources and efforts towards the common objectives in the European, national and regional landscape. They are expected to develop *close synergies* with national and regional programmes, bring together a *broad range of actors* to work towards a common goal, translate *common priorities* into concrete roadmaps and coordinated activities, and turn research and innovation into *socio-economic results and impacts*.

The exact budget dedicated to European Partnerships under Horizon Europe will be agreed only upon decisions on the multiannual financial framework (MFF) 2021-2017 and the overall budget for Horizon Europe. In December 2017, the Council nevertheless introduced the principle of a "possible capping of partnership instruments in the FP budget".[4] Accordingly, it reached the common understanding, with the European Parliament, that "the majority of the budget in Pillar II [€52.7bn] shall be allocated to actions outside of

[3] European Commission (2019) *Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe*. Co-design via web open consultation. Summer 2019.

[4] Council of the European Union (2017) *From the Interim Evaluation of Horizon 2020 towards the ninth Framework Programme*. Council conclusions 15320/17.

European Partnerships" (Article 8.2(a) of the Common Understanding on the proposal for a regulation establishing Horizon Europe).[5]

1.1.3 Key evolutions as regards the partnership approach

The European R&I partnerships were initially conceived as a means to increase synergies between the European Union and the Member States (Article 181 of the Treaty on the Functioning of the European Union TFEU). Their objectives were to pool the forces of all the relevant actors of R&I systems to achieve breakthrough innovations; strengthen EU competitiveness; and, tackle major societal challenges. The core activities of the European partenrships consist therefore of building critical mass mainly through collaborative projects, jointly developing visions, and setting strategic agendas. They help accelerate the emergence of a programming approach in European R&I with the involvement of all relevant actors and provide flexible structures for partnerships that can be tailored to their goals.[6]

In the consecutive Framework Programmes up to the current Horizon 2020, the partnerships and their forms have mushroomed, leading to an increasing complexity of the partnership landscape. The Horizon 2020 interim evaluation highlighted that the overall landscape of EU R&I funding had become overly complex and fragmented, and a need to improve the partnerships' openness and transparency. The Lamy report suggested that the European Partnerships should focus on those areas with the greatest European Added Value, contribute to EU R&I missions and would need a simplified and flexible co-funding mechanism.

The Competitiveness Council conclusions of December 2017 called on the Commission and the Member States to jointly consider ways to rationalise the EU R&I partnership landscape. In 2018, the ERAC Ad-hoc Working Group on Partnerships concluded, "the rationalisation of the R&I partnership landscape is needed in order to ensure that the portfolio of R&I partnerships makes a significant contribution to improving the coherence, functioning and quality of Europe's R&I system and that the individual initiatives are able to fully achieve their potential in creating positive scientific and socio-economic impacts and/or in addressing societal challenges".

Horizon Europe has taken on board these concerns. The Impact Assessment of Horizon Europe gave a clear analysis of the achievements of Partnerships so far as well as the expectations for the new generation of Partnerships. Greater transparency and openness of the partnerships were considered as essential, as well a clear European added value and long-term commitments of the stakeholders involved.

A list of criteria to decide how European Partnerships will be selected, implemented, monitored, evaluated and phased-out was attached as an Annex III to the proposal to establish Horizon Europe (as revised by the partial political agreement). The rationalisation of the Partnership portfolio in Horizon Europe is expected to allow for a reduction from the current 120 to between 45 and 50 partnerships.

[5] Council of the European Union (2019) *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rule for participation and dissemination*. Common understanding 7942/19.

[6] European Commission (2011) Partnering in Research and Innovation. Communication from the Commission COM(2011) 572 final.

1.1.4 Overview of legal provisions

The Horizon Europe Regulation (common understanding) defines 'European Partnership' as "an initiative where the Union, prepared with early involvement of Member States and/or Associated Countries, together with private and/or public partners (such as industry, universities, research organisations, bodies with a public service mission at local, regional, national or international level or civil society organisations including foundations and NGOs), commit to jointly support the development and implementation of a programme of research and innovation activities, including those related to market, regulatory or policy uptake." It stipulates that "parts of Horizon Europe may be implemented through European Partnerships".

The Horizon Europe Regulation (common understanding) also stipulates that the European Partnerships are expected to adhere to the "principles of Union added value, transparency, openness, impact within and for Europe, strong leverage effect on sufficient scale, long-term commitments of all the involved parties, flexibility in implementation, coherence, coordination and complementarity with Union, local, regional, national and, where relevant, international initiatives or other partnerships and missions." The provisions and criteria set out for the selection and implementation of the European Partnerships reflect these principles.

1.1.5 Overview of the eight Partnership areas

The Horizon Europe Regulation also identifies the following "Areas for possible institutionalised European Partnerships on the basis of Article 185 TFEU or Article 187 TFEU":

- Partnership Area 1: Faster development and safer use of health innovations for European patients, and global health.
- Partnership Area 2: Advancing key digital and enabling technologies and their use, including but not limited to novel technologies such as Artificial Intelligence, photonics and quantum technologies.
- Partnership Area 3: European leadership in Metrology including an integrated Metrology system.
- Partnership Area 4: Accelerate competitiveness, safety and environmental performance of EU air traffic, aviation and rail.
- Partnership Area 5: Sustainable, inclusive and circular bio-based solutions.
- Partnership Area 6: Hydrogen and sustainable energy storage technologies with lower environmental footprint and less energy-intensive production.
- Partnership Area 7: Clean, connected, cooperative, autonomous and automated solutions for future mobility demands of people and goods.
- Partnership Area 8: Innovative and R&D intensive small and medium-sized enterprises.

Considering the realm of these partnership areas, potential synergies exist with the future **missions**. Horizon European introduced these cross-discipline and cross-sector policy instruments as part of its core objective of stimulating further excellence-based and impact-driven R&I. In contrast with the challenges targeted in Horizon 2020, the missions aim at the achievement of well-defined goals to provide solutions, within a specified timeframe, to scientific, technological, economical and/or societal problems. As part of the preparation of Horizon Europe, the European Commission set up five boards to formulate the future missions in the following areas:

- Adaptation to climate change including societal transformation

- Cancer
- Healthy oceans, seas, coastal and inland waters
- Climate-neutral and smart cities
- Soil health and food

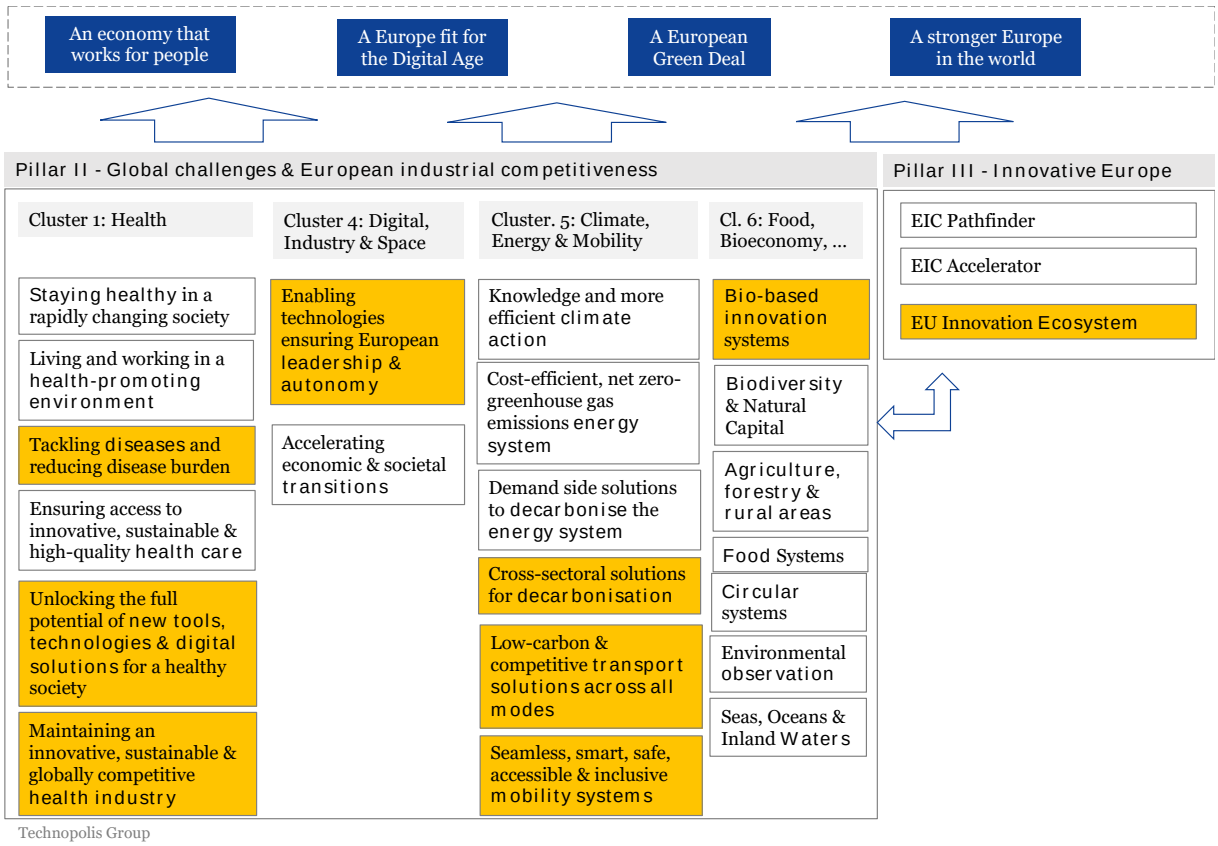
1.2 Typical problems and problem drivers

The European Partnerships are integral part of the framework programme and its three-pillar structure. They are predominantly funded under Pillar 2 "Global Challenges and European industrial competitiveness" and four of its thematic clusters. These clusters cover sectors and technologies, in which research and innovation activities are deemed of crucial importance in solving pressing scientific, societal or economic challenges and ensuring the scientific, technological and industrial leadership of Europe. Only one European Partnership, targeting innovative and R&D intensive SMEs, will instead act under Pillar 3 "Innovative Europe".

The European Partnerships are intended to contribute to the attainment of the pillars' and clusters' **challenges and R&I priorities**. Overarching EU policy priorities addressed are predominantly the European Green Deal, a people-centred economy, the fit for the Digital Age, and a stronger Europe in the world.

In Figure 2, below, the R&I priorities in the Pillars II and III to which the candidate *Institutionalised* Partnerships intend to contribute are highlighted in yellow.

Figure 2: Contribution of Candidate European Institutionalised Partnerships to the Horizon Europe priorities in Pillars II and III



The European Partnerships under Horizon Europe most often find their rationale in addressing **systemic failures**. Their primary function is to create a platform for a strengthened collaboration and knowledge exchange between various actors in the European R&I system and an enhanced coordination of strategic research agenda and/or R&I funding programmes.

The concentration of efforts and resources and pooling of knowledge, expertise and skills on common priorities in a view of solving complex and multi-faceted societal and economic challenges is at the core of these initiatives. Enhanced cross-disciplinary and cross-sectoral collaboration and an improved integration of value chains and ecosystems are among the key objectives of these policy instruments. In the light of Horizon Europe, the aim often is to drive system transitions and transformations.

Especially in fast-growing technologies and sectors such as ICT, the envisaged European Partnerships also react on emerging opportunities and address systemic failures such as shortage in skills or critical mass or cross-sectoral cooperation along the value chains that would hamper attainment of future European leadership and/or strategic autonomy.

Transformational failures addressed aim at reaching a better alignment of the strategic R&I agenda and policies of public and private R&I funders in order to pool available resources, create critical mass, avoid unnecessary duplication of research and innovation efforts, and leverage sufficiently large investments where needed but hardly achievable by single countries.

Market failures are less commonly addressed and relate predominantly to enhancing industry investments thanks to the sharing of risks.

1.3 Description of the options

The proposal for a regulation establishing Horizon Europe[7] stipulates that parts of the Horizon Europe Framework Programme may be implemented through European Partnerships and establishes three implementation modes: Co-programmed European Partnerships, Co-funded European Partnerships, and Institutionalised Partnerships in accordance with Article 185 TFEU or Article 187 TFEU.

1.3.1 Baseline option – Traditional calls under the Framework Programme

Under this option, strategic programming for research and innovation in the field will be done through the mainstream channels of Horizon Europe. The related priorities will be implemented through traditional calls under the Framework Programme covering a range of activities, but mainly calls for R&I and/or innovation actions. Most actions involve consortia of public and/or private actors in ad hoc combinations, some actions are single actor (mono-beneficiary). There will be no dedicated implementation structures and no further support other than the Horizon Europe actions foreseen in the related Horizon Europe programme or cluster.

Strategic planning mechanisms in the Framework Programmes allow for a high level of flexibility in their ability to respond to particular needs over time, building upon additional input in co-creation from stakeholders and programme committees involving MS. The broad scope of the stakeholders providing their input to the research agenda, however, implies a lower level of directionality than what can be achieved through the partnerships. Often, the long-term perspective of the stakeholder input is limited, which risks reducing strategic capacity in addressing priorities.

The Horizon Europe option also implies a lower level of EU budgetary long-term commitment for the priority. Without a formal EU partnership mechanism, it is also less likely that the stakeholders will develop a joint Strategic Research Agenda and commit to its implementation or agree on mutual financial commitments beyond the single project participation.

[7] Proposal for a Regulation of the European Parliament and of the Council stablishing Horizon Europe - the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination - Common understanding', March 2019

1.3.2 European Partnership

All European Partnerships will be designed in line with the new policy approach for more objective-driven and impactful partnerships. They are based on the common criteria in Annex III of the Horizon Europe Regulation, with few distinguishing elements for the different forms of implementation. All European Partnerships will be based on an agreed Strategic Research and Innovation Agenda / roadmap agreed among partners and with the Commission. For each of them the objectives, key performance and impact indicators, and outputs to be delivered, as well as the related commitments for financial and/or in-kind contributions of the partners will be defined ex-ante.

Option 1 - Co-programmed European Partnership

This form of European Partnership is based upon a *Memorandum of Understanding* or a *Contractual Arrangement* signed by the European Commission and the private and/or public partners. Private partners are typically represented by one or more industry association, which also functions as a back-office to the partnership. It allows for a *high flexibility* in the profile of organisation involved, objectives pursued, and/or activities implemented.

Co-programmed European Partnerships address *broader communities* across a diverse set of sectors and/or value chains and where the actors have *widely differing capacities and capabilities*. They may encompass one or more associations of organisations from industry, research, NGOs etc as well as foundations and national R&I funding bodies, with no restriction on the involvement of international partners from Associated and non-associated third countries. Different configurations are possible: private actors only, public entities only, or a combination of the two.

The basis, as for all European Partnerships, is the rationale is to create a *platform for 'concertation'*, i.e. in-depth and ongoing consultation of the relevant actors in the European R&I system for the co-development of a strategic research and Innovation agenda, typically covering the period of the next 10 years. The primary ambition is to generate *commitment to a common strategic research and innovation agenda* (SRIA). For the private actors involved, this would allow for a de-risking of their R&I investments and provide predictability of investment paths, for the public actors, it serves as a means to: inform national policy-makers on EU investments and allows for coordination and alignment of their efforts to support R&I in the field at the national level.

The *level of 'additionality is possibly lower than for other partnerships*. There is no expectation of a legally binding commitment from the partners to taking an integrated approach in their individual R&I implementation and it is based on 'best efforts'. However, the Union contribution to the partnership is defined for the full duration and has a comparable level of certainty for the partnerships than in the other forms of implementation. The priorities for the calls, proposed by the partnership members for integration in the Framework Programme Work Programmes, are subject to further input from Member States (comitology) and Commission Services. The full implementation of the Union contribution in the Framework Programme implies that the full array of Horizon Europe funding instruments in the related Pillar can be used, ranging from RIAs to CSAs and including grants, prizes, and procurement.

Option 2 – Co-funded European Partnership

The Co-funded Partnership is based on a Grant Agreement between the Commission and the consortium of partners, resulting from a call for a proposal for a programme co-fund action implementing the European Partnerships in the Horizon Europe Work Programme. Programme co-fund actions provide co-funding to a programme of activities established and/or implemented by entities managing and/or funding research and innovation programmes. Therefore, this form of implementation only allows to address public partners

at its core (comparable to the Article 185 initiatives below), while industry can nevertheless be addressed by the activities of the partnerships, but not make formal commitments and contributions to it. The expectation is that these entities would cover most if not all EU Member States (MS). Also 'international' funding bodies can participate as partners, which creates the potential for an efficient interaction with strategic international partners. Legal entities in countries that are not part of the programme co-fund consortium, are usually excluded from funding under the calls launched by the consortium.

The basic rationale for this partnership option is to bring MS together to invest at scale in key R&I issues of general and common interest. The joint programme of activities is agreed by the partners and with the EU and typically focuses on societal grand challenges and specifically, areas of high public good where EU action will add value while reflecting national priorities and/or policies. The ultimate intent is to create the greatest possible impact by pooling and/or coordinating national programmes and policies with EU policies and investments, helping to overcome fragmentation of the public research effort. Member States that are partners in this partnership become the 'owners' of the priority and take sole responsibility for its funding. Commitments of the partners and the European Union are ensured through the Grant Agreement.

Based on national programmes, this partnership option shows a particularly high level of flexibility in terms of activities to be implemented - directly by the national funding bodies (or governmental organisation "owning" institutional programmes), or by third parties receiving financial support (following calls for proposals launched by the consortium). The broad range of possible activities include support for networking and coordination, research, innovation, pilot actions, and innovation and market deployment actions, training and mobility actions, awareness raising and communication, dissemination and exploitation, any relevant financial support, such as grants, prizes, procurement, as well as Horizon Europe blended finance or a combination thereof.

Option 3 – Institutionalised European Partnership

This type of Partnership is the most complex and high-effort arrangement and will be based on a Council Regulation (Article 187) or a Decision by the European Parliament and Council (Art 185) and implemented by dedicated structures created for that purpose. The legal base for this type of partnership limits the flexibility for a change in core objectives, partners, and/or commitments as these would require amending legislation.

The basic rationale for this type of partnership is the need for a strong integration of R&I agenda's in the private and/or public sectors in Europe in order to address a strategic challenge or realise an opportunity. The focus is on major long-term strategic challenges and priorities beyond the framework of a single Framework Programme where collective action – by private and/or public sectors – is necessary to *achieve critical mass* and *address the full extent of the complexities* of the ecosystem concerned.

The long-term commitment expected from the European Union and its partners is therefore much larger than for any of the other options, given the considerably higher investment in the preparation and implementation of the Partnership. As a result, this type of partnership can be selected only if other parts of the Horizon Europe programme, including other forms of European Partnerships, would not achieve the objectives or would not generate the necessary expected impacts. The commitment for contributions by the partnership members is expected to be at least equal to 50% and may reach up to 75% of the aggregated European Partnership budgetary commitments.

The partnership members have a high degree of autonomy in developing the strategic research agenda and annual work programmes and call topics, based on a transparent and accessible process, and subject to the approval of the Commission Services. The choice of topics addressed in the (open) calls are therefore strongly aligned with the needs defined. Normally, the strategic priorities are fully covered by the annual work programmes in the

partnership, even though it is in principle possible to keep certain topics for calls in the FP thus complementing the activities in the partnership. The full integration in the Framework Programme implies that the full array of Horizon Europe funding instruments in the related Pillar can be used, ranging from RIAs to CSAs and including grants, prizes, and procurement.

Two forms of Institutionalised Partnerships are of direct relevance to this study, influencing the constellation of partners involved.

Institutionalised Partnerships based upon Art 185 TFEU

Article 185 of the TFEU allows the Union to participate in programmes jointly undertaken by Member States and limits therefore the scope of partners to Member States and Associated Third countries. This type of Institutionalised Partnership aims therefore at reaching the greatest possible impact through the integration of national and EU funding, aligning national strategies in order to optimise the use of public resources and overcome fragmentation of the public research effort.

It brings together R&I governance bodies of most if not all EU Member States (legal requirement: at least 40% of Member States) as well as Associated Third Countries that designate a dedicated legal entity (Dedicated Implementation Structure) for the implementation. By default, membership of non-associated Third Countries is not foreseen. Such membership is possible only if it is foreseen in the basic act and subject to conclusion of an international agreement. Eligibility for participation and funding follows by default the rules of the Framework programme, unless a derogation is introduced in the basic act.

Institutionalised Partnerships under Art. 187 TFEU

This type of Institutionalised Partnership aims at reaching the greatest possible impact by integrating the strategic R&I agendas of private and/or public actors and by leveraging the partners' investments in order to tackle R&I and societal challenges and/or contribute to Europe's wider competitiveness goals.

It brings together a stable set of partners with a strong commitment to taking a more integrated approach and requires the set-up of a dedicated legal entity (Union body, Joint Undertaking) that carries full responsibility for the management of the partnership and implementation of the calls.

Different configurations are possible: partnerships focused on creating strategic industrial partnerships where, most often, the partner organisations are represented by one or more industry associations, or in some cases individual private partners; partnerships coordinating national ministries, public funding agencies, and governmental research organisations in the Member States and Associated Countries; or a combination of the two (the so-called tripartite model). By default, membership of non-associated Third Countries is not foreseen. Such membership is possible only if it is foreseen in the basic act and subject to conclusion of an international agreement. Eligibility for participation and funding follows by default the rules of the Framework programme, unless a derogation is introduced in the basic act.

2 The Candidate European Partnerships under Horizon Europe – What needs to be decided

2.1 Portfolio of candidates for Institutionalised Partnerships under Horizon Europe

2.1.1 The process for identifying the priorities for Institutionalised Partnerships under Horizon Europe

In May 2019, the European Commission consulted the Member States on a list of 44 possible candidates for European Partnership which it had identified as part of the preparation of the first Strategic Planning of Horizon Europe. This list was also part of the

Orientations towards the first Strategic Plan implementing Horizon 2020[8] which served as a basis for an Open Public Consultation from July to October 2019. In October and November 2019, the European Commission and the Member States agreed on increasing the number of candidate European partnerships to 49. Subsequent discussions until the adoption of Horizon Europe will focus on ensuring the overall consistency of the EU partnership landscape and its alignment with the EU overarching priorities and on defining the precise implementation modalities.

In parallel, the European Commission completed inception impact assessments on the candidate institutionalised European partnerships. Stakeholders had the opportunity to provide their feedback on these inception impact assessments in August 2019. A web-based open public consultation to collect opinions on all candidate institutionalised partnerships (but the candidate EuroHPC partnership) was organised between September and October 2019.

2.1.2 Overview of the overall landscape of candidate European Partnerships subject to the impact assessment

Figure 3, below, gives an overview of all European Partnerships that are currently envisaged for funding under Horizon Europe. The candidate Institutionalised Partnerships that are the subject for this impact assessment study are coloured in dark orange.

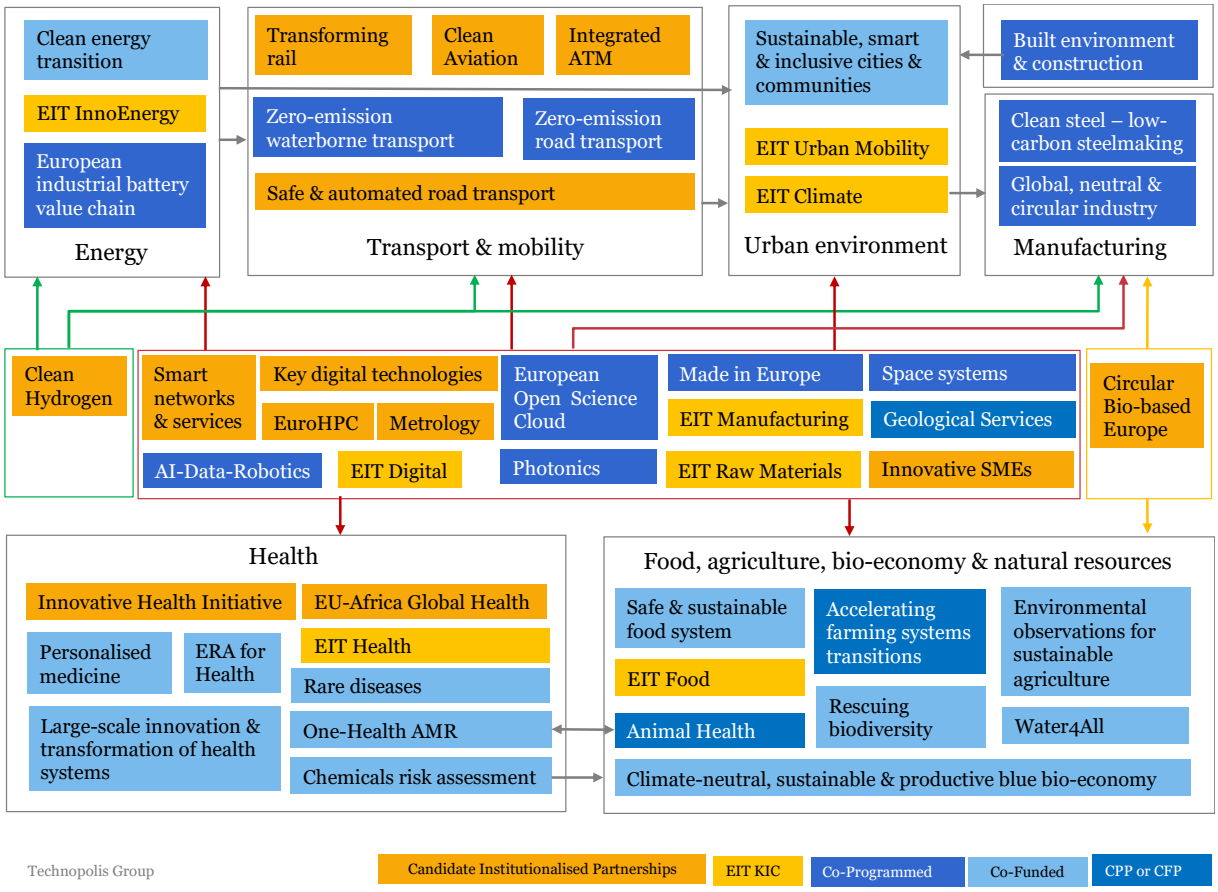
The European Partnerships can be categorised into two major groupings: *'horizontal' partnerships* focused on the development of technologies, methods, infrastructures and resources/materials, and *'vertical' partnerships* focused on the needs and development of a specific application area, be it industrial or societal.

The diagram below shows the central position of the **'horizontal' partnerships** in the overall landscape, developing methodologies, technologies or data management infrastructures for application in the other priority areas. These 'horizontal' partnerships are predominantly proposed as Institutionalised or Co-programmed Partnerships, in addition to a number of EIT KICs. The European Open Science Cloud (EOSC) partnership, for example, will support research partnerships by providing an infrastructure for the storage, management, analysis and re-use of research data.

The upper banner of the diagram groups the **industry-oriented 'vertical' partnerships**. Under Horizon Europe, they have in common a pronounced focus on enhancing sustainability. In this context, the banner includes also one of the most recent agreed-upon partnerships focused on the urban environment. This partnership illustrates the introduction under Horizon Europe of *challenge-oriented* cross-cluster partnerships. Multiple interconnections are envisaged among the 'vertical' partnerships in the different industry sectors covered. In the transport sector, the partnerships are predominantly proposed as Institutionalised Partnerships. In the other sectors, we see a mix of Co-Programmed Partnerships and EIT KICs. There are only two Co-Funded Partnerships.

[8] Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe, Co-design via Web Open Consultation (2019), see more here https://ec.europa.eu/research/pdf/horizon-europe/ec_rtd_orientations-towards-the-strategic-planning.pdf

Figure 3: Landscape of European Partnerships under Horizon Europe (2019)



The lower banner includes the '**vertical' partnerships in the societal application areas**. Striking is the dominance of the Co-Funded Partnerships (to be noted that in the Food/agriculture cluster, the partnership type still needs to be decided for several envisaged partnerships). We also note the limited interconnections that are envisaged between the two areas. An exception is the newly envisaged cross-cluster European Partnerships 'One Health AMR'.

2.2 Assessing the necessity of a European Partnership, possible options for implementation and their cost-effectiveness

In this section we set out the methodological framework that underpins the impact assessment studies. In line with the Better Regulation Guidelines, the impact assessment is intervention logic-based and impact-oriented.

The impact assessment allowed also for the conduct of the 'necessity test' for a European Partnership as set out in the Horizon Europe regulation. Pivotal in this context was the identification of the Horizon Europe calls as Option 0 as well as Baseline Option, allowing for a comparative analysis of the three partnership forms (Options 1-3) along all of the assessment dimensions – in relation to each other as well as to the Horizon Europe calls. The options assessment therefore incorporated the required 'necessity test'.

2.2.1 Assessment of the selection criteria

The common methodological framework that we defined for the 13 individual Impact Assessment studies reflects the approach defined in the Better Regulation guidelines. It also integrates the specific criteria for the use of the different types of European Partnerships as they are defined in the Horizon Europe Common Understanding (Article 8 and Annex III). Specifically this regards the **selection criteria** which have to be demonstrated as a minimum in order to justify the necessity of a European Partnership instead of regular Horizon Europe calls only and the implementation criteria in Article 8

1(a), (b) and (c) with certain elements distinguishing the use of the different partnership implementation modes (Table 1).

Table 1: Horizon Europe selection criteria for the European Partnerships

Common selection criteria and principles	Specifications
More effective (Union added value) clear impacts for the EU and its citizens	• delivering on global challenges and research and innovation objectives
	• securing EU competitiveness
	• securing sustainability
	• contributing to the strengthening of the European Research and Innovation Area
	• where relevant, contributing to international commitments
Coherence and synergies	• within the EU research and innovation landscape
	• coordination and complementarity with Union, local, regional, national and, where relevant, international initiatives or other partnerships and missions
Transparency and openness	• identification of priorities and objectives in terms of expected results and impacts
	• involvement of partners and stakeholders from across the entire value chain, from different sectors, backgrounds and disciplines, including international ones when relevant and not interfering with European competitiveness
	• clear modalities for promoting participation of SMEs and for disseminating and exploiting results, notably by SMEs, including through intermediary organisations
Additionality and directionality	• common strategic vision of the purpose of the European Partnership
	• approaches to ensure flexibility of implementation and to adjust to changing policy, societal and/or market needs, or scientific advances, to increase policy coherence between regional, national and EU level
	• demonstration of expected qualitative and significant quantitative leverage effects, including a method for the measurement of key performance indicators
	• exit-strategy and measures for phasing-out from the Programme
Long-term commitment of all the involved parties	• a minimum share of public and/or private investments
	• In the case of institutionalised European Partnerships, established in accordance with article 185 or 187 TFEU, the financial and/or in-kind, contributions from partners other than the Union, will at least be equal to 50% and may reach up to 75% of the aggregated European Partnership budgetary commitments

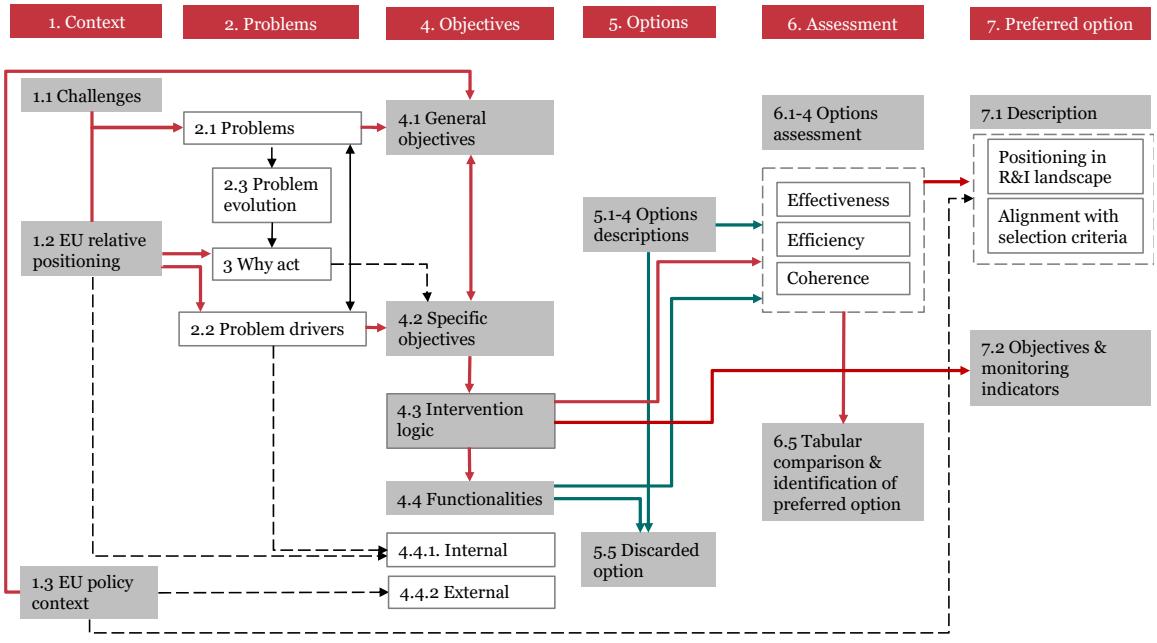
The **Better Regulation guidelines** remained the primary point of reference for the 13 individual Impact Assessment studies. The different steps of the IA process were carried out in a consistent manner in the 13 individual IA studies, supported by horizontal analyses (i.e. common to all studies) such as bibliometrics/patent analysis, social network analysis, the partnership portfolio mapping and analysis, as well as the analysis of the Open Public Consultation data.

The **selection criteria** for the European Partnerships related to effectiveness and coherence fit reasonably well in the Better Regulation impact assessment structure. More problematic was the coverage of the other three criteria groupings, i.e. the criteria of Openness and Transparency, Additionality and Directionality, and the Ex-ante demonstration of commitment.

The solution was the introduction of a section on the **'Functionalities of the initiative'**, in which set out our view on *how* the initiative should *concretely* respond to the selection criteria of 'coherence and synergies', 'openness and transparency' and 'additionality and directionality' in order to reach its objectives. We focused on those aspects that are not covered in other sections of this report, such as coherence and synergies, and covered those elements that from our analysis of the partnership options resulted being **key distinguishing features** of the partnership options, i.e. the composition of the partnership ('openness', including from a geographical perspective), the type of activities implemented ('flexibility'), and the level of directionality and integration of the stakeholders' R&I strategies needed ('directionality and additionality').

The logical process is summarised in Figure 4, below. The diagram shows how the 'functionality' sections constituted an important passage from the objectives and intervention logic sections to the options assessment. Building upon information collected in the previous sections (context, problem and objectives analysis) and in combination with the description of the available options, the description of the desirable 'functionalities' allowed for, on the one hand, the identification of the discarded option(s) and, on the other hand, the options assessment against coherence and against the selection criteria of 'Openness and Transparency' and 'Additionality and Directionality'. In the final chapter of the Impact Assessment report, the alignment of the preferred option with the criteria for the selection of European Partnerships was described, emphasising the outcomes of the 'necessity test'.

Figure 4: Flow of the analysis



Notes: the numbers indicate the related chapters or sections in the Impact Assessment reports

2.2.2 Methodological approach

Overview of the methodologies employed

The understanding of the overall context of the candidate institutionalised European Partnerships relies on a desk research partly covering the main impacts and lessons learned

from their predecessor partnerships (if any). This was complemented with a set of quantitative analyses of the Horizon 2020-funded partnerships, or in case these did not exist, the H2020-funded projects in the field. The analyses included a portfolio analysis, a stakeholder and social network analysis in order to profile the actors involved as well as their co-operation patterns, and an assessment of the partnerships' outputs (bibliometrics and patent analysis). A cost modelling exercise was performed in order to feed into the efficiency assessments of the partnership options (see below).

Public consultations (open and targeted) supported the comparative assessment of the policy options. Each study interviewed up to 50 relevant stakeholders (policymakers, business including SMEs and business associations, research institutes and universities, and civil organisations, among others). They also used the results from the Open Public Consultation organised by the European Commission (Sep – Nov 2019) and the feedback on the Inception Impact Assessments of the 13 candidate institutionalised European Partnerships that the European Commission received in September 2019.

The timing of the Impact Assessment studies, in parallel to the negotiations between the European Commission and the existing Joint Undertakings on the specific implementation of the rules for the future European Partnership, as well as the ongoing discussions within the existing partnership on their future research directions, has set potential limits to the validity of the input and feedback collected from the stakeholders during the consultations.

A more detailed description of the methodology is provided in the Annexes C of each impact assessment report.

Method for identifying the preferred choice

The four policy options were compared along a range of key parameters. The comparison along these parameters was carried out in an evidence-based manner. A range of quantitative and qualitative evidence was used, including ex-post evaluations; foresight studies; statistical analyses of Framework Programmes application and participation data and Community Innovation Survey data; analyses of science, technology and innovation indicators; econometric modelling exercises producing quantitative evidence in the form of monetised impacts; reviews of academic literature on market and systemic failures and the impact of research and innovation, and of public funding for research and innovation; sectoral competitiveness studies; expert hearings; etc.

Options assessment related to effectiveness and coherence

On the basis of the evidence collected and gathered, the Impact Assessment study teams assessed the effectiveness of the retained policy options along three dimensions corresponding to the different categories of likely impacts: scientific, economic and technologies, and societal (including environmental) impacts. The Impact Assessment study teams considered to which extent the retained policy options fulfilled the desirable 'functionalities' and were therefore likely to produce the targeted impacts. This analysis resulted in a scoring of the policy options along a three-point scale.[9] Instead of a compound score, the assessment of the effectiveness of the policy options concluded on as many scores as there are expected impacts.

Likewise, the impact assessment study teams attributed scores (using the same approach as above) reflecting the potential of each retained policy option for ensuring coherence with programmes and initiatives within (internal coherence) and beyond (external coherence) Horizon Europe.

[9] Scores vary from + to +++, where + refers to low potential for presenting a low potential for reaching the likely impacts, ++ to a good potential, and +++ to a high potential.

Scores were justified in a consistent and detailed manner in order to avoid arbitrariness and spurious accuracy. A qualitative or even quantitative explanation was provided of why certain scores were given to specific impacts.

When assessing the respective efficiency of the retained policy options, the Impact Assessment study teams considered the scores related to effectiveness and the identified costs to conduct a "value for money" (or cost-effectiveness) analysis. They accordingly attributed a comparative score to each of the options ranging from 1 (option with the highest costs) to 3 (options with the lowest costs).

Options assessment related to efficiency

A standard cost model

The 'horizontal' team has reviewed the cost categories and costs for each of the four policy options, at some length. Our first model used published data from past partnerships and Horizon 2020 calls working with the Commission's standard accounting codes (Title 1, Title 2, Title 3). The analysis revealed wide-ranging differences in costs across partnerships and functions, which was thought to be too complex to be helpful to the current exercise. As a result, we created a static, common model using average costs as a means by which to indicate the order of magnitude of effort and thereby reveal the principal differences between each of the policy options.

The model was developed jointly with the European Commission services and is presented in the study Data report (D1.2), along with an explanation of the data sources used and the assumptions made.

It is important to note that the costs identified are theoretical and do not reflect the actual costs of any existing individual partnership. In light of this fact, and to avoid any risk of misunderstanding, we have transposed the financial estimates into a qualitative presentation using + / - system in order to compare the various cost elements for each policy option with the equivalent costs for the baseline policy options (see Table 2).

The principal differences in costs as compared with regular Horizon Europe calls relate to the European Partnerships' one-off costs (e.g. developing the proposal and Strategic Research and Innovation Agenda), additional supervision by the European Commission and any additional programme management effort. The main difference between the three types of European Partnership are twofold: (i) the extent to which a partnership will need to run a limited or comprehensive programme management unit and (ii) the extent to which a new partnership may benefit from a pre-existing programme management unit that will greatly reduce or eliminate the set-up costs that would apply to a wholly new partnership.

Table 2: Intensity of additional costs compared with HEU Calls (for Partners, stakeholders, public and EC)

Cost items	Option 0	Option 1	Option 2	Option 3 -Art. 185	Option 3 -Art. 187
Preparation and set-up costs					
Preparation of a partnership proposal (partners and EC)	0	++	++	++	++
Set-up of a dedicated implementation structure	0	0	0	Existing: + New: ++	Existing: ++ New: +++
Preparation of the SRIA / roadmap	0	++	++	++	++

Cost items	Option 0	Option 1	Option 2	Option 3 -Art. 185	Option 3 -Art. 187
Ex-ante Impact Assessment for partnership	0	0	0	+++	+++
Preparation of EC proposal and negotiation	0	0	0	+++	+++
Running costs (Annual cycle of implementation)					
Annual Work Programme preparation	0	+	0	+	+
Call and project implementation	0	0 In case of MS contributions: +	+	+	+
Cost to applicants	Comparable, unless there are strong arguments of major differences in oversubscription				
Partners costs not covered by the above	0	+	0	+	+
Additional EC costs (e.g. supervision)	0	+	+	+	++
Winding down costs					
EC	0	0	0	0	+++
Partners	0	+	0	+	+

Notes: 0: no additional costs, as compared with the baseline; +: minor additional costs, as compared with the baseline; ++: medium additional costs, as compared with the baseline; +++: higher costs, as compared with the baseline

Rationale for the comparative scoring on 'overall costs' and 'cost-efficiency' in the scorecard

In the scorecard analysis, the scores related to the set-up and implementation costs will allow the study teams to consider the scale of the expected benefits and thereby allow a simple "value for money" analysis (cost-effectiveness).

Table 3 shows how we translated the cost analysis into a series of numerical scores.

Table 3: Cost-efficiency matrix

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 2: Co-funded	Option 3: Institutionalised
Overall cost	3	2	1	1
Cost-efficiency	3	3	2	2

For the 'overall cost' dimension, we assigned a score 1 to the option with the highest additional costs and a score 3 to the option with the lowest additional costs compared to the baseline. This was based on the following considerations:

- **Horizon Europe regular calls** will have the lowest overall cost among the policy options and have therefore been **scored 3** on this criterion, using a scale of 1-3 where 3 is best (lowest additional costs). This adjudged score is based on two facts: firstly, that Horizon Europe will not entail any additional one-off costs to set up or discontinue

the programme, where each of the other policy options will require at least some additional set-up costs; and secondly, that Horizon Europe will not require any additional running costs, where each of the other policy options will involve additional efforts by the Commission and partners in the carrying out of necessary additional tasks (e.g. preparing annual work programmes).

- A **co-programmed partnership** (Option 1 - CPP) will entail slightly higher overall costs as compared with the baseline policy option and has therefore been given a **score of 2**, using a scale of 1-3 where 3 is best (lowest additional costs). There will be some additional set-up costs linked for example with the creation of a strategic research and innovation agenda (SRIA) and additional running costs linked with the partners role in the creation of the annual work programmes and the Commission's additional supervisory responsibilities. A CPP will have lower overall costs than each of the other types of European Partnership, as it will function with a smaller governance and implementation structure than will be required for a Co-Funded Partnership or an Institutionalised Partnership and – related to this – its calls will be operated through the existing HEU agencies and RDI infrastructure and systems.
- The **Co-Funded Partnership (**Option 2 – CFP) has been **scored 1** on overall cost, using a scale of 1-3 where 3 is best (lowest additional costs). This reflects the additional set-up costs of this policy option and the substantial additional running costs for partners, and the Commission, of the distributed, multi-agency implementation model.
- The **Institutionalised Partnership** (Option 3 - IP) has been **scored 1** on overall cost, using a scale of 1-3 where 3 is best (lowest additional costs). This reflects the substantial additional set-up costs of this policy option – and in particular the high costs associated with preparing the Commission proposal and negotiating that through to a legal document – and the substantial additional running costs for the Commission associated with the supervision of this dedicated implementation model.

In relation to **cost-efficiency**, we considered that while there is a clear gradation in the overall costs of the policy options, the cost differentials are less marked when we take into account financial leverage (co-financing rates) and the total budget available for each of the policy options, assuming a common Union contribution. From this perspective, there are only one or two percentage points that split the most cost-efficient policy options – the baseline and CPP policy options – and the least cost-efficient – the CFP and IP. We have therefore assigned a score of 3 to the baseline Option 0 and CPP options for cost-efficiency (no or minor additional costs, as compared with the baseline) and a score of 2 for the CFP and IP policy options (medium additional costs, as compared with the baseline).

Scorecard analysis for the final options assessment

The scorecard analysis built a hierarchy of the options by individual criterion and overall. The scorecard exercise supported the systematic appraisal of alternative policy options across multiple types of monetary, non-monetary and qualitative dimensions. It also allowed for easy visualisation of the pros and cons of alternative options.

Each option was attributed a value of 1 to 3, scoring the adjudged performance against each criterion with the three broad appraisal dimensions of effectiveness, efficiency and coherence.

Scores were justified in a consistent and detailed manner in order to avoid arbitrariness and spurious accuracy. A qualitative or even quantitative explanation was provided of why certain scores were given to specific impacts, and why one option scores better or worse than others.

The scorecard analysis allowed for the identification of a single preferred policy option or in case of an inconclusive comparison of options, a number of 'retained' options or hybrid. The final selection is a policy decision.

2.3 Cross-partnership challenges in Horizon Europe clusters

In this section we set the envisaged and candidate partnerships in the context of the Horizon Europe clusters and the related higher-level EU policy objectives and priorities. We focus on the evolution of the policy context including the new European Green Deal/climate neutrality objectives, the Horizon Europe Framework relevant to this cluster, and the link to the relevant Sustainable Development Goals. Seeing the focus on the Pillar II clusters, this section excludes the candidate *Institutionalised Partnership for Innovative SMEs*.

2.3.1 Cluster 1 – Health

Research and innovation (R&I) actions under this cluster will aim at addressing the major socio-economic and societal burden that diseases and disabilities pose on citizens and health systems of the EU and worldwide.

The R&I activities funded under the Pillar II Cluster Health aim at contributing to the achievement of the Sustainable Development Goal 'Ensuring healthy lives and promoting well-being for all at all ages' resulting from investments in research and innovation focused on three overarching EU policy objectives: 'An economy that works for people', 'A Europe fit for the Digital Age', and 'A European Green Deal' (see Figure 5, below). The Horizon Europe proposal for a regulation defined the areas for possible institutionalised European partnerships on the basis of Article 185 TFEU or Article 187 TFEU as "*Partnership Area 1: Faster development and safer use of health innovations for European patients, and global health".*

At the core in this cluster are the R&I orientations that aim at ensuring that citizens *stay healthier throughout their lives* due to improved health promotion and disease prevention and the adoption of healthier behaviours and lifestyles, the development of *effective health services* to tackle diseases and reduce their burden, and an improved access to *innovative, sustainable and high-quality health care*. These objectives require an unlocking of the full potential of *new tools, technologies and digital solutions* and ensuring a *sustainable and globally competitive health-related industry* in the EU, allowing for the delivery of, e.g. personalised healthcare services. Last but not least, the citizens' health and well-being need to be *protected from environmental degradation and pollution*, addressing a.o. climate-related challenges to human health and health systems.

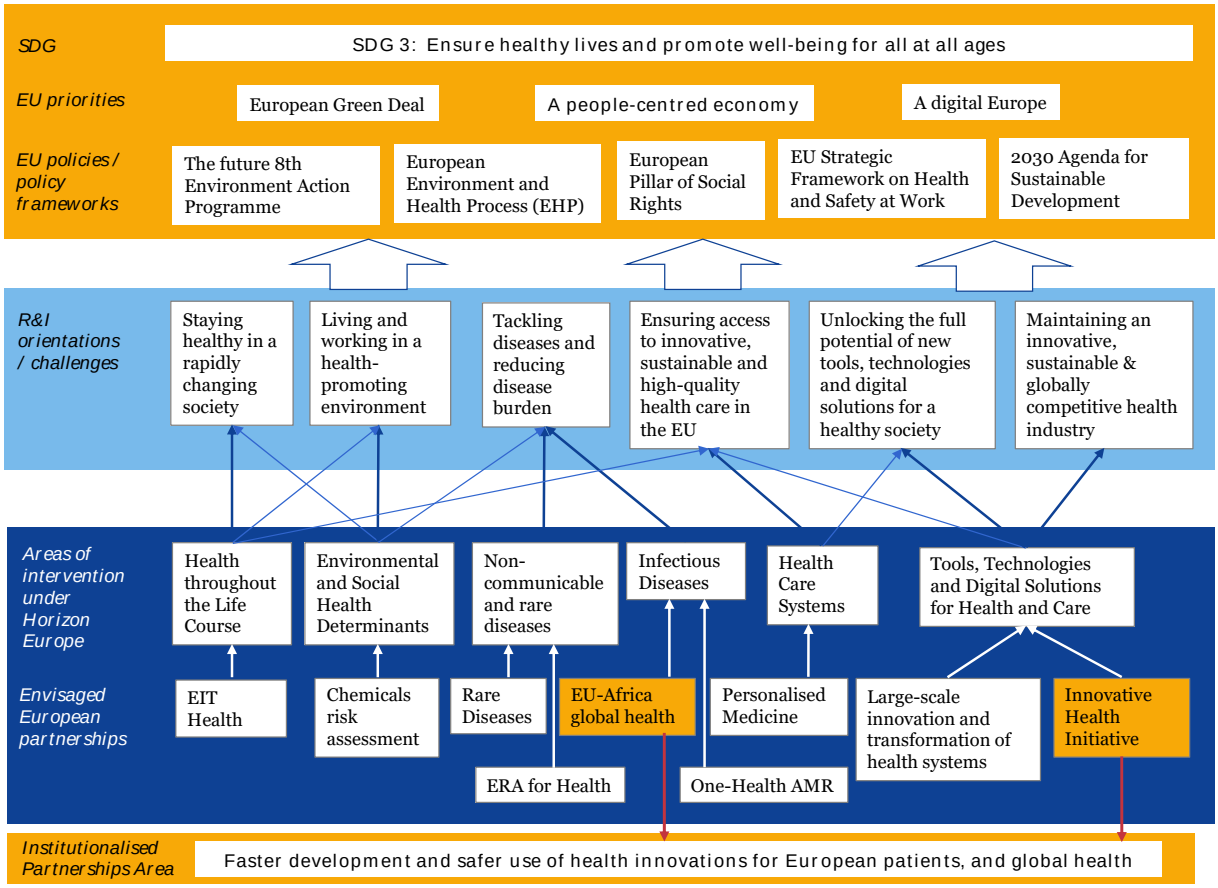
Figure 5, below, shows that the portfolio of envisaged European Partnerships in this cluster[10] aims to contribute to all of the R&I orientations in this cluster. However, there is a pronounced focus on the 'tackling diseases and reducing the disease burden' objective, addressed by five out of the ten partnerships (amongst which there is one candidate Institutionalised Partnership). The objectives focused on an improved exploitation of digital solutions and competitiveness of the EU health-related industry are addressed by two partnerships amongst which one is a candidate Institutionalised Partnership.

In this context, it should be noted that the portfolio of European Partnerships in this cluster predominantly encompasses Co-funded Partnerships, focused on joining the R&I programmes and investments at the national level. There is therefore overall a limited level of involvement of the private sector in the development of the SRIAs (i.e. as partners of the envisaged partnerships), be it from the supply or user side in the value chains. The only exceptions are the Innovative Health Initiative and the EIT KIC Health. European Partnerships also provide limited support for the assessment of environmental and social health determinants, uniquely addressed from a chemical risks perspective.

[10] As proposed in the Horizon Europe 'Orientations towards the first Strategic Plans', dd. December 2019

The description of the interconnections between the partnerships in this cluster and the ones funded in the context of other clusters, provided in the reports of the individual impact assessment studies, sheds more light on this topic.

Figure 5: R&I priorities and higher-level objectives of the Horizon Europe Cluster 1 – Health



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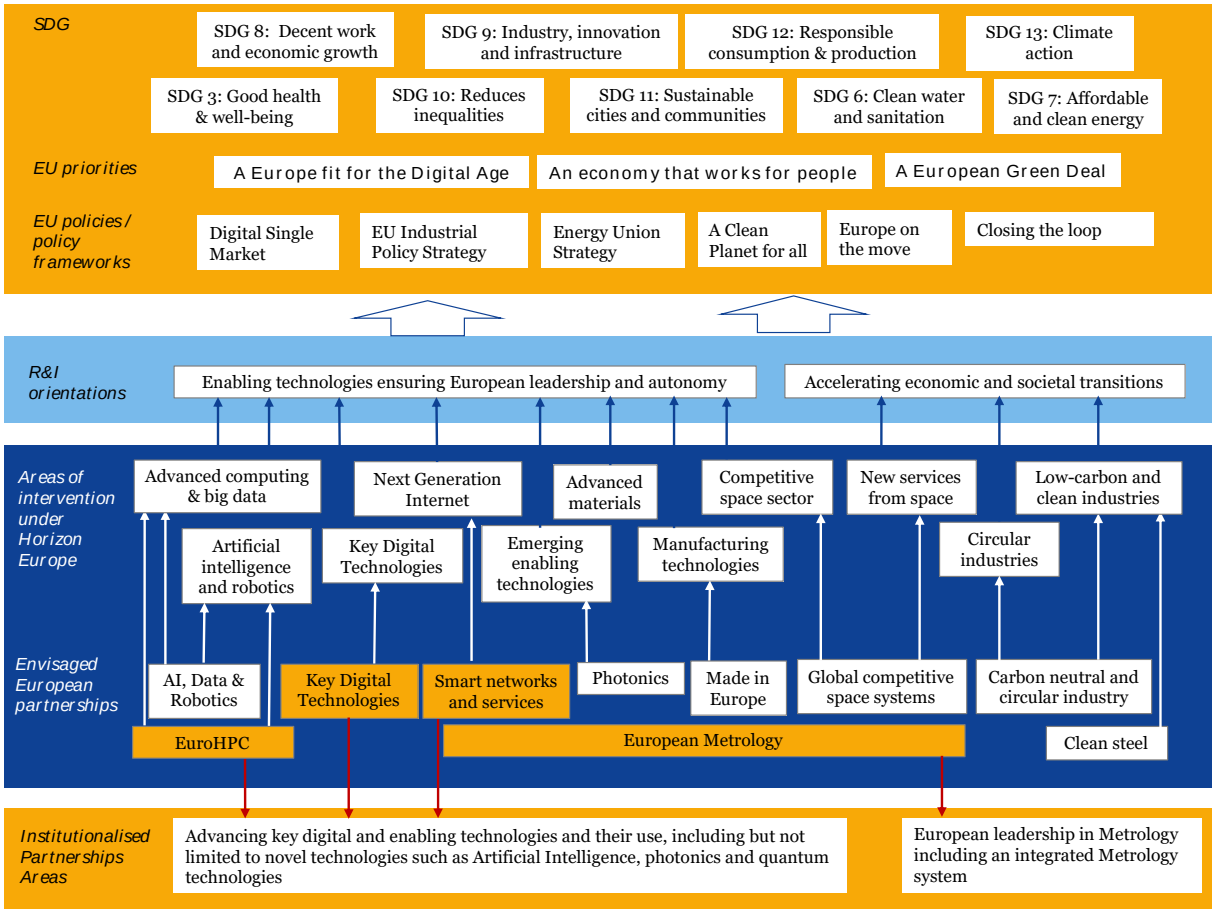
2.3.1 Cluster 4 – Digital, Industry and Space

In this cluster the focus is on the digitisation of European industry and on advancing key enabling, digital and space technologies which will underpin the transformation of our economy and society at large. The overarching vision for R&I investments in this cluster is "a European industry with global leadership in key areas, fully respecting planetary boundaries, and resonant with societal needs – in line with the renewed EU Industrial Policy Strategy." The expected effects on the European economy and society imply that the R&I activities under this cluster will contribute to various Sustainable Development Goals and respond to three key EU policy priorities: 'A European Green deal', 'A Europe fit for the digital age', and 'An economy that works for people' (Figure 6).

The cluster pursues three objectives: 1) ensuring the competitive edge and sovereignty of EU industry; 2) fostering climate-neutral, circular and clean industry respecting planetary boundaries; and 3) fostering social inclusiveness in the form of high-quality jobs and societal engagement in the use of technologies. A human-centred approach will be taken, i.e. technology development going hand in hand with European social and ethical values.

The key R&I priorities are grouped in two general categories: (I) Enabling technologies ensuring European leadership and autonomy; and (II) Accelerating economic and societal transitions (these will be complemented by priorities of other clusters). European Partnerships envisaged to support the R&I in the specific intervention areas are mainly co-programmed partnerships. Exceptions are the three candidate Institutionalised Partnerships in the digital field and the candidate Institutionalised Partnership in metrology, reflecting their related Partnership Areas.

Figure 6: R&I priorities and higher-level objectives of the Horizon Europe Cluster 4 – Digital, Industry and Space



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Multiple convergences exist between the technologies that are covered in the first strand of the priorities in this cluster, i.e. "enabling technologies ensuring European leadership and autonomy". In their function of 'enabling' technologies, they will also make critical contributions to the attainment of the desired 'transitions' in the 'vertical' industry sectors targeted in the second strand of priorities in this cluster as well as in the other clusters. A major contribution from this perspective can be expected from the four candidate Institutionalised Partnerships as well as from the 'Made in Europe' partnership, focused on manufacturing technologies.

2.3.2 Cluster 5 – Climate, Energy and Mobility

The main objectives of this cluster are to fight climate change, improve the competitiveness of the energy and transport industry as well as the quality of the services that these sectors bring to society. This is supportive of several Sustainable Development Goals including affordable and clean energy (SDG7); industry, innovation & infrastructure (SDG9); sustainable cities & communities (SDG11); sustainable consumption & production (SDG12); and climate action (SDG13). The cluster is most closely aligned to the EU priority for 'A European Green Deal' but also has synergy with two of the other five priorities; 'An economy that works for people' and 'A Europe fit for the Digital Age'. This extends across various policies including a Clean Planet for all, the Energy Union strategy, Single European Railway Area, European ATM Master Plan, Single European Sky, and Europe on the Move (Figure 7).

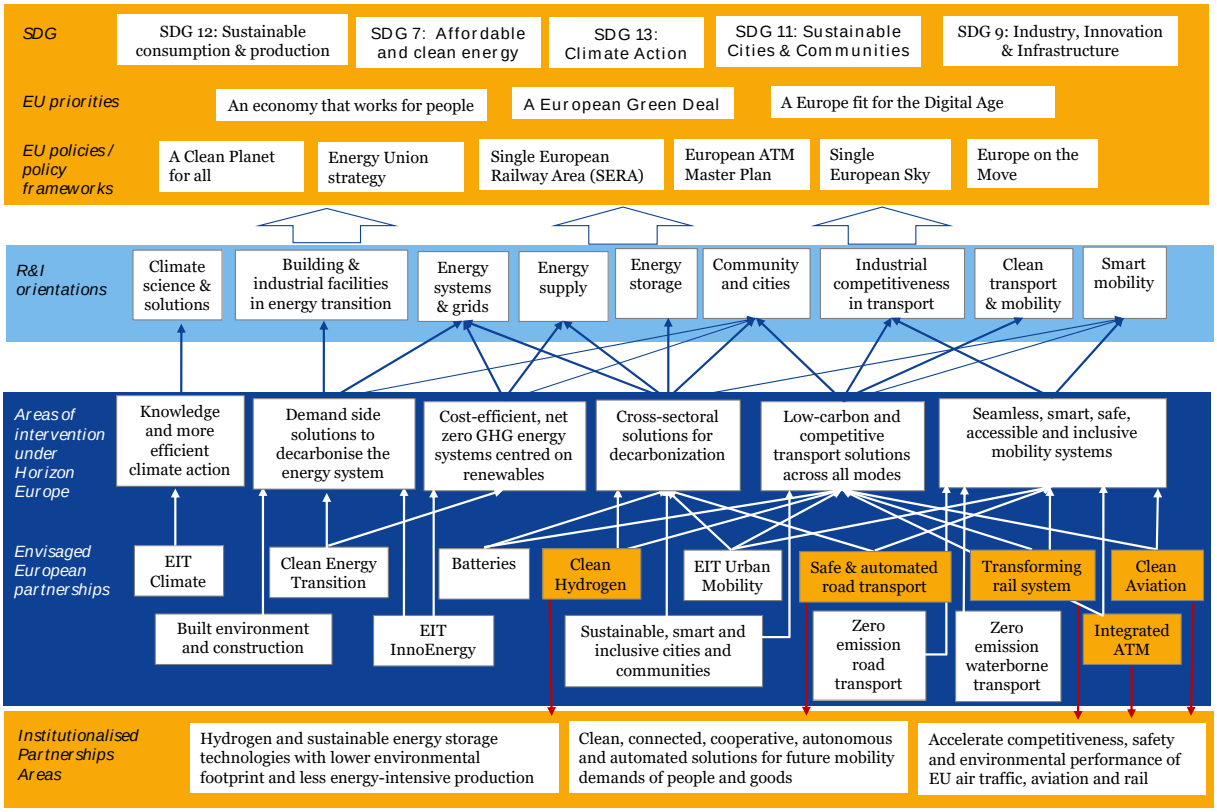
The cluster is directly relevant to several of the areas for possible institutionalised European partnerships on the basis of Article 185 TFEU or Article 187 TFEU, namely:

- Partnership Area 4: Accelerate competitiveness, safety and environmental performance of EU air traffic, aviation and rail

- Partnership Area 6: Hydrogen and sustainable energy storage technologies with lower environmental footprint and less energy-intensive production
- Partnership Area 7: Clean, connected, cooperative, autonomous and automated solutions for future mobility demands of people and goods

Cluster 5 is structured under six areas of intervention under Horizon Europe and nine R&I orientations. Figure 7, below, shows the portfolio of envisaged European Partnerships that are relevant to this cluster and their link to the areas of intervention.

Figure 7: R&I priorities and higher-level objectives of the Horizon Europe cluster Climate, Energy and Mobility



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There are 14 candidate Partnerships that align with this cluster of which eight are possible Institutionalised Partnerships, including five Article 187 initiatives and three EIT-KICs. There are no candidate Article 185 Partnerships in this cluster. The other partnerships are envisaged as either Co-programmed and/or Co-funded Partnerships.

The diagram above shows the strong orientation of the possible Institutional Partnerships towards the mobility area and more limited direct synergies between the envisaged Partnerships and the 'climate science & solutions' priority. Of course, the climate change challenge underpins the whole of this cluster, except where the focus is on industrial competitiveness, but this will also be at least partially dependent on innovation related to clean energy and mobility products and services.

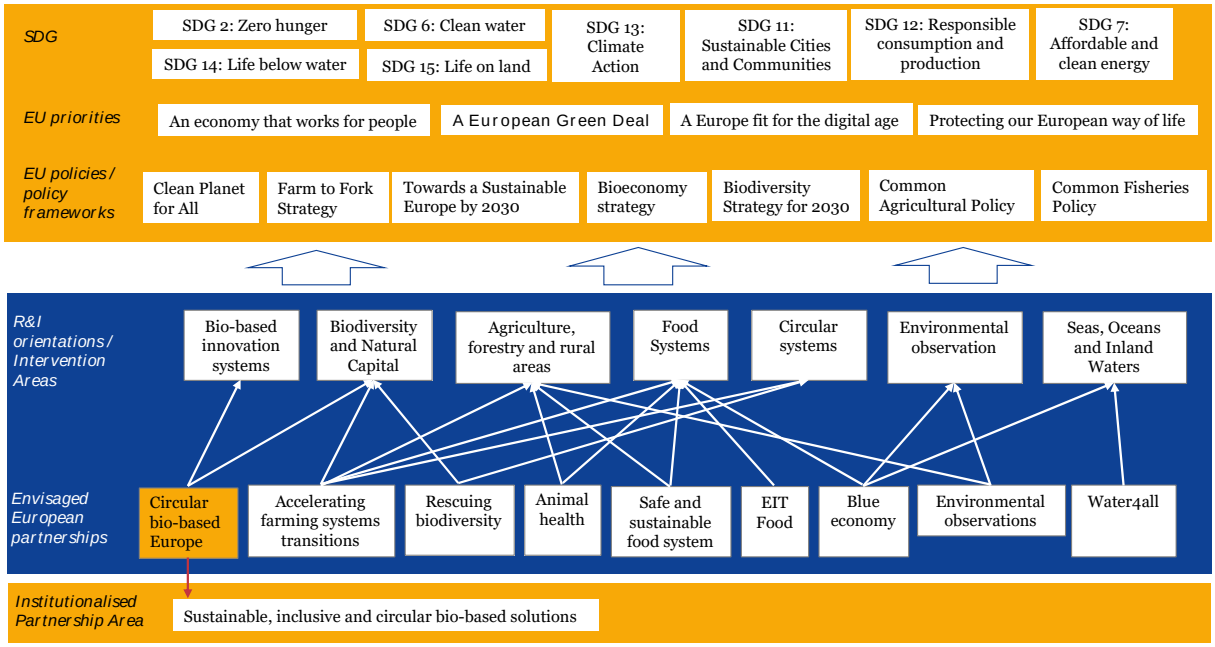
2.3.3 Cluster 6 – Food, Bioeconomy, Natural Resources, Agriculture and Environment

The key objective of Cluster 6, 'Food, Bioeconomy, Natural Resources, Agriculture and Environment' is to advance knowledge, expand capacities and deliver innovative solutions to accelerate the transition towards the sustainable management of natural resources (such as biodiversity, water and soils). The cluster has a large realm and aims to address a wide range of challenges relating to climate change, biodiversity and ecosystems, natural resources, and the production and consumption patterns that may affect them. It encompasses a single area for possible institutionalised European Partnerships aimed at the development of "sustainable, inclusive and circular, bio-based solutions".

The R&I activities funded under the Pillar II Cluster 6 contribute first and foremost to the 'European Green Deal'. More precisely, they will be instrumental to the announced climate change actions, the Biodiversity Strategy for 2030, the "Farm to Fork Strategy", the zero-pollution ambition, the New Circular Economy Action Plan, and the comprehensive strategy on Africa and trade agreements. However, through cooperation with the other clusters, Cluster 6 may make some contribution to the other EU overarching policy priorities. The R&I activities funded under this cluster therefore aim to contribute to the achievement of several United Nations SDGs including: SDG 2: Zero hunger; SDG 6: Clean water and sanitation; SDG 7: Affordable and clean energy; SDG 11: Sustainable cities and communities; SDG 12: Responsible consumption and production; SDG 13: Climate action; SDF 14: Life below water; and, SDG 15: Life on land.

Cluster 6 is structured around six targeted impacts and seven research and innovation orientations, as shown in Figure 8, below. The R&I activities funded under this cluster aim to (1) develop solutions for mitigation of, and adaptation to, *climate change*; (2) halt the *biodiversity* loss and foster the restoration of *ecosystems*; (3) encourage the sustainable (and circular) management and use of *natural resources*; (4) stimulate inclusive, safe and health *food and bio-based systems*; (5) a better understanding of the determinants of *behavioural, socio-economic and demographic changes* to accelerate system transformation; and, (6) improve solutions for *environmental observations and monitoring systems*.

Figure 8: R&I priorities and higher-level objectives of the Horizon Europe Cluster 6 – Food, Bioeconomy, Natural Resources, Agriculture and Environment



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The European Commission envisages nine partnerships under Cluster 6, two of which would be institutionalised (Circular bio-based Europe and EIT Food), four would be either co-programmed or co-funded (Animal Health; A climate-neutral, sustainable and productive Blue Economy; Safe and Sustainable Food Systems for People, Planet and Climate; Water4All), and three would be co-funded (Accelerating Farming System Transition; Agriculture for Data; Rescuing Biodiversity to safeguard life on Earth).

There is seemingly a good balance between the three types of partnerships. However, industry may have some interest in being involved in the design of the Strategic Research and Innovation Agendas regarding living labs and other research infrastructure ('Towards more sustainable Farming' envisaged partnership) to develop solutions for accelerating the transition of farming systems, and technologies to collect agriculture data.

The proposed portfolio of European Partnerships covers the full range of R&I orientations under Cluster 6.

All but one of the proposed partnerships contribute to orienting R&I activities towards the development of food systems that will ensure both sustainable and healthy diets and food and nutrition security for all. The food system has an impact on several challenges. It directly relates to nutrition and diets, access to food, food security, and has an influence on the use of natural resources, water and soil pollution, climate change. Food waste is a key component of circular systems and biomass has strong potential to offer bio-based energy solutions. Finally, the transformation of food systems should take into consideration demographic changes and the accelerating urbanisation (which reduces lands available for food production but offers opportunities for new types of agriculture such as urban farming).

Two R&I orientations are covered by less than half of the proposed partnerships: Environmental Observations (even though achievement in this area could make significant contribution to the other areas) and Bio-based innovation systems (which is nevertheless at the core of the candidate institutionalised partnership for a circular bio-based Europe).

EUROPEAN COMMISSION

Part I. Impact Assessment Studies for the Candidate Institutionalised European Partnerships

11. Candidate institutionalised European Partnership on Clean Hydrogen

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2020 Directorate-General for Research and Innovation EN

Abstract

This document is the final report of the Impact Assessment Study for the candidate Institutionalised European Partnership on Clean Hydrogen under Horizon Europe. The study was conducted by Technopolis Group and Trinomics from July to December 2019. The methodological framework reflects the Better Regulation Guidelines and operationalises the selection criteria for European Partnerships set out in the Horizon Europe Regulation.

The report assesses the impact of potential initiatives to support, through research and innovation, the growth and development of clean hydrogen, among which an Institutionalised European Partnership is one of the options assessed. The existing challenges for clean hydrogen include the limited high-level scientific capacity and fragmented research activities, the insufficient deployment of hydrogen applications, and consequently weaker EU scientific and industrial value chains. Environmental, health and mobility pressures are also driving the need for cleaner hydrogen generation, deployment and use. An initiative for clean hydrogen must have as a main objective the strengthening and integration of EU scientific capacities, to support the creation, capitalisation and sharing of knowledge. This is necessary to accelerate the development and improvement of advanced clean hydrogen applications, the market entry of innovative competitive clean solutions, to strengthen the competitiveness of the EU clean hydrogen value chains (and notably the SMEs within them), and to develop the hydrogen-based solutions necessary to reach climate neutrality in the EU by 2050.

The study concluded that Institutionalised Partnership is the preferred option for the implementation of this initiative.

Executive Summary

This document is the final report of the Impact Assessment Study for the candidate Institutionalised European Partnership on Clean Hydrogen under Horizon Europe. The study was conducted by Trinomics from July to December 2019, under the coordination of Technopolis Group. The methodological framework for this study (described in the report on the overarching context to the impact assessment studies) reflects the Better Regulation Guidelines and operationalises the selection criteria for European Partnerships set out in the Horizon Europe Regulation.

Considering that "the role of hydrogen is likely to become more prominent in a fully decarbonised energy system" (A Clean Planet for all), hydrogen and fuel cells are "transformational carbon-neutral solutions that EU research should focus on".

Hydrogen applications have progressed significantly over the past decade, but are not yet playing a 'prominent' role in the energy system. Continuous R&D will be required to ensure hydrogen applications are technically improved, highly efficient, as cost competitive as possible and have a long lifetime. It is important in the upcoming years to increase market uptake by accelerating the necessary cost reductions and further increasing sector integration and coupling to decarbonize progressively EU economy. This will need to provide solutions for the EU's waterborne, aviation, rail, road transport sectors, and the gas and power sectors. The lack of local regulations and appropriate standards currently limits the development of a clean hydrogen industry.

EU action in the field of RD&I should focus on:

- Strengthening and integrating EU scientific capacities to support the creation, capitalisation and sharing of knowledge;
- Strengthening the competitiveness of the EU clean hydrogen value chain (notable SMEs), accelerating market entry;
- Developing the hydrogen-based solutions necessary to reach climate neutrality in the EU by 2050.

The conclusion of this impact assessment study is that an Institutionalised Partnership (IP) is the preferred option. With a broad, strong and expanding existing community, an IP is the option with the highest scientific and economic impact, achieved by significantly increasing collaboration, bolstering EU industry (especially SMEs), therefore contributing most to maintaining EU's leading position. Given the versatility of hydrogen, an IP is the option with the highest impact in supporting the decarbonisation of difficult-to-decarbonise sectors, supporting the deployment of infrastructure at scale and improving market conditions to accelerate uptake. With valuable expert knowledge management capacities internal to the IP, it can more efficiently support building hydrogen ecosystems by providing support to regional and local authorities, more adequately select projects, challenge the industries that might remain conservative and provide coordination capacities to bring together all stakeholders along the whole value chain.

The Institutionalised Partnership is the option that will most efficiently integrate the Strategic R&I Agenda into a broader spectrum, outside of just R&I, including through awareness raising, public outreach, training and by providing a strong link with the decision makers responsible for setting up the MS and EU hydrogen plans. It would ensure a more coherent approach for the whole hydrogen economy from R&I to market uptake, addressing specifically the "valley of death" challenge and the standards and regulatory frameworks development. To maximise complementarities and synergies with all concerned sectors, EU and international initiatives and programmes, an IP is also clearly the best option.

Résumé exécutif

Ce document est le rapport final de l'étude de support à l'analyse d'impact de la proposition de partenariat européen institutionnalisé pour l'hydrogène propre dans le cadre d'Horizon Europe. L'étude a été menée par Trinomics et coordonnée par Technopolis entre juillet et décembre 2019. Le cadre méthodologique de cette étude (décrit dans le rapport sur le contexte général des études de soutien aux analyses d'impact) tient compte des lignes directrices pour une meilleure réglementation et opérationnalise les critères de sélection des partenariats européens définis dans le règlement d'Horizon Europe.

Il est de plus en plus reconnu que « le rôle de l'hydrogène deviendra fort probablement très important dans un système énergétique entièrement décarboné » (*Une planète propre pour tous*) et que l'hydrogène et les piles à combustible sont des « solutions transformationnelles neutres en carbone sur lesquelles la recherche Européenne devrait concentrer ses efforts ».

Les applications de l'hydrogène ont considérablement progressé au cours de la dernière décennie, mais ne jouent pas encore un rôle « déterminant » dans le système énergétique. Pour aider l'Europe à relever les défis de la décarbonisation, une recherche et un développement continus sont nécessaires afin de garantir que les applications de l'hydrogène seront techniquement améliorées, hautement efficaces, aussi compétitives que possible, avec une longue durée de vie. Il importe, dans les années à venir, de parvenir au stade de commercialisation, d'accélérer la nécessaire réduction des coûts et de poursuivre l'intégration et le couplage des secteurs, en fournissant des solutions aux secteurs européens de la navigation, de l'aviation, du rail, du transport routier, des secteurs du gaz et de l'électricité, afin de décarboner progressivement l'économie européenne. L'absence de réglementations locales et de normes appropriées limite actuellement le développement d'une industrie de l'hydrogène propre.

Pour relever ces défis, l'action de l'UE dans le domaine de la RD&I devrait viser à :

- Renforcer et intégrer les capacités scientifiques de l'UE pour soutenir la création, la capitalisation et le partage des connaissances
- Renforcer la compétitivité de la chaîne de valeur de l'hydrogène propre de l'UE (notamment les PME) en accélérant la mise sur le marché
- Développer les solutions à base d'hydrogène nécessaires pour atteindre la neutralité carbone dans l'UE d'ici 2050

Les options politiques pertinentes pour cette analyse étaient les appels à projet d'Horizon Europe, et les partenariats co-programmés et institutionnalisés. Notre conclusion est qu'un partenariat institutionnalisé (PI) est l'option préférée. Avec une communauté existante étendue, forte et en expansion, un PI aura des impacts scientifiques et économiques plus importants en augmentant considérablement la collaboration, en renforçant l'industrie de l'UE (en particulier les PME), en contribuant le plus concrètement au maintien de la position de leader de l'UE. Compte tenu de la polyvalence de l'hydrogène, un PI aura un impact plus important pour soutenir la décarbonisation des secteurs difficiles à décarboner, soutenir le déploiement des infrastructures à grande échelle et améliorer les conditions de marché pour en accélérer le démarrage. Doté de précieuses capacités de gestion des connaissances internes, le PI peut soutenir plus efficacement la construction d'écosystèmes d'hydrogène en fournissant un soutien aux autorités régionales et locales, en sélectionnant plus adéquatement les projets, en poussant les industries qui pourraient rester conservatrices et en fournissant des capacités de coordination pour rassembler toutes les parties prenantes de la chaîne de valeur.

Le partenariat institutionnalisé intégrera plus efficacement le Programme Stratégique de Recherche et d'Innovation dans un contexte plus large, au-delà de la R&I, notamment en

matière de sensibilisation, de formation et du lien fort avec les décideurs responsables de la mise en place des plans hydrogène des États membres et de l'UE. Il assurerait une approche plus cohérente pour l'ensemble de l'économie de l'hydrogène, de la RD&I à la mise sur le marché, en s'attaquant spécifiquement au défi de la « vallée de la mort » ainsi qu'à l'élaboration de normes et de cadres réglementaires. Afin de maximiser les complémentarités et les synergies avec tous les secteurs concernés, les initiatives et programmes européens et internationaux, un PI est également clairement l'option idéale.

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Glossary

BEV	Battery Electric Vehicle
CCS / CCU	Carbon Capture and Storage/Carbon Capture and Utilisation
CEF	Connecting Europe Facility
CHP	Combined Heat and Power
COSME	Competitiveness of Enterprises and SMEs programme
EP	European Partnerships under HEU
FCEV	Fuel Cell Electric Vehicle
FCH JU (and FCH 2 JU)	Fuel Cells and Hydrogen Joint Undertaking, the current EU partnership on hydrogen research and innovation under Horizon 2020
GHG	Greenhouse Gas
HRS	Hydrogen Refuelling Station
InnovFin EDP	Energy Demo projects funded by the European Investment Bank's InnovFin programme
IPCEI	Important Projects of Common European Interest
KBA	Knowledge and research Based Actor
LNG	Liquid Natural Gas
MHV	Material-Handling Vehicle
NECP	National Energy and Climate Plan
OEM	Original Equipment Manufacturer
PEM	Polymer electrolyte membrane (refers to electrolysis or type of electrolyser)
PV	Photovoltaic Solar
SME	Small and Medium Enterprises
SMR	Steam Methane Reformer
SRIA	Strategic Research and Innovation Agenda
SOFC	Solid Oxide Fuel Cell (can refer type of electrolysis)
TRL	Technology readiness level

1 Introduction: Political and legal context

This document presents the impact assessment of the candidate institutionalised partnership on Clean Hydrogen, one of the initiatives behind the Commission's vision for the period beyond 2020 under Horizon Europe Pillar II, specifically the Climate, Energy and Mobility Cluster. It is envisaged as a European Partnership in Partnership Area 6: "Hydrogen and sustainable energy storage technologies with lower environmental footprints and less energy-intensive production."

1.1 Broad policy context of hydrogen

Hydrogen has interested the EU **since the early 2000s**. Support for the growth and development of clean hydrogen applications—those which use hydrogen generated with renewable electricity or fossil derived hydrogen combined with CCS/U (Carbon Capture and Storage / Carbon Capture and Utilisation)—featured heavily in the implementation of Horizon 2020. Hydrogen, as an energy carrier, is progressively viewed as a means through which to increase the share of renewables in European energy markets, to store and transport large amount of electricity and to provide energy for sectors otherwise difficult to decarbonise. Hydrogen enables sector "coupling" between the electricity system and industry and between buildings and transport. The focus on hydrogen applications has evolved gradually and in the future will increasingly centre on clean hydrogen, meaning "near-to-zero" hydrogen.

In November 2018, the European Commission published "**A Clean Planet for all**", the strategic long-term vision of the Commission for a prosperous, modern, competitive and climate-neutral economy by 2050. The communication sets out a clear vision of how to achieve **climate neutrality by 2050**, recognising "the role of hydrogen is likely to become more prominent in a fully decarbonised energy system," and including hydrogen and fuel cells in its list of "transformational carbon-neutral solutions that EU research should focus on."[1] In order to become a carbon neutral economy by 2050, EU will need clean hydrogen as an integral part of the clean energy transition.

In September 2018, the Commission, 27 EU Member States (all except the UK), Iceland and Switzerland signed on to the **Hydrogen Initiative** and affirmed their collective aim to maximise the potentials of sustainable hydrogen technology.

In the **European Green Deal**,[2] the Commission highlights the need for "EU industry 'climate and resource frontrunners' to develop the first commercial applications of breakthrough technologies in key industrial sectors by 2030," and states that "priority areas include clean hydrogen, fuel cells and other alternative fuels, energy storage, and carbon capture, storage and utilisation."

In Summer 2019, the Commission published an overview of its open consultation on "**Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe**" emphasising the relevance of clean hydrogen as a cross-sectoral solution for decarbonisation. The aim to "strengthen

[1] European Commission (2018), A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Communication from the Commission to the European Parliament, the European Council, the Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank COM(2018)773, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

[2] Communication released on 11/12/2019: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

the European value chain for low-carbon hydrogen and fuel cells" is included as a key R&I orientation.[3]

There is no longer any doubt that hydrogen will play a key role in the energy transition, addressing climate challenges in the upcoming years and decades.

1.2 Emerging challenges in the field

Hydrogen applications have progressed significantly over the past decade.[4,5,6] Several important technologies have been developed from low-level R&D stages to market-readiness, with the scope of hydrogen applications continually broadening.[7,8] Still, hydrogen applications have not yet entered European markets at scale. These applications could reduce greenhouse gas emissions in the EU's difficult-to-decarbonise sectors, but some heavy industry and heavy transport market players do not yet view hydrogen as an economical decarbonisation solution.[9,10,11]

In upcoming years it will be important for hydrogen applications at higher technology readiness levels to reach market scale in their respective sectors.[12] Once hydrogen value chains are well-established and an EU-wide hydrogen ecosystem is developed, it will be easier for these applications to achieve cost reductions and be further integrated into existing industries.[13,14] Wide adoption will prompt larger-scale hydrogen product industrialisation, which will in turn reduce their costs.[15,16]

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[3] European Commission (2019), Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe – available at https://ec.europa.eu/research/pdf/horizon-europe/ec_rtd_orientations-towards-the-strategic-planning.pdf

[4] Fuel Cells and Hydrogen Joint Undertaking (2018), FCH JU – Success Stories: A partnership dedicated to clean energy and transport in Europe – available at https://www.fch.europa.eu/sites/default/files/FCHJU-successstories-brochure-WEB-fin.pdf

[5] World Energy Council (2018), Hydrogen an enabler of the Grand Transition: Future Energy Leader position paper – available at https://www.worldenergy.org/assets/downloads/1Hydrogen-an-enabler-of-the-Grand-Transition_FEL_WEC_2018_Final.pdf

[6] Financial Times (2019), Hydrogen could help decarbonise the global economy – available at https://www.ft.com/content/959d08e2-a899-11e9-984c-fac8325aaa04

[7] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[8] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[9] Vattenfall (2019), Hydrogen, an important step towards independence from fossil fuels – available at https://group.vattenfall.com/press-and-media/news--press-releases/newsroom/2019/hydrogen-an-important-step-towards-independence-from-fossil-fuels

[10] Hydrogen Europe (2017), Decarbonise Industry, available at https://hydrogeneurope.eu/decarbonise-industry

[11] Power Engineering International (2019), Hydrogen: The hope for 'hard-to-decarbonise' sectors – available at https://www.powerengineeringint.com/2019/09/26/hydrogen-the-hope-for-hard-to-decarbonise-sectors/

[12] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[13] E4tech (2017), Study on Supply Chain for Hydrogen and Fuel Cells Technologies

[14] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[15] Hydrogenics (2018), Cost Reduction Potential for Electrolyser Technology – available at https://www.humsterlandenergie.nl/resources/LInks-duurzaam/Linkpagina/20180619_Hydrogenics_EU-P2G-Platform_for-distribution.pdf

[16] National Renewable Energy Laboratory (2011), Hydrogen Production Cost Analysis – available at https://www.nrel.gov/hydrogen/production-cost-analysis.html

For the EU's hydrogen economy to thrive, increasing cross-sector integration will also be necessary. As further hydrogen applications develop, supply chains connecting potential producers to distributors and end-users become more complex.[17] Potential hydrogen producers will need to collaborate with potential distributors and end-users. Players in the renewables sector will need to collaborate with gas grid operators, heavy-duty vehicle fleet owners and energy intensive industries in order to develop feasible and competitive business plans to support hydrogen integration into their existing operations.[18,19]

Developing the hydrogen economy will require investments in hydrogen generation and end-use equipment in all concerned sectors. It will also require investments in hydrogen storage, transportation, and distribution infrastructure – the lack of which is currently stalling the rollout of market-ready hydrogen applications.[20,21] The adaptation of existing infrastructure (especially the natural gas networks and the related gas knowledge), the exploitation of natural storage capacities (salt caverns), the deployment and adaptation of harbour's infrastructure (LNG – Liquefied Natural Gas terminals, ammonia terminals and storage tanks) are very important for large scale deployment of clean hydrogen.

Importing cheap green hydrogen produced using wind and solar power outside of Europe (e.g., in North Africa, Ukraine, or Scotland) will also become more important in the near future. These deployments should prompt the establishment of international standards and the development of the required infrastructure.

Large scale integrated hydrogen generation systems will be developed (e.g. clean hydrogen from PV – Photovoltaic solar and wind power, combined with biomass or coal gasification, whereby the oxygen from the electrolyser can be used in the gasification process; reverse osmosis could produce demineralised water as feedstock to produce hydrogen by electrolysis, etc.).

At the same time, continuous research and development will be required to ensure that hydrogen technologies are technically improved, highly efficient, as competitive as possible and have a long lifetime. Improvements to technologies will be consistently required, and the need for new technologies and applications is likely to emerge as hydrogen technologies are rolled out.[22,23,24]

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[17] IRENA (2019), Sector Coupling – available at https://www.irena.org/energytransition/Power-Sector-Transformation/Sector-Coupling

[18] Jorg Gigler and Marcel Weeda on behalf of TKI Nieuw Gas (2018), Outlines of a Hydrogen Roadmap – available at https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/20180514%20Roadmap%20Hydrogen%20TKI%20Nieuw%20Gas%20May%202018.pdf

[19] US Department of Energy Hydrogen Program (2006), Analysis of the Hydrogen Production and Delivery Infrastructure as a Complex Adaptive System – available at https://www.hydrogen.energy.gov/pdfs/progress06/viii_11_jones.pdf

[20] World Energy Council (2019), New Hydrogen Economy – Hope or Hype?: Innovation Insights Brief – available at https://www.worldenergy.org/assets/downloads/WEInnovation-Insights-Brief-New-Hydrogen-Economy-Hype-or-Hope.pdf

[21] The International Council on Clean Transportation (2017), Developing hydrogen fueling infrastructure for fuel cell vehicles: A status update – available at https://theicct.org/sites/default/files/publications/Hydrogen-infrastructure-status-update_ICCT-briefing_04102017_vF.pdf

[22] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[23] ScienceDaily (2019), Researchers design a roadmap for hydrogen supply network – available at https://www.sciencedaily.com/releases/2019/09/190912124835.htm

[24] Phys.org (2019), Scientists find way to help fuel cells work better, stay clean in the cold – available at https://phys.org/news/2019-01-scientists-fuel-cells-cold.html

The lack of regulatory frameworks supporting and governing the use of hydrogen applications compounds these challenges.[25] For many years, hydrogen applications were not technologically advanced enough to motivate the EU to develop and adopt hydrogen legislation. However, policy guidelines at local, national and EU-levels are increasingly necessary to enable hydrogen's market entry at large scales.[26,27,28]

Table 1 below provides an overview of key emerging challenges in the field of clean hydrogen.

[25] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[26] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

[27] Fuel Cells and Hydrogen Joint Undertaking 10th Stakeholder Forum (2017), Fuel Cell and Hydrogen Technology: Europe's Journey to a Greener World, available at https://op.europa.eu/en/publication-detail/-/publication/15d2c3b7-c502-11e7-9b01-01aa75ed71a1

[28] Hydrogen Europe (2018), EU Legislative framework for implementation of Hydrogen in different applications – available at https://www.waterstofnet.eu/_asset/_public/powertogas/Conference/10-Nicolas-Brahy_Hydrogen-Europe-HyLaw-_Regulation-Overview.pdf

Table 1: Overview of the emerging challenges

Social	The safety of hydrogen applications is increasingly becoming a concern as hydrogen diversifies from industrial use to use by the wider public[29]
Technical and technological	The scope of hydrogen applications is increasing from its present focus on transport, FCs and electrolysers, and is expanding to include the energy sector (power, heating and gas), industry and new transport applications (maritime, aviation, rail, heavy transport).[30] With the regular emergence of new applications, the supply chain becomes more complex and continuous improvements[31] (new materials[32], efficiency, reliability, lifetime[33], cost[34], …) are still needed for all applications. Producing clean hydrogen is costly at the moment. Cost reductions, even for some ready-to-market applications, are still expected (and needed). Current hydrogen use (primarily by industry) is almost entirely supplied from natural gas and coal. Harnessing this existing consumption whilst keeping on track for a clean energy future requires both the capture of CO_2 from hydrogen production from fossil fuels and greater supplies of hydrogen from renewable electricity. Hydrogen produced from renewable electricity is a versatile energy carrier that can respond to a high share of renewables in the electricity grid (expected 55% in 2030) by providing flexibility through large-scale/long-term energy storage capability, it can also increase the flexibility and efficiency of the entire energy system through sectoral integration.
Economic	The development of hydrogen infrastructure is slow and holding back hydrogen transport, distribution and use. Gas infrastructure, because of its cost-efficiency compared to electricity transmission lines, could transport hydrogen generated with electricity produced by large renewable offshore plants.[35]

[29] Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies, Evidence Report, E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc, Oct 2018 (called the "Competitiveness Analysis"). This study shows how safety is addressed by Industries, Knowledge Associations through projects and research.

[30] The scope expansion has been addressed in the frame of the structured consultation of Member States fiche for Clean Hydrogen, June 2019

[31] The Appendix: Analytical report on the Strategic Value Chain (SVC) on Hydrogen technologies and systems in the frame of the Strategic Forum on IPCEI (called the "IPCEI Appendix"), points out the special techno-economic challenges of reducing the cost, increasing the efficiency and reducing the use of Critical Raw Materials (from FCH JU lists) (p 29)

[32] The "IPCEI Appendix" addresses, as example, the development and qualification of new materials to continue improving high pressure hydrogen storage (p 10)

[33] Example of buses lifetime addressed in the "Competitiveness Analysis" (p 67)

[34] The "IPCEI Appendix" points out the cost of producing hydrogen should be reduced (p 13), FCEV should cost similar to electrical vehicles (p14), technologies cost reduction is also a question of competitiveness with other regions especially Asian competitors (p28);

The "Competitiveness Analysis" illustrates cost decrease expectations by 2030, for many different applications, depending on mass production (p 48)

[35] Study on the "Hydrogen – The Bridge between Africa and Europe" http://profadvanwijk.com/wp-content/uploads/2019/09/Hydrogen-the-bridge-between-Africa-and-Europe-5-9-2019.pdf

	The market risks, the cost of hydrogen and (currently low) hydrogen demand are among the barriers to rapid hydrogen uptake (with the exception of the most mature transport applications, e.g. buses) Cost reduction strongly depends on mass production, challenge is to achieve higher volumes and cost reductions.[36] Wide deployment of hydrogen-powered vehicles is limited in part by the "chicken and egg" problem of needing to deploy infrastructure and vehicles in tandem.
Environmental	European nations, regions and cities need to take action now to achieve their ambitious Greenhouse Gas (GHG) emission reduction targets and to improve local air quality.
Political, policy and regulatory framework	Production pathways should be aligned with the Paris Agreement and global climate policy. The Linz Declaration (Austrian presidency 2018) shows political attention from Member States. Hydrogen is gaining momentum at international level, e.g. through the Clean Energy Ministerial (CEM) hydrogen Initiative, Mission Innovation Challenge 8 "Renewable and Clean Hydrogen", the international Partnership for Hydrogen in the Economy (IPHE), the Hydrogen Energy Ministerial (HEM). Those who move faster will seize the best opportunities from hydrogen development. The lack of local regulations and appropriate standards (e.g. for Hydrogen Refuelling Stations (HRS) regarding safety,…) currently limits the development of a clean hydrogen industry. Government and industry must work together Achieving sustainable deployment and avoiding a cycle of disappointment requires public support and intervention. Securing appropriate policy support, especially, but not only, at national (MS) level is essential to drive growth and uptake.

1.3 EU relative positioning

1.3.1 Competitive positioning of Europe in the field

European industry is active across all areas of the hydrogen economy's value chain.[37] Principle trends in Europe can be summarised as follows:

Clean hydrogen production is the critical first link in the value chain for hydrogen. The production of clean hydrogen will progressively occur through two primary pathways. Firstly, it will be produced using three main electrolysis technologies (i.e., Alkaline, Proton Exchange Membrane [PEM] and Solid Oxide Electrolysis Cell [SOEC] electrolysers).[38] The EU is a scientific and industry leader in today's global alkaline electrolysis industry, with

[36] The "IPCEI Appendix" highlights the need to scale up industrial electrolysis to get competitive (p 8), fuel cell technologies and systems (p 11)

[37] The main trends are coming from the study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies, Evidence Report, E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc, oct 2018. These are completed by the Hydrogen, enabling a zero emission Europe, technology roadmaps full pack, Sept 2018, Hydrogen Europe

[38] ScienceDirect (2019), Electrolysers: an Overview – available at https://www.sciencedirect.com/topics/engineering/electrolysers

highly active competitors in China and Japan and less active competitors the US.[39] PEM electrolysis is a much younger technology than alkaline electrolysis and could become an essential hydrogen production mechanism in the future as it develops further.[40] The US, through initial development for military purposes, has pioneered the technology and has a strong industrial presence in PEM electrolyser production.[41] European developers are also commercialising their own PEM electrolysers. A key US PEM electrolyser manufacturer was recently acquired by NEL, such that Europe is now to be better positioned competitively in this technological field. SOEC electrolysers are still at their earliest stage of development and remain a focus of research base actors and academia.[42,4344]

Clean hydrogen will also be produced using other near-zero carbon technologies, including Steam Methane Reforming with Carbon Capture Storage/Use (SMR+CCS/U), but also biomass gasification, solar hydrogen, waste gasification, biological production from algae. Much of the global activity on these novel methods of production remains at the University/Research Institute level, with EU institutions well positioned in these fields. European companies are also well-placed to capitalise on these technologies once they are further developed.[45]

Currently, the bulk of hydrogen (though not clean hydrogen) is produced via Steam Reforming of natural gas without Carbon Capture and Storage. This production method counteracts CO_2 reduction objectives (as it is estimated that the production of 1 kg of hydrogen via SMR leads to 10 kg of CO2 emissions). SMR without Carbon Capture and Storage does not require investments in research and innovation.

Hydrogen distribution and storage that is cost-effective, efficient and safe is crucial to the development of value chains for transporting and distributing large volumes of generated hydrogen to end users.[46] Currently hydrogen is distributed via dedicated networks or via road transportation, and hydrogen is stored at industrial sites.

There remain significant opportunities for improvements to distribution technologies.47,48 EU industry and particularly EU SMEs are at the forefront of hydrogen handling and logistics

[39] Euractiv (2019), EU-wide innovation support is key to electrolysis in Europe – available at https://www.euractiv.com/section/energy-environment/opinion/eu-wide-innovation-support-is-key-to-electrolysis-in-europe/

[40] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[41] US Department of Energy Office of Energy Efficiency & Renewable Energy (2019), Hydrogen Production: Electrolysis – available at https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

[42] Fuel Cells and Hydrogen Joint Undertaking (2018), European Developments in Electrolyser Technology: Technical and Economic Outlook – available at https://www.waterstofnet.eu/_asset/_public/powertogas/Conference/4-Nikolaos-Lymperopoulos_-FCH-JU.pdf

[43] Hydrogenics (2019), State of Play and Developments of Power-to-Hydrogen Technologies – available at https://etipwind.eu/wp-content/uploads/A2-Hydrogenics_v2.pdf

[44] Industrialization of water electrolysis, IndWede study, 2018

[45] ScienceDirect (2019), Hydrogen Production: An overview – available at https://www.sciencedirect.com/topics/chemistry/hydrogen-production

[46] US Department of Energy Hydrogen Program (2006), Analysis of the Hydrogen Production and Delivery Infrastructure as a Complex Adaptive System – available at https://www.hydrogen.energy.gov/pdfs/progress06/viii_11_jones.pdf

[47] Jorg Gigler and Marcel Weeda on behalf of TKI Nieuw Gas (2018), Outlines of a Hydrogen Roadmap – available at https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/20180514%20Roadmap%20Hydrogen%20TKI%20Nieuw%20Gas%20May%202018.pdf

[48] Joint Research Centre (2016), 4th International Workshop on Hydrogen Infrastructure and Transportation Report – available at

with many leading companies focusing on multiple applications and technologies, including hydrogen refuelling stations (HRS), liquefaction facilities, hydrogen-rich aromatic and alicyclic molecules handling, and ammonia and methanol conversion plants.49 The range of hydrogen storage technologies varies widely, with applications at dramatically different stages of development. For most storage technologies, Europe is generally well-positioned, with suppliers or developers in all areas. Compressed storage is an area of relative weakness given strong Asian and North American science and industry actors50, including the lack of EU manufacturing for carbon fibres.

Hydrogen end uses in transport: Hydrogen and fuel cells can play an important role fostering a low-carbon road transport system.[51] In particular, hydrogen is envisioned to play a vital decarbonisation role in long-distance transport (e.g. for long-haul heavy goods vehicles and coaches), in buses and truck fleets, in aviation (i.e., through synthetic fuels based on hydrogen), and in train transport, and in the maritime sector (i.e., through the use of hydrogen fuel-cell-powered units).[52] The long-term Strategy of the Commission (November 2018) stated that electrification of light duty vehicles transport will effectively move markets towards electrification, and that after the adoption of the Regulation on CO_2 emission standards for new passenger cars and vans. Across these potential end use sectors in transport:

- The leading OEM integrators for Fuel Cell Electric Vehicles (**FCEVs)** (**cars and light commercial vehicles**) are in Asia. Daimler is currently the only European OEM with a 'commercial' product, which is in very limited production. Europe does however have several entrepreneurial integrators targeting different applications;
- Europe is well placed in **fuel cell bus** development[53], having deployed most of the early roll-out buses, though China is now deploying more vehicles;
- **Fuel cell forklifts** markets and providers are predominantly concentrated in North America. The potential exists in Europe for FC forklifts to be produced and deployed, with an important gap in demand related to the comparatively weak economics of the systems. This may require costs to come down before fuel cell forklifts are deployed in the EU;
- In Europe, several hydrogen trucks (**Heavy Duty Vehicles [HDVs]**) have been integrated into existing systems. There is growing interest in zero-emission logistics in Europe, particularly from major retailers and their transport solutions providers. This will help to generate an early market. The FC truck sector includes multiple segments,

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103586/4%20int%20workshop%20on%20h2%20infra%20final%20pdfonline.pdf

[49] Hydrogen Europe (2017), Hydrogen safety – available at https://hydrogeneurope.eu/hydrogen-safety

[50] IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030 – available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf

[51] A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy, p111

[52] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[53] The "Competitiveness Analysis" (p 68), with as main weakness: Stacks from EU suppliers who might supply buses have not yet proven long lifetimes, so buyer confidence is less than for non-EU suppliers. And as main threat: If costs do not come down, local authorities may not be able to justify budgets for FCEBs

the most promising of which for FCs include long haul 26-40 tonne trucks, logistics applications, and refuse collection trucks;[54]

- In Europe, Germany leads in regional **trains**[55] powered by hydrogen fuel cells, which are now certified for passenger use.[56] China is also relatively advanced in the deployment of fuel cells for rail, with some light rail and tramway applications already in service. China currently uses systems from Canadian suppliers;
- Europe has several Knowledge and Research Based Actors (KBAs) with FCH skills specific to the **maritime sector,**[57] especially in Nordic countries. The European supply chain is beginning to scale up. With multiple demonstration projects ongoing or in preparation, Europe could become a market leader in optimised technological solutions for maritime applications. This is exemplified by the range of European companies that are active in the fuel cell maritime space;[58]
- **Aeronautics** is one of the EU's key high-tech sectors in the global market. With world-leading aircraft companies and expertise in fuel cell technologies, Europe could achieve a leading position integrating hydrogen within the aviation sector

Hydrogen end uses in energy: Hydrogen could supply heating and power for buildings (leading to decarbonisation of the natural gas grid through blending & and the potential upgrading of the natural gas grid to pure hydrogen grid), power generation (providing seasonal storage for generated renewable electricity), and power for industry (by replacing natural gas to generate process heat). Across potential end use sectors in the energy sector:

- The European **micro-CHP** domestic market is developing, but only a few thousand units are in currently use, in contrast to the ~300,000 units installed in Japan to date.[59] Europe has strong heating appliance integrators with varied but increasing degrees of participation in fuel cells, but very few have in-house fuel cell stack development. No European player has the depth of experience that can be found in Japan;
- There are very few PEM commercial **FC prime power**[60] and **CHP** integrators either in Europe or abroad. Nevertheless, this area could potentially grow into a stronger market than that for micro-CHPs;
- The market for **large FC CHP** and **primary power**[61] in Europe has been slow to develop as few support schemes exist, and almost all installations are concentrated in Asia and the US, due to ongoing industrial development and interaction. North America and Japan have a stronger base of manufacturers for such fuel cells;

[54] Hydrogen, enabling a zero emission Europe, technology roadmaps full pack, Sept 2018, Hydrogen Europe, page 52

[55] The "Competitiveness Analysis" (p 73)

[56] Alstom Press Release. Available at: https://www.alstom.com/press-releases-news/2018/7/coradia-ilint-hydrogen-train-receives-approval-for-commercial-operation-in-german-railway-networks

[57] The "Competitiveness Analysis" (p 75)

[58] Hydrogen, enabling a zero emission Europe, technology roadmaps full pack, Sept 2018, Hydrogen Europe, page 61

[59] Ene-Farm programme: https://fuelcellsworks.com/news/fcw-exclusive-tokyo-fuel-cell-expo-2019-300000-ene-farms/

[60] The "Competitiveness Analysis" (p 89)

[61] The "Competitiveness Analysis" (p 95)

- European gas turbines producers have signed commitments[62] to deliver technologies that can operate with high shares of hydrogen (20% by 2020 and 100% by 2030);
- Europe has strong heating appliance integrators with varied but increasing degrees of participation in fuel cells. Many manufacturers, like the boiler manufacturers, have a long history in heating appliances and in technology integration. Some are now introducing boilers on the market. Those manufacturers are also deploying hybrid heat pump-hydrogen boilers.

Hydrogen end uses in industry: Hydrogen can supply industry feedstock and partially replace natural gas as feedstock in combination with CCU/CCS. Potential end-use sectors for hydrogen in industry include steel and iron manufacturers, refineries, and ammonia and other fertiliser manufacturers. Organisations involved with the multiple demonstration projects ongoing in Europe will soon have unrivalled expertise in the integration of clean hydrogen as a feedstock for industry.[63,64,65] Europe could eventually become a market leader in the use of clean hydrogen in industry.

1.3.2 Support for the field in the previous Framework Programme

Appendix D includes a summary of the First Interim Evaluation of the FCH JU,[66] the Second Interim Evaluation of the FCH JU,[67] and the Final Evaluation of the FCH JU.[68]

The main conclusions of the Interim Evaluation of the FCH 2 JU[69] are as follows:

- On **continued relevance**, the JU has further reinforced a community of industry and research bodies around a common long-term research agenda and gathered a portfolio of projects that reflects the specific objectives assigned to it. The JU continues to be relevant. The evaluation concludes that the JU is supporting work across the right spectrum of technologies to ensure they may be effectively deployed in Europe in the light of the specific needs and circumstances of various regions.
- **Implementation of the PPP** has been successful in most relevant aspects. The Industry Grouping has organised its participation effectively. The JU has successfully created an active FCH community and extended this to include municipalities and regions through a Memorandum of Understanding. Financial management appears to be robust and the views of the public and beneficiaries sought in the consultations are strongly positive. The overall operational efficiency of the FCH 2 JU has improved as the institution has matured. It should be noted that the JU has continued to exceed the level

[62] https://powertheeu.eu/

[63] The H2FUTURE project, for example, is injecting green hydrogen into steel production, thereby eliminating greenhouse gas emissions that would normally ensue. Demonstrating that even energy-dependent sectors can rely on this technology will make for increasingly green industrial production (The FCH JU success stories)

[64] Refhyne, launched in January 2018, is on course to build the largest hydrogen electrolysis plant of its kind in the world, with a capacity of 10MW, at the Rhineland refinery in Germany (The FCH JU success stories)

[65] In 2016, SSAB, LKAB and Vattenfall formed a joint venture project with the aim of replacing coking coal in ore-based steel making with H2. In 2018, a pilot plant was planned and designed in Lulea and the Norbotten iron ore fields to provide a testing facility for green H2(produced by electrolysis) to be used as a reducing agent in steelmaking. Project partners state that using this production method could make steel (the Technology Roadmap, Hydrogen Europe)

[66] First Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking (from 12/2010 to 04/2011)

[67] Second Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking (12/2013 to 07/2013)

[68] Final Evaluation of the Fuel Cells and Hydrogen Joint Undertaking (2008-2014) operating under FP7 (June 2017)

[69] Interim Evaluation of the Fuel Cells and Hydrogen 2 Joint Undertaking (2014-2016) operating under Horizon 2020

of participation by SMEs specified for Horizon 2020. In terms of overcoming fragmentation within Europe, the challenges of delivering improved coordination between Member States' FCH research and innovation support remain. There is little evidence that the SRG is effective in this regard, and this continues to be a priority for improvement for the FCH 2 JU.

- **Added value and necessary leverage**: The FCH 2 JU has an explicit added value amongst the FCH innovation community. The decision to proceed with FCH 2 JU bringing together 93 industrial organisations from 22 European countries can be regarded as a substantial achievement for Europe, and was almost certainly enabled by the unifying presence of the FCH JU programme. Though hard evidence is lacking to definitively assess the leveraging position of the FCH JU, the assessment of contributions can be considered an indication of the leverage achieved by EU funds and is clearly a strong sign that the JU is successfully aligned on industrial priorities. For the period 2014-2015, the FCH 2 JU generated 1.63 of total leverage.
- **Coherence with EU policies**: The work of the JU is coherent with policies of the EU in energy, environment, transport and competitiveness. The technologies being developed with the support of the JU are capable of significant contributions to the security of energy supply, to the reduction of global and local pollution, to a clean and sustainable transport sector and to a more competitive European economy in a carbon-limited world.
- **The future after FCH 2 JU**: The IEG is of the opinion that there will be a continued need for support in the field of fuel cells and hydrogen beyond the FCH 2 JU. The PPP approach remains a viable option, and it is desirable that the community created through the FCH 2 JU be maintained. However, the PPP scheme should be revised if support to deployment is given. As with renewable energy technologies, FCH competitiveness can only be achieved with appropriate regulatory support, which is not in place at present, so the exploitation route for JU outputs is incompletely prepared. Any new PPP should be considered in the context of the probable need for accompanying deployment support for FCH technologies if the research and innovation outcomes are to successfully transition to commercial use.

Research undertaken in a collaborative European environment such as FCH 2 JU has been shown to be beneficial and should be continued as a means through which to efficiently support the development of necessary new technologies.

The previous programmes (FP7 and H2020) managed by the Fuel Cell and Hydrogen Joint Undertakings (FCH JU and FCH 2 JU) have partially addressed all stages/fields of the hydrogen value chain described above, by focusing on:[70]

- **Transport**, with demonstration activities concerning over 1,900 light-duty vehicles; the deployment of 45 buses in 10 cities (in operation in 2018), with the aim to deploy 310[71]; the demonstration of material-handling vehicles (MHVs)[72] including 226 forklift trucks and 188 MHV covering 10 different MHV models;[73] and with considerable progress made on the production of state-of the-art stacks for automotive application.[74]

[70] All these data are coming from the FCH JU Annual Activity Report 2018

[71] This European FCH bus deployment can be considered as worldwide state-of-art having progressed significantly throughout FCH 2 JU projects (https://www.fuelcellbuses.eu/projects/jive)

[72] With the 2 projects HyLIFT-EUROPE and HAWL

[73] Deployed in 2018 at 3 sites

[74] Through the AUTOSTACK CORE, INSPIRE, and VOLUMETRIQ projects

- **Infrastructure**, with cross-cutting activities contributing to standardisation, RCS and safety; demonstration and deployment of infrastructure network;[75] supporting the deployment of Hydrogen Refuelling Stations (HRS) to reach 99 units (of which 48 in 2018); supporting the deployment of an HRS network for cars in 11 countries; and with two projects[76] currently working towards building and testing a prototype compressor (HRS equipment);
- **Hydrogen production**, including the development of PEM manufacturing,[77] the development and testing of three principal types of electrolysers in various projects[78] (though the development of electrolysers and their technical integration with renewable power plants should remain a prominent scientific focus of the initiative);
- **Power production**, with the relevant FC (stationary FC CHP) technology steadily demonstrated in real installations,[79] and one project[80] has demonstrated a CHP PEM fuel cell power plant integrated into a chlorine-alkali production plant;

To conclude, the FCH JU and FCH2JU have developed successful mechanisms for fostering continued technological innovation. There is still a need, however, for testing new production processes for technologically advanced hydrogen applications that could result in cost reductions. There is also a need for increased demonstration projects that can generate and open markets to hydrogen technologies. And finally, there is a need to increase the scope of applications by involving more sectors.81

Several weaknesses of the FCH JU and FCH 2 JU were identified. Allocated funds were mainly concentrated in Western European Member States (like DE, FR, IT, DK and the UK, as can be seen in Appendix D). And the participation of all Member States (including low R&I performing Member States) in H2 R&D activities is still not fully achieved and should be improved. These issues should be addressed in the next initiative.

1.4 EU policy context beyond 2021

As set out in the report on the overarching context to the impact assessment studies, the R&I activities funded under the Horizon Europe Pillar II Cluster "Climate, Energy and Mobility" will contribute to the attainment of at least three of the six main ambitions for Europe: 'A European Green Deal', 'A people-centred economy' and 'A Digital Europe.' These activities will support several Sustainable Development Goals, particularly Climate Actions (SDG13) and Sustainable Cities and Communities (SDG11).

A detailed analysis of synergies for the envisaged and candidate partnerships in the ***climate & energy cluster*** is shown in Figure 1. This shows not only the central positioning of the proposed hydrogen and battery partnerships, in terms of providing solutions to the challenges for sustainable mobility and energy, but also synergies with many of the partnerships in other clusters (especially the digital and industry cluster). Likewise, the

[75] In the frame of 2 FCH 2 JU projects

[76] The COSMHYC55 and H2REF56 projects, with great potential for improving the techno-economics for compression (and hence for HRS)

[77] On the side, four projects focus on the development of PEM manufacturing, balance of plant and quality control practices for transport and MHV applications: DIGIMAN, Fit-4-AMandA, INLINE, INN-BALANCE projects

[78] The International Energy Agency (2019), The Future of Hydrogen – Seizing today's opportunities, Report prepared by the IEA for the G20, Japan, available at https://webstore.iea.org/the-future-of-hydrogen

[79] While most of targets set in the Multi-Annual-Work-Program (MAWP) have been met

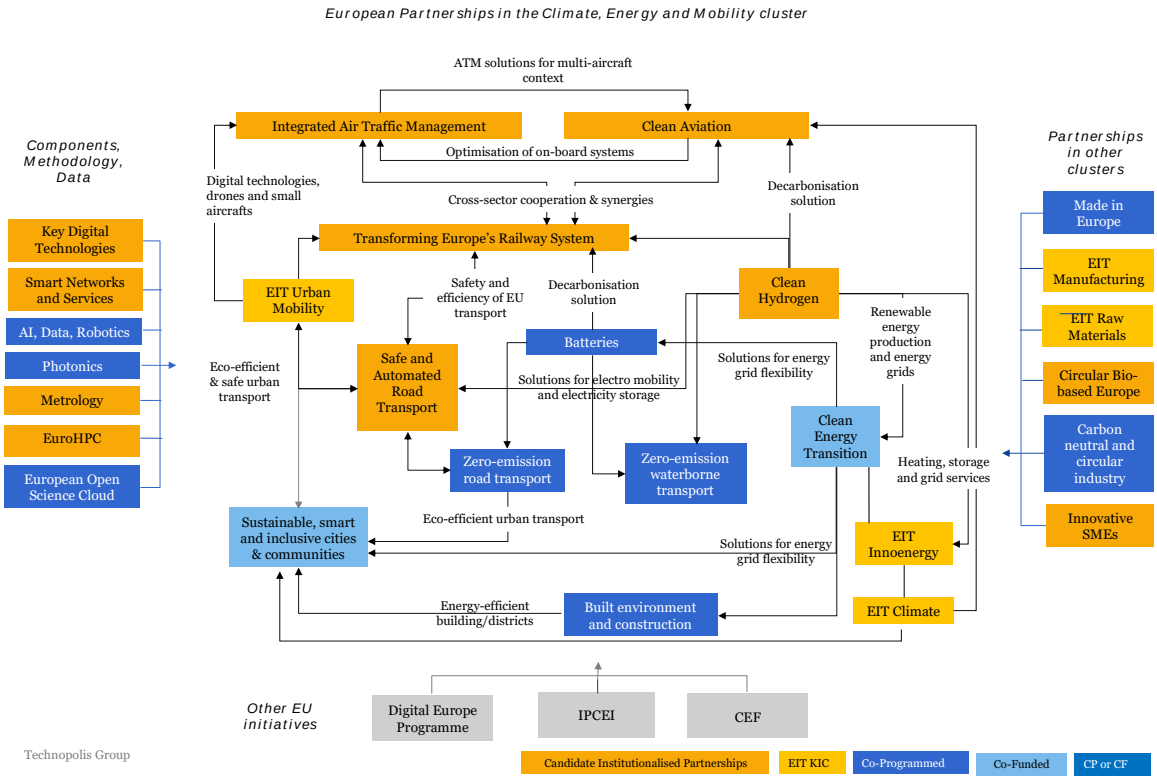
[80] The DEMCOPEM-2MW project

[81] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

cross-pillar European Open Science Cloud partnership will provide 'horizontal' (infrastructural) support to collaborative research and innovation within each envisaged partnership in Cluster 5, while also facilitating exchange and re-use of research data for the integration of new technologies into energy and mobility solutions.

There are clearly many opportunities for collaboration between partnerships and across clusters for the delivery and end-use of hydrogen. Though the Clean Hydrogen initiative would be the only partnership focused on addressing hydrogen production.

Figure 1: Interconnections between the envisaged partnerships in the Climate, Energy and Mobility cluster



The European Commission recently confirmed its intention to work on the barriers identified[82] (regulatory hurdles, infrastructure fit for hydrogen, sectoral integration in general) through initiatives that will be put forward in 2020 in order to support the rollout of advanced hydrogen applications. Until now, policy development has been limited to planning and had not yet reached implementation stages.[83] National policy papers detailing legal and administrative processes, identifying best practices, legal barriers and providing policy recommendations are being regularly published. The HyLAW project continues to

[82] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[83] Hydrogen Europe (2018), EU Legislative framework for implementation of Hydrogen in different applications – available at https://www.waterstofnet.eu/_asset/_public/powertogas/Conference/10-Nicolas-Brahy_Hydrogen-Europe-HyLaw-_Regulation-Overview.pdf

highlight the need for a pan-European legislative structure so that a hydrogen ecosystem can fully advance.[84,85,86,87]

To facilitate the growth of cohesive hydrogen value chains, policy makers will need to address the need for regulation governing hydrogen storage, hydrogen transportation (potentially through existing gas grids), hydrogen distribution (through standardised refuelling stations), and hydrogen end-use.[88] Safety standards will need to be adopted across all potential applications for hydrogen.[89] While regulatory research has been conducted and several potential frameworks proposed at international, European and national levels, very few have been considered by lawmakers and enacted.[90,91]

The hydrogen economy will comprise many different technological solutions and applications, concerning different actors and linkages to various sectors. Adequate collaboration and connections between relevant sectors will therefore be required along the whole value chain.[92,93] There is a need to maintain and reinforce coherence and collaboration, and to initiate new collaborations with:

- The initiative for **Transforming EU's rail system**, based on the Shift2Rail JU and the FCH 2 JU's joint study on the use of fuel cells and hydrogen in the railway environment,[94] which could be used as a strong common framework for collaboration
- The initiative for **Clean Aviation**, based on joint experiences like the FCH JU and Clean Sky joint workshop on aeronautical applications of fuel cells[95]

[84] HyLAW (2019), Deliverable 4.5 EU policy Paper – available at https://www.hylaw.eu/sites/default/files/2019-06/EU%20Policy%20Paper%20%28June%202019%29.pdf

[85] HyLAW (2019), Deliverable 4.4 EU regulations and directives which impact the deployment of FCH technologies – available at https://www.hylaw.eu/sites/default/files/2019-02/D4.4%20-%20EU%20regulations%20and%20directives%20which%20impact%20the%20deployment%20of%20FCH%20technologies_0.pdf

[86] HyLAW (2018), D4.1 Cross-country comparison – available at https://www.hylaw.eu/sites/default/files/2018-11/D.4.1%20-%20Analysis%20of%20commonalities%20and%20differences%20between%20countries.pdf

[87] Hydrogen Europe (2018), EU Legislative framework for implementation of Hydrogen in different applications – available at https://www.waterstofnet.eu/_asset/_public/powertogas/Conference/10-Nicolas-Brahy_Hydrogen-Europe-HyLaw-_Regulation-Overview.pdf

[88] HyLAW (2019), Deliverable 4.5 EU policy Paper – available at https://www.hylaw.eu/sites/default/files/2019-06/EU%20Policy%20Paper%20%28June%202019%29.pdf

[89] Hydrogen Europe (2017), Hydrogen safety – available at https://hydrogeneurope.eu/hydrogen-safety

[90] HyLAW (2018), Deliverable 4.2 List of Legal Barriers – available at https://www.hylaw.eu/sites/default/files/2019-01/D4.2%20-%20List%20of%20legal%20barriers.pdf

[91] Dennis Hayter for HyLAW (2018), Hydrogen Law and removal of legal barriers to the deployment of fuel cells and hydrogen applications – UK National Policy Paper – available at https://www.hylaw.eu/sites/default/files/2019-01/HyLaw%20UK%20Policy%20Paper_Final_December%202018.pdf

[92] International Renewable Energy Agency (2018), Hydrogen from renewable power: Technology outlook for the energy transition – available at https://www.irena.org/publications/2018/Sep/Hydrogen-from-renewable-power

[93] Element Energy Ltd on behalf of the UK Department for Business, Energy & Industrial Strategy (2018), Hydrogen supply chain evidence base – available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf

[94] https://shift2rail.org/publications/study-on-the-use-of-fuel-cells-and-hydrogen-in-the-railway-environment/

[95] https://www.fch.europa.eu/news/joint-cleansky-fch-ju-workshop-aeronautical-applications-fuel-cells-and-hydrogen-technologies

- The initiatives on **Smart Networks and Services** and on **Key digital technologies**, based on the fuel cell power plants at the heart of smart grids project[96]
- The initiative for **Circular bio-based Europe**, based on the HyTime project[97] and the UNIfHy project[98]
- The initiative on **Clean Steel** (low carbon steelmaking), based on the H2FUTURE project[99]
- **SPIRE** (cPPP on Sustainable Process Industry through Resource and Energy Efficiency), based on the Refhyne project[100]
- The proposed initiative on the **waterborne sector**, that could be based on the experience extracted from the Flagship project[101], the Maranda project[102], and the workshop[103] on "Fuel Cells and Hydrogen for maritime and harbour applications: current status and future perspectives in the EU"
- The proposed partnership "Towards zero-emission road transport (2ZERO)", based on the experience extracted from JIVE project[104], ZEFER, TAYHA[105]…

There is also a need to initiate new collaborations with all RD&I activities related to Carbon Neutral and Circular Industry; the built environment and construction; Clean Energy Transition; Batteries - Towards a competitive European industrial battery value chain.

Strong collaboration is needed between the Clean Hydrogen initiative and the aforementioned initiatives to ensure proper integration of technologies into applications aimed at decarbonising concerned sectors.

New coherence and collaboration opportunities should also be pursued with sectors not addressed by initiatives, including:

- The power and especially the renewable energy sector
- The gas sector and especially gas grid operators

Synergies are also expected with other EU programmes and networks, including:

- The **European Energy Research Alliance (EERA)**, currently the largest energy research community in Europe. Organised into 17 Joint Research Programmes, of which

[96] https://www.fch.europa.eu/news/fuel-cell-power-plants-heart-smart-grids

[97] The low temperature hydrogen production from 2d generation biomass https://www.fch.europa.eu/project/low-temperature-hydrogen-production-2nd-generation-biomass

[98] Unique gasifier for hydrogen production https://www.fch.europa.eu/project/unique-gasifier-hydrogen-production

[99] injecting green hydrogen into steel production

[100] the largest hydrogen electrolysis plant of its kind in the world, with a capacity of 10MW, at the Rhineland refinery in Germany (The FCH JU success stories)

[101] https://www.fch.europa.eu/news/flagships-project-deploy-two-hydrogen-vessels

[102] https://www.fch.europa.eu/sites/default/files/documents/ga2011/2_Session%204_MARANDA%20%28ID%204811767%29.pdf

[103] https://www.fch.europa.eu/news/fuel-cells-and-hydrogen-maritime-and-harbour-applications

[104] https://www.fuelcellbuses.eu/projects/jive

[105] https://www.fch.europa.eu/page/transport

the "Joint Programme on Fuel Cells and Hydrogen"[106] aims to accelerate and harmonise long-term research on fuel cells and electrolysers in Europe. EERA coordinates energy research to achieve more efficient and cheaper low carbon energy technologies;

- The **Programme for Environment & Climate Action (LIFE)** under the Natural Resources and Environment heading, dedicated to the EU environmental and climate objectives, with the strategic objective of bridging the gap between the development of new knowledge and its implementation[107]
- The **High-Level Expert Group on Energy-Intensive Industries[108]** which is developing technology roadmaps referenced in the Masterplan for a competitive transformation of EU Energy Intensive Industries enabling a climate neutral, circular economy

The initiative could provide access to funds and financing mechanisms that would help to bridge the so-called "valley of death" beyond the R&I phase. It would support the innovation and industrialisation phase for clean hydrogen applications, whereby they could enter markets at larger scales. These funds might be sourced from:

- The **Strategic Forum for Important Projects of Common European Interest (IPCEI[109])** which has identified six key strategic value chains[110] of specific importance for EU's industries and competitiveness, including the "Hydrogen technologies and systems" value-chain. It has recommended the development of "a roadmap for a future European Hydrogen Economy"
- The **Connecting European Facility** (CEF) which aims to develop and modernise the trans-European networks in the fields of transport, energy and digital and facilitate cross-border cooperation with an emphasis on synergies between sectors[111], i.e. in the areas of connected and autonomous mobility, and clean mobility based on alternative fuels and energy storage[112]
- The **ETS Innovation Fund**[113] which is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies. It can probably be relied on to support the industrialisation phase of hydrogen applications

[106] https://www.eera-set.eu/eera-joint-programmes-jps/list-of-jps/fuel-cells-and-hydrogen/

[107] Proposal for a European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing a Programme for the Environment and Climate Action (LIFE) and repealing Regulation (EU) No 1293/2013, COM(2018) 385

[108] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3326

[109] https://www.clustercollaboration.eu/news/call-applications-strategic-forum-important-projects-common-european

[110] https://ec.europa.eu/commission/sites/beta-political/files/euco-sibiu-eu_industry_fit_for_the_future.pdf, where in total, three of the value chains are directly relevant to hydrogen: the "Hydrogen technologies and systems", "Low CO2 emissions industry" and "Clean, connected and autonomous vehicles"

[111] EC (2018), Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility and repealing Regulations (EU) No 1316/2013 and (EU) No 283/2014, COM(2018) 438 final

[112] EPRS (2018), Connecting Europe Facility 2021-2027 - Financing key EU infrastructure networks, BRI (2018)628247

[113] https://ec.europa.eu/clima/policies/innovation-fund_en

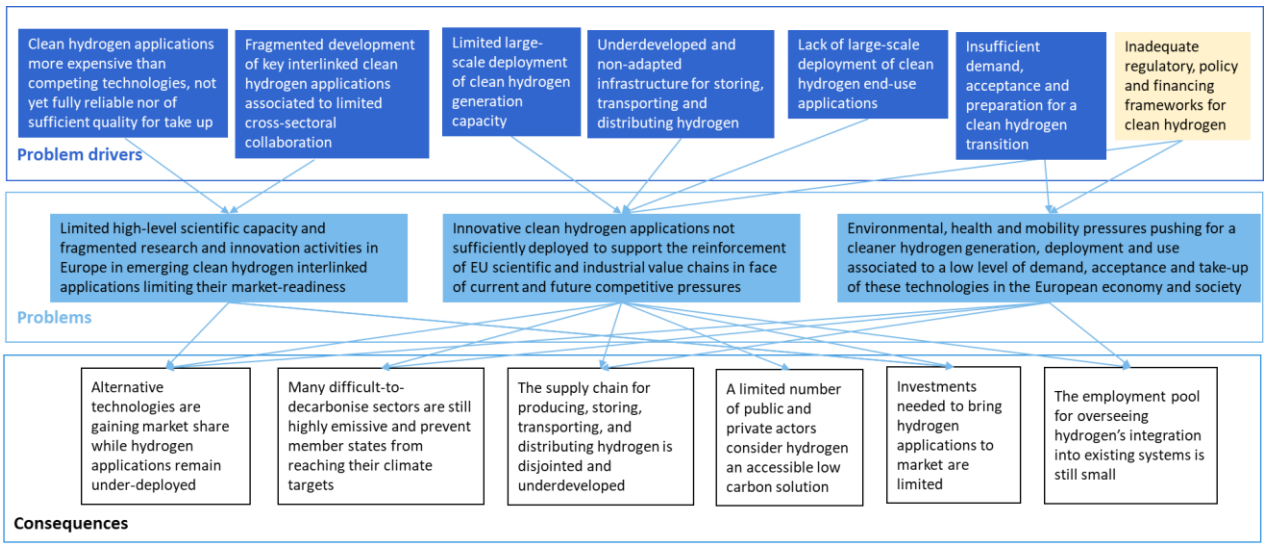
- The **European Investment Bank,** which on November 14, 2019 launched an ambitious new climate strategy and Energy Lending Policy,[114] like the loans provided by InnovFin EDP[115]
- The **Multi-annual Financial Framework** (MFF) 2021-27, which extends beyond Horizon Europe

2 Problem definition

This section discusses problems that must be addressed in relation to the emerging challenges presented in Section 1.1, drawing on evidence from desk research and the findings of the stakeholder consultation undertaken as part of this study. While the problems identified by the FCH 2 JU impact assessment have been addressed to some extent through FCH 2 JU management of industry and research during Horizon 2020, it is clear that several underlying issues remain and that the main problems described in the previous section will persist for emerging or new applications, and will likely re-emerge in the absence of ongoing policy intervention.

A problem tree portraying related problems, their drivers and consequences is presented in Figure 2 and described in detail in the following sections.

Figure 2: Problem tree for the initiative on Clean Hydrogen



Source: Trinomics

The problem tree presented in Figure 2 above portrays related problems, their drivers in the scientific, technological/economic and societal spheres, and their consequences. They are further described in detail in the following sections. This diagram will further feed the objective tree and the intervention logic presented in the following sections of the report, addressing the need for EU R&I action.

2.1 What are the problems?

EU research and innovation action is needed to address several key problems in the field of Clean Hydrogen, given current and anticipated challenges in the sector. These issues are explicated below. One crucial problem – the EU-wide absence of strong regulatory

[114] https://www.eib.org/en/press/all/2019-313-eu-bank-launches-ambitious-new-climate-strategy-and-energy-lending-policy

[115] European Commission (2019) European Partnership on Clean Hydrogen. Fiche for the consultation with Member States

frameworks governing the use of key hydrogen technologies – cannot be addressed exclusively through research and innovation. However, it is included as it relates to the problem drivers described in section 2.2.

2.1.1 Limited scientific capacity and fragmentation in clean hydrogen interlinked applications limiting their market-readiness

Hydrogen applications have been developed to different levels of technological readiness. Those at higher TRLs – including stationary fuel cells, light FCEVs, fuel cell buses and electrolysers – are ready for market deployment; however, they remain comparatively more expensive than competitor technologies.[116,117,118] Substantial R&I effort is still needed to develop even the technologies/applications which are mature enough to enter the market, to improve their efficiency, cost, durability and manufacturability.[119]

Due to their versatility, hydrogen applications can be used in a large variety of sectors and sub-sectors. For some applications, clean hydrogen directly competes with less expensive alternatives; in other cases, it is the only low-carbon option for decarbonisation, such that its relative expensiveness is less important. Other applications could become more interesting than competitor options because of unique advantages like longer lifetimes and higher energy storage capacities. Though from a general perspective, hydrogen applications remain expensive, there is no common rule when it comes to their comparison to other options. Each option must be assessed separately regarding its comparative cost and maturity (which is the purpose of a Strategic Research and Innovation Agenda and not of this study).

The efficiency of hydrogen production/transformation should be considered as a critical aspect and therefore needs to be stressed and assessed for each application. Having sufficient conversion rates is essential to ensure long term viability of each hydrogen application.

Competitor technologies are gaining shares in markets where hydrogen could play a role, but where higher costs are preventing its uptake.[120,121,122] For example, renewable power plant operators increasingly rely on batteries to store excess electricity, rather than on electrolysers and hydrogen storage options.[123] Consumers are opting for battery-powered

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[116] Financial Times (2019), Hydrogen could help decarbonise the global economy – available at https://www.ft.com/content/959d08e2-a899-11e9-984c-fac8325aaa04

[117] World Energy Council (2018), Hydrogen an enabler of the Grand Transition: Future Energy Leader position paper – available at https://www.worldenergy.org/assets/downloads/1Hydrogen-an-enabler-of-the-Grand-Transition_FEL_WEC_2018_Final.pdf

[118] Power Engineering International (2019), Hydrogen: The hope for 'hard-to-decarbonise' sectors – available at https://www.powerengineeringint.com/2019/09/26/hydrogen-the-hope-for-hard-to-decarbonise-sectors/

[119] Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019 (p 10)

[120] Smart Energy International (2019), 2019 energy storage trends – available at https://www.smart-energy.com/industry-sectors/storage/2019-energy-storage-trends/

[121] McKinsey & Company (2017), Battery storage: The next disruptive technology in the power sector – available at https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Battery%20storage%20The%20next%20disruptive%20technology%20in%20the%20power%20sector/Battery-storage-The-next-disruptive-technology-in-the-power-sector.ashx

[122] Deloitte (2019), New market. New entrants. New challenges. Battery Electric Vehicles – available at https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-battery-electric-vehicles.pdf

[123] Paul Denholm, Jacob Nunemaker, Pieter Gagnon and Wesley Cole for the National Renewable Energy Laboratory of the US Department of Energy (2019), The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States – available at https://www.nrel.gov/docs/fy19osti/74184.pdf

passenger vehicles and bus fleets rather than FCEVs.[124] The result is vicious circle: because hydrogen technologies are not achieving economies of scale, the costs of hydrogen production, storage, transportation and distribution remain high.[125,126]

Though demand for low-carbon technologies in these markets is evident, relatively higher costs have stalled funding for hydrogen deployment, as investors are disinclined to back a decarbonisation solution that currently lags behind its competitors.[127,128]

To develop an efficient clean hydrogen ecosystem, hydrogen will need to be produced in the power sector mainly from decarbonised electricity, distributed via the gas-transmission sector or via the transport sector, and used in the transport, industry, and buildings sectors.[129,130] It is difficult to motivate actors across these traditionally independent sectors to develop strong collaborative frameworks to support the development and integration of hydrogen applications.[131,132]

Scientific advancement for key hydrogen technologies is still required, and current energy-use systems in heavy industry and heavy transport will need to be technically adapted before they can use hydrogen as a fuel.[133]

In order for clean hydrogen to become competitive with conventional fuels for transport and fossil-based feedstock (with the inclusion of the cost of carbon), some technology routes need further improvements – especially in the areas of investment cost reduction and efficiency increases.[134]

The reliability, cost and footprints of hydrogen refuelling stations could also be improved through novel design concepts and the introduction of new components (e.g. liquid hydrogen pumps for liquid stations).[135]

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[124] International Energy Agency (2019), Global EV Outlook 2019 – available at https://www.iea.org/publications/reports/globalevoutlook2019/

[125] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[126] Boston Consulting Group (2019), The Real Promise of Hydrogen – available at https://www.bcg.com/publications/2019/real-promise-of-hydrogen.aspx

[127] World Energy Council (2019), New Hydrogen Economy – Hope or Hype?: Innovation Insights Brief – available at https://www.worldenergy.org/assets/downloads/WEInnovation-Insights-Brief-New-Hydrogen-Economy-Hype-or-Hope.pdf

[128] Hydrogenics (2018), Cost Reduction Potential for Electrolyser Technology – available at https://www.humsterlandenergie.nl/resources/LInks-duurzaam/Linkpagina/20180619_Hydrogenics_EU-P2G-Platform_for-distribution.pdf

[129] International Journal of Hydrogen Energy (2019), Flexible sector coupling with hydrogen: A climate-friendly fuel supply for road transport – available at https://www.sciencedirect.com/science/article/abs/pii/S0360319919312121

[130] Clean Energy Wire (2018), Sector coupling – Shaping an integrated renewable energy system – available at https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system

[131] Gas Infrastructure Europe (2018), Sector coupling and policy recommendations – available at https://ec.europa.eu/info/sites/info/files/gie_-_position_paper_-_sector_coupling_p2g.pdf

[132] Eurelectric for the 32nd European Regulatory Gas Forum (2019), Sector coupling: The electricity industry perspective – available at https://ec.europa.eu/info/sites/info/files/eurelectric_-_sector_coupling.pdf

[133] Joint Research Centre of the European Commission (2018), "Green hydrogen opportunities in selected industrial processes" – available at https://ec.europa.eu/jrc/en/science-update/green-hydrogen

[134] Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019 (p 19), also confirmed by interviews

[135] Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019 (p 53), also confirmed by interviews

2.1.2 Insufficient deployment to reinforce EU value chains

In addition to its relatively high costs, its "difficult-to-prove" quality, reliability and efficiency, several other factors have inhibited hydrogen's integration into existing large-scale systems and markets. For technologies/applications that are technologically ready for deployment, the main challenge will be to set policies that can push their introduction into markets to achieve volumes that will further decrease their costs. [136] Important players in industry and in the public sector have not yet developed strong, coordinated policies or set strategic visions regarding the future role of hydrogen.[137,138] Thus larger-scale markets for hydrogen production and use have not yet been created.[139]

As hydrogen applications do not currently play larger roles in the power, industry and transport sectors, the hydrogen supply chain remains disjointed and underdeveloped.[140,141,142]

Currently, few complete value chains for hydrogen, from production to end-use, are operational across the EU.[143,144] Several hydrogen applications still need to be technologically improved and tested before they can be successfully implemented into larger scale systems.[145,146] While recent demonstration projects have affirmed the success and potential value of individual hydrogen technologies, knowledge transfer between project teams and across industries remains limited.[147] Limited collaboration and

[136] Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019 (p 10), also confirmed by interviews

[137] McKinsey & Company (2018), Decarbonization of industrial sectors: The next frontier – available at https://www.mckinsey.com/business-functions/sustainability/our-insights/how-industry-can-move-toward-a-low-carbon-future

[138] Norton Rose Fulbright (2019), The potential of hydrogen to accelerate the energy transition – available at https://www.nortonrosefulbright.com/en/knowledge/publications/e9f3153d/the-potential-of-hydrogen

[139] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[140] E4tech (2017), Study on Supply Chain for Hydrogen and Fuel Cells Technologies

[141] Element Energy Ltd on behalf of the UK Department for Business, Energy & Industrial Strategy (2018), Hydrogen supply chain evidence base – available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf

[142] HyTrEc2 in collaboration with the Aberdeen City Council and Pale Blue Dot (2018), Hydrogen Supply Chain Mapping Report – available at https://northsearegion.eu/media/9504/hydrogen-supply-chain-mapping-report-30.pdf

[143] E4tech (2017), Study on Supply Chain for Hydrogen and Fuel Cells Technologies

[144] Lei Li, Hervé Manier, Marie-Ange Manier (2019), Renewable and Sustainable Energy Reviews, Hydrogen supply chain network design: An optimization-oriented review, available at https://www.sciencedirect.com/science/article/abs/pii/S1364032118308633

[145] CE Delft (2018), Feasibility study into blue hydrogen: Technical, economic & sustainability analysis – available at https://www.cedelft.eu/en/publications/download/2585

[146] Academic Press (2018), Hydrogen Supply Chains: Design, Deployment and Operation, Chapter 7 Hydrogen Applications: Overview of the Key Economic Issues and Perspectives – available at https://www.sciencedirect.com/science/article/pii/B9780128111970000075

147 Fuel Cells and Hydrogen Joint Undertaking (2018), FCH JU – Success Stories: a partnership dedicated to clean energy and transport in Europe -- available at https://www.fch.europa.eu/sites/default/files/FCHJU-successstories-brochure-WEB-fin.pdf

knowledge-sharing has thus far prevented a clean hydrogen ecosystem with fully integrated value chains from developing.[148]

The building of a full EU-wide ecosystem is critical to ensure a sufficient size of the market, the treatment of cross-border issues (infrastructure, codes, regulations), the capitalisation of efforts at scale and the trading system at an international level. However, smaller practical steps could make sense before such full-fledged ecosystem is deployed at EU level, like the deployment of local ecosystems (e.g. small production units with a captive fleets, the conversion of fossil-based hydrogen use by renewable hydrogen).

As stated by the IEA,[149] "for novel applications (especially those at low technology readiness levels) and complex demonstrations, there might still be a case for public R&D support. Demonstration projects must be linked to overall energy policies and strategies, to avoid one-off projects that do not contribute to sustainable scale-up. In the steel sector, 100% hydrogen Direct Reduced Iron (DRI) needs further R&I[150] and demonstration, and the emergent option of ammonia in DRI can be investigated. To facilitate large-scale demand for hydrogen and hydrogen-based products, proving and improving the (co-)firing of hydrogen in turbines and (co-)firing of ammonia in boilers/turbines/fuel cells are needed for de-risking. Improvements to the storage of hydrogen, including as liquid hydrogen, would also be valuable."

Regarding the distribution of hydrogen, the development of infrastructure is slow and holding back widespread adoption.[151] Infrastructural construction will require planning and coordination that brings together national and local governments, industry and investors.

Transport, storage and distribution are at risk of becoming a bottleneck for the accelerated rollout of hydrogen technologies at scale. This central pillar between production and consumption will require new (pipelines, refuelling stations) and old (existing gas infrastructure, salt caverns) solutions to work together in a decarbonised energy system.[152]

2.1.3 Environmental, health and mobility challenges while demand, acceptance and take-up of clean hydrogen are low

Difficult-to-decarbonise sectors including maritime transport, aviation, heavy-duty trucking, rail, and energy-intensive industry remain high emitters, where clean hydrogen could significantly contribute to their decarbonisation.[153,154] Without the decarbonisation of these key sectors, EU Member States will find it much more difficult to meet their climate targets.[155]

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[148] E4tech (2019), Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cell Technologies – available at https://www.fch.europa.eu/sites/default/files/Findings%20Report%20v4.pdf

[149] IEA, the Future of hydrogen, 2019, page 181

[150] IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773, page 245

[151] IEA, the Future of hydrogen, 2019, page 14

[152] Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019 (p 10)

[153] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[154] Hydrogen Europe (2017), Decarbonise Industry, available at https://hydrogeneurope.eu/decarbonise-industry

[155] Power Engineering International (2019), Hydrogen: The hope for 'hard-to-decarbonise' sectors – available at https://www.powerengineeringint.com/2019/09/26/hydrogen-the-hope-for-hard-to-decarbonise-sectors/

Recent research initiatives focused on the public perception of hydrogen show that public awareness of hydrogen technologies is still relatively limited.[156,157] There are lingering concerns among the public regarding hydrogen safety.[158,159] Primarily because of this lack of awareness, public support for hydrogen integration is relatively low.

At the same time, very few public initiatives have focused on educating the public with respect to hydrogen.[160,161] Successfully integrating hydrogen into existing systems will require trained engineers, expert executives, and informed policy makers.[162,163] Many Member States in the EU still lack a knowledgeable base of actors who can support hydrogen's integration into their industries and their economies.[164,165]

Market-enabling regulatory frameworks to govern the production and use of key clean hydrogen applications are currently not adequate.[166,167,168 169] However, as clean hydrogen has gained traction as a potential decarbonisation solution, policy makers at the European level and in some Member States have started to consider designing and implementing coordinated strategic guidelines and regulations for hydrogen.[170]

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[156] Wuppertal Institute for Climate, Environment and Energy (2010), Public attitudes towards and demand for hydrogen and fuel cell vehicles: A review of the evidence and methodological implications – available at https://epub.wupperinst.org/frontdoor/deliver/index/docId/3370/file/3370_Yetano_Roche.pdf

[157] Revista Internacional de Sociología (2017), The Public Acceptance of Hydrogen Fuel Cell Applications in Europe – available at https://dspace.library.uu.nl/handle/1874/370207

[158] HySafe (2019), Safety of Hydrogen as an Energy Carrier – available at http://www.hysafe.org/IA_strategy

[159] MATGAS 2000 AIE (2015), Hydrogen: applications and safety considerations – available at https://www.h2euro.org/wp-content/uploads/2017/09/Hydrogen-applications-and-safety-considrations.pdf

[160] International Congress on Education, Innovation and Learning Technologies (2015), The Challenge to teach hydrogen energy in engineering – available at https://www.researchgate.net/publication/282704070_The_Challenge_to_Teach_Hydrogen_Energy_in_Engineering_A_Proposal_of_a_Computer_Simulation_Tool

[161] Fuel Cell and Hydrogen Joint Undertaking (2017), Project NET – Novel Education and Training Tools Based on Digital Applications Related to Hydrogen and Fuel Cell Technology – available at https://www.fch.europa.eu/project/novel-education-and-training-tools-based-digital-applications-related-hydrogen-and-fuel-cell

[162] Hydrogen and Fuel Cells Program of the US Department of Energy (2019), Education – available at https://www.hydrogen.energy.gov/education.html

[163] Fuel Cells and Hydrogen Joint Undertaking (2011), Project Hyprofessionals – Development of Educational Programmes and Training Initiatives Related to Hydrogen Technologies and Fuel Cells in Europe – available at https://www.fch.europa.eu/project/development-educational-programmes-and-training-initiatives-related-hydrogen-technologies-an

[164] TeacHy (2017), European Higher Training Network in Fuel Cells and Hydrogen – available at http://www.teachy.eu/about-teachy.php

[165] European Commission COSME (2017), European Higher Training Network in Fuel Cells and Hydrogen – available at https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/fch-04-3-2017

[166] Lloyd's Register (2017), Hydrogen – Safety Considerations and Future Regulations – available at https://www.fch.europa.eu/sites/default/files/3.%20Joseph%20Morelos%20-%20H2Safety.pdf

[167] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[168] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[169] Hydrogen Europe Vision on the Role of Hydrogen and Gas Infrastructure on the Road Toward a Climate Neutral Economy – A Contribution to the Transition of the Gas Market, April 2019, https://fsr.eui.eu/wp-content/uploads/2019_Hydrogen-Europe-Vision-on-the-role-of-Hydrogen-and-Gas-Infrastructure.pdf

[170] Hydrogen Europe (2018), EU Legislative framework for implementation of Hydrogen in different applications identifies EU framework that could be adapted to support adequately hydrogen like the RED, the AFID, the

Additionally, the EU and Member States have the potential to stimulate investments in clean hydrogen by adopting adequate measures that would drive widespread emission reductions in difficult-to-decarbonise sectors.[171,172] Such measures could create market conditions for hydrogen applications in sectors where it's currently difficult for hydrogen to gain access.[173]

As affirmed by a **respondent to the Inception Impact Assessment consultation representing a national association**, and shared by both industry and research organisations, "strongly welcome the proposed approach driving R&I activities on cost reduction targets."

In the **Open Public Consultation**, respondents were asked to provide their views on the relevancy of research and innovation efforts at EU level to address the following problems in relation to hydrogen and fuel cells, specifically on three types of problems: problems in uptake of hydrogen and fuel cells innovations (UI-P), structural and resource problems (SR-P) and research and innovations problems (RI-P).

With regard to the uptake in innovation problems, 278 respondents indicated that it is very relevant for research and innovation efforts at EU level to address the problem of high costs of clean hydrogen and fuel cells solutions that hinder mass commercialisation until serial production is achieved, factoring-in economies of scale (73.74%). Similarly with regard to the uptake in innovation problems, market failures due to inadequate industry investment has the least amount of very relevant answers (45.50%), while most respondents still have indicated that they view this issue as very relevant.

The research and innovation problem that most respondents indicated as very relevant was the innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products, with 267 respondents choosing this answer (70.82%). The problem that was least often indicated as very relevant, is also a research and innovation problem, namely: lack of interest of major market players to engage in hydrogen and fuel cells research (121, 32.01%).

The respondents to the **Open Public Consultation**, when asked to indicate their views of the needs of the future European Partnerships under Horizon Europe, indicated that many of the options presented were very relevant, with a focus on making a significant contribution to the EU efforts to achieve climate-related goals.

2.2 What are the problem drivers?

The key problem drivers affecting R&I performance in Clean Hydrogen in Europe are discussed in more detail in the following paragraphs

2.2.1 Clean hydrogen applications are more expensive than competing technologies and are not yet fully reliable nor of sufficient quality for take up

emission standards, the ETS, the EMD– available at https://www.waterstofnet.eu/_asset/_public/powertogas/Conference/10-Nicolas-Brahy_Hydrogen-Europe-HyLaw-_Regulation-Overview.pdf

[171] European Commission Press Release (2019), Energy Union: Commission calls on Member States to step up ambition in plans to implement Paris agreement – available at https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_19_2993/IP_19_2993_EN.pdf

[172] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

[173] Fuel Cells and Hydrogen Joint Undertaking 10th Stakeholder Forum (2017), Fuel Cell and Hydrogen Technology: Europe's Journey to a Greener World, available at https://op.europa.eu/en/publication-detail/-/publication/15d2c3b7-c502-11e7-9b01-01aa75ed71a1

Because research on many technologies is still relatively novel, mechanisms for producing and using hydrogen are still expensive and relatively unrefined. Technologies for hydrogen production, distribution and end-use should still be technically and systematically improved.[174]

Scientific advancement will be required to secure cost reductions and efficiency improvements in the production and use of applications at higher TRLs. Cost reduction and efficiency gains will ensure that hydrogen technologies can compete and gain market share in end-use sectors that cheaper low-carbon technologies currently dominate.[175,176]

Consistent scientific development will also be necessary to ensure that Europe's hydrogen technologies achieve the highest possible technical quality so they can compete with their international equivalents as hydrogen markets develop worldwide.[177,178] This will require continued research into innovative technologies at lower TRLs, which could potentially enhance or augment technologies currently on the market.

2.2.2 Fragmented development of key interlinked clean hydrogen applications associated to limited cross-sectoral collaboration

- The FCH JU and FCH 2 JU primarily supported the development of key hydrogen applications to higher TRLs.[179] Though in recent years the partnership increasingly prioritised cross-sector collaboration, only a few pilot projects so far have included multi-sector actors from multiple links in the hydrogen value chain.[180]
- Research on different hydrogen applications is increasingly integrated, but overall the development of key applications remains fragmented, with restricted co-creation of new products and services and a limited capitalisation from high TRL to lower TRL applications along all value chains. Lack of coordination leads to inefficiencies that can increase the costs of hydrogen technologies. Fragmented technological development adds complexity to hydrogen's entry into mass markets.[181]
- Increasing collaboration between researchers, SMEs and industry players will be necessary to facilitate the entrance of hydrogen into multiple markets. It will also enable the development of a more cohesive, complete hydrogen ecosystem with strongly linked value chains from clean production to efficient end-use.[182]

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[174] World Energy Council (2019), Innovation Insights Brief: New Hydrogen Economy, Hope or Hype? – available at https://www.worldenergy.org/assets/downloads/WEInnovation-Insights-Brief-New-Hydrogen-Economy-Hype-or-Hope.pdf

[175] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[176] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[177] IEA Hydrogen (2017), Global Trends and Outlook for Hydrogen – available at https://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen_Dec2017_WEB.aspx

[178] IRENA (2018), Hydrogen from Renewable Power: Technology Outlook for the Energy Transition – available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Sep/IRENA_Hydrogen_from_renewable_power_2018.pdf

[179] Consensus from the majority of interviewees.

[180] Fuel Cells and Hydrogen Joint Undertaking (2018), Success Stories: A partnership dedicated to clean energy and transport in Europe – available at https://www.fch.europa.eu/sites/default/files/FCHJU-successstories-brochure-WEB-fin.pdf

[181] E4tech (2019), Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cell Technologies – available at https://www.fch.europa.eu/sites/default/files/Findings%20Report%20v4.pdf

[182] Ibid.

To enable a cohesive hydrogen transition, researchers, industry players and public authorities will need to effectively coordinate their strategies and actions. The FCH 2 JU has worked to promote increasing collaboration between these stakeholders; continued effort will be required to ensure that the pace of innovation is maintained, and markets are prepared for the integration of new hydrogen technologies.[183,184]

2.2.3 Limited large-scale deployment of clean hydrogen generation capacity

There have been too few large-scale demonstration projects on clean hydrogen production, especially in large scale-scale coupling with renewable power plants to generate necessary investments in mass manufacturing capacity for production equipment.[185]

Large-scale demonstration projects are vital in proving the feasibility of and potential for using large-scale electrolysers.[186] They instil in investors the confidence necessary to back wider market deployment of these technologies. While the FCH 2 JU has overseen several successful demonstration projects in recent years, there have been too few to generate the levels of interest and funding necessary to prepare technologies for mass market entry. This prevents market-ready applications from reaching scale and thereby achieving cost reductions.[187]

Further R&D investment in demonstration projects will be necessary to incite large-scale industrialisation of hydrogen generation coupled with renewable electricity production.

2.2.4 Underdeveloped and non-adapted infrastructure for storing, transporting and distributing hydrogen

Transportation, distribution, and refuelling infrastructure will be necessary to enable the uptake of hydrogen in the power, transport, and industry sectors.[188] Cross-border infrastructural networks spanning significant distances between Member States will need

[183] HyLAW (2019), Deliverable 4.4 EU regulations and directives which impact the deployment of FCH technologies – available at https://www.hylaw.eu/sites/default/files/2019-02/D4.4%20-%20EU%20regulations%20and%20directives%20which%20impact%20the%20deployment%20of%20FCH%20technologies_0.pdf

[184] Dennis Hayter for HyLAW (2018), Hydrogen Law and removal of legal barriers to the deployment of fuel cells and hydrogen applications – UK National Policy Paper – available at https://www.hylaw.eu/sites/default/files/2019-01/HyLaw%20UK%20Policy%20Paper_Final_December%202018.pdf

[185] Consensus following interviews with stakeholders in industry and in research organisations.

[186] Fuel Cells and Hydrogen Joint Undertaking (2018), Success Stories: A partnership dedicated to clean energy and transport in Europe – available at https://www.fch.europa.eu/sites/default/files/FCHJU-successstories-brochure-WEB-fin.pdf

[187] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[188] Jorg Gigler and Marcel Weeda on behalf of TKI Nieuw Gas (2018), Outlines of a Hydrogen Roadmap – available at https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/20180514%20Roadmap%20Hydrogen%20TKI%20Nieuw%20Gas%20May%202018.pdf

to be constructed to connect optimal clean hydrogen production regions to optimal hydrogen consumption regions.[189,190]

This infrastructure has not yet been comprehensively planned or built, as that will require intense coordination between industrial players and policy makers in different Member States. Infrastructure development has stalled partly in response to a perceived lack of demand for hydrogen (the result of the so-called "chicken-and-egg" problem referenced as an emerging challenge in Section 1).[191,192] However, hydrogen applications cannot enter mass markets or deploy at large scale until this infrastructure is in place.

The construction of an integrated infrastructural network will also bring together important players from different segments of the hydrogen value chain and will form the backbone of a more cohesive, complete hydrogen ecosystem.[193]

2.2.5 Lack of large-scale deployment of clean hydrogen end-use applications

There have been too few large-scale demonstration projects on key technologies to generate necessary investments in mass manufacturing capacity for end-use products and equipment.[194]

Large-scale demonstration projects are vital in proving the feasibility of and potential for using large-scale fuel cell applications (CHP, vehicles,…), burners or turbines.[195] They instil in investors the confidence necessary to back wider market deployment of these technologies. While the FCH 2 JU has overseen several successful demonstration projects in recent years, there have been too few to generate the levels of interest and funding necessary to prepare technologies for mass market entry. This prevents market-ready applications from reaching scale and thereby achieving cost reductions.[196]

Further R&D investment in demonstration projects will be necessary to incite large-scale industrialisation of hydrogen applications.

2.2.6 Lack of processing infrastructure (i.e. biorefineries), both small and large

Public awareness and public knowledge on hydrogen are still limited. Existing and previous partnerships on clean hydrogen have prioritised technological development, with less

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[189] Joint Research Centre (2016), 4th International Workshop on Hydrogen Infrastructure and Transportation Report – available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103586/4%20int%20workshop%20on%20h2%20infra%20final%20pdfonline.pdf

[190] Compendium of Hydrogen Energy (2016), Building a hydrogen infrastructure in the EU – available at https://www.sciencedirect.com/science/article/pii/B9781782423645000129?via%3Dihub

[191] David Kramer for Physics Today (2017), Hydrogen-powered vehicles: A chicken and egg problem – available at https://physicstoday.scitation.org/doi/10.1063/PT.3.3690

[192] The International Council on Clean Transportation (2017), Developing hydrogen fueling infrastructure for fuel cell vehicles: A status update – available at https://theicct.org/sites/default/files/publications/Hydrogen-infrastructure-status-update_ICCT-briefing_04102017_vF.pdf

[193] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[194] Consensus following interviews with stakeholders in industry and in research organisations.

[195] Fuel Cells and Hydrogen Joint Undertaking (2018), Success Stories: A partnership dedicated to clean energy and transport in Europe – available at https://www.fch.europa.eu/sites/default/files/FCHJU-successstories-brochure-WEB-fin.pdf

[196] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

research devoted to engaging and educating the public. Very few initiatives have sought to educate the public on the role hydrogen might play in large-scale decarbonisation.[197] While more press attention has been paid to hydrogen technologies in recent years, most members of the public still lack general knowledge on the wide-ranging applications of clean hydrogen.[198]

Local and regional community organisations and authorities – which can play instrumental roles advocating for clean hydrogen integration into their regional economies – often lack the up-to-date information needed to design policy proposals and to allocate funding efficiently.[199] There is also evidence to suggest that the public remains concerned regarding the safety of hydrogen technologies.[200,201,202] Designing effective education platforms to deliver the latest information on hydrogen to the public will be necessary to allay concerns and generate public support for hydrogen technologies.

Additionally, further educational efforts will be required to train the engineers, executives, and policy-makers necessary to support the integration of hydrogen into existing systems and markets. Initiatives to develop a "hydrogen workforce" are sparse and concentrated in select Member States. They will need to be expanded to develop the capacity required to enable a cross-sectoral hydrogen transition.[203]

2.2.7 Inadequate regulatory, policy and financing frameworks for clean hydrogen

Though interest in clean hydrogen applications has increased in recent years (thanks in part to the efforts of predecessor partnerships),[204] especially these last months, policy makers at both EU and Member State levels have yet to develop and implement the kinds of policies necessary to encourage growth in the hydrogen sector.[205,206]

First, policy makers have not amended regulatory frameworks to govern the production and use of clean hydrogen applications. EU regulation concerning renewable energy, alternative fuel infrastructure, gas infrastructure, market design, CO2 emission standards,

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[197] Revista Internacional de Sociología (2017), The Public Acceptance of Hydrogen Fuel Cell Applications in Europe – available at https://dspace.library.uu.nl/handle/1874/370207

[198] Hyacinth (2017), Public Awareness and Social Acceptance – available at http://hyacinthproject.eu/public-awareness-and-social-acceptance/

[199] Fuel Cells and Hydrogen Joint Undertaking 10th Stakeholder Forum (2017), Fuel Cell and Hydrogen Technology: Europe's Journey to a Greener World, available at https://op.europa.eu/en/publication-detail/-/publication/15d2c3b7-c502-11e7-9b01-01aa75ed71a1

[200] Hydrogen Europe (2017), Hydrogen safety – available at https://hydrogeneurope.eu/hydrogen-safety

[201] MATGAS 2000 AIE (2015), Hydrogen: applications and safety considerations – available at https://www.h2euro.org/wp-content/uploads/2017/09/Hydrogen-applications-and-safety-considrations.pdf

[202] Hydrogen Europe (2017), Hydrogen safety – available at https://hydrogeneurope.eu/hydrogen-safety

[203] Fuel Cells and Hydrogen Joint Undertaking (2011), Project Hyprofessionals – Development of Educational Programmes and Training Initiatives Related to Hydrogen Technologies and Fuel Cells in Europe – available at https://www.fch.europa.eu/project/development-educational-programmes-and-training-initiatives-related-hydrogen-technologies-an

[204] Fuel Cells and Hydrogen Joint Undertaking 10th Stakeholder Forum (2017), Fuel Cell and Hydrogen Technology: Europe's Journey to a Greener World, available at https://op.europa.eu/en/publication-detail/-/publication/15d2c3b7-c502-11e7-9b01-01aa75ed71a1

[205] European Commission Press Release (2019), Energy Union: Commission calls on Member States to step up ambition in plans to implement Paris agreement – available at https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_19_2993/IP_19_2993_EN.pdf

[206] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

clean vehicle could be adequately adapted in order for clean hydrogen to be recognised for its climate contribution. [207] A clear definition of hydrogen and clean hydrogen seems to be the first step to ensure the proper integration into all regulatory frameworks. The HyLaw[208] project identified the legislation and regulations relevant to fuel cell and hydrogen applications and legal barriers to their commercialisation. It could be extended to more Member States. Though they have set some standards related to FCEVs, regulatory frameworks have not kept pace with technological advancements.[209] The lack of coordinated regulatory frameworks complexifies hydrogen's entry into mass markets. Harmonised regulatory frameworks would encourage investors and enable more hydrogen applications to be deployed at larger scales.

Second, policy makers are only starting to implement and enforce climate policies that would mandate intensive decarbonisation in heavy industry and heavy transport sectors in which clean hydrogen applications represent some of the only feasible carbon-reduction solutions.[210] In fact, current policies that provide for fossil fuel subsidies as an externality effectively increase the relative prices of competitor hydrogen fuels and power. Strengthening climate measures to support clean energy sources and mandate emission reductions would likely motivate further interest and investment from aforementioned sectors in clean hydrogen development.[211]

2.3 How will the problem(s) evolve?

Without any policy action, it is anticipated that:

- Hydrogen applications will not be able to be deployed at scale, nor will they be able to achieve cost reductions;
- Improving the environmental performance of energy intensive industries will be more complex, lengthy, expensive and riskier; and
- Several European industrial sectors will be at greater risk of losing competitiveness in the global market.

The core problems in the field of clean hydrogen will persist and worsen over time, if action is not taken to address them.[212]

The costs of clean hydrogen solutions will not decrease on their own. Competitor low-carbon technologies like BEVs and battery storage will likely achieve further cost reductions and efficiency gains as they have already achieved economies of scale.[213] Over time, then,

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[207] Hydrogen Europe (2018), EU Legislative framework for implementation of Hydrogen in different applications – available at https://www.waterstofnet.eu/_asset/_public/powertogas/Conference/10-Nicolas-Brahy_Hydrogen-Europe-HyLaw-_Regulation-Overview.pdf

[208] https://www.hylaw.eu/: HyLaw stands for Hydrogen Law and removal of legal barriers to the deployment of fuel cells and hydrogen applications. It is a flagship project aimed at boosting the market uptake of hydrogen and fuel cell technologies providing market developers with a clear view of the applicable regulations whilst calling the attention of policy makers on legal barriers to be removed.

[209] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

[210] European Commission Press Release (2019), Energy Union: Commission calls on Member States to step up ambition in plans to implement Paris agreement – available at https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_19_2993/IP_19_2993_EN.pdf

[211] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[212] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

213 McKinsey & Company (2017), Battery storage: The next disruptive technology in the power sector – available at

hydrogen solutions will become even less economical in comparison and it will be more difficult to argue for their continued growth. Europe's competitive positioning in the hydrogen industry will deteriorate.[214]

It will become increasingly difficult for hydrogen solutions to enter mass markets and deploy at large scales, if policy makers and industrial players begin to regard hydrogen as a less viable solution. Unless efforts are made to synthesise technological advancements across sectors and develop cohesive, complete value chains for hydrogen production, distribution, and use, heavy industry and heavy transport sectors will likely not be able to integrate clean hydrogen solutions into their operations. [215] Mass manufacturing capacities will not be developed, and the hydrogen value chains will not effectively industrialise, preventing efficiency gains and potential cost reductions.[216] Sector coupling will likely be regarded as unfeasible. Difficult-to-decarbonise sectors will remain highly emissive and Member States will not be able to achieve their climate targets.[217]

If the public is not sufficiently educated regarding hydrogen solutions, they are unlikely to garner the support they need for wider-scale deployment. Additionally, it will be more difficult to overcome concerns regarding hydrogen safety if proper educational mechanisms are not put into place. Finally, the workforce required to enable a cross-sector, cross-border hydrogen transition will be underequipped if further educational efforts are not made to build capacity.[218]

3 Why should the EU act?

3.1 Subsidiarity: Necessity of EU action

First of all, it is more and more largely recognised that clean hydrogen is a key enabler in the decarbonisation of the EU economy contributing to the 2050 climate neutrality target. Hydrogen is considered as the "fuel of the future" and a "huge opportunity for our EU economy" or engaging a "transport revolution" together with electric vehicles. Member States engaged in a national strategy are calling for an "acceleration at EU level". All Member State's Leaders recall that "we aim to maximise the great potentials of sustainable hydrogen technology for the decarbonisation of multiple sectors, the energy system and for the long-term energy security of the EU."[219] There is no doubt that EU action is needed to transform high level commitments into concrete and coordinated policies and measures.

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https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Battery%20storage%20The%20next%20disruptive%20technology%20in%20the%20power%20sector/Battery-storage-The-next-disruptive-technology-in-the-power-sector.ashx

[214] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[215] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[216] E4tech (2019), Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cell Technologies – available at https://www.fch.europa.eu/sites/default/files/Findings%20Report%20v4.pdf

[217] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

[218] Hydrogen and Fuel Cells Program of the US Department of Energy (2019), Education – available at https://www.hydrogen.energy.gov/education.html

[219] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals?, October 2019, available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

The rationale for EU intervention follows directly from the previous development of the problems and their drivers. European hydrogen industry and research stakeholders, whether acting alone or through small size consortia, do not have all required knowledge from fundamental scientific to market oriented, are not integrating all concerned sectors and are not able to manage all the risks. In addition, they do not have sufficient size for the type of risk-sharing projects involved for expensive demonstration of innovative solutions.

The nature and magnitude of the issues are such that action at EU level is needed, rather than the Member States acting alone. Support of innovation and incentives already exist in Europe at the national level, but not equally spread among Member States. Programmes that increase or aim to foster R&D and innovation exist in several Member States alongside hydrogen research funding mechanisms. In addition, coordination between MS is needed to ensure coherence among agendas, avoid duplications and foster synergies. Exchange and pooling of knowledge between stakeholders is critical to avoid duplication, extract lessons and capitalise successes in order to improve the fundamental and applied research. This exchange and pooling would be stronger at EU level.

While funding at the national level provides an important contribution, the scale of the research, innovation and funding that is required for improving the whole value chains and the important amount of applications is bigger than what can be achieved by a single Member State alone or by private companies alone. National programmes are also often restricted to allocating funding at the national level only. Given the need for a coordinated European climate agenda and the European nature of clean hydrogen as a priority solution to tackle climate challenges, having only national programmes inevitably results in major gaps in some areas as well as overlaps in other research areas. Overlaps result in reduced efficiency and prevent advances in other areas.

Due to the increasing number of applications (derived from existing emerging uses), collaboration and coordination between Industry and Knowledge and Research Base Actors active in the hydrogen economy or not is essential in developing innovation at European level. It is essential if the industry and research are to make the expected contribution to a reduction in greenhouse gas emissions and outdoor air pollution generated by conventional fuels and the use of non "clean hydrogen" while retaining the competitive position of the concerned industrial sectors.

Collaborative research allows participants to break away from their natural choice of partners, spurring new opportunities with different types of organisations (academia, research centres, industry), preferably in the EU. This is something which is not traditionally provided at MS level due to the limited size of national markets and therefore the number of players. In fact, due to the long supply chain, all components and fields of the hydrogen economy are spread across a large territory, meaning there would be more probability to address the whole chain from an EU perspective, than at MS level. So this is an area where EU intervention is needed.

In the context of the specific complex and interlinked value chains of the clean hydrogen where costs, risks and important number of players for new developments depend on effective cooperation, inter-sectoral collaboration at the European level is essential to succeed in demonstration and deploying at scale. Cooperation between all concerned stakeholders is critical, both in the development stages as well as during the maturing of innovative technologies and their industrialisation phase.

The competitiveness of green hydrogen will depend on more than just decreasing CAPEX costs. First and foremost, the competitiveness will depend on the availability and cost of renewable electricity. This will also require Europe to look beyond its borders to explore

the opportunity of importing green hydrogen from countries with great renewable energy potential and exceptionally low renewable electricity production costs.[220]

For the IEA[221], European and "International cooperation are vital to accelerate the growth of versatile, clean hydrogen around the world. If governments work to scale up hydrogen in a coordinated way, it can help to spur investments in factories and infrastructure that will bring down costs and enable the sharing of knowledge and best practices. Trade in hydrogen will benefit from common international standards." The IEA to add "Enhanced international cooperation is needed across the board but especially on standards, sharing of good practices and cross-border infrastructure." Europe could play a leading role in preparing standards and norms to advocate at the international level with a harmonised voice.

Complementarities of different international markets and backgrounds also indicate good potentials for technical cooperation and mutual learning, as suggested for Germany and Japan.[222]

3.2 Subsidiarity: Added value of EU action

There are several national R&I schemes, some with significant budgets: Germany, France, Denmark and Italy through their national research programmes committed a total of ~1 billion Euros of funding over a seven-year period.[223] However, these schemes are insufficiently coordinated within the Member States, between Member States and with the EU. In some cases, national interest in local employment and technology leads to non-complementary policies, with a possible duplication of activities.[224] Platforms exist for the coordination of energy research for a low carbon Europe (EERA), or for regionally focussed stakeholder organisations like the European Regions Research and Innovation Network (ERRIN), as well as instruments for the coordination of initiatives within Horizon 2020 (ERA-NET).

Even with the achievements these last years, fragmentation remains. With a clear climate policy, there is strong need for directionality of European investments as well as additionality. EU action would complement with national schemes to provide a clearer policy approach, especially as innovations are urgently needed to realise the climate action plan.

Overall, the results of the Member States consultation[225] confirm the relevance of the proposed European Partnership on Clean Hydrogen, with 82% considering it to be very or somewhat relevant for their research organisations, including universities, and 79% for their national policies and priorities, while 72% of the respondents found the proposed partnership as relevant for their industry.

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[220] https://www.euractiv.com/section/energy-environment/opinion/eu-wide-innovation-support-is-key-to-electrolysis-in-europe/

[221] IEA, the Future of Hydrogen, 2019, pages 15 and 16

[222] The role of clean hydrogen in the future energy systems of Japan and Germany (p 16), August 2019

[223] Figures from the IEA's Energy Technology RD&D Budget Database, 2011-2018

[224] Competitiveness of the EU Aerospace Industry with focus on Aeronautics Industry, Ecorys, 2009

[225] European Partnerships under Horizon Europe: results of the structured consultation of Member States,

Draft Report for the meeting of the Shadow Configuration of the Strategic Programme Committee on 27 June 2019

In terms of overcoming fragmentation within Europe, the challenges of delivering improved coordination between Member States' clean hydrogen research and innovation support remain significant,[226] therefore increasing the importance of an EU action.

The respondents to the **Open Public Consultation** indicated needs around international policy and industrial competition as well as the development of technology for clean hydrogen fuels and cells in justifying the relevance of efforts of the candidate European Partnership to address problems.

For more than 80% of the respondents to the **Open Public Consultation**, the main areas[227] of partnership specific problems were deemed (very) relevant for the candidate European Partnership, emphasizing the relevance of EU level efforts to address the problems.[228]

4 Objectives: What is to be achieved?

4.1 General objectives

In order to tackle the problems identified in Section 2, it is important to clarify the objectives of EU action in the field of research and innovation. We have identified three general objectives corresponding to the main problems discussed in Section 2.1

- Strengthen and integrate EU scientific capacities to support the creation, capitalisation and sharing of knowledge to accelerate the development and improvement of advanced clean hydrogen applications ready to market
- Strengthen the competitiveness of the EU clean hydrogen value chain (notably SMEs) making the most of all future opportunities, accelerating the market entry of innovative competitive clean solutions to support the decarbonisation of the EU economy
- Develop hydrogen solutions necessary to reach climate neutrality in the EU by 2050 and contribute to the greening of hydrogen generation, deployment and use through innovative solutions

These objectives address the clean hydrogen economy from a broad perspective and are aligned with the objectives of the Horizon Europe framework. If pursued, they will contribute to the pursuit of several Sustainable Development Goals including: SDG7 (Affordable and clean energy); SDG8 (Decent work and economic growth); SDG9 (Industry, innovation and infrastructure); SDG11 (Sustainable Cities and communities); and SDG13 (Climate action).[229]

4.2 Specific objectives

In order to achieve the general objectives, we defined seven specific objectives. These specific objectives correspond to each of the problem drivers discussed in Section 2.2. The relationship between the general and specific objectives is shown in Figure 3.

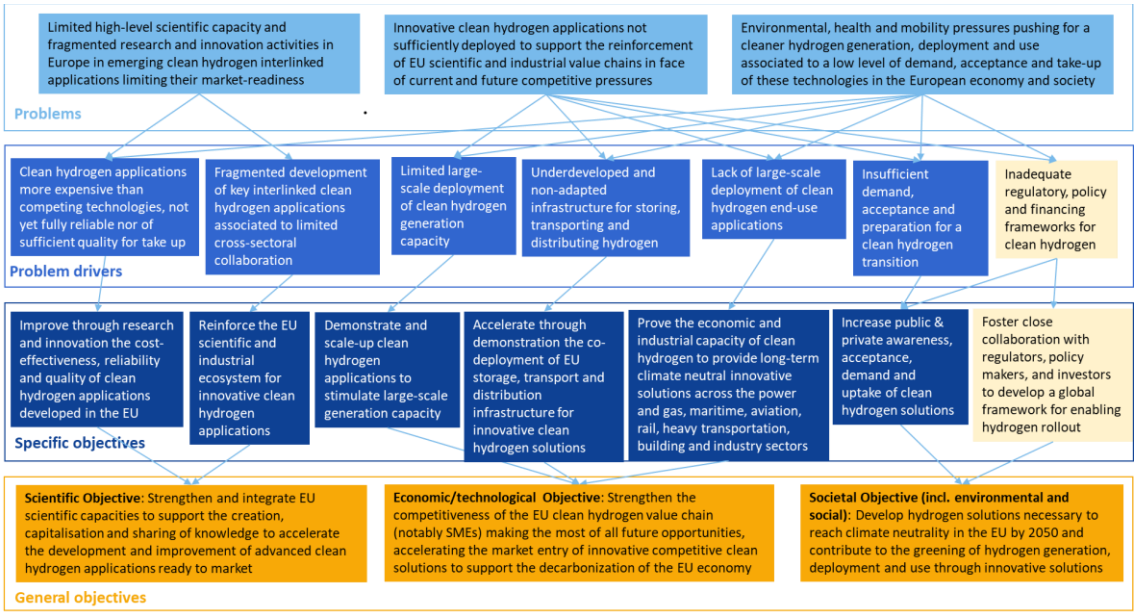
[226] Interim Evaluation of the Fuel Cells and Hydrogen 2 Joint Undertaking (2014-2016) operating under Horizon 2020

[227] Research and innovation problems, Structural and resource problems and Problems in the uptake of innovations

[228] Refer to Appendix D, section on "OPC - Relevance of research and innovation efforts at the EU level to address problems with Clean Hydrogen"

[229] European Commission International Cooperation and Development (2019), The Sustainable Development Goals – available at https://ec.europa.eu/europeaid/policies/sustainable-development-goals_en

Figure 3: Objectives tree for the initiative on Clean Hydrogen



Source: Trinomics

Note that one of these specific objectives is outside of the scope of the initiative: policy, regulatory and financial inadequacies have to be addressed so that the initiative is enabled to achieve its objectives and effectively contribute to the climate policies and targets from a broader perspective. This objective will need to be coordinated and achieved by other actors, including international, European, national and regional authorities. The achievement of this external action will ensure that Clean Hydrogen research and technological outputs will be deployed in markets, ensuring the deployment of mass production and market uptake quickly enough for Europe to remain a worldwide leader in the hydrogen space.

The initiative would accelerate the development and improvement of advanced clean hydrogen applications and facilitate the creation, capitalisation and sharing of high-quality new fundamental and applied knowledge and skills. Its principal scientific aim will be to improve through research and innovation the cost-effectiveness, reliability and quality of clean hydrogen applications developed in the EU.

Scientific advancement of hydrogen applications will be pursued with the intent to: reduce costs, enhance efficiency and quality. This objective can be achieved by setting explicit technical goals for research projects and adapting these goals as improvements are achieved. Scientifically enhancing clean hydrogen applications will mature existing technologies and will give rise to new technologies; if costs can be cut, efficiency gained, and quality guaranteed through scientific advancement, hydrogen applications will be more competitive within EU and international markets.[230,231]

It would be more difficult to set precise goals for developing applications that can decarbonise new sectors and sub-sectors (like the maritime and heavy industry sectors).

[230] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[231] World Energy Council (2019), New Hydrogen Economy – Hope or Hype?: Innovation Insights Brief – available at https://www.worldenergy.org/assets/downloads/WEInnovation-Insights-Brief-New-Hydrogen-Economy-Hype-or-Hope.pdf

A continuous collaboration framework will be necessary to ensure the sharing of best practices and experience and to profit from new developments.

To facilitate the creation, capitalisation and sharing of high-quality new fundamental and applied knowledge and skills, the initiative needs to support increased knowledge diffusion between industrial players, public sector authorities and members of the public to generate support for clean hydrogen technologies. It needs to establish a basis of information that can be relied upon to assuage concerns related to hydrogen safety.[232]

It also needs to research the most effective ways to educate a new workforce in the scientific skills and knowledge necessary for supporting a "hydrogen transition." It needs to design effective programmes to provide training and build awareness among engineers, executives, and policy makers on hydrogen applications and ensure that knowledge capacity is built to manage the safe and effective integration of hydrogen technologies into existing systems.

The initiative will demonstrate and scale-up clean hydrogen applications to stimulate large-scale generation capacity. If large-scale production capacity is justified and developed, it will be available to facilitate new technologies' entry into markets.[233] Large-scale production capacity will enable the development of a strong, extended hydrogen ecosystem.[234,235]

It will accelerate through demonstration the co-deployment of EU storage, transport and distribution infrastructure for innovative clean hydrogen solutions. These projects will be designed to prompt the effective planning and construction of infrastructure networks necessary to enable the safe and reliable transport and storage of hydrogen from producers in the power sector to end users in the transport and industry sectors. These infrastructural networks will be vital enablers of mass market entry for several hydrogen applications.[236,237] More large-scale demonstration projects on hydrogen transport will instil confidence in investors and mitigate the "chicken-and-egg" problem that has stalled infrastructural investment in the past.[238,239]

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[232] HySafe (2019), Safety of Hydrogen as an Energy Carrier – available at http://www.hysafe.org/IA_strategy

[233] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[234] Hydrogenics (2018), Cost Reduction Potential for Electrolyser Technology – available at https://www.humsterlandenergie.nl/resources/LInks-duurzaam/Linkpagina/20180619_Hydrogenics_EU-P2G-Platform_for-distribution.pdf

[235] Shell New Energies (2018), Shell Hydrogen Refuelling Station Cost Reduction Roadmap – available at https://www.hydrogen.energy.gov/pdfs/htac_dec18_06_munster.pdf

[236] Joint Research Centre (2016), 4th International Workshop on Hydrogen Infrastructure and Transportation Report – available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103586/4%20int%20workshop%20on%20h2%20infra%20final%20pdfonline.pdf

[237] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[238] David Kramer for Physics Today (2017), Hydrogen-powered vehicles: A chicken and egg problem – available at https://physicstoday.scitation.org/doi/10.1063/PT.3.3690

[239] The International Council on Clean Transportation (2017), Developing hydrogen fueling infrastructure for fuel cell vehicles: A status update – available at https://theicct.org/sites/default/files/publications/Hydrogen-infrastructure-status-update_ICCT-briefing_04102017_vF.pdf

It will prove the economic and industrial capacity of clean hydrogen to provide long-term climate neutral innovative solutions across the power and gas, maritime, aviation, rail, heavy transportation, building and industry sectors. To do so, it will prioritise cross-collaboration between hydrogen generation and difficult-to-decarbonise sectors and encourage the technical modification of equipment for hydrogen end-use. Only through extensive collaboration will players in the power, industry, and transport sectors be able to implement effective sector coupling mechanisms. Further collaboration will result in increased technology sharing and will strengthen cross-border hydrogen value chains. It will likely also result in efficiency gains that could lead to cost reduction and enhance the competitiveness of EU hydrogen technologies and networks.[240,241,242]

It will support more demonstration projects to prove the increasing feasibility of sector coupling and the versatility of hydrogen end-use applications. Successful demonstration projects will connect major players in different industries and mitigate fragmentation between different hydrogen applications.[243] They will evidence the feasibility of large-scale hydrogen production using renewable energy and/or relying on CCS/CCU.[244] They will prove that hydrogen can be effectively integrated into the existing systems of energy-intensive industries, maritime transport vessels, aviation vessels, and heavy-duty trucks and trains. Numerous large-scale demonstration projects on sector coupling applications will reinforce private- and public-sector interest and investment in clean hydrogen.[245,246,247]

By implementing all previously mentioned objectives, it will reinforce the EU scientific and industrial ecosystem for innovative clean hydrogen applications.

In order to develop hydrogen solutions to the level necessary to reach climate neutrality in the EU by 2050, the societal objectives of the initiative[248] would focus on increasing public and private awareness, acceptance, demand for and uptake of clean hydrogen solutions, and fostering close collaboration with regulators, policy makers and investors to develop a global framework for enabling hydrogen rollout.

[240] Hydrogen Council (2017), Hydrogen Scaling Up: A sustainable pathway for the global energy transition – available at https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-Scaling-up_Hydrogen-Council_2017.compressed.pdf

[241] Centre for Energy Economics Research at the University of Groningen (2019), Outlook for a Dutch hydrogen market – available at https://www.rug.nl/ceer/blog/ceer_policypaper_5_web.pdf

[242] Academic Press (2018), Hydrogen Supply Chains: Design, Deployment and Operation, Chapter 7 Hydrogen Applications: Overview of the Key Economic Issues and Perspectives – available at https://www.sciencedirect.com/science/article/pii/B9780128111970000075

[243] Siemens (2019), Hydrogen Sector coupling: A Pathway to deep decarbonization – available at http://www.cercind.gov.in/2019/expert-group/Stakeholders%20Comments/SIEMENS.pdf

[244] CE Delft (2018), Feasibility study into blue hydrogen: Technical, economic & sustainability analysis – available at https://www.cedelft.eu/en/publications/download/2585

[245] Refhyne (2019), Construction starts on the world's largest PEM electrolyser at Shell's Rheinland Refinery – available at https://refhyne.eu/construction-starts-on-the-worlds-largest-pem-electrolyser-at-shells-rheinland-refinery/

[246] Power Engineering International (2019), Cleaner ammonia production feasible thanks to hydrogen – available at https://www.powerengineeringint.com/2019/10/01/cleaner-ammonia-production-feasible-thanks-to-hydrogen/

[247] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[248] In-depth analysis in support of the commission communication COM(2018) 773 report, page 245

In order to facilitate the low-carbon transition, hydrogen applications should be further improved to develop clean hydrogen generation technologies, storage, delivery and hydrogen end-use applications to decarbonise all concerned sectors.[249]

In addition to climate goals, the transformation away from a fossil fuel-based economy will be a vital pillar of sustainable development.[250] The deployment of clean hydrogen applications will improve human health and air quality, bring greater energy security and more efficient resource use.

The initiative will encourage societal outreach on the environmental benefits of clean hydrogen applications. It will seek to increase public support for clean hydrogen deployment and prompt policy makers at local, national, and EU levels to incorporate clean hydrogen into their long-term decarbonisation strategies. It will also aim to connect regulatory authorities with researchers and industry players to inform their policymaking and ensure that a framework is designed and enacted to support hydrogen integration into existing markets.

Finally, the creation of market uptake conditions and FCH competitiveness can only be achieved with appropriate regulatory support, which is not currently in place, as stated in the interim evaluation of the FCH 2 JU.[251] This regulatory support is essential to properly exploit the JU outputs. Any new PPP should be considered in the context of the probable need for accompanying deployment support for FCH technologies if the research and innovation outcomes are to make a successful transition to commercial exploitation.

Many of the respondents to the **Open Public Consultation** took the opportunity to underline key messages regarding the initiative:

- he global positioning of Europe: outlining the role of global competition (including the role of technology), the importance of autonomy for Europe and the ability of Europe to act as a key player at the global level;
- The balance between policy objectives and private sector interests;
- The importance of the transition between research and innovation (implementing research results in the market);
- The importance of multidisciplinary, and specifically cross-sectoral/cross-partnership collaboration;
- The importance of the long term commitment of a wide range of relevant stakeholders;

Those main concerns are addressed within the following specific objectives.

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business association, and shared by both industry and research organisations, "any new partnership should take into account the necessary role of gas infrastructure to connect hydrogen production and consumption centres."

4.3 Intervention logic and targeted impacts of the initiative

4.3.1 Likely scientific impacts

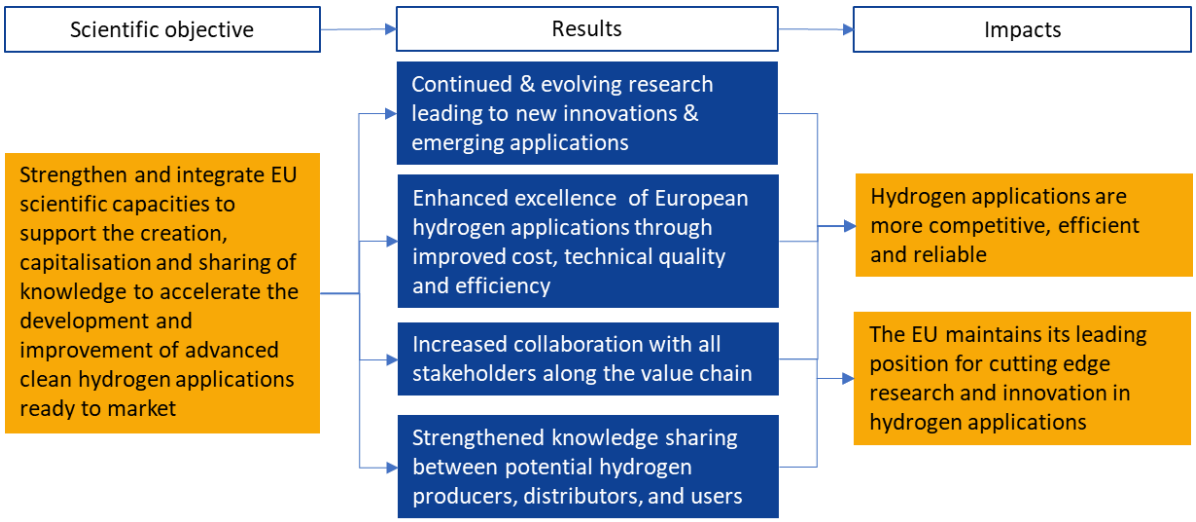
The initiative is likely to lead to two key scientific impacts, as illustrated in Figure 4 and further described below.

[249] In-depth analysis in support of the commission communication COM(2018) 773 report, page 304

[250] In-depth analysis in support of the commission communication COM(2018) 773 report, page 13

[251] See section 1.2 of the present report

Figure 4: Impact pathway leading to scientific impacts



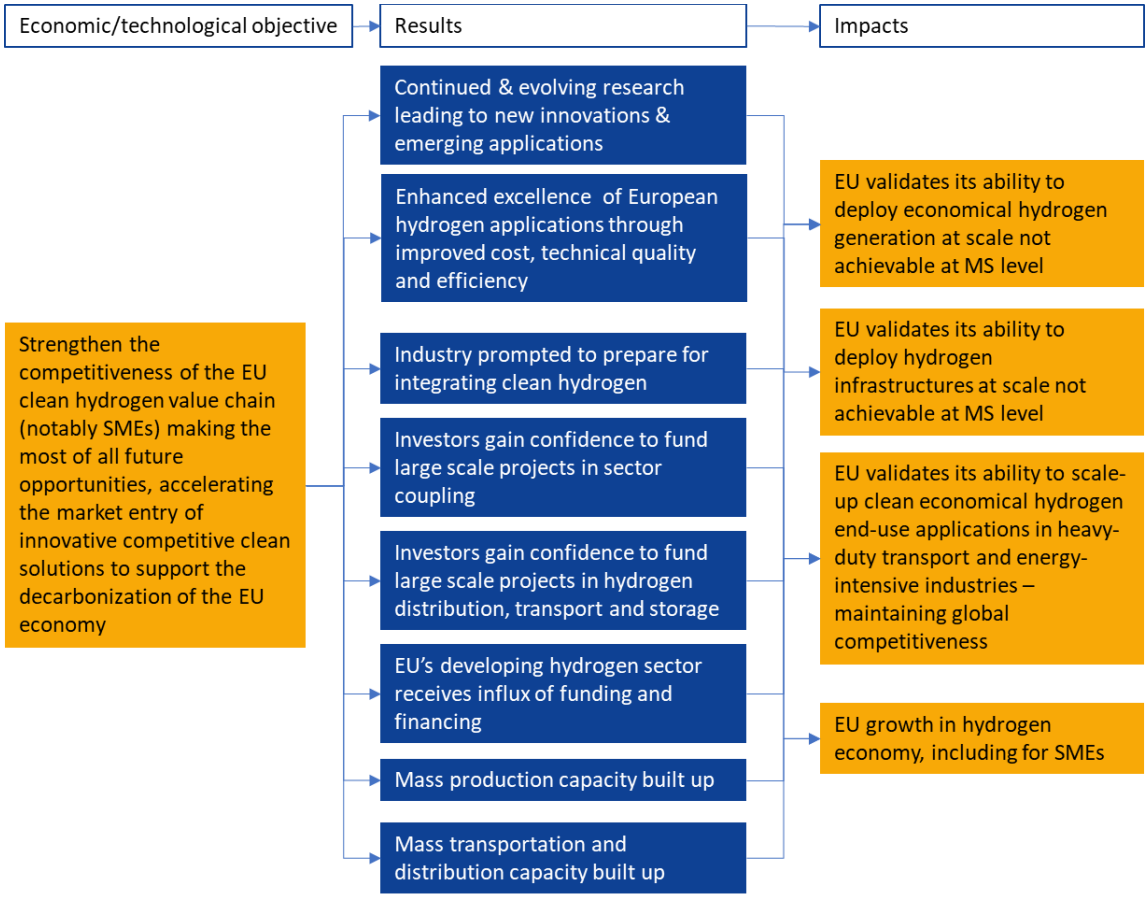
Source: Trinomics

If the partnership can push for continued technical improvement of hydrogen applications and encourage distinct industries to collaborate on research projects, new potential applications for hydrogen are likely to emerge. Additionally, the EU will be able to maintain the role it currently plays as a leading global hub for hydrogen research and innovation. The EU's leading research institutions and innovative SMEs will be primarily affected by these impacts in the short and long term. These scientific impacts are likely to contribute to the economic/technological impacts discussed in the subsequent section.

4.3.2 Likely economic/technological impacts

The likely economic/technological impacts of the initiative's specific objectives are mapped in Figure 5.

Figure 5: Impact pathway leading to economic/technological impacts



Source: Trinomics

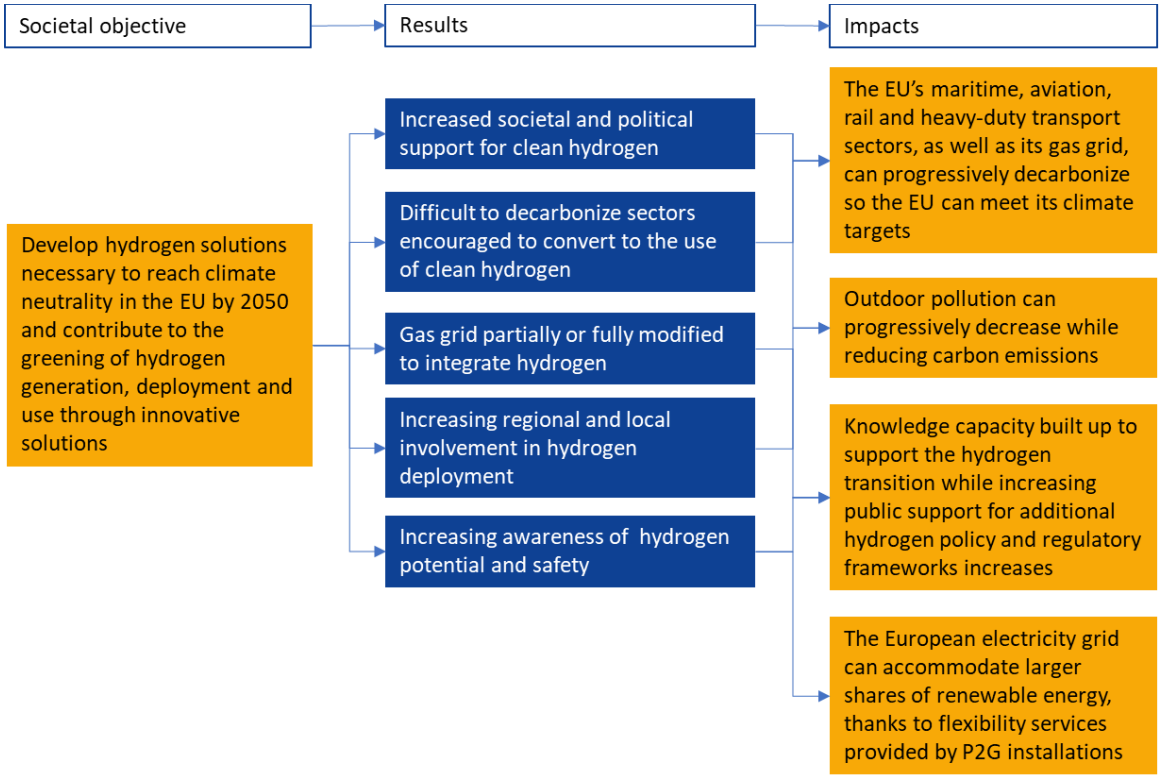
The partnership's objectives are likely to generate several crucial economic/technological impacts. Successful realisation of the objectives will result in a strengthened EU hydrogen industry. The EU will be able to pursue its climate targets while protecting the competitiveness of its energy intensive industries and heavy transport sectors. SMEs which have developed innovative hydrogen technologies are likely to thrive and receive increased funding. There is also potential for localised economic growth in areas where hydrogen hubs are developed.

These economic and technological effects will impact stakeholders across the EU; Member States which can capitalise on hydrogen development and uptake could incorporate a new, competitive industry into their economies. Across industrial and transport sectors, companies will be equipped to comply with climate standards without sacrificing competitiveness. There are substantial opportunities for SMEs to grow successful business and position themselves strongly within the hydrogen supply chain.

4.3.3 Likely societal impacts

The scientific and economic/technological impacts discussed above will also support the attainment of societal impacts as shown in Figure 6.

Figure 6: Impact pathway leading to societal impacts



Source: Trinomics

Likely environmental impacts

If executed in full, the partnership's objectives could lead to substantial environmental impact. Especially in sectors that are difficult to decarbonise, increased support for and investment in hydrogen applications would enable energy-intensive industries and heavy-duty transport to fully decarbonise. In turn, this would strengthen the EU low carbon society and enable EU to meet its climate targets. This would impact a wide range of stakeholders in the long-term, from company owners to citizens and local, Member State, and EU-level policy makers.

In addition to decarbonisation goals, a clean hydrogen economy can significantly contribute to decrease outdoor pollution thanks to the replacement of fossil-based fuels and feedstock.

Likely social impacts

Additional demonstration projects are likely to generate further public interest in hydrogen. At the same time, increased public outreach and education on hydrogen will likely create a basis of public support for hydrogen applications. This will facilitate the integration of innovative solutions into societies, from local to national to international levels.

Proof of hydrogen solutions' feasibility will likely prompt policy makers to act quickly and develop regulatory frameworks that can effectively govern applications' uses.

Objectives to increase public outreach on hydrogen will in turn increase public support for hydrogen; in a best case scenario, policy makers will receive public mandates/public pushes for developing policies that enable hydrogen's integration into existing systems, similar to how public support for renewables integration bolstered EU policymakers' support for renewable power in recent years.

Finally, the deployment of hydrogen produced from renewable electricity will significantly facilitate and enable the deployment of renewable electricity production at scale.

4.3.4 Likely impacts on simplification and/or administrative burden

Due to its versatility and cross-sectoral integration, clean hydrogen development should be addressed through close collaboration frameworks with other programmes and initiatives that create synergies and avoid duplications. It is essential to ensure the governance of the initiative appropriately addresses these collaborations to clarify administrative procedures. An initiative able to provide support to potential project partners could also simplify administrative procedures.

4.3.5 Likely impacts on fundamental rights

The partnership's specific objectives are unlikely to impact fundamental rights in the EU or abroad.

4.4 Functionalities of the initiative

This section outlines the functionalities that need to be considered when assessing the policy options set forth in Section 6, reflecting the selection criteria for European Partnerships defined in the Commission proposal for the Horizon Europe Regulation.[252] In the following paragraphs, we discuss the implications of the criteria relating to the type and composition of the actors involved, the range of activities to be undertaken and the directionality required if the initiative is to deliver the objectives discussed above. We also consider the complementarities and synergies with other, related initiatives under Horizon Europe and beyond.

4.4.1 Internal factors

Type and composition of the actors involved

This functionality relates to the criterion *"Involvement of partners and stakeholders from across the entire value chain, from different sectors, backgrounds and disciplines, including international ones when relevant and not interfering with European competitiveness"*. It concerns the need to involve the full range of stakeholders that can usefully contribute to delivering the future R&I agenda.

All sectors concerned by the hydrogen economy should be given the possibility to get involved in preparing and implementing the Research Agenda, to seize the continuously emerging opportunities of new hydrogen applications. The concerned sectors (industries and SMEs), in addition to the hydrogen component manufacturing actors, should at least comprise:

- The heavy industry using hydrogen as feedstock (iron and steel for the reduction of iron ore, chemistry and refineries) and to produce high temperature heat and steam (furnace, boilers and gas turbines on 100% hydrogen)
- The biomass/biogas sector for the production of green hydrogen and CO2 from biogas;
- The power sector, where hydrogen can act as long-term storage for renewables generation and to provide flexibility to the electricity system (provide balancing services). Hydrogen can also be used in existing power plants (turbines fuelled up to 100% with hydrogen) and CHP plants could be replaced by Fuel Cell-Heat Pump plants;
- The gas and grid operators, to convert infrastructure to transport hydrogen and decarbonise the whole gas chain

[252] European Commission (2018), Proposal for a Regulation of the European Parliament and of the Council establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018PC0435&from=EN

- The transport sector, including those in the maritime, aviation, rail and heavy road transportation branches
- The building and heating sectors, where residential CHPs can be deployed, hydrogen hub communities can develop
- Integrators and project developers that can coordinate efforts in project implementation (production, delivery and end use), especially to facilitate sector coupling

All research activities related to these sectors should also be involved in setting up and implementing the agenda.

This involvement can be addressed in two ways:

- Collaboration with other partnerships (to align the agenda, avoid duplications or even contradictory approaches, ensure coherence and coordination between funding instruments) ;
- A specific body in the governance structure of the initiative (like a "Stakeholder's Committee") gathering representatives of all concerned sectors ;

In addition to the industry and research, the public sector should also be involved, especially:

- Regional authorities, being close to potential end-users with the ability to gather various actors, responsible for territory issues (planning, permitting, low carbon roadmap, funding);
- National authorities, being responsible for developing climate policies (ideally by integrating hydrogen into the NECP 2030) and measures (market mechanisms) to fill the huge gap between ready-to-market technology development and large-scale uptake. National authorities should also address cross-border issues like infrastructure and corridors (pipelines, HRS, …), norms and standards. Appropriate coordination could contribute to setting up a proper framework to launch market deployment. Therefore the Member State involvement is crucial but should be achieved in a coordinated way in order to address the coherent integration of hydrogen within the overall energy system.

Finally, the initiative could act as a platform for coordination of relevant international cooperation efforts in the hydrogen economy, in order to create synergies, avoid duplications and anticipate market developments, when not interfering with European competitiveness and with a focus on:

- Non-EU market players with their own strengths that can complement EU company operations
- Well-established partnerships with international actors via participation in the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)
- New Energy and Industrial Technology Development Organisation (NEDO) in Japan, with a long-standing history of collaborating with European initiatives
- Rare materials market players in international environments
- Collaboratives to initiate demonstration projects in international markets – e.g., European expertise in PEM electrolysers opening new markets for greening Chinese industry
- The USA's Department Of Energy, having already collaborated with EU funding programmes.

Type and range of activities

- This functionality relates to the criterion "Approaches to ensure flexibility of implementation and to adjust to changing policy, societal and/or market needs, or scientific advances". It concerns the types of activity that the initiative is intended to encourage, such that it is able to respond effectively to the challenges and problems described in Section 2.
- Whilst the general objectives can be expected to remain the same throughout the programming period, the RD&I development cannot expect to be planned once and for all at the outset as there is no clear understanding, nor a clear roadmap based on identified scientific and/or technological solutions to this day. Flexibility in the selection of projects, implementation and possibly membership will be crucial to ensure that Clean Hydrogen is empowered enough to deliver. In practice, there is need for a balance between long term vision and stability of the programmes and flexibility to ensure it remains relevant and responsive to new market, industry and technological developments. The policy intervention will need to accommodate the appropriate balance. At the same time, there should also be some flexibility in the allocation of budget so that as technologies develop or market needs evolve, funding can be adapted to handle emerging topics.
- The initiative should conduct the following activities in order to ensure flexibility of implementation, to reach its objective and create the expected results:
- Run joint R&I programmes with other sectors, with or without the relevant initiative;
- Coordinate R&I actions ranging from concept to demonstration and validation activities (covering all Technology Readiness Levels), ensuring inclusion of new actors and integration of extended value chains
    - Coordination is needed on fundamental research to increase existing technologies efficiency, to replace rare materials, to develop new applications and concepts ;
    - Support for demonstration projects at scale will be necessary for applications close to maturity (TRL>7) by strengthening networks among research, industry, local authorities and end users, especially for sector coupling projects (direct electrolysis from renewable electricity) to come out with new business models, for the rail sector, for the heavy industry (feedstock and fuel supplies) and for large building applications ;
    - For maritime and aviation applications, coordinated demonstration projects will need to be conducted for pre-selected technologies in order to be able to compare them and further develop the most promising ones ;
    - Awareness will need to be increased among potential end users (industry, transport operators, building owners, utilities), among local and regional authorities and train them to strengthen their facilitating role
- Develop deployment and piloting activities to ensure flexibility over time across the range of applications implemented:
    - Sharing and diffusing experience from projects and research will allow speeding up developments from concept to ready-to-market technologies
    - For ready-to-market applications and technologies, access to funding for industrialisation and for financing should be facilitated
    - Financially supporting the development and maintenance of the infrastructure
- Communication and dissemination activities to ensure societal and political support for envisaged developments and overseeing actions fostering regulation or standardisation
    - A large community composed by research and industrial actors would be at the best place to address, from the perspective of concrete R&D projects (mainly from

demonstrations, but also fundamental for issues like safety that can be addressed from the earliest stage), regulation and standardisation. The community could suggest issues to address and provide the technical background and knowledge

- Co-creating solutions with end-users, emphasising the importance of flexibility in addressing different target groups over time (potential down-stream and end-users, public authorities and broader stakeholder communities), including:
    - Industrial end users where low carbon alternatives are not evident. Their involvement is key from a technology perspective as the applications still need to be improved and integrated, from a strategic and policy perspective as there is need for their low carbon commitment and from a financial perspective as the higher cost of hydrogen should be supported by private and public actors. New industries could join the H2 roadmap.
    - The maritime and the aviation sectors which should provide attractive low carbon services to end users. They should be deeply involved considering their own sectorial carbon roadmaps with huge sensitisation needs. There is urgency to demonstrate at scale some of the most promising technologies in order to deploy those that are most relevant, considering their technical, economic and environmental impacts. The rail sector could be addressed the same, considering the replacement of fossil driven trains;
    - Public authorities which have an important role to play in planning and delivering low carbon strategies in a semi-decentralised way (central view at a decentralised scale). They could provide guidelines, create networking between all local actors in the value chain (production, delivery and end use);
    - Public transport operators as key players. They also should provide to end users attractive low carbon services. They should be deeply involved considering their own sectorial carbon roadmaps with huge sensitisation needs;
    - Public procurements (specific fleets of vehicles) as key driver should be deeply mainstreamed considering the public example role and its huge sensitisation impact;
    - The logistics sector (road transport, on site logistic with material-handling vehicles), which will comprise key players with a limited number of low carbon alternatives so far. It should be deeply involved considering its own sectorial carbon roadmaps;
    - The electricity and, in particular, the renewable power sector, as planning for integration with electrolysers and fuel cells will be paramount to successful rollout of clean hydrogen applications;
    - The gas sector, as the existing infrastructure may transport and store hydrogen at low marginal cost.[253]
    - New sectors which might have the opportunity to join in the future, depending on the evolution of applications;
    - Local ecosystems like ports[254] (with many different activities that could benefit from hydrogen applications) or industrial and economic areas.[255]

Directionality and additionality required

This functionality relates to the criteria "Common strategic vision of the purpose of the European Partnership" and "Creation of qualitative and significant quantitative leverage effects". The former highlights the importance of ensuring that all participating stakeholders have a common understanding of the purpose of the policy intervention and the direction of the R&I activity it is intended to encourage. The leverage effects relate to

[253] IEA, 2019 "The future of Hydrogen"

[254] https://www.fch.europa.eu/news/port-valencia-receives-prestigious-award-hydrogen-project

[255] https://teesvalley-ca.gov.uk/plans-to-bring-hydrogen-trains-cars-and-buses-to-the-region-takes-a-step-forward/

the creation of spill over effects of the knowledge gained in the broader community as well as the crowding-in effects on private investments in R&I – both among participating stakeholders and in the broader community, and/or the pooling of resources from EU Member States.

A common vision for the initiative and the preparation of an integrated Strategic Research and Innovation Agenda cannot be achieved in the absence of a strong commitment of the industry, the research organisations and the public sector in Europe.[256]

It is critical that stakeholders with long-term commitments in the hydrogen sector remain involved in the initiative. Industry should be ready to continuously improve technologies and applications, once uptake is starting in order to constantly improve efficiency, cost, reliability and performance. Clean hydrogen RD&I activities (under Horizon Europe) should encourage cooperation between consortia of stakeholders which are otherwise competitors, working together on the basis of consented multi-annual (and possibly multi-projects) actions targeted at specific technological goals. The final aim would be to create broad European value. In this respect, there are benefits of clear roadmaps and planning phases as positive instruments to ensure converging and coherent efforts, spanning a chain of linked projects or financed actions.

Less mature applications still need to be improved and will need to involve research and industry players in the long term. Political commitment from both Member State's and the EC is of utmost importance – as hydrogen technologies are not yet economically competitive, strong signalling and support from governments is necessary to ensure that hydrogen applications will play a long-term role in future energy/industry/transport landscapes.

- The governance model that is required to support the policy objectives is complex, and common strategic visions and directionality are necessary to ensure that the partnership can achieve its goals. The following features could be implemented to focus the directionality of the partnership:
- Due to the versatility of H2 and the huge number of stakeholders, in order to avoid a complex governance model, cross-collaboration of sectors could be implemented (as explained in functionality 1 on type and composition of the actors involved)
- Different standards and market mechanisms that are required across the spectrum of hydrogen applications could be developed by coordinated initiatives between Member States and sector representatives
- A governance body is necessary to support integration between sectors and industries not used to working with one another

To conclude, the level of directionality should be as high as possible for the initiative to reach its expected impacts. The strategic vision should be shared and implemented as much as possible by the key stakeholders along the value chain.

4.4.2 External factors

The proposed Regulation for Horizon Europe also identifies the need to consider *"Coordination and complementarity with Union, local, regional, national and, where relevant, international initiatives or other partnerships and missions"* when assessing the case for a partnership. It concerns the potential for linkages with other relevant R&I initiatives proposed or planned for the forthcoming Framework Programme, at the EU level in the context of the MFF 2021-27, and beyond.

[256] The Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019, p 7

In order to maximise complementarities and synergies with all concerned sectors, clear and strong collaboration with other initiatives and EU programmes is a key factor in reaching the expected impacts.

Given the versatility of hydrogen and its capacity for incorporation into many sectors, the initiative should ensure an industry and research-led approach when shaping its strategic vision so that efforts can be prioritised, capitalised, adapted to market developments and focused on achieving the climate objectives. The initiative should be able to recycle lessons from higher TRL development projects to lower TRL in order to maximise the capitalisation of efforts. Therefore, driving the agenda of low TRL applications should be mainstreamed within a broader agenda encompassing all stages of maturity evolution.

To achieve the expected impacts concerning the next steps after the R&I (scaling up, market deployment, regulatory and other frameworks, infrastructure deployment, customer acceptance, …), there is a need to facilitate access to other crucial funding and financing mechanisms, in order to create synergies, where relevant. To this end, the initiative should consider collaboration with at least:

- The **Connecting Facility Europe** from demonstration projects on the deployment of HRS or the adaptation of the gas grid in the perspective of building European corridors
- The ETS **Innovation fund**[257] to boost growth by empowering companies and supporting innovation to take off and reach the market. Support for the industrialisation phase could also be considered
- Risk capital players, to finance scaling up activities
- The financial institutions, to bring solutions to the market, like the European Investment Bank (EIB); the Regional Operational Programmes supported by ERDF funding for low-carbon energy solutions and sustainable mobility
- The national funding programmes
- The Europe's programme for small and medium-sized enterprises COSME

The **interviewees** from both research and industry stressed the importance of, and potential for, coordination with local, regional national and European initiatives. Coordination with regions or cities could contribute to the mobilisation of significant resources and especially SMEs to deploy local ecosystems.

As affirmed comprehensively in **interviews with stakeholders from both research and industry** coordination will avoid duplication and fragmentation of efforts. Coordination in the area of standards is critical in two ways. Firstly, the research results and the knowledge produced by the initiative can feed the efforts for generating standards and secondly the standards should be adopted and applied by and with the concerned sectors.

As affirmed in **several interviews with stakeholders from both research and industry**, it is crucial to share views on how to integrate hydrogen into the most relevant sectors (e.g. rail, maritime, gas and power, grids, aviation, building, …) and ideally to share a common vision to define where to concentrate efforts. Joint calls, including their funding and management, should be the next step in ensuring full coherence with other initiatives' agendas.

[257] https://ec.europa.eu/clima/policies/innovation-fund_en

Table 2: Mapping of envisaged inputs and type of collaboration between the Clean Hydrogen initiative and other partnerships, programmes and networks, and with funding and financing mechanisms

Initiatives	Input from Clean Hydrogen	Input to Clean Hydrogen	Type of collaboration
Priority Initiatives for collaboration			
Global, neutral and circular industry	• Fast-track and early access to past experience to accelerate hydrogen applications improvement and development • Efficient systems using alternative hydrogen-based fuels	• Dissemination and interaction with potential users for end-user requirements, validation etc. to achieve end-user leverage/impact • Assessment of impact on environment	• Co-creation of solutions with end-users • Exchange of requirements and demonstration and assessment of the impact of circular economy approaches
Initiatives serving as application areas			
Transforming EU's rail system	• Fast-track and early access to past experience from other applications to accelerate stack integration • Efficient engines using alternative hydrogen-based fuels	• Sectoral low carbon commitment and roadmap • Dissemination and interaction with potential users for end-user technical and regulatory requirements, validation etc. to achieve end-user leverage/impact • Demonstration of pilot systems	• Co-creation of solutions and fuel selection with end-users • Sharing of a common vision/roadmap • Exchange of requirements and demonstration • Joint calls
Clean Aviation	• Fast-track and early access to past experience from other applications to accelerate stack integration • Efficient propulsion systems using alternative hydrogen-based fuels		• Co-creation of solutions and fuel selection with end-users • Sharing of a common vision/roadmap • Exchange of requirements and demonstration • Joint calls
Waterborne sector	• Fast-track and early access to past experience from other applications to accelerate stack integration • Efficient engines using alternative		• Co-creation of solutions and fuel selection with end-users • Sharing of a common vision/roadmap • Exchange of requirements and demonstration • Joint calls

Initiatives	Input from Clean Hydrogen	Input to Clean Hydrogen	Type of collaboration
	hydrogen-based fuels		
Towards zero-emission road transport	• Fast-track and early access to past experience from other applications to accelerate stack integration • Efficient engines using alternative hydrogen-based fuels		• Co-creation of solutions and fuel selection with end-users • Sharing of a common vision/roadmap • Exchange of requirements and demonstration • Joint calls
Clean Steel	• Fast-track and early access to past experience from other applications to accelerate stack integration • Efficient Direct Reduced Iron processes and industrial energy systems using alternative hydrogen-based fuels	• Sectoral low carbon commitment and roadmap • Dissemination and interaction with potential users for end-user technical requirements, validation etc. to achieve end-user leverage/impact • Demonstration on pilot systems	• Co-creation of solutions • Share of a common vision/roadmap • Exchange of requirements and demonstration • Joint calls
SPIRE[258]	• Fast-track and early access to past experience from other applications to accelerate hydrogen use • Efficient processes and industrial energy systems using alternative hydrogen-based fuels		• Co-creation of solutions • Share of a common vision/roadmap • Exchange of requirements and demonstration • Joint calls

[258] Sustainable Process Industry through Resource and Energy Efficiency

Initiatives	Input from Clean Hydrogen	Input to Clean Hydrogen	Type of collaboration
Smart Networks and Services **&** **Key digital technologies**	• Dissemination and interaction with end-users for technical requirements • Dissemination and interaction with hydrogen production manufacturers for technical requirements to improve efficiency and foster sector coupling	• Fast-track and early access to advanced key digital technologies leading to foster market uptake • Access to European devices for infrastructure monitoring and control • Power electronics to support efficient conversion of energy • Processing, sensors and software	• Co-creation of solutions with end-users • Exchange of requirements and demonstration of energy monitoring and control technologies as well as high efficiency energy conversion
Interconnections with other EU programmes and networks			
European Energy Research Alliance (EERA)	• Strategic Research & Innovation Agenda and Multi-Annual Framework preparation	• Research priorities and funding programmes	• Collaboration on synergies and skills development • Ensure full alignment of hydrogen agenda into the global energy RD&I agenda
Programme for Environment and Climate Action (LIFE)	• Strategic Research & Innovation Agenda and Multi-Annual Framework preparation	• Research priorities and funding programmes on low carbon related RD&I • Support in bridging the gap between the development and implementation of new knowledge (e.g. deployment phase of ready-to-market hydrogen applications)	• Collaboration on synergies and skills development
High-Level Expert Group on Energy-Intensive Industries	• Efficient processes and industrial energy systems applications using alternative hydrogen-based fuels	• Technology roadmaps for a competitive transformation of EU Energy Intensive Industries	• Collaboration on synergies • Ensure integration of relevant hydrogen applications
Access to other crucial funding and financing mechanisms (to support market deployment)			
Connecting Facility Europe (CEF)	• Research and market priorities related to hydrogen infrastructure	• Funding program and technology roadmaps	• Collaboration on complementarities • Ensure coherence between RD&I results on hydrogen

Initiatives	Input from Clean Hydrogen	Input to Clean Hydrogen	Type of collaboration
			infrastructure and CEF priorities • Share views on the adaptation of the gas grid in the perspective of building European corridors
ETS Innovation fund	• Research and market priorities related to hydrogen EU mass production opportunities	• Priorities regarding company empowerment and innovation support in taking off and reaching the market • support the industrialisation phase of hydrogen applications	• Collaboration on complementarities • Ensure coherence between RD&I results on hydrogen and Innovation fund priorities • Share views on market uptake conditions

The initiative should also ensure close collaboration with policy makers and regulators as a central element in spurring the setting up of regulatory frameworks and the establishment of conditions to facilitate and incentivise market uptake. It should also work closely with investors ready for the industrialisation phase in order to provide them support and guidance. The funding of demonstration projects should therefore be adequate to leverage as much private funds as possible.

5 What are the available policy options?

In this chapter, we provide an overview of the key characteristics of the policy options for this initiative. The Horizon Europe regulations put forward three forms of European Partnerships that constitute the policy options for this initiative; standard Horizon Europe calls are a fourth option while acting also as a baseline against which the three partnership options will be compared.

To ensure a correct assessment of the different options and their effectiveness, it is crucial to take into consideration both the objectives and the functional requirements outlined in Section 4.4. The descriptions of the options in the sections below therefore focus on the implications of the options' characteristics related to these functionalities. They are based on the options' characteristics specifically related to the functionalities presented in Section 4.4. A full description of the options is provided in the report on the overarching context to the impact assessment studies.

5.1 Option 0: Horizon Europe calls (baseline)

In the field of clean hydrogen, a baseline option would mainly promote standard RD&I projects. Standard calls will likely receive responses from research institutions, universities and industries with dedicated hydrogen projects and departments. Funded projects are likely to have clear, achievable, short-term objectives.

Table 3: Key characteristics of Option 0

	Implications of option
Enabling appropriate profile of participation (*actors involved*)	• The Commission would need to prepare the Strategic Research and Innovation Agenda (SRIA) by extensively consulting a wide range of actors, i.e. all hydrogen equipment manufacturers, all end-use sectors (energy intensive and hydrogen feedstock industry, heavy transportation, building) and their equipment manufacturing industry, gas operators and industries, the gas and power sectors (including renewable), all related research organisations and academia and representatives of local and regional authorities or communities (as key player to build ecosystems). This could be challenging, considering the current evolution of the hydrogen economy and the early stage of building up a clean hydrogen EU strategy (not existing at the moment) • The implementation of the SRIA would need further consultation with research and industrial organisations to deal with technical, economical and industrial knowledge as deep expertise is needed to address hydrogen versatility in an evolving landscape • A well-defined process would be needed to ensure that the programme committees were properly informed about RD&I priorities, including key demonstration projects. For the latter, higher leverage from the industry is expected, meaning that a deep understanding of the economics of hydrogen applications is key and would probably necessitate deep training of the committee. • The specification of calls over the period of the Framework Programme will reflect the need for an evolving profile of participation, with different consortia forming at different stages to take different types of activity forward.
Supporting implementation of R&I agenda (*activities*)	• Implementation would rely on standard infrastructure underpinning the open calls procedure, drawing on resources of relevant executive agencies and Commission IT systems. • Administrative costs for the European Commission would be significantly reduced. • Calls for proposals would be published in the work programmes of Horizon Europe. • Transparency and open publication of results would ensure their availability to interested parties. • Dissemination of knowledge and sharing of practice would only happen among partners within calls consortia. There would be no broader sharing with a broader community, and therefore no large scale capitalisation of efforts.

	Implications of option
Ensuring alignment with R&I agenda (*directionality*)	• Work programmes would need to reflect the requirement for RD&I activity across TRLs, with input from representatives of all relevant stakeholders. • Specification of calls for activity at higher TRLs, particularly demonstration projects, would need substantial inputs from industry. • Calls would need to be informed by FCH 2 JU to ensure continuity where appropriate. • RD&I activity would focus on the short- to medium-term needs of the industry and fundamental research, although it would also include long-term applications and trends. • Commission input into specification and oversight of calls would ensure alignment with overarching policy objectives but full integration with other programmes and concrete measures would require additional coordination. • Selection of high TRL projects would require provision of external (and independent) expert advice to the Commission.
Securing leveraging effects (*additionality*)	• Progress of RD&I effort would depend largely on EU funding, with no expectation of significant leveraging of industry support. • Demonstration programmes would require significant in-kind support and collaboration from industry, but there are some unknown as to whether critical mass could be reached. • Given more limited funding than in the past, critical R&I priorities would need to be identified at the outset, probably through stakeholder consultation

5.2 Option 1: Co-programmed European Partnership

A co-programmed partnership would provide for focused input from partners into the determination of the R&I agenda and clear aspirations for leveraged funding of activities while continuing to rely on the Commission and/or executive agencies for administration. At the same time, while it would allow for flexibility in the profile of stakeholder participation, progress in the delivery of the R&I programme would depend on the willingness of stakeholders to support individual projects rather than on legally binding commitments.

Table 4: Key characteristics of Option 1

	Implications of option
Enabling appropriate profile of participation (*actors involved*)	• The partnership would enable participation by all key stakeholders potentially contributing to the specification and delivery of the strategic R&I agenda. • It would need to consult with a wide range of stakeholders to ensure that the R&I agenda, and ultimately the work programme, was aligned with industry, research and market needs. • At the same time, it would offer the flexibility to change the profile of participation over time, with new partners joining to support new areas of activity in response to emerging results and changing priorities.

Supporting implementation of R&I agenda (*activities)*	• Implementation would rely on standard administrative infrastructure underpinning the open calls procedure, drawing on resources of relevant executive agencies and Commission IT systems. • Calls for proposals would be published in the work programmes of Horizon Europe. • Transparency and open publication of results would ensure their availability to interested parties.
Ensuring alignment with R&I agenda (*directionality*)	• Work programmes would need to reflect the requirement for RD&I activity across TRLs, with input from the various partners to achieve an appropriate balance of activity directed towards different markets. • The partnership would be responsible for ensuring that priorities for calls were specified in line with RD&I priorities, including demonstration projects. • Specification of calls would need to be informed by FCH 2 JU to ensure continuity where appropriate. • RD&I activity would be likely to focus on the medium-term needs of the industry and research. • The transport Programme Committee would ensure alignment with overarching policy objectives and coordination with related programmes.
Securing leveraging effects (*additionality*)	• Aspirations for partner contributions would be clearly defined at the outset. • Industry or research commitments would not be legally binding. • Expected in-kind contributions from the private sector would be identified in the work programme. • Given more limited funding than in the past, critical R&I priorities would need to be identified at the outset.

5.3 Option 2: Co-funded European Partnership

The Co-funded Partnership is based on a *Grant Agreement* between the Commission and the consortium of partners, resulting from a call for a proposal for a programme co-funded action implementing the European Partnerships in the Horizon Europe Work Programme.

Table 5: Key characteristics of Option 2

	Implications of option
Enabling appropriate profile of participation (*actors involved*)	• Partners can include *any national funding body or governmental research organisation*, Possible to include also *other type of actors*, including foundations. • It is not possible to have industry associations as partners. • Requires substantial national R&I programmes (competitive or institutional) in the field and therefore limiting the participation to few MS with existing national Clean Hydrogen programmes.

	Implications of option
	• Usually only legal entities from countries that are part of the consortia can apply to calls launched by the partnership, under national rules.
Supporting implementation of R&I agenda (*activities)*	• Activities may range from R&I, pilot, deployment actions to training and mobility, dissemination and exploitation, but according to national programmes and rules. • Decision and implementation by partners receiving institutional funding for Clean Hydrogen programmes, or by "third parties" receiving financial support, following calls for proposals launched by the consortium. • The scale and scope of the initiative is limited and depends on the participating programmes. The resulting funded R&I actions are typically smaller in scale than FP projects.
Ensuring alignment with R&I agenda (*directionality*)	• The strategic R&I agenda/roadmap is agreed between the MS and EC without the participation of industry. • The annual work programme drafted by partners, approved by EC. • Objectives and commitments are set in the Grant Agreement. • The coherence of the partnership with other actions can be ensured by partners and EC. • There are strong synergies with national/regional programmes and activities, and they can be ensured by the MS. • Synergies with other European programmes or industrial strategies are limited.
Securing leveraging effects (*additionality*)	• Low possibilities for leverage of industry contribution as industry does not participate in the decision making.

5.4 Option 3: Institutionalised European Partnership

5.4.1 Institutionalised Partnerships under Art 185 TFEU

Article 185 of the TFEU is a complex and high-effort arrangement and is based on a Decision by the European Parliament and Council and implemented by dedicated structures created for that purpose. It allows the Union to participate in programmes jointly undertaken by MS and Associated Countries.

Table 6: Key characteristics of Option 3: Institutionalised Partnership Art 185

	Implications of option
Enabling appropriate profile of participation (*actors involved*)	• Partners can include *MS and Associated Countries*.

	Implications of option
	• Non-associated third countries can only be included as partners if foreseen in the basic act and subjected to conclusion of dedicated international agreements. • Good geographical coverage is required with participation of at least 40% of Member States • The existence of substantial national R&I programmes (competitive or institutional) in the field is required • While by default the FP, rules apply for eligibility for funding/participation, in practice (subject to derogation) often only legal entities from countries that are Participating States can apply to calls launched by the partnership, under national rules.
Supporting implementation of R&I agenda (*activities*)	• Horizon Europe's standard actions that allow a broad range of coordinated activities from R&I to uptake apply. • In case of implementation based on national rules (subject to derogation) the activities follow the national programmes and rules. • The option allows the integration of national funding and Union funding into the joint funding of projects
Ensuring alignment with R&I agenda (*directionality*)	• The strategic R&I agenda/roadmap is agreed between partners and the EC • The objectives and commitments are set in the legal base. • The annual work programme is drafted by partners and approved by the EC • The commitments include the obligation for financial contributions (e.g. to administrative costs, from national R&I programmes).
Securing leveraging effects (*additionality*)	• Coherence among partnerships and with different parts of the Annual Work programme of the FP can be ensured by partners and EC • Synergies with national/regional programmes and activities, and with other programmes • Synergies with industrial strategies are limited

5.4.2 Institutionalised Partnerships under Art. 187 TFEU

An institutional partnership established under Article 187 of TFEU would provide a structured framework for bringing together the capabilities of all research and industry stakeholders who might potentially contribute to hydrogen-related RD&I under Horizon Europe. It would include dedicated administrative resources to support the development of the strategic RD&I agenda for the whole of the Framework Programme and legally binding funding arrangements.

By extension, partnership could also involve a broader community like local or regional communities, or even Member States.

Table 7: Key characteristics of Option 3: Institutionalised Partnership Art 187

	Implications of option
Enabling appropriate profile of participation (*actors involved*)	• The partnership would enable the participation by all key stakeholders concerned by the hydrogen economy and member of the partnership in order to specify and deliver the Strategic Research and Innovation Agenda (SRIA). • The implementation of the agenda would not need further consultation, as the structure, thanks to its technical, economical and industrial knowledge and acquired expertise, allows it to be self-managed. • It would provide a forum or even a platform for consulting stakeholders on RD&I priorities and the work programme, ensuring that they are aligned with industry, research and market needs and with the agenda of other partnerships and sectoral programmes. • Requires a rather stable set of partners (e.g. if a sector has small number of key companies), but it might nevertheless be possible to change the profile of participation over time, with new partners joining to support new areas of activity in response to emerging challenges and evolving priorities. • By default open to legal entities from 3rd countries, but subject to policy considerations.
Supporting implementation of R&I agenda (*activities)*	• By having research and industry together with the EC and closely collaborating in shaping the Multi-Annual Work Programme, this option can identify priority research areas that would support EU policies and that industry would be ready to pick up and bring to a higher level of maturity. This option would be able to manage related activities at all TRLs, from fundamental R&D up to market-readiness • The key strength of this option is that it would support closer collaboration between research, industry and decision makers to define the work plan for activities. This is particularly valuable for activities which require greater coordination (demonstration of complex projects, technology comparison, awareness, new business models, …). Considering the complex supply chains of hydrogen applications and the spread of actors, coordination is essential • The presence of a back-office allows for dedicated staff to oversee an integrated portfolio of projects, establishing a "system" with a pipeline of support to accelerate and scale up the achievements of the partnership, including those related to regulations and standardisation and developing synergies with other funds (e.g., setting up clean hydrogen ecosystems and promoting their replication by additional investments from MS/ private sector) • A dedicated administrative structure would be established to coordinate the specification of R&I activity, manage implementation and report on the results (with administrative expenditure limited to 4% of the budget and subject to 50:50 allocation between the Commission and private partners).

	Implications of option
	• Calls for proposals would be published broadly by the administrative structure. • Transparency and open publication of results would ensure their availability to interested parties. • Dissemination of knowledge and sharing of practices would occur among the stakeholders of the community, with potential diffusion activities managed by the partnership structure. The entire community would be able to capitalise on past efforts.
Ensuring alignment with R&I agenda **(*directionality*)**	• The partnership would be responsible for specifying a work programme fully in line with the RD&I priorities identified by the industry and research organisations to fulfil the European policy needs, combining activities across low and high TRLs and in different areas. • The work programme would reflect the medium- and long-term needs of the industry, the research organisations and the society in adopting clean hydrogen solutions. • The work programme would build on, but not be constrained by, the current FCH 2 JU to ensure continuity and coherence where appropriate. • Commission participation in the partnership governance arrangements and approval of the work programme would help to ensure alignment with overarching policy objectives and enable integration with other programmes and initiatives.
Securing leveraging effects **(*additionality*)**	• Legally binding funding requirements would be clearly defined at the outset, with private sector partners expected to provide between 50% and up to 75% of partnership resources through in-kind and/or financial commitments. • The programme office of the current JU has experts on FCH technology able to monitor KPIs across projects and make sure the upcoming calls can support a real improvement in KPIs. This type of good technical knowledge will allow the initiative to adequately assess projects in the selection process, to provide technical assistance where needed and even to challenge the industries that might remain conservative, in order to increase the speed of development. Knowledge management of this kind is an important asset and only exists in this option. • Given more limited funding than in the past, critical RD&I priorities would need to be identified at the outset. • Back office staff could provide support to standardisation and developing synergies with other funds.

5.5 Options discarded at an early stage

The co-funded partnership and an institutional partnership created under Article 185 of the TFEU are not considered relevant for the impact assessment of the candidate Institutionalised Partnership on Clean Hydrogen.

In a co-funded partnership option, the partners do not include private sector companies or private research organisations and instead include only public authorities with research

funders (or governmental research organisations) and other public authorities at the core of the consortium.

These types of partnerships rely on pooling and/or coordinating national programmes and policies with Union policies and investments to help overcome fragmentation. This form of implementation only allows to address the interests of the public partners at its core (comparable to the Article 185 initiatives), with the Member States that are partners in this partnership becoming the 'owners' of the priority and taking sole responsibility for its funding. The industry and research RD&I can nevertheless be addressed by the activities of the partnership, but it does not make formal commitments and financial contributions, nor does it decide on the RD&I priorities.

In the context of Clean Hydrogen, the involvement of industry and research is vital as there is a definite need for the industry and research to plan, deliver and fund research and innovation in a concerted manner taking into account:

- The significant differences between Member State commitments, as most EU countries have developed only limited R&D Strategic Research and Innovation Agendas on Clean Hydrogen which would be difficult to compile into a global EU agenda;
- Industry and KBA (knowledge and research base actors) can more adequately manage R&I priorities in this fast-evolving sector with continuously emerging applications than Member States;
- The versatile characteristics of hydrogen necessitate coordination between many different sectors where industries and KBA are active;
- Involving industry and KBA in a partnership on clean hydrogen is a critical element synchronising and advancing fundamental perspectives on applied applications and market needs. Their direct participation will be a vital when setting up the Strategic Research and Innovation Agenda.
- Respondents to the Open Public Consultation clearly see stakeholders from industry as the most relevant in setting joint long-term agenda, followed by academia.

The same rationale applies for institutional partnerships created under Article 185 of the TFEU, where the partners are simply Member States and do not include private partners. For these reasons, these two options have been discarded at an early stage and are not considered suitable for Clean Hydrogen where a public-private partnership is sought.

6 Comparative assessment of the policy options

6.1 Assessment of effectiveness

Based on the intervention logic, the initiative aims to deliver scientific, economic/technological and societal (including environmental) impacts through a set of pathways (Section 4.3). These pathways require that a set of functionalities are included in any initiative, which address the internal and external factors in the best possible way (Section 4.4).

This section assesses the extent to which each policy option might generate scientific, economic/technological and societal impacts, based on their core characteristics (Section 5). At the end of each section we summarise the outcomes of the assessment by assigning a non-numerical score to each option according to each desired impact.

The assessments in this section set the basis for the comprehensive *comparative* assessment of all retained options against all dimensions in Section 6.4.

Table 8 lists the desired impacts in the three impact areas.

Table 8: Likely impacts of the initiative

Impact area	Likely impacts
Scientific impact	Hydrogen applications are more competitive, efficient and reliable
	The EU maintains its leading position for cutting edge research and innovation in hydrogen applications
Economic / technological impact	The EU validates its ability to deploy economically viable hydrogen generation at scale not achievable at MS level
	EU validates its ability to deploy hydrogen infrastructures at scale not achievable at MS level
	EU validates its ability to scale-up clean economically viable hydrogen end-use applications in heavy-duty transport and energy-intensive industries – maintaining global competitiveness
	EU growth in hydrogen economy, especially for SMEs
Societal impact	The EU's maritime, aviation, rail and heavy-duty transport sectors, as well as its gas grid, can progressively decarbonise so the EU can meet its climate targets
	Reduction of carbon emissions and pollution to air, water and soil
	Knowledge capacity built up to support the hydrogen transition while increasing public support for additional hydrogen policy and regulatory frameworks increases
	The European electricity grid can accommodate larger shares of renewable energy, thanks to flexibility services provided by P2G installations

6.1.1 Scientific impacts

Option 0: Horizon Europe calls (baseline)

Improving efficiency and reliability: This option can contribute to improving the efficiency and reliability of hydrogen applications and equipment. But as described in section 4.4, a long-term perspective and commitment is critical to building up a hydrogen economy, securing effective climate policy and achieving core R&I objectives. Without a long-term focus and commitment from both the research and the industry communities, Europe's hydrogen sector will not be able to adapt quickly enough to changing competitive forces, to the delivery of new low carbon solutions and the emergence of low carbon challenges.[259,260] This option is unlikely to contribute to the emergence of new applications for clean hydrogen as it will struggle to reach new sectors and to prepare and implement a long-term agenda.[261] This option could easily manage fundamental RD&I activities (and could be complementary to any type of partnership) if there was a clear centralised agenda pinpointing the climate and industrial priorities. Activities which need more coordination (including the demonstration of complex projects, technology comparison, increasing public awareness, and developing new business models) would need closer collaboration between research, industry and decision-makers to define cohesive work plans. This option

[259] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[260] World Energy Council (2019), New Hydrogen Economy – Hope or Hype?: Innovation Insights Brief – available at https://www.worldenergy.org/assets/downloads/WEInnovation-Insights-Brief-New-Hydrogen-Economy-Hype-or-Hope.pdf

[261] Boston Consulting Group (2019), The Real Promise of Hydrogen – available at https://www.bcg.com/publications/2019/real-promise-of-hydrogen.aspx

does not provide such a framework or ecosystem of actors. However, this option could deliver improvements for low TRL applications if a clear agenda is set up through consultation or by an existing community. On balance, for this aspect this option is scored a ++.

EU leading position in research and innovation: This option may allow some European organisations to maintain market-leading positions and cutting-edge research initiatives. However, without the deep involvement of the industry in developing a roadmap and providing directionality, or without openness to a wide range of stakeholders, and given that the clean hydrogen economy and market are evolving constantly, it would be difficult to properly seize emerging market opportunities based on EU strengths and weaknesses in the framework of this option.[262,263] This option is scored a +.

Option 1: Co-Programmed

Improving efficiency and reliability: This option could contribute to improved efficiency and reliability in applications and equipment. With the effective involvement of the research and the industry communities, this option could contribute to the emergence of new applications.[264] This option could deliver improvements in low TRL applications if a clear agenda is set up through a consultation or by an existing community. But when it comes to higher TRL applications, a strong community with all actors is needed in order for all potential partners to liaise on complex projects. This option could manage all types of RD&I activities if there is a clear centralised agenda pinpointing the climate and industrial priorities, but could not manage the complex supply chains of hydrogen applications and the spread of actors. This option could deliver slightly more impact than the baseline option, but not enough to justify a higher score, therefore it is also scored ++.

EU leading position in research and innovation: This option could help European organisations to maintain their leading positions, their cutting edge research and innovation initiatives, primarily because some industry involvement would be maintained.[265] However, without the deep involvement of the industry, and given that the clean hydrogen economy and market are evolving all the time, it would become more difficult to effectively seize and anticipate emerging market opportunities based on EU strengths and weaknesses. This option could deliver more impact than the baseline, and is scored ++.

Option 3: Institutionalised Art 187

Improving efficiency and reliability: Of the options, this one most fully involves the research and the industry with a long-term commitment. This option could contribute to the emergence of new applications and to continuous efficiency, quality and reliability

[262] Thomas Reiss for the European Commission and Fraunhofer ISI (2016), Study on EU Positioning: An Analysis of the International Positioning of the EU Using Revealed Comparative Advantages and the Control of Key Technologies – available via https://ec.europa.eu/info/sites/info/files/research_and_innovation/groups/rise/final-report_eu-positioning.pdf

[263] Centre for Energy Economics Research at the University of Groningen (2019), Outlook for a Dutch hydrogen market – available at https://www.rug.nl/ceer/blog/ceer_policypaper_5_web.pdf

[264] Power Engineering International (2019), Hydrogen: The hope for 'hard-to-decarbonise' sectors – available at https://www.powerengineeringint.com/2019/09/26/hydrogen-the-hope-for-hard-to-decarbonise-sectors/

[265] Thomas Reiss for the European Commission and Fraunhofer ISI (2016), Study on EU Positioning: An Analysis of the International Positioning of the EU Using Revealed Comparative Advantages and the Control of Key Technologies – available via https://ec.europa.eu/info/sites/info/files/research_and_innovation/groups/rise/final-report_eu-positioning.pdf

improvements in applications and equipment. In doing so it would play a catalytic role in bringing new sectors and actors into hydrogen RD&I.[266,267]

Given its dedicated network structure and activities as well as its capacity for knowledge management and expertise, this partnership structure would accelerate the development and improvement of advanced clean hydrogen applications and facilitate the creation, capitalisation and sharing of high-quality new fundamental applied knowledge and skills.

To achieve the specific scientific objectives of the initiative, a Multi-Annual Work Plan should set explicit technical goals for research projects and adapt these goals as improvements are achieved. Given its dedicated structure, this option would have the ability to prepare and implement a Strategic Research and Innovation Agenda based on EU organisation's strengths and weaknesses. As it would be more difficult to set precise goals for developing applications that can decarbonise new sectors and sub-sectors, a continuous collaboration framework would be necessary to ensure the sharing of best practices and experience and to profit from new developments. This option has the flexibility to provide such a framework.

This translates into a high degree of impact, scored as +++.

EU leading position in research and innovation: Through strong involvement of the research and the industry community, this option can contribute to maintaining the leading position of European organisations, cutting edge research and innovations.[268,269] This involvement will provide for good knowledge of EU strengths and weaknesses and greater possibilities to adapt to the evolving economy of hydrogen and to anticipate and seize emerging opportunities. This option resembles the existing JU in these aspects, where the existing JU has been assessed to support work across the right spectrum of technologies to ensure they may be effectively deployed in Europe[270]. This option is assessed to lead to a high level of impact, and is scored as +++.

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business, and shared by both industry and research organisations, "In our opinion, a European partnership based on article 187 TFEU (option 2) is the best solution to leverage funding for research, innovation and deployment of the hydrogen industry"

As affirmed by a respondent to the Inception Impact Assessment consultation representing an end-use industry association, and shared by many others, "Whilst this Institutionalised Partnership would support and enable cooperation between the actors of the wider Hydrogen Value Chain, it needs to be complemented, first, by sector-specific Hydrogen activities, secondly, by activities focusing specifically on aspects of industrial cross-sectorial nature, third, by Hydrogen-related infrastructural investment as well as, fourth, the regulatory environment."

Just over 50% of the respondents to the Open Public Consultation indicated that institutionalised partnerships (as average for all of them) were the best fitting intervention,

[266] Academic Press (2018), Hydrogen Supply Chains: Design, Deployment and Operation, Chapter 7 Hydrogen Applications: Overview of the Key Economic Issues and Perspectives – available at https://www.sciencedirect.com/science/article/pii/B9780128111970000075

[267] Centre for Energy Economics Research at the University of Groningen (2019), Outlook for a Dutch hydrogen market – available at https://www.rug.nl/ceer/blog/ceer_policypaper_5_web.pdf

[268] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[269] As affirmed in nearly every interview with stakeholders.

[270] See section 1.2 of the present report

where just over 65% indicated that an institutionalised partnership is the best intervention for Clean Hydrogen.

The respondents to the Open Public Consultation were asked what they perceived to be the main advantages and disadvantages of participation in an Institutionalised European Partnership under Horizon Europe. The results of the analysis (keyword from an open question) showed the respondents mentioned focus on the development of technology, overall collaboration between industry and research institutions, and the long-term commitment as advantages. Disadvantages mentioned are mainly administrative burdens. When focusing on an Institutionalised European Partnership, long term commitment and collaboration were mentioned as advantages and efficient management and higher visibility in as disadvantages.

When asked to assess the relevance of the candidate European Institutionalised Partnership on their capacity to deliver on scientific impacts, around 70% of respondents to the Open Public Consultation indicated that the Institutionalised Partnership would significantly (positively) impact all listed categories in the area of science.

As comprehensively affirmed in interviews with stakeholders from both research and industry institutions, there is a need through further RD&I to spur further cost decreases, quality improvements and performance enhancements of all technologies and applications. In all sectors and for all applications there is still room for improvement, even for applications that are ready-to-market. The Joint Undertaking has demonstrated its ability to develop technologies to expected maturity levels in the direction of market uptake, and has proven its ability to strengthen the hydrogen community and encourage shared practices and knowledge at all TRLs.

To deploy new applications (low TRL), or even to improve existing ones (middle and high TRL), there is a need for strong coordination between research and industry as the former has knowledge/views on fundamental R&D and emerging technologies and the latter is well-versed in market needs and trends. A community that gathers both types of stakeholders is very important and should be strengthened to ensure complementarity along the whole hydrogen value chain. As stated by both industry and research organisations through interviews, an institutionalised partnership is the most appropriate option for maintaining and reinforcing the strong, existing European hydrogen community.

As hydrogen is versatile and can be integrated into various sectors using many different applications, it is vital to prepare a coherent Strategic Research and Innovation Agenda (SRIA) which is able to draw from current efforts and results to develop a longer term vision. A large community, hosted by an institutionalised partnership, is the best option to prepare such agenda with research and industry input, as comprehensively affirmed in interviews with stakeholders from both research and industry institutions.

It is important to address all levels of technological readiness in the RD&I agenda, but also to prioritise some over others. Most stakeholders interviewed, from both the industry and research organisations, but mainly from the industry, agree that over the next ten years, RD&I should be concentrated on technologies at high, nearly market-ready levels and at low, potentially innovative levels. EU contributions should decrease when addressing higher TRL projects, to ensure higher private contributions for demonstration projects. All stakeholders agree that an institutionalised partnership is the most appropriate structure to prompt increasing industry leverage. A long-term shared vision, a long-term financial and structural commitment and the existence of a strong community are the 3 key pillars to tackle the evolving challenges of the clean hydrogen economy, not only from an RD&I perspective, but also more broadly to address regulatory, policy and awareness issues. For the majority of the interviewed stakeholders from both the industry and the research organisations, the existing FCH 2 JU does provide these three pillars.

As comprehensively affirmed in interviews with stakeholders from both research and industry institutions, knowledge of global market trends and industrial developments for clean hydrogen is essential to follow up and strengthen the leading position of EU organisations and is properly handled by the existing FCH 2 JU.

Summary

Table 9 below, lists the scores we assigned for each of the policy options, based upon the assessments above, as well as taking into account the support expressed by the different stakeholders.

Table 9: Overview of the options' potential for reaching the scientific impacts

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
Hydrogen applications are more competitive, efficient and reliable	++	++	+++
The EU maintains its leading position for cutting edge research and innovation in hydrogen applications	+	++	+++

Notes: Score +++ : Option presenting a *high* potential; Score ++: Option presenting a *good* potential; Score +: Option presenting a *low* potential

6.1.2 Economic/technological impacts

Option 0: Horizon Europe calls (baseline)

EU deployment of hydrogen generation at scale: This option could contribute to decarbonising hydrogen feedstocks use by funding demonstration projects aiming to couple large renewable electricity production plants with hydrogen generation.[271,272] This kind of funding is straightforward and could easily be handled by this option. If a research agenda can be centrally defined and precise demonstration requirements identified, this option could contribute to directly reducing the cost of hydrogen production. However, the sharing and diffusion of experience will remain limited with this option. On balance this option is scored as ++.

EU deployment of hydrogen infrastructure at scale: If a research agenda can be centrally defined, this option could contribute to developing, improving and adapting the hydrogen distribution, transport and storage infrastructure. However, the sharing and diffusion of experience will remain limited and this option is unlikely to significantly increase collaboration across or bolster EU industry, as there is no community or network framework outside of the project consortia. As a result of these limitations this option is scored as +.

[271] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[272] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

EU scale up of competitive hydrogen end-uses: This option could help industry and heavy transport maintain their competitiveness while decarbonising.[273] However, for these sectors, close collaboration is the first necessity to convince all actors along the long value chain to act and to integrate hydrogen into their decarbonisation options.[274] It is much more difficult to achieve this without a strong community able to ensure cross-sector collaboration.

This option will not significantly support the scaling up of ready-to-market applications as there is no mechanism to facilitate bridging from R&D to market deployment.[275] In conclusion, this option will partially contribute to enabling the EU's heavy-duty transport and energy-intensive industries to maintain competitiveness whilst also decarbonising using cost-effective clean hydrogen solutions.[276] On balance this score would therefore be ++.

EU growth of hydrogen economy: EU economic growth will depend more on market uptake than on RD&I activities. The option's ability to deliver such growth depends on its ability to create market conditions and contribute to the excellence of the different clean hydrogen applications, but the baseline option is assessed to only have a very low impact on these. In terms of openness due to the intensity of the call process, administrative burden and the absence of "support" structures (e.g. from a JU team), calls under this option are generally won by larger groups. It is more difficult for SMEs (as summarised in section 1.2.2 of this report) – which are key for the conception, development and deployment of clean hydrogen applications – to access funding under this option. This option would probably be less efficient in creating new networks or linking hydrogen and non-hydrogen players to potential partners dealing with complex projects than options with a community (e.g. energy intensive industry as potential end users, public transport operators, building owners, local or regional communities). Therefore, this option is unlikely to significantly contribute to creating market conditions, generating a low score +.

Option 1: Co-Programmed

Addressing a broad community with the flexibility to evolve depending on the progress and achievements is a key element that could be handled through this option. However, this option is better adapted to a predetermined set of actors for a precise sector and therefore would probably not be efficient reaching new non-hydrogen players (e.g. energy intensive industry as potential end user, public transport operators, building owners, local authorities, …). This option might also not be able to set up and coordinate the type of facilitatory structures necessary to enable cross-sectoral integration, as these kinds of entities/companies still need to be developed, supported by industry, and commercialized.

EU deployment of hydrogen generation at scale: If a research agenda can be centrally defined and identify precise demonstration requirements, this option could contribute to directly reducing the cost of hydrogen production. However, the lack of a long-term

[273] Hydrogen Europe (2017), Decarbonise Industry, available at https://hydrogeneurope.eu/decarbonise-industry

[274] Element Energy Ltd on behalf of the UK Department for Business, Energy & Industrial Strategy (2018), Hydrogen supply chain evidence base – available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf

[275] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[276] Jorg Gigler and Marcel Weeda on behalf of TKI Nieuw Gas (2018), Outlines of a Hydrogen Roadmap – available at https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/20180514%20Roadmap%20Hydrogen%20TKI%20Nieuw%20Gas%20May%202018.pdf

industrial commitment might limit the leverage of private sector involvement which is needed to finance expensive demonstrations. This would translate into an average degree of impact as the critical functionalities needed would only be partially provided by this option. As a result, this option is scored ++.

EU deployment of hydrogen infrastructure at scale: If a research agenda can be centrally defined, this option could contribute to directly developing, improving and adapting the hydrogen distribution, transport and storage infrastructure.[277] However, the less formal nature of the community might limit the sharing and diffusion of experience among the key actors involved in hydrogen RD&I and limit the coordination and collaboration necessary to address cross-border issues.[278] This option could modestly increase collaboration or bolster EU industry, as there is limited community or network framework outside of the project consortia. This would translate into a degree of average impact since critical factors needed would be partially provided, score would therefore be balanced with ++.

EU scale up of competitive hydrogen end-uses: This option can contribute to directly decrease the cost of hydrogen applications. However, the sharing and diffusion of knowledge among actors involved on a longer-term basis would facilitate and even increase efficiency in R&I. With a broad community, this option can provide a collaborative framework which will contribute to bolster EU industry and can contribute to maintaining the competitiveness of the industry and decarbonising heavy transport.[279] For these sectors, there is a need to collaborate closely in order to, first, convince all actors along the long value chain, and second, integrate hydrogen into their decarbonisation options. This would be best handled by a community able to expand and to put together all the actors of the supply chain, which is not completely addressed in this option. In conclusion, this option can partly contribute to enabling the EU's heavy-duty transport and energy-intensive industries to maintain competitiveness while decarbonising using economically viable hydrogen solutions. This contribution could be strengthened if a research agenda can be centrally defined and coordinated. Overall this option would be expected to have an average degree of impact since the critical functionalities needed would be partially provided. Therefore it is scored as ++.

EU growth of hydrogen economy: EU economic growth will depend more on market uptake than on RD&I activities. The option's ability to deliver depends on its ability to create market conditions and contribute to the excellence of the different clean hydrogen applications. This option is assessed to have a moderate impact on these aspects. Therefore, this option is unlikely to significantly contribute to create market conditions, score would therefore be low +.

Option 3: Institutionalised Art 187

Based on its past success in building large communities, this type of structure is the best option to reach new non-hydrogen players (e.g. energy intensive industry as potential end user, public transport operators, building owners, …). With some of these actors, a structured collaboration framework is essential. This option can set up and coordinate the kinds of facilitatory structures necessary to enable cross-sectoral integration, as these kinds of entities/companies still need to be developed, supported by industry, and

[277] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[278] As affirmed comprehensively in interviews with stakeholders from both research and industry institutions.

[279] Joint Research Centre (2016), 4th International Workshop on Hydrogen Infrastructure and Transportation Report – available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103586/4%20int%20workshop%20on%20h2%20infra%20final%20pdfonline.pdf

commercialised. Another way to ensure the implication of new actors is through collaboration with other initiatives (or partnerships like Clean Steel, Clean Aviation, …).

Very good knowledge of industrial actors, as brought together by this option, would enable EU industries to quickly catch up and meet contemporary challenges as well as reorient project partnerships to support initiatives for EU deployment and export. This could result in reinforced industrial partnerships with key worldwide actors. Building strong knowledge of the global hydrogen ecosystem like this will take time to develop but can only happen within this option.

EU deployment of hydrogen generation at scale: This option can contribute to directly reducing the cost of hydrogen production, thanks to the long-term industrial commitment allowing high leverage of the private sector which is needed to finance expensive demonstrations. The community structure will also ensure the sharing and diffusion of experience among the key actors involved in hydrogen R&I. With a broad, strong and expanding community[280], this option can provide a collaborative framework which will contribute to bolstering EU industry. This would translate into a high level of impact, since the critical functionalities needed would be fully provided, therefore it is scored +++.

EU deployment of hydrogen infrastructure at scale: Thanks to its ability to gather a broad community and to prepare a Strategic Research and Innovation Agenda , this option could contribute to directly developing, improving and adapting the hydrogen distribution, transport and storage infrastructure. The community would allow the sharing and diffusion of experience among the key actors involved in hydrogen R&I and the coordination and collaboration necessary to address cross-border issues.[281] This option can significantly increase collaboration and bolster EU industry. This would translate into a degree of high impact since critical functionalities needed would fully be provided, therefore it is scored +++.

EU scale up of competitive hydrogen end-uses: This option can contribute to directly reduce the cost of hydrogen applications by bringing together research and industry.[282,283] The option's community could maximise the sharing and diffusion of knowledge among actors involved on a longer-term basis to increase efficiency in research. With a broad, strong and expanding community, this option can provide a collaborative framework which will contribute to bolstering EU industry. The knowledge of the industrial players at EU and global scale, of their strengths and of complementarities will reinforce the possibilities for EU collaborations.[284,285] With a broad community, this option can contribute to maintaining the competitiveness of industry and to the decarbonisation of heavy transport. For these sectors, there is a need to closely collaborate in order to, first, convince all actors along the long value chain, and second, integrate hydrogen into their decarbonisation

[280] Expanding the community could start by strengthening the collaboration with the concerned sectors (being or not a partnership), then involve stakeholders in preparing the Strategic Research and Innovation Agenda

[281] As affirmed comprehensively in interviews with stakeholders from both research and industry institutions.

[282] Hydrogenics (2018), Cost Reduction Potential for Electrolyser Technology – available at https://www.humsterlandenergie.nl/resources/LInks-duurzaam/Linkpagina/20180619_Hydrogenics_EU-P2G-Platform_for-distribution.pdf

[283] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

[284] World Energy Council (2019), New Hydrogen Economy – Hope or Hype?: Innovation Insights Brief – available at https://www.worldenergy.org/assets/downloads/WEInnovation-Insights-Brief-New-Hydrogen-Economy-Hype-or-Hope.pdf

[285] International Energy Agency (2019), The Future of Hydrogen – available at https://www.iea.org/hydrogen2019/

options.[286,287] This could be handled by a community able to expand and to put together all the actors of the supply chain, which is fully addressed in this option. In conclusion, this option can fully contribute to enabling EU's heavy-duty transport and energy-intensive industries to maintain competitiveness while decarbonizing using economically viable hydrogen solutions. This would translate into a degree of high impact since critical functionalities are fully provided by this option, it is scored as +++.

EU growth of hydrogen economy: EU economic growth depends more on market uptake than on RD&I activities. The option's ability to deliver depends on its ability to create market conditions and contribute to the excellence of the different clean hydrogen applications. In terms of openness, thanks to the "support" structure of this option (e.g. the JU team) and the network informing the community about the programme, calls under this option are likely to be equally shared between larger groups and SMEs – which are key for the conception, development and deployment of clean hydrogen applications.

This option, being the continuity of the JU, is the most appropriate to prepare market conditions and to contribute to the excellence of the different clean hydrogen applications.[288] This option would probably be the best structure for involving and stimulating SMEs which are key for the deployment of H2 applications and to pull the market. SMEs are especially involved in bringing new technologies to maturity (and potentially spinning off into innovative applications).[289] It should be noted that the existing FCH 2 JU has exceeded the level of participation by SMEs specified for Horizon 2020.[290] However, the concrete deployment and the contribution to EU economic growth will be handled outside the RD&I activities, and not directly by the RD&I partnership. Therefore, this option is scored as ++.

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business association, and shared by many others, "the uptake of the production and consumption of renewable or decarbonised hydrogen is slowed down by lack of political commitment, perfectible market design, important investment costs and varying technology readiness levels (TRL). Nevertheless, Europe has the potential to be a leader in this sector."

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business association, and shared by other actors, "welcome a focus on improving market conditions and infrastructure, especially for those technologies with a higher TRL."

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business, and shared by other actors, "The importance of the opportunity created by the development of a large scale, near-zero hydrogen sector in Europe and the scale of the challenge associated with the market failures for first movers and the fragmentation among players does necessitate the development of the more ambitious option 2."

As affirmed by a respondent to the Inception Impact Assessment consultation representing an end-use industry association, and shared by many others, "This requires a structured

[286] Lei Li, Hervé Manier, Marie-Ange Manier (2019), Renewable and Sustainable Energy Reviews, Hydrogen supply chain network design: An optimization-oriented review, available at https://www.sciencedirect.com/science/article/abs/pii/S1364032118308633

[287] Element Energy Ltd on behalf of the UK Department for Business, Energy & Industrial Strategy (2018), Hydrogen supply chain evidence base – available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf

[288] Confirmed in several interviews with SMEs involved in the current FCH 2 JU partnership

cooperation with the renewable sector; with the transport sector (incl. heavy-duty, rail, maritime, etc.) – Hydrogen Europe has signed an MoU with the Waterborne Platform, indicating the common interest to develop hydrogen technologies and systems together - ; and with the energy-intensive industries (iron & steel, cement, chemical, refineries, fertilisers, and all industries that require large quantities of high-grade heat that are hard to electrify). The power, heat and gas sectors are also linked, through "power-to-hydrogen/gas/liquid" and a structured cooperation is necessary. New technologies, now producing or using hydrogen have also seen the light of day and should be further pursued, including hydrogen turbines, engines and others."

When asked to assess the relevance of the candidate European Institutionalised Partnership to deliver on economic/technological impacts, around 80% of the respondents to the Open Public Consultation suggested it would have a significant (positive) effect on/be 'very relevant' for increasing industrial leadership in hydrogen technologies and the uptake of new technologies, for provision of a solution for storing renewable energy for later use, and for provision of low-carbon and competitive solutions for heavy duty and long-distance transport.

From the Open Public Consultation (as summarised in section 1.2.2 of this report), the current FCH 2 JU exceeds the Horizon 2020 level of participation by SMEs, thanks to the dynamic and efficient community of actors. It should therefore be good to ensure a continuity in the involvement of SMEs.

In the frame of the Open Public Consultation, respondents were asked about the relevance of Partnership composition, such as flexibility in the composition of partners over time and involvement of a broad range of partners (including across disciplines and sectors), to reach Partnership objectives. Ensuring involvement of a broad range of partners has more 'very relevant' answers (143, 39.0%) than the flexibility in the composition of partners (112, 30.6%).

Based on the interviews and as shown in the results of the Open Public Consultation,291 the results and impacts of the initiative can best be achieved if industrial and research players are involved at all stages, starting from basic research up to ready-to-market level, in order to develop and bring hydrogen technologies to large-scale deployment. This level of involvement would ensure that research and development is in line with the overarching goals, and also avoid fragmentation and duplication of efforts.

Respondents to the Open Public Consultation clearly see stakeholders from industry (323 respondents or 86.1%) as the most relevant in setting a joint long-term agenda, followed by academia (215, 58.6%) and Member States and Associated Countries (201, 53.5%).

Based on interviews with stakeholders and as shown in several recent reports published by the FCH 2 JU, the results and impacts of the initiative can best be achieved if the existing community is strengthened, in order to seize industrial opportunities and maintain EU industry pole positioning.

As affirmed in interviews with stakeholders from both research and industry institutions, the lack of a community structure might limit the sharing and diffusion of experience

[291] The respondents of the Open Public Consultation were asked how relevant the involvement of actors is in setting a joint long-term agenda to ensure that the proposed European Partnership would meet its objectives. The highest amount of respondents indicated that the involvement of Industry is very relevant (86.1%). A large part of respondents also indicated that the involvement of Academia (58.6%) and Member States and Associated Countries (53%).

among the key actors involved in hydrogen R&I and limit the coordination and collaboration necessary to address cross-border issues.

As affirmed comprehensively in interviews with stakeholders from both research and industry, there is still a strong need for R&D efforts in developing hydrogen applications, but whereas in the past R&D really focused on scientific and technological development, industry actors emphasised there's a much stronger need for research focused on production processes and commercial deployment now. The industrialisation phase of hydrogen applications will depend on market uptake. For both research and industry organisations, R&D funds can go into validating the applications (as the phase of industrialisation remains outside the R&D sphere). Complementarity could be articulated with the Innovation Fund (from ETS) to support this phase of industrialisation, where an IP, with good knowledge management, could also provide some support (in preparing calls or screening projects). For some of the industry actors, R&D could be directly relevant to the industrialisation phase.

As affirmed particularly in interviews with industry players, if well-coordinated by the partnership team, the institutionalised partnership can provide support and guidance to get further funding or financing for scaling up or entering into the industrialisation phase. If well-coordinated with other funding and financing sources, the institutionalised partnership can provide help for scaling up hydrogen applications ready-to-market. This also depends on the setting up of market mechanisms.[292]

As affirmed comprehensively in interviews by all stakeholders, with more emphasis from the industry, there is a need for market uptake of several technologies considered ready-to-market (including FC buses, FC forklifts, stationary FCs, microgrids, and certain types of electrolysers). Further improvement of these applications could be prompted by industry deploying technologies at scale, as recognised by industry interviewed. However, necessary market conditions are missing, jeopardising their deployment. The risk of losing the benefits of past years' RD&I efforts is high, if market uptake does not increase within the EU. While it is no longer the role of RD&I to support market uptake, an IP could provide vital support in pushing for the requisite market conditions (both regulatory and policy).

As affirmed comprehensively in interviews with stakeholders from both research and industry, hydrogen applications are entering a phase of real demonstration. Many demonstration projects will be managed at MS level, with important industry leverage. EU level intervention and monitoring will remain important to ensure coordination addresses cross-border projects and liaisons between different actors throughout Europe, addresses regulatory gaps, and finally validates hydrogen generation, delivery and end-use applications for larger deployment. In some cases, direct EU leverage would be useful as an accompaniment to MS initiatives, or even to catalyse larger projects.

As affirmed comprehensively in interviews with stakeholders from both research and industry, FCH JU plays a vital role supporting SMEs. According to two stakeholders from the industry, there is a feeling (even from some national governments) that larger industrial players dominate conversations on strategies for hydrogen, and steer national funding towards their own organisations. But the FCH JU provides a forum for SMEs to substantially contribute to/engage in strategic discussions, and there's more of a feeling that funding is allocated to projects which really merit it. Dialogue in the framework of an

[292] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

IP generates harmonized voices, and gives less "lobby power" to large organizations (both on research and industry sides).

As affirmed in interviews, SMEs and research organisations in particular note the value of an institutionalised partnership in the hydrogen sector. The partnership allows smaller companies, which have developed niche products to serve growing hydrogen markets, to connect with larger industrial players that can support their development. The partnership allows research organisations to liaise with all potential partners, from other research or from the industry.

As affirmed comprehensively in interviews with stakeholders from both research and industry, the development of infrastructure (gas pipelines and refuelling stations) is considered as a key enabler to deploy clean hydrogen at scale, but cannot be addressed in the frame of RD&I. For research organisations and for the industry (mainly the new comers, like the gas sector, the waterborne or aviation sectors), there is also a need to define the form in which hydrogen will be transported (e.g., compressed, liquid). The initiative should provide support to ensure that infrastructure investments are encouraged, even if they must be realised by the industry with private capitals (connections to receive support from the CEF could help).

A thriving hydrogen economy can only be developed in Europe with the full backing of not only Member States but also the European Commission. Stakeholders interviewed, both from research and industry, seriously doubt whether hydrogen can be integrated into the EU's power, industry, and transport sectors if it loses institutionalised partnership support to R&D.

Summary

Table 10 below, lists the scores we assigned for each of the policy options, based upon the assessments above, as well as taking into account the support expressed by the different stakeholders.

Table 10: Overview of the options' potential for reaching the likely economic/technological impacts

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
Through demonstration EU validates its ability to deploy economical hydrogen generation at scale	++	++	+++
EU demonstrates its ability to deploy hydrogen infrastructures at scale	+	++	+++
EU validates its ability to scale-up clean economical hydrogen end-use applications in heavy-duty transport and energy-intensive industries – maintaining global competitiveness	++	++	+++
EU growth in hydrogen economy, especially for SMEs	+	+	++

Notes: Score +++ : Option presenting a *high* potential; Score ++: Option presenting a *good* potential; Score +: Option presenting a *low* potential

6.1.3 Societal impacts

Option 0: Horizon Europe calls (baseline)

Decarbonisation of transportation, industry and buildings: Continuous collaboration is needed to increase the maturity levels of hydrogen applications in transportation, industry and buildings. Collaborative projects will need long-term commitments and a vision for the hydrogen economy to ensure that funding will remain accessible during the whole life cycle of these projects.[293] For example, there is need for a long-term vision and commitment to demonstrate at scale and validate the deployment of cross-border infrastructure along potential hydrogen-transport corridors.[294] This will require continuous collaboration between Member States and the EU as they plan large-scale infrastructure development.[295] e assess that this option is not well suited for this goal. Given the short-term perspective of the calls, this option tends to support applications with very short development timelines, meaning it could not enable all the opportunities the hydrogen economy could offer to support EU's climate goals. This option would only weakly contribute to developing clean hydrogen solutions for the EU's maritime, aviation, rail and heavy-duty transport sectors, as well as its gas grid. Under this option, full-scale deployment of hydrogen applications would not be supported, and would only be partly achieved. The scaling benefits that could be accessed through increased hydrogen uptake would remain out of reach for EU industries. Hence, EU sectors – especially heavy industry and heavy transport – would likely not be able to fully decarbonise by 2050. Therefore, as this option is unlikely to achieve the desired collaboration framework, it would have a correspondingly weak contribution to EU climate targets and goals. It is therefore scored +.

Reducing pollution: The reduction of outdoor pollution is directly dependent on the ability to deploy at scale, especially in the transport sector, but also in the heating and cooling and industry sectors. For similar reasons as the last paragraph, This is also scored +.

Policy capacity and public support: Without the knowledge management capacities to provide support to national, regional and local authorities, or the ability to support the increase of awareness and coordinate many stakeholders, this option would not be able to promote growth of a strong hydrogen ecosystem. As there is no community outside of the projects consortia, this option is not the most appropriate for achieving this impact. The optimal governance model for the initiative for hydrogen would be complex, cross-sectoral, and international in scope and would require advanced coordination between industry and policy stakeholders. This would facilitate the synchronised governmental action necessary to support policy objectives. This option does not provide such a governance model and therefore would not provide the necessary facilitation and support. In addition, the middle/long term plan for clean hydrogen should be mainstreamed within the broader framework of a low carbon roadmap that ensures compliance with EU and MS strategies. In conclusion, it will only weakly contribute to the growth of knowledge and capacity to support the hydrogen transition and more supportive hydrogen policy and regulatory

[293] Fuel Cells and Hydrogen Joint Undertaking 10th Stakeholder Forum (2017), Fuel Cell and Hydrogen Technology: Europe's Journey to a Greener World, available at https://op.europa.eu/en/publication-detail/-/publication/15d2c3b7-c502-11e7-9b01-01aa75ed71a1

[294] Jorg Gigler and Marcel Weeda on behalf of TKI Nieuw Gas (2018), Outlines of a Hydrogen Roadmap – available at https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/20180514%20Roadmap%20Hydrogen%20TKI%20Nieuw%20Gas%20May%202018.pdf

[295] Joint Research Centre (2016), 4th International Workshop on Hydrogen Infrastructure and Transportation Report – available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103586/4%20int%20workshop%20on%20h2%20infra%20final%20pdfonline.pdf

frameworks. This would translate into a degree of low impact since the necessary critical functionalities would not be strongly provided, it is therefore scored +.

Support higher RES share in electricity: The ability of the electricity system to increase the share of renewable energy production is correlated to the large scale deployment of Power-to-Gas (P2G), which depends on the competitiveness and market conditions of clean hydrogen production from renewable energy. This option could contribute to decarbonising hydrogen feedstock production by funding demonstration projects aiming to couple large renewable electricity production plants with hydrogen generation.[296,297] This kind of funding is straightforward and could easily be handled by this option. However, this option would have a limited impact regarding the market uptake (as explained under the economic impact). This would translate into a low level of impact since critical factors needed would be weakly provided, it is therefore scored +.

Option 1: Co-Programmed

Decarbonisation of transportation, industry and buildings: Continuous collaboration efforts are still needed to increase the level of maturity of the transportation, industry and building applications.[298] These efforts require a long-term commitment and vision for the hydrogen economy to ensure the funding will remain accessible during the whole life cycle of these projects.[299] Therefore, this option seems not fully appropriate. There is need for long-term vision and commitment to demonstrate at scale and validate the deployment of cross-border infrastructure along potential corridors. This requires continuous collaboration between countries and EU planning of large-scale infrastructure deployment. Therefore, this option seems not appropriate. With a medium-term perspective, this option can support only applications with a limited timeline, meaning it would only deliver some of the opportunities offered by the hydrogen economy to support the EU's climate goals. In conclusion, this option can partially contribute to provide solutions for the EU's maritime, aviation, rail and heavy-duty transport sectors, as well as its gas grid, to progressively decarbonise so the EU can meet its climate targets. This would translate into a medium level of impact since necessary critical functionalities would be partially provided, resulting in a score of ++.

Reducing pollution: The reduction of outdoor pollution is directly dependent on the ability to deploy at scale, especially in the transport sector, but also in the heating and cooling and industry sectors. The score can be considered the same as for the achievement of the climate goals ++.

Policy capacity and public support: This option can support the public commitment for additional hydrogen policy and regulatory framework, but in a limited way as the community of researchers and industry actors from different sectors is not broad and strong enough. This option would likely be able to facilitate meetings between policy stakeholders, who would then have the responsibility to develop a coordinated governance

[296] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[297] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

[298] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[299] Hydrogen Europe (2017), Decarbonise Industry, available at https://hydrogeneurope.eu/decarbonise-industry

model with industry backing. With the ability to prepare and implement a medium term plan, this option could ensure compliance with medium term Member States strategies. A medium term clean hydrogen RD&I agenda would only partially fit with the broader framework of the low carbon roadmap, in compliance with EU and MS strategies. In conclusion, this option will contribute to the build-up of knowledge and capacity to support the hydrogen transition while public support for additional hydrogen policy and regulatory frameworks increases.[300] This would translate into a medium degree of impact since necessary critical functionalities would be only partially provided, resulting in a score of ++.

Support higher RES share in electricity: This option could fund demonstration projects aiming to couple large renewable electricity production plants with hydrogen generation.[301,302] This kind of funding is straightforward and could easily be handled by this option. However, this option would have a limited impact regarding the market uptake (as explained under the economic impact). This would translate into a low level of impact since critical factors needed would be weakly provided, score would therefore be low with +.

Option 3: Institutionalised Art 187

This option, by involving research organisations, industry and the public sector, is the strongest of the options in being able to design and see through a long-term vision and strategy and integrate a Strategic Research & Innovation Agenda into a broader spectrum. This spectrum, out of the R&I, would include awareness, public outreach, training and a strong link with decision makers responsible to set up the MS and EU hydrogen plans. It will ensure a coherent approach for the whole hydrogen economy from R&I to market uptake, addressing specifically the "valley of death" challenge. Therefore, autonomy in programming activities is important to quickly address evolutions and emerging opportunities.

Decarbonisation of transportation, industry and buildings: This option can contribute to decarbonising hydrogen feedstock use by funding demonstration projects aiming to directly couple large renewable electricity production plants with hydrogen generation.[303,304,305] The strong community and network development under this option could bring together the required actors to build local or regional ecosystems, large transportation corridors and the related infrastructure that would link producers and

[300] International Journal of Hydrogen Energy (2018), Supporting hydrogen technologies deployment in EU regions and Member States: The Smart Specialisation Platform on Energy (S3PEnergy) – available at https://www.sciencedirect.com/science/article/pii/S0360319918315313

[301] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[302] European Commission and Joint Research Centre (2019), Hydrogen use in EU decarbonisation scenarios, available at https://ec.europa.eu/jrc/sites/jrcsh/files/final_insights_into_hydrogen_use_public_version.pdf

[303]International Energy Agency (2019), Hydrogen: A key part of a clean and secure energy future – available at https://www.iea.org/topics/hydrogen/demand/

[304] Refhyne (2019), Construction starts on the world's largest PEM electrolyser at Shell's Rheinland Refinery – available at https://refhyne.eu/construction-starts-on-the-worlds-largest-pem-electrolyser-at-shells-rheinland-refinery/

[305] Air Liquide (2019), Clean hydrogen: Producing hydrogen in a low-carbon process – available at https://energies.airliquide.com/energies-clean-energy-supply/clean-hydrogen

consumers.[306] This option seems to be the most appropriate, as it provides a strong basis for the necessary collaborative approach, long term commitment and vision for the hydrogen economy. This option does depend on external factors like the willingness of the concerned sectors to seize the opportunity of hydrogen. Therefore, coordination with these sectors is key. This option can strongly support EU cross border infrastructure development by bringing the view of research and industry in a coordinated way. However, it strongly depends on the policy commitment of the concerned parties.[307] With a long-term perspective, this option can support the required applications to ensure the hydrogen economy opportunities support EU's climate goals.[308] In conclusion, this option can fully contribute to provide solutions for the EU's maritime, aviation, rail and heavy-duty transport sectors, as well as its gas grid, to progressively decarbonize so the EU can meet its climate targets. This would translate into a degree of high impact since necessary critical functionalities would be fully provided, it is therefore scored high +++.

Reducing pollution: The reduction of outdoor pollution will directly dependent on the ability to deploy hydrogen applications at scale, especially in the transport sector but also in the heating and cooling and industry sectors. The score can be considered the same as for the achievement of the climate goals +++.

Policy capacity and public support: This option can support the building of capacities, by capitalising on experience, knowledge and expertise of a dynamic community of researchers and different industrial sectors. This option also brings valuable knowledge management capacities to provide support to regional and local authorities, with a strong ability to support the increase of awareness and with coordination capacities to bring many stakeholders together, this option can efficiently support building hydrogen ecosystems. This option can support the public commitment for additional hydrogen policy and regulatory framework by bringing together research organisations, industry and the policy makers. In conclusion, this option can contribute to building up knowledge and capacity to support the hydrogen transition while public support for additional hydrogen policy and regulatory frameworks increases. This would translate into a degree of high impact since necessary critical functionalities would fully be provided, it is therefore scored high +++.

Support higher RES share in electricity: This option could play a role regarding the market uptake (as explained under the economic impact). This would translate into a degree of medium impact since critical factors needed would fully be provided, score would therefore be medium with ++.

As affirmed by a respondent to the Inception Impact Assessment consultation representing the civil society, "it is imperative that various industries don't rely exclusively on the unlimited availability of renewable hydrogen in the near future."

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business association, and shared by many others, "We support the institutionalised

[306] The Green Hydrogen@Blue Danube IPCEI project is a very good example of bringing together all actors along the whole value chain, involving many different actors. The institutionalised partnership is not an absolute necessity, but would be very helpful in networking

[307] International Journal of Hydrogen Energy (2018), Supporting hydrogen technologies deployment in EU regions and Member States: The Smart Specialisation Platform on Energy (S3PEnergy) – available at https://www.sciencedirect.com/science/article/pii/S0360319918315313

[308] European Commission Press Release (2019), Energy Union: Commission calls on Member States to step up ambition in plans to implement Paris agreement – available at https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_19_2993/IP_19_2993_EN.pdf

European Partnership based on Article 187 TFEU (option 2) where the EU would set up a joint undertaking implementing a jointly developed research programme"

As affirmed by a respondent to the Inception Impact Assessment consultation representing research organisations, and shared by many others, " Perhaps more important are the economic benefits to society, and SMEs more particularly. Indeed, as mentioned by the roadmap, a future institutional partnership on hydrogen can be expected to be of strategic importance for their survival and continued success. Secondly, the overall leverage achieved in the FCH JU (i.e. level of private investment compared with EU finding) to date stands at 1.96, compared to 1.09 during the FP7 programme. This leverage effect is forecast to rise to 3.0"

As affirmed by a respondent to the Inception Impact Assessment consultation representing research organisations, and shared by many others, "Beyond the cooperation expected from an R&D programme, the creation of an IEP has led to many additional coordination efforts: MoUs with 90+ regions and cities ; various hydrogen mobility initiatives across Member States ; better synergies with other European programmes such as CEF, ETS Innovation Fund, etc.; co-funding with national and regional programmes; and more"

As affirmed by two respondents to the Inception Impact Assessment consultation representing national associations, "Hydrogen is needed, and cooperation between EC and industry is key. However, the FCH JU has favoured west EU countries heavily so far, what is visible very well on the EU map of hydrogen projects. EU 13 is an almost white place until today. Enabling the technology to scale up across the EU as a whole should be a key message"

As affirmed by a respondent to the Inception Impact Assessment consultation representing an national government, "it would be desirable to have a concrete, sustainable R & D roadmap with (development) objectives, including upstream and downstream processes, or at least statements on their establishment, including links to other EU programs and the involvement of MS." & "It should also emphasize the need for a cross-border approach to MS for both the supply and the supply chain " & "In addition to the industries involved, greater involvement of MS and local level representatives should be part of the governance structure."

In the frame of the Open Public Consultation, the following activities were considered relevant: a joint R&D programme, collaborative R&D projects, deployment and piloting activities, input to regulatory aspects and co-creation of solutions with end-users. About 78% of the respondents indicated that deployment and piloting activities are very relevant to ensure that the Partnership would meet its objectives. The respondents were also asked to provide any comment that they may have on the proposed scope and coverage for the initiative. The keyword analysis showed the respondents used this question to talk about low TRL levels, flagship projects and the production and distribution of hydrogen technology.

When asked to assess the relevance of the candidate European Institutionalised Partnership to deliver on societal impacts, around 80% of respondents to the Open Public Consultation considered it would be 'very relevant' to deliver on those impacts (except for the category "improved working conditions").

The Open Public Consultation noted amongst the advantages of an institutionalised partnership, the focus on the long-term commitment. This type of commitment will be essential for hydrogen which due to its versatility addresses many different sectors with many new and continuously emerging applications.

The respondents to the Open Public Consultation indicated that it was very relevant to set up a specific legal structure for the partnership to achieve a more effective implementation

of activities (62.7%) and to increase financial leverage (60.9%), which is considered as a key element for the demonstration phase

As affirmed through collective interview input, particularly based on industry feedback, it is more efficient to build capacities by relying on a broad and strong community of researchers and industrial players from different sectors in order to capitalise on the knowledge and expertise.

Corroborated through interviews with research institutions and with industry players, without knowledge management capacities to provide support to regional and local authorities, and with limited ability to support the increase of awareness and coordinate many stakeholders, it becomes difficult building hydrogen ecosystems. Building capacities. is also more efficient with a community of researchers and industry actors from different sectors in order to capitalise the knowledge and expertise.

As affirmed through interviews by some stakeholders from the industry, sharing best practices will bring Member States on board "naturally." But for others, from organisations and the industry, outreach is still needed in order to increase interest. At Member State level, the European HyNet project has made a very good start engaging with authorities, as it plans to support exchanges on market trends, to present best practices and leverage downstream development. For both the industry and research organisations, an institutionalised partnership would be the most appropriate option to further support knowledge sharing between stakeholders and Member States.

Hydrogen's capacity to facilitate the decarbonisation of heavy industry and heavy transport within the EU is seen as its core strength. However, in order to fully decarbonise these sectors through hydrogen use extensive development is still required. Stakeholders, from research and industry, continuously argued through interviews that the partnership is best positioned to most quickly and effectively prompt the large-scale integration of hydrogen applications into Member States' societies and to contribute to the vital environmental goal of full decarbonisation of the EU by 2050.

Local authorities have an important role to play in enabling clean hydrogen uptake. They are involved with public awareness, permitting, coordination, setting low carbon roadmaps, creating early market conditions, responding to local needs, and bringing funds for projects. Therefore, depending on the specific needs of a project or an application that can be deployed at a local level, their involvement in a partnership could become essential. As affirmed comprehensively in interviews with stakeholders from both research and industry, an institutionalised partnership would be the most appropriate structure to support knowledge sharing and to connect with important local actors and develop local hydrogen communities.

The Strategic Research and Innovation Agenda (SRIA) should ideally ensure that there is a proper articulation between the long-term CO2 strategy objectives and the applications where we can expect cost decreases. As affirmed comprehensively in interviews with stakeholders from both research and industry, coupling the SRIA and H2 strategy is essential and could be best managed by an institutionalised partnership.

The initiative should work at a global level, or at least be connected to all relevant counterparts to ensure compliance with international standards, to secure the role of EU industry in different hydrogen spaces, and to make sure regulatory issues are addressed properly. As stated by interviewed stakeholders from both research and industry, but mainly from research organisations, an institutionalised partnerships probably the most appropriate initiative to foster collaboration at international levels, given its expertise and knowledge management.

Summary

Table 11 below, lists the scores we assigned for each of the policy options, based upon the assessments above, as well as taking into account the support expressed by the different stakeholders.

Table 11: Overview of the options' potential for reaching the likely societal impacts

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
The EU's maritime, aviation, rail and heavy-duty transport sectors, as well as its gas grid, can progressively decarbonise so the EU can meet its climate targets	+	++	+++
Outdoor pollution can progressively decrease while reducing carbon emissions	+	++	+++
Knowledge capacity built up to support the hydrogen transition, while increasing public support for additional hydrogen policy and regulatory frameworks	+	++	+++
The European electricity grid can accommodate larger shares of renewable energy, thanks to flexibility services provided by P2G installations	+	+	++

Notes: Score +++ : Option presenting a *high* potential; Score ++: Option presenting a *good* potential; Score +: Option presenting a *low* potential

6.2 Assessment of coherence

6.2.1 Internal coherence

In this section we assess the extent to which the policy options exhibit the potential for ensuring and maximising coherence with other programmes and initiatives under Horizon Europe, in particular European Partnerships.

Option 0: Horizon Europe calls (baseline)

Under this option, coherence between activities in the area of Clean Hydrogen with activities under Cluster 5 of Horizon Europe and the other initiatives presented in Table 2 are ensured by the European Commission. However, exploitation of synergies between Clean Hydrogen and other initiatives, including exchanges of knowledge and experience between project teams and stakeholders, would require an additional level of coordination beyond Programme Committees. As a result of this limitation, this option is scored as +.

Option 1: Co-Programmed

Under the Co-Programmed option, synergies could be exploited more easily than under the baseline option. The European Commission could ensure coordination at the level of research agendas, while the Clean Hydrogen associations could proactively bring together projects and stakeholders from various initiatives to work together on common problems or tackle common challenges. However, as the Co-Programmed option does not promote a strong community or a network framework outside of project consortia, it is unlikely that it will establish an effective long-term framework and vision, nor increase cross-sector collaboration. Its score would therefore be medium with ++.

Option 3: Institutionalised Art 187

The Institutionalised Art 187 partnership could provide for the highest level of coordination. The structure provides roles for the European Commission and for Clean Hydrogen associations, but it is built on a central coordination layer which can increase the effectiveness of its efforts. Since its management body organises the funding and implementation of projects, the Clean Hydrogen partnership can (together with other institutionalised partnerships) set concrete objectives and lay out a roadmap of activities and projects that can be implemented.

A dedicated management team responsible for the development of a long-term strategy and supporting work programmes for clean hydrogen RD&I would ensure that these are fully aligned with relevant strategies and programmes developed by other partnerships and initiatives within the EU research and innovation landscape. This would also enable the development of a shared vision and better exploitation of synergies from joint programmes and calls, in areas such as Clean Aviation, Battery Technology, Transforming EU's rail system, Smart Networks and Services, Circular bio-based Europe, Clean Steel, Sustainable Process Industry, waterborne sector, towards zero-emission road transport (2ZERO), Clean Energy Transition, and the power and the gas sectors.

This would translate into a high score +++.

Many stakeholders who are also interested in/involved with other candidate partnerships believe that strongly coordinated efforts between partnerships and other EU programmes will be required to ensure internal coherence. The **interviewees from both research and industry** argue that an institutionalised partnership with a dedicated coordination function is the best way to ensure that unnecessary overlap is avoided while potential synergies are properly exploited.

As affirmed through **collective interviews with both industry and research players**, the need for strong coordination can be better met through an IP than through any other option. For example, the gas sector will play a key role in hydrogen's rollout, but there is no existing initiative on decarbonising gas grids so it will be important for the partnership to involve gas sector stakeholders. This is true for several "end use" sectors.

The **interim evaluation of the FCH 2 JU** concluded that the work of the JU is undoubtedly coherent with policies of the EU in energy, environment, transport and competitiveness. The technologies being developed with the support of the JU are capable of significant contributions to the security of energy supply, to the reduction of global and local pollution, to a clean and sustainable transport sector and to a more competitive European economy in a carbon-limited world.

About 49% of the respondents to the **Open Public Consultation**, when asked if it would be possible to rationalise the candidate European Institutionalised Partnership and its activities and/or better link it with other comparable initiatives, indicated that they think rationalisation and linking with other sectors would be possible. Respondents think the initiative could be linked with other comparable initiatives related to hydrogen, such as renewable energy and the application of hydrogen as well as clean aviation and rail systems.

6.2.2 External coherence

In this section we assess the extent to which the policy options show the potential of ensuring and maximising coherence with EU-level programmes and initiatives beyond the Framework Programme and/or national and international programmes and initiatives.

Option 0: Horizon Europe calls (baseline)

International organisations play important roles in the development of clean hydrogen. This option typically remains focused on the EU28 alone.

This option would not support motivating additional Member State participation, where increasing their involvement to ensure alignment with their own R&D agendas and low carbon roadmaps is essential.[309]

This option would not be helpful for putting together market uptake mechanisms outside the R&I sphere for the applications developed to market readiness where these are needed (e.g. buses, handling forklift, cars, stationary FC).

In section 4.4.2 several opportunities for collaboration and development of synergies with non-FP initiatives have been identified. Under this option, some coordination with other European Commission activities is possible at the level of priorities. However, coordination at the level of implementation is somewhat limited or even not feasible.

Collaboration with national or regional initiatives such as national programmes for the support of Clean Hydrogen or the coordination with regional clusters is not feasible under this option. As a result of this limitation, this option is scored as +.

Option 1: Co-Programmed

Under this option, the European Commission can contribute to some extent to the coordination with European non-FP initiatives at the level of the strategy. The non-systematic participation of Member States provides the opportunity for coordination with the national programmes and initiatives and the regional clusters. Member States and Clean Hydrogen associations could coordinate with the national and industry efforts to ensure alignment with their own R&D agendas and low carbon roadmaps and fully engage in the Clean Hydrogen IPCEI. Score would therefore be medium with ++.

Option 3: Institutionalised Art 187

This option ensures continuous dialogue among all players, including international, national, regional and local authorities and therefore does provide a clear global framework which would be necessary to mainstream clean hydrogen RD&I efforts into a global low carbon roadmap.[310]

But this option does not focus on the engagement of Member States and will need to take care to involve them all. MS should not be forced to join the H2 R&D dynamic but should be convinced of the strategic importance and from showing best practices. Experience-sharing platforms would therefore be relevant and powerful. This option would be the most relevant to set up such a framework and ensure its large diffusion.

This option, with the direct involvement of the EC and Member States, could facilitate the development of an effective, cross-sectoral, cross-border governance model necessary to enable agile rollout of hydrogen applications, and to open broader markets to these technologies.

Under this option, the possibilities of coordination and exploitation of synergies offered by the Co-Programmed option are expanded by the existence of the central coordination level

[309] Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

[310] European Commission and Hydrogen Europe (2019), Hydrogen for Climate Action: How to kick start the EU Hydrogen Industry to achieve the EU climate goals? –available at https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

which can improve and extend the collaboration at the level of projects. This would translate into a high score +++.

As affirmed by a **respondent to the Inception Impact Assessment consultation representing a business**, "Consequently, the development of any R&D programme should exploit synergies with other EC activities, for example the alternative fuel work of DG MOVE's European Sustainable Shipping Forum (ESSF)."

The initiative should operate at a global level, or at least be connected to all relevant counterparts to ensure compliance with international standards, to secure the role of EU industry in different hydrogen spaces, and to ensure that regulatory issues are addressed properly. As affirmed comprehensively in **interviews with stakeholders from both research and** industry, an institutionalised partnership is probably the most appropriate initiative to foster collaboration at international levels, given its expertise and knowledge management.

For some **EU13 national associations interviewed**, Member States would expect more international collaboration and more involvement in EU calls in order to align Clean Hydrogen with their national low carbon strategies, including funding policies.

Summary

Table 12 below, lists the scores we assigned for each of the policy options, based upon the assessments above, as well as taking into account the support expressed by the different stakeholders.

Table 12: Overview of the options' potential for ensuring and maximising coherence

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
Internal coherence	+	++	+++
External coherence	+	++	+++

Notes: Score +++ : Option presenting a *high* potential; Score ++: Option presenting a *good* potential; Score +: Option presenting a *low* potential

6.3 Comparative assessment of efficiency

In order to compare the policy options under common standards, we developed a standard cost model for all 13 candidate Institutionalised Partnership studies. The model and the underlying assumptions and analyses are set out in report on the overarching context to the impact assessment studies.

The 'study-specific' methodology did not carry out any specific analysis/modelling on Clean Hydrogen, and was only based on qualitative assessment of the interviews.

Table 13 below, shows the intensity of additional costs against specific cost items for the various options as compared to the baseline, i.e. Option 0 (Horizon Europe calls). In this table we have taken into account that for Option 3 (Institutionalised Partnership) there would be a moderate additional costs for the set-up of a dedicated implementation structure seeing that such a structure already exists through the FCH 2 JU. For Option 1

(Co-programmed), we considered only an additional cost for the calls and project implementation as, ideally, Member States would be providing contributions.

Table 13: Intensity of additional costs compared with HEU Calls (for Partners, stakeholders, public and EC)

Cost items	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art. 187
Preparation and set-up costs			
Preparation of a partnership proposal (partners and EC)	0	++	++
Set-up of a dedicated implementation structure	0	0	++
Preparation of the SRIA / roadmap	0	++	
Ex-ante Impact Assessment for partnership	0	0	+++
Preparation of EC proposal and negotiation	0	0	+++
Running costs (Annual cycle of implementation)			
Annual Work Programme (AWP) preparation	0	+	+
Call and project implementation	0	0 In case of MS contributions: +	+
Cost to applicants	0	0	0
Partners costs not covered by the above	0	+	+
Additional EC costs (e.g. supervision)	0	+	++
Winding down costs			
EC	0	0	+++
Partners	0	+	+

Notes: 0: no additional costs, as compared with the baseline; +: minor additional costs, as compared with the baseline; ++: high additional costs, as compared with the baseline; +++: very high additional costs, as compared with the baseline

The scores related to the costs set out above allow for a "value for money" analysis (cost-effectiveness) in the final scorecard analysis in Section 6.4. For this purpose, in Table 14 we provide the scores for the scorecard analysis, based on our insights and findings and based on the scores above, we assign a score 1 to the option with the highest costs and a score 3 to the lowest.

Table 14: Matrix on 'overall costs' and 'cost-efficiency'

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
Overall cost	3	2	1
Cost-efficiency	3	3	2

Notes: Score 1 = Substantial additional costs, as compared with the baseline; score 2 = Medium additional costs, as compared with the baseline; score 3 = No or minor additional costs, as compared with the baseline

We considered that while there is a clear increase in the overall costs of the policy options, from baseline to option 2, the cost differentials are less marked when we take into account financial leverage (co-financing rates) and the total budget available for each of the policy options, assuming a common Union contribution. From this perspective, there are only one or two percentage points that split the most cost-efficient policy options – the baseline Option 0 and the Co-Programmed policy options – and the least cost-efficient – the Institutionalised Partnership option. We have therefore assigned a score of 3 to the Option 0 and the Co-Programmed policy options for **cost-efficiency** and a score of 2 for the Institutionalised Partnership policy option.

In the case of the current FCH 2 JU, even if there is no hard evidence, the assessment of the contributions can be considered an indication of the leverage achieved by EU funds and is clearly a strong sign that the JU is successfully aligned on industrial priorities.[311] For the period 2014-2015, the FCH 2 JU has generated 1.63 of total leverage (i.e. EUR 1.63 of private investment attracted for every EUR 1 of EU money).

It should be noted that the potential for the creation of crowding-in effects for industry has been taken into account when assessing the effectiveness of the policy options, above.

Financial management of the existing FCH 2 JU, as stated in its interim evaluation, appears to be robust and the views of the public and beneficiaries sought in the consultations are strongly positive. The overall operational efficiency of the FCH 2 JU has improved as the institution has matured.[312]

6.4 Comprehensive comparison of the options and identification of the preferred option

Building upon the outcomes of the previous sections, this section presents a comparison of the options' 'performance' against the three dimensions of effectiveness, efficiency and coherence.

In Section 6.4.1, we first compare the policy options against each other for each criterion in the effectiveness and coherence dimensions, resulting in a scorecard with scores from 1 to 3 where 3 stands for a substantially higher performance. Combined with the results from the comparative assessment for efficiency in Section 6.3, above, the final scorecard will allow for the identification of the preferred option in Section 6.4.2, taking all dimensions and criteria into account.

[311] See section 1.2 of the present report

[312] See section 1.2 of the present report

6.4.1 Comparative assessment

Effectiveness

Regarding the **scientific impact**, the baseline option and the co-programmed partnership option would not be as effective as an institutionalised partnership in delivering impact, due to the absence of a long-term commitment of all parties, of a long-term vision for clean hydrogen RD&I and of a long term perspective on the role of hydrogen in a low carbon economy. The baseline and co-programmed options would also have a more limited impact than the institutionalised partnership on strengthening the competitiveness of EU organisations due to a more limited involvement of industry and the research community. Given that the clean hydrogen economy and market are evolving constantly, this means that they would also struggle to properly seize emerging market opportunities based on EU strengths and weaknesses. The institutionalised partnership would also be more efficient than the baseline and the co-programmed options in supporting increased knowledge diffusion between industrial players, public sector authorities and members of the public thanks to its broad community and internal expertise.[313] The institutionalised partnership has the scope to establish a basis of information to assuage hydrogen-related safety concerns. Therefore, the institutionalised partnership would allow for greater effectiveness regarding the scientific impacts than the two other options.

Regarding the **economic impacts**, the baseline option would achieve less in capacity development and uptake than the 2 other options, due to the lack of a community structure limiting the share and diffusion of experience among the key actors involved in hydrogen RD&I. Both the baseline option and the co-programmed partnership would have a more limited impact than the IP in generating positive systemic effects due to weak coordination, lack of collaboration frameworks to address cross-border issues and the lack of a mechanism to influence market conditions. These are necessary to facilitate successful market uptake and to help to maintain EU organisation's competitiveness through targeting SMEs. Therefore, the institutionalised partnership would allow for greater effectiveness regarding the economic impacts than the two other options.

Regarding the **societal impacts**, the baseline option and the co-programmed partnership are less able than the IP to deliver the required systemic effects to and contributing to EU climate goals. This is due to the short-term perspective of the calls, the lack of a long-term vision and commitment to deploy cross-border infrastructure, a weak collaboration framework between Member States and the EU and the limited capacity to build knowledge. These options will have a lower speed in uptake, due to the weak ability to support large-scale deployment and to support the deployment of local/regional clean hydrogen ecosystems. These 2 options will have less capacity than the IP to involve all necessary actors due to the lack of knowledge management in supporting and identifying key stakeholders in the EU. Therefore, the institutionalised partnership would allow for greater effectiveness regarding the societal impacts than the two other options.

Regarding the **type and composition of actors**, the baseline option and the co-programmed partnership are less capable of involving all necessary actors, especially SMEs, due to their weaknesses in creating a structured collaboration framework to deploy complex demonstration projects. These options will have more limited impact than the IP in creating systemic effects through their activities due to weaknesses in identifying the priorities and the required technologies, contextualising the RD&I clean hydrogen agenda within a broader framework and in fostering close collaboration between research, industry and decision-makers.

[313] As affirmed comprehensively in interviews with stakeholders from both research and industry institutions

Regarding **directionality**, the baseline option and the co-programmed partnership have more limited impacts than the IP in creating systemic effects and in ensuring compliance with EU and Member States policies due to a weaker capacity to coordinate industry, research and policy stakeholders to address complex, cross-sectoral, and international issues, and due to the lack of capacity to mainstream within the broader framework of a low carbon roadmap. Therefore, the institutionalised partnership would allow for greater effectiveness regarding directionality than the two other options.

Coherence

Regarding **internal coherence**, synergies and coherence (ensured by the European Commission) between Clean Hydrogen and other initiatives would require an additional level of coordination than provided by the baseline option. The Co-Programmed option would be able to provide this coherence, but it will unlikely establish an effective long-term framework and vision, nor increase cross-sector collaboration. Therefore, the institutionalised partnership would allow for greater internal coherence than the two other options, expanding the possibilities of coordination and exploitation of synergies offered by the Co-Programmed option by the existence of the central coordination level.

Regarding the **external coherence**, the baseline option and the co-programmed partnership are assessed to be less successful than an institutionalised partnership in creating the required systemic effects. This is due to their weaknesses in addressing the international community, ensuring adequate coordination with other programs, third countries and international organisations, aligning with their own R&D agendas and low carbon roadmaps, and for facilitating market uptake support to be put in place. Therefore, the institutionalised partnership would allow for greater external coherence than the two other options.

Table 15: Scorecard of the policy options

	Criteria	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
Effectiveness	**Scientific impacts**			
	Hydrogen applications are more competitive, efficient and reliable	2	2	3
	The EU maintains its leading position for cutting edge research and innovation in hydrogen applications	1	2	3
	Economic/technological impacts			
	Through demonstration EU validates its ability to deploy economical hydrogen generation at scale	2	2	3
	EU demonstrates its ability to deploy hydrogen infrastructures at scale	1	2	3
	EU validates its ability to scale-up clean economical hydrogen end-use applications in heavy-duty transport and energy-intensive industries – maintaining global competitiveness	1	2	3
	EU growth in hydrogen economy, especially for SMEs	1	1	2
	Societal impacts			

	Criteria	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 3: Institutionalised Art 187
	The EU's maritime, aviation, rail and heavy-duty transport sectors, as well as its gas grid, can progressively decarbonize so the EU can meet its climate targets	1	2	3
	Outdoor pollution can progressively decrease while reducing carbon emissions	1	2	3
	Knowledge capacity built up to support the hydrogen transition while increasing public support for additional hydrogen policy and regulatory frameworks increases	1	2	3
	The European electricity grid can accommodate larger shares of renewable energy, thanks to flexibility services provided by P2G installations	1	1	2
Coherence	**Internal coherence**	1	2	3
	External coherence	1	2	3
Efficiency	**Overall cost**	3	2	1
	Cost-efficiency	3	3	2

Notes: Scores for effectiveness and coherence: 3 = *substantially higher performance*; 2 = *higher performance*; 1 = *lower performance*. Scores for efficiency: 1 = *substantial additional costs*, as compared with the baseline; 2 = *medium additional costs*, as compared with the baseline; 3 = *No or minor additional costs*, as compared with the baseline

6.4.2 Identification of the preferred option

The scorecard in Table 15 shows that Option 0 performs less well against close to all dimensions and criteria compared to Option 1 and Option 3. Even though it was assessed to have a higher score against the scientific impact and cost efficiency criteria, we considered that this does not weigh up against its lower performance against all other dimensions.

The scorecard also shows that **benefits are clearly maximised under option 3, the Institutionalised Partnership**. In particular, compared with Option 1 and 0, the Institutionalised Partnership would provide greater effectiveness by

- Maximising structuring and leverage effects,
- Speeding up scientific development, supporting deployment at scale,
- Strengthening the EU organisations
- Contributing to the climate goals through strengthening the existing community,
- Coordinating efforts and activities, ensuring the sharing and diffusion of results and knowledge,

- Committing partners to long-term involvement, determining the priorities and long term agenda
- Integrating clean hydrogen RD&I into a broader climate vision.
- Enhancing the involvement of key actors with an increasing number of sectors,
- Improving the delivery of all required activities,

It would improve coherence by ensuring the alignment with national priorities and by addressing the international community.

Even though it reached a lower score against the cost efficiency, the conclusion of our assessment is that institutionalised partnership established under Article 187 of TFEU is the preferred option.

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business association, "In view of the challenges that the development of a hydrogen-based energy system is facing, the described option 0 ("no partnership") would be insufficient. In our view, a broad and ambitious European Partnership, be it co-programmed (option 1) or institutionalised (option 2), is established by the European Union"

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business, "Based on the previous two Fuel Cells & Hydrogen Joint Undertakings (FCH JU) that have significantly contributed to developing hydrogen and fuel cell technologies within the EU and strengthened the European value chain, we would prefer the continuation of the current institutionalised European Partnership based on Article 187 TFEU (option 2)."

As affirmed by a respondent to the Inception Impact Assessment consultation representing a business association, and shared by many others, "welcomes the initiative to establish a European Partnership on clean hydrogen in the form of a Joint Undertaking (option 2) as firm financial commitments and a clear institutional structure have proven to be efficient in the previous Joint Undertaking on fuel cells and hydrogen. Coordination between economic actors and between sectors, such as mobility, energy, heating and industry, is key and can be better achieved within this type of structure, which can also leverage more resources for research and innovation"

As affirmed by respondents to the Inception Impact Assessment consultation representing both the industry and research, "We support the proposal to create a new, revisited Partnership on Clean Hydrogen under Horizon Europe and the use of an institutionalised European Partnership (IEP) based on Article 187 TFEU (option 2) as it has proven, under horizon 2020, to be the most effective way to address the R&I needs of European companies and research organisations and do so in line with European policy objectives and guidance of the European Commission"

As affirmed by respondents to the Inception Impact Assessment consultation representing both the industry and research, "The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) has been instrumental in building a well-structured innovation ecosystem of industry, research and technology organizations as well as universities. This ecosystem has developed key technologies and brought a first generation of products. It is essential to build on this success and have a renewed programme which covers the whole technology readiness chain from low TRL research up to market ready solutions in order to develop the next generation of technologies. The JU is recognized as a highly effective means of implementation of the programme, the right instrument in an area requiring substantial resources (financial, know-how and research capabilities) and where EU global competitiveness is at stake."

There is a consensus among interviewees that calls for funding should remain open, but it is considered important (strategically and financially) to ensure that there are incentives that keep members of the IP's community consistently interested in its efforts.

7 The preferred option

7.1 Description of the preferred option

An institutionalised partnership established under Article 187 of TFEU would best ensure that private and public sectors remain fully engaged in the development and implementation of a long-term strategy for clean hydrogen RD&I. It is also consistent with the aim of leveraging industry financial and in-kind resources, such that the impact of funding provided by the Commission is maximised.

This form of partnership, building upon the existing JU structure, will continue to provide a stable framework for encouraging the participation of organisations from all concerned sectors (including those outside the hydrogen industry), securing and allocating resources, managing a wide range of RD&I projects across all TRLs and creating synergies with other partnerships and initiatives within and outside the Climate, Energy and Mobility cluster. It is also considered appropriate for developing a strategy for hydrogen that is fully aligned with the European Green Deal priorities, and especially with the European climate commitment and several sustainable development goals.

In its interim evaluation,[314] the explicit EU added value within the FCH 2 JU was affirmed. Bringing together 93 industrial organisations from 22 European countries was a substantial achievement for Europe, and was enabled by the unifying presence of the FCH JU programme.

In Table 16 below, we indicate the alignment of the preferred option with the selection criteria for European Partnerships defined in Annex III of the Horizon Europe Regulation. Seeing that the design process of the candidate Institutionalised Partnerships is not yet concluded and several of the related topics are still under discussion at the time of writing, the criteria of additionality/directionality and long-term commitment are covered in terms of *expectations* rather than ex-ante demonstration.

Table 16: Alignment with the selection criteria for European Partnerships

Criterion	Alignment of the preferred option
Higher level of effectiveness	As demonstrated in Section 6, an institutionalised partnership would be considerably more effective in addressing global challenges and delivering research and innovation objectives, in securing EU competitiveness and, where relevant, in contributing to international commitments (e.g. on standards). The institutionalised partnership would be also be effective in ensuring environmental sustainability (the final goal of "clean" hydrogen) and in strengthening the European Research and Innovation Area.
Coherence and synergies	A dedicated management team responsible for the development of a long-term strategy and supporting work programmes for clean hydrogen RD&I would ensure that these are fully aligned with relevant strategies and programmes developed by other partnerships and initiatives within the EU research and innovation landscape. This would also enable the development of a shared vision and better exploitation of synergies from joint programmes and calls, in areas such as Clean Aviation, Battery Technology, Transforming EU's rail system, Smart Networks and Services, Circular bio-based Europe, Clean Steel, Sustainable Process Industry, waterborne sector, towards zero-emission road transport (2ZERO), Clean Energy Transition, and the power and the gas sectors.

[314] See section 1.2 of this report

Criterion	Alignment of the preferred option
	A dedicated management team would also ensure proper coordination and complementarity with Union, local, regional, national and, where relevant, international initiatives or other partnerships and missions.
Transparency and openness	As demonstrated in Section 6, an institutionalised partnership would generate more impact in identifying priorities and objectives in terms of expected results and impacts, in involving partners and stakeholders from across the entire value chain, from different sectors, backgrounds and disciplines, including international ones when relevant and not interfering with European competitiveness. SMEs would receive appropriate support from the partnership. Nevertheless, a dedicated management team would also be able to put into place clear modalities for promoting participation of SMEs and for disseminating and exploiting results, notably by SMEs, including through intermediary organisations. An institutional partnership would ensure that the outputs of RD&I programmes are transparent and available to stakeholders inside and outside the hydrogen community. The framework governing participation would allow any organisation meeting defined criteria to participate, with a proportion of funded activity subject to open calls. This framework could provide support and guidance, help networking and build up consortia when addressing complex projects throughout the whole value chain.
Additionality and directionality	As demonstrated in Section 6, an institutionalised partnership would be considerably more effective in defining a common strategic vision of the purpose of the European Partnership. Particularly in demonstrating expected qualitative and significant quantitative leverage effects, including a method for the measurement of key performance indicators and in creating synergies within the EU research and innovation landscape An institutionalised partnership would be able to set up the appropriate approaches to ensure flexibility of implementation and to adjust to changing policy, societal and/or market needs, or scientific advances. In this way it can increase policy coherence between regional, national and EU level.
Long-term commitment	In the case of institutionalised European Partnerships, established in accordance with Article 187 TFEU, the financial and/or in-kind, contributions from partners other than the Union, will at least be equal to 50% and may reach up to 75% of the aggregated European Partnership budgetary commitments

With some of these actors, a structured collaboration framework might be useful[315] (e.g. MoU with the maritime sector), to identify the priorities and the required technologies

7.2 Objectives and corresponding monitoring indicators

7.2.1 Operational objectives

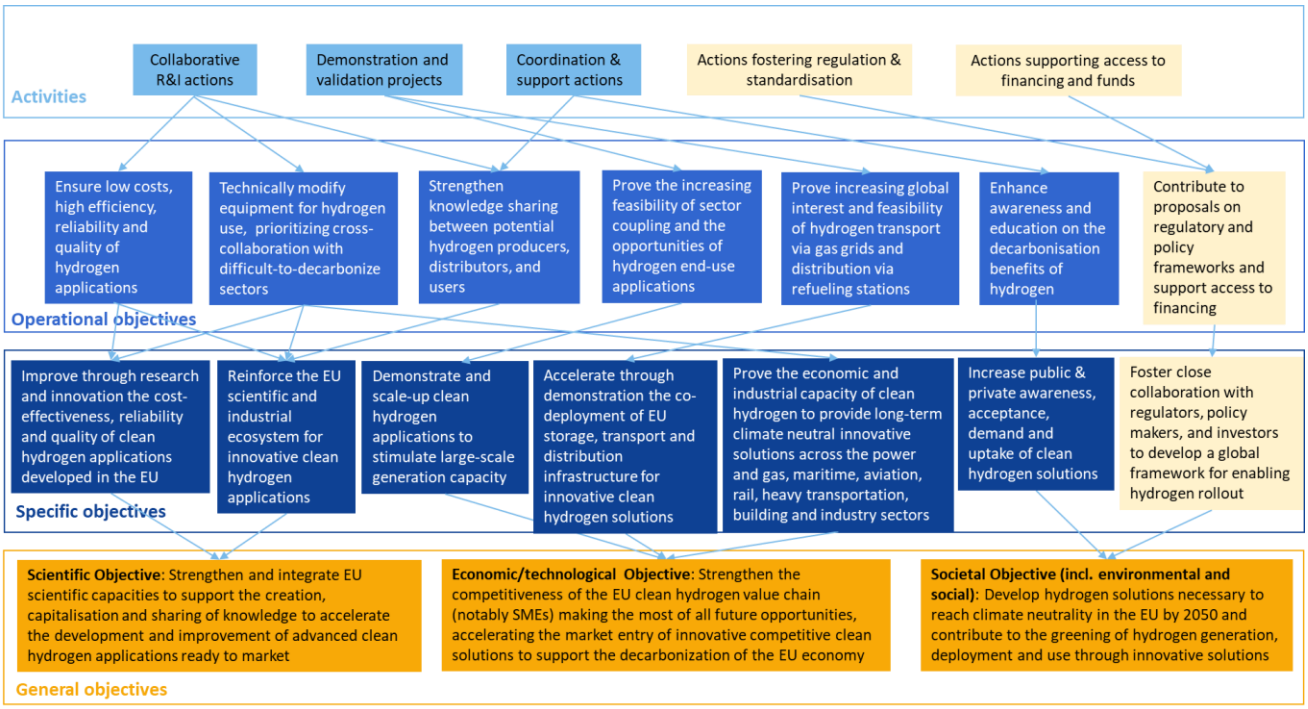
We have identified several operational objectives which would enable the partnership to achieve its specific objectives, as shown in Figure 7 below.

The figure also lists a range of actions and activities, going beyond R&I activities that can be implemented under Horizon Europe (which are highlighted in yellow). This reflects the definition of European Partnerships in the Horizon Europe regulation as initiatives whereby the Union and its partners "commit to jointly support the development and implementation

[315] Fuel Cells and Hydrogen Joint Undertaking 10th Stakeholder Forum (2017), Fuel Cell and Hydrogen Technology: Europe's Journey to a Greener World, available at https://op.europa.eu/en/publication-detail/-/publication/15d2c3b7-c502-11e7-9b01-01aa75ed71a1

of a programme of research and innovation activities, including those related to market, regulatory or policy uptake."

Figure 7: Operational objectives of the initiative



Source: Trinomics

7.2.2 Monitoring indicators

We have identified short, medium and long-term monitoring indicators to enable the progress of the partnership towards meeting its objectives. These are shown in Table 17.

Table 17: Monitoring indicators in addition to the Horizon Europe key impact pathway indicators

	Short-term (typically as of year 1+)	Medium-term (typically as of year 3+)	Long-term (typically as of year 5+)
Scientific impact	Number of projects resulting in one or more journal citations Number of projects resulting in increasing clean hydrogen applications' TRLs Number of individuals working on projects initiated by the partnership	Number of times that journal citations generated by the partnership are cited in the global literature Number of mature clean hydrogen applications Number of occupied and advertised jobs in clean hydrogen	Number of patents registered by the clean hydrogen industry and research organisation located in Europe Number of staff transferring between research-based institutions and the industry
Technological / economic impact	Number of projects involving organisations outside the hydrogen industry Number of projects with a documented strategy identifying	Number of projects leading to validated demonstration of clean hydrogen applications Number of years for programmed projects to reach TRL 8	Number of projects leading to market uptake Number of clean hydrogen pilots demonstrating readiness for market uptake

	Short-term (typically as of year 1+)	Medium-term (typically as of year 3+)	Long-term (typically as of year 5+)
	the potential application of results to defined market needs Number of clean hydrogen applications arrived at ready-to-market level		Time for clean hydrogen pilots demonstrating readiness for market uptake Value of exports generated by the European hydrogen sector Direct and indirect employment generated by the European clean hydrogen economy
Societal impact	Number of projects developing sector specific low carbon solutions, including the large public	Level and intensity of the hydrogen-related R&I (in percentage of turn-over)	Changes in local outdoor air pollution Changes in public acceptance of clean hydrogen solutions The share of hydrogen in the energy mix The increase in public procurement of hydrogen solutions for power generation and transport
Incl. Environmental / sustainability impact	Number of projects developing sector specific low carbon solutions, to target the large public	Number of projects focusing on rail, maritime, aviation, heavy duty transportation, energy intensive industry (i.e. steel), gas, power generation and building sectors	Evolution in CO_2, emissions reduction in Europe

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Appendix B Synopsis report on the stakeholder consultation – Focus on the candidate European Partnership for Clean Hydrogen

Disclaimer: the views expressed in the contributions received are those of the respondents and cannot under any circumstances be regarded as the official position of the Commission or its services.

B.1 Introduction

Following the European Commission's proposal for Horizon Europe in June 2018,[316] 12 candidates for institutionalised partnerships within 8 partnership areas have been proposed, based on the political agreement with the European Parliament and Council on Horizon Europe reached in April 2019.[317] Whether these proposed institutionalised partnerships will go ahead in this form under the next research and innovation programme is subject to an impact assessment.

In line with the Better Regulation Guidelines,[318] the stakeholders were widely consulted as part of the impact assessment process, including national authorities, the EU research community, industry, EU institutions and bodies, and others. These inputs were collected through different channels:

- A feedback phase on the inception impact assessments of the candidate initiatives in August 2019, gathering 350 replies for all 12 initiatives;
- A structured consultation of Member States performed by the EC services over 2019;
- An online public stakeholder consultation administered by the EC, based on a structured questionnaire, open between September and November 2019, gathering 1635 replies for all 12 initiatives;
- A total of 608 Interviews performed as part of the thematic studies by the different study teams between August 2019 and January 2020.

This document is the synopsis report for the initiative "Clean Hydrogen". It provides an overview of the responses to the different consultation activities. A full analysis of the results is provided in the study Data Report.

[316] https://ec.europa.eu/commission/presscorner/detail/en/IP_18_4041

[317] https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_19_2163

[318] https://ec.europa.eu/info/files/better-regulation-guidelines-stakeholder-consultation_en

B.2 Feedback to the inception impact assessment on candidate initiatives for institutionalised partnerships

Following the publication of the inception impact assessment, a feedback phase of 3 weeks allowed any citizen to provide feedback on the proposed initiatives on the "Have your say" web portal. In total 350 feedbacks were collected for all initiatives.

For the initiative "Clean Hydrogen" 38 individual feedbacks were collected, mainly from company/business organisations (15) and business associations (12).[319] Among the elements mentioned were:

- This new partnership should build on the progress made by the FCH 2 JU ("Fuel Cells and Hydrogen 2 Joint Undertaking) during the last decade which has demonstrated effectiveness especially for the coordination of the programme and alignment of priorities between the various stakeholders
- 14 respondents clearly wrote that the institutionalised European Partnership based on Article 187 TFEU (option 2) offers the most effective way of delivering the objectives of the initiative
- Uptake of the production and consumption of renewable or decarbonised hydrogen is slowed down by a lack of political commitment, perfectible market design, important costs and varying technology readiness levels (TRL)

Coordination between economic actors and between sectors, such as mobility, energy, heating and industry, is key and can be better achieved within an iPPP

Openness to EU-13 MS is essential and needs to be improved

Key components: gas infrastructure & underground storage (to transport and store renewable hydrogen) to meet demand from the power, industry, land and marine transportation and heating sectors

The overall leverage achieved in the FCH JU (i.e. level of private investment compared with EU finding) to date stands at 1.96, compared to 1.09 during the FP7 programme. This leverage effect is forecasted to rise to 3.0

Beyond the cooperation expected from an R&D programme, the creation of an IEP has led to many additional coordination efforts: MoUs with 90+ regions and cities; various hydrogen mobility initiatives across MS; better synergies with other European programmes (CEF, ETS Innovation Fund, etc.); co-funding with national and regional programmes; and more

Whilst this Institutionalised Partnership would support and enable cooperation between the actors of the wider Hydrogen Value Chain, it needs to be complemented: first, by sector-specific Hydrogen activities; secondly, by activities focusing specifically on aspects of industrial cross-sectorial nature; third, by Hydrogen-related infrastructural investment; as well as, fourth, the regulatory environment, which would provide access to the CO2-lean electricity (needed to operate the Hydrogen Value Chain) at costs, which do not undermine the global economic feasibility of this value chain

B.3 Structured consultation of the member states on European partnerships

A structured consultation of Member States through the Shadow Strategic Configuration of the Programme Committee Horizon Europe in May/June 2019 provided early input into the preparatory work for the candidate initiatives (in line with the Article 4a of the Specific Programme of Horizon Europe). This resulted in 44 possible candidates for European

Partnerships identified as part of the first draft Orientations Document towards the Strategic Plan for Horizon Europe (2021-2024), taking into account the areas for possible institutionalised partnerships defined in the Regulation.

The feedback provided by 30 countries (all Member States, Iceland and Norway) has been analysed and summarised in a report, with critical issues being discussed at the Shadow Strategic Programme Committee meetings.

For the initiative *"Clean Hydrogen" the following overall feedback was received from Member States. "Countries support the proposed partnership, and its objectives. Key issues raised by delegations and that may need further discussion include the need to ensure systems aspects and sectoral coupling for the use of hydrogen technologies, and agreeing on the areas for applications".*

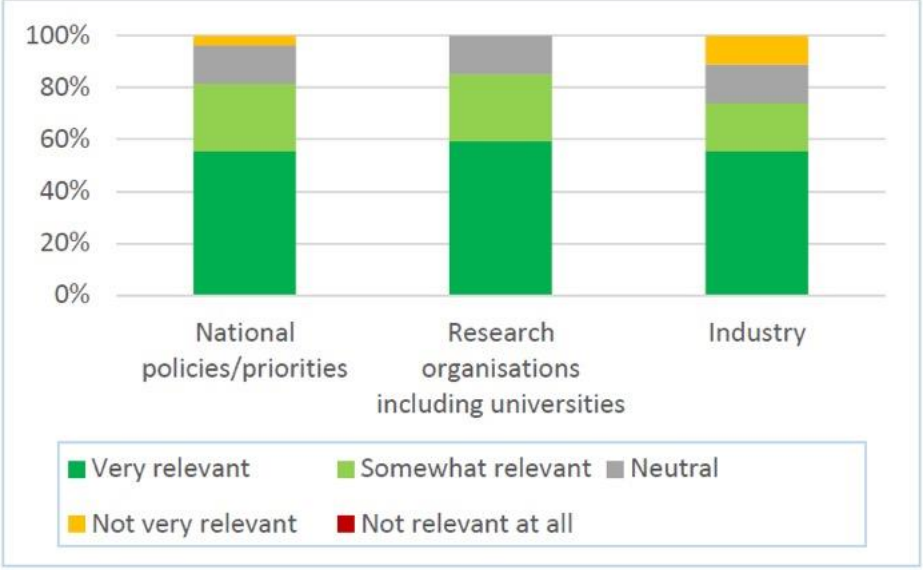
"Overall there is a good agreement on the use of a partnership approach in addressing energy transition through clean hydrogen technologies (64% consider it very and 11% somewhat relevant). There is broad agreement (71%) that the partnership is more effective in achieving the objectives and delivering clear impacts for the EU and its citizens, but to a lesser degree (43%) that it would contribute to improving the coherence and synergies within the EU R&I landscape. "

"Delegations identified further of aspects that could be reinforced in the proposal a partnership *that would increase its relevance for national priorities, e.g.*[320] *ensure synergies with other related partnerships (e.g. Clean Hydrogen)"… "Other comments were related to avoiding duplications with other Partnerships (notably on Integrated Air Traffic Management and Hydrogen), and clarifying objectives".*

Section on "clean hydrogen"

"Overall the results of the consultation confirm the relevance of the proposed European Partnership on Clean Hydrogen, with 82% considering it very or somewhat relevant for their research organisations, including universities, 79% for their national policies and priorities, and 72% of respondents found the proposed partnership to be relevant for their industry.

Figure 8: Relevance of the European Partnership for Clean Hydrogen in the national context



[320] Comments on scope and content have to be assessed in the context of the overall priority setting to ensure coherence.

Source: European Partnerships under Horizon Europe: results of the structured consultation of Member States (figure 43)

On the question of existing national/regional R&I strategies, plans and/ or programmes in support of the proposed Partnership for Clean Hydrogen, 25 countries report to have relevant elements in place. National economic sectoral strategies and/or plans with a strong emphasis on research and innovation (54%, AT, CZ, DE, DK, EE, FR, HR, IT, LUC, LV, NL, SE, SI, SK, NO) and regional R&I and/or smart specialisation strategies (54%, AT, BE, DE, DK, EL, ES, FR, HR, NL, PL, PT, SE, SI, SK, UK) were identified most frequently, followed by national R&I strategies or plans (50%, DE, DK, EE, FR, HR, LV, NL, PT, RO, SE, SI, SK, IS, NO), dedicated R&I funding programmes or instruments (46%, AT, DE, DK, ES, FR, HR, NL, RO, SE, SI, SK, UK, NO). Eight countries (FR, HR, HU, IE, NL, PT, SE, SK) reported other policies/ programmes, such as national /state support plans and cross-sectoral roadmaps.

B.3.1 Overall feedback for the initiative "Clean Hydrogen"

Delegations identified a number of aspects that could be reinforced in the proposal for this partnership that would increase its relevance for their national priorities. Several delegations emphasise the need to ensure systems aspects and sectoral coupling, notably by developing demonstrators for the use of hydrogen technologies in energy, transport and industry. In a similar manner, several countries indicated specific areas of interest for applications, e.g.: all types of road transport (not just heavy-duty transport), the maritime sector, small-scale hydrogen usage, transportation and storage. Various comments also pointed out the need to ensure alignment with national activities, as well as the complementarity and synergies with other related partnerships/initiatives/programmes to cover the entire Hydrogen value chain. Other individual comments suggest to, e.g.:

- Include infrastructure for heavy-duty and FCEVs
- Ensure R&I activities among the whole value chain
- Extend the scope to the development of fuels with high energy density
- Include hydrogen sensor as an important field of application
- Assess the role of Carbon Capture & Storage as a means of achieving the scale required both for volume and cost
- Include technologies for distribution of hydrogen through pipelines
- Focus on near-zero carbon hydrogen production pathways

Many countries (64%) are undecided concerning their interest to participate in an initiative. At this stage 9 countries (BE, DE, EE, ES, FR, IT, MT, RO, NO) expressed interest to join as a partner, and only one country (CY) indicated that there is no national interest to participate. Governmental research organisations (61%), research infrastructures (50%), and planned national R&I programmes (50%) are most frequently identified as potential partners or contributors.

While many are undecided concerning their participation, all countries show interest in having access to results produced in the context of the partnership.

Feedback on objectives and impacts

Overall there is a good agreement on the use of a partnership approach in addressing energy transition through clean hydrogen technologies (64% consider it to be very relevant and 11% see it as somewhat relevant). There is broad agreement (71%) that the partnership is more effective in achieving the objectives and delivering clear impacts for the EU and its citizens, but to a lesser degree (43%) that it would contribute to improving the coherence and synergies within the EU R&I landscape.

Countries indicate strong agreement with the proposed short, medium and long term objectives, as well as with the expected scientific, economic and societal impacts at the European level (79%). Slightly fewer MS (75%) consider the impacts to be relevant in the national context. Three-quarters (75%) of the countries find the envisaged duration of the proposed partnership to be adequate, although some delegations point out that there is insufficient information to assess the appropriate timeframe. In additional comments, delegations reiterated some of the points made regarding elements to be reinforced, notably sector coupling and inclusion of all transport modes. Additional individual comments highlighted the need to allow technology-neutral solutions (in this context, one delegation suggested a merger with 2ZERO), to consider international initiatives in the field, and to include H2 production from renewables through water electrolysis, water thermochemical splitting and biomass gasification, and photochemical water splitting.

Views on partners, contributions and implementation

Around two-thirds (64%) of the countries agree on the type and composition of partners, whilst 18% remain neutral and 7% disagree. In additional comments, several countries' delegates emphasised the need to ensure stronger involvement of Member States and local authorities in the partnership to guarantee alignment with national activities. Other comments stressed the need to ensure a more balanced participation from other countries, stakeholders and actors compared to the current set-up of the Fuel Cells and Hydrogen Joint Undertaking, notably by ensuring increased involvement of smaller suppliers for the hydrogen industry.

At this stage, the majority of the countries' respondents (79%) indicated that they would need more information on the contributions and level of commitments expected from partners.

More than half (61%) of the countries needed more information to assess the proposed mode of implementation based on Article 187 TFEU, while 8 countries are in favour and 3 against. In the additional comments, three countries favour explicitly implementation through a co-programmed model, and two countries stress the need for comprehensive assessments as to whether a co-programmed or institutionalised model is more effective. One country supported implementation through competitive calls in Horizon Work Programmes."

B.4 Targeted consultation of stakeholders related to the initiative "Clean Hydrogen"

In addition to the consultation exercises coordinated by EC services, the external study thematic teams performed targeted consultations with businesses, research organisations and other partners on different aspects of potential European Partnerships.

B.4.1 Approach to the targeted consultation

The objectives of the interviews were to

- Clarify, make more precise and/or validate the main challenges for the sector from an R&I point of view, focusing on EU industry and research organisations;
- Clarify, make more precise and/or validate the main problems, objectives (general and specific) and expected impacts of an initiative on Clean Hydrogen (whether it is a partnership or not), and assess their importance;
- Determine the key aspects of expected functionalities and characteristics of an initiative according to the interviewees. These key aspects were intended to be compared with the key features of the partnership/initiative forms.

Few actors have experience with different types of initiatives (usually actors involved in H2 funding have only experience with either standard EU programme calls or with the FCH JU, but not with a co-programmed or co-funded scheme). Therefore, it was difficult to ask them for their opinions on the "best option." With each topic, the main objective for the interviewers was to collect data that would allow for distinguishing between the options to determine which was best, given their characteristics. The co-funded initiative and Article 185 were quickly deemed out of scope, so that interviewers focused on the baseline, the co-programmed and the existing Article 187 options. It was obvious that all interviewees – even the five actors that were not currently involved in FCH JU calls – favoured an IP (some strongly, others with some nuances). These actors favoured an IP due to the increasing scope of applications in the hydrogen field, and the growing need for coordination and a strong community within the sector.

The partnership in Clean Hydrogen would require engagement not only with stakeholders from across the European Hydrogen community, but also from across new non-H2 sectors, in order to fulfil low carbon objectives. An outline of stakeholders targeted for interviews is presented in the table below; it was drafted by taking into account current trends in the field of H2.

The selection was based on:

- Stakeholders being able to provide the information that needed to be collected across the different topics addressed;
- Ensuring that stakeholders would provide sufficient representativeness across the majority of Member States as well as across the different types of relevant stakeholders;
- Striking a balance between interviews focused on the options/measures for the envisaged partnership (targets: actors with good knowledge on the current/future partnership) and those focused on the problems/objectives of the needed 'initiative' (new actors);
- Soliciting feedback from actors not involved in previous (or even current) FCH 2 JU programmes and activities in order to counterbalance the feedback of involved stakeholders

We developed the list of interviewees by referencing participants in the Open Public Consultation conducted in Summer 2019, by contacting stakeholders proposed by Hydrogen Europe, and by contacting stakeholders suggested by our panel of experts.

We contacted all the interviewees (48) by e-mail; after receiving direct replies from 1/3 of the interviewees, we contacted stand-by interviewees one week after the first e-mail was sent. From about 1/5 of the contacts, we received no answer even after follow-ups, so we managed to replace them with new subjects. We were not able to conduct all of the expected 50 interviews due to long response times and time constraints at the end of the project. However, considering the high level of convergence across the 48 interviews conducted, we determined that the added value of two additional interviews would be limited, as they would not have been likely to produce new "critical" information. Pressing for two additional interviews was therefore considered to be unproductive.

A topic guide for the stakeholder interviews was used in each discussion. This questionnaire was designed with the intent to guide the stakeholder interviews. Nonetheless, it was not used as a script, but rather as a guideline for the interviews, as we expected interviews to be organised in a semi-structured manner.

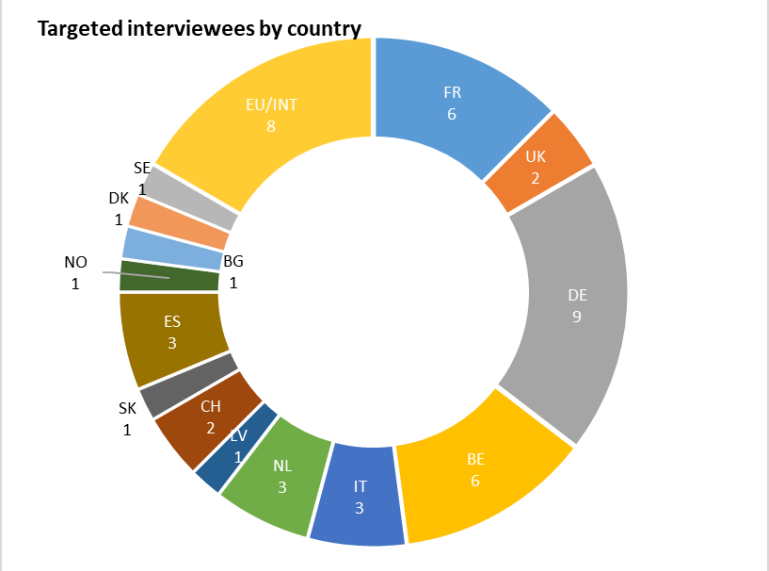
B.4.2 Overview of respondents to the targeted consultation

The table below shows that targeted interviewees were well-distributed across categories, with strong representation from Research and Academia, End-use industry and Manufacturing industry. The subsequent figure illustrates how interviewees were primarily based in areas with strong national hydrogen programmes, including Germany, France, the Netherlands and Spain. Efforts were also made to reach out to relevant Eastern and Southern European countries in order to collect a diversity of perspectives.

Table 18: Number of interviews per stakeholder category

Stakeholder category	Number	Share (%)
Manufacturing industry	7	15%
Association	4	8%
Grid operator	2	4%
Research & academia	13	27%
Civil society	1	2%
National associations	3	6%
End use industry	8	17%
MS and EU Commission	6	13%
Industry (utilities)	2	4%
Local authority representatives	1	2%
Integrators / developers	1	2%
TOTAL	**48**	**100%**

Figure 9: Number of interviews per country



B.4.3 Key results/messages from the targeted consultation

The interviewees shared similar opinions regarding the optimal design and implementation of a European Partnership on Clean Hydrogen. The principal points of their feedback are summarised consequently.

Scope of the initiative

Focus on Clean Hydrogen complete chains :

The focus of a partnership should be on hydrogen generation, delivery (transport, distribution and storage) and end-use, covering all relevant sectors and applications. There is no need for continuing the targeted focus on Fuel Cells, as other technologies have developed for end use (like turbines, burners, furnaces, industrial processes).

The partnership should only support the scale-up of clean hydrogen applications, i.e., technologies that produce and use hydrogen from low carbon sources (like renewable or other low carbon electricity, or SMR combined with CCUS).

Sectors that should be involved include: industry (H2 as feedstock or fuel), maritime, rail, aviation, public transport, logistics, energy incl. heating and power, heavy duty transport.

Technology neutral:

The initiative should not focus on specific technologies or applications but should remain open to all potential developments.

Sector coupling & infrastructure development:

The coupling of renewable electricity production and hydrogen generation is seen as a key technology route for propagating clean hydrogen and a key enabler for the deployment of renewables. The FCH JU has been instrumental in reaching out to renewables companies and other potential end-users to increase their interest in hydrogen applications – many new organisations across several different sectors have incorporated hydrogen into their long-term strategies (e.g., power companies, gas distributors) largely due to FCH JU outreach.

The development of infrastructure (gas pipelines and refuelling stations) is considered as a key enabler to deploy clean hydrogen at scale. There is also a need to define the form in which hydrogen will be transported (e.g., compressed, liquid). The initiative should provide

support to ensure that infrastructure investments are encouraged, even if they must be realised by the industry with private capitals (connections to receive support from the CEF could help).

Continuous improvement:

Through further RD&I, there is need to spur further cost decreases, quality improvements and performance enhancements of all technologies, applications and stacks. There is still room for improvement in all sectors and for all applications, even for applications that are ready-to-market. The JU has demonstrated its ability to develop technologies to expected maturity levels in the direction of market uptake, and has proven its ability to strengthen the hydrogen community and encourage shared practices and knowledge at all TRLs.

Coordination with other sectors and/or initiatives:

The initiative will have to ensure coordination with other initiatives in concerned sectors. The need for strong coordination can be better handled with an IP than with any other option. For example, the gas sector will play a key role in hydrogen's rollout, but there is no existing initiative on decarbonising gas grids, so it will be important for the partnership to involve gas sector stakeholders. This is true for several "end use" sectors.

Collaboration between all sectors relevant to clean hydrogen is of paramount importance, as they complement one another while sharing a broad low-carbon vision and the scientific knowledge and skills necessary to adapt existing technologies appropriately.

Policy and regulatory vacuum

No market conditions

There is a need for market uptake of several technologies considered ready-to-market (including FC buses, FC forklifts, stationary FCs, microgrids, and certain types of electrolysers). Further improvement of these applications could be prompted by industry deploying technologies at scale. However, necessary market conditions are missing, jeopardising their deployment. The risk of losing the benefits of past years' RD&I efforts is high, if market uptake does not increase within the EU. While it is no longer the role of RD&I to support market uptake, an IP could provide vital support to foster requisite market conditions (both regulatory and policy).

Absence of regulation:

As H2 applications are maturing within all sectors, the need for regulation is increasing. An optimal first space for addressing regulatory requirements is within the RD&I sphere, as it contains actors with the required knowledge (both industry- and research-based actors) and with views on market constraints (industry actors).

In addition, the dominance of a strong hydrogen community at an EU level would make discourse with other global regions more efficient, as the EU could address international norms and standards with a single voice. A strong community would also support the leading position of EU organisations.

Therefore, all stakeholders insisted on the importance of addressing the issue of regulation within the framework of RD&I supported by a community hosted by an IP.

Missing vision:

The lack of a cohesive European hydrogen policy is a big issue. Without a long-term vision on hydrogen rollout, stakeholders are confident there will be insufficient commitment to launch new markets and secure investors.

The JU is the most appropriate framework for proposing and implementing a clear vision on sequential next steps for hydrogen uptake: design, develop, improve, integrate and deploy at scale.

Coordination and cooperation

Between KBA and industry:

In order to deploy new applications (low TRL), or even to improve existing ones (middle and high TRL), there is a need for strong coordination between Research and Industry as the former has knowledge/views on fundamental R&D and emerging technologies and the latter is well-versed in market needs and trends. A community that gathers both types of stakeholders is very important and should be strengthened to ensure complementarity along the entire hydrogen value chain. An IP is the most appropriate option for maintaining and reinforcing the strong, existing European hydrogen community.

Addressing all areas of development and looking at all opportunities are key, as innovation and research in one specific field can create opportunities in other fields. Therefore, networking between research and industry is essential, but so too is networking between research institutions.

A community addressing all related topics:

In order to ensure coherence, the clean hydrogen community should address technology development, regulation and demonstration of complex projects (multi-stakeholders).

Community coordination is essential in order to help establish a clear agenda that identifies priorities and necessary activities in the clean hydrogen space. This community can most effectively be hosted by an IP.

Involving authorities

MS involvement

For some stakeholders, sharing best practices will bring MS on board "naturally." But for others, outreach is still needed in order to increase interest.

At the MS-level, the European HyNet project has made a very good start in engaging with authorities, as it plans to support exchanges on market trends, to present best practices and leverage downstream development.

An IP would be the most appropriate to support knowledge-sharing between stakeholders and MS.

Local authorities involvement

Local authorities have an important role to play in enabling clean hydrogen uptake; they are involved with public awareness, permitting, coordination, setting low carbon roadmaps, creating early market conditions, responding to local needs, and bringing funds for projects. Therefore, depending on the specific needs of a project or an application that can be deployed at the local level, their involvement in a partnership could become essential. An IP would be the most appropriate structure to support knowledge-sharing and to liaise with important local actors and develop local hydrogen communities.

Awareness

Specific vs general

There is no need to raise more general awareness (in fact there is the risk of creating a gap between expectations and non-existent markets or technologies/applications).

Awareness must be properly fostered. Outreach on hydrogen should correctly explain the technical, economic and environmental characteristics of different hydrogen applications.

Extensive diffusion

Established best practices should be encouraged and propagated in all concerned industries.

EU positioning

Relevant for all applications

The supply chain for clean hydrogen applications is dispersed across sectors and industries; knowledge management encourages collaboration and linkages between potential partners. An appropriate IP provides such effective knowledge management.

Targeted areas for R&D should be determined based on identified needs (among end-users) rather than on established practices (what EU industry is doing). Therefore, even in segments and with technologies where other regions are gaining prominence (e.g., Asia, which leads in FCEV rollout), it is still important to support R&I, given the need for building blocks and considering that assemblers play a role within hydrogen value chains as well. However, there is still a need to set fixed, achievable R&D priorities.

As examples: the FC sector is the most advanced in EU, while the EU maritime sector is outpacing global competitors, thanks to continuous technology innovation (added value), and will remain competitive. Together they create significant opportunities for EU organisations to realise synergies. An IP would facilitate and support such synergies.

Vital for SMEs

FCH JU plays a **vital role in supporting SMEs**. Within national governments, there is a feeling that larger industrial players dominate the conversations on the strategies for hydrogen, and that they steer national funding towards their own organisations. But the FCH JU provides a forum for SMEs to substantially contribute to/engage in strategic discussions, and there is more of a sense that funding is allocated to projects which really merit it.

Dialogue within the framework of a JU is generates harmonised voices, and provides less "lobby power" to large organisations (both on research and industry sides).

Market uptake

Demonstration

There is a consensus among stakeholders that hydrogen applications are entering a phase of real demonstration. Many demonstration projects will be managed at the MS level, with important industry leverage. EU level intervention and monitoring will remain important to ensure that coordination addresses cross-border projects and linkages between different actors throughout Europe, to address regulatory gaps, and to finally validate hydrogen generation, delivery and end-use applications for larger deployment. In some cases, direct EU leverage would be useful as an accompaniment to MS initiatives or even to catalyse larger projects.

Industrialisation

There is still a strong need for R&D efforts in developing hydrogen applications; whereas in the past R&D mainly focused on scientific and technological development, there is now a much stronger need for research focused on production processes and commercial deployment. The industrialisation phase of hydrogen applications will depend on market uptake. R&D funds can go into validating the applications (as the phase of industrialisation

remains outside the R&D sphere). Complementarity could be developed with the Innovation Fund (from ETS) to support this phase of industrialisation. This is where an IP, with good knowledge management, could also provide some support (in preparing calls or screening projects). For a few actors, R&D could be directly relevant to their industrialisation phase.

Financing

Where competitiveness of end use applications is market volume-dependent, an effective market launch will be possible only with policy incentives. Decision makers should therefore seize all opportunities of an H2 economy by setting up adequate support frameworks. An IP, with deep expertise, can provide support in developing and deploying incentives.

The deployment of hydrogen infrastructure (pipelines, stations and storage) is also essential, but cannot be addressed in the framework of RD&I. Links with other financing instruments (like CEF or national budgets) will be important. However, there is need for a global overview on funding at the EU level in order to ensure consistency and avoid redundancy (e.g., to avoid converting natural gas pipelines in some areas but not in others, creating a gap in required infrastructure).

Strategic Research & Innovation Agenda

Address a long term vision

As H2 is versatile and can be integrated into various sectors using many different applications, it is vital to prepare a coherent Strategic Research and Innovation Agenda (SRIA), which is able to draw from current efforts and results to develop a longer term vision. A large community, hosted by an IP, is the best option to prepare such an agenda with research and industry input.

The SRIA should ideally ensure that there is a proper articulation between the long-term CO2 strategy objectives AND the applications where we can expect cost decreases. Coupling the SRIA and H2 strategy is essential and could be best managed by an IP.

Industry players would identify market challenges and opportunities, and research players would propose potential scientific and technology pathways.

Balance between low and high TRLs

It is important to address all levels of technological readiness in the RD&I agenda, but also to prioritise some over others. Most stakeholders agree that over the next ten years, RD&I should be concentrated on technologies at high, nearly market-ready levels and at low, potentially innovative levels. EU contributions should decrease when addressing higher TRL projects, to ensure higher private contributions for demonstration projects. An IP is the most appropriate structure through which to prompt increasing industry leverage.

Openness

Work at a global level

The initiative should work at a global level, or at least be connected to all relevant counterparts to ensure compliance with international standards, to secure the role of EU industry in different hydrogen spaces, and to make sure that regulatory issues are addressed properly. An IP is probably the most appropriate initiative to foster collaboration at international levels, given its expertise and knowledge management.

Open calls

There is a consensus among the interviewees that calls for funding should remain open, but it is considered important (strategically and financially) to ensure that there are incentives that keep members of the IP community consistently interested in its efforts.

Long term commitment

Public / private collaboration on long term is key

Long-term involvement is critical in the H2 economy, as some applications require years to develop and improve. The cycling process – i.e., extracting lessons from higher TRLs to lower TRLs and emerging applications – should ensure continuity on a long term basis. A co-programmed initiative would not be appropriate in securing long-term commitments, as its priorities can regularly be changed. An IP is considered the most appropriate structure for ensuring follow-up and engaging both public and private players in the long run.

Fundamental R&D could be facilitated and reinforced by providing structural funding to centres and academia in a more programmatic ways, avoiding the need to regularly submit new project proposals. With clear and strict monitoring, programming could ensure a longer-term and coherent vision of the R&D agenda, and alleviate the process of launching new calls.

Long-term application selection

For some applications (e.g. in the maritime or aviation sectors), there is need to test out different technologies and alternatives in order to be able to later see which is the most appropriate for deployment at scale. It takes years to test applications and requires long-term commitments to carbon emission reduction at large scales.

B.5 Open public consultation on the Candidate institutionalised European Partnerships

B.5.1 Approach to the open public consultation

The consultation was open to everyone via the EU Survey online system.[321] The survey contained two main parts and an introductory identification section. The two main parts collected responses on general issues related to European partnerships (in Part 1) and specific responses related to one or more of the 12 candidate initiatives (as selected by a participant).

The survey contained open and closed questions. Closed questions were either multiple choice questions or matrix questions that offered a single choice per line, on a Likert-scale. Open questions were asked to clarify individual choices.

The survey was open from 11 September till 12 November 2019. The consultation was available in English, German and French. It was advertised widely through the European Commission's online channels as well as via various stakeholder organisations.

[321] https://ec.europa.eu/eusurvey/runner/ConsultationPartnershipsHorizonEurope

B.5.2 Overview of respondents to the open public consultation

Profile of respondents

In total, 1635 respondents filled in the questionnaire of the open public consultation. Among them, 272 respondents (16.64%) were identified to have responded to the consultation as part of a campaign (coordinated responses). Based on the Better Regulation Guidelines, the groups of respondents where at least 10 respondents provided coordinated answers were labelled as 'campaigns', segregated and analysed separately and from other responses. In total 11 campaigns were identified. In addition, 162 respondents in the consultation also display similarities in responses but in groups smaller than 10 respondents. Hence, these respondents were not labelled as campaigns and therefore were not analysed separately from the general analysis.

Among the 1635 respondents, 1178 (72.05%) completed the online consultation in English, 141 (8.62%) in German, 89 (5.44%) in French, 58 (3.55%) in Italian and 47 (2.87%) in Spanish, see Figure 10. Respondents that belong to the 11 campaigns follow the same pattern of language distribution, with English being the dominant language of respondents in that group. Table 19 shows that over 50% of respondents come from 4 Western and Southern European countries – Germany, Italy, France and Spain. Overall, the number of respondents from Eastern and Northern Europe is lower, while among non-EU countries the greater number of respondents come from Switzerland, Norway and Turkey, which are countries associated to the Framework Programme. In the group of respondents labelled as campaigns, most respondents are from Germany (48 respondents or 17.65%), France (39 respondents or 14.34%), Italy (37 respondents or 13.6%), Belgium (23 respondents or 8.46%), the Netherlands (21 respondents or 7.72%) and Spain (17 respondents or 6.25%). Hence, a similar pattern of country of origin is observed in the entire sample of respondents and for the campaigns.

Across all respondents 40.80% indicated to answer to the open public consultation in a public way (non-anonymous) and 20.67% of all respondents indicated their Transparency Register number.

Figure 10: Language of the consultation that selected respondents (N=1635) (non-campaign replies) Aggregation of responses of all candidate initiatives

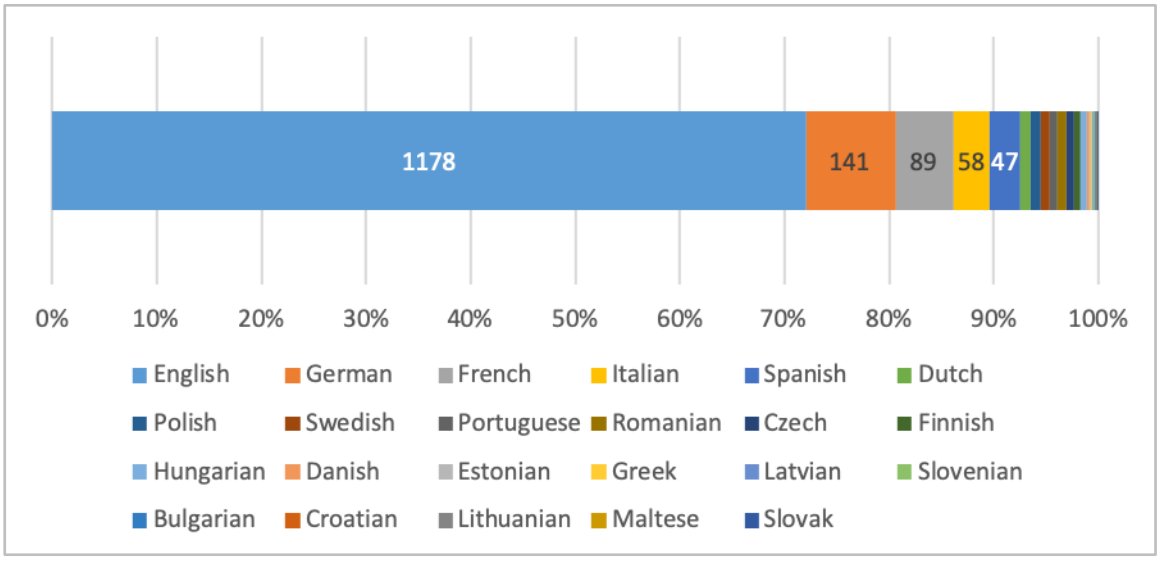


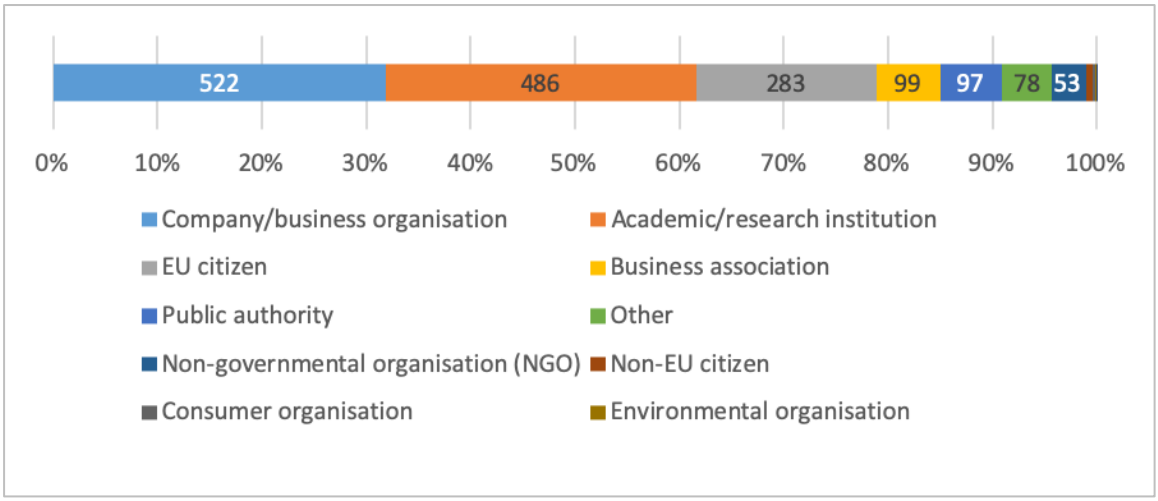
Table 19: Country of origin of respondents (N=1635)

Country	Number of respondents	Percentage of respondents
Germany	254	15.54%
Italy	221	13.52%
France	175	10.70%
Spain	173	10.58%
Belgium	140	8.56%
The Netherlands	86	5.26%
Austria; United Kingdom	61	3.73%
Finland	49	3.00%
Sweden	48	2.94%
Poland	45	2.75%
Portugal	32	1.96%
Switzerland	28	1.71%
Czechia	24	1.47%
Greece	23	1.41%
Norway; Romania	22	1.35%
Denmark	20	1.22%
Turkey	19	1.16%
Hungary	14	0.86%
Ireland	12	0.73%
United States	11	0.67%
Estonia; Slovakia; Slovenia	10	0.61%
Bulgaria; Latvia	9	0.55%
Bosnia and Herzegovina	7	0.43%
Lithuania	4	0.24%
Canada; Croatia; Israel	3	0.18%
China; Ghana; Iceland; Japan; Luxembourg; Morocco	2	0.12%
Bhutan; Botswana; Cyprus; Iran; Malta; Mexico; Moldova; Mongolia; Palestine; Russia; Serbia; South Africa; Tunisia; Ukraine; Uruguay	1	0.06%

According to Figure 11, the three biggest groups of respondents are companies and business organisations (522 respondents or 31.93%), academic and research institutions (486 respondents or 29.72%) and EU citizens (283 respondents or 17.31%). Business associations, representing multiple businesses, were the fourth largest responding group (99 respondents or 6.05%), no other types of associations were presented amongst the

selectable options for respondents. Among the group of respondents that are part of campaigns, most respondents are provided by the same groups of stakeholders, namely companies and business organisations (121 respondents or 44.49%), academic and research institutions (54 respondents or 19.85%) and EU citizens (42 respondents or 15.44%).

Figure 11: Type of respondents (N=1635) (non-campaign replies) Aggregation of responses of all candidate initiatives



Respondents were asked to indicate the organisational size of the companies, organisations and institutions they work for. Based on Table 20, a greater number of respondents work in large companies and business organisations (295 respondents out of 522 or 56.51%) and large academic and research institutions (348 respondents out of 486 or 71.60%). A greater number of respondents that are employed by business associations and NGOs indicated an organisation size of 1 to 9 employees. Among the group of respondents that are marked as campaigns, a greater number of respondents work in large companies and business organisations (82 respondents out of 121 or 67.77%) and academic and research institutions (39 out of 54 respondents or 72.22%).

Table 20: Size of organisations that represent consultation respondents (N=1635)

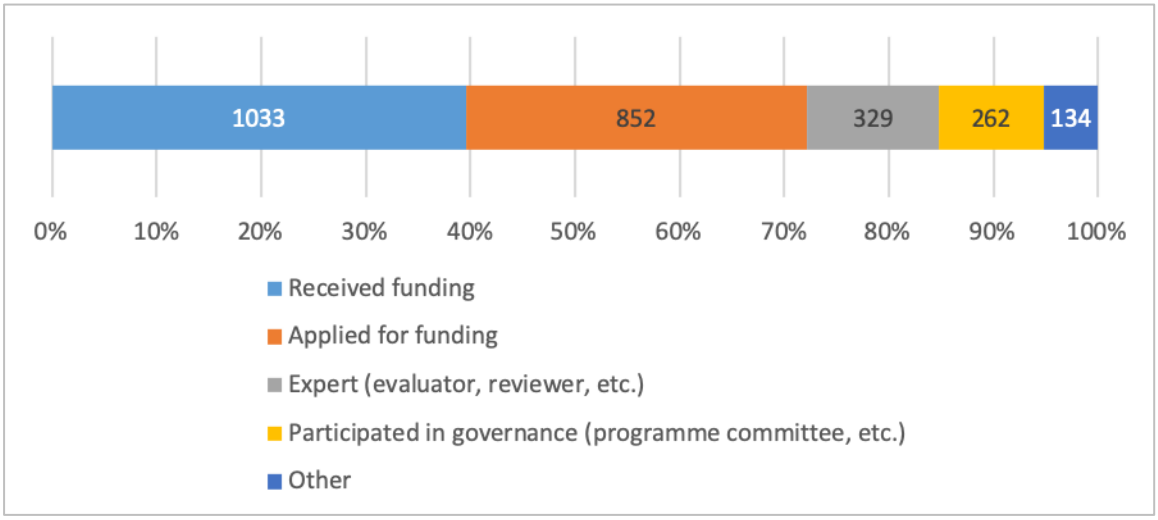
	Organisation size			
Type of respondents' organisations	**Large (250 employees or more)**	**Medium (50 to 249 employees)**	**Small (10 to 49 employees)**	**Micro (1 to 9 employees)**
Company/business organisation	295	66	90	71
Academic/research institution	348	95	31	12
Business association	15	6	34	44
Public authority	58	33	6	0
Non-governmental organisation (NGO)	7	9	11	26
Consumer organisation	1	0	2	1
Environmental organisation	0	0	1	0
Trade union	0	0	1	0

	Organisation size			
Type of respondents' organisations	**Large (250 employees or more)**	**Medium (50 to 249 employees)**	**Small (10 to 49 employees)**	**Micro (1 to 9 employees)**
Other	24	16	19	19

Among all consultation respondents, 1303 (79.69%) have been involved in the on-going research and innovation framework programme Horizon 2020 or the preceding Framework Programme 7, while 332 respondents (20.31%) were not. In the group of campaign respondents, the share of those who were involved in these programmes is higher (245 respondents out of 272 or 90.07%) than in the group of non-campaign respondents (1058 out of 1363 or 77.62%). When respondents that participated in the Horizon2020 or in the preceding Framework Programme 7 were asked to indicate in which capacity they were involved in these programmes, the majority stated that they were a beneficiary (1033 respondents or 39.58%) or applicant (852 respondents or 32.64%).

The main stakeholder categories, e.g. companies/business organisation, academic/research institutions, etc., show a similar distribution across the capacities in which they 'have been involved in Horizon 2020 or in the Framework Programme 7' as the overall population of consultation respondents (see distribution in Figure 12). However, a few stakeholder categories have mainly been involved in the capacity of "Received funding" and/or "Applied for funding", this applies to business associations, NGOs and public authorities.

Figure 12: Capacity in which respondents were involved in Horizon 2020 or in the Framework Programme 7 (N=1303)(non-campaign replies) Aggregation of responses of all candidate initiatives, multiple options allowed



Among those who have been involved in the on-going research and innovation framework programme Horizon 2020 or the preceding Framework Programme 7, 1035 respondents (79.43%) are/were involved in a partnership. The share of respondents from campaigns that are/were involved in a partnership is higher than for non-campaign respondents, 89.80% versus 77.03% respectively. The list of partnerships under Horizon 2020 or its predecessor Framework Programme 7 together with the numbers, percentages of participants is presented in Table 21, the table also show the key stakeholder categories for each partnership.

Most consultation respondents participated in the following partnerships: Fuel Cells and Hydrogen 2 (FCH2) Joint Undertaking, Clean Sky 2 Joint Undertaking, European Metrology Programme for Innovation and Research (EMPIR) and in Bio-Based Industries Joint

Undertaking. The comparison between the non-campaign and campaign groups of respondents shows that the overall distribution is quite similar. However, there are some differences. For the campaign group almost a half of respondents is/was involved in the Fuel Cells and Hydrogen 2 (FCH2) Joint Undertaking, a higher share of campaign respondents is/was participating in Clean Sky 2 Joint Undertaking and in Single European Sky Air Traffic Management Research (SESAR) Joint Undertaking.

Table 21: Partnerships in which consultation respondents participated (N=1035)

Name of the partnership	Number and % of respondents from both groups (n=1035)	Number and % of respondents from a non-campaign group (n=815)	Academic/research institutions	Business associations	Company/business organisations (<250)	Company/business organisations (250+)	EU citizens	NGOs	Public authority
Fuel Cells and Hydrogen 2 (FCH2) Joint Undertaking	354 (33.33%)	247 (30.31%)	97	9	37	43	41	8	5
Clean Sky 2 Joint Undertaking	195 (18.84%)	145 (17.79%)	57	2	10	27	37	1	7
European Metrology Programme for Innovation and Research (EMPIR)	150 (14.49%)	124 (15.21%)	64	0	13	9	14	2	19
Bio-Based Industries Joint Undertaking	142 (13.72%)	122 (14.97%)	39	8	20	27	14	1	6
Shift2Rail Joint Undertaking	124 (11.98%)	101 (12.40%)	31	7	5	31	14	3	7
Electronic Components and Systems for European Leadership (ECSEL) Joint Undertaking	111 (10.72%)	88 (10.80%)	42	2	7	20	12	0	5
Single European Sky Air Traffic Management Research (SESAR) Joint Undertaking	66 (6.38%)	46 (5.64%)	10	3	3	20	3	2	3
5G (5G PPP)	53 (5.12%)	47 (5.77%)	20	1	6	14	5	0	1

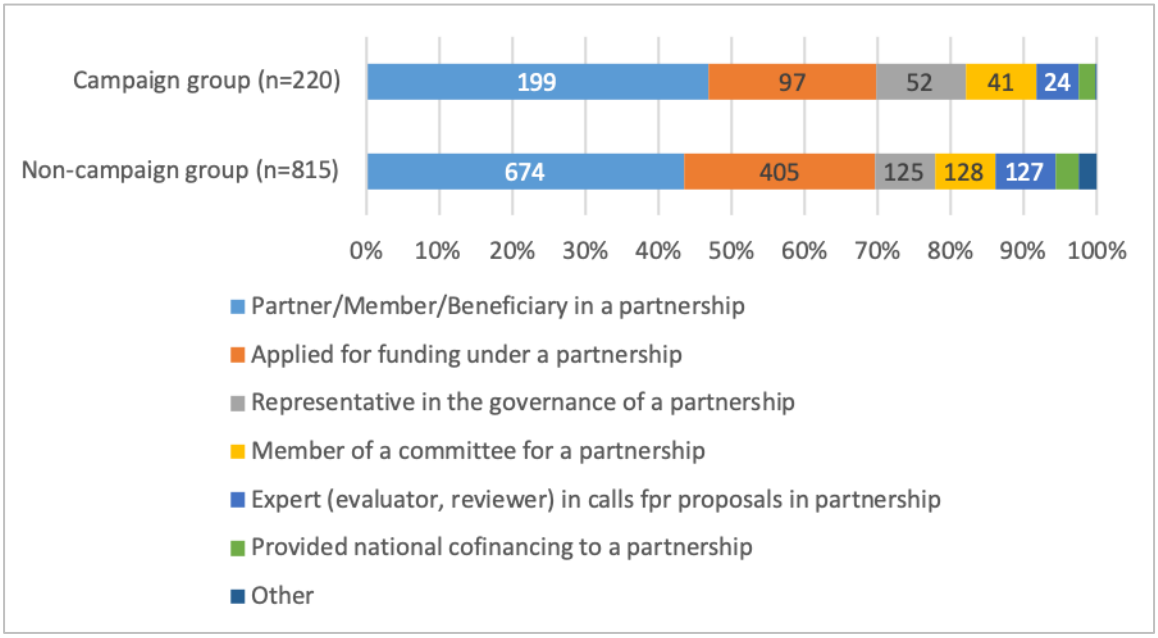
Name of the partnership	Number and % of respondents from both groups (n=1035)	Number and % of respondents from a non-campaign group (n=815)	Academic/research institutions	Business associations	Company/business organisations (<250)	Company/business organisations (250+)	EU citizens	NGOs	Public authority
Eurostrars-2 (supporting research-performing small and medium-sized enterprises)	44 (4.25%)	40 (4.91%)	17	0	6	1	7	0	6
Innovative Medicines Initiative 2 (IMI2) Joint Undertaking	37 (3.57%)	35 (4.29%)	18	2	3	3	2	4	3
Partnership for Research and Innovation in the Mediterranean Area (PRIMA)	28 (2.71%)	26 (3.19%)	15	0	3	1	2	0	2
European and Developing Countries Clinical Trials Partnership	25 (2.42%)	24 (2.94%)	12	0	1	2	3	3	2
Ambient Assisted Living (AAL 2)	22 (2.13%)	21 (2.58%)	11	2	1	1	3	0	3
European High-Performance Computing Joint Undertaking (EuroHPC)	22 (2.13%)	18 (2.21%)	6	0	2	3	5	0	2

When respondents were asked in which role(s) they participate(d) in a partnership(s), over 40% indicated that they act(ed) as partner/member/beneficiary in a partnership (see, Figure 13). The second largest group of respondents stated that they applied for funding under a partnership. The roles selected by non-campaign and campaign respondents are similar.

The few respondents that selected "Other" as their role were provided with the opportunity to outline their role. A total of 25 people did provided description. The answers provided were very varied and could not be clustered in sub-groups, a few examples are: former

communication and stakeholder relationship officer, chair of steering board, system engineer, grant manager, Joint Programming Initiative (JPI), or a role in advocacy of the partnership.

Figure 13: Role of respondents in a partnership (N=1035) (non-campaign replies) Aggregation of responses of all candidate initiatives



In the open public consultation respondents could provide their views on each of the candidate Institutionalised European Partnerships, and each respondent could select multiple partnerships to provide their views on. The table below presents the number and percentage of respondents for each partnership. It is visible that the majority of respondents (31.37%) provided their views on the Clean Hydrogen candidate partnership. More than 45% of respondents from the campaigns selected this partnership. Around 15% of all respondents provided their views for the candidate partnerships European Metrology, Clean Aviation and Circular bio-based Europe. The share of respondents in the campaign group that chose to provide views on the Clean Aviation candidate partnership is of 20%. The smallest number of respondents provided opinions on the candidate initiative 'EU-Africa research partnership on health security to tackle infectious diseases – Global Health'.

Table 22: Future partnerships for which consultation respondents provide responses (N=1613)

Name of the candidate Institutionalised European partnership	Number and % of respondents from both groups (n=1613)	Number and % of respondents from a non-campaign group (n=1341)	Academic/research institutions	Business associations	Company/business organisations (<250)	Company/business organisations (250+)	EU citizens	NGOs	Public authority
Clean Hydrogen	506 (31.37%)	382 (28.49%)	123	21		55	74	8	13
European Metrology	265 (16.43%)	225 (16.78%)	112	3	21	11	34	3	28
Clean Aviation	246 (15.25%)	191 (14.24%)	57	5	21	34	54	3	8

Name of the candidate Institutionalised European partnership	Number and % of respondents from both groups (n=1613)	Number and % of respondents from a non-campaign group (n=1341)	Academic/research institutions	Business associations	Company/business organisations (<250)	Company/business organisations (250+)	EU citizens	NGOs	Public authority
Circular bio-based Europe: sustainable Innovation for new local value from waste and biomass	242 (15%)	215 (16.03%)	63	19	36	35	31	7	13
Transforming Europe's rail system	184 (11.41%)	151 (11.26%)	29	14	23	39	31	2	7
Key Digital Technologies	182 (11.28%)	162 (12.08%)	55	13	20	22	35	5	7
Innovative SMEs	111 (6.88%)	110 (8.20%)	19	12	39	4	14	4	10
Innovative Health Initiative	110 (6.82%)	108 (8.05%)	35	6	9	12	16	16	5
Smart Networks and Services	109 (6.76%)	107 (7.98%)	34	9	12	17	21	2	6
Safe and Automated Road Transport	108 (6.70%)	102 (7.61%)	25	12	11	19	10	3	9
Integrated Air Traffic Management	93 (5.77%)	66 (4.92%)	8	7	4	24	9	2	7
EU-Africa research partnership on health security to tackle infectious diseases – Global Health	49 (3.04%)	47 (3.50%)	15	2	4	3	12	6	4

Campaigns per candidate Institutionalised European Partnership

As was mentioned above, 11 campaigns were identified, the largest of them includes 57 respondents. The table below presents the campaigns that replied for each candidate partnership. As presented, the candidate Institutionalised Partnership Clean Hydrogen has the highest number of campaigns, namely 5. A few partnerships, such as Innovative SMEs, Smart Networks and Systems, were not targeted by campaigns. Some campaign respondents decided to provide opinions about several partnerships, therefore, campaign #2 and #6 feature in several partnerships.

Table 23: Overview of campaigns across partnerships

Name of the candidate Institutionalised European partnership	Number of a campaign group (total number of respondents in a campaign)	Number of respondents that provided views about a partnership
Clean Hydrogen	Campaign #1 (57 respondents)	57 respondents
	Campaign #2 (41 respondents)	25 respondents
	Campaign #7 (18 respondents)	18 respondents
	Campaign #9 (14 respondents)	13 respondents
	Campaign #11 (10 respondents)	9 respondents
Clean Aviation	Campaign #2 (41 respondents)	17 respondents
	Campaign #6 (19 respondents)	19 respondents
	Campaign #8 (14 respondents)	13 respondents
Integrated Air Traffic Management	Campaign #2 (41 respondents)	10 respondents
	Campaign #6 (19 respondents)	12 respondents
European Metrology	Campaign #3 (36 respondents)	35 respondents
Circular bio-based Europe: sustainable Innovation for new local value from waste and biomass	Campaign #5 (20 respondents)	20 respondents
Transforming Europe's rail system	Campaign #4 (31 respondents)	29 respondents
Key Digital Technologies	Campaign #10 (12 respondents)	12 respondents
Innovative SMEs	-	-
Innovative Health Initiative	-	-
Smart Networks and Services	-	-
Safe and Automated Road Transport	-	-
EU-Africa research partnership on health security to tackle infectious diseases – Global Health	-	-

B.5.3 Responses to the open public consultation at programme level

The following section of the report presents the analysis of responses at programme level, meaning all respondents (excluding campaigns) were included, independent of which candidate European Partnerships respondents selected to provide their views on. The results for responses as part of campaigns are presented separately.

Characteristics of future candidate European Partnerships

Respondents were asked to assess what areas, objectives, aspects need to be in the focus of the future European Partnerships under Horizon Europe and to what extent. According to Figure 14, a great number of respondents consider that a significant contribution by the

future European Partnerships is 'fully needed' to achieve climate-related goals, to the development and effective deployment of technology and to EU global competitiveness in specific sectors/domains. Overall, respondents' views reflect that many aspects require attention of the Partnerships. The least attention should be paid to responding towards priorities of national, regional R&D strategies, including smart specialisation strategies, according to respondents.

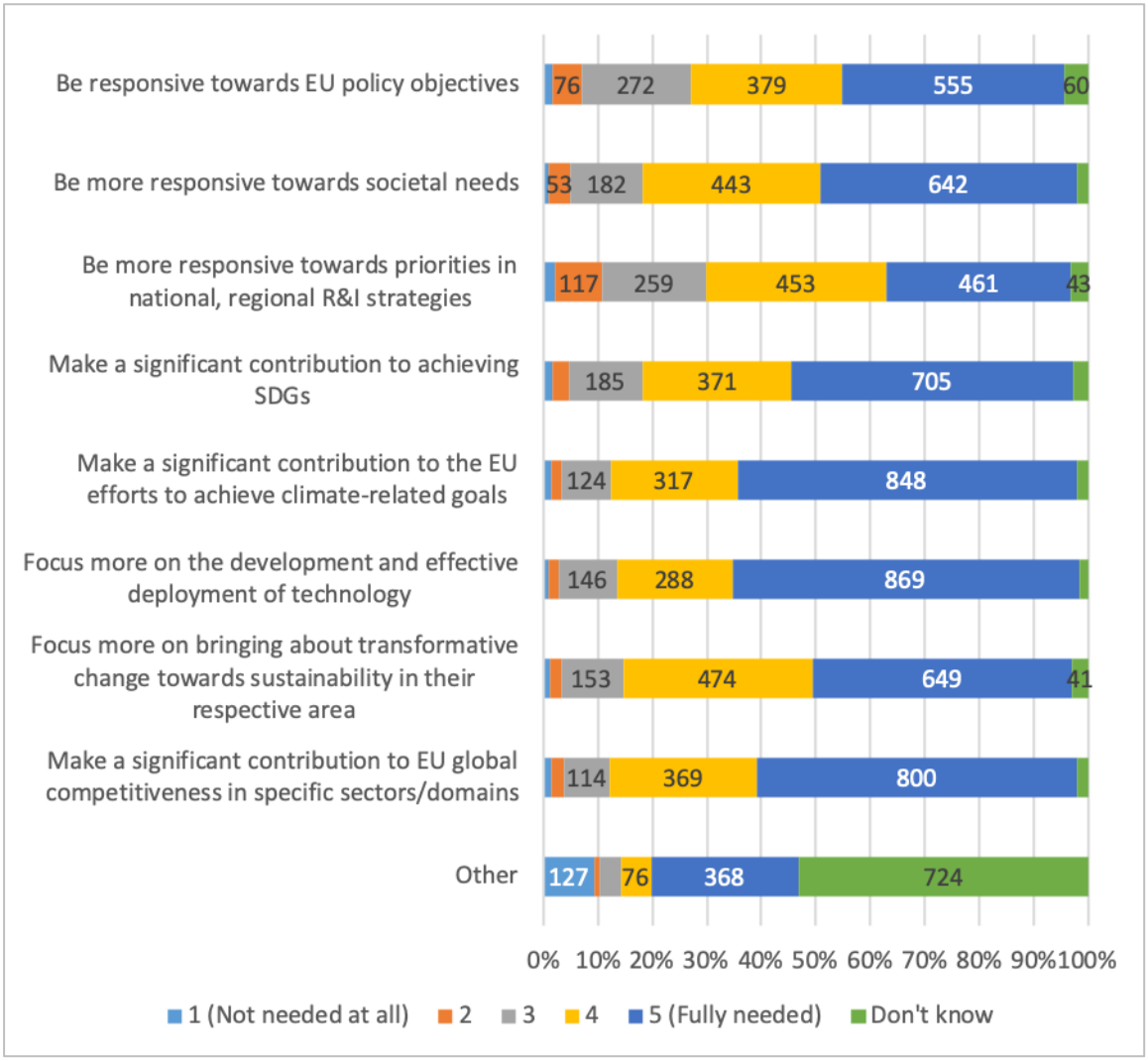
Overall, only minor differences can be found between the main stakeholder categories. Academic/research institutions value the responsiveness towards EU policy objectives and focus on development and effective deployment of technology a little less than other respondents. Business associations, however, find that the future European Partnerships under Horizon Europe should focus a little bit more on the development and effective deployment of technology than other respondents. Furthermore, business associations, large companies as well as SMEs (companies with less than 250 employees) value role of the future European Partnerships for significant contributions to EU global competitiveness in specific sectors domains a little higher than other respondents. Finally, both NGOs and Public authorities put a little more emphasis on the role of the future European Partnerships for significant contributions to achieving the UN SDGs.

The views of citizens (249, or 18.27%), both EU and non-EU citizens, that participated in the open public consultation do not reflect significant differences with other types of respondents. However, respondents that are/were directly involved in a partnership under Horizon 2020 or its predecessor Framework Programme 7 assign a higher importance of the future European Partnerships to be more responsive towards EU policy objectives and to make a significant contribution to achieving the UN's Sustainable Development Goals.

Among 272 respondents that are classified as **campaigns,** the majority (86.76%) indicated that the future European Partnerships should focus more on the development and effective deployment of technology. Other categories of presented needs that received a high score among many campaign respondents are the need to make a significant contribution to the EU efforts to achieve climate-related goals, Sustainable Development Goals and to EU global competitiveness in specific sectors/domains. The least number of campaign respondents valued the need to be more responsive towards priorities in national, regional R&I strategies (54 respondents gave a score "5 Fully needed", or 19.85%) and to be more responsive towards societal needs (71 respondents gave a score "5 Fully needed", or 26.10%).

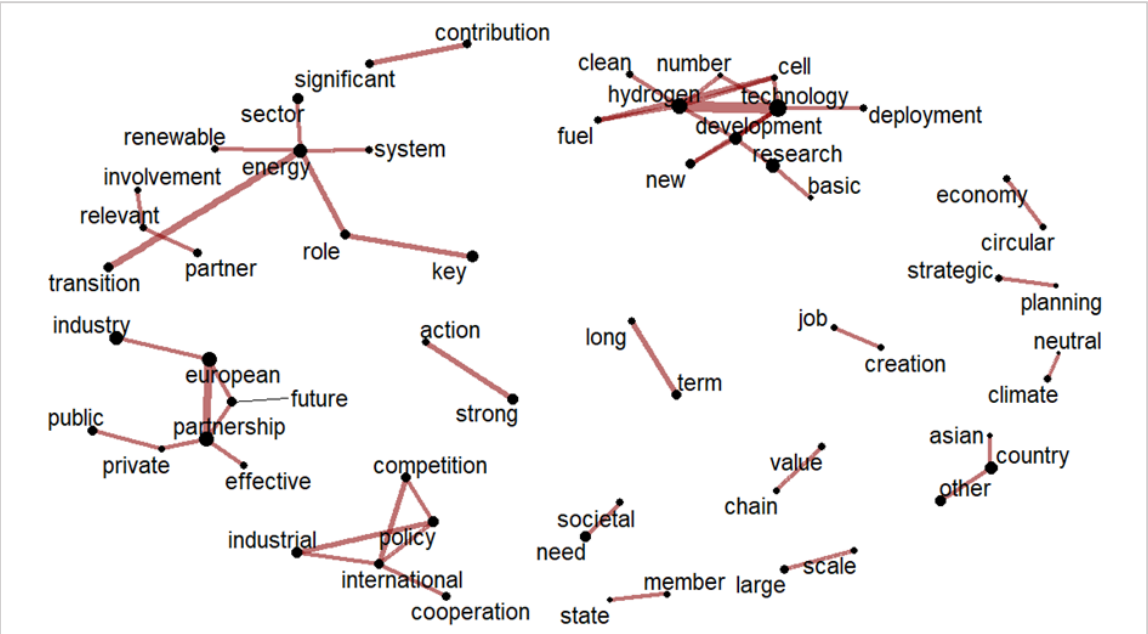
Similarly, as for non-campaign respondents, we find only minor differences between the main stakeholder categories amongst campaign respondents. Academic/research institutions indicated that the future European Partnerships need to focus a little less on development and effective deployment of technology than other respondents. On the contrary, large companies find the focus on the development and effective deployment of technology a little more needed than other respondents, as do public authorities. Furthermore, large companies feel responsiveness towards priorities in national, regional R&I strategies is a little less needed than other respondents. Public authorities, however, value the responsiveness towards societal needs and priorities in national, regional R&I strategies more than others.

Figure 14: To what extent do you think that the future European Partnerships under Horizon Europe need to (N=1363) (non-campaign replies) Aggregation of responses of all candidate initiatives



The analysis of the open answers provided to explain the "Other" field show that many respondents included the set-up of public-private European partnerships and the link between industrial policy and international competition and cooperation (see Figure 15). This is confirmed through qualitative analysis of answers, many of which mention the importance of collaboration and integration of relevant stakeholders to tackle main societal challenges and to contribute to policy goals. Against this backdrop, fragmentation of funding and research efforts across Europe should be avoided. Additionally, several respondents suggested that faster development and testing of technologies, acceleration of industrial innovation projects, science transfer and market uptake are deemed as priorities. Next to that, many respondents provided answers related to the fields of hydrogen and the energy transition, which corresponds to the high number of respondents that provided answers to the candidate European Partnership specific questions related to these topics.

Figure 15: Assessment of needs, open answers to "Other" field, 50 most common co-occurring keywords (N=734) (non-campaign replies) Aggregation of responses of all candidate initiatives



Many of the respondents that are classified as campaigns took the opportunity of the "Other" field to underline their key messages. The main aspects mentioned were:

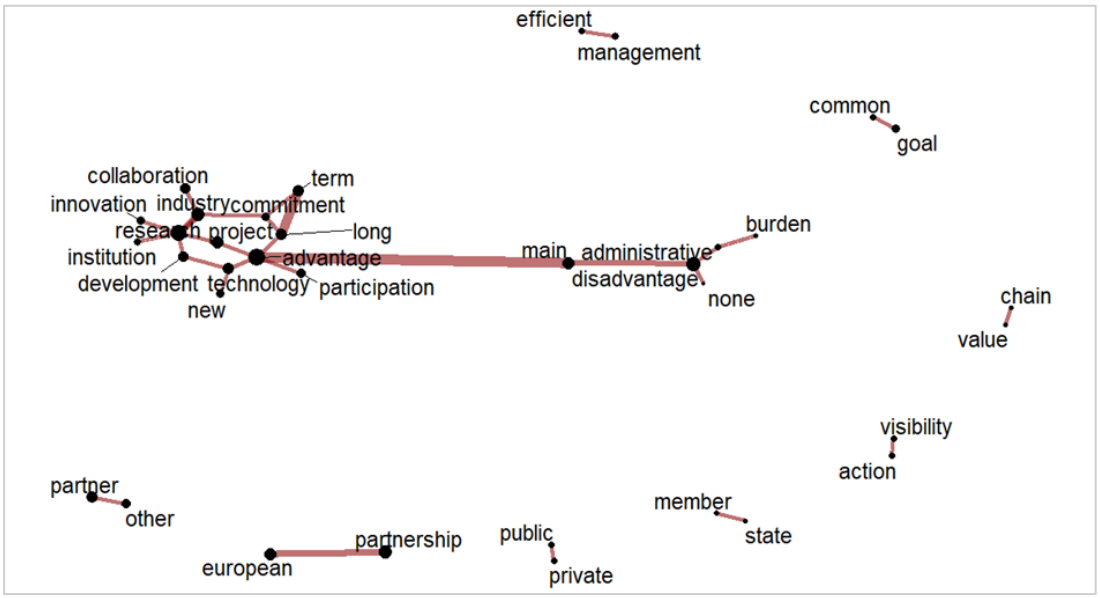
- The global positioning of Europe: outlining the role of global competition (including the role of technology), the importance of autonomy for Europe and the ability of Europe to act as a key player at the global level.
- The balance between policy objectives and private sector interests: Partnerships are regarded as an instrument to secure industry commitments due to the stability required for investments that serve policy goals.
- The importance of the transition between research and innovation (implementing research results in the market).
- The importance of multidisciplinary, and specifically cross-sectoral/cross-partnership collaboration.
- The importance of the long-term commitment of a wide range of relevant stakeholders.

Next to that many respondents as part of campaigns stressed the importance of the energy transition, hydrogen and the environment, which corresponds to the high number of respondents that provided answers to the candidate European Partnership specific questions related to these topics.

Main advantages and disadvantages of Institutionalised European Partnerships

In the next question, respondents were asked to outline the main advantages and disadvantages of participation in an Institutionalised European Partnership (as a partner) under Horizon Europe. This was an open question for which a keyword analysis was used (see the main results in Figure 16). As can be observed, the advantages mentioned focus on the development of technology, overall collaboration between industry and research institutions, and the long-term commitment. Disadvantages mentioned are mainly administrative burdens.

Figure 16: What would you see as main advantages and disadvantages of participation in an Institutionalised European Partnership (as a partner) under Horizon Europe? (non-campaign replies) Aggregation of responses of all candidate initiatives, 30 most common co-occurring keywords (N=1551)



When asked about the main advantages and disadvantages of participation in an Institutionalised European Partnership (as a partner) under Horizon Europe, the following points were mentioned by respondents that are classified as campaigns:

Advantages:

- Long term commitment, stability, and visibility in financial, legal, and strategic terms
- Participation of wide range of relevant stakeholders in an ecosystem (large/small business, academics, researchers, experts, etc.)
- Complementarity with other (policy) initiatives at all levels EU, national, regional
- Efficient and effective coordination and management
- High leverage of (public) funds
- Some innovative field require high levels of international coordination/standardisation (at EU/global level)
- Ability to scale up technology (in terms of TRL) through collaboration
- Networking between members
- Direct communication with EU and national authorities

Disadvantages:

- Slow processes
- System complexity
- Continuous openness to new players should be better supported as new participants often bring in new ideas/technologies that are important for innovation
- Lower funding percentage compared to regular Horizon Europe projects
- Cash contributions
- Administrative burdens

- Potential for IPR constraints

Relevance of EU level efforts to address problems in selected areas of Partnerships

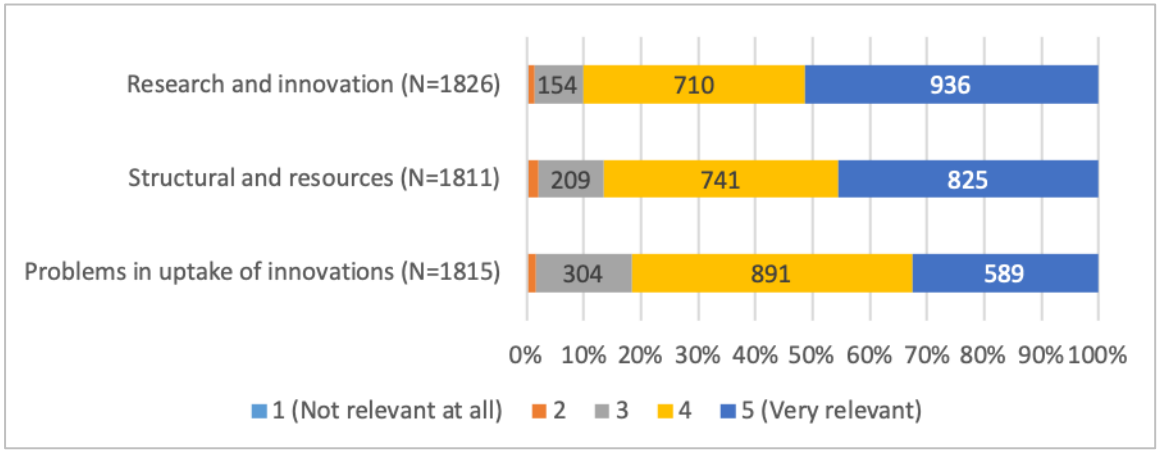
Per candidate European Partnership respondents were asked to rate the relevance of partnership specific problems in three main areas: Research and innovation problems, Structural and resource problems and Problems in the uptake of innovations. To aggregate results the average of the responses on partnership specific problems were calculated.

As presented in Figure 17, research and innovation related problems were rated as most relevant by the respondents across all candidate initiatives, followed by structural and resources problems and problems in the uptake of innovations. Overall, all three areas were deemed (very) relevant across the partnerships, as more than 80% of respondents found these challenges (very) relevant.

Only minor differences were found between the main stakeholder categories of respondents. Research and innovation problems were found slightly more relevant by academic/research institutions, yet slight less relevant by large companies and SMEs. Structural and resource problems were indicated as slightly more relevant by NGOs, but slightly less by academic/research institutions. While both NGOs and public authorities find it slightly more relevant to address problems in uptake of innovation than other respondents.

The views of citizens, both EU and non-EU citizens, are the same as other respondents (no significant differences). Respondents that are/were directly involved in a current/preceding partnership (Horizon 2020 or Framework Programme 7) find, however, the uptake of innovation problems slightly more relevant than other respondents.

Figure 17: To what extent do you think this is relevant for research and innovation efforts at EU level to address the following problems in relation to the candidate partnership in question? (non-campaign replies) Aggregation of responses of all candidate initiatives

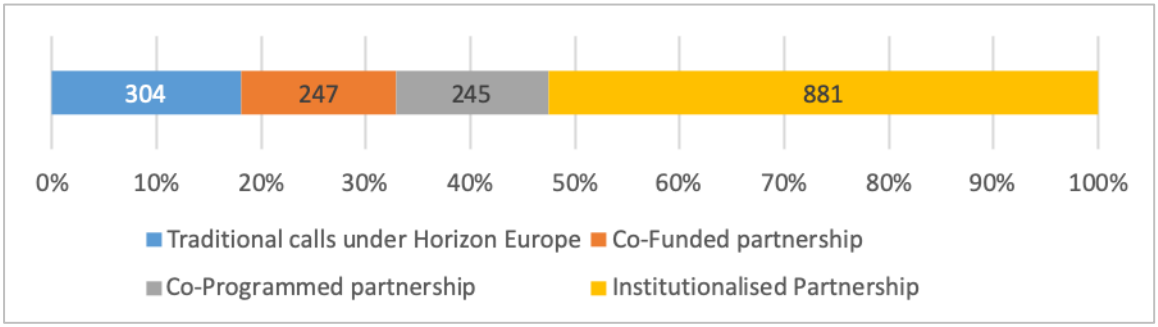


Horizon Europe mode of intervention to address problems

After providing their views on the relevance of problems, respondents were asked to indicate how these challenges could be addressed through Horizon Europe intervention. As shown in Figure 18, just over 50% of all respondents indicated that institutionalised partnerships were the best fitting intervention, however, relatively strong differences between stakeholder categories were found. The intervention of institutionalised partnerships was indicated more by business associations and large companies, but less by academic/research institutions and SMEs. While academic/research institutions valued traditional calls more often, this was not the case for business associations, large companies and public authorities. Public authorities indicated a co-programmed intervention more often than other respondents. Citizens, compared to other respondents,

indicated slightly less often that institutionalised partnerships were the best fitting intervention. Respondents that are/were directly involved in a current/preceding partnership, however, selected the institutionalised partnership intervention in far higher numbers (nearly 70%).

Figure 18: In your view, how should the specific challenges described above be addressed through Horizon Europe intervention? (non-campaign replies) Aggregation of responses of all candidate initiatives



When asked to reflect on their answers, respondents that pointed to the need for using the "institutionalised partnership" intervention mentioned the long-term commitment of collaboration, a common and ambitious R&I strategy as well as the overall collaboration between industry and research institutions. Respondents that referred to possible approaches, sometimes gave examples of good experiences in with other interventions:

- Traditional calls because of their flexibility and integration of a wide range of actors, as long as the evaluation panels do not deviate from the policy premier. This was mentioned by 94 participants, evenly distributed across companies (25 of them), academics (26) and EU citizens (25).
- Co-funded partnership, as a mechanism to ensure that all participants take the effort seriously, while allowing business partnerships to develop. This approach was deemed suitable based on previous experiences with ERANETs. This was raised by 84 participants, 36 of them academic respondents, 18 companies and 16 EU citizens.
- Co-programmed partnerships to tackle the need to promote and engage more intensively with the private sector. This was mentioned by 97 participants, most of them companies (34), followed by academics (22), business associations (15) and EU citizens (11).

Relevance of a set of elements and activities to ensure that the proposed European Partnership would meet its objectives

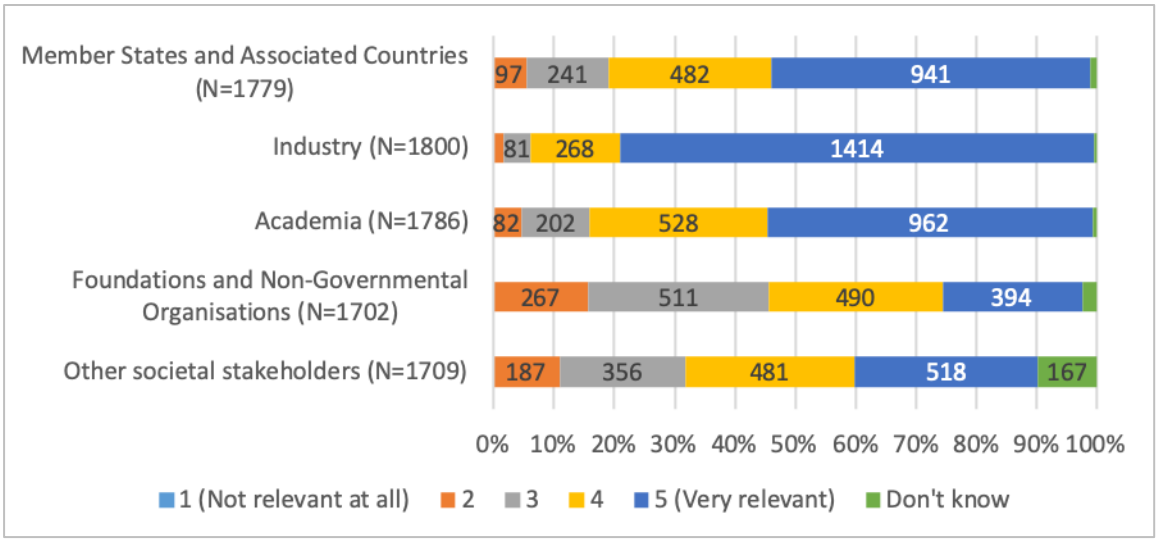
Setting joint long-term agendas

Respondents were asked how relevant it is for the proposed European Partnerships to meet their objectives to have a strong involvement of specific stakeholder groups in setting joint long-term agenda. As presented in Figure 19, collectively all respondents see stakeholders from industry as the most relevant, followed by academia and governments (Member States and Associated Countries). The involvement of foundations and NGOs as well as other societal stakeholders were, however, still found to be (very) relevant by more than 50% of the respondents.

When looking at the differences between the answers of the main stakeholder categories only minor differences could be found. Overall, it could be observed that most respondents indicated the stakeholder group they belong to themselves or that represent them as relevant to involve. Academic/research institutions find it more relevant to involve academia and less relevant to involve industry when compared to other respondents. The other way around large companies, SMEs and business associations find it more relevant to involve industry and less relevant to involve academia, Member States and Associated

Countries and NGOs. The involvement of Member States and Associated Countries was found more relevant by academic/research institutions and public authorities. NGOs also values their own involvement and those of other societal stakeholders more than other respondents. The views of citizens also show a slightly higher relevance for foundations and NGOs. This is less so the case for respondents that are/were directly involved in a current/preceding partnership (most predominantly companies and academia).

Figure 19: In your view, how relevant are the following elements and activities to ensure that the proposed European Partnership would meet its objectives - Setting joint long-term agenda with strong involvement of: (non-campaign replies) Aggregation of responses of all candidate initiatives

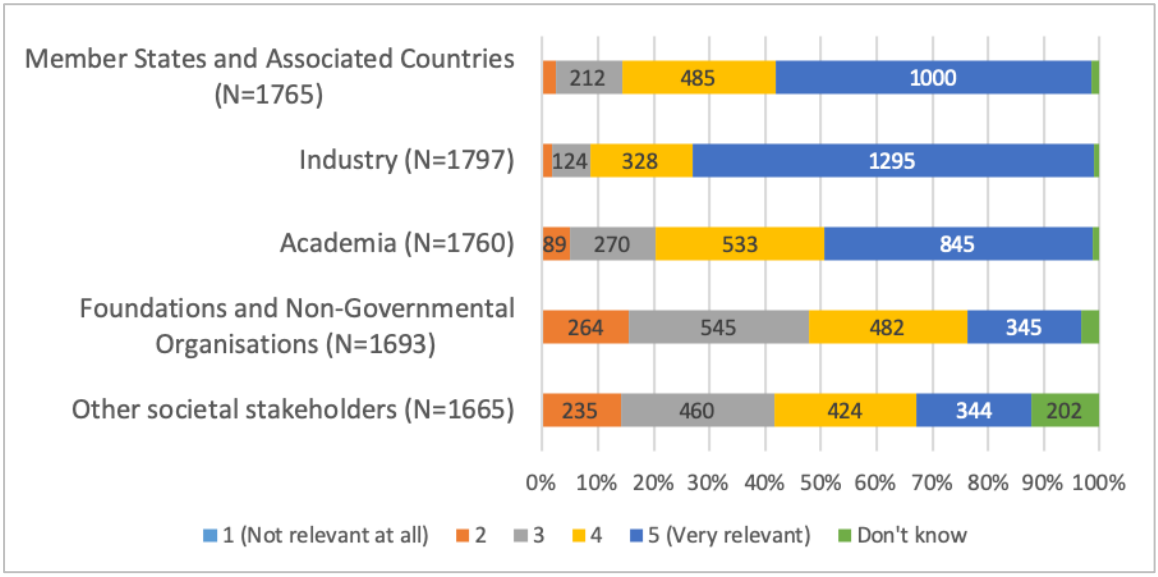


Pooling and leveraging resources through coordination, alignment and integration with stakeholders

Respondents were also asked how relevant it is for the proposed European Partnership to meet its objectives to pool and leverage resources (financial, infrastructure, in-kind expertise, etc.) through coordination, alignment and integration with specific groups of stakeholders. As shown in Figure 20 - similarly as for the previous questions-, respondents also see stakeholders from industry as the most relevant, followed by academia and governments (Member States and Associated Countries). The involvement of foundations and NGOs as well as other societal stakeholders are also still found to be (very) relevant for more than 50% of the respondents.

Similarly as described for the question on setting joint long-term agendas, most stakeholder categories valued their own involvement higher than other respondents – although also here differences between stakeholder categories were minor. As such, academic/research institutions see the relevance of academia higher, while large companies, SMEs and business association indicated a lower relevance of academia than other respondents. Similarly, these private sector stakeholders valued the relevance of industry higher than others while valuing the relevance of NGOs and other societal stakeholders less. NGOs value themselves and other societal stakeholders however higher than other respondents, and also public authorities indicated a higher relevance for Member States and Associated Countries then other respondents. Citizens mainly put more emphasis on the role of NGOs and other societal stakeholders then other respondents.

Figure 20: In your view, how relevant are the following elements and activities to ensure that the proposed European Partnership would meet its objectives – Pooling and leveraging resources (financial, infrastructure, in-kind expertise, etc.) through coordination, alignment and integration with: (non-campaign replies) Aggregation of responses of all candidate initiatives

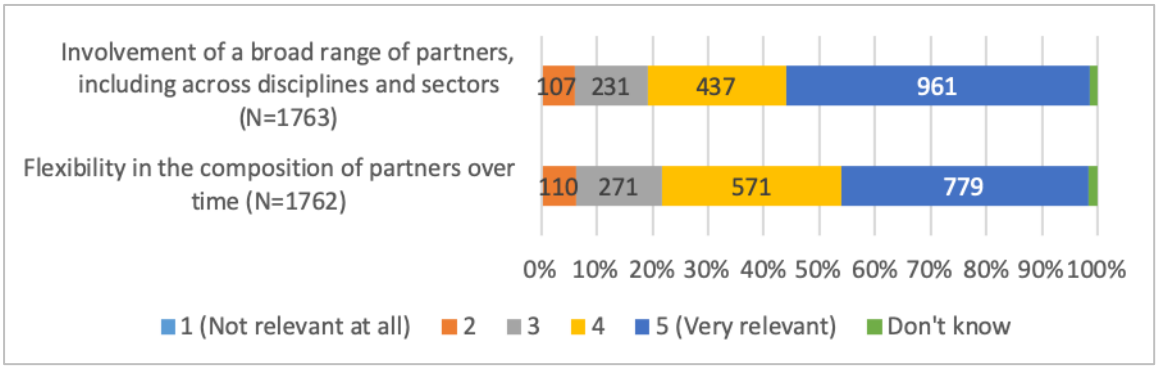


Composition of the partnerships

Regarding the composition of the partnership most respondents indicated that for the proposed European Partnership to meet its objectives the composition of partners needs to be flexible over time and that a broad range of partners, including across disciplines and sectors, should be involved (see Figure 21).

When comparing stakeholder groups only minor differences were found. Academic/research institutions and public authorities found the involvement of a broad range of partners and flexibility in the composition of partners over time slightly more relevant than other respondents, while large companies found both less relevant. SMEs mainly found the flexibility in the composition of partners over time less relevant than other respondents, while no significant differences were found regarding the involvement of a broad range of partners. Citizens provided a similar response to non-citizens. Respondents that are/were directly involved in a current/preceding partnership, when compared to respondents not involved in a current/preceding partnership, indicated a slightly lower relevance of the involvement of a broad range of partners and flexibility in the composition of partners over time.

Figure 21: In your view, how relevant are the following elements and activities to ensure that the proposed European Partnership would meet its objectives – Partnership composition (non-campaign replies) Aggregation of responses of all candidate initiatives

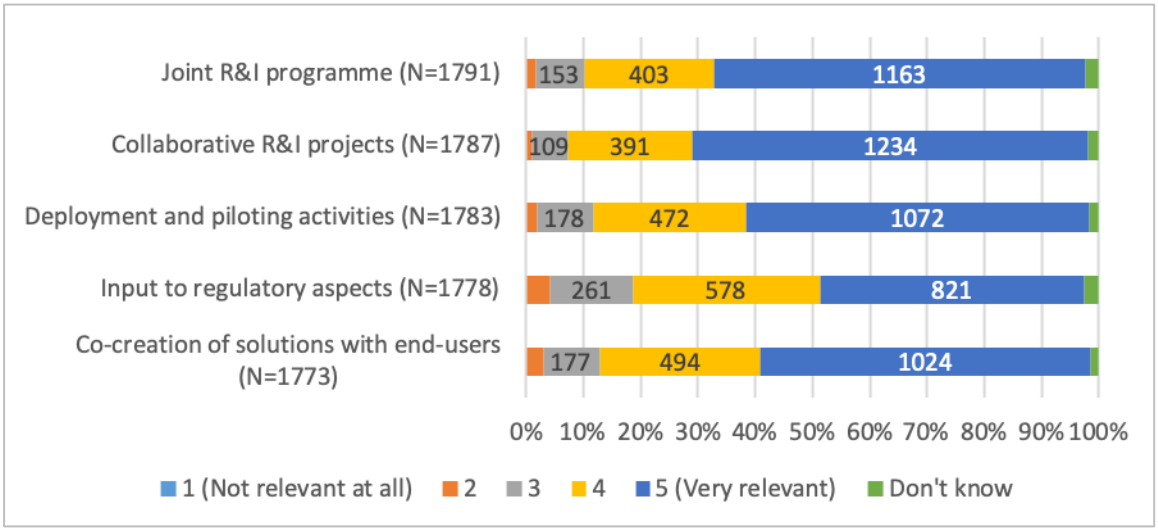


Implementation of activities

Most respondents indicated that implementing activities like a joint R&I programme, collaborative R&I projects, deployment and piloting activities, providing input to regulatory aspects and the co-creation of solutions with end-users are all (very) relevant for the partnerships to be able to meet its objectives (see Figure 22).

Minor differences were found between the main stakeholder categories, the differences found were in line with their profile. As such, academic/research institutions found joint R&I programme & collaborative R&I projects slightly more relevant and deployment and piloting activities, input to regulatory aspects and co-creation with end-users slightly less relevant than other respondents. For SMEs an opposite pattern is shown. Large companies, however, also found collaborative R&I projects slightly more relevant than other respondents, as well as input to regulatory aspects. The views of citizens are similar to non-citizens. Respondents that are/were directly involved in a current/preceding partnership, when compared to respondents not involved in a current/preceding partnership, show a slightly higher relevance across all activities shown in Figure 22.

Figure 22: In your view, how relevant are the following elements and activities to ensure that the proposed European Partnership would meet its objectives – Implementing the following activities (non-campaign replies) Aggregation of responses of all candidate initiatives



Relevance of setting up a legal structure (funding body) for the candidate European Partnerships to achieve improvements

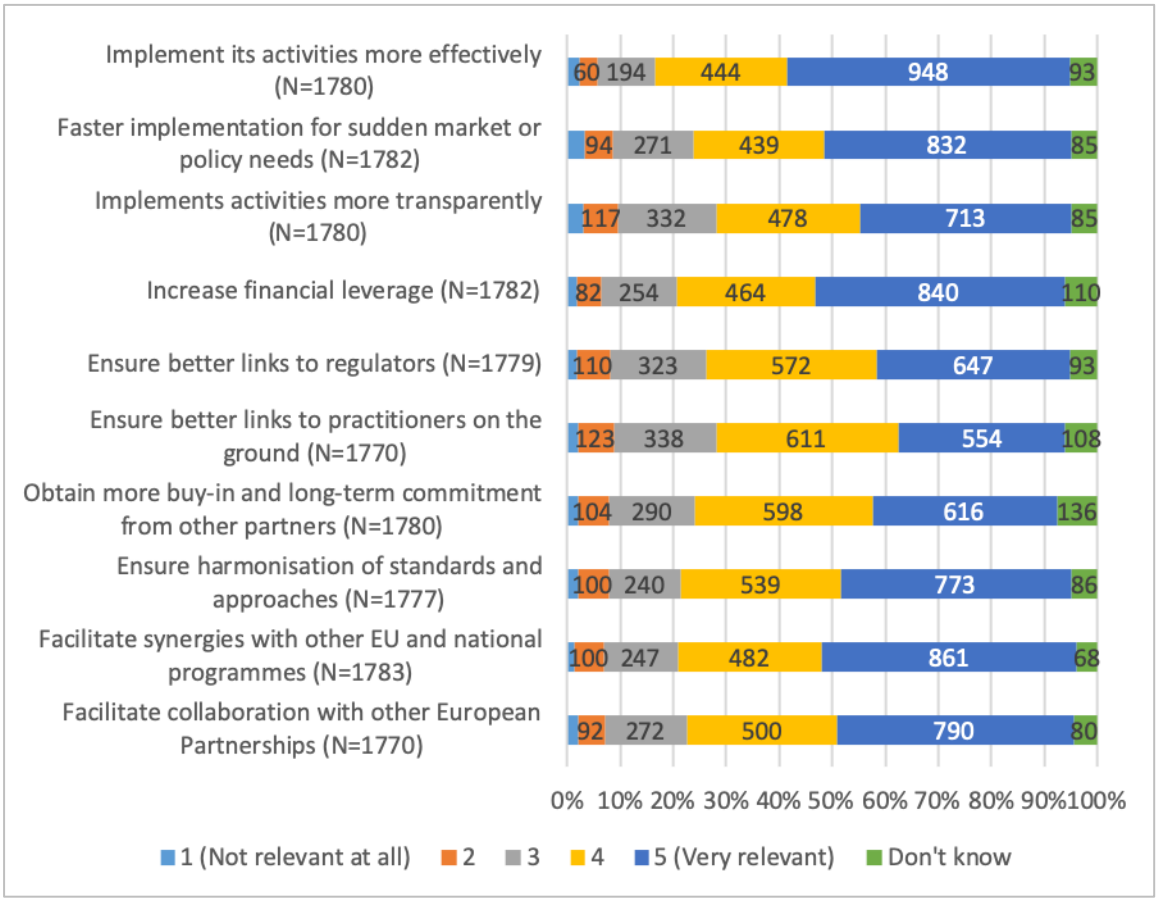
Respondents were then asked to reflect on the relevance of setting up a legal structure (funding body) for achieving a set of improvements, as presented in Figure 23. In general, 70%-80% of respondents find a legal structure (very) relevant for these activities. The legal structure was found most relevant for implementing activities in a more effective way and least relevant for ensuring a better link to practitioners on the ground, however differences are small.

When comparing the main stakeholder categories we found minor differences. Academic/research institutions indicated a slightly lower relevance for transparency, better links to regulators as well as obtaining the buy-in and long-term commitment of other partners. SMEs also indicated a lower relevance regarding obtaining the buy-in and long-term commitment of other partners. Large companies showed a slightly higher relevance for implementing activities effectively, ensure better links to regulators, obtaining the buy-in and long-term commitment of other partners, synergies with other EU/MS programmes and collaboration with other EU partnerships than other open consultation respondents. NGOs find it slightly more relevant to implement activities faster for sudden market or

policy needs. Public authorities, however, find it slightly less relevant to facilitate collaboration with other European Partnerships than other respondents.

The views of citizens show a slightly lower relevance for a legal structure in relation to implementing activities in an effective way. Quite different results are shown for respondents that are/were directly involved in a current/preceding partnership when compared to respondents not involved in a current/preceding partnership, they indicated a higher relevance across all elements presented in Figure 23.

Figure 23: In your view, how relevant is to set up a specific legal structure (funding body) for the candidate European Partnership to achieve the following? (non-campaign replies) Aggregation of responses of all candidate initiatives



Scope and coverage of the candidate European Partnerships based on their inception impact assessments

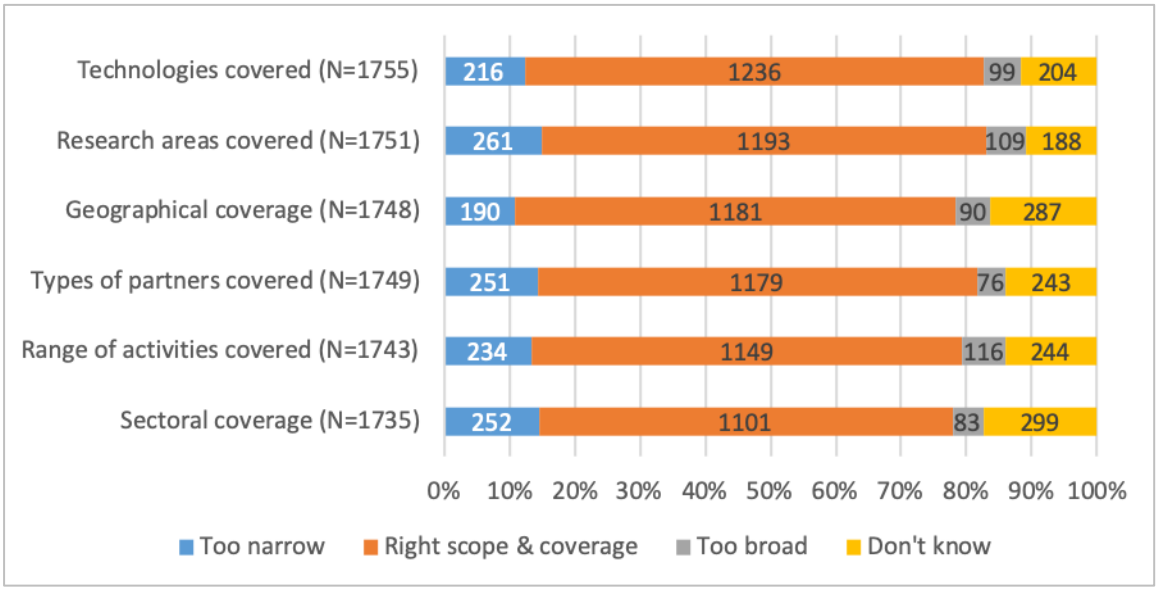
The response regarding the scope and coverage for the partnerships, based on inception impact assessments, shows that the large majority feels like the scope and coverage initially proposed in the inception impact assessments is correct. Figure 24 shows the results. However, about 11% to 15% of the respondents indicated the scope and coverage to be too narrow. About 11%-17% of respondents answered "Don't know". In the open answers respondents mostly reflected on specific aspects of the geographical and sectoral scope and coverage of the specific candidate European Partnerships, no overall lessons could be extracted.

Overall, differences between the main stakeholder categories were found to be minor. Academic/research institutions indicated slightly more often that the research area was "too narrow" then other respondents. SMEs on the other hand indicated slightly more often that the research area and the geographical coverage were "too broad". NGOs and public authorities, however, found the geographical coverage slightly more often "too narrow" when compared to other respondents. Large companies found the range of activities

slightly more often "too broad" and the sectoral focus slightly more often "too narrow" when compared to other respondents.

The views of citizens are the same as for other respondents. Most notably, respondents that are/were directly involved in a current/preceding partnership, when compared to respondents not involved in a current/preceding partnership, more often indicated that the candidate institutionalised European Partnership have the "right scope & coverage".

Figure 24: What is your view on the scope and coverage proposed for this candidate institutionalised European Partnership, based on its inception impact assessment? (non-campaign replies) Aggregation of responses of all candidate initiatives



Scope for rationalisation and alignment of candidate European Partnerships with other initiatives

When asked whether it would be possible to rationalise a specific candidate European Institutionalised Partnership and its activities, and/or to better link with other comparable initiatives, nearly two thirds of respondents answered "Yes" (1000, or 62.15%), while over one third answered "No" (609, or 37.85%). Nearly no differences were found between the main stakeholder categories, only large companies and SMEs indicated slightly more often "Yes" in comparison to other respondents.

The views of citizens are the same as for other respondents. Respondents that are/were directly involved in a current/preceding partnership, indicated "No" more often, the balance is about 50/50 between "Yes" and "No" for this group.

In the open responses respondents often referred to specific similar/comparable and complementary initiatives discussing the link with a specific candidate European Partnership, no overall lessons could be extracted, but more detailed results can be found in the partnership specific result sections.

Relevance of European Partnerships to deliver targeted scientific, economic/technological and societal impacts

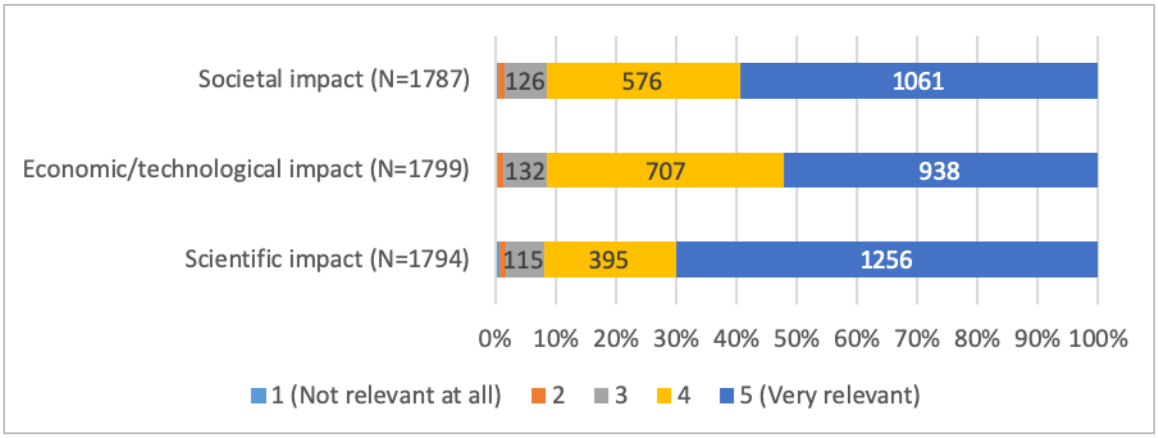
Finally, respondents were asked to rate the relevance of partnership specific impacts in three main areas: Societal impacts, Economic/technological impacts and Scientific impacts. To aggregate results the average of the responses on partnership specific impacts were calculated.

As presented in Figure 25, overall, all three areas were deemed (very) relevant across the candidate partnerships. Scientific impact was indicated as the most relevant impact, more than 90% of respondents indicated that these impacts were (very) relevant.

Only minor difference between stakeholder groups were found. Academic/research institutions found scientific impacts slightly more relevant, while large companies found economic and technological impacts slightly more relevant than other respondents. NGOs found societal impact slightly more relevant, while SMEs found this slightly less important.

Citizens, both EU and non-EU citizens, did not a significantly different view when compared to other respondents. Respondents that are/were directly involved in a current/preceding partnership find all impacts slightly more relevant than other respondents.

Figure 25: In your view, how relevant is it for the candidate European Institutionalised Partnership to deliver on the following impacts? (non-campaign replies) Aggregation of responses of all candidate initiatives



B.6 Responses to the open public consultation for the candidate partnership "Clean hydrogen"

B.6.1 Introduction

This section outlines the results of the Open Public Consultation for the candidate European Partnership on Circular bio-based Europe: sustainable innovation for new local value from waste and biomass. The section outlines the following:

- Results on general questions, segregated for this candidate European Partnership:
  - Views on the needs of the future European Partnerships under Horizon Europe
  - Views on the advantages and disadvantages of participation in an Institutionalised European Partnership
- Results on specific questions for this candidate European Partnership:
  - Relevance of research and innovation efforts at the EU level to address problems
  - Views on Horizon Europe interventions to address these problems
  - Views on the relevance of elements and activities in: setting a joint long-term agenda; pooling and leveraging resources; partnership composition; implementation of activities.
  - Views on setting up a specific legal structure (funding body)
  - Views on the proposed scope and coverage of this candidate European Partnership
  - Views on the alignment of the European Partnership with other initiatives
  - Relevance of this candidate European Partnership to deliver impacts

B.6.2 Characteristics of respondents

There are 382 respondents who have answered (part of) the consultation for the Clean Hydrogen Partnership. Of these respondents, 76 (19.90%) were citizens. The largest group of respondents were businesses and academic and research institutions, each with 123 respondents (32.20%). There were 21 respondents from business associations (5.50%). The other respondents were representatives of public authorities (13, 3.4%), non-

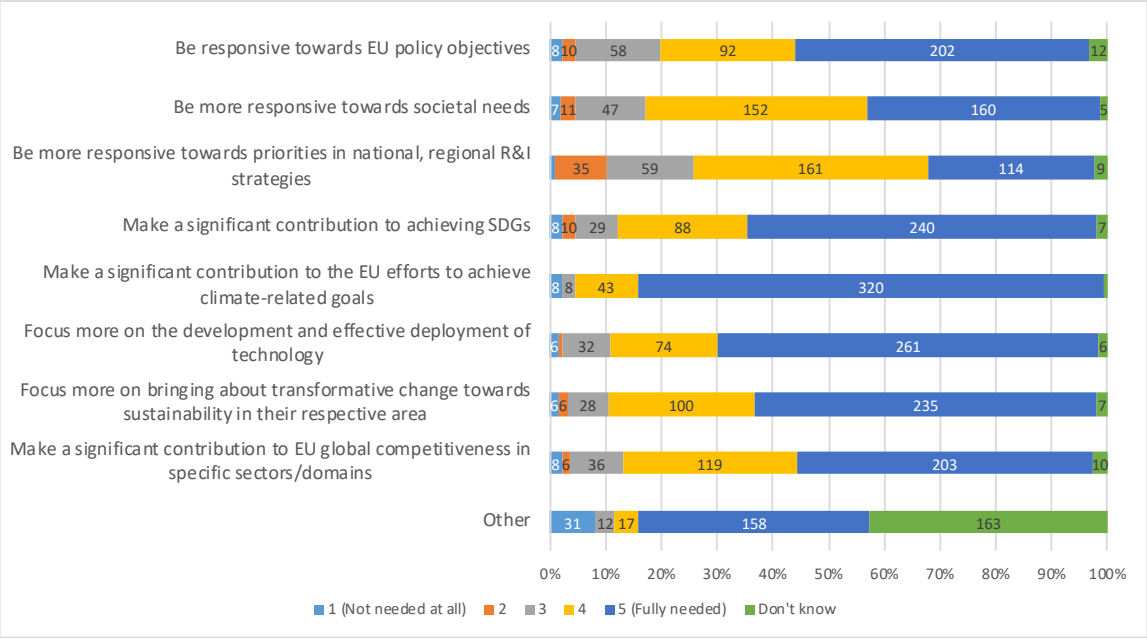
governmental organisations (8, 2.09%) or other (17, 4.45%). Over three-quarters of respondents, namely 293 (76.70%), have been involved in the on-going research and innovation framework programme, of which 245 respondents (83.62%) were directly involved in a partnership under Horizon 2020 or its predecessor, the Seventh Framework Programme.

B.6.3 Characteristics of future candidate European Partnerships – as viewed by respondents to the Clean Hydrogen initiative

At the beginning of the consultation, the respondents of this partnership were asked to indicate their views of the needs of the future European Partnerships under Horizon Europe. All 382 respondents answered this question. Overall, the respondents indicated that many of the options presented were very relevant. The option where most respondents agreed that they were very relevant was in making a significant contribution to the EU efforts to achieve climate-related goals (320 respondents, 83.77%), which is not surprising considering the focus of this partnership. The option where the fewest respondents indicated that improvements were very relevant was in being more responsive towards priorities in national and/or regional R&I strategies (114, 29.84%).

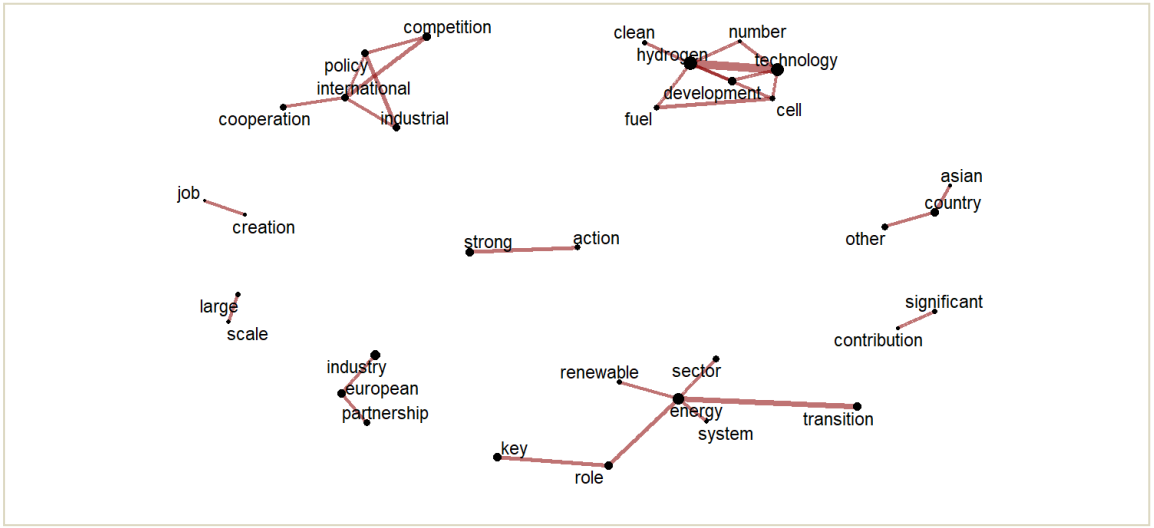
No statistical differences were found between the views of citizens and other respondents.

Figure 26: Views of the respondents in regard to the needs of future European Partnerships under Horizon Europe (N=382)



The respondents also had the option to indicate other needs. The results of the analysis resulted in the graph shown in Figure 27 demonstrating the co-occurrences of keywords. The results show that respondents have indicated needs around international policy and industrial competition as well as the development of technology for clean hydrogen fuels and cells.

Figure 27: Assessment of open answers of other needs, 30 most common co-occurring keywords (N=193)



The main trends in the answers to the open question "To what extent do you think that the future European Partnerships under Horizon Europe need to:... Other" (mainly from the Academic/research institution, the Company/business organisations and Business associations, but also from the majority of the NGOs, public authorities and the citizens) can be quoted :

- Industrial policy and international competition: There is now a worldwide consensus that hydrogen technology will play a key role in the energy transition. This calls for international cooperation, but also generates fierce competition with well-established countries like Japan, Korea and the US, and now China invests huge amounts in hydrogen technology to replicate the leadership it achieved in batteries and PV. EU industry still leads in a number of hydrogen technologies, but without strong action it will be overtaken
- Job creation

And to a minor extent, but mentioned by several respondents :

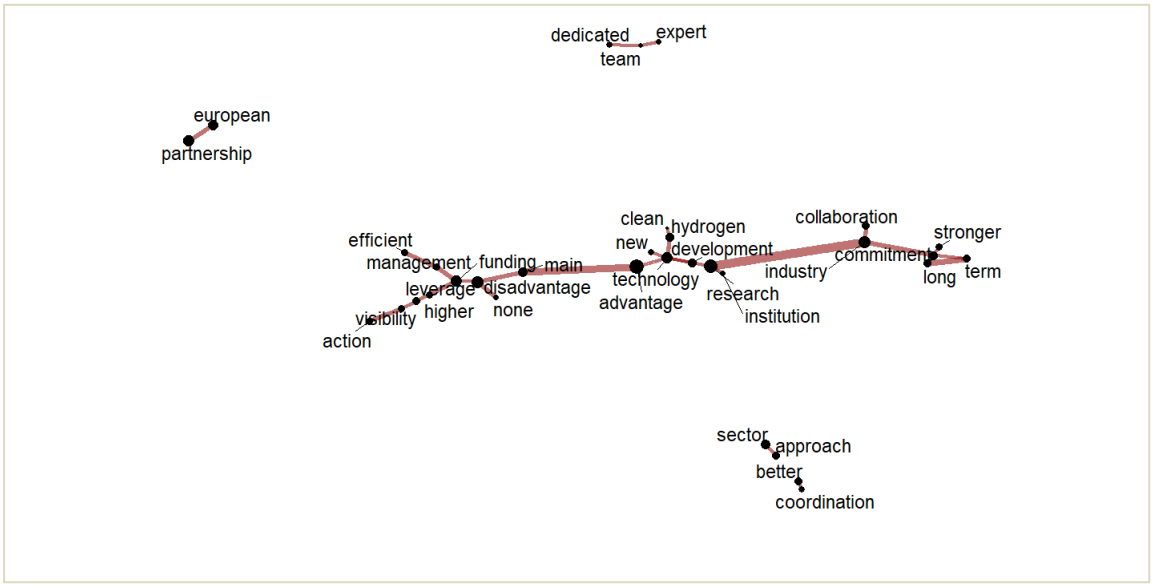
- Strengthen competitiveness of SMEs by fostering their participation in EU-RI
- Establish financial support programmes dealing with the commercialisation of hydrogen technologies and products. The challenge is also to better articulate different sources of funding and to make sure that all the stakeholders of the value chain are involved
- Systematically address environmental, social and societal impacts and the emerging risks associated with new technologies to identify and address the keys to success and the failure factors of technology deployment and associated benefits
- Better involve regional authorities in the activities of the partnerships: regional authorities support large scale demonstration projects and offer a direct link to the end-users of the innovative solutions developed within the partnerships (important issue for the public authorities, but also addressed by other stakeholders)
- respond to needs of EU-13 countries
- Lower the administrative burden on partners
- In order to decarbonise our energy demand, we need a strong, pro-active EU to provide a European hydrogen infrastructure. The EU should take leadership to build this infrastructure and enable industry to both provide and use a clean and potential independent energy source as hydrogen

- Renewable Hydrogen will play a role in future industrial applications. The developments and the industrialisation need to be supported to be competitive on a worldwide market.

B.6.4 Main advantages and disadvantages of Institutionalised European Partnerships

The respondents were asked what they perceived to be the main advantages and disadvantages of participation in an Institutionalised European Partnership (as a partner) under Horizon Europe. The results of the analysis resulted in the graph shown in Figure 28 demonstrating the co-occurrences of keywords. This analysis shows that the respondents mentioned long term commitment and collaboration in relation to advantages and efficient management and higher visibility in relation to disadvantages.

Figure 28: Assessment of open answers with advantages and disadvantages of participation in an Institutionalised European Partnership, 30 most common co-occurring keywords (N=329)



The major trend of the answers to the open question "What do you see as main advantages and disadvantages of participation in an Institutionalised European Partnership (as a partner) under Horizon Europe?" (mainly from the Academic/research institution, the Company/business organisations and Business associations, but also from the NGOs, public authorities and citizens) can be quoted :

- Long-term planning and stronger commitment of industry, research and EU
- Pooling of resources and the collaboration between industry and academia creates a greater leverage and forces the research to focus even more on solving technological challenges
- Creation of an ecosystem dedicated to engagement
- Collaboration between industry and research leads to synergies and easier scale-up of technologies
- Higher flexibility of the management to adapt to technological and societal changes
- More coordination within the industry
- Better efficiency management of EU funding
- Concrete action : demonstrator, POC, ecosystem, offer
- Higher visibility of EU action
- PO with an expert and dedicated team; More efficient management

- Transparency in funding instruments and procedures
- The large majority are considering there are no disadvantages

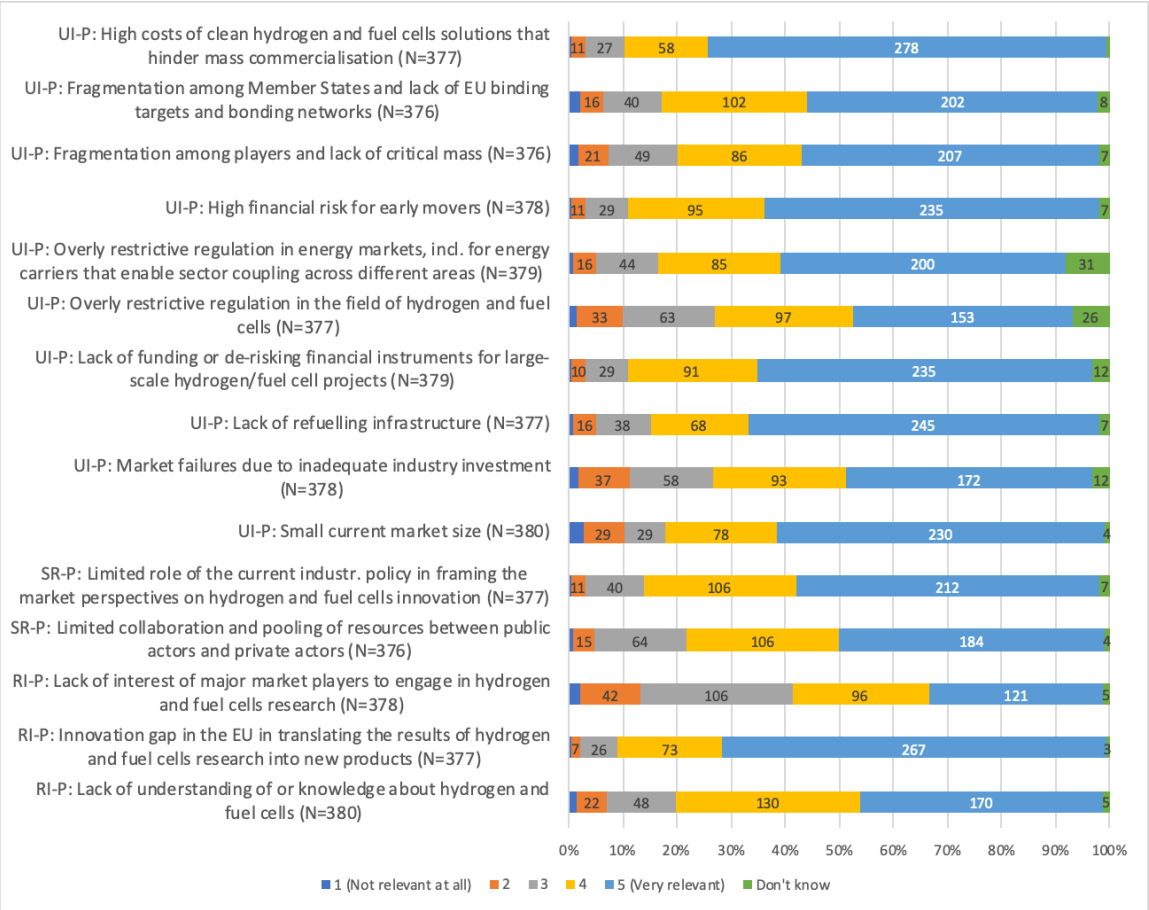
And to a minor extent, but mentioned by several respondents :

- From an administrative point of view, simplified rules and higher funding rates under H2020 have made participation more attractive
- Better alignment of different activities
- Being at the pulse of scientific community
- A significant advantage is having a well-defined program with clear objectives, specific KPIs, useful program publications, review days event and strong support and assistance from the FCH JU office in managing projects and resolving specific issues
- Where research focuses more on solving technological challenges, it is both an advantage and disadvantage: on one hand the European industry becomes more competitive, but on the other hand less emphasis is put on basic research that can be used in future technologies (risk highlighted by 1 respondent)
- Knowledge sharing and research informed advancements of the relevant technologies
- This cross-country and multi-stakeholder approach will trigger the allocation of resources in the most appropriate way to foster quick business development and market creation
- Disadvantages: excess of bureaucracy that consumes many energies which are subtracted from research and development. This excess of bureaucracy keeps the small research and industrial entities away. In this way, good ideas encounter a lot of difficulties to get to be financed. An excess of bureaucracy does not mean greater control and efficiency of the system
- Good communication and collaboration among nations (Hydrogen cannot be realised by one nation)
- European experience feedback for third countries and development of training and awareness (mainly from NGOs)
- 2 disadvantages from EU-citizens: additional cost, compared to topics covered by "regular" EU calls the Partnership will lead to a further reduction of the available funding for R&D compared to Demo
- Regions should be fully associated to the definition of the partnerships' activities (raised mainly by the public authorities)

B.6.5 Relevance of EU level efforts to address problems in relation to the Clean Hydrogen field

In the consultation, respondents were asked to provide their view on the relevancy of research and innovation efforts at EU level to address the following problems in relation to hydrogen and fuel cells, specifically on three types of problems: problems in uptake of hydrogen and fuel cells innovations (UI-P), structural and resource problems (SR-P) and research and innovations problems (RI-P). In Figure 29, the responses to these answers are presented.

Figure 29: Views of respondents on relevance of research and innovation efforts at the EU level to address problems in relation to hydrogen and fuel cells



With regard to the uptake in innovation problems, 278 respondents have indicated that it is very relevant for research and innovation efforts at the EU level to address the problem of high costs of clean hydrogen and fuel cells solutions that hinder mass commercialisation until serial production is achieved, factoring-in economies of scale (73.74%). Regarding the problems in uptake of innovation, market failures due to inadequate industry investment received the fewest responses as being "very relevant" (45.50%), while most respondents still indicated that they view this issue as very relevant.

There were only two structural and resource problems that the respondents were asked to reflect on. Of these, the limited role of current industrial policy in framing the market perspectives related to hydrogen and fuel cells innovation received the most responses as being very relevant, namely 60% of responses.

The research and innovation problem that most respondents have indicated as "very relevant" is the innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products, with 267 respondents choosing this answer (70.82%). The problem that was least often indicated as very relevant is also a research and innovation problem, namely: lack of interest of major market players to engage in hydrogen and fuel cells research (121, 32.01%).

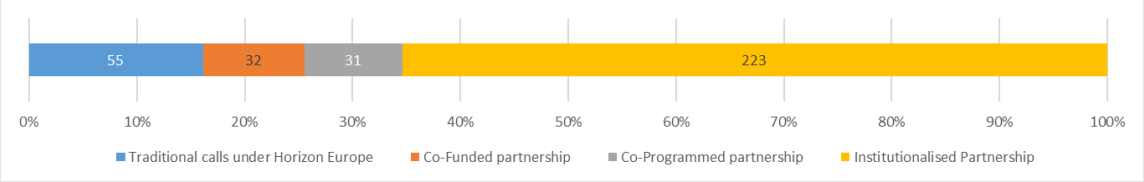
No statistical differences were found between the views of citizens and other respondents. Respondents that are/were involved in a current/preceding partnership (Horizon 2020 or Framework Programme 7) found all uptake in innovation problems to be more relevant than other respondents.

B.6.6 Horizon Europe mode of intervention to address problems

After providing their views on the relevance of problems, respondents were asked to indicate how these challenges could be addressed through Horizon Europe intervention. As shown in Figure 30, just over 65% of respondents indicated that institutionalised partnerships were the best fitting intervention.

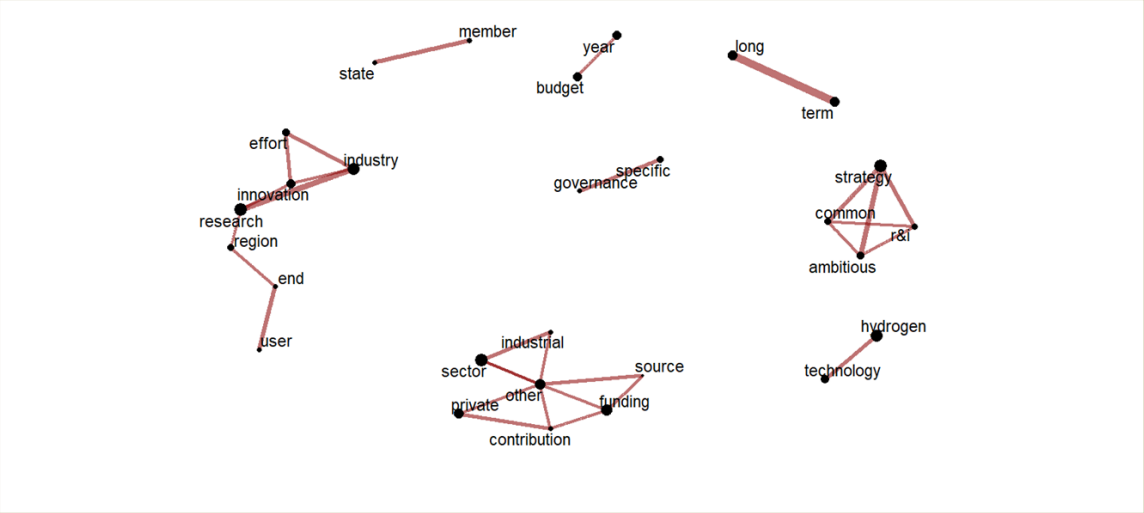
No statistical differences were found between the views of citizens and other respondents.

Figure 30: Assessment of Horizon Europe intervention



The respondents were asked to briefly explain their answers to the question above. People who stated that an institutionalised partnership was the best fitting answer, mentioned long term, research and innovation and private funding (Figure 31). Respondents who did not select the institutionalised partnership as their preferred intervention (N=110) indicated traditional calls, large scale projects and a wide range of stakeholders (not pictured).

Figure 31: Assessment of open answers to explain their choice institutionalised partnership in the assessment of the Horizon Europe intervention, 30 most common co-occurring keywords (N=190)



The major trend of the answers to the open question "In your view, how should the specific challenges described above be addressed through Horizon Europe intervention? Please explain briefly your choice" (mainly from the Academic/research institutions, the Company/business organisations and Business associations, but also from the NGOs, public authorities and citizens) can be quoted :

- IPPP is unique in structuring of an FCH R&D environment
- IPPP with its specific governance and 7 year budget is more effective in helping the sector to define and implement a common long-term R&I strategy
- IPPP is unique in coordinating innovation efforts beyond industry and research with regions, end-users, Members States, other industrial sectors, other EU programmes
- IPPP superior in leveraging EU funding with private contributions and other funding sources
- IPPP office offers an efficient, knowledgeable and dedicated team

- Hydrogen needs more push than the "classic" approach
- Structuring of an R&I FCH ecosystem
- Coordination of non-industry innovation efforts

And to a minor extent, but mentioned by several respondents :

- Hydrogen and Fuel Cells, after overcoming the current demonstration phase, would require a strong PPP to move to the commercialisation phase
- Industry in fact needs a stable framework to secure its investments in the sector, which is something that a long-term Institutionalised Partnership would be best fit to provide
- The sector is an infant, with a wide range of business and research organisations active at various levels with hydrogen technologies, but usually with no first mover advantage, which is proceeding in a policy vacuum. So it badly needs to be held together and a critical mass of RD&I to be established that far exceeds that which has been achieved to date. An institutionalised Partnership is the best and most appropriate way to do this
- Might be the best approach towards a fast deployment of hydrogen infrastructure (especially to achieve long distance zero emission travel)
- It is also the option most likely to attract industry due to the independent character of the partnership
- This tool must also be able to deal with essential cross-cutting issues such as environmental impact or safety independently of any competitive logic
- high added value (structuring of the sector, knowledge management and expertise, coordination among key stakeholders in diversity of sectors, EU, national, regional, local actors)
- European Partnership as the most effective legal form to undertake the numerous challenges of the nearly-zero-carbon & renewable hydrogen economy (in terms of innovation, ecosystem, leverage of public & private finance) and foster transversality.
- It has the ability to implement a dedicated roadmap for Europe -- with holistic & cross-border approaches of the hydrogen economy, its applications & stakeholders (including outside Europe)
- Only an institutional partnership can respond to the complex problem definition which precludes clean hydrogen technologies
- Long term visibility enabling the sector to join the coordination of the strategy hence increasing their commitment, creation of a focal point at EU level for the development and deployment of the technology

B.6.7 Relevance of a set of elements and activities to ensure that the proposed European Partnership would meet its objectives

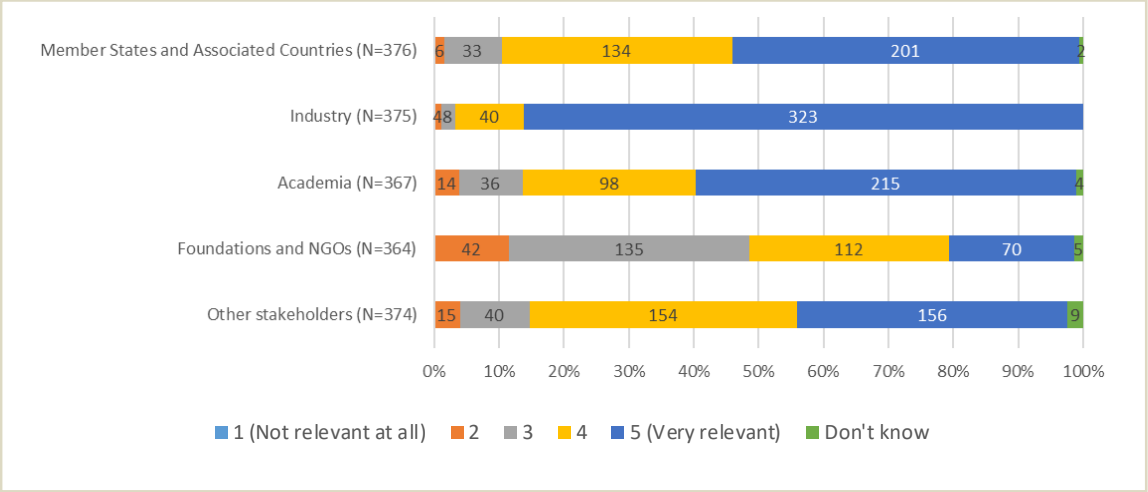
Setting joint long-term agendas

Respondents were asked how relevant the involvement of actors is in setting a joint long-term agenda to ensure that the proposed European Partnership would meet its objectives (see Figure 32). The highest number of respondents indicated that the involvement of Industry is very relevant (323 respondents or 86.13%). A majority of respondents also indicated that the involvement of Academia (215, 58.58%) and Member States and Associated Countries (201, 53.46%) is very relevant. With regard to Foundations and NGOs, respondents indicated that their involvement is seen as less relevant, with only 70

(19.23%) respondents indicating that their involvement is very relevant and a 135 respondents (37.09%) indicating that their involvement is a 3 on the relevance scale.

No statistical differences were found between the views of citizens and other respondents.

Figure 32: Views of respondents on relevance of actors in setting joint long-term agenda

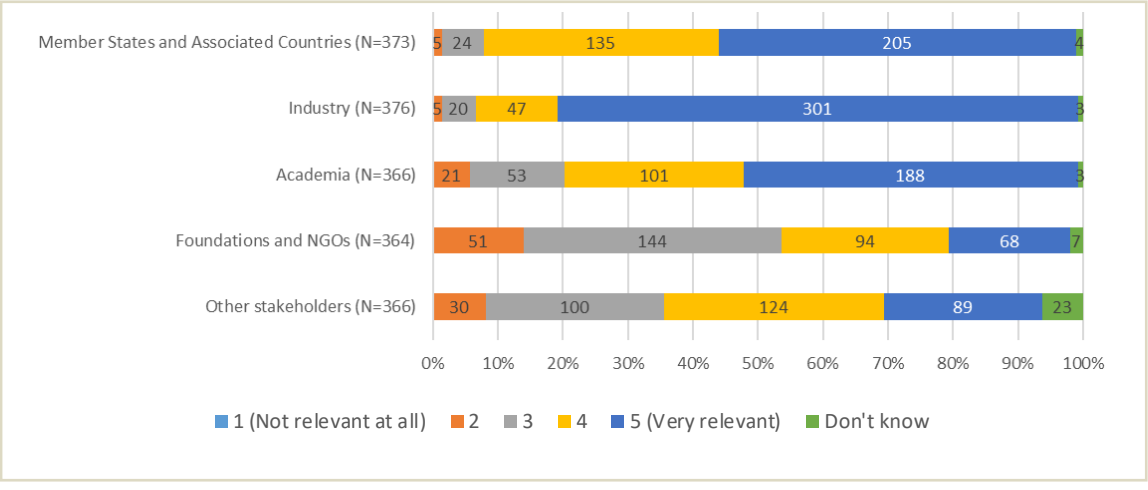


Relevance of elements and activities in pooling and leveraging resources

With respect to the relevance of actors in pooling and leveraging resources (such as financial, infrastructure, in-kind expertise etc.) to meet Partnership objectives, the patterns in the views are similar. First, 301 respondents (80.05%) indicated that industry was very relevant, which is much higher than for any of the other stakeholders; 205 (54.14%) respondents felt that Member States and Associated Countries were very relevant and 188 (51.37%) of respondents indicated that Academia were very relevant. Foundations and other stakeholders were deemed less relevant, since only 68 (18.68%) and 89 (24.31%) respondents, respectively, indicated that these stakeholders were very relevant. No respondents indicated that any of the categories was "Not relevant at all".

No statistical differences were found between the views of citizens and other respondents.

Figure 33: Views of respondents on relevance of actors for pooling and leveraging resources



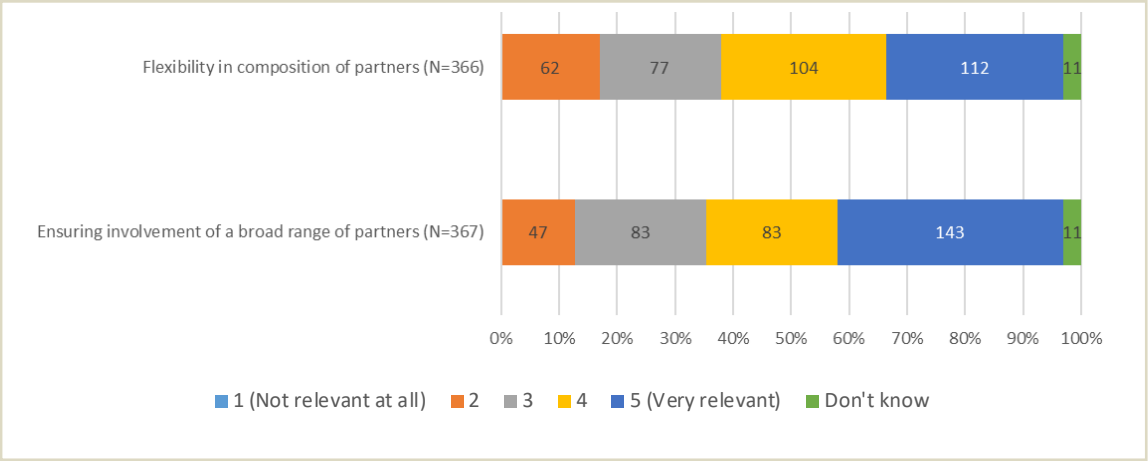
Relevance of elements and activities for the partnership composition

Respondents were asked about the relevance of Partnership composition, such as flexibility in the composition of partners over time and involvement of a broad range of partners (including across disciplines and sectors), to reach Partnership objectives. As can be seen in Figure 34, ensuring involvement of a broad range of partners has more responses as

being 'very relevant' (143, 38.96%) than the flexibility in the composition of partners (112, 30.60%). Almost 17% (16.94%) of respondents indicated that flexibility in composition is worth a 2 on the relevancy scale, for ensuring involvement of a broad range of partners--this is the case for 47 respondents (12.81).

No statistical differences were found between the views of citizens and other respondents. Respondents that are/were directly involved in a current/preceding partnership found flexibility in the composition of partners to be less relevant.

Figure 34: Views of respondents on relevance of partnership composition elements

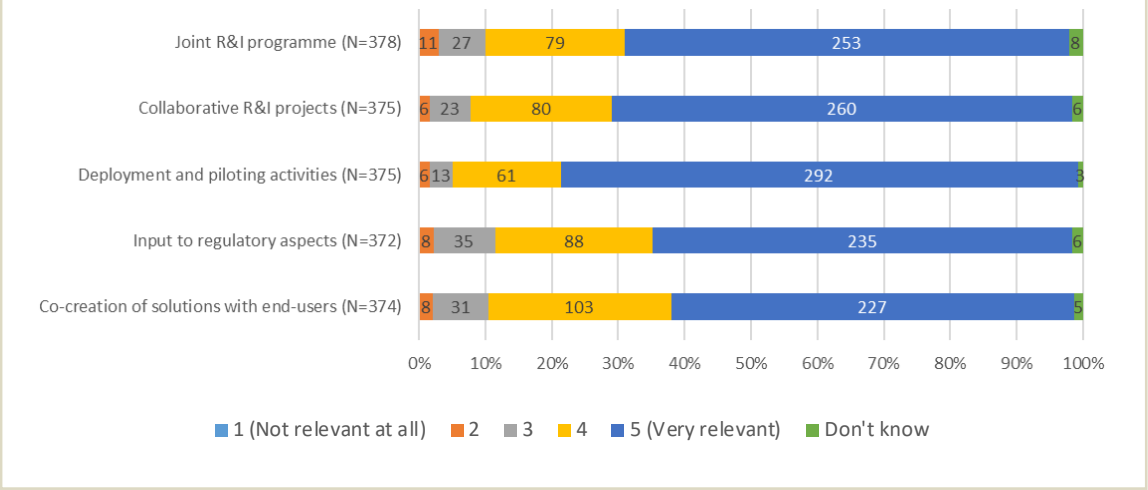


Relevance of implementation of activities

Respondents were asked to provide opinions on the relevance of implementation of several activities for meeting objectives of the Clean Hydrogen Partnership. Among the activities listed were joint R&D programme, collaborative R&D projects, deployment and piloting activities, input to regulatory aspects and co-creation of solutions with end-users. Out of 375 respondents, 292 (77.86%) indicated that deployment and piloting activities are very relevant to ensure that the Partnership would meet its objectives. For all the other options, the majority (over 60%) of all respondents have indicated that these are very relevant. See Figure 35.

No statistical differences were found between the views of citizens and other respondents. Respondents that are/were directly involved in a current/preceding partnership found most activities slightly more relevant than other respondents.

Figure 35: Views of respondents on relevance of implementation of the following activities

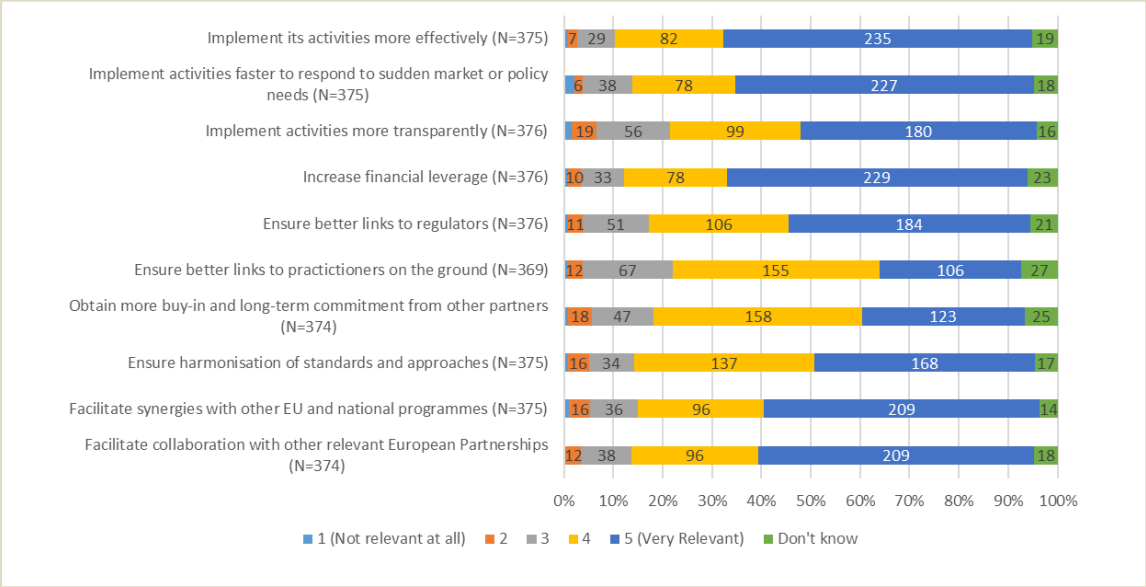


B.6.8 Relevance of setting up a legal structure (funding body) for the candidate European Partnerships to achieve improvements

Respondents were also asked to assess the relevance of a specific legal structure (funding body) for the candidate European Partnership to achieve several activities. According to Figure 36, respondents indicated that it was very relevant to set up a specific legal structure for the partnership to achieve a more effective implementation of activities (235, 62.67%) and to increase financial leverage (229, 60.90%). Although 'to ensure better links to practitioners on the ground' and 'to obtain more buy-in and long term commitment from other partners' have received the least responses as being "very relevant" (106 and 123 respectively), they have received the most responses scored as 4 . This could indicate that they are still seen as important, just slightly less important than the other options.

No statistical differences were found between the views of citizens and other respondents. Respondents that are/were directly involved in a current/preceding partnership found a legal structure slightly more relevant for most objectives.

Figure 36: Views of respondents on relevance of a specific legal structure

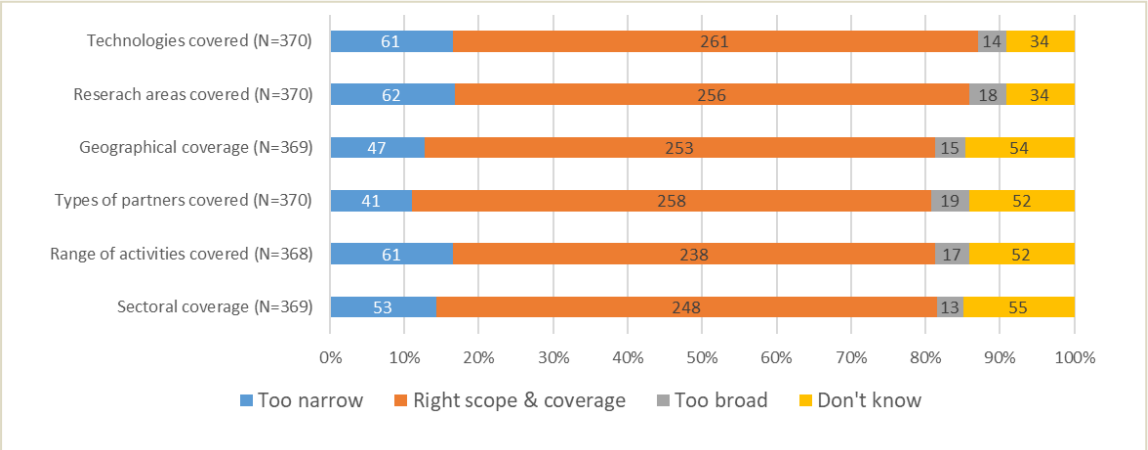


B.6.9 Scope and coverage of the candidate European Partnerships based on their inception impact assessments

Respondents were asked to assess the scope and coverage of the proposed Clean Hydrogen Partnership, based on its inception impact assessment. The clear majority of the respondents have indicated that the partnership has the right scope and coverage across all areas. The respondents have been the most positive with regard to technologies covered, where 261 respondents (70.54%) have indicated the partnership has the right scope and coverage. The respondents who have indicated that the scope and coverage are not right, have indicated that it was too narrow more often than they viewed it as too broad.

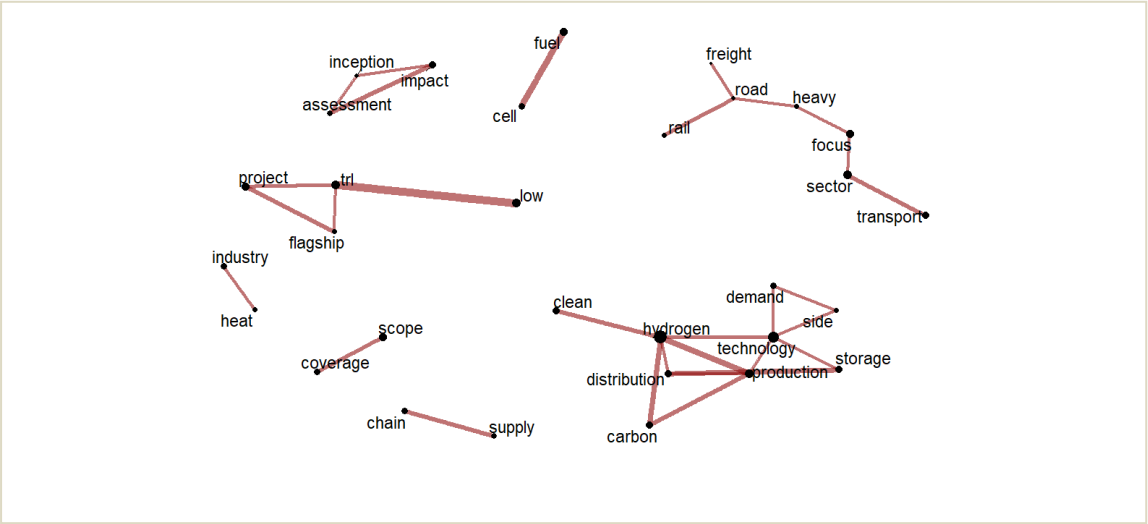
No statistical differences were found between the views of citizens and other respondents.

Figure 37: Views of respondents on the scope and coverage proposed for the Clean Hydrogen partnership



Aside from this multiple choice question, the respondents were also asked to provide any comment that they may have on the proposed scope and coverage for this candidate Institutionalised Partnership. The keyword analysis used for open questions resulted in the graph shown in Figure 38. This analysis shows that the respondents used this question to talk about low TRL levels, flagship projects and the production and distribution of hydrogen technology.

Figure 38: Assessment of open answers with regard to the proposed scope and coverage for this candidate Institutionalised Partnership, 30 most common co-occurring keywords (N=133)



The major trends in the responses to the open question "What is your view on the scope and coverage proposed for this candidate institutionalised European Partnership, based on its inception impact assessment? Please provide any comment you may have on the proposed scope and coverage for this candidate Institutionalised Partnership:" (mainly from the Academic/research institution, the Company/business organisations and Business associations, but also from the NGOs, public authorities and citizens) can be quoted :

- Inception impact assessment says little. PPP info sheet for Member States included excellent description with three pillars: 1. Near-zero carbon hydrogen production + 2. Technologies distribution and storage + 3. Demand side technologies for (a) power and/or heat in industry, (b) and building and (c) in the transport sector with a focus on heavy duty road freight, rail, and water-borne. Programme to include adapted instruments to support low TRL, flagship projects and EU supply chain
- More activities to bring technology to the market would be desirable

- The main challenges are: to reduce costs by significant advances in production and storage technologies, to broaden the uses and thus the market so as to pool the costs and benefits of research and obtain scale effects, to deal with the issues cross-cutting environmental impacts, safety and acceptability for new users
- What is important is to tackle holistically the hydrogen ecosystem, from production of clean hydrogen, distribution and storage to end-use. All applications within this system should be covered (to varying degrees

And to a minor extent, but mentioned by several respondents :

- For sector coupling, the stronger involvement of utilities would be appreciated
- Further reduce focus on mobility. More focus on green hydrogen for a sustainable society
- The scope and coverage of the proposed Clean Hydrogen institutionalised partner appears very appropriate and well-focused
- Hydrogen as a unique CO2 neutral energy carrier should be implemented in multiple sectors such as heating, cooling, electricity, transport. Sector coupling is essential whereby hydrogen technologies should be integrated into the future power grids, i.e. into smart grids. Flexibility trading, demand side management, engaging the majority of users via ICT solutions is essential
- Either a broad scope with a much larger budget allocation is needed, or strategically the scope should be narrowed. If not there is a danger of too much diversity/dilution
- Focus on maximising intrinsically clean and renewable solutions and by rapidly increasing scale and volume of application facilitating economic feasibility much faster
- Ensure large-scale flagship projects bringing solutions to the market. For industrial applications, H2 is important for steel, and conversion to ammonia as an intermediate product used in the chemical sector, including fertilisers, household products and in manufacturing
- If this partnership is only focused on R&I, FCH will not achieve market entry. Funding for large scale deployment is critical. We have created a big hype and we will not deliver. A different system that proves the commitment of large industries is essential, see the case of an EU vehicle OEM (Daimler): they have not delivered and no consequences after receiving lots of EU money and controlling the agenda. Most impacts below depend on large-scale deployments, not on the R&I partnership. Products are ready
- Regional authorities should be added to the list of partners proposed in the Inception impact assessment.
- Focus on how to integrate hydrogen with industrial GHG reduction
- For one research centre, it should be focused on high TRL
- R&D funds should prioritise aspects related to infrastructure since hydrogen needs an appropriate infrastructure to connect production to consumption. As such, European gas infrastructure have a major role to play in developing the hydrogen economy and integrating hydrogen into the Internal Energy Market
- Breakthrough seems mandatory for the future of hydrogen technology
- Should focus on green hydrogen from renewables. Improves energy independence and self-supply, local, regional and national energy flexibility

- Three public authorities suggest doubling the Horizon Europe contribution to the Clean Hydrogen budget (€1.2 billion compared to €600 million for the FCH 2 JU) in order to ensure a just transition covering all EU regions

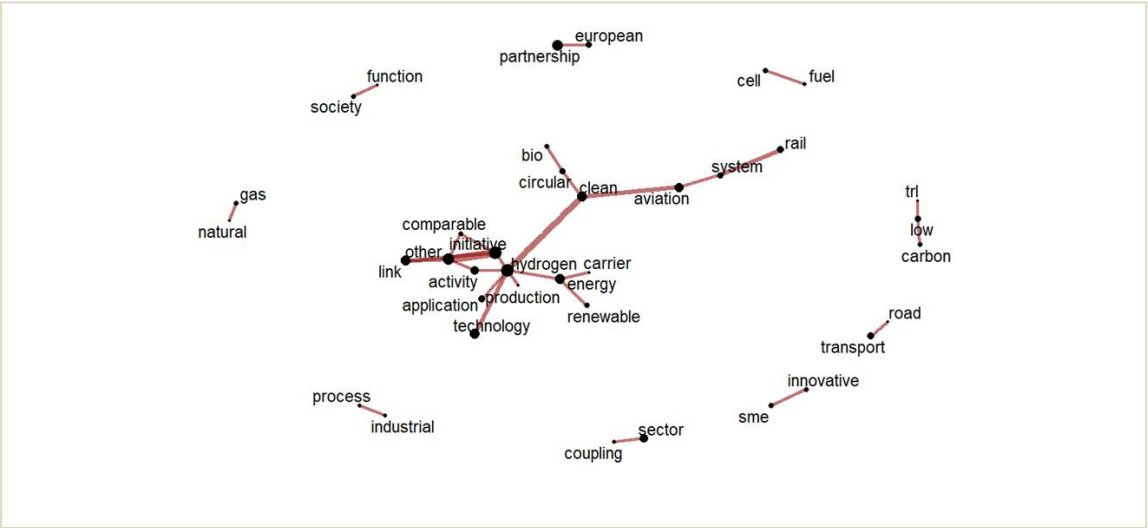
B.6.10 Scope for rationalisation and alignment of candidate European Partnerships with other initiatives

The respondents were also asked if they thought it would be possible to rationalise the candidate European Institutionalised Partnership and its activities, and/or to better link it with other comparable initiatives. 165 respondents (48.53%) have indicated that they think this is the case.

No statistical differences were found between views of citizens and other respondents.

The respondents who answered affirmatively were asked with which other comparable initiatives it could be linked. The results of the analysis resulted in the graph shown in Figure 39 showing the co-occurrences of keywords. The results show that respondents think that the initiative could be linked with other comparable initiatives related to hydrogen, renewable energy and the application of hydrogen as well as clean aviation and rail systems.

Figure 39: Assessment of open answers on the question on which other comparable initiatives it could be linked with, 30 most common co-occurring keywords (N=110)



Some of the answers received to the open question "In your view, would it be possible to rationalise the candidate European Institutionalised Partnership and its activities, and//or to better link it with other comparable initiatives? (Yes) Please explain why? Which other comparable initiatives could it be linked with?" (mainly from the Academic/research institution, the Company/business organisations and Business associations, but also from the public authorities) can be quoted :

- The FCH sector should have its proper dedicated partnership, as H2 is by itself an energy carrier for many sectors; but it should be linked to as many initiatives as possible, at least with Clean Aviation, Transforming Europe's rail system, Circular bio-based Europe (sustainable innovation for new local value from waste and biomass), Safe and automated Road Transport, Innovative SMEs, Clean and Low Carbon Steel, Clean and Circular Industry
- No added value can be seen in merging Clean Hydrogen with any other partnerships as hydrogen is an energy vector overarching many energy and transport sectors. It would just lead to dilute the development efforts of a strong European ecosystem. Nevertheless, focused cooperation with a number of proposed partnerships in particular

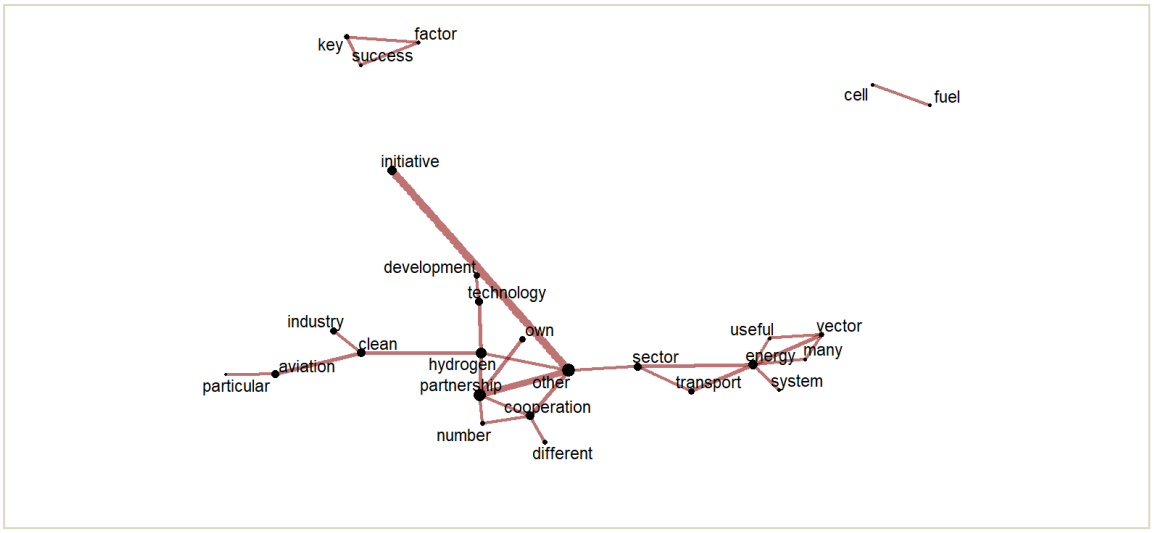
are relevant: Clean Aviation, Transforming EU Rail, Waterborne, Built Environment, Clean and LowCarbon Steel, Clean and Circular Industry, Batteries and 2Zero

- To envision the total energy spectrum, i.e. electricity and heat, in order to avoid competition between heat pumps and hydrogen storage devices, it would be good to harmonise subsidies/legislation covering both
- Hydrogen activities could, for the sake of realising sector coupling, be somehow coupled/linked with actions for (a) clean / renewable power, (b) hydrogen chemical industry (ammonia, fertilisers, oil refining) and (c) heat (domestic and industrial heating
- We shall ensure not having undefined research zones, for instance development of materials for energy application, is it better to propose this in Material Calls or in FCH-JU calls?
- There is still a need for close and targeted focus of activities to succeed in the industrialisation of hydrogen technologies
- It is recommended to link the Clean Hydrogen Partnership with the EERA Joint Programme on Fuel Cells and Hydrogen to ensure independent assessment of low-TRL needs and cross-links to other energy technologies, all covered within the EERA organisation. These have been partly formulated in the JP FCH Implementation Plan
- The future partnerships also improve the integration of EU regions in their activities – Need to better align practices towards regions

As a conclusion, the rationalisation was not interpreted as a merger with another field (being a partnership or not), but as way to increase synergies with other initiatives/partnerships. None of the respondents is advocating for a merger.

For the respondents who answered negatively on the previous question, the results of the analysis resulted in the graph in Figure 40 demonstrating the co-occurrences of keywords. The results show that respondents mention key success factors, other initiatives, other partnerships and the energy system and energy transport.

Figure 40: Assessment of open answers on the question why other comparable initiatives are not suitable to be linked, 30 most common co-occurring keywords (N=93)



Some of the answers received to the open question "In your view, would it be possible to rationalise the candidate European Institutionalised Partnership and its activities, and/or to better link it with other comparable initiatives? (No) Please explain why? Which other comparable initiatives could it be linked with?" (mainly from the Academic/research

institution, the Company/business organisations and Business associations, but also from the NGOs and citizens) can be quoted :

- No added value can be seen in merging Clean H2 with any other partnerships, as H2 is an energy vector useful for many energy and transport sectors.
- Not a black and white question. We believe that Hydrogen should have its proper partnership and there is no value in merging it with another partnership. It would increase complexity, lose the focus, which is key success factor of an IPPP, lead to a dilution of the focus on clean hydrogen and lead to dilute the development efforts of a strong European ecosystem. No added value can be seen in merging Clean Hydrogen with any other partnerships as hydrogen is an energy vector useful for many energy and transport sectors.
- Nevertheless, we value focussed cooperation with a number of partnerships in particular Clean Aviation, Transforming EU Rail, Waterborne, Built Environment, Clean and Low Carbon Steel, Clean and Circular Industry, Batteries and 2Zero
- Merging in other topics reduces the focus. Hydrogen is the key topic for a zero emission society and the global climate goal. Thus, in our view an own partnership is justified.

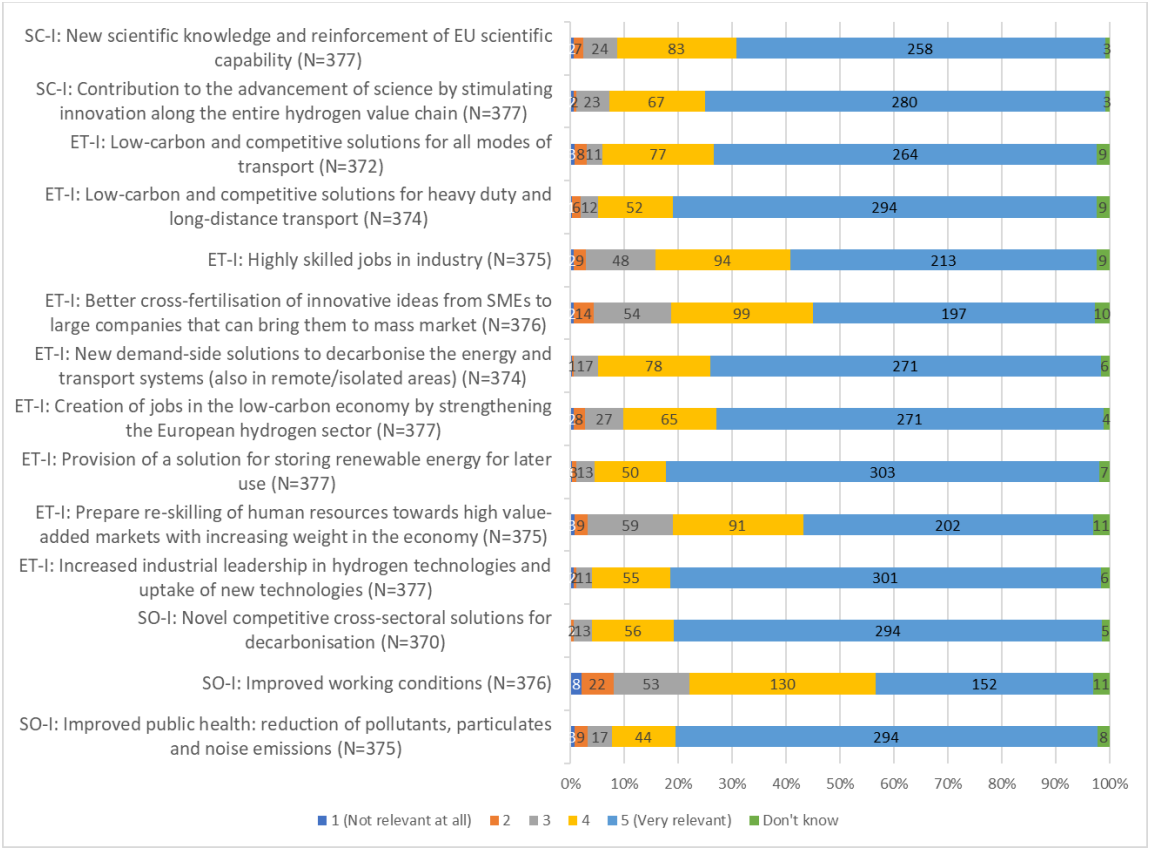
In conclusion, it is evident that these respondents are all very convinced that there is no added value in merging Clean Hydrogen with any other initiative/partnership.

B.6.11 Relevance of European Partnerships to deliver targeted scientific, economic/technological and societal impacts

Respondents were asked to assess the relevance of the candidate European Institutionalised Partnership to deliver on listed impacts. Based on Figure 41, among presented societal impacts, only the category "improved working conditions" has a relatively low number of respondents that consider that the Partnership would be 'very relevant' for this impact category. In other categories, around 80% of respondents consider that the Partnership would be 'very relevant' to deliver on those impacts. Similarly, of the listed economic/technological impacts, around 80% of respondents suggest that the Partnership would have a significant effect on/be 'very relevant' for increasing industrial leadership in hydrogen technologies and uptake of new technologies, for provision of a solution for storing renewable energy for later use, and for provision of low-carbon and competitive solutions for heavy duty and long-distance transport. In contrast, the least number of respondents, namely 197 out of 376 (52.39%), expect a significant impact of the candidate Partnership on better cross-fertilisation of innovative ideas from SMEs to large companies. Around 70% of respondents indicated that the Partnership will have a significant impact on all listed categories in the area of science.

No statistical differences were found between the views of citizens and other respondents. Respondents that are/were involved in a current/preceding partnership found most economic/technological and scientific impacts more relevant than other respondents.

Figure 41: Views of respondents on the relevance of the candidate European Institutionalised Partnership to various impacts



B.6.12 Summary of campaigns results for this specific initiative

Five campaigns were identified among respondents that provided answers for the current candidate Partnership:

- campaign #1 includes 57 respondents
- campaign #2 includes 25 respondents
- campaign #7 includes 18 respondents
- campaign #9 includes 13 respondents
- campaign #11 includes 9 respondents

Table 24: Overview of responses of the first campaign (campaign #1) (N=57)

Question category	Summary of responses
Research and innovation problems	The answer category "Innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products" was assessed as 'very relevant' by all respondents. Other categories have mixed and lower scores on average.
Structural and resource problems	With exception of three respondents, all respondents gave a high score (5 'very relevant') for both answer categories.
Problems in uptake of digital innovations	Across all answer categories, most respondents selected the option 5 'very relevant'.
Preferred Horizon Europe intervention	Institutionalised Partnership was selected by all respondents. When respondents were asked to explain their choice, all of them used the following quote: *"IPPP with its specific governance and 7 year budget enables the sector to define and*

Question category	Summary of responses
	implement a common ambitious R&I strategy. IPPP unique in coordinating innovation effort beyond industry and research with regions, end-users, members states, other industrial sectors, other EU programmes. IPPP superior in leveraging EU funding with private contributions and other funding sources".
Relevance of actors for setting join long-term agenda	A higher number of respondents consider that the involvement of industry and academia is 'very relevant'. Foundations and NGOs received the lowest score (3.21), on average.
Relevance of actors for pooling and leveraging resources	A higher number of respondents consider that the involvement of industry and academia is 'very relevant'. Foundations and NGOs received the lowest score (3.30), on average.
Partnership composition	Both categories received a relatively low score (between 2 and 3) on average.
Implementation of activities	Across all categories, the majority of respondents indicated that listed activities are 'very relevant'.
Relevance of the legal structure	On average, across all categories, respondents indicated that the legal structure would be 'very relevant'. The exceptions include the following categories "ensure better links to practitioners on the ground", "obtain more buy-in and long-term commitment from other partners" and "ensure harmonisation of standards and approaches". In these categories, on average, respondents gave a score of 4 'relevant'.
Scope and coverage of the candidate Partnership	Across all answer categories, most respondents consider that the elements are of right scope and coverage. Respondents were offered an opportunity to provide comments on the proposed scope and coverage of the Institutionalised Partnership. Most of them included the following quote: *"Inception impact assessment says little. PPP infosheet for member states included excellent description with three pillars: 1. Near-zero carbon hydrogen production + 2. Technologies distribution and storage + 3. Demand side technologies for (a) power and/or heat in industry, (b) and building and the (c) In the transport sector with focus on heavy duty road freight, rail, and water-borne. Programme to include adapted instruments to support low TRL, flagship projects and EU supply chain"*.
Rationalisation of the candidate Partnership and linking to other initiatives	Out of 57 respondents, 53 (92.98%) consider that it would not be possible to rationalise the candidate Partnership and its activities, and/or to better link it with other comparable initiatives. Respondents were asked to explain their answer. Regardless of the answer option, all of them inserted a following quote: *"We believe that Hydrogen should have its proper partnership and there is no value in merging it with another partnership. It would increase complexity and lose the focus which is key success factor of an IPPP. Nevertheless we value focussed cooperation with a number of partnerships in particular Clean Aviation, Transforming EU Rail, Waterborne, Built Environment, Clean and Low Carbon Steel, Clean and Circular Industry, Batteries and 2Zero"*.
Societal impact	Almost all respondents consider that the Partnership would be 'very relevant' to deliver on the following results: "improved public health, reduction of pollutants etc." and "novel competitive cross-solutions for decarbonisation". The other

Question category	Summary of responses
	suggested impact is considered 'relevant', on average, by respondents.
Economic/technological impact	Across all listed categories, majority of respondents indicated that impacts are 'very relevant'.
Scientific impact	Across all listed categories, majority of respondents indicated that impacts are 'very relevant'.

Table 25: Overview of responses of the first campaign (campaign #2) (N=25)

Question category	Summary of responses
Research and innovation problems	The answer category "Innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products" and "Lack of understanding of or knowledge about hydrogen and fuel cells" was assessed 'very relevant' by most respondents. The remaining answer category was considered 'relevant', on average.
Structural and resource problems	Both answer categories were considered 'relevant', on average, by respondents.
Problems in uptake of digital innovations	Most answer categories received a high score - 5 'very relevant' by most respondents. The lower average score is given to categories: "lack of funding and re-risking financial instruments etc.", "high financial risks for early movers" and "fragmentation among Member States and lack of EU binding targets and bonding networks".
Preferred Horizon Europe intervention	Institutionalised Partnership was selected by all respondents. When respondents were asked to explain their choice, all of them used the following quote: *"-Its specific governance and 7 years budget enables the sector to define and implement a common ambitious R&I strategy* *-Unique in structuring coordinating an FCH R&I ecosystem ensuring to focus R&I, in particular low TRL ones, on industry needs* *-Unique in coordinating innovation effort beyond industry and research with regions, end-users, Member States, other industrial sectors, other EU programmes.* *-Superior in leveraging EU funding with private contributions and other funding sources".*
Relevance of actors for setting join long-term agenda	All respondents consider that the involvement of industry and academia is 'very relevant'. Other categories are given a lower score on average.
Relevance of actors for pooling and leveraging resources	With exception of one respondent, all respondents consider that the involvement of industry and academia is 'very relevant'. Other categories are given a lower score on average.
Partnership composition	The category "ensuring a broad range of partners etc." received a slightly higher score (3.42), on average, versus 2.8 of the other category.
Implementation of activities	Across all categories, almost all respondents indicated that listed activities are 'very relevant'. The lowest number of high scores were given to a category "co-creation of solutions with end-users".

Question category	Summary of responses
Relevance of the legal structure	Across all categories, respondents indicated that the legal structure would be 'very relevant'. The exceptions include the following categories "ensure better links to regulators", "obtain more buy-in and long-term commitment from other partners" and "ensure harmonisation of standards and approaches". In these categories, on average, respondents gave a score of 4 'relevant'.
Scope and coverage of the candidate Partnership	Across all answer categories, most respondents consider that the elements are of right scope and coverage. Respondents were offered an opportunity to provide comments on the proposed scope and coverage of the Institutionalised Partnership. Most of them included the following quote: *"Inception impact assessment is not very descriptive unlike PPP info sheet for Member States with the description of three pillars. Programme to include adapted instruments to support low TRL, flagship projects and EU supply chain".*
Rationalisation of the candidate Partnership and linking to other initiatives	Out of 25 respondents, 23 (92%) consider that it would not be possible to rationalise the candidate Partnership and its activities, and/or to better link it with other comparable initiatives. Respondents were asked to explain their answer. All respondents that stated that it would not be possible to rationalise the candidate Partnership and its activities used the following quote: "No added value can be seen in merging Clean Hydrogen with any other partnerships as hydrogen is an energy vector useful for many energy and transport sectors. It would just lead to dilute the development efforts of a strong European ecosystem. Nevertheless, we value focused cooperation with a number of proposed partnerships in particular: Clean Aviation, Transforming EU Rail, Waterborne, Built Environment, Clean and LowCarbon Steel, Clean and Circular Industry, Batteries and 2Zero".
Societal impact	Almost all respondents consider that the Partnership would be 'very relevant' across all categories.
Economic/technological impact	Almost all respondents consider that the Partnership would be 'very relevant' across all categories.
Scientific impact	Almost all respondents consider that the Partnership would be 'very relevant' across all categories.

Table 26: Overview of responses of the first campaign (campaign #7) (N=18)

Question category	Summary of responses
Research and innovation problems	The answer category "Innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products" was assessed 'very relevant' by most respondents. The remaining answer category was considered 'relevant', on average.
Structural and resource problems	Both answer categories were considered 'very relevant' by almost all respondents.
Problems in uptake of digital innovations	All answer categories received a high score - 5 'very relevant' by almost all respondents.
Preferred Horizon Europe intervention	Institutionalised Partnership was selected by all respondents.

Question category	Summary of responses
	When respondents were asked to explain their choice, all of them used the following quote: *"IPPP with its specific governance and 7 year budget enables the sector to define and implement a common ambitious R&I strategy. IPPP is unique in structuring an FCH R&I ecosystem. IPPP is unique in coordinating innovation effort beyond industry and research with regions, end-users, members states, other industrial sectors, other EU programmes. IPPP superior in leveraging EU funding with private contributions and other funding sources"*.
Relevance of actors for setting join long-term agenda	With exception of one respondent, all respondents consider that the involvement of industry and academia is 'very relevant'. The category "Member States and Associated Countries" were given a lower score (4 'relevant'), on average. The lowest score (between 3 and 4) received a category "foundations and NGOs".
Relevance of actors for pooling and leveraging resources	With exception of one respondent, all respondents consider that the involvement of industry and academia is 'very relevant'. The category "Member States and Associated Countries" were given a lower score (4 'relevant'), on average. The lowest score (between 3 and 4) received a category "foundations and NGOs".
Partnership composition	Both answer categories received a relatively low score (between 2 and 3).
Implementation of activities	With exception of one respondent, all respondents consider all listed categories 'very relevant'.
Relevance of the legal structure	Across all categories, respondents indicated that the legal structure would be 'very relevant'. The exceptions include the following categories "ensure better links to regulators", "obtain more buy-in and long-term commitment from other partners" and "ensure harmonisation of standards and approaches". In these categories, on average, respondents gave a score of 4 'relevant'.
Scope and coverage of the candidate Partnership	Across all answer categories, most respondents consider that the elements are of right scope and coverage. Respondents were offered an opportunity to provide comments on the proposed scope and coverage of the Institutionalised Partnership. Most of them included the following quote: *"Inception impact assessment says little. There are three main pillars:* *1. Near-zero carbon hydrogen production* *2. Technologies distribution and storage* *3. Demand side technologies for (a) power and/or heat in industry, (b) and building and the (c) In the transport sector with focus on heavy-duty road freight, rail, and water-borne. Programme to include adapted instruments to support low TRL, flagship projects and EU supply chain"*.
Rationalisation of the candidate Partnership and linking to other initiatives	Out of 17 respondents, 15 (88.24%) consider that it would not be possible to rationalise the candidate Partnership and its activities, and/or to better link it with other comparable initiatives. Respondents were asked to explain their answer, most of them inserted a following quote: *"Hydrogen should have a dedicated partnership and there is no need for combining it with another*

Question category	Summary of responses
	partnership as otherwise the complexity of such combined partnership may become too complex. However, a focused cooperation might be useful".
Societal impact	Almost all respondents consider that the Partnership would be 'very relevant' to deliver on the following results: "improved public health, reduction of pollutants etc." and "novel competitive cross-solutions for decarbonisation". The other suggested impact is considered 'relevant', on average, by respondents.
Economic/technological impact	Almost all respondents consider that the Partnership would be 'very relevant' across all categories.
Scientific impact	Almost all respondents consider that the Partnership would be 'very relevant' across all categories.

Table 27: Overview of responses of the first campaign (campaign #9) (N=13)

Question category	Summary of responses
Research and innovation problems	The answer category "Innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products" was assessed 'very relevant' by most respondents. The remaining answer category was considered 'relevant', on average.
Structural and resource problems	Both answer categories were considered 'very relevant' by most respondents.
Problems in uptake of digital innovations	All answer categories received a high score - 5 'very relevant' by most respondents.
Preferred Horizon Europe intervention	Institutionalised Partnership was selected by all respondents. When respondents were asked to explain their choice, all of them used a different version of the following quote: *"IPPP with its specific governance and 7 year budget enables the sector to define and implement a common ambitious R&I strategy. IPPP unique in structuring an FCH R&I ecosystem. IPPP unique in coordinating innovation effort beyond industry and research with regions"*.
Relevance of actors for setting join long-term agenda	All respondents consider that industry is 'very relevant' for setting join long-term agenda. The category "Academia" were given a slightly lower score (between 4 and 5). The lowest score (between 3 and 4) received a category "foundations and NGOs".
Relevance of actors for pooling and leveraging resources	With exception of one respondent, all respondents consider that industry is 'very relevant'. The category "Academia" were given a slightly lower score (between 4 and 5). The lowest score (between 3 and 4) received a category "foundations and NGOs".
Partnership composition	Both answer categories received a relatively low score (between 2 and 3).
Implementation of activities	Almost all respondents consider all listed categories 'very relevant'.
Relevance of the legal structure	Across all categories, respondents indicated that the legal structure would be 'very relevant'. The exceptions include the following categories "ensure better links to regulators", "obtain

Question category	Summary of responses
	more buy-in and long-term commitment from other partners" and "ensure harmonisation of standards and approaches". In these categories, on average, respondents gave a score of 4 'relevant'.
Scope and coverage of the candidate Partnership	Across all answer categories, most respondents consider that the elements are of right scope and coverage. Respondents were offered an opportunity to provide comments on the proposed scope and coverage of the Institutionalised Partnership. Several of them included the following quote: *"Inception impact assessment is not descriptive unlike PPP info sheet for members states with the description of three pillars. Programme to include adapted instruments to support low TRL"*.
Rationalisation of the candidate Partnership and linking to other initiatives	Almost all respondents (12, 92.31%) consider that it would not be possible to rationalise the candidate Partnership and its activities, and/or to better link it with other comparable initiatives. Respondents were asked to explain their answer, a few of them inserted different versions of the following quote: "We believe that hydrogen should have its proper partnership and there is no value in merging it with another partnership".
Societal impact	Almost all respondents consider that the Partnership would be 'very relevant' to deliver on the following results: "improved public health, reduction of pollutants etc." and "novel competitive cross-solutions for decarbonisation". The other suggested impact is considered 'relevant', on average, by respondents.
Economic/technological impact	Most respondents consider that the Partnership would be 'very relevant' across all categories.
Scientific impact	Most respondents consider that the Partnership would be 'very relevant' across all categories.

Table 28: Overview of responses of the first campaign (campaign #11) (N=9)

Question category	Summary of responses
Research and innovation problems	All respondents gave the highest score, namely 5 'very relevant', to the answer category "Innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products". The remaining answer categories were considered 'relevant' on average.
Structural and resource problems	Both answer categories received mixed scores, which, on average, reflect that respondents consider both answer categories 'relevant'.
Problems in uptake of digital innovations	All respondents gave the highest score - 5 'very relevant' to the category "High costs of clean hydrogen and fuel cells solutions that hinder mass commercialisation etc.". Other categories, on average, received the score of 4 'relevant'.
Preferred Horizon Europe intervention	Institutionalised Partnership was selected by all respondents. When respondents were asked to explain their choice, all of them used a different version of the following quote: *"The specific governance and 7 year budget enables the sector to define and implement a common ambitious R&I strategy.*

Question category	Summary of responses
	Unique in structuring coordinating an FCH R&I ecosystem ensuring to focus R&I, in particular at low TRL, on industry needs. Good in coordinating innovation effort beyond industry and research with regions, end-users, members states, other industrial sectors, other EU programmes. Leveraging of EU funding with private contributions and other funding sources".
Relevance of actors for setting join long-term agenda	All respondents consider that industry and academia are 'very relevant' for setting join long-term agenda. Other categories have mixed scores.
Relevance of actors for pooling and leveraging resources	Most respondents consider that industry and academia are 'very relevant' for pooling and leveraging resources. Other categories have mixed scores. The lowest scores (between 3 and 4) were given to the category "Foundations and NGOs".
Partnership composition	Both answer categories, on average, received scores between 3 and 4.
Implementation of activities	Most respondents consider all listed categories 'very relevant'.
Relevance of the legal structure	Across all categories most respondents indicated that the legal structure would be 'very relevant'. The exceptions include the following categories: "increase financial leverage", "ensure better links to practitioners", "obtain more buy-in and long-term commitment from other partners" and "ensure harmonisation of standards and approaches". In these categories, on average, respondents gave a score of 4 'relevant'.
Scope and coverage of the candidate Partnership	Across all answer categories, all respondents consider that the elements are of right scope and coverage. Respondents were offered an opportunity to provide comments on the proposed scope and coverage of the Institutionalised Partnership. Most of them included the following quote: *"The Inception impact assessment is not very descriptive as it stands. PPP info sheet for Member States with the description of three pillars is more complete. The Programme should include adapted instruments to support low TRL, flagship projects and EU supply chain"*.
Rationalisation of the candidate Partnership and linking to other initiatives	Only a third of respondents (3, or 33.33%) consider that it would be possible to rationalise the candidate Partnership and its activities, and/or to better link it with other comparable initiatives. Respondents were asked to explain their answer. Regardless of the answer choice, several of them inserted the following quote: *"No added value can be seen in merging Clean Hydrogen with any other partnerships as hydrogen is an energy vector overarching many energy and transport sectors. It would just lead to dilute the development efforts of a strong European ecosystem. Nevertheless focused cooperation with a number of proposed partnerships in particular are relevant: Clean Aviation, Transforming EU Rail, Waterborne, Built Environment, Clean and LowCarbon Steel, Clean and Circular Industry, Batteries and 2Zero"*.
Societal impact	Almost all respondents consider that the Partnership would be 'very relevant' to deliver on all listed impacts.
Economic/technological impact	Most respondents consider that the Partnership would be 'very relevant' across all categories. The exception is the category "better cross-fertilisation of innovative ideas from SMEs to large

Question category	Summary of responses
	companies that can bring them to mass market". That category received the lowest score, which, on average, is 4 'relevant'.
Scientific impact	All respondents consider that the Partnership would be 'very relevant' across all categories.

Appendix C Methodological Annex

The Impact Assessment studies for all 13 candidate institutionalised European Partnerships mobilised a mix of qualitative and quantitative data collection and analysis methods. These methods range from desk research and interviews to the analysis of the responses to the Open Consultation, stakeholder analysis and composition/portfolio analysis, bibliometrics/patent analysis and social network analysis, and a cost-effectiveness analysis.

The first step in the impact assessment studies consisted in the definition of the context and the problems that the candidate partnerships are expected to solve in the medium term or long run. The main data source in this respect was desk research. The Impact Assessment Study Teams went through grey and academic literature to identify the main challenges in the scientific and technologic fields and in the economic sectors relevant for their candidate partnerships. The review of official documentations, especially from the European Commission, additionally helped understand the main EU policy proprieties that the initiatives under assessment could contribute to achieve.

Almost no candidate institutionalised European Partnership is intended to emerge ex nihilo. Partnerships already existed under Horizon 2020 and will precede those proposed by the European Commission. In the assessment of the problems to address, the Impact Assessment Study Teams therefore considered the achievements of these ongoing partnerships, their challenges and the lessons that should be drawn for the future ones. For that purpose, they reviewed carefully the documents in relation to the preceding partnerships, especially their (midterm) evaluations conducted. The bibliography in Appendix A gives a comprehensive overview of the documents and literature reviewed for the present impact assessment study.

Finally, the description of the context of the candidate institutionalised European Partnerships required a good understanding of the corresponding research and innovation systems and their outputs already measured. The European Commission services and, where needed the ongoing Joint Undertakings or implementation bodies of the partnerships under Article 185 of the TFEU, provided data on the projects that they funded and their participants. These data served as basis for descriptive statistic of the numbers of projects and their respective levels of funding, the type of organisations participating (e.g. universities, RTOs, large enterprises, SMEs, public administrations, NGOs, etc.) and how the funding was distributed across them. Special attention was given to the countries (and groups of countries, such as EU, Associated Countries, EU13 or EU15) and to the industrial sectors, where relevant. The sectoral analysis required enriching the eCORDA data received from the European Commission services with sector information extracted from ORBIS. We used the NACE codification up to level 2. These data enabled identified the main and, where possible, emerging actors in the relevant systems, i.e. the organisations, countries and sectors that will need to be involved (further) in the future partnerships.

The horizontal teams also conducted a Social Network Analysis using the same data. It consisted in mapping the collaboration between the participants in the projects funded under the ongoing European partnerships. This analysis revealed which actors – broken down per type of stakeholders or per industrial sector – collaborate the most often together, and those that are therefore the most central to the relevant research and innovation systems.

The data provided by the European Commission finally served a bibliometric analysis aimed at measuring the outputs (patents and scientific publications) of the currently EU-funded research and innovation projects. A complementary analysis of the Scopus data enabled to determine the position and excellence of the European Union on the international scene, and identify who its main competitors are, and whether the European research and innovation is leading, following or lagging behind.

All together, these statistical analyses will complement the desk research for a comprehensive definition of the context in which the candidate institutionalised European Partnerships are intended to be implemented. The conclusions drawn on their basis will be confronted to the views of experts and stakeholders collected via three means:

- The comments to the inception impact assessments of the individual candidate institutionalised European partnerships received in August 2019
- The open public consultation organised by the European Commission from September to November 2019
- The interviews (up to 50) conducted by each impact assessment study team conducted between August 2019 and January 2020.

For instance, in all three exercises, the respondents were asked to reflect on the main challenges that the candidate institutionalised European Partnerships should address. In the open public consultations, they mainly reacted to proposals from the European Commission like when they were given to opportunity to give feedback to the inception impact assessment.

The views of stakeholders (and experts) were particularly important for determining the basic functionalities that the future partnerships need to demonstrate to achieve their objectives as well as their most anticipated scientific, economic and technological, and societal impacts. The interviews allowed more flexibility to ask the respondents to reflect about the different types of European Partnerships. Furthermore, as a method for targeted consultation, it was used to get insights from the actors that both the Study Teams and the European Commission were deemed the most relevant. For the comparative assessment of impacts, the Study Teams confronted the outcomes of the different stakeholder consultation exercises to each other with a view of increasing the validity of their conclusions, in line with the principles of triangulation. Appendix B includes also the main outcomes of these three stakeholder consultation exercises.

The comparison of different options for European partnerships additionally relied on a cost-effectiveness analysis. When it comes to research and innovation programmes, the identification of costs and benefits should primarily be aimed at identifying the "value for money" of devoting resources from the EU (and Member States) budget to specific initiatives. Based on desk research and consultation with the European Commission services, the horizontal study team produced financial estimates for different types of costs (preparation and setup costs, running costs and winding down costs) and per partnership option. The costs were common to all candidate European Partnerships. The results of the cost model were displayed in a table, where each cost was translated on a scale using "+" in order to ease the comparison between the partnership options.

A scorecard analysis, which allocated each option a score between 1 and 3 against selected variables, was used to highlight those options that stand out as not being dominated by any of the other options in the group: such options are then retained as the preferential ones in the remainder of our analysis. It also allowed for easy visualisation of the pros and cons of alternative options.

Appendix D Additional information on the policy context

D.1 Hydrogen value chain

There is a growing awareness that the global energy transition will not succeed unless it finds ways to decarbonise the "hard-to-abate" sectors like industry and heavy transport.[322] Clean hydrogen is one of the few options available to achieve this, and is regarded as an ideal complement to green electrification and therefore is rapidly **gaining momentum in various leading countries around the world**.

Hydrogen can help tackle various critical energy challenges. It offers ways to decarbonise a range of sectors, can also help improve air quality and strengthen energy security.[323] Hydrogen is versatile and can enable renewables to provide an even greater contribution, whilst also providing flexibility to help balance electricity grids all year round.

The supply of hydrogen is well established in the oil refining, chemical and metal industries. Existing production methods, which are based on fossil fuels, could supply the early stages of a "hydrogen economy".

With respect to the future, first, hydrogen is the best (or only choice) for at-scale decarbonisation of selected segments in transport, industry and buildings, specifically: decarbonising the **gas grid** that connects Europe's industry and delivers to households and power generation ; in **transport,** it is the most promising decarbonisation option for trucks, buses, ships, trains, large cars, and in aviation**,** hydrogen and synthetic fuels based on hydrogen are the only at-scale option for direct decarbonisation. In addition, hydrogen refuelling infrastructure has significant advantages compared to fast charging (less space, flexibility, avoid grid upgrade), and industry can burn hydrogen to produce **high-grade heat** and use the fuel in several processes as **feedstock,** either directly or together with CO_2 as synfuel/electrofuel.

Second, hydrogen will play a systemic role in the transition to **renewable energy sources** by providing a mechanism to flexibly transfer energy **across sectors** (EU's energy transition requires almost completely decarbonised power generation, which implies large renewables grid integration), **time** (due to the need for increased balancing across the year and seasonal energy storage), and **place** (Hydrogen provides a link between regions with low-cost renewables and those that are centres of demand. Hydrogen enables the long-distance transportation of energy in pipelines, ships, or trucks, whether gaseous, liquified, or stored in other forms, which costs much less than power transmission lines).

Hydrogen is therefore seen as a viable energy carrier to address all three pillars of any energy policy:

- security (of supply) – by using endogenous renewable energy sources;
- economic competitiveness – (i) to make the best use of Europe's increasing renewables', (ii) potentially optimise the utilisation of existing gas and liquid infrastructure and (iii) enabling sound competition between energy grids; and
- environmental sustainability – decarbonising the gas and liquid fuel sectors

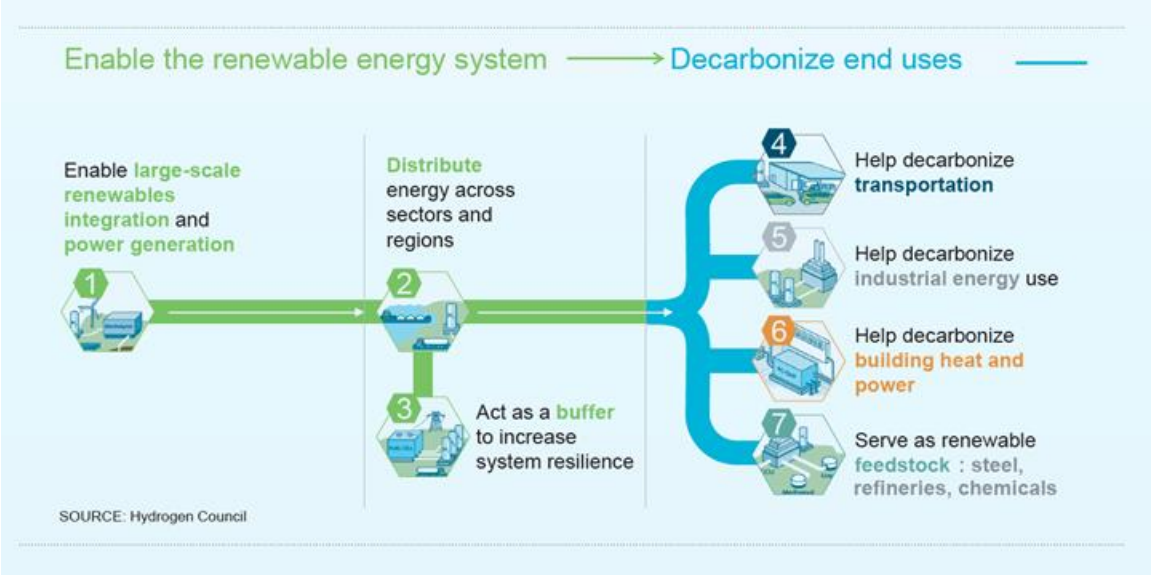
For the analytical work of this Impact Assessment, applications and technologies are clustered into the three stages of the overarching Strategic Value Chain (Generation, Distribution & Storage, Utilisation). This value chain follows the stages/fields relevant for

[322] https://www.iea.org/newsroom/news/2018/december/how-northwest-europe-can-shape-a-clean-hydrogen-market.html

[323] The Future of Hydrogen, Report prepared by the IEA for the G20, Japan, Seizing today's opportunities https://webstore.iea.org/the-future-of-hydrogen

a future hydrogen economy as identified and described in the "Hydrogen Roadmap Europe" and reaffirmed in the work for the Important Projects of Common European Interest (IPCEI).

Figure 42: Value chain and Sub-value chain picture



D.2 Positioning of Europe in the field

The European industry is active in all areas of the hydrogen economy along the entire value chain.[324] Main trends can be summarised:

D.2.1 Production

The study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies, Evidence Report, E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc, oct 2018 points out the following main trends:

- Three **commercial electrolysers** technologies and one emerging technology are considered here: Alkaline, PEM and Solid Oxide respectively. Europe is one of the leaders in today's global alkaline electrolysis industry with the two major manufacturers, Nel and Hydrogenics, producing in Norway and Belgium respectively, and with other companies such as McPhy gaining momentum. Major players such as ThyssenKrupp have technologies used for chlor-alkali production which could be used for water electrolysis. China, Japan and the US also have production capacity, but are less active in the global market than the European actors. European companies are well positioned to benefit from market growth. The components for alkaline electrolysers can generally be sourced within Europe. PEM electrolysis is a much younger technology than alkaline. Its commercialisation was pioneered in the US, building on developments for the military. Several North American companies have developments or products including Giner, now in partnership with Spanish company H2B2, and Proton OnSite, now owned by Norway's Nel, as well as Hydrogenics in Canada. European developers such as Siemens, Areva, and ITM Power are also commercialising their own PEM electrolysers, most of them in view of expected market growth as part of the energy transition. Europe is well positioned all along the PEM electrolyser supply chain, however, the electrolyser-specific supply chain is in general less developed compared with PEM fuel cells as there

[324] Hydrogen Roadmap Europe (2019): Fuel Cell and Hydrogen Joint Undertaking, Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition, January 2019. https://www.fch.europa.eu/studies

are fewer electrolyser manufacturers. The KBA sector in Europe is very active in electrolysis and strong in many of the related areas of expertise

- Regarding the other **production technologies** (incl. SMR+CCS/U, but also from biomass gasification, solar hydrogen, waste gasification, biological production from algae), much of the activity on novel methods of production is at the University/Research Institute level (with a good positioning in EU) but European companies are well placed to capitalise on hydrogen production technology

D.2.2 Distribution and Storage

The study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies, Evidence Report, E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc (Oct. 2018) points out the following main trends:

- Today, the equipment for distribution exists, but there is considerable scope for optimisation of the efficiency and cost of these components, on: compression, metering, purification and separation. European companies supply world leading components which remove the existing technical barriers to the hydrogen distribution (from early stage research to innovation levels). European companies are undoubtedly leading in the field of hydrogen logistics and handling for hydrogen applications (incl. Nel, Linde, HyET, Hystorsys). Two of the main industrial gas companies (Linde and Air Liquide) are based in Europe and there is considerable experience within the European oil and gas and chemicals industries

- There is interest in a variety of chemistries for hydrogen carriers, like liquefaction, hydrogen-rich aromatic and alicyclic molecules, ammonia, methanol, with several EU companies already active in these areas. Large industrial gas companies such as Linde and Air Liquide (based in Europe) have expertise in liquefaction technologies and are well placed to exploit this market. European SMEs such as Hydrogenious and ArevaH2Gen are active in developing liquid organic hydrogen carriers and could capitalise on this with the continued research and development in this market.

- Europe has several **Hydrogen Refuelling Station** (HRS) integrators with a global reputation and reach, including Linde, Air Liquide, Nel (H2 Logic) and ITM Power. Europe is also well positioned across most key components in HRS, and some European actors are working on the development of new components (e.g. the dispenser and hosing). There is still a lack of flow meters that meet the accuracy requirements of weights and measures authorities, but there is relevant development activity by some European actors. Europe has several hydrogen compressor suppliers to choose from, including some that have developed – or are still developing – novel compression technologies such as electrochemical routes. Europe suffers from the same gaps as other global regions, so is not specifically at a disadvantage. However, successful development and commercialisation of higher performing and lower cost dispensing equipment, hoses, metering equipment and sensors would position Europe well.

- **Hydrogen storage** comprises a very wide range of technologies with dramatically different supply chains and scales, as well as levels of commercial readiness. These include compressed and liquid storage, plus solid state materials (e.g. metal hydrides), liquid organic carriers and cryo-compressed. For the different technologies mentioned above, Europe is generally well-positioned, with suppliers or developers in all areas. Although compressed storage appears to have many players, not all produce tanks in Europe, and this remains a weakness in the supply chain. Hydrogen compressed tank supply has some strong Asian and North American actors, with specialist materials, notably high-grade carbon fibre, coming more from Asia. While Europe has a very deep and broad set of capabilities in hydrogen storage generally, it is spread across a great many areas, including solid state systems. Overall, European KBAs rank well against

their counterparts in Asia and North America, and may even have a slight advantage over the latter, as slightly more activity seems to be underway in Europe;

- Europe's industry is possessing the required geological knowledge to build **new salt caverns**
- **Regarding the distribution technology**, there is considerable scope for optimisation of the efficiency and cost of the equipment on: compression, metering, purification and separation. European companies supply world leading components which remove the existing technical barriers to the hydrogen distribution and leading in the field of hydrogen logistics and handling. There is interest in a variety of chemistries for hydrogen carriers, like liquefaction, hydrogen-rich aromatic and alicyclic molecules, ammonia, methanol, with several EU companies already active in these areas. European SMEs are active in developing liquid organic hydrogen carriers.

D.2.3 Utilisation – transport

The study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies, Evidence Report, E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc, oct 2018 points out the following main trends:

- The leading OEM integrators for **FCEVs** (**cars and light commercial**) are in Asia, with Hyundai, Toyota and Honda all well advanced. Daimler is currently the only European OEM with a 'commercial' product, in very limited production, though Audi, BMW, Fiat and others have suggested that they may have vehicles around 2020. Europe does however have several entrepreneurial integrators targeting different applications: French company Symbio offers converted Renault Kangoo vehicles with range-extender fuel cells, German company Streetscooter intends to produce FC range-extender electric vehicles and UK-based Riversimple has designed a car from the ground up. The European supply chain for fuel cell stacks and systems is not as mature as those in other countries (notably Japan and the USA). It is however developing rapidly with large tier 1 manufacturers getting involved (incl. Bosch, Michelin, ElringKlinger) and with stack suppliers (incl. PowerCell, Symbio, Nedstackand Proton Motor) maturing rapidly. A number of tank manufacturer are now based in Europe (incl. Hexagon and Luxfer).
- Europe is well placed in **fuel cell bus** development, having seen the majority of the early roll-out, though China is now deploying more vehicles. Both European and Chinese manufacturers have been largely dependent on Canadian technology from Ballard and Hydrogenics for stacks and subsystems, though Europe has suppliers (e.g. Proton Motor) developing these capabilities and who could fill this gap if the technology can be suitably well proven. European bus OEMs are well placed at global level (incl. Van Hool, Solaris, VDL, EvoBus, Wrightbus, Solbus, Alexander Dennis).
- **Fuel cell forklifts** were one of the earliest fuel cell applications to be commercialised. The market and the providers are predominantly North American, with Plug Power dominant, using Ballard stacks and increasingly its own in-house models. Nuvera also provides stacks and systems, integrated by Hyster-Yale, its parent company and materials handling vehicle producer. In Europe, H2Logic's activities were taken over by Ballard through Danish subsidiary Dantherm and a collaboration continues with Taiwanese company M-Field. Linde also manufactures FC forklifts, and outside of Europe Toyota has some activities. The potential exists in Europe for FC forklifts to be produced and deployed, with an important gap in demand related to the comparatively weak economics of the systems. This may require costs to come down before it can be resolved.
- In this analysis, **High Goods Vehicle** (HGVs, medium and heavy duty trucks >3.5t). In Europe, a few trucks have been integrated, including Renault Maxity, Scania and MAN

vehicles, the latter modified by ESORO. These are conversions by specialist external integrators, and no truck OEM is currently building vehicles, though some are showing interest. Stacks come from Symbio, from PowerCell and from Hydrogenics. Outside of Europe, Kenworth class 8 trucks have been repowered by Toyota, using Mirai stacks, by US Hybrid, and by Ballard. Nikola Motor is designing and developing its own long-haul unit with stacks from PowerCell in Sweden. Toyota is also working with 7-11 in Japan to provide fuel cell versions of its Hino trucks. European OEMs are well placed at global level (incl. IVECO, MAN, Scania, Daimler, and VDL). Several European FC system / component suppliers are also active in FC truck sector (incl. Swiss Hydrogen, eTrucks, SymbioFCell, ElringKlinger).

- In Europe, Germany has taken a lead and regional **trains** powered by hydrogen fuel cells are now certified for passenger use. The trains are made by Alstom and fuel cell systems come from Hydrogenics. Ballard has also announced a tie-up with Siemens aimed at the same market. In fuel cells for rail China is relatively advanced with some light rail and tramway applications entering service, currently also using systems from the Canadian suppliers

- Europe has several KBAs with FCH skills specific to the **maritime sector**, including in the Nordic countries. Others are those with more general FCH system capabilities. Europe is probably marginally stronger than many other regions as this area has been a focus for some time, even though activity has been limited. With multiple demonstration projects on-going/in preparation, Europe could become the market leader for optimised technological solutions for maritime applications. The European supply chain is beginning to scale up, with large joint ventures announced between fuel cell suppliers and shipping powertrain providers (incl. Powercell & Siemens, ABB & Ballard). Norwegian company HyOn has been formed specifically to target this market (including partners: PowerCell, Nel and Hexagon). A range of European companies are active in the fuel cell maritime space (incl. Fincantieri, Ferguson Marine, Viking Cruises, Kongsberg Maritime and BrødreneAA).

- **Aviation :** Aeronautics is one of the EU's key high-tech sectors on the global market. With world leading aircraft expertise in fuel cell technologies, Europe could play a vital role in driving the transformation of aviation to reduce emissions. With world leading aircraft companies (incl. AIRBUS, SAFRAN, Rolls-Royce) and expertise in fuel cell technologies, Europe has leading positioning in integrating hydrogen in the aviation sector.

D.2.4 Utilisation – energy system

Hydrogen can supply the heating and power for buildings (Decarbonisation of natural gas grid through blending & upgrade of natural gas to pure hydrogen grid) ; power generation (providing seasonal storage on renewable electricity) ; industry energy by replacing natural gas for process heat

The study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies, Evidence Report, E4tech (UK) Ltd for FCH 2 JU in partnership with Ecorys and Strategic Analysis Inc, oct 2018 points out the following main trends:

The electrical output of a **micro-CHP** ranges from 500W to 5kW and is typically used for domestic applications. In Europe, most installed units are between 0.7kW and 2kW. Both PEMFC and SOFC are used, though SOFC units are a more common offering in Europe, and increasingly so globally. The European domestic market is developing, however, only a few thousand units are in use, in contrast to installations of around 250,000 in Japan in 2017 alone. Europe has strong heating appliance integrators with varied but increasing degrees of participation in fuel cells, but very few have in-house fuel cell stack development. No European player has the depth of experience that is found in Japan

There are very few PEM commercial **FC prime power** and **CHP** integrators either in Europe or globally. The German company RBZ Fuel Cells have developed a small commercial 5kW PEM CHP unit, and Horizon Fuel Cells in China claims a commercial scale offering, but few others. Nevertheless, this area is considered as potentially a stronger market than micro-CHP. Europe has underlying strengths in reformer chemistry, specialist alloys, ceramic powders and cell manufacture and in some areas of stack production, but very few units have been produced in this 'commercial' size range. Several actors are targeting this market however, typically using developments and sales in micro-CHP as part of their development pathway;

The market for **large FC CHP** and **primary power**[325] in Europe has been slow to develop as few support schemes exist, and almost all installations are in Asia and the US. Korea accounts for a large proportion of the global market, targeting primary power FCs to fulfil renewables obligations and meet co-generation requirements for new buildings, while in the US installations benefit from federal Investment Tax Credits and local state-based subsidies. In this area Europe's capabilities are strong but regions with more commercial activity (Japan, Korea, North America) are likely to be stronger, simply due to the ongoing industrial development and interaction. There are strong European[326] fuel cell micro-CHP system integrators (incl. CHP system integrators such as; Bosch, Valliant, Ceragen, SOLIDpower, Viessmann) as well as stack developers (incl. Elcomax, ElringKlinger, Serengy; Ceres Power, Sunfire and Hexis)

European gas turbines producers signed commitments to deliver technologies that can operate with high shares of hydrogen (20% by 2020 and 100% by 2030);

Europe has strong heating appliance integrators with varied but increasing degrees of participation in fuel cells. Many, like the boiler manufacturers, have a long history in heating appliances and in technology integration. Some are now introducing boilers on the market. Those manufacturers are also deploying hybrid heat pump-hydrogen boilers.

D.2.5 Utilisation – industry

Hydrogen can supply Industry feedstock and replace natural gas as feedstock in combination with CCU

- Industry (mainly steel and iron, refineries, ammonia manufacture and other fertilisers) : With multiple demonstration projects taking place in Europe, organisations involved will have unrivalled expertise in the integration of clean H2 as a feedstock for industry[327,328,329]. Europe could become a market leader in the use of clean hydrogen in industry. Companies producing clean hydrogen (such as Air Liquide, ITM Power, Vattenfall, SSAB) could have leading position at global level

[325] The "Competitiveness Analysis" (p 95)

[326] Hydrogen, enabling a zero emission Europe, technology roadmaps full pack, Sept 2018, Hydrogen Europe

[327] The H2FUTURE project, for example, is injecting green hydrogen into steel production, thereby eliminating greenhouse gas emissions that would normally ensue. Demonstrating that even energy-dependent sectors can rely on this technology will make for increasingly green industrial production (The FCH JU success stories)

[328] Refhyne, launched in January 2018, is on course to build the largest hydrogen electrolysis plant of its kind in the world, with a capacity of 10MW, at the Rhineland refinery in Germany (The FCH JU success stories)

[329] In 2016, SSAB, LKAB and Vattenfall formed a joint venture project with the aim of replacing coking coal in ore-based steel making with H2. In 2018, a pilot plant was planned and designed in Lulea and the Norbotten iron ore fields to provide a testing facility for green H2(produced by electrolysis) to be used as a reducing agent in steelmaking. Project partners state that using this production method could make steel (the Technology Roadmap, Hydrogen Europe)

D.3 Support for the field in the previous Framework Programmes

In the First Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking (from 12/2010 to 04/2011), the independent expert group (IEG) concluded that the overall technical objectives of the FCH JU were ambitious and internationally competitive; it commended the concept of public-private partnership for technology development and demonstration. The group found the FCH JU to enjoy strong stakeholder representation and to provide stability in an uncertain funding climate. The group criticised the length of time taken to establish the JU; it noted the low and unpredictable funding rates and the modest technical resources of the Programme Office. External relations were, in its view, insufficient in particular the collaboration with Member States' related programmes and international engagement.

Recommendations were divided into five blocks: reinforce the portfolio management; ensure high agility of operations and adaptability to changing competitive forces; improve visibility, communication and outreach ; improve collaboration and alignment with Member States; ensure high efficiency of operations.

In the Second Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking (12/2013 to 07/2013), the expert group convened for the purpose found that most of the recommendations of the first evaluation concerning implementation bottlenecks had been adopted, but that compliance with some of the recommendations to reinforce portfolio management and to improve communications with stakeholders was only partial. Overall, the second IEG concluded that performance had progressed and that the JU had successfully demonstrated the viability of a Public-Private Partnership (PPP) for research in FCH. The JU had developed an adequate governance structure, improved the dialogue between industry and research around a common strategic agenda, and had initiated the implementation of that agenda. The expression of a long-term political commitment by EU institutions that was manifest in the FCH JU, coupled with stable funding, had given confidence to industry and helped the sector through difficult times. In the view of the second IEG, the FCH JU continued to be relevant to the grand challenges facing Europe, in particular climate change and energy security, and it recommended therefore that the FCH JU should be continued under Horizon 2020.

The IEG nevertheless found several areas that could be improved, some related to the findings of the first evaluation, and made recommendations for: programme governance, design and management; technology monitoring and policy support; engagement with Member States and regions, and communication and dissemination.

An action plan to address the recommendations of the Second Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking was adopted in November 2014.

The authors of the "**Final Evaluation of the Fuel Cells and Hydrogen Joint Undertaking (2008-2014) operating under FP7 (June 2017)"** have assessed the status of the JU and the extent to which the recommendations of the Second Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking have been addressed.

The IEG concluded that the recommendations have been generally addressed in a satisfactory way. Most of the issues detected by the Second Interim Evaluation have been dealt with even if not always in the way that had been recommended. Good compliance is noted for: knowledge management, financial engineering and communication where new staff members have been appointed and for the relationship with regions and municipalities where there is significant progress as well. The coherence between the activities of the JU and public policy goals of the EU is still not entirely satisfactory and better alignment with other activities of H2020 still needs attention. The involvement of Member States is poor; this is a serious concern.

It should be highlighted that due to timing most of the recommendations of the Second Interim Evaluation of the Fuel Cell & Hydrogen Joint Undertaking were implemented only in the FCH 2 JU that was initiated in July 2014. More information is therefore available in the First Interim Evaluation of the Fuel Cells and Hydrogen 2 Joint Undertaking.

The main conclusions of the "**Interim Evaluation of the Fuel Cells and Hydrogen 2 Joint Undertaking (2014-2016) operating under Horizon 2020" are summarised:**

- **On continued relevance**: the FCH 2 JU has continued to demonstrate the merits commended in the second interim evaluation of the FCH JU; it has further reinforced a Community of industry and research bodies around a common long-term research agenda and gathered a portfolio of projects that reflects the specific objectives assigned to it. The JU continues to be relevant. In a carbon-limited world, hydrogen could be an important energy vector. It is difficult to foresee precisely how hydrogen technologies will eventually be deployed and how technologies within the energy and transport sectors will relate. In the event of abundant hydrogen from renewable sources there may also be interest from the manufacturing and process industries. The IEG is of the opinion that the JU is supporting work across the right spectrum of technologies to ensure they may be effectively deployed in Europe in the light of the specific needs and circumstances of various regions.
- **Implementation of the PPP** has been successful in most relevant aspects. The JU has discharged its funding obligations admirably. The Industry Grouping has organised its participation most effectively. The JU has successfully created an active FCH community and extended this to include municipalities and regions through a Memorandum of Understanding. Financial management appears to be robust and the views of the public and beneficiaries sought in the consultations are strongly positive. The overall operational efficiency of the FCH 2 JU has improved as the institution has matured. Settlements of prepayments and costs claims (TTP) were never late, which is a very important fact in particular for SMEs and beneficiaries of large demonstration projects. The TTG of Call 2014 was slightly longer than foreseen under H2020 rules, but subsequently decreased with maturity of processes. There is still a problem with complex and technically demanding projects. The cost efficiency of the programme management and internal controls improved steadily throughout the period. It should be noted that the JU has continued to exceed the level of participation by SMEs specified for Horizon 2020. In terms of overcoming fragmentation within Europe, the challenges of delivering improved coordination between Member States' FCH research and innovation support remain. There is little evidence that the SRG is effective in this regard, and this continues to be a priority for improvement during the life of FCH 2 JU. A resolution of these shortcomings is an important part of improving overall EU cohesion, and should be addressed as a matter of urgency
- **Added value and necessary leverage**: FCH 2 JU has an explicit EU added value and amongst the FCH innovation community, there continue to be strong benefits received from the work of FCH 2 JU. The decision to proceed with FCH 2 JU bringing together 93 industrial organisations from 22 European countries can be regarded as a substantial achievement for Europe, and was almost certainly enabled by the unifying presence of the FCH JU programme. Leverage: even if there is no hard evidence, the assessment of contributions can be considered an indication of the leverage achieved by EU funds and is clearly a strong sign that the JU is successfully aligned on industrial priorities. For the period 2014-2015, the FCH 2 JU has generated 0.98 of operational leverage (total participant contribution in projects divided by EU contribution) and 0.65 of additional leverage (certified IKAA divided by EU contribution), yielding a total figure of 1.63.
- **Coherence with EU policies** : the work of the JU is undoubtedly coherent with policies of the EU in energy, environment, transport and competitiveness. The technologies

being developed with the support of the JU are capable of significant contributions to the security of energy supply, to the reduction of global and local pollution, to a clean and sustainable transport sector and to a more competitive European economy in a carbon-limited world.

- **The future after FCH 2 JU**: the IEG is of the opinion that there will be a continued need for support in the field of fuel cells and hydrogen beyond the FCH 2 JU. The PPP approach remains a viable option, and it is desirable that the community created through the FCH 2 JU be maintained. However, the PPP scheme should be revised if support to deployment is given, in view of the specific financial and regulatory needs this step will require. The absence of a deployment support framework of the nature provided for other new energy technologies such as renewables is likely to be a barrier to commercial development of FCH technologies. Without this, there was no incentive for exploitation of technologies still at an early stage of development and this is a material economic disadvantage for potential FCH applications. Similarly to renewable energy technologies FCH competitiveness can only be achieved with appropriate regulatory support, which is not place at present, so the exploitation route for JU outputs is incompletely prepared. Any new PPP should be considered in the context of the probable need for accompanying deployment support for FCH technologies if the research and innovation outcomes are to make a successful transition to commercial exploitation.

Research undertaken in a collaborative and European environment such as FCH 2 JU has been shown to be beneficial and should continue as a mean to efficiently support the development of the new technologies needed.

The previous programmes (FP7 and H2020) managed by the Fuel Cell and Hydrogen Joint Undertakings (FCH JU and FCH 2 JU) have partially addressed all stages/fields of the hydrogen value chain described above, mainly focusing on:[330]

- **Transport**, with demonstration activities concerning over 1,900 light-duty vehicles; the deployment of 45 buses in 10 cities (in operation in 2018), with the aim to deploy 310,[331] the demonstration of material-handling vehicles (MHVs)[332] involving 226 forklift trucks and 188 MHV covering 10 different MHV models,[333] as regards research-oriented activities for transport applications, the EU has made considerable progress on the production of state-of the-art stacks for automotive application.[334]
- **Infrastructure**, with cross-cutting activities contributing to standardisation, RCS and safety; demonstration and deployment of infrastructure network,[335] supporting the deployment of Hydrogen Refuelling Stations (HRS) to reach 99 units (of which 48 in 2018); supporting the deployment of an HRS network for cars in 11 countries; two projects[336] currently working towards building and testing a prototype compressor (HRS equipment);

[330] All these data are coming from the FCH JU Annual Activity Report 2018

[331] This European FCH bus deployment can be considered as worldwide state-of-art having progressed significantly throughout FCH 2 JU projects (https://www.fuelcellbuses.eu/projects/jive)

[332] With the 2 projects HyLIFT-EUROPE and HAWL

[333] Deployed in 2018 at 3 sites

[334] Through the AUTOSTACK CORE, INSPIRE, and VOLUMETRIQ projects

[335] In the frame of 2 FCH 2 JU projects

[336] The COSMHYC55 and H2REF56 projects, with great potential for improving the techno-economics for compression (and hence for HRS)

- **Hydrogen production**: the development of PEM manufacturing,[337] developing and testing three principal types of electrolysers (Alkaline being the most mature and commercial technology, PEM having in recent years made significant inroads in the European market and SOEC still at the earliest stage) in various projects[338]. The development of electrolysers and their technical integration with renewable power plants should remain a prominent scientific focus of the initiative;
- **Power production**, the relevant FC (stationary FC CHP) technology has been steadily demonstrated in real installations,[339] one project[340] has demonstrated a CHP PEM fuel cell power plant integrated into a chlorine-alkali production plant;

To conclude, the FCH JU and FCH2JU have developed successful mechanisms for fostering continued technological innovation. There is still a need, however, for testing new processes that could result in cost reductions for the production processes of technologically advanced hydrogen applications. There is also a need for increased demonstration projects that can open markets to hydrogen technologies. And finally, there is a need to increase the scope of applications by involving more sectors.[341]

On the weakest issues, the allocated funds were mainly concentrated in western Member States (like DE, FR, IT, DK and UK). The participation of all Member States, including low R&I performing Member States, in H2 R&D activities is still not fully achieved and should be improved.

D.4 OPC - Relevance of research and innovation efforts at the EU level to address problems with Clean Hydrogen

In the consultation, respondents were asked to provide their view on the relevancy of research and innovation efforts at EU level to address the following problems in relation to hydrogen and fuel cells, specifically on three types of problems: problems in uptake of hydrogen and fuel cells innovations (UI-P), structural and resource problems (SR-P) and research and innovations problems (RI-P). In Figure 43, the responses to these answers are presented.

[337] **On the side**, four projects[337] focus on the development of PEM manufacturing, balance of plant and quality control practices for transport and MHV applications : DIGIMAN, Fit-4-AMandA, INLINE, INN-BALANCE projects

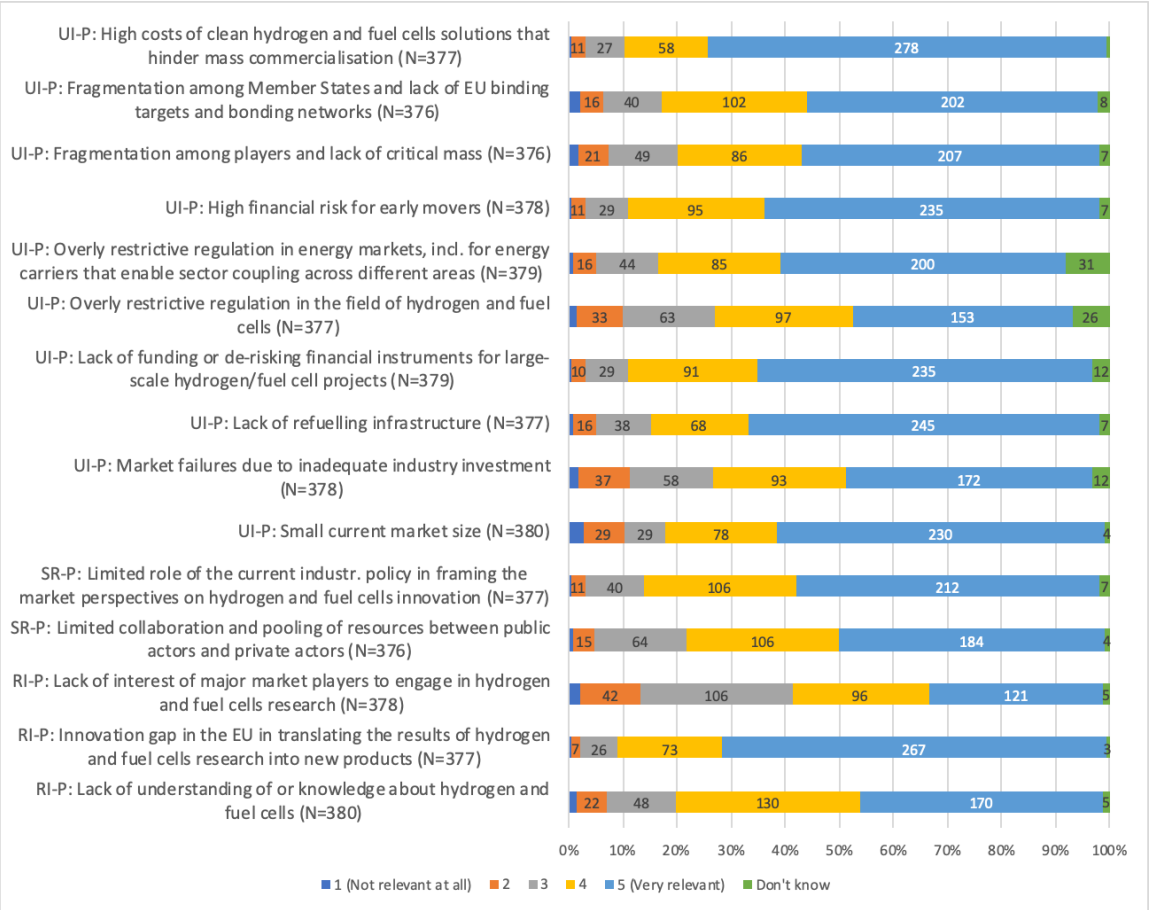
[338] The International Energy Agency (2019), The Future of Hydrogen – Seizing today's opportunities, Report prepared by the IEA for the G20, Japan, available at https://webstore.iea.org/the-future-of-hydrogen

[339] While most of targets set in the Multi-Annual-Work-Program (MAWP) have been met

[340] the DEMCOPEM-2MW project

341 Fuel Cell and Hydrogen 2 Joint Undertaking (2019), Hydrogen Roadmap Europe, available at https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

Figure 43: Views of respondents on relevance of research and innovation efforts at the EU level to address problems in relation to hydrogen and fuel cells



With regard to the uptake in innovation problems, 278 respondents have indicated that it is very relevant for research and innovation efforts at EU level to address the problem of high costs of clean hydrogen and fuel cells solutions that hinder mass commercialisation until serial production is achieved, factoring-in economies of scale (73.74%). Of the uptake in innovation problems, market failures due to inadequate industry investment has the least amount of very relevant answers (45.50%), while most respondents still have indicated that they view this issue as very relevant.

There were only two structural and resource problem that the respondents were asked to reflect on. Of these the limited role of current industrial policy in framing the market perspectives related to hydrogen and fuel cells innovation, received more answers scoring 5 (very relevant), namely for 60.53% of responses.

The research and innovation problem that most people have indicated as very relevant is the innovation gap in the EU in translating the results of hydrogen and fuel cells research into new products, with 267 respondents choosing this answer (70.82%). The problem that was least often indicated as very relevant, is also a research and innovation problem, namely: lack of interest of major market players to engage in hydrogen and fuel cells research (121, 32.01%).

No statistical differences were found between the views of citizens and other respondents. Respondents that are/were involved in a current/preceding partnership (Horizon 2020 or Framework Programme 7) found all uptake in innovation problems more relevant than other respondents.

Appendix E Additional information related to the problem definition

E.1 Taxonomy of failures requiring policy intervention

Market failures	
Market power	Inadequate market structures due to the degree of competition and barriers to entry such as strongly concentrated / closed industry sectors or markets
Externalities	Low return on investments due to difficulties, for innovators, appropriating the outcomes of their investments and limiting undesired spill overs to the benefit of competitors. Those externalities often cause low (private) investments, especially for uncertain and risky R&D activities.
Information asymmetry	Actors within a particular market (or system) have uneven access to information. Some may lack the information they need to develop and exploit their innovative products/services.
Systemic failures	
Capability	Factors related to the individuals' and organisations' absence or shortage of the necessary capabilities to acquire and absorb new knowledge, to adapt to new and changing circumstances, to grasp (technological) opportunities, and to switch from old to new (technological) trajectories. At a systemic level, it relates to 'sufficient scale' or 'critical mass'
Network	Interactions between a set of actors are too dense to allow for novel insights or inspirations to emerge. Strong dependence on few partners may lead to lock-in phenomena. *Weak network failure:* Too limited exchange and collaboration between organisations and individuals, which limit co-creation and co-development of new products and services,
Institutional	Norms and rules (regulatory framework) hinder innovation; social norms and values, and culture hinder innovation
Infrastructural	Lack of the physical (R&D facilities, ICT infrastructure, transport etc.) and knowledge (knowledge, skills, database etc.) infrastructures needed to enable and stimulate innovation activities.
Transformational failures	
Directionality	Lack of shared vision regarding the goal and direction of the required system transformation process. No coordination between the actors involved in system transformation. Absence of targeted funding for R&I activities and infrastructures, which would define collectively accepted trajectories of development.
Demand articulation	A deficit in anticipating and learning about user needs and constraints. Insufficient use of public demand to orient and leverage wider demand and influence innovation activities. Lack of mechanisms to articulate the demand from various groups of actors.

Policy coordination	Missing or weak coherence between the activities of national, regional, sectoral and technological institutions: lack of coordination between innovation and sectoral policies; lack of coordination between ministries and implementing agencies; no alignment between public and private organisations; mismatches in the timing of policy intervention
Reflexivity	Insufficient ability to monitor progress of (transformative) policy interventions towards the achievement of their objectives, to develop adaptation strategies, to anticipate changes (e.g. by developing strategies with open options taking into consideration uncertainty), and to involve a wide range of actors in the governance process. Absence of opportunities for experimenting policy instruments.

Source: Technopolis Group (2018), Modified from Weber & Rohracher (2012)

Appendix F Additional information related to the policy options descriptions

F.1 Degree of coverage of the different functionalities by policy option

Table 29: Type and composition of actors (including openness and roles)

Option 0: Horizon Europe calls	Option 2: Co-funded	Option 3: Institutionalised Art 185	Option 1: Co-programmed	Option 3: Institutionalised Art 187
What is possible? *Any legal entity* in a consortiu**m** can apply to Horizon Europe calls in ad hoc combinations Calls are open to participation from across Europe and the world (not all entities from third countries are eligible for funding)	***What is possible?*** Partners can include *any national funding body or governmental research organisation*, Possible to include also *other type of actors*, including foundations.	***What is possible?*** Partners can include *MS and Associated Countries*.	***What is possible?*** Suitable for *all types of partners*: private and/or public partners, including MS, regions, foundations. By default open to AC/ 3rd countries, but subject to policy considerations. Can cover a *large and changing community.* HE rules apply by default to calls included in the FP Work Programme, so any legal entity can apply to these.	***What is possible?*** Suitable for *all types of partners*: private and/or public partners, including MS, foundations. By default open to legal entities from AC/ 3rd countries, but subject to policy considerations. In case of countries participating non-associated third countries can only be included as partners if foreseen in the basic act and subjected to conclusion of dedicated international agreements HE rules apply by default, so any legal entity can apply to partnership calls.
What is limited? Systematic/ structured engagement with public authorities, MS, regulators, standard making bodies, foundations and NGOs.	***What is limited?*** Requires substantial national R&I programmes (competitive or institutional) in the field. Usually only legal entities from countries that are part of the consortia can apply to calls launched by the	***What is limited?*** Non-associated third countries can only be included as partners if foreseen in the basic act and subjected to conclusion of dedicated international agreements. Needs good geographical coverage – participation of at least 40% of Member States is required	***What is limited?*** If MS launch calls under their responsibility, usually only legal entities from countries that are part of the consortia can apply to these, under national rules	***What is limited?*** Requires a *rather stable set of partners* (e.g. if a sector has small number of key companies). Basic act can foresee exceptions for participation in calls / eligibility for funding.

Option 0: Horizon Europe calls	Option 2: Co-funded	Option 3: Institutionalised Art 185	Option 1: Co-programmed	Option 3: Institutionalised Art 187
	partnership, under national rules.	Requires substantial national R&I programmes (competitive or institutional) in the field. While by default the FP rules apply for eligibility for funding/participation, in practice (subject to derogation) often only legal entities from countries that are Participating States can apply to calls launched by the partnership, under national rules.		
What is not possible? To have a joint programme of R&I activities between the EU and committed partners that is implemented based on a common vision.	***What is not possible?*** To have industry/ private sector as partners.	***What is not possible?*** To have industry/ private sector as partners.		

Table 30: Type and range of activities (including flexibility and level of integration)

Option 0: Horizon Europe calls	Option 2: Co-funded	Option 3: Institutionalised Art 185	Option 1: Co-programmed	Option 3: Institutionalised Art 187
What is possible? Horizon Europe standard actions that allow *broad range of individual activities* from R&I to TRL 7 or sometimes higher. Calls for proposals published in the Work Programmes of Horizon Europe (adopted via comitology).	***What is possible?*** Activities may range from R&I, pilot, deployment actions to training and mobility, dissemination and exploitation, but according to national programmes and rules. Decision and implementation by "beneficiaries" (partners in the co-fund grant agreement) e.g. through institutional funding programmes, or by "third parties" receiving financial support, following calls for proposals launched by the consortium.	***What is possible?*** Horizon Europe standard actions that allow a broad range of coordinated activities from R&I to uptake. In case of implementation based on national rules (subject to derogation) Activities according to national programmes and rules. Allows integrating national funding and Union funding into the joint funding of projects	***What is possible?*** *Horizon Europe standard actions* that allow a broad range of coordinated activities from R&I to uptake. The association representing private partners allows to continuously build further on the results of previous projects, including activities related to regulations and standardisation and developing synergies with other funds Union contribution is implemented via calls for proposals published in the Work Programmes of Horizon Europe based on the input from partners (adopted via comitology). Open and flexible form that is simple and easy to manage.	***What is possible?*** *HE standard actions* that allow to build a portfolio with broad range of activities from research to market uptake. The back-office allows dedicated staff to implement integrated portfolio of projects, allowing to build a "system" (e.g. *hydrogen*) via pipeline of support to accelerate and scale up the take-up of results of the partnership, including those related to regulations and standardisation and developing synergies with other funds. E.g. setting up biorefinery plants and promoting their replication by additional investments from MS/ private sector. Procuring/purchasing jointly used equipment (e.g. HPC) Allows integrating national funding and Union funding into the joint funding of projects
What is limited?	***What is limited?*** Scale and scope of the programme the resulting funded R&I actions and depend on the participating programmes, typically		***What is limited?*** Limited control over precise call definition, resulting projects and outcomes, as they are implemented by EC agencies.	***What is limited?*** Limited flexibility because objectives, range of activities and partners are defined in the Regulation, and negotiated in the Council (EP).

Option 0: Horizon Europe calls	Option 2: Co-funded	Option 3: Institutionalised Art 185	Option 1: Co-programmed	Option 3: Institutionalised Art 187
	smaller in scale than FP projects			
What is not possible? To design and implement in a systemic approach a portfolio of actions. To leverage additional activities and investments beyond the direct scope of the funded actions				

Table 31:Directionality

Option 0: Horizon Europe calls	Option 2: Co-funded	Option 3: Institutionalised Art 185	Option 1: Co-programmed	Option 3: Institutionalised Art 187
What is possible? Strategic Plan (as implementing act), annual work programmes (via comitology). Possible also to base call topics on existing or to be developed SRIA/roadmap	***What is possible?*** Strategic R&I agenda/roadmap agreed between partners and EC Annual work programme drafted by partners, approved by EC Objectives and commitments are set in the Grant Agreement.	***What is possible?*** Strategic R&I agenda/roadmap agreed between partners and EC Objectives and commitments are set in the legal base. Annual work programme drafted by partners, approved by EC Commitments include obligation for financial contributions (e.g. to administrative costs, from national R&I programmes).	***What is possible?*** Strategic R&I agenda/roadmap agreed between partners and EC Objectives and commitments are set in the contractual arrangement. Input to FP annual work programme drafted by partners, finalised by EC (comitology) Commitments are political/best effort, but usually fulfilled	***What is possible?*** Strategic R&I agenda/roadmap agreed between partners and EC Objectives and commitments are set in the legal base. Annual work programme drafted by partners, approved by EC (veto-right in governance) Commitments include obligation for financial contributions (e.g. to administrative costs, from national R&I programmes).
What is limited? No continuity in support of priorities beyond the coverage of the strategic plan (4 years) and budget (2 years Annual work programme).				
What is not possible? Coordinated implementation and funding linked to the concrete objectives/ roadmap, since part of overall project portfolio managed by agency				

Table 32: Coherence (internal and external)

Option 0: Horizon Europe calls	Option 2: Co-funded	Option 3: Institutionalised Art 185	Option 1: Co-programmed	Option 3: Institutionalised Art 187
What is possible? Coherence between different parts of the Annual Work programme of the FP ensured by EC	***What is possible?*** Coherence among partnerships and with different parts of the Annual Work programme of the FP can be ensured by partners and EC Synergies with national/regional programmes and activities	***What is possible?*** Coherence among partnerships and with different parts of the Annual Work programme of the FP can be ensured by partners and EC Synergies with national/regional programmes and activities Synergies with other programmes	***What is possible?*** Coherence among partnerships and with different parts of the Annual Work programme of the FP can be ensured by partners and EC If MS participate: Synergies with national/regional programmes and activities Synergies with industrial strategies	***What is possible?*** Coherence among partnerships and with different parts of the Annual Work programme of the FP can be ensured by partners and EC Synergies with other programmes or industrial strategies If MS participate: Synergies with national/regional programmes and activities
What is limited? Synergies with other programmes or industrial strategies	***What is limited?*** Synergies with other programmes or industrial strategies	***What is limited?*** Synergies with industrial strategies	***What is limited?*** Synergies with other programmes	
What is not possible? Synergies with national/regional programmes and activities				

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