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IMPACT ASSESSMENT REPORT

Accompanying the document

Proposal for a COUNCIL REGULATION establishing the Joint Undertakings under Horizon Europe

European Partnership for Clean Hydrogen

{COM(2021) 87 final} - {SEC(2021) 100 final} - {SWD(2021) 38 final}

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Glossary

Term or acronym	*Meaning or definition*
BEV	Battery Electric Vehicle
CCS / CCU	Carbon Capture and Storage/Carbon Capture and Utilisation
CEF	Connecting Europe Facility
CHP	Combined Heat and Power
EP	European Partnerships under Horizon Europe
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
NECP	National Energy and Climate Plan
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
SoA	State of the Art
SOFC	Solid Oxide Fuel Cell
TRL	Technology readiness level

PART 1 - COMMON FOR ALL CANDIDATE INSTITUTIONALISED EUROPEAN PARTNERSHIPS

1. BACKGROUND AND CONTEXT TO EUROPEAN PARTNERSHIPS IN HORIZON EUROPE AND FOCUS OF THE IMPACT ASSESSMENT– WHAT IS DECIDED

1.1. Focus and objectives of the impact assessment

This impact assessment accompanies the Commission proposal for Institutionalised European Partnerships to be funded under Horizon Europe, the 2021-2027 Framework Programme for EU Research and Innovation (R&I).[1] It sets out to **help decide in a coordinated manner the right form of implementation for specific candidate initiatives** based on a common approach and methodology to individual assessments[2]. It also provides an **horizontal perspective on the portfolio of candidate European Partnerships** to identify further efficiency and coherence gains for more impact.

European Partnerships are initiatives where the Union, together with private and/or public partners (such as industry, public bodies or foundations) commit to support jointly the development and implementation of an integrated programme of R&I activities. The rationale for establishing such initiatives is to achieve the objectives of Horizon Europe more effectively than what can be attained by other activities of the programme.[3]

Based on the Horizon Europe Regulation, European Partnerships may be set up using **three different forms**: "Co-funded", "Co-programmed" and "Institutionalised". The setting-up of **Institutionalised Partnerships** involves new EU legislation and the establishment of dedicated implementing structures based on Article 185 or 187 of the Treaty on the Functioning of the EU (TFEU). This requires an impact assessment to be performed.

The Horizon Europe Regulation defines **eight priority areas,** scoping the domains in which Institutionalised Partnerships could be proposed[4]. Across these priority areas, **13 initiatives** have been identified **as suitable candidate initiatives** for Institutionalised Partnerships because of their objectives and scope. This impact assessment aims to identify whether 12 of these initiatives[5] need to be implemented through this form of implementation and would not deliver equally well with traditional calls of Horizon Europe or other lighter forms of European Partnerships under Horizon Europe. This means assessing whether each of these initiatives meets the necessity test set in the **selection criteria** for European Partnerships in the Horizon Europe Regulation, Annex III.

This assessment is done **without any budgetary consideration**, as the overall budget of the Multiannual Financial Framework of the EU – and hence of Horizon Europe – for the next financing period is not known at this stage.[6]

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[1] Horizon Europe Regulation (common understanding), https://data.consilium.europa.eu/doc/document/ST-7942-2019-INIT/en/pdf

[2] Based on the European Commission Better Regulation framework (SWD (2017) 350) and supported by an external study coordinated by Technopolis Group (to be published in 2020).

[3] For further details on these points, see below Section 1.2.2.

[4] Set out in the Annex Va of the Horizon Europe Regulation (common understanding). https://data.consilium.europa.eu/doc/document/ST-7942-2019-INIT/en/pdf

[5] Only 12 are subject to this impact assessment, as one initiative on High Performance Computing has already been subject to an impact assessment in 2017 (SEC(2018) 47).

[6] EU budget commitments to the European Partnership candidates can only be discussed and decided following the political agreement on the overall Multiannual Financial Framework and Horizon Europe budgetary

1.2. The political and legal context

1.2.1. Shift in EU priorities and Horizon Europe framework

European priorities have evolved in the last decades, and reflect the social, economic, and environmental challenges for the EU in the face of global developments. In her Political Guidelines for the new European Commission 2019 – 2024[7], the new Commission President put forward six overarching priorities, which reach well beyond 2024 in scope[8]. Together with the Sustainable Development Goals (SDGs), these priorities will shape future EU policy responses to the challenges Europe faces, and thus also give direction to EU research and innovation.

As part of the Multi-annual Financial Framework (MFF) 2021-27 the new EU Framework Programme for Research and Innovation **Horizon Europe will play a pivotal role for Europe to lead the social, economic, and environmental transitions needed to achieve these European policy priorities**. It will be more impact driven with a strong focus on delivering European added value, but also be more effective and efficient in its implementation.[9] Horizon Europe finds its rationale in the daunting challenges that the EU 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*." While Horizon Europe continues the efforts of strengthening the scientific and technological bases of the Union and foster competitiveness, a more strategic and impact-based approach to EU R&I investment is taken. Consequently, the **objectives of Horizon Europe** highlight the need *to deliver on the Union strategic priorities and contribute to the realisation of EU objectives and policies, contribute to tackling global challenges, including the Sustainable Development Goals by following the principles of the Agenda 2030 and the Paris Agreement.* [10]

In this context, **at least 35 % of the expenditure from actions under the Horizon Europe Programme will have to contribute to climate action**. Furthermore, a **Strategic Plan** is co-designed with stakeholders to identify **key strategic orientations for R&I support** for 2021-2024 in line with the EU priorities. In the Orientations towards the first Strategic Plan for Horizon Europe, the need to strategically 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, that actions under Pillar II of Horizon Europe "Global Challenges and European Industrial Competitiveness" will target only selected themes of especially high impact that significantly contribute to delivering on the political priorities of the Union. Most of the candidate European Partnerships fall under this Pillar.

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envelopes. The level of EU contribution for individual partnerships should be determined once there are agreed objectives, and clear commitments from partners. Importantly, there is a ceiling to the partnership budgets in Pillar II of Horizon Europe (the legal proposal specifies that *the majority of the budget in pillar II shall be allocated to actions outside of European Partnerships*).

[7] https://ec.europa.eu/info/strategy/priorities-2019-2024_en

[8] 1.A European Green Deal; An economy that works for people; A Europe fit for the Digital Age; Promoting our European way of life; A Stronger Europe in the World; and 6.A New push for European Democracy

[9] 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

[10] Article 3, Common understanding regarding the proposal for Horizon Europe Framework Programme.

1.2.2. Key evolutions in the approach to partnerships in Horizon Europe

Since their start in 1984 the successive set of Framework Programmes uses a variety of instruments and approaches to support R&I activities, address global challenges and industrial competitiveness. Collaborative, competition-based and excellence-driven R&I projects funded through Work Programmes are the most traditional and long-standing approach for implementation. Since 2002, available tools also include **partnerships**, whereby the Union together with private and/or public partners commit to jointly support the development and implementation of a R&I programme. These were introduced as part of creating the European Research Area (ERA) to align national strategies and overcome fragmentation of research effort towards an increased scientific, managerial and financial integration of European research and innovation. Interoperable and integrated national research systems would allow for better flows of knowledge, technology and people. Since then, the core activities of the partnerships consist of building critical mass mainly through collaborative projects, jointly developing visions, and setting strategic agendas.

As analysed in the **interim evaluation of Horizon 2020**[11], a considerable repertoire of partnership initiatives have been introduced over time, with 8 forms of implementation[12] and close to 120 partnership initiatives running under Horizon 2020 - without clear exit strategies and concerns about their degree of coherence, openness and transparency. Even if it is recognised that these initiatives allow setting long-term agendas, structuring R&I cooperation between otherwise dispersed actors, and leveraging additional investments, the evaluation points to the complexity generated by the proliferation of instruments and initiatives, and their insufficient contribution to policies at EU and national level.

Box 1 Key lessons from the interim evaluation of Horizon 2020 and R&I partnerships

- The **Horizon 2020 Interim Evaluation** concludes that the overall partnership landscape has become overly complex and fragmented. It identifies the need for rationalisation, improve their openness and transparency, and link them with future EU R&I missions and strategic priorities.

- The **Article 185 evaluation** finds that these public-public partnerships have scientific quality, global visibility and networking/structuring effects, but should in the future focus more on the achievement of policy impacts. From a systemic point of view, it found that the EU public-to-public cooperation (P2P) landscape has become crowded, with insufficient coherence.

- The **Article 187 evaluation** points out that Public-Private Partnership (PPP) activities need to be brought more in line with EU, national and regional policies, and calls for a revision of the Key Performance Indicators. As regards the **contractual PPPs (cPPPs)** their reviews identified challenges of coherence among cPPPs and the need to develop collaborations and synergies with other relevant initiatives and programmes at EU, national and regional level.

Over 80% of respondents to the Open Public Consultation (OPC) indicated that a significant contribution by future European Partnerships is 'fully needed' to achieve climate-related goals, to develop and effectively deploy technology, and for EU global competitiveness in specific sectors/domains. Views converged across all categories of respondents, including citizens, industry and academia.

[11] Interim evaluation of Horizon 2020, Commission Staff Working Document, SWD(2017)221 and 222
Interim evaluation of the Joint Undertakings operating under Horizon 2020 (Commission Staff Working Document, SWD(2017) 339); Evaluation of the Participation of the EU in research and development programmes undertaken by several Member States based on Article 185 of the TFEU, Commission Staff Working Document, SWD (2017)340)

[12] E.g. initiatives based on Article 187 (Joint Technology Initiatives), Article 185 TFEU, Contractual Public-Private Partnerships (cPPPs), Knowledge & Innovation Communities of the European Institute of Innovation & Technology (EIT-KICs), ERA-NETs, European Joint Programmes, Joint Programming Initiatives.

The impact assessment of Horizon Europe identifies therefore the need to **rationalise the EU R&I funding landscape**, in particular with respect to partnerships, as well as to **re-orient partnerships towards more impact** and delivery on EU priorities. To address these concerns and to realise the higher ambition for European investments, Horizon Europe puts forward **a major simplification and reform for the Commission's policy on R&I partnerships**[13]. Reflecting its pronounced systemic nature aimed at contributing to EU-wide 'transformations' towards the sustainability objectives, Horizon Europe indeed intends to make a more effective use of these partnerships with a **more strategic, coherent and impact-driven approach**. Key related changes that apply to all forms of European Partnerships encapsulated in Horizon Regulation are summarised in the Box below.

Box 2 Key features of the revised policy approach to R&I partnerships under Horizon Europe based on its impact assessment

- ✓ **Simpler architecture & toolbox** by streamlining 8 partnership instruments into 3 implementation forms (Co-Funded, Co-Programmed, Institutionalised), under the umbrella 'European Partnerships'
- ✓ **More systematic and transparent approach** to selecting, implementing, monitoring, evaluating and phasing out all forms of partnerships (**criteria** for European Partnerships):
  - The selection of Partnerships is embedded in the strategic planning of Horizon Europe, thereby ensuring coherence with the EU priorities. The selection criteria require that partnerships are established with stronger ex-ante commitment and higher ambition.
  - The implementation criteria stipulate that initiatives adopt a systemic approach in achieving impacts, including broad engagement of stakeholders in agenda-setting and synergies with other relevant initiatives to promote the take-up of R&I results.
  - A harmonised monitoring & evaluation system will be implemented, and ensures that progress is analysed in the wider context of achieving Horizon Europe objectives and EU priorities.
  - All partnerships need to develop an exit strategy from Framework Programme funding. This new approach is underpinned by principles of openness, coherence and EU added value.
- ✓ **Reinforced impact orientation:**
  - Partnerships are established only if there is evidence they support achieving EU policy objectives more effectively than other Horizon Europe actions, by demonstrating a clear vision and targets (**directionality**) and corresponding long-term commitments from partners (**additionality**).
  - European Partnerships are expected to provide mechanisms – based on a concrete roadmap - to join up R&I efforts between a broad range of actors towards the development and uptake of innovative solutions in line with EU priorities, serving the economy and society, as well as scientific progress.
  - They are expected to develop close synergies with national and regional initiatives, acting as dynamic change agents, strengthening linkages within their respective ecosystems and along the value chains, as well as pooling resources and efforts towards the common EU objectives.

Under Horizon Europe, a 'European Partnership'[14] is defined 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."*

The Regulation further specifies that European Partnerships shall 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."*

[13] Impact assessment of Horizon Europe, Commission Staff Working Document, SWD(2018)307.
[14] Article 8 and Annex III of the Horizon Europe Regulation (common understanding))

1.3. Why should the EU act

1.3.1. Legal basis

Proposals for Institutionalised European Partnerships are based on:

1) Article 185 TFEU which allows the Union to make provision, in agreement with the Member States concerned, for participation in research and development programmes undertaken by several Member States, including participation in the structures created for the execution of those programmes; or
2) Article 187 TFEU according to which the Union may set up joint undertakings or any other structure necessary for the efficient execution of Union research, technological development and demonstration programmes.[15]

1.3.2. Subsidiarity

The EU should act only in areas where there is demonstrable advantage that the action at EU level is more effective than action taken at national, regional or local level. Research is a shared competence between the EU and its Member States according to the TFEU. Article 4 (3) specifies that in the areas of research, technological development and space, the EU can carry out specific activities, including defining and implementing programmes, without prejudice to the Member States' freedom to act in the same areas.The candidate initiatives focus on areas where there is a demonstrable value added in acting at the EU level due to the scale, speed and scope of the efforts needed for the EU to meet its long-term Treaty objectives and deliver on its strategic policy priorities and commitments. In addition, the proposed initiatives should be seen as complementary and reinforcing national and sub-national activities in the same area. Overall European Partnerships find their **rationale in addressing a set of systemic failures**[16]:

- 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 agendas and/or R&I funding programmes. They aim to address **transformational failures** to better align agendas and policies of public and private funders, pool available resources, create critical mass, avoid unnecessary duplication of efforts, and leverage sufficiently large investments where needed but hardly achievable by single countries.
- The concentration of efforts and pooling of knowledge on common priorities to solve multi-faceted societal and economic challenges is at the core of these initiatives. Specifically, enhanced cross-disciplinary and cross-sectoral collaboration and an improved integration of value chains and ecosystems are among the key objectives of these instruments. In the light of Horizon Europe, the aim is to **drive system transitions and transformations towards EU priorities**.
- Especially in fast-growing technologies and sectors such as ICT, there is a need to **react to 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.
- They also aim to address **market failures** predominantly to enhancing industry investments thanks to the sharing of risks.

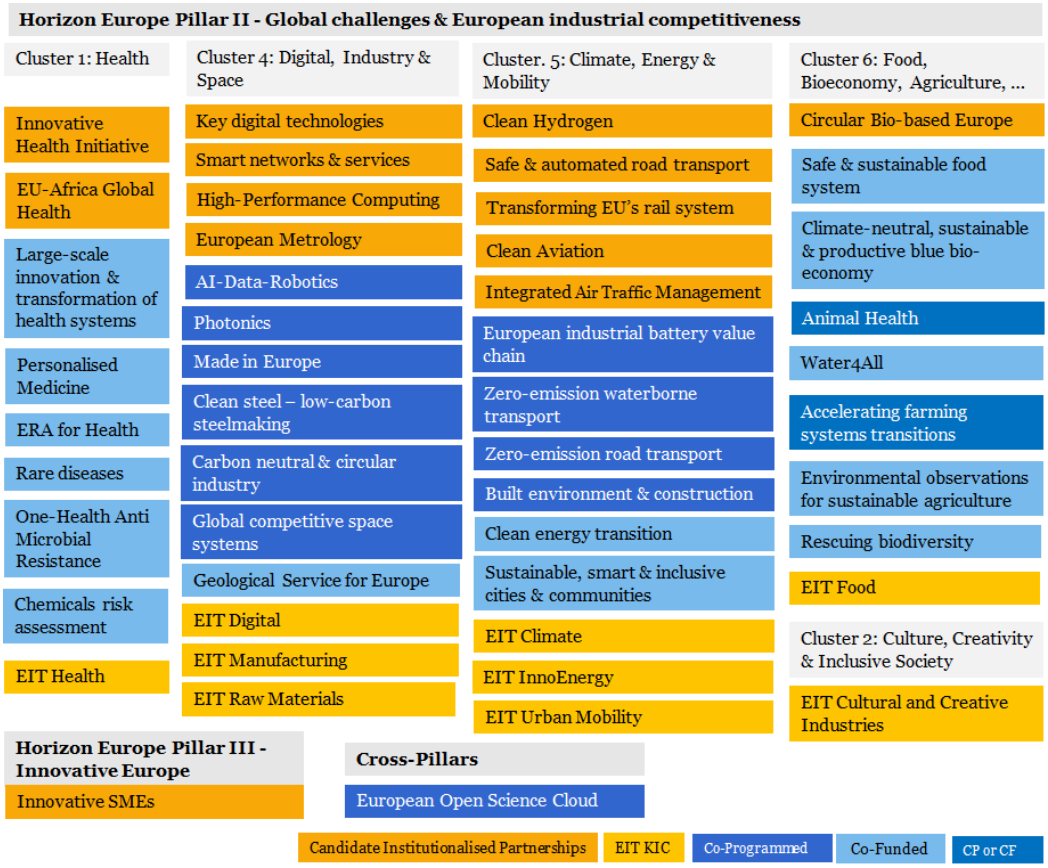
[15] Both Articles are under Title XIX of the TFEU - Research and Technological Development and Space.
[16] The Interim Evaluation of Horizon 2020 and the impact assessment of Horizon Europe provide qualitative and quantitative evidence on these points. Sections 1 and 2 of each impact assessment on candidate European Partnerships include more detail on the necessity to act at EU level in specific thematic areas.

2. THE CANDIDATE EUROPEAN PARTNERSHIPS – WHAT NEEDS TO BE DECIDED

2.1. Portfolio of candidates for Institutionalised European Partnerships

The new approach for more objective-driven and impactful European Partnerships is reflected in the way candidate Partnerships have been identified. It involved a co-design exercise aiming to better align these initiatives with societal needs and policy priorities, while broadening the range of actors involved. Taking into account the 8 areas for Institutionalised European Partnerships set out in the Horizon Europe Regulation[17], a co-design exercise as part of the Strategic Planning process of Horizon Europe lead to the identification of **49 candidates for Co-funded, Co-programmed or Institutionalised European Partnerships**[18]. Out of these, **13 were identified as suitable candidate Institutionalised Partnerships because of their objectives and scope**[19]. Whilst the Co-Funded and Co-Programmed Partnerships are linked to the comitology procedure (including the adoption of the Strategic Plan and the Horizon Europe Work Programmes), Institutionalised Partnerships require the adoption of legislation and are subject to an impact assessment. The Figure below gives an overview of all candidate European Partnerships according to their primary relevance to Commission priorities for 2019-2024.

Figure 1 - Overview of the candidates for Co-Funded, Co-Programmed and Institutionalised European Partnerships according to Horizon Europe structure



Source: Technpolis group (2020)

[17] Horizon Europe Regulation (common understanding), Annex Va.

[18] Shadow configuration of Strategic Programme Committee for Horizon Europe. The list of candidate European Partnerships is described in "Orientations towards the Strategic Plan of Horizon Europe" - Annex 7

[19] Only 12 are subject to this impact assessment, as one initiative on High Performance Computing has already been subject to an impact assessment in 2017 (SEC(2018) 47)

There are only three partnerships for which implementation as an Institutionalised Partnership under Article 185 is an option, i.e. European Metrology, the EU-Africa Global Health partnership, and Innovative SMEs. Ten partnerships are candidates for Institutionalised Partnerships under Article 187. Overall the initiatives can be categorised into '*horizontal*' partnerships and '*vertical*' partnerships.

The **'horizontal' partnerships** have a central position in the overall portfolio, as they are expected to develop methodologies and technologies for application in the other priority areas, ultimately supporting European strategic autonomy in these areas as well as technological sovereignty. These 'horizontal' partnerships are typically proposed as Institutionalised or Co-programmed Partnerships, in addition to a number of EIT KICs, they cover mainly the digital field in addition to space, creative industries and manufacturing, but also the initiative related to Innovative SMEs. '**Vertical' partnerships** are focused on the needs and development of specific application areas, and are primarily expected to support enhanced environmental sustainability thereby addressing Green Deal related objectives. They also deliver on policies for more people centred economy, through improved wellbeing of EU citizen and the economy, like health related candidate European Partnerships.

2.2. Assessing the necessity of a European Partnership and possible options for implementation

Horizon Europe Regulation Article 8 stipulates that Institutionalised European Partnerships based on Article 185 and 187 TFEU *shall be implemented only where 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, and if justified by a long-term perspective and high degree of integration.* At the core of this impact assessment is therefore the need to demonstrate that the impacts generated through a Partnership approach go beyond what could be achieved with traditional calls under the Framework Programme – the Baseline Option. Secondly, it needs to assess if using the Institutionalised form of a Partnership is justified for addressing the priority.

For all candidate Institutionalised European Partnerships the options considered in this impact assessment are the same, i.e.:

- Option 0 – Baseline option – Traditional calls under the Framework Programme
- Option 1 – Co-programmed European Partnership
- Option 2 – Co-funded European Partnership
- Option 3 – Institutionalised Partnership
    - Sub-option 3a Institutionalised Partnerships based on Art 185 TFEU
    - Sub-option 3b Institutionalised Partnerships based on Art 187 TFEU

2.2.1. Option 0 - Baseline option – Traditional calls

Under this option, strategic programming for R&I in the priority area will be done through the mainstream channels of Horizon Europe. The related priorities will be implemented through **traditional calls** of Horizon Europe covering a range of actions, mainly R&I and/or innovation actions but also coordination and support actions, prizes or procurement. Most actions involve consortia of public and/or private actors in ad hoc combinations, while some actions are single actor (mono-beneficiary). There will be no dedicated implementation structure and no support other than what is foreseen in the related Horizon Europe Work Programme. This means that discontinuation costs/benefits of predecessor initiatives should be factored in for capturing the baseline situation when relevant.

Under this option, strategic planning mechanisms in the Framework Programme will allow for a high level of flexibility in the ability of traditional calls to respond to particular needs over time, building upon additional input in co-creation from stakeholders and programme committees involving Member States. The Union contribution to addressing the priority covers the full duration of the initiative, during the lifetime of Horizon Europe. Without a formal EU partnership mechanism, it is less likely that the stakeholders will develop a joint Strategic Research Agenda and commit to its implementation or agree on mutual commitments and contributions outside their participation in funded projects.

2.2.2. European Partnerships

Under this set of options, three different forms of implementation are assessed: Co-funded, Co-Programmed, Institutionalised European Partnerships. These have **commonalities that cannot serve as a distinguishing factor in the impact assessment process**. They are all based on agreed objectives and expected impacts and underpinned by Strategic Research and Innovation Agendas / roadmaps that are shared and committed to by all partners in the partnership. They all have to follow the same set of criteria along their lifecycle, as defined in the Horizon Europe Regulation (Annex III), including ex ante commitment from partners to mobilise and contribute resources and investments. The Union contribution is defined for the full duration of the initiative for all European Partnerships. The Horizon Europe legal act introduces few additional requirements for Institutionalised Partnerships, e.g. the need for long-term perspective, strong integration of R&I agendas, and financial contributions.

Figure 2 - Key differences in preparation and implementation of European Partnerships

Type	**Legal form**	**Implementation**
Co-Programmed	Contractual arrangement / MoU	**Division of labour**, whereby Union contribution is implemented through Framework rogramme and partners' contributions under their responsibility.
Co-Funded	Grant Agreement	Union provides co-funding for an **integrated programme with distributed implementation** by entities managing and/or funding national research and innovation programmes
Institutionalised based on Article 185/187 TFEU	Basic act (Council regulation, Decision by European Parliament and Council)	**Integrated programme with centralised implementation**

The main differences between the different forms of European Partnerships are in their preparation and in the way they function, as well as in the overall impact they can trigger. The Co-Programmed form is assessed as the simplest, and the Institutionalised the most complex to prepare and implement. The functionalities of the different form of Partnerships – compared to the baseline option – are presented in Figure 3. They relate to the types of actors Partnerships can involve and their degree of openness, the types of activities they can perform and their degree of flexibility, the degree of commitment of partners and the priority setting system, and their ability to work with their external environment (coherence), etc. These key distinguishing factors will be at the basis of the comparison of each option to determine their overall capacity to deliver what is needed at a minimised cost.

Figure 3 Overview of the functionalities provided by each form of European Partnerships, compared to the traditional calls of Horizon Europe (baseline)

Baseline: Horizon Europe calls	**Option 1: Co-Programmed**	**Option 2: Co-Funded**	**Option 3a: Institutio-nalised Art 185**	**Option 3b: Institutionalised Art 187**
Type and composition of actors (including openness and roles)				
Partners: N.A., no common set of actors that engage in planning and implementation Priority setting: open to all, part of Horizon Europe Strategic planning Participation in R&I activities: fully open in line with Horizon Europe rules	Partners: Suitable for all types: private and/or public partners, foundations Priority setting: Driven by partners, open stakeholder consultation, MS in comitology Participation in R&I activities: fully open in line with Horizon Europe rules	Partners: core of national funding bodies or govern-mental research organisations Priority setting: Driven by partners, open stakeholder consultation Participation in R&I activities: limited, according to national rules of partner countries	Partners: National funding bodies or governmental research organisation Priority setting: Driven by partners, open stakeholder consultation Participation in R&I activities: fully open in line with Horizon Europe rules, but possible derogations	Partners: Suitable for all types: private and/or public partners, foundations Priority setting: Driven by partners, open stakeholder consultation Participation in R&I activities: fully open in line with Horizon Europe rules, but possible derogations
Type and range of activities (including additionality and level of integration)				
Activities: Horizon Europe standards that allow broad range of individual actions Additionality: no additional activities and investments outside the funded projects Limitations: No systemic approach beyond individual actions	Activities: Horizon Europe standard actions that allow broad range of individual actions, support to market, regulatory or policy/ societal uptake Additionality: Activities/investments of partners, National funding Limitations: Limited systemic approach beyond individual actions	Activities: Broad, according to rules/programmes of participating States, State-aid rules, support to regulatory or policy/ societal uptake Additionality: National funding Limitations: Scale & scope depend on participating programmes, often smaller in scale	Activities: Horizon Europe standards that allow broad range of individual actions, support to regulatory or policy/societal uptake, possibility to systemic approach Additionality: National funding	Activities: Horizon Europe standards that allow broad range of individual actions, support to regulatory or policy/societal uptake, possibility to systemic approach (portfolios of projects, scaling up of results, synergies with other funds. Additionality: Activities/investments of partners/ national funding
Priority-setting process and directionality				
Priority setting: Strategic Plan and annual work programmes, covering max. 4 years. Limitations: Fully taking into account existing or to be developed SRIA/ roadmap	Priority setting: Strategic R&I agenda/ roadmap agreed between partners & EC, covering usually 7 years, incl. allocation of Union contribution Input to FP annual work programme drafted by partners, finalised by EC (comitology) Objectives & commitments set in contractual arrangement	Priority setting: Strategic R&I agenda/ roadmap agreed between partners & EC, covering usually 7 years, incl. allocation of Union contribution Annual work programme drafted by partners, approved by EC Objectives & commitments set in Grant Agreement	Priority setting: Strategic R&I agenda/ roadmap agreed between partners & EC, covering usually 7 years, incl. allocation of Union contribution Annual work programme drafted by partners, approved by EC Objectives & commitments set in legal act	Priority setting: Strategic R&I agenda/ roadmap agreed between partners & EC, covering usually 7 years, incl. allocation of Union contribution Annual work programme drafted by partners, approved by EC (veto-right in governance) Objectives & commitments set in legal act
Coherence: internal (Horizon Europe) & external (other Union programmes, national programmes, industrial strategies)				
Internal: Coherence between different parts of the FP Annual Work programme can be ensured by EC External: Limited for other Union programmes, no synergies with national/regional programmes & activities	Internal: Coherence among partnerships & with parts of the FP Annual Work programme can be ensured by partners & EC External: Limited synergies with other Union programmes & industrial strategies. If MS participate, with national/ regional programmes & activities	Internal: Coherence among partnerships & with parts of the FP Annual Work programme can be ensured by partners & EC External: Synergies with national/ regional programmes & activities	Internal: Coherence among partnerships & with parts of the FP Annual Work programme can be ensured by partners & EC External: Synergies with national/ regional programmes & activities	Internal: Coherence among partnerships & with parts of the FP Annual Work programme can be ensured by partners & EC External: Synergies with other Union programmes and industrial strategies If MS participate, with national/ regional programmes & activities

2.2.2.1. 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 Commission and the private and/or public partners. Private partners are represented by industry associations, which also support the daily management of the partnership. This type of partnership would allow for a large degree of flexibility for the activities, partners and priorities to continuously evolve. The commitments of partners are political efforts described in the contractual arrangement and the contributions from partners are provided in kind more than financially. The priorities for the calls, proposed by the Partnership's members for integration in the Horizon Europe's Work Programmes, are subject to further input from Member States (comitology) and Commission services. The Union contribution is implemented within the executive agency managing Horizon Europe calls for research and innovation projects proposals. The full array of Horizon Europe instruments can be used, ranging from research and innovation (RIA) types of actions to coordination and support actions (CSA) and including grants, prizes, and procurement.

2.2.2.2. Option 2 – Co-funded European Partnership

The Co-funded European Partnership is **based on a Grant Agreement** between the Commission and a consortium of partners, resulting from a specific call in the Horizon Europe Work Programme. This form of implementation only allows to address public partners at its core. Typically these provide co-funding to a common programme of activities established and/or implemented by entities managing and/or funding national R&I programmes. The recipients of the EU co-funding implement the initiative under their responsibility, with national funding/resources pooled to implement the programme with co-funding from the Union. The expectation is that these entities would cover most if not all EU Member States. Calls and evaluations would be organised centrally, beneficiaries in selected projects would be funded at national level, following national funding rules.

2.2.2.3. Option 3 – Institutionalised European Partnership

This type of Partnership is the most complex and high-effort arrangement, and requires meeting additional requirements. Institutionalised European Partnership are **based on a Council Regulation (Article 187 TFEU or a Decision by the European Parliament and Council (Article 185 TFEU)** and are implemented by dedicated structures created for that purpose. These regulatory needs limit the flexibility for a change in the 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 agendas in the private and/or public sectors in the EU in order to address a strategic challenge. It is therefore necessary to demonstrate that other forms of implementation would not achieve the objectives or would not generate the necessary expected impacts, and that a long-term perspective and high degree of integration is needed. For both Article 187 and 185 initiatives, contributions from partners can be in the form of financial and in-kind contributions. Eligibility for participation and funding follows by default the rules of Horizon Europe, unless a derogation is introduced in the basic act.

Option 3a - Institutionalised Partnerships based on Article 185 TFEU

Article 185 of the TFEU allows the Union to participate in programmes jointly undertaken by Member States and limits therefore the scope to **public partners** which are 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 legal entity (Dedicated Implementation Structure) of their choice for the implementation. By default, participation of non-associated Third Countries is not foreseen. Such participation is possible only if it is foreseen in the basic act and subject to conclusion of an international agreement.

Option 3b - Institutionalised Partnerships based on Article 187 TFEU

Article 187 of the TFEU allows the Union to set up joint undertakings or any other structure necessary for the efficient execution of EU research, technological development and demonstration programmes. This type of Institutionalised Partnership brings together a stable set of **public and private 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 (JU)) 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.

Participation of non-associated Third Countries is only possible if foreseen in the basic act and subject to conclusion of an international agreement.

2.3. Overview of the methodology adopted for the impact assessment

The methodology for each impact assessment is based on the Commission Better Regulation Guidelines[20] to evaluate and compare options with regards to their **efficiency, effectiveness and coherence**. This also integrates **key selection criteria for European Partnerships**.

Box 2 Summary of European Partnerships selection criteria[21]

- ***Effectiveness*** in achieving the related objectives and impacts of the Programme;
- ***Coherence*** and synergies of the European Partnership within the EU R&I landscape;
- ***Transparency*** & ***openness*** as regards the identification of priorities and objectives and the involvement of partners & stakeholders from the entire value chain, backgrounds & disciplines;
- Ex-ante demonstration of ***additionality*** and ***directionality***;
- Ex-ante demonstration of the partners' ***long term commitment***.

2.3.1. Overview of the methodologies employed

In terms of **methods and evidence used**, the impact assessments draw on an external study covering all candidate Institutionalised European Partnerships in parallel to ensure a high level of coherence and comparability of analysis, in addition to an horizontal analysis.[22] For

[20] European Commission (2017), Better Regulation Guidelines (SWD (2017) 350)
[21] For a comprehensive overview of the selection criteria for European Partnerships, see Annex 6.
[22] Technopolis Group (2020), Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe, Final Report, Study for the European Commission, DG Research & Innovation

all initiatives, the understanding of the overall context of the candidate institutionalised European Partnerships relied on desk research, including among others the lessons learned from previous partnerships. This was complemented by the analysis of a range of quantitative and qualitative evidence, including evaluations of past and ongoing initiatives; foresight studies; statistical analyses of Framework Programmes application and participation data, and Community Innovation Survey data; analyses of science, technology and innovation indicators; reviews of academic literature; sectoral competitiveness studies and expert hearings. 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, as described below. Public consultations (both open and targeted) supported the comparative assessment of the policy options. For each initiative, up to 50 relevant stakeholders were interviewed by the external contractor (policymakers, business including SMEs and business associations, research institutes and universities, and civil organisations, among others). In addition, the analysis was informed by the results of the Open Public Consultation run between September and November 2019, the consultation of Member States through the Strategic Programme Committee and the online feedback received on the Inception Impact Assessments of the set of initiatives.

A more detailed description of the methodology and evidence base that were mobilised, completed by thematic specific methodologies, is provided in Annexes 4 and 6.

2.3.2. Method for identifying the preferred option

The first step of the assessments consisted in scoping the problems that the initiatives are expected to solve given the overall economic, technological, scientific and social context, including the lessons to be learned from past and ongoing partnerships on what worked well and less well. This supported the identification of the objectives of the initiative in the medium and long term with the underlying intervention logic – showing how to get there.

Given the focus of the impact assessment on comparing different forms of implementation, the Better Regulation framework has then been adapted to introduce "**key functionalities needed**" - making the transition between the definition of the objectives and what would be crucial to achieve them *in terms of implementation*. The identification of "key functionalities needed" for each initiative as an additional step in the impact assessment is based on the distinguishing factors between the different options (see Section 2.2.1). In practical terms, each option is assessed on the basis of the degree to which it would allow for the key needed functionalities to be covered, as regards e.g. the type and composition of actors that can be involved ('openness'), the range of activities that can be performed (including additionality and level of integration), the level of directionality and integration of R&I strategies; the possibilities offered for coherence and synergies with other components of Horizon Europe, including other Partnerships (internal coherence), and the coherence with the wider policy environments, including with the relevant regulatory and standardisation framework (external coherence). This approach guides the identification of discarded options while allowing at the same time a structured comparison of the options not only as regards their effectiveness, efficiency and coherence, but also against a set of other key selection criteria for European Partnerships (openness, transparency, directionality)[23].

[23] The criterion on the ex-ante demonstration of partners' long term commitment depends on a series of factors that are unknown at this stage, and thus fall outside the scope of the analysis.

In line with the Better Regulation Framework, the assessment of the effectiveness, efficiency and coherence of each option is made compared to the baseline. Therefore, for each of these aspects the performance of using traditional calls under Horizon Europe is first estimated and scored 0 to serve as a reference point. This includes the discontinuation costs/benefits of existing implementation structures when relevant. The policy options are then scored compared to the baseline with a + and – system with a two-point scale, to show a slightly or highly additional/lower performance compared to the baseline. A scoring of 0 of a policy option means that it would deliver as much as the baseline option.

On the basis of the evidence collected, the intervention logic of each initiative and the key functionalities needed, the impact assessments first evaluate the **effectiveness** of the various policy options to deliver on their objectives. To be in line with the Horizon Europe impact framework, the fulfilment of the specific objectives of the initiative is translated into 'expected impacts' - how success would look like -, differentiating between scientific, economic/ technological, and societal (including environmental) impacts. Each impact assessment considers to which extent the different policy options provides the 'key functionalities needed' to achieve the intended objectives. The effectiveness assessment does not use a compound score but shows how the options would deliver on the different types of expected impacts. This is done to increase transparency and accuracy in the assessment of options[24].

A similar approach is followed to evaluate the coherence of options with the overarching objectives of the EU's R&I policy, and distinguishes between **internal** and **external coherence**. Specifically, internal coherence covers the consistency of the activities that could be implemented with the rest of Horizon Europe, including European Partnerships (any type). External coherence refers to the potential for synergies and/or complementarities (including risks of overlaps/gaps) of the initiative with its external environment, including with other programmes under the MFF 2021-27, but also the framework conditions at European, national or regional level (incl. regulatory aspects, standardisation).

To compare the expected costs and benefits of each option (**efficiency**), the thematic impact assessments broadly follow a cost-effectiveness approach[25] to establish to which extent the intended objectives can be achieved for a given cost. A preliminary step in this process is to obtain a measure of the expected costs of the policy options, to be used in the thematic assessments. As the options correspond to different implementation modes, relevant cost categories generally include the costs of setting-up and running an initiative. For instance, set-up costs includes items such as the preparation of a European Partnership proposal and the preparation of an implementation structure. The running costs include the annual work programme preparation costs. Where a Partnership already exists, discontinuation costs and cost-savings are also taken into account[26]. The table below provides an overview of the cost categories used in the impact assessment and a qualitative scoring of their intensity when compared to the baseline option (traditional calls). Providing a monetised value for these

[24] In the thematic impact assessments, scores are justified in a detailed manner to avoid arbitrariness and spurious accuracy. A qualitative or even quantitative explanation is provided of why certain scores were given to specific impacts, and why one option scores better or worse than others.

[25] For further details, see Better Regulation Toolbox # 57.

[26] Discontinuation costs will bear winding down and social discontinuation costs and vary depending on e.g. the number of full-time-equivalent (FTEs) staff concerned, the type of contract (staff category and duration) and applicable rules on termination (e.g. contracts under Belgian law or other). If buildings are being rented, the cost of rental termination also apply. As rental contracts are normally tied to the expected duration of the current initiatives, these termination costs are likely to be very limited. In parallel, there would also be financial cost-savings related to the closing of the structure, related to operations, staff and coordination costs in particular. This is developed further in the individual efficiency assessments.

average static costs would have been misleading, because of the different features and needs of each candidate initiative.[27] The table shows the overall administrative, operational and coordination costs of the various options. These costs are then put into context in the impact assessments to reflect the expected co-financing rates and the total budget available for each of the policy options, assuming a common Union contribution (cost-efficiency):

- The costs related to the baseline scenario (traditional calls under Horizon Europe) are pre-dominantly the costs of implementing the respective Union contribution via calls and project, managed by the executive agencies (around 4%, efficiency of 96% for the overall investment).
- For a Co-Programmed partnership the costs of preparation and implementation increase only marginally compared to the baseline (<1%), but lead to an additional R&I investment of at least the same amount than the Union contribution[28] (efficiency of 98% for the overall investment).
- For a Co-Funded partnership the additional R&I investment by Member States accounts for 2,3 times the Union contribution[29]. The additional costs compared to the baseline of preparing and implementing the partnership, including the management of the Union contribution implemented by the national programmes, can be estimated at 6% of the Union contribution (efficiency of 98% related to the overall investment).
- For an Article 185 initiative the additional R&I investment by Member States is equal to the Union contribution[30]. The additional costs compared to the baseline of preparing and implementing the partnership, including the management of the Union contribution implemented by the dedicated implementation structure, can be estimated at 7% of the Union contribution (efficiency of 96% related to the overall investment).
- For an Article 187 initiative the additional R&I investment by partners is equal to the Union contribution[31]. The additional costs compared to the baseline of preparing and implementing the partnership, including the management of the Union contribution implemented by the dedicated implementation structure, can be estimated at 9% of the Union contribution (efficiency of 94% related to the overall investment).

Figure 4 - Intensity of additional costs compared with Horizon Europe Calls (for Partners, stakeholders, public and EU)

Cost items	Baseline: traditional calls	Option 1: Co-programmed	Option 2 Co-funded	Option 3a - Art. 185	Option 3b -Art. 187
Preparation and set-up costs					
Preparation of a partnership proposal (partners and EC)	0	↑↑			
Set-up of a dedicated implementation structure	0			Existing: ↑ New: ↑↑	Existing: ↑↑ New: ↑↑↑
Preparation of the SRIA / roadmap	0	↑↑			
Ex-ante Impact Assessment for partnership	0			↑↑↑	
Preparation of EC proposal and negotiation	0			↑↑↑	

[27] A complete presentation of the methodology developed to assess costs as well as the sources used is described in the external study supporting this impact assessment (Technopolis Group, 2020).
[28] Minimum contributions from partners equal to the Union contribution
[29] Based on the default funding rate for programme co-fund actions of 30%, partners contribute with 70% of the total investment.
[30] Based on the minimum requirement in the legal basis that partners contribute at least 50% of the budget.
[31] Based on the minimum requirement in the legal basis that partners contribute at least 50% of the budget.

Cost items	Baseline: traditional calls	Option 1: Co-programmed	Option 2 Co-funded	Option 3a - Art. 185	Option 3b -Art. 187
Running costs (Annual cycle of implementation)					
Annual Work Programme preparation	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				↑↑↑
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.

The cost categories estimated for the common model are then used to develop a scorecard analysis and further refine the assessment of options for each of the 12 candidate Institutionalised Partnerships. Specifically, the scores related to the set-up and implementation costs are used in the thematic impact assessments to consider the scale of the expected benefits and thereby allow a simple "value for money" analysis (**cost-effectiveness**)[32]. In carrying out the scoring of options, the results of fieldwork, desk research and stakeholder consultation undertaken and taken into account.

For the **identification of the preferred option,** the scorecard analysis builds a hierarchy of the options by individual criterion and overall in order to identify a single preferred policy option or in case of an inconclusive comparison of options, a number of 'retained' options or hybrid. This exercise supports the systematic appraisal of alternative options across multiple types of monetary, non-monetary and qualitative dimensions. It also allows for easy visualisation of the pros and cons of each option. Each option is attributed a score of the adjudged performance against each criterion with the three broad appraisal dimensions of effectiveness, efficiency and coherence.

As a last step, the alignment of the preferred option with key criteria for the selection of European Partnerships is described, reflecting the outcomes of the '**necessity test'**.[33] The monitoring and evaluation arrangements are concluding the assessment, with an identification of the key indicators to track progress towards the objectives over time.

2.4. Horizontal perspective on candidate Institutionalised European Partnerships

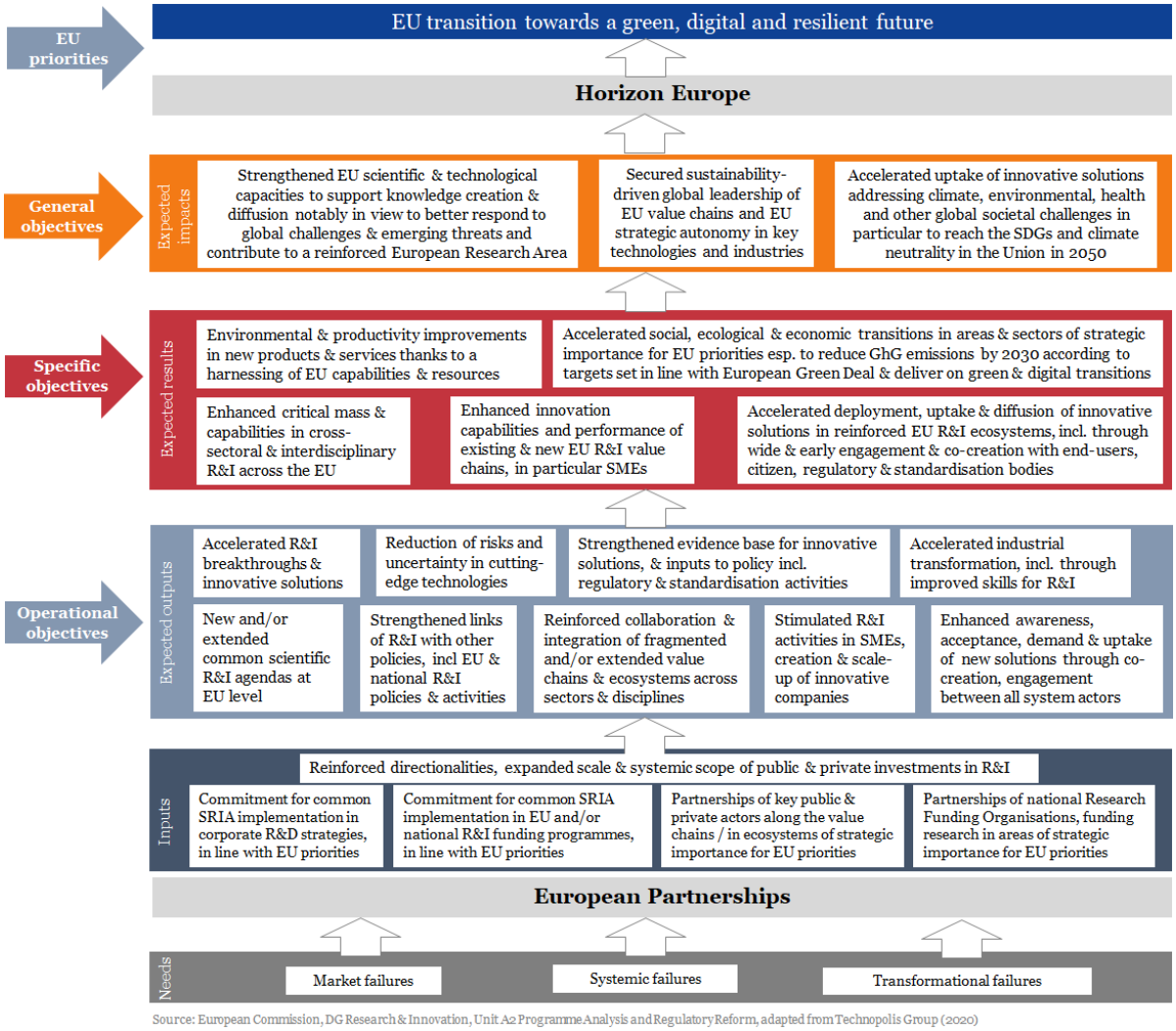
2.4.1. Overall impact orientation, coherence and efficiency needs

The consolidated **intervention logic** for the set of candidate Institutionalised European Partnerships in the Figure below builds upon the objectives as reported in the individual impact assessments.

[32] More details on the methodology can be found in Annex 4.

[33]Certain aspects of the selection criteria will be further addressed/ developed at later stages, notably in the context of preparing basic acts (e.g. Openness and Transparency; Coherence and Synergies), in the Strategic Research and Innovation Agendas (e.g. Directionality and Additionality), and by collecting formal commitments (Ex-ante demonstration of partners' long-term commitment).

Figure 5 – Overall intervention logic of the European Partnerships under Horizon Europe



Source: European Commission, DG Research & Innovation, Unit A2 Programme Analysis and Regulatory Reform, adapted from Technopolis Group (2020)

When analysed as a package the 12 candidate Institutionalised European Partnerships are expected to support the achievement of the European policy priorities targeted by Horizon Europe by pursuing the following joint general objectives:

a) Strengthening and integrating EU scientific and technological capacities to support knowledge creation and diffusion notably in view to better respond to global challenges and emerging threats and contribute to a reinforced European Research Area;
b) Securing sustainability-driven global leadership of EU value chains and EU strategic autonomy in key technologies and industries; and
c) Accelerate the uptake of innovative solutions addressing climate, environmental, health and other global societal challenges contributing to Union strategic priorities, in particular to reach the Sustainable Development Goals and climate neutrality in the Union in 2050.

In terms of specific objectives, they jointly aim to:

a) Enhance the critical mass and scientific capabilities in cross-sectoral and interdisciplinary research and innovation across the Union;
b) Accelerate the social, ecological and economic transitions in areas and sectors of strategic importance for Union priorities, in particular to reduce greenhouse gas

emissions by 2030 according to the targets set in line with the European Green Deal, and deliver on the green and digital transition;

c) Enhance the innovation capabilities and performance of existing and new European research and innovation value chains, in particular SMEs;
d) Accelerate the deployment, uptake and diffusion of innovative solutions in reinforced European R&I ecosystems, including through wide and early engagement and co-creation with end-users, citizen and regulatory and standardisation bodies;
e) Deliver environmental and productivity improvements in new products and services thanks to a harnessing of EU capabilities and resources.

In terms of their operations, taking an horizontal perspective on all initiatives allows for the identification of further possible collective efficiency and coherence gains for more impact:

- **Coherence for impact:** The extent and speed by which the expected results and impacts will be reached, will depend on the scale of the R&I efforts triggered, the profile of the partners involved, the strength of their commitments, and the scope of the R&I activities funded. To be fully effective it comes out clearly that future partnerships need to operate over their whole life cycle in full coherence with their environment, including potential end users, regulators and standardisation bodies. This relates also to the alignment with relevant EU, national or regional policies and synergies with R&I programmes. This needs to be factored in as of the design stage to ensure a wide take-up and/or deployment of the solutions developed, including their interoperability.

- **Collaboration for impact:** Effectiveness could also be improved collectively through enhanced cross-disciplinary and cross-sectoral collaboration and an improved integration of value chains and ecosystems. An adequate governance structure appears in particular necessary to ensure cross-fertilisation between all European Partnerships. This applies not only to initiatives where similar R&I topics are covered and/or the same stakeholders involved or targeted, but also to the interconnections needed between the 'thematic' and the 'vertical' Partnerships, as these are expected to develop methodologies and technologies for application in EU priority areas. Already at very early stages of preparing new initiatives**,** Strategic Research and Innovation Agendas and roadmaps need to be aligned, particularly for partnerships that develop enabling technologies that are needed in other Partnerships. The goal should be to achieve greater impacts jointly in light of common challenges.

- **Efficiency for impact:** Potential efficiency gains could also be achieved by joining up the operational functions of Joint Undertakings that do not have a strong context dependency and providing them through a common back-office[34]**.** A number of operational activities of the Joint Undertakings are of a technical or administrative nature (e.g. financial management of contracts), or procured from external service providers (e.g. IT, communication activities, recruitment services, auditing) by each Joint Undertaking separately. If better streamlined this could create a win-win situation for all partners leading to better harmonization, economies of scales, and less complexity in supervision and support by the Commission services.

[34] See Annex 6 for an overview of key functions/roles that could be provided by a common back office.

2.4.2. Analysis of coherence of the overall portfolio of candidate initiatives at the thematic level

Looking at the coherence of the set of initiatives at the thematic level, the "**digital centric**" initiatives have a strong focus on supporting the digital competitiveness of the EU ecosystem. Their activities are expected to improve alignment and coordination with Member States and industry for the development of world-competitive EU strategic digital technology value chains and associated expertise. Addressing the Key Digital Technologies, the 5G and 6G connectivity needs as part of a Smart Networks and Services initiative and the underlying supercomputing capacities through a European High Performance Computing initiative present potential for synergies that can be addressed through cooperative actions (e.g. joint calls, coordinated support activities, etc.). They may as well profit from and contribute to Partnerships envisaged for Photonics, AI, data, robotics, Global competitive space system and Made in Europe, together with the EIT Digital. Synergies between these initiatives and several programmes (Digital Europe and Connecting Europe as well as cohesion programmes) are needed in areas where EU industry has to develop leadership and competitiveness in the global digital economy. They are expected to impact critical value chains including on sectors where digital is a strong enabler of transformation (health, industrial manufacturing, mobility/transport, etc.).

The **transport** sector face systemic changes linked to decarbonisation and digitalisation. Large scale R&I actions are needed to prepare the transition of these complex sectors to provide clean, safer, digital and economically viable services for citizens and businesses. Past decades have shown that developing and implementing change is difficult in transport due to its systemic nature, many stakeholders involved, long planning cycles and large investments needed. A systemic change of the air traffic network through an Integrated Air Traffic Management initiative should ensure safety and sustainability of aviation, while a Clean Aviation initiative should focus on the competitiveness of tomorrow's clean aircrafts made in Europe. The initiative for Transforming Europe's rail system would comprehensively address the rail sector to make it a cornerstone in tomorrow's clean and efficient door-to-door transport services, affordable for every citizen as well as the most climate-friendly mode of transport for freight. Connected and Automated Mobility is the future of road transport, but Europe is threatened to fall behind other global regions with strong players and large harmonised markets. The initiative Safe and Automated Road Transport would bring stakeholders together, creating joint momentum in digitalising road transport and developing new user-based services. Stronger links and joint actions will be established between initiatives to enable common progress wherever possible. The Clean Hydrogen initiative would be fundamental to that regard. Synergies would also be sought with partnerships driving the digital technological developments.

To deliver a deep decarbonisation of highly emitting industrial sectors such as the steel, transport and chemical industries would require the production, distribution and storage of **hydrogen** at scale. The candidate hydrogen initiative would have a central positioning in terms of providing solutions to the challenges for sustainable mobility and energy, but also is expected to operate in synergies with other industry related initiatives. The initiative would interact in particular with initiatives on the zero emission road and water transport, transforming Europe's railway system, clean aviation, batteries, circular industry, clean steel and built environment partnerships. There are many opportunities for collaboration for the delivery and end-use of hydrogen. However, the Clean Hydrogen initiative would be the only partnership focused on addressing hydrogen production technologies.

Metrology, the science of measurement, is an enabler across all domains of R&I. It supports the monitoring of the Emissions Trading System, smart grids and pollution, but also

contributes to meeting demands for measurement techniques from emerging digital technologies and applications. More generally, emerging technologies across a wide range of fields from biotechnologies, new materials, health diagnostics or low carbon technologies are giving rise to demands requiring a world-leading EU metrology system.

The initiative for a **Circular Bio-based Europe** is intended to solve a shortage of industry investments in the development of bio-based products whose markets do not have yet certain long-term prospects. The **Innovative Health Initiative** and **EU-Africa Global Health** address the lack of investments in the development of solutions to specific health challenges. The initiative on **Innovative SMEs** supports innovation-driven SMEs in participating in international, collaborative R&I projects with other innovative firms and research-intensive partners. As a horizontal initiative it is expected to help innovative SMEs to grow and to be successfully embedded in global value chains by developing methodologies and technologies for potential application in the other partnership areas or further development by the instruments of the European Innovation Council.

The description of the interconnections between all initiatives for each Horizon Europe cluster is provided in the policy context of each impact assessment and further assessed in the coherence assessment for each option.

PART 2 - THE CANDIDATE EUROPEAN PARTNERSHIP ON CLEAN HYDROGEN

1. INTRODUCTION: THE POLITICAL AND LEGAL CONTEXT

Hydrogen is the most abundant element in the universe, making up more than 90 percent of all of the atoms. However, nature does not provide hydrogen in its elemental form. Hydrogen can be derived from water and other chemical compounds. Electricity or heat is needed to liberate hydrogen from the chemical compound. Among its many uses, researchers have been studying hydrogen with great interest because of its potential as a sustainable energy source. While hydrogen is a clean fuel, with no emissions at all, it is still more expensive than other energy sources, and its production is not pollution free as most of the hydrogen currently produced comes from natural gas, a process that generates carbon dioxide (CO_2). Researchers have therefore been looking for alternative and more environmentally friendly ways of producing **'clean hydrogen'** that would ideally eliminate CO_2 emissions from the process. Hydrogen, as an energy carrier, is progressively viewed as a means to increase the share of renewables in European energy markets, to store and transport large amounts of electricity and to provide energy for sectors otherwise difficult to decarbonise. Hydrogen enables sector integration 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. Due to the flexibility and versatility of hydrogen and a multitude of hydrogen end-use applications, deployment of clean hydrogen at scale would support the targeted transition to carbon neutrality by 2050 in the EU. This document focuses on assessing the most effective, efficient and coherent way of implementing an initiative which would focus on joint European research and innovation activities on Clean Hydrogen under Horizon Europe.

1.1. Emerging challenges in the field

Achieving a climate-neutral EU economy by 2050 calls for the EU to ensure a deep decarbonisation of highly emitting industrial sectors such as steel, transport and chemical industries (refineries and fertilizers plants). That would require production, distribution and storage of hydrogen at scale. Hydrogen applications have progressed significantly over the past decade.[35,36] Several important technologies have been developed from low technology readiness levels to market-readiness, with the scope of hydrogen applications continuously broadening.[37,38,39,40,41]

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[35] 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

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

[37] 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

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

[39] 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

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

[41] 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/

Nevertheless, the sector is still in a pre-deployment stage and massive cost reductions across the entire supply chain are necessary to enable mass commercialisation to meet decarbonisation needs at energy system level. In order to achieve these cost reductions, the sector must tackle problems such as market failure for first movers and fragmentation among players and lack of critical mass. By virtue of hydrogen's versatility, the 'sector' is spread over various applications in energy, transport and industry, but also over actors and countries.

Developing the hydrogen economy requires investments in hydrogen generation and end-use equipment in sectors that are difficult to decarbonize by other means, such as heavy duty transport. It will also require investments in hydrogen storage, transportation, and distribution infrastructure – whose absence is currently stalling the rollout of market-ready hydrogen applications.[42,43] Large scale integrated hydrogen generation systems will be developed (e.g. clean hydrogen from photovoltaics and wind).

At the same time, continuous research and development will be required to ensure that hydrogen technologies are technically improved, highly efficient, and as competitive as possible.[44,45,46] The scope of hydrogen applications is increasing from its present focus on transport, fuel cells and electrolysers, and is expanding to include the energy sector (power, heating and gas), industry and new transport applications (maritime, aviation, rail, heavy transport).[47] With the constant emergence of new applications, the supply chain becomes more complex and continuous improvements[48] (new materials[49], efficiency, reliability, lifetime[50], cost[51]) are still needed for all applications.[52]

The lack of a regulatory framework supporting and governing the use of hydrogen applications adds to these challenges.[53] For many years, hydrogen applications were not

[42] 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

[43] The International Council on Clean Transporation (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

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

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

[46] 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

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

[48] 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)

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

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

[51] 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)

[52] See Annex 6 for general information on the hydrogen sector.

[53] 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

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 on a large scale.[54,55,56]

Finally the international dimension of hydrogen deployment and upscaling of production at global level has to be addressed. For example, the import of cheap clean hydrogen from wind and solar energy, produced outside of Europe, might become more important in the mid-term. These deployments urge the setting up of international standards, the development of the required infrastructure and developing a methodology on defining emissions from each unit of hydrogen produced.

1.2. EU relative positioning in the field

Europe is currently in an excellent position to achieve a significant level of penetration of hydrogen and fuel cell technologies over the next decade, at a level that can: (a) prove that hydrogen can fulfil a key role towards fighting climate change and improving public health; (b) act as a central pillar in decarbonisation and elimination of other harmful emissions of everyday activities; and (c) positively impacting the economy thanks to a broad and competitive supply chain that keeps Europe in a leading position and creates a new wave of highly skilled jobs.

The latter was recognized by the **Strategic Forum for Important Projects of Common European Interest (IPCEI[57])** which identified six key strategic value chains[58] of specific importance for EU's industries and competitiveness among which an **"Hydrogen technologies and systems"** value-chain. It is worth mentioning that European industry is active in all areas of the hydrogen economy along the whole value chain[59]. To name a few:

- **In Clean hydrogen production** firstly, through electrolysis technologies.[60] The EU is a scientific and industrial leader in today's global electrolysis industry, with competitors in China, Japan and the US less active.[61] Second, through other technologies (incl. Steam

https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5d9f23c486e0ee312c6380a7/1570710475026/Framework_H2+for+Climate+Action_final.pdf

[54] 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

[55] 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

[56] 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

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

[58] 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"

[59] 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, 2018. These are completed by the Hydrogen, enabling a zero emission Europe, technology roadmaps full pack, Sept 2018, Hydrogen Europe.

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

[61] 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/

Methane Reforming with Carbon Capture Storage/Use[62]) which could be useful in a transition phase, although not all of them are necessarily relevant for the proposed Clean Hydrogen initiative, but rather for other funding instruments.

- **In Hydrogen distribution and storage:**[63] EU industry and particularly EU SMEs are at the forefront of hydrogen handling and logistics with many leading companies focusing on multiple applications and technologies, including hydrogen refuelling stations (HRS), liquefaction facilities, and ammonia and methanol conversion plants.[64]
- **In Hydrogen end use in transport where** hydrogen and fuel cells can play an important role fostering a low-carbon road transport system.[65] 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, in rail transport, and in the maritime sector.[66] Although Directive 2014/94/EU "on the deployment of alternative fuels infrastructure" does not set out any obligation for Member States to indicate an appropriate number of publicly accessible hydrogen supply points in their national policy frameworks (NPFs), hydrogen is included in 14 NPFs and some Member States, for example Germany, have defined ambitious targets for hydrogen infrastructure. [67]
- **In Hydrogen end use –** there are solutions for hydrogen to decarbonise the natural gas grid through the blending & upgrade of natural gas to a pure hydrogen grid and then supplying heating and power for buildings. In the European decarbonisation context, these solutions may be appropriate in certain market segments or in specific conditions, e.g. islands; power generation (providing seasonal storage on renewable electricity); hydrogen replacing natural gas for process heat in industry.
- **In Hydrogen end uses in industry:** Clean hydrogen can be supplied as industrial feedstock. Potential end-use sectors for hydrogen in industry include steel and iron manufacturers. Main current end-users such as refineries, ammonia plants and other chemical manufacturers could be supplied with clean hydrogen. 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.[68,69,70]

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

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

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

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

[66] 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

[67] The Commission Delegated Regulation (EU) 2019/1745 of 13 August 2019 "supplementing and amending Directive 2014/94/EU amends the technical specifications for hydrogen refuelling points for motor vehicles set out in the Annex II of the Directive. The amended standards will apply from 12 November 2021.

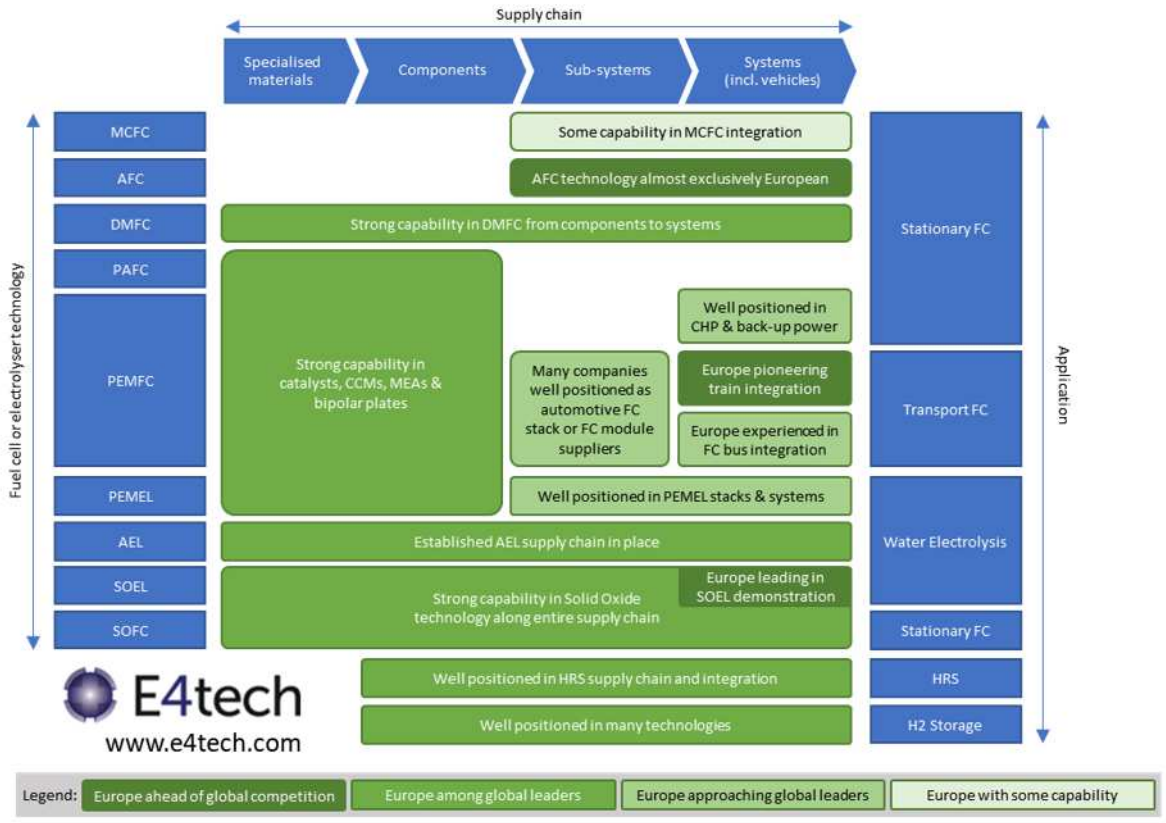
[68] e.g. the H2FUTURE project is injecting green hydrogen into steel production, thereby eliminating greenhouse gas emissions that would normally ensue. Demonstrating that even energy-dependent sectors can rely on this technology will make for increasingly green industrial production (FCH JU success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

[69] Refhyne, launched in 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 (FCH JU success stories)

[70] 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 steel-making. Project partners state that using this production method could make steel (the Technology Roadmap, Hydrogen Europe)

At global level, Europe is confronted with fierce competition from countries which are also promoting the use of hydrogen as a clean and alternative energy vector and have developed hydrogen strategies and policies. This is the case for the United States, Japan, Korea and China which are all developing large R&I programmes addressing similar segments of the Hydrogen value-chain mentioned above. However, one can notice from Figure 6 below that Europe has a relatively privileged position being ahead of global competition or among the global leaders in a few segments of the hydrogen value-chain.

Figure 6 – European global leadership in various hydrogen technologies[71]



In terms of R&I performance and in particular - publishing[72], Europe is showing strong leadership in publishing peer reviewed papers concerning electrolysis technologies (884 papers vs 1,568 papers from the rest of the world) as well as non-electrolysis production methods (1,549 papers vs 4,266). As regards fuel cell technologies, Europe (with 4,971 papers) is competing with the United States for the second position against Asia (10,493 papers). Asia's strong publications record in this field is often using their national language and publishing in national journals.

Overall, Europe is exceptionally active in PEM fuel cells with namely 2,780 papers and 448 patents filed covering this topic. Concerning patenting, Asia is the frontrunner compared to the rest of the world. Among the various sectors, Europe is clearly advancing well in Solid Oxide and PEM Electrolysis technologies, with more than 500 patents filed.

[71] 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

[72] Source: TIM FCH-adapted datasets available at https://www.fch.europa.eu/page/tools-innovation-monitoring-tim.

Box 3 Support for the field in the previous Framework Programmes – key strengths & weaknesses identified

What was/is being done with EU research and innovation funding until now

Dedicated R&I activities related to hydrogen applications have been supported since 2008. This covers traditional (collaborative) projects but also support provided through the Fuel Cell and Hydrogen Joint Undertakings (FCH JU and FCH 2 JU) under FP7 and Horizon 2020, which cover all stages/fields of the hydrogen value chain described above.

The first FCH JU was set up in 2008 as a public-private partnership between the EU, industry and the research community with a budget of EUR 470 million. The objective was to promote coordination and collaboration across Europe's fragmented FCH sector, to pool resources and to develop a long term, integrated, pan-European research and innovation agenda.

The programme entered its second phase, with FCH 2 JU, in Horizon 2020.

FCH 2 JU is a public-private partnership with 3 members: the industry grouping Hydrogen Europe, the research grouping Hydrogen Europe Research and the European Commission. The focus is on accelerating the commercialisation of fuel cells and hydrogen technologies to ensure a world leading, competitive European FCH industry while increasing jobs. The objectives of FCH 2 JU, organised around the energy and transport, pillars are the following:

- Clean transport: Reduce fuel cell system costs for transport applications

- Green hydrogen production: Increase efficiency and reduce costs of hydrogen production, mainly from water electrolysis and renewables

- Heat & electricity production: Increase fuel cell efficiency and lifetime

- Hydrogen storage for grid balancing: Demonstrate on a large-scale hydrogen's capacity to harness power from renewables and support its integration into the energy system

- Minimal use of critical raw materials: Reduce platinum loading

What has or is being achieved so far

The main achievements of the FCH JU and FCH 2 JU are that they contributed[73] to structure and mobilise an otherwise fragmented landscape of different sectors and industries by convincing competing or different, unrelated stakeholders to work together towards clear objectives[74], and that they developed successful mechanisms for fostering continued technological innovation.

For example, FCH 2 JU enabled key European fuel cell stack manufacturers such as Nedstack, Proton-motor, Powercell, Symbio and Elringklinger to nurture and to kick start competitive industrial-scale production of automotive fuel cell stacks in the EU, allowing Europe to compete with other regions of the world. FCH 2 JU was also instrumental in scaling up electrolysis technology, through recent projects such as REFHYNE[75] and

[73] Commission Staff Working Document - Interim Evaluation of the Joint Undertakings operating under Horizon 2020, {SWD (2017) 339 final}

[74] The objectives of the FCH JU, as laid down it its founding regulation.

[75] https://refhyne.eu/

DJEWELS[76]. However, further improvements are still needed in terms of costs, efficiency, reliability, while reaching the Giga-Watt scale. The FCH JU is also supporting initiatives at regional level, such as the HEAVENN project[77], which can help create local/regional value chains and demonstrate the role of hydrogen to integrate renewables in the energy system and decarbonise sectors that lag behind like transport and industry.

What are the key areas for improvement & unmet challenges?

However, a number of systemic challenges already identified in the interim evaluation of FCH 2 JU[78] risk derailing the progress already achieved and will have to be better addressed in a new Clean Hydrogen Initiative. These challenges include:

i) Pre-Normative Research (PNR) and even though not directly addressed in the proposed initiative, Regulation, Codes and Standards barriers, most notably the lack of technical regulations and/or accepted standards which prevent large scale, international deployment of standardised products;

ii) Funding concentration, and the need to ensure that the current geographical distribution of projects supported by the present JU is not reinforced by any lack of information/openness/transparency to entities from countries where participation is low, in particular EU13;

iii) The involvement of Member States and in particular the role of the State Representative Group which is not as effective as it should be;

iv) Knowledge management, open data and knowledge transfer, human resource developments and trainings are all necessary components to ensure that deployment takes place consistently in different sectors of the economy and finally,

v) The need for more attention to safety of FCH technologies necessary to building the confidence needed for widespread take-up. The relatively few projects introducing hydrogen in new settings (in buses, homes or in refuelling stations alongside conventional fuels) has not allowed products to be rolled-out commercially.

1.3. EU policy context beyond 2021

Hydrogen has been a field of interest for the EU since a few decades. However, the political context has evolved very significantly in the last five years with all Member States of the EU having signed and ratified the Conference of the Parties (COP21) Paris agreement and the European Union committing to contribute to delivering the Sustainable Development Goals (SDGs).

In 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 that "the role of hydrogen is likely to become more

[76] https://www.fch.europa.eu/news/fch-ju-funds-pioneering-green-hydrogen-project
[77] https://www.fch.europa.eu/page/energy#HEAVENN
[78] Commission Staff Working Document - Interim Evaluation of the Joint Undertakings operating under Horizon 2020, {SWD (2017) 339 final}

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."[79]

At the end 2019, the Commission presented its new priorities for the coming years, including the European Green Deal, a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy, where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. It states that EU industry needs 'climate and resource frontrunners' to develop the first commercial applications of breakthrough technologies in key industrial sectors by 2030. Priority areas include **clean hydrogen, fuel cells** and other alternative fuels, energy storage, and carbon capture, storage and utilisation. In this context, Hydrogen is also prominent in the Strategies and Communications for Hydrogen[80] for Energy System Integration[81] as well as the launch of the European Clean Hydrogen Alliance. The European Clean Hydrogen Alliance[82] aims to bring all stakeholders together and identify technology needs, investment opportunities, regulatory barriers and enablers to build a clean hydrogen ecosystem in the EU. On 28 May the Communication on "Europe's moment: Repair and Prepare for the Next Generation", was adopted which highlights in particular the important role of hydrogen in the EU economic recovery plan. The second pillar of this proposal is particularly relevant and includes clean hydrogen among the clean technologies and value chains which need to be supported and strengthened.

Actions are starting to enforce climate policies that would trigger intensive/deep decarbonisation in heavy industry and heavy transport sectors in which clean hydrogen applications represent some of the only feasible carbon-reduction solutions.[83]

In Horizon Europe, Hydrogen is part of the research and innovation activities funded under the Pillar II, Cluster: Climate, Energy and Mobility which aims at contributing 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'. It is supportive of several of the Sustainable Development Goals, particularly SDG7 (Affordable and clean energy), Climate Actions (SDG13) and Sustainable Cities and Communities (SDG11). The long term targeted impact of this cluster corresponds directly to the main objectives of fostering climate action, while at the same time improving the sustainability, security and competitiveness of the energy and transport industry, as well as the quality of the services that these sectors bring to citizens and society at large. The hydrogen economy addresses many different technological solutions and applications concerning different actors and linkages to various sectors. Adequate collaboration and connection with the relevant sectors are therefore required along the whole value chain.

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[79] 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

[80] COM(2020) 301 final: A hydrogen strategy for a climate-neutral Europe

[81] COM(2020) 229 final: Powering a climate-neutral economy: An EU Strategy for Energy System Integration

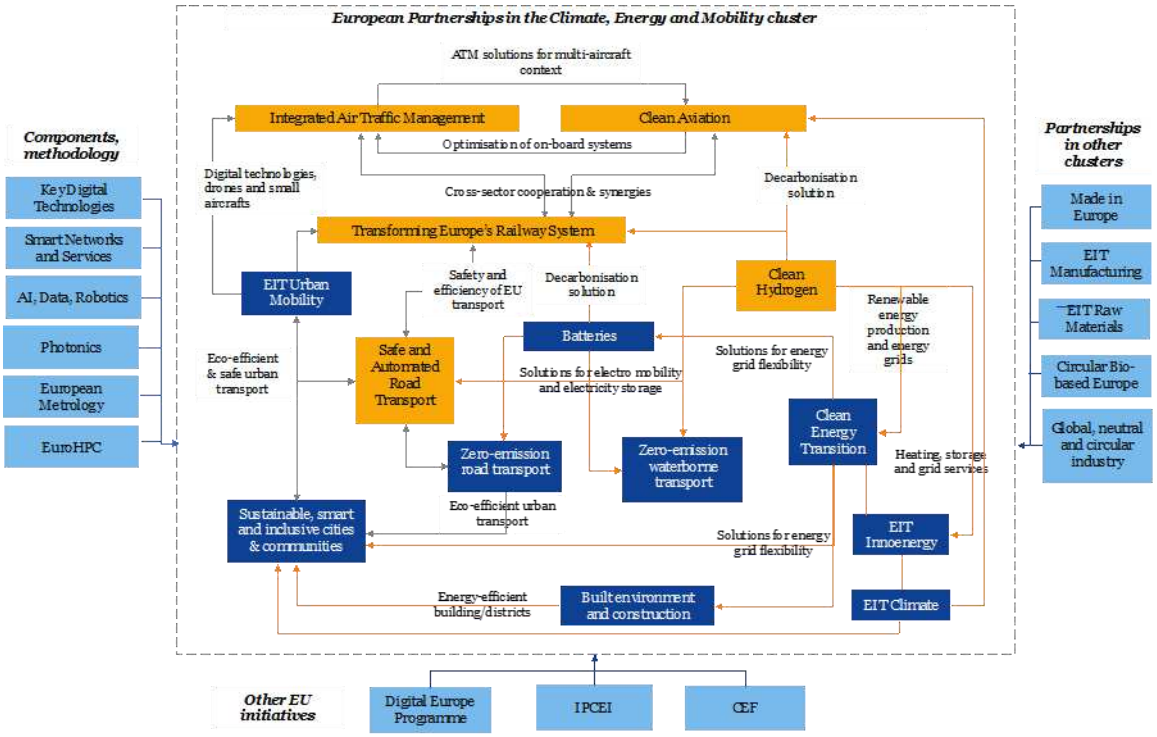
[82] https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

[83] 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

In addition to an initiative for Clean Hydrogen, other initiatives are put forward as possible partnerships under Horizon Europe. Potential initiatives in the Climate, Energy and Mobility cluster are shown in Figure 7. This shows not only the horizontal positioning of the potential Clean Hydrogen initiative, in terms of providing solutions to the challenges for sustainable mobility and energy, but also opportunities for synergies with a wide set of initiatives in other clusters (especially the digital and industry cluster). In addition, an initiative related to Clean Hydrogen would need to also link with the maritime sector, the power (especially the renewable energy sector), and the gas sector (especially gas grid operators). Strong collaboration would be needed between these initiatives to ensure proper integration of technologies into applications aiming to decarbonize the concerned sectors. It is important to note that some of these initiatives would probably not succeed or have the expected impact without an ambitious Clean Hydrogen Initiative able to supply hydrogen at scale.

Synergies with other EU programmes and networks which address hydrogen would also be needed, in particular: the **European Energy Research Alliance (EERA)** and its "Joint Programme on Fuel Cells and Hydrogen"[84]; the High Level Expert Group on Energy-Intensive Industries which developed the **Industrial Transformation Master Plan for climate-neutral industry by 2050**[85] highlighting the key role of hydrogen; funds and financing mechanisms that would support innovation and industrialisation and would help to bridge the "valley of death", in particular the **Connecting European Facility** (CEF)[86], the **ETS Innovation Fund**, and the **European Investment Bank,** with loans provided by InnovFin EDP.

Figure 7: Potential interconnections between partnership initiatives in the Climate, Energy and Mobility cluster of Horizon Europe



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

[85] Masterplan for a Competitive Transformation of EU Energy-intensive Industries Enabling a Climate-neutral, Circular Economy by 2050, Report from the High-Level Group on Energy-Intensive Industries

[86] EC (2018), Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility, COM(2018) 438 final

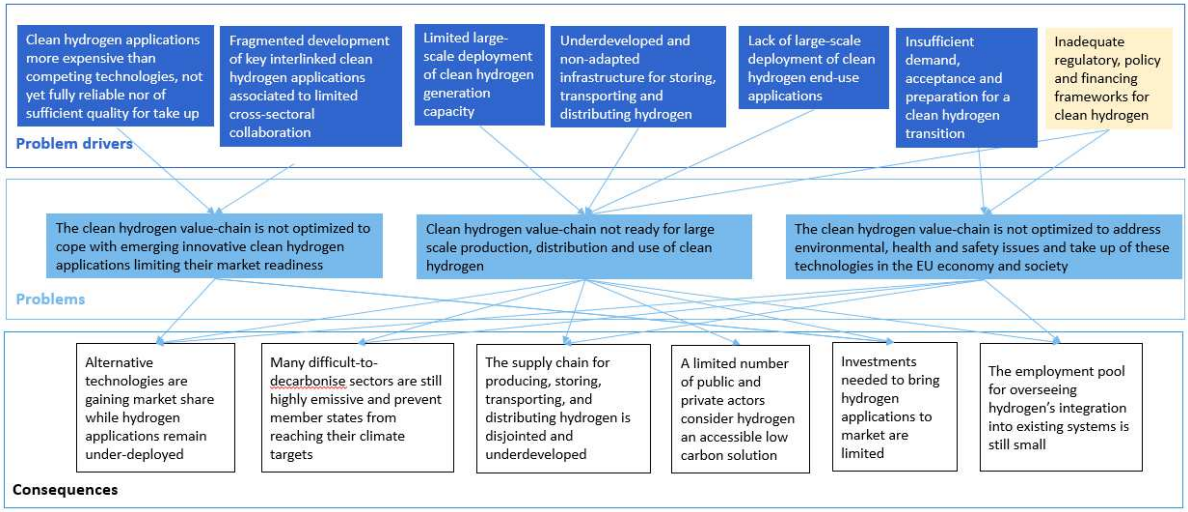
Source: Technopolis Group (2020)

2. PROBLEM DEFINITION

2.1. What is/are the problems?

Given the scale of the challenges ahead for a sustainable energy transition, the current scientific, technological and economic positioning of Europe in the field, and the overarching EU policy context, a set of problems have been identified where EU research and innovation in the field of Clean Hydrogen would have a specific role to play (see Figure 8).

Figure 8: Problem tree behind an initiative for European research and innovation on Clean Hydrogen



The part in yellow is not within the scope of the proposed Clean Hydrogen initiative. Important to mention is that the initiative seeks to address in particular **research aspects related to production, distribution, infrastructure and storage of hydrogen**.

2.1.1. The clean hydrogen value-chain not optimized to cope with emerging clean hydrogen applications limiting their market readiness.

Hydrogen applications have been developed in the FCH 2 JU to different levels of technological readiness. Those at higher Technology Readiness Levels (TRL) – including stationary fuel cells, light FCEVs, fuel cell buses and small scale electrolysers – are basically ready for market deployment; however, they remain comparatively more expensive than competitor technologies.[87,88,89] Substantial R&I effort is still needed to improve their efficiency, cost, durability and manufacturability.[90]

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

[88] 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

To develop an efficient clean hydrogen ecosystem, hydrogen will need to be produced in the power sector mainly from renewable energy sources, distributed via the gas-transmission sector or via the transport sector, and used in the transport, industry, and building sectors.[91,92] However, it is difficult to motivate actors across these traditionally independent sectors to work together on collaborative R&I projects and develop strong collaborative frameworks.[93,94]

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.[95]

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 in particular in sectors that are difficult to decarbonise by other means, such as heavy duty transport (trucks, coaches, trains and ships) – especially in the areas of investment cost reduction and efficiency increases[96].

2.1.2. The Clean hydrogen value-chain not ready for large scale production, distribution and use of hydrogen

Currently, few complete value chains for hydrogen, from production to end-use, are operational across the EU.[97,98] Several hydrogen applications still need to be technologically improved and tested before they can be successfully implemented into larger scale systems.[99,100] This will be the core focus of the proposed partnership. 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.[101,102] As stated by the IEA,[103] "for novel applications (especially those at low TRLs)

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[89] 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/

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

[91] 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

[92] 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

[93] 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

[94] 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

[95] 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

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

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

[98] 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

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

[100] 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

[101] 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

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".

Regarding the distribution of hydrogen, there are still many different R&I issues to address which is leading to a slow development of infrastructure and holding back widespread adoption.[104] Infrastructural construction requires 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.[105]

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. 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.[106,107] Even though there is today a consensus around the fact that clean hydrogen is the best and sometimes only alternative to decarbonise hard to abate sectors, larger-scale markets for hydrogen production and use have not yet been created.[108] Competing technologies are gaining a share in markets where hydrogen could play a role, but where higher costs are preventing its uptake.[109,110,111] For example, renewable power plant operators increasingly rely on batteries to store excess electricity, rather than on electrolysers and hydrogen storage options.[112] As hydrogen applications do not currently play larger roles in the power, industry and transport sectors, the hydrogen supply chain remains disjointed and underdeveloped.[113,114,115]

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[102] 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
[103] IEA, the Future of hydrogen, 2019, page 181
[104] IEA, the Future of hydrogen, 2019, page 14
[105] Strategic Research and Innovation Agenda, Hydrogen Europe, December 2019 (p 10)
[106] 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
[107] 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
[108] 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
[109] Smart Energy International (2019), 2019 energy storage trends – available at https://www.smart-energy.com/industry-sectors/storage/2019-energy-storage-trends/
[110] 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
[111] 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
[112] P. Denholm, J. Nunemaker, P. Gagnon, W. 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
[113] E4tech (2017), Study on Supply Chain for Hydrogen and Fuel Cells Technologies
[114] Element Energy Ltd on behalf of the UK Department for Business, Energy & Industrial Strategy (2018), Hydrogen supply chain evidence base – available at

Market-enabling regulatory frameworks to govern the production and use of key clean hydrogen applications are currently not adequate.[116,117,118] [119] 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.[120]

2.1.3. The clean hydrogen value-chain not optimized to address environmental, health and safety issues and take up of these technologies in the EU economy and society

The 382 respondents to the Open Public Consultation on the Clean Hydrogen initiative, expressing their views on the needs of the future European Partnerships under Horizon Europe, indicated that this initiative would make a significant contribution to the EU efforts to achieve climate-related goals.

Difficult-to-decarbonise sectors including maritime transport, aviation, heavy-duty trucking, rail, and energy-intensive industry remain high emitters. Without the decarbonisation of these key sectors, it will be almost impossible for EU Member States to meet their climate targets.[121] It is widely recognised that clean hydrogen can significantly contribute to this effort.[122,123]

Nevertheless, recent research initiatives focused on the public perception of hydrogen show that public awareness of hydrogen technologies is still relatively limited.[124,125] There are also

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https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf

[115] 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

[116] 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

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

[118] 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

[119] 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

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

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

[122] 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

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

[124] 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

lingering concerns among the public regarding hydrogen safety.[126,127] At the same time, very few public initiatives have focused on educating the public with respect to hydrogen.[128,129]

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.[130,131] Such measures could create market conditions for hydrogen applications in sectors where it is currently difficult for hydrogen to gain access.[132]

2.2. What are the problem drivers?

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

Since 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.[133]

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.[134,135]

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[125] 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

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

[127] 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

[128] 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

[129] 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

[130] 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

[131] 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

[132] 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

[133] 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

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

[135] 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

Consistent scientific development at lower TRLs 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.[136,137]

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[138] though only a few pilot projects so far have included multi-sector actors from multiple links in the hydrogen value chain.[139]

Research on different hydrogen applications is starting to become 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 ready to lower TRL ready 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.[140]

2.2.3. *Limited large-scale deployment of clean hydrogen generation capacity*

Many industrial and research stakeholders interviewed for the impact assessment consider that the FCH 2 JU has not supported enough large-scale demonstration projects on clean hydrogen production, especially in large-scale coupling with renewable power plants to generate necessary investments in mass manufacturing capacity for production equipment.[141] Large-scale demonstration projects are vital in proving the feasibility of and potential for using large-scale electrolysers.[142] They instil in investors the confidence necessary to back wider market deployment of these technologies. This issue will be partly addressed in the Horizon 2020 Green Deal Call, under preparation.

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.[143] Cross-border infrastructural networks spanning significant distances between Member States will need to

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

[137] 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

[138] Consensus from the majority of interviewees.

[139] 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

[140] 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

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

[142] 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

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

be constructed to connect optimal clean hydrogen production regions to optimal hydrogen consumption regions.[144,145] Development of the required infrastructure will require R&I activities, for example to address the challenges of injection of hydrogen into the gas grid, demonstration of large volume refuelling stations (> 1 tonne of hydrogen per day) and to address issues related to transportation of liquid hydrogen by trucks.

Infrastructure development goes beyond the scope of the proposed partnership and will be supported by other funding programmes such as the Connecting Europe Facility (CEF). However, this requires 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. 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.[146]

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

There have not been enough large-scale demonstration projects on key technologies to generate the necessary investments in mass manufacturing capacity for end-use products and equipment.[147] Large-scale demonstration projects are vital in proving the feasibility of and potential for using large-scale fuel cell applications (Combined Heat and Power (CHP) systems, vehicles…), burners or turbines.[148]

2.2.6. Insufficient demand, acceptance and preparation for clean hydrogen solutions

Public awareness and public knowledge on hydrogen are still limited. Existing and previous partnerships on clean hydrogen have prioritised technological development, with less 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.[149][150]

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

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

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

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

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

[148] 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

[149] 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

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

efficiently.[151] There is also evidence to suggest that the public remains concerned regarding the safety of hydrogen technologies.[152,153,154]

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 and to develop the capacity required to enable a cross-sectoral hydrogen transition.[155]

Beyond education and communication, one of the roles of the proposed initiative will be on co-creating solutions, starting from the users' needs (user which can be citizen but also public authorities), along with testing and experimentation. Research on social sciences and humanities will be key to understand and analyse how to get citizens' engagement on these relatively disruptive hydrogen solutions.

2.2.7. Inadequate regulatory, policy and financing frameworks for clean hydrogen

This issue is out of the direct scope of the proposed initiative but it is important that these aspects should be considered early enough to be able to engage with standardisation and regulatory bodies, anticipating what would be needed for increased demand, acceptance, and ultimately uptake of hydrogen solutions. In this context, Pre-Normative Research (PNR) will be an important aspect of the proposed initiative.

Policy makers would need to develop a regulatory framework to govern the production and use of clean hydrogen applications. EU regulation concerning renewable energy, alternative fuel infrastructure, gas infrastructure, market design, CO_2 emission standards and clean vehicles would need to be adapted in order for clean hydrogen to be recognised for its climate contribution. [156] A clear definition of clean hydrogen should be the first step to ensure the proper integration into all regulatory frameworks. The lack of coordinated regulatory frameworks complicates hydrogen's entry into mass markets. Needless to say, harmonised regulatory frameworks would encourage investors and enable more hydrogen applications to be deployed at larger scales.

2.3. How will the problem(s) evolve?

Without any action, it is anticipated that:

[151] 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

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

[153] 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

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

[155] 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

[156] 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

- 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 will hinder reaching the 2050 targets; 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.[157]

The costs of clean hydrogen solutions will not decrease on their own. Without action hydrogen technologies will not be in a position to compete with competitor low-carbon technologies like BEVs and battery storage, since those will likely achieve further cost reductions and efficiency gains as they have already achieved economies of scale.[158]. As a consequence, Europe's competitive positioning in the hydrogen industry will deteriorate.[159]

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 promote technological advancements across sectors and develop cohesive, complete value chains for hydrogen production, distribution, and use, heavy industry and heavy transport sectors will not be able to integrate clean hydrogen solutions into their operations. [160] Sector coupling will then likely be regarded as infeasible. Difficult-to-decarbonise sectors will remain highly emissive and Member States will not be able to achieve their climate targets.[161]

Mass manufacturing capacities will not be developed, and the hydrogen value chains will not effectively industrialise, preventing efficiency gains and potential cost reductions.[162]

If the public is not sufficiently educated regarding hydrogen solutions, these 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.[163]

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

[158] McKinsey & Company (2017), Battery storage: The next disruptive technology in the power sector 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

[159] 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

[160] 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

[161] 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

[162] 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

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

3. WHY SHOULD THE EU ACT?

3.1. Subsidiarity: Necessity of EU action

In the context of the specific complex and interlinked value chains of clean hydrogen where costs, risks and an 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 deployment at scale. The exchange and pooling of knowledge between the stakeholders is critical to avoid duplication, extract lessons and especially successes in order to improve fundamental and applied research. Standards and norms should be addressed at international level, where the EU should ensure having only one voice.

The European hydrogen industry and research stakeholders, when acting alone or through small size consortia, do not have all the 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 the size of the challenges also go beyond the capacity of individual Member States.

Due to the increasing number of applications, derived from existing emerging uses and targeted in the proposed initiative, collaboration and coordination between industrial and research base actors active in the hydrogen economy is essential. It is a prerequisite to retain the competitive position of the concerned industrial sectors.

3.2. Subsidiarity: Added value of EU action

There are several national R&I schemes, such as in Germany, France, Denmark and Italy which are, committing significant budgets on hydrogen - in total approximately EUR 1 billion funding over a seven-year period.[164] However, these are insufficiently coordinated within the Member States, between Member States and with the EU, thus leading to a possible duplication of activities[165] and lack of efficiency.

With a clear climate policy and clear objectives for 2030 and for 2050, there is a strong need for directionality of European investments as well as additionality. EU action would complement the national schemes (reflected in NECPs) to provide a clearer policy approach, especially as innovations are urgently needed to realise the climate action plan and its objectives.

Overall the results of the Member States consultation on the Inception Impact Assessment confirm the relevance of the proposed initiative 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% respondents found the proposed partnership as relevant for their industry. In terms of overcoming fragmentation within Europe, the challenges of delivering improved coordination between Member States' clean hydrogen research and innovation support remain significant, therefore increasing the importance of an EU action.

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

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

1. European Partnerships under Horizon Europe: results of the structured consultation of Member States

4. OBJECTIVES: WHAT IS TO BE ACHIEVED?

4.1. General objectives of the initiative

Based on the identified problems, the overall objective of the proposed Clean Hydrogen initiative is to produce noticeable, quantifiable contributions towards the achievement of climate targets in 2030 and pave the way for climate neutrality by 2050. Reaching this long term vision means capacity to supply hydrogen at scale and simultaneously boosting demand. Therefore, the scope of hydrogen applications has to increase from its present focus in FCH 2 JU on transport applications (passenger cars and buses), fuel cells and electrolysers, by addressing R&I issues related to production, distribution and storage of clean hydrogen to supply hard to decarbonise sectors such as heavy industries (steel, cement, chemical, …) and heavy duty transport applications (trucks, buses, rail, ships, …). With the emergence of these new applications, the supply chain has become more complex and continuous improvements[166] (new materials[167], efficiency, reliability, lifetime[168], cost[169]) are needed for all applications.[170]
The following general objectives have been identified:

- Strengthen and integrate EU scientific capacity to support the creation, exploitation and sharing of knowledge to accelerate the development and improvement of advanced clean hydrogen applications ready for market, across energy, transport, building and industrial end-uses.
- Enable large scale deployment capacity for key parts of the clean hydrogen value chain and 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.[171]
- Ensure a safe and frictionless deployment of clean hydrogen technologies for the greening of hydrogen generation 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); SDG11 (Sustainable Cities and communities); and SDG13 (Climate action) and to a lesser extend SDG8 (Decent work and economic growth) and SDG9 (Industry, innovation and infrastructure).[172]

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[166] 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)
[167] The "IPCEI Appendix" addresses, as example, the development and qualification of new materials to continue improving high pressure hydrogen storage (p 10)
[168] Example of buses lifetime addressed in the "Competitiveness Analysis" (p 67)
[169] 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)
[170] See Annex 6 for general information on the hydrogen sector.
[171] Please see Chapter 1 f or an in-depth discussion on EU competitive positioning across member states and different hydrogen applications.
[172] European Commission International Cooperation and Development (2019), The Sustainable Development Goals – available at https://ec.europa.eu/europeaid/policies/sustainable-development-goals_en

4.2. Specific objectives of the initiative

In order to achieve the general objectives, seven specific objectives are defined. These specific objectives respond to each of the problem drivers discussed in Section 2.2. The list of specific objectives is the following:

- Improve through research and innovation the cost-effectiveness, reliability and quality of clean hydrogen applications developed in the EU. The objective is to deliver hydrogen based solutions at a price equivalent to the alternatives by 2030;
- Reinforce the EU scientific and industrial ecosystem for innovative clean hydrogen applications;
- Demonstrate and scale-up clean hydrogen applications to stimulate large-scale generation capacity. The objective is to produce clean hydrogen at a cost of ~EUR 1.5-3/kg by 2030, allowing penetration into mass markets [173];
- Accelerate through demonstration the co-deployment of EU storage, transport and distribution infrastructures for innovative clean hydrogen solutions. The objective is to reduce the distribution costs to less than EUR 1/kg of hydrogen at scale by 2030 [174];
- 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 duty transportation, building and industrial sectors;
- Increase public and private awareness, acceptance, demand and uptake of clean hydrogen solutions.

Note that issues relating to the policy, regulatory and financial framework have to be addressed in parallel and/or factored in so that the initiative is enabled to achieve its objectives and effectively contribute to the climate policies and targets from a broader perspective.

Intervention logic of the initiative

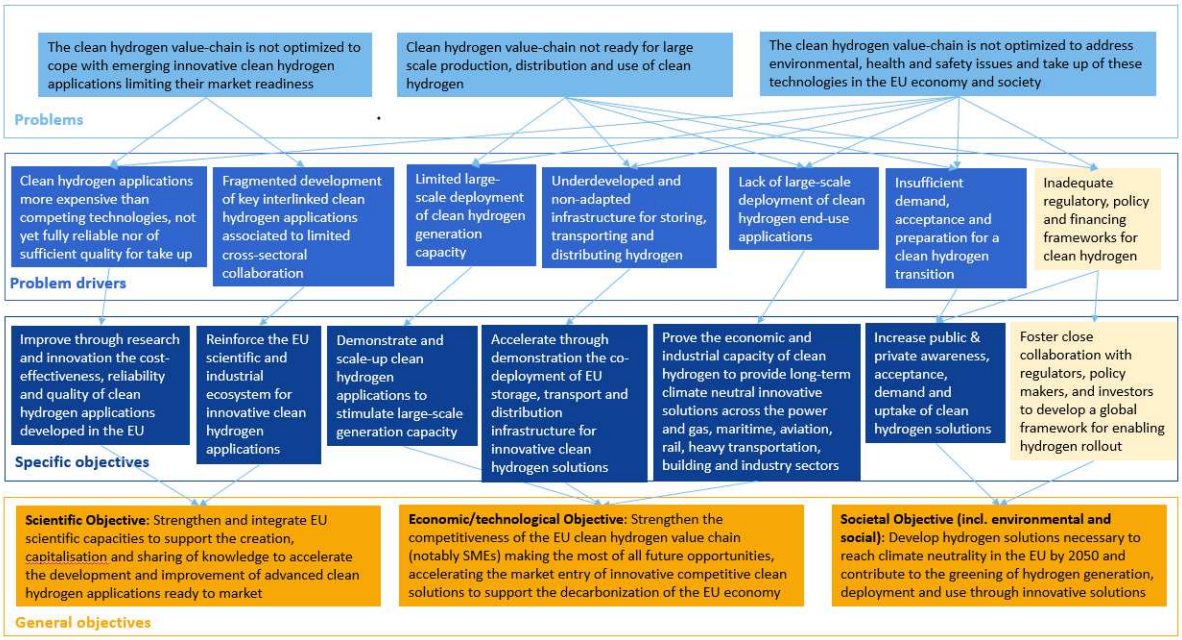
Many of the respondents to the Open Public Consultation took the opportunity to underline key messages regarding the initiative:
- The global positioning of Europe: outlining the role of global competition (including the role of technology), the importance of autonomy for Europe and the ability of Europe to act as a key player at the global level.
- The need for a 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 relationship between the general and specific objectives of the potential initiative on Clean Hydrogen is shown in Figure 9.

[173] Production costs of clean hydrogen are linked to Electrolyser costs. Those have already been reduced by 60% in the last ten years, and are expected to halve in 2030 compared to today with economies of scale. In areas with low-cost renewable electricity, electrolysers are expected to be able to compete with fossil-fuel hydrogen in 2030.

[174] Distribution costs can vary dramatically between transport means (e.g. pipeline (15 cents/kg) versus trucks versus liquid carriers, etc….) and context of usage. The figure of "less than 1 euro" is for the specific case of transport by truck for mobility application.

Figure 9: Intervention Logic for the initiative on Clean Hydrogen



How would success look like?

Should the initiative deliver on its specific objectives, it is expected that it would translate in practice into the following impacts:

Scientific impacts

- Hydrogen applications are more competitive, efficient and reliable. A key milestone would be the achievement of the time-bound targets of producing clean hydrogen at a cost of ~EUR 1.5-3/kg and to reduce the distribution costs to less than EUR 1/kg of hydrogen at scale by 2030. The EU maintains its leading position for cutting edge research and innovation in hydrogen applications

If the initiative can push for continued technical improvement of hydrogen applications and encourage distinct industries to collaborate on research projects, new potential science- and technology-based applications for hydrogen are likely to emerge. Additionally, the EU will be able to maintain the role it currently plays as a global hub for hydrogen research and innovation for the primary benefit of EU leading research institutions and innovative SMEs.

Economic/technological impacts and impact on SMEs

- EU validates its ability to deploy economically viable hydrogen generation at scale
- EU validates its ability to deploy hydrogen infrastructures at scale
- 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 the hydrogen economy, especially for SMEs

Successful realisation of the objectives would result in a strengthened EU hydrogen industry. The EU would 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 would be likely to thrive and receive increased investment. There is also potential for localised economic growth in areas where hydrogen hubs or valleys are developed. This would 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 businesses and position themselves strongly within the hydrogen supply chain.

Societal impacts

- 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
- 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

Environmental impacts

If executed in full, the initiative could lead to a 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 the 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.

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 would likely create a basis of public support for hydrogen applications. Getting citizens' engagement and co-creating solutions, starting from the users' needs would facilitate the integration of innovative solutions into societies, from local to national to international levels. Proof of hydrogen solutions' feasibility would also likely prompt policy makers to act quickly and develop regulatory frameworks that can effectively govern applications' uses.

Increased public outreach on hydrogen would in turn increase public support for hydrogen; in a best case scenario, policy makers would 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 would significantly facilitate and enable the deployment of renewable electricity production at scale.

Based on the interviews and as shown from the result of the Open Public Consultation, the results and impacts of the initiative can best be achieved if industry and research 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 deployment scales. This would ensure that research and development are in line with the overarching goals, and also avoid fragmentation and duplication of efforts.

4.3. What is needed to achieve the objectives – Key functionalities needed

Given the focus of the impact assessment on comparing different forms of implementation, the identification of "**key functionalities needed**" allows making the transition between the

definition of the objectives and what would be crucial to achieve them *in terms of implementation*. These functionalities relate to the type and composition of actors that have to be involved, the type and range of activities that should be performed, the degree of directionality needed and the linkages needed with the external environment.

4.3.1. Type and composition of actors to be involved

To be able to achieve the scientific objectives of the proposed clean hydrogen initiative, all sectors concerned by the hydrogen economy should be given the possibility to get involved in preparing and implementing the Research and Innovation Agenda, in particular priority should be given to solutions and actors that can contribute most to the energy and climate objectives of the EU. The concerned sectors (involving industry and SMEs), in addition to the hydrogen manufacturing actors, should comprise of at least heavy industry using hydrogen as feedstock, the biomass/biogas sector, the power sector, where hydrogen can act as long-term storage for renewables generation, the gas and grid operators, the transport sector, the building and heating sector and project developers who can coordinate efforts in project implementation, especially to facilitate sector coupling. In addition, the public sector should also be involved, especially regional and national authorities, the latter being responsible to set up climate policies (ideally by integrating hydrogen into the NECP 2030) and measures (market mechanisms) to fill in 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, hydrogen refuelling stations …), norms and standards.

Despite the potential of hydrogen to contribute to the decarbonisation of many different sectors, one has to acknowledge that the deployment of hydrogen and fuel cells is only marginal today (see Annex 6). As a consequence, there is no evidence of anti-competitive behaviour from the side of partners or in product markets. To accelerate the commercial readiness of hydrogen technologies, the proposed Clean Hydrogen Partnership is building on the work of FCH 2 JU which made the start of commercialisation of a first series of applications possible. It will aim at bringing a second series of applications to commercial level in particular in industry heat and feedstock, power generation and hard to abate transport sectors.

This increased collaboration between researchers, SMEs and industrial players will also be critical to achieve the economic/technological objectives by facilitating the entry 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.[175]

Finally, the initiative would benefit from involving non-EU market players with their own strengths that can complement EU R&I actors and from the coordination of well-established partnerships with international actors e.g., the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE); Mission Innovation – Renewable and Clean Hydrogen Challenge, Clean Energy Ministerial (CEM) Hydrogen Initiative, Hydrogen Energy Ministerial (HEM), and so on.

All categories of respondents to the Open Public Consultation clearly see stakeholders from industry as the most relevant in setting a joint long-term agenda, followed by academia and governments (Member States and Associated Countries).

4.3.2. Type and range of activities needed

For hydrogen, we are talking today about a very dynamic sector and community. Responsiveness to new technological developments will be a must, meaning that it should be ensured that the partnership will be able to react quickly and efficiently in particular considering the proposed substance of cooperation with the partnership seeking now to address broader **research and innovation aspects related to production, distribution, infrastructure and storage of hydrogen**. As such, it is open to newcomers as mentioned in paragraph 4.3.1.

A number of activities have been identified to ensure flexibility of implementation and create the expected impacts such as:

(i) Seek synergies with R&I programmes of other sectors and initiatives - strong links are already identified with the candidate European Partnerships on: towards zero emission road transport transforming EU's railway system, clean aviation, clean steel, zero emission waterborne transport and processes 4 planet;
(ii) Coordinating 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;
(iii) Developing deployment and piloting activities to ensure flexibility over time across the range of applications implemented;
(iv) Communication and dissemination activities to ensure societal and political support for envisaged developments and overseeing actions fostering regulation or standardisation
(v) Co-creating solutions with end-users, emphasising the importance of flexibility in addressing different target groups over time, including industrial end users for which low carbon alternatives are not evident.

4.3.3. Priority setting system and level of directionality required

A common vision for the initiative addressing an integrated research and innovation agenda cannot be achieved in the absence of a strong commitment of industry, the research organisations and the public sector in Europe.[176] 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 R&I activities (under Horizon Europe) should be based on cooperation between consortia of stakeholders, working together on the basis of consented multi-annual (and possibly multi-projects) actions targeted at specific technological goals.

In the Open Public Consultation, the following activities were considered the most relevant: deployment and piloting activities, joint R&D programme, collaborative R&D projects, whereas input to regulatory aspects and co-creation of solutions with end-users scored less.

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 States' and the

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

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

4.3.4. Coherence needed with the external environment

Due to its versatility and cross-sectoral integration, clean hydrogen should be addressed through close collaboration frameworks with other programmes and initiatives to create synergies and limit duplications. Regarding other initiatives, it is crucial to share views on the ways to integrate hydrogen into the concerned sectors (e.g. trucks, coaches, rail, maritime, gas and power, grids, aviation, building, …) and ideally to share a common vision to define where to concentrate efforts. Complementary calls, including their funding and management, would be the next step to ensure full coherence with other initiative's agendas.

Other key elements related to the framework conditions will play a role in the ability of the initiative to reach its objectives. This concerns in particular the next steps after R&I activities, namely scaling up, market deployment, regulatory frameworks, infrastructure deployment, customer acceptance, etc. For supportive framework conditions, the initiative should ensure close collaboration and engagement with end users, citizen, policy makers and regulators. Furthermore there is a need to link with other crucial funding and financing mechanisms, in particular articulation with the Connecting Europe Facility; ETS Innovation fund; IPCEI and risk capital players to finance scaling up and deployment activities and financing institutions to bring solutions to the market will be considered.

5. WHAT ARE THE AVAILABLE POLICY OPTIONS?

This section describes the specific functionalities that could be provided under the baseline scenario of traditional calls and the different options of different types of European partnerships.

5.1. What is the baseline from which options are assessed?

The baseline scenario used in this impact assessment is a situation without a Partnership and only traditional calls of Horizon Europe. Given that there is a predecessor Partnership as well as other funding sources in the area, these will continue generating effects even if there is no new Partnership. In particular it is expected that these already existing initiatives will still have an impact in the coming years.. This is taken into account in the effectiveness assessment.

In parallel, the baseline situation means that the current implementation structure of the Article 187 would be closed, which bears winding down and social discontinuation costs. There would also be financial cost-savings related to the closing of the structure, related to operations, staff and coordination costs in particular. This is taken into account in the efficiency assessment.

Table 1: Key characteristics of the baseline situation - Horizon Europe calls

	What is feasible under this option - Functionalities of option

Enabling appropriate profile of participation	- The Commission would need to prepare the Strategic Research and Innovation Agenda (SRIA) by consulting a wide range of actors, i.e. hydrogen equipment manufacturers, 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), 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 expertise is needed to address hydrogen versatility in an evolving landscape. - 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	- 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 share of practice would happen predominantly among partners within the calls consortia.
Ensuring alignment with R&I agenda	- Work programmes would need to reflect the requirement for R&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 input from industry. - R&I activity would focus on the short to medium term needs of 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 as well as integration with other programmes. - Selection of high TRL projects would require provision of external expert (and independent) advice to the Commission.
Securing effective leveraging of resources	- Progress of R&I effort would depend on EU funding, with leveraging of industry support coming mainly from their financial contributions determined by Horizon Europe rules. - Demonstration programmes would require significant in-kind support and collaboration from industry.
Key differences compared to the current situation	The commission would need to complete the SRIA and recruit new resources i.e. Policy Officers to design, implement and monitor the research programme. There would be significantly weakened contacts with industry & research, since in the absence of a partnership Hydrogen Europe and Hydrogen Europe Research Organisations may well cease operation. Dissemination of results, promotion of safety and standards through the partnership would no longer occur.

5.2. Description of the policy options

Table 2: Key characteristics of Option 1 – Co-Programmed European Partnership

	What is feasible under this option - Functionalities of option
Enabling appropriate profile of participation	- The partnership would enable participation by all key stakeholders contributing to the specification and delivery of the SRIA. - It would need to consult with a wide range of stakeholders, within its membership to ensure that the SRIA, and ultimately the work programme, is 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	- 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	- Work programmes would need to reflect the requirement for R&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 R&I priorities, including demonstration projects. - R&I activity would be likely to focus on the medium-term needs of industry and research. - Programme Committee would ensure alignment with overarching policy objectives and coordination with related programmes.
Securing effective leveraging of resources	- 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.

Table 3: Key characteristics of Option 2 – Institutionalised European Partnership (Article 187 TFEU)

	What is feasible under this option - Functionalities of option
Enabling appropriate profile of participation	- The partnership would enable participation by all key stakeholders contributing to the specification and delivery of the 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 self-management. - It would provide a forum or even a platform for consulting stakeholders on R&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. - Participation would be less flexible than under other options, 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.
Supporting implementation of R&I agenda	- 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 a percentage of the budget). - 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 share of practices would happen among the stakeholders of the community, with potential diffusion activities managed by the partnership structure.
Ensuring alignment with R&I agenda	- The partnership would be responsible for specifying a work programme fully in line with the R&I priorities identified by 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 industry, the research organisations and society in adopting clean hydrogen solutions. - 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 effective leveraging of resources	- 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.

5.3. 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 on the Clean Hydrogen initiative. 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 public partners at its core (comparable to the Article 185 initiatives), with Member States that are partners in this partnership becoming the 'owners' of the priority and taking sole responsibility for its funding. Industry and research RD&I can nevertheless be addressed by the activities of the partnerships, but it does not make formal commitments and financial contributions, or decide the R&I priorities. In the context of a Clean Hydrogen initiative, industry and research involvement is vital as there is a definite need for industry and research to plan, deliver and fund research and innovation.

6. HOW DO THE DIFFERENT POLICY OPTIONS COMPARE?

Based on the objectives pursued by the initiative and the key functionalities identified to be able to achieve them, each option for implementation is assessed in terms of effectiveness, efficiency and coherence compared to the baseline scenario of traditional calls. The analysis is primarily based on the degree to which the different options would cater for the key needed functionalities. All options are compared to the baseline situation of traditional calls, which is thus consistently scored at 0 to serve as reference point.

6.1. Effectiveness

To be in line with the Horizon Europe impact framework, the fulfilment of the specific objectives of the initiative is translated into 'expected impacts' - how success would look like -, differentiating between scientific, economic/ technological, and societal (including environmental) impacts. This section considers to which extent the different policy options would allow delivering these expected impacts – confronting what is needed (functionalities) with what each form of implementation can provide in practice. The assessments in this section set the basis for the comprehensive comparative assessment of all retained options against all dimensions in Section 6.4, based on a scoring system[177].

Scientific impacts

Concerning the efficiency and reliability of hydrogen applications and equipment, 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.

The baseline 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.[178] This option could easily manage fundamental R&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 does not

[177] A more in depth and detailed analysis of each policy option is provided in Technopolis Group (2020)

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

provide such a framework or ecosystem of actors. However, this option could deliver improvements for low and medium TRL applications if a clear agenda is set up.

Option 1 could deliver more impact than the baseline option when it comes to higher TRL applications where a strong community with all actors is needed in order for all potential partners to liaise on complex projects. Its score would therefore be good compared to the baseline with +.

Option 2, by most fully involving research and industry with a long-term commitment, could contribute to the emergence of new applications and to continuous efficiency, quality and reliability improvements in applications and equipment. Its score would therefore be high compared to the baseline with ++.

With regard to the second scientific impact e.g. EU maintains its leading position for cutting edge research and innovation in hydrogen applications, **the baseline option** may allow some European organisations to maintain market-leading positions and cutting-edge research initiatives. However, without the deep involvement of 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.

Compared to the baseline, **Option 1** could also help European organisations to maintain their leading positions because some industry involvement would be maintained and is therefore given a score of +.[179]

However, **Option 2** through strong involvement of the research and the industrial community, would be more efficient than Option 1 and provide greater possibilities to adapt to the evolving hydrogen economy and to anticipate and seize emerging opportunities. It would also support increased knowledge diffusion between industrial players, public sector authorities and members of the public thanks to its broad community and internal expertise.[180] Its score would therefore be higher with ++.

Stakeholder opinion (from interviews)

A long-term shared vision, 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. The existing FCH 2 JU does provide these three pillars.

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.

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. 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.

[179] 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, https://ec.europa.eu/info/sites/info/files/research_and_innovation/groups/rise/final-report_eu-positioning.pdf

[180] As affirmed comprehensively in interviews with stakeholders from both research and industry institutions, Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe – Candidate Institutionalised European Partnership on Clean Hydrogen

Economic/Technological impacts

The baseline option could contribute to achieve technological impacts, for example by reducing the cost of hydrogen production. However, the lack of a community structure beyond the project consortia might limit the sharing and diffusion of experience among the key actors involved in hydrogen R&I[181] and limit the coordination and collaboration necessary to address cross-border issues.[182] In addition, this option will not significantly support the scaling up of ready-to-market applications as there is no clear mechanism to facilitate the bridge from R&D to market deployment[183] and it is assessed as more difficult for SMEs to access funding. 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 and local or regional communities)..

A research agenda could be centrally defined under **Option 1**, so this Option could contribute to deploy hydrogen generation and infrastructures at scale. With a broader community than in the baseline option, this option can provide a collaborative framework which will contribute to bolster EU industry and can contribute to maintaining the competitiveness of industry and decarbonising heavy transport.[184] (score of +, see Table 5).

Thanks to the long term industrial commitment, **Option 2** allows high leverage of the private sector which is needed to finance expensive demonstrations. With a broad community, this option can contribute to maintaining the competitiveness of industry and to the decarbonisation of heavy transport. The community structure will also ensure the sharing and diffusion of experience among the key actors involved in hydrogen R&I. If well-coordinated with other funding and financing sources, this option can provide help for scaling up hydrogen applications ready-to-market (score of ++, see Table 5).

Stakeholder opinion

A thriving hydrogen economy can only be developed in Europe with the full backing of the European Commission and Member States. Stakeholders doubt whether hydrogen can be integrated into the EU's power, industry, and transport sectors if it loses institutionalised R&D support.

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 research or from industry.

Around 80% of the respondents to the Open Public Consultation suggested the Institutionalised Partnership would have a significant (positive) effect on or be 'very relevant' for increasing industrial leadership in hydrogen technologies and the uptake of new technologies, for the provision of a solution for storing renewable energy for later use, and for the provision of low-carbon and competitive solutions for heavy duty and long-distance transport.

[181] As affirmed comprehensively in interviews with stakeholders from both research and industry institutions.
[182] As affirmed comprehensively in interviews with stakeholders from both research and industry institutions.
[183] 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
[184] Joint Research Centre (2016), 4th International Workshop on Hydrogen Infrastructure and Transportation Report,https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103586/4%20int%20workshop%20on%20h2%20infra%20final%20pdfonline.pdf

Societal impacts (including environmental, social, fundamental rights)

Continuous collaboration is needed to increase the maturity levels of transportation, industrial and building applications. **The baseline option,** given the short-term perspective of the calls, tends to support applications with short development timelines, meaning it could not enable all the opportunities the hydrogen economy could offer to support EU's climate goals. The capacity to reduce carbon emissions and pollution to air, water and soil would be rather limited under the baseline option since this is directly dependent on the ability to deploy at scale. Without knowledge management capacities to provide support to national, regional and local authorities, without the ability to support the increase of awareness and without the support to coordinate many stakeholders, this option would not be able to support the growth of a strong hydrogen ecosystem.

Compared to the baseline, Option 1, having a medium term perspective, would bring some of the opportunities the hydrogen economy offers to support EU's climate goals. Option 1 can contribute to build up knowledge capacity to support the hydrogen transition and can contribute to decarbonising hydrogen feedstock use by funding demonstration projects aiming to couple large renewable electricity production plants with hydrogen generation.[185,186] (score of +)

Under **Option 2**, the strong community and network could bring together the required actors to build local or regional ecosystems, large transportation corridors and the related infrastructure that would connect producers and consumers[187]. These efforts need a long-term commitment and vision for the hydrogen economy so that the EU can meet its climate targets. This option can support the building of capacities, by capitalising on experience, knowledge and expertise of a dynamic community of researchers and industrials from different sectors and on skills of an internal structure. Option 2 can also contribute to decarbonising hydrogen feedstock and it could also have an important impact regarding the market uptake (as explained under the economic impact) (score of ++).

None of the above options is expected to impact fundamental rights in the EU or abroad.

Directionality and additionality required

As regards the level of directionality and additionality required, **the baseline option** would not be able to facilitate the synchronised actions necessary to support policy objectives, Even if this option could ensure partial alignment with EU strategies, it would not be effective enough to significantly contribute to achieving them.

With the ability to prepare and implement a medium term plan **Option 1** could ensure compliance with EU and Member States strategies. However, a medium term clean hydrogen R&I agenda could only partially fit with the broader framework of a low carbon roadmap.

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[185] 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

[186] 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

[187] 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

A long-term vision and strategy will be essential for hydrogen which is a versatile solution addressing many different sectors with continuously emerging applications. By involving research organisations, industry and the public sector, **Option 2** is considered as the most appropriate since it ensures a long-term commitment. Integrating the Strategic R&I Agenda into a broader spectrum is also essential. Option 2 will ensure a coherent approach for the whole hydrogen economy from R&I to market uptake, addressing in particular the "valley of death" challenge.

Stakeholder opinion

Hydrogen's capacity to facilitate the decarbonisation of heavy industry and heavy transport within the EU is seen as its core strength. In order to fully decarbonise these sectors through hydrogen use, however, extensive development is still required. Stakeholders continuously argued that the partnership which most quickly and effectively can prompt the large-scale integration of hydrogen applications into Member States' societies will be best positioned to contribute to the vital environmental goal of full decarbonisation of the EU by 2050.

The large majority of respondents to the Open Public Consultation considered the Institutionalised Partnership would be 'very relevant' to deliver on societal impacts with the exception for the category "improved working conditions".

Table 5 summarises the scores assigned for each policy option, based upon the assessments above, as well as taking into account the support expressed by the different stakeholders.

Table 5: Overview of the options' effectiveness compared to the baseline

	Baseline: Horizon Europe calls	Option 1: Co-programmed	Option 2: Institutionalised Article 187 TFEU
Scientific impact			
Hydrogen applications are more competitive, efficient and reliable	0	+	++
The EU maintains its leading position for cutting edge research and innovation in hydrogen applications	0	+	++
Economic/technological impact			
Through demonstration EU validates its ability to deploy economical hydrogen generation at scale	0	0	+
EU demonstrates its ability to deploy hydrogen infrastructures at scale	0	+	++
EU validates its ability to scale-up clean economical hydrogen end-use applications in heavy-duty transport and energy-intensive industries – maintaining global competitiveness	0	+	++
EU growth in hydrogen economy, especially for SMEs	0	+	++
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	0	+	++
Outdoor pollution can progressively decrease while reducing carbon emissions	0	+	++
Knowledge capacity built up to support the hydrogen transition, while increasing public support for additional hydrogen policy and regulatory frameworks	0	+	++

Notes: Score ++: Option presenting a *high* potential compared to baseline; Score +: Option presenting a *good* potential compared to baseline; Score 0: Potential of the baseline.

6.2. Efficiency

In order to compare the policy options consistently in terms of their efficiency, a standard cost model was developed for the external study supporting the impact assessment for the set of candidate Institutionalised Partnerships. The model and the underlying assumptions and analyses are set out in the Common Part of this impact assessment, Section 2.3.2 and in the Methodology Annex 4. A dedicated Annex 3 also provides more information on who is affected and how by this specific initiative in line with the Better Regulation framework. The scores related to the costs set out in this context allow for a "value for money" analysis (cost-effectiveness) in the final scorecard analysis in Section 6.4.

In addition, for this specific initiative under the baseline scenario of traditional calls, there would be winding down and social discontinuation costs for the existing implementation structure of the current Article 187 initiative. The impact assessment and Annex 3 in particular have estimated the costs of running an Institutionalised Partnership under Article 187 at € 2.9 million, corresponding to 27 full time equivalent staff. In contrast, the baseline (Horizon Europe calls) would rely on Horizon Europe structures and also require winding down the current JU Secretariat. Winding down costs would essentially be linked to the termination of existing contracts. As most of these contracts were already tied to the foreseen initial duration of the existing JU, the winding down costs are expected to be limited and much lower than the € 2.9 million recurring costs for the proposed Institutionalised Partnership. Overall it is estimated that the overall longer term cost savings from using traditional calls instead of an existing Article 187 initiative would considerably exceed the costs incurred for winding down operations. This overall situation is set as the starting point for the comparison of options. The score of this baseline scenario (traditional Horizon Europe calls) is set to 0 to be used as a reference point.

On this basis, the scores for the costs of the different options range from a value of 0, in case an option does not entail any additional costs compared to the baseline, to a score of (-) when an option introduces limited additional costs when compared to the baseline and a score of (-)(-) when substantial additional costs are expected in comparison with the baseline. In case the scores are lower than for the baseline scenario, (+) and (+)(+) are used.

It is considered that while there is a clear gradation in the overall costs of the policy options, the cost differentials are less marked when one takes into account the expected 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 (traditional calls) and the Co-Programmed policy option – and the least cost-efficient – the Institutionalised Partnership option. Indeed, in terms of cost-efficiency, the Co-Programmed Partnership (Option 1) is 2 percentage points more efficient than the baseline and an Article 187 Partnership is 2 percentage points less cost-efficient than the baseline. This refers to the proportion of "total costs and investments" that is available to be spent on "R&I investment". These figures were estimated for the different forms of implementation, as described in the common part of the impact assessment. On the basis of this ratio, the baseline appears to be 2% more efficient than the Article 187 Institutionalised Partnership. The main differences between the costs structures of the various implementation forms are described in Annex 4, p. 52. A score of

(+) is therefore assigned for **cost-efficiency** to the Co-Programmed options and a score of (-) for the Institutionalised Partnership policy option[188].

Looking at cost-efficiency on the broader perspective of attracting higher level of investments from stakeholders, **Option 2 may appear much more cost-efficient**. The reason is a much higher total investment in R&I and a much higher contribution from the private actors (fact identified within the current FCH 2 JU, where for a flagship large-scale project like the "Hydrogen Valley" the contribution from the partners is three times higher than the Union contribution).

In the case of the current FCH 2 JU, the assessment of the contributions can be considered as an indication of the leverage achieved by EU funds and is clearly a strong sign that the JU is successfully aligned on industrial priorities[189]. As mentioned in the Annual Activity report 2019, the FCH 2 JU has generated 2.24 of total leverage.

The majority of 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 and to increase financial leverage, which is considered as a key element for the demonstration phase.

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.

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[190] in particular on budget execution level, commitment and payment appropriations, time to contract and time to payment. The proposed initiative will build on this strength.

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Table 6: Matrix on 'overall costs' and 'adjusted cost scoring'

	Baseline: Horizon Europe calls	Option 1: Co-programmed	Option 2: Institutionalised Article 187 TFEU
Administrative, operational and coordination costs	**0**	**(0)**	**(-)(-)**
Administrative, operational and coordination costs adjusted per expected co-funding (i.e. cost-efficiency)	**0**	**(+)**	**(-)**

Notes: Score 0 = same costs as for the baseline; score (-) = limited additional costs compared with the baseline; score (-)(-) = substantial additional costs compared with the baseline.

[188] The baseline (traditional calls) is scored 0, as explained above.

[189] See section 1.3.3 of the present report

[190] See section 1.3.3 of the present report

6.3. Coherence

6.3.1. Internal coherence

In this section we assess the extent to which the policy options show the potential of ensuring and maximising coherence with other actions, programmes and initiatives under Horizon Europe, in particular European Partnerships (internal coherence).

Baseline: Horizon Europe calls

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 Figure 1 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. Option 0 could easily manage fundamental R&I activities. However, it is considered sub-optimal to address activities which need more coordination (for example demonstration activities) and closer collaboration between research, industry and decision-makers to define cohesive work plans.

Option 1: Co-Programmed European Partnership

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. Option 1 could better manage all types of R&I activities thanks to a better agenda setting pinpointing the climate and industrial priorities. However, Option 1 is not considered optimum to address the complex supply chains of hydrogen applications and the spread of actors. Its score would therefore be good compared to the baseline with +.

Option 2: Institutionalised European Partnership under Article 187 TFEU

The Institutionalised Article 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 could (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, Clean Steel, Sustainable Process Industry (Process4Planet), waterborne sector (ZEWT), towards zero-emission road transport (2ZERO), Clean Energy Transition, and the power and the gas sectors. Option 2 would manage all TRLs related activities, from fundamental R&D up to market-readiness. Good knowledge management is also an asset

under this option - to allow the initiative to adequately assess projects in the selection process, to provide technical assistance where needed and even to challenge the industries in order to increase the speed of development. This would translate into a high score compared to the baseline set at ++.

Stakeholder opinion

Stakeholders overwhelmingly argue that only through an institutionalised partnership can all necessary actors be involved, the ideal range of activities undertaken, and the strategic directionality be designed and implemented as required. They agree that if an institutionalised partnership were not pursued, vital stakeholders would be left out of important conversations, an inadequate/partial range of activities and projects would be funded, and the strategic directionality established would lack clarity and vision.

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 are important. The respondents think 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.

6.3.2. External coherence

In this section we assess the extent to which the policy options show the potential of ensuring and maximising coherence with their external environment, including EU-level programmes and initiatives beyond the Framework Programme and/or national and international programmes and initiatives, but as well as with overarching framework conditions, such as regulation, standardisation, etc. (external coherence).

Baseline: Horizon Europe calls

In absence of a clear engagement with relevant stakeholders, 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, fuel cells, electrolysers, …). Despite that under this option, some coordination with other European Commission activities is possible at the level of priorities, coordination at the level of implementation is somewhat limited or even not feasible. In addition, this option typically remains focused on the EU27 alone. International organisations play an important role in the development of clean hydrogen. However, the baseline option does not allow for implementation of a coherent international cooperation strategy. In addition, 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.[191] Finally, 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.

Option 1: Co-Programmed European Partnership

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-

[191] 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

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 good compared to the baseline with +.

Option 2: Institutionalised European Partnership under Article 187 TFEU

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.[192] 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 hydrogen R&D dynamic but should be convinced of its strategic importance. 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. Furthermore, 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. Finally, 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 which can improve and extend the collaboration at the level of projects. This would translate into a high score compared to the baseline with ++.

Stakeholder opinion

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 external coherence. They 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.

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.

Table 7, below, lists the scores assigned for each of the policy options, based upon the assessments above, as well as taking into account the views expressed by the different stakeholders.

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

[192] 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

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 programmes, 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 from of partnership would allow for greater external coherence than the two other options.

Table 7: Overview of the options' potential for ensuring and maximizing coherence

	Option 0: Horizon Europe calls	Option 1: Co-programmed	Option 2: Institutionalised Article 187 TFEU
Internal coherence	0	0/+	++
External coherence	0	+	++

Notes: Score ++: Option presenting a *high* potential compared to baseline; Score +: Option presenting a *good* potential compared to baseline; Score 0: Potential of the baseline.

6.4. Tabular comparison of options and identification of preferred option

Building upon the outcomes of the analysis, this section presents a comparison of the options' 'performance' against the dimensions of effectiveness, efficiency and coherence.

Table 8: Overall scorecard of the policy options for all criteria

	Criteria	Baseline: Horizon Europe calls	Option 1: Co-programmed	Option 2: Institutionalised Article 187 TFEU
Effectiveness	**Scientific impacts**			
	Hydrogen applications are more competitive, efficient and reliable	0	+	++
	The EU maintains its leading position for cutting edge research and innovation in hydrogen applications	0	+	++
	Economic/technological impacts			
	Through demonstration EU validates its ability to deploy economical hydrogen generation at scale	0	0	+
	EU demonstrates its ability to deploy hydrogen infrastructures at scale	0	+	++
	EU validates its ability to scale-up clean economical hydrogen end-use applications in heavy-duty transport and energy-intensive industries – maintaining global competitiveness	0	+	++
	EU growth in hydrogen economy, especially for SMEs	0	+	++
	Societal impacts			
	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	0	+	++
	Outdoor pollution can progressively decrease while reducing carbon emissions	0	+	++
	Knowledge capacity built up to support the hydrogen transition while increasing public support for additional hydrogen policy and regulatory frameworks increases	0	+	++

Coherence	**Internal coherence**	0	0/+	++
	External coherence	0	+	++
Efficiency	**Overall cost**	0	0	--
	Adjusted cost-scoring	0	+	-

Notes: Scores for effectiveness and coherence: Score ++: Option presenting a *high* potential compared to baseline; Score +: Option presenting a *good* potential compared to baseline; Score 0: Potential of the baseline. Scores for efficiency: Score 0 = same costs as for the baseline; score (-) = limited additional costs compared with the baseline; score (-)(-) = substantial additional costs compared with the baseline

Box 2 Comparison between the preferred option & the current partnership existing in the area taking into account lessons from past evaluations

What continues	What is different
• Art 187 Union Body, with EC, Hydrogen Europe and Hydrogen Europe Research as founding members • Blending of funds for large demonstration projects: Horizon, CEF • Members contributing to running costs of the JU • Preparation of Multiannual and Annual Work Programmes based on Strategic Research and Innovation Agenda • Management of evaluation calls and running projects	• Enlargement of the scope of the initiative addressing the entire value-chain from production to end-use of hydrogen • Better member state involvement/ renewed role of state representative group • Actions to increase wider participation from all EU 27 • Potentially higher leverage of private investment • Higher impact of investments due to closer links with industrialisation/ market uptake (e.g. the proposed Clean Hydrogen Alliance) • Better synergies with other Horizon Europe, national and regional initiatives

Overall the implementation of the Clean Hydrogen initiative through an **institutionalised partnership established under Article 187 of TFEU is the preferred option** as it would best ensure that private and public sectors remain fully engaged in the development and implementation of a long-term strategy for clean hydrogen R&I. It is also consistent with the aim of leveraging industrial financial and in-kind resources, such that the impact of funding provided by the Commission is maximised. This form of partnership would 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 to develop a strategy for hydrogen that is fully aligned with European Green Deal priorities, and especially the European climate commitment, and with several sustainable development goals.

7. THE PREFERRED OPTION - HOW WILL ACTUAL IMPACTS BE MONITORED AND EVALUATED?

7.1. The preferred option

- In Table 9, below, the alignment of the preferred option of Institutionalised European Partnership under Article 187 TFEU with the selection criteria for European Partnerships defined in Annex III of the Horizon Europe Regulation is depicted.

Seeing that the design process of the candidate Institutionalised Partnerships is not yet concluded and several of the related topics are still under discussion such as finalisation of Strategic Research and Innovation Agenda, Governance of the proposed partnership, partners signing up to final, commonly agreed objectives and committing the resources and investments needed from their side to achieve them, e.g. partners' financial contribution, the criteria of additionality/directionality and long-term commitment are covered in terms of *expectations* rather than ex-ante demonstration.

Table 9: Alignment with the selection criteria for European Partnerships

Criterion	Alignment of the preferred option
Higher level of effectiveness	As demonstrated in Chapter 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 also be effective in securing sustainability (the final goal of "clean" hydrogen) and in strengthening the European Research and Innovation Area.
Coherence and synergies	A dedicated management structure similar to the Programme Office in current FCH 2 JU, 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, Transforming EU's rail system, Clean Steel, Sustainable Process Industry (Process4Planet), waterborne sector (ZWET), towards zero-emission road transport (2ZERO), Clean Energy Transition, and the power and the gas sectors. A dedicated management structure would also ensure proper coordination and complementarity with European Union, local, regional, national and, where relevant, international initiatives on hydrogen or other partnerships and missions.
Transparency and openness	As demonstrated in Chapter 6, an institutionalised partnership would be better placed to identify priorities and objectives in terms of expected results and impacts, in involving partners and stakeholders from across the entire clean hydrogen value chain, from different sectors, backgrounds and disciplines, including international ones when relevant. SMEs would have the most appropriate support from the partnership. A dedicated management structure would also be able to put into place clear modalities for promoting participation of SMEs and for disseminating and exploiting results, 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, in an open and transparent way. 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 chapter 6, an institutionalised partnership would be much better placed to define a common strategic vision of the purpose of the European Partnership, 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 adjust to changing policy, societal and/or market needs, or scientific advances, to 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

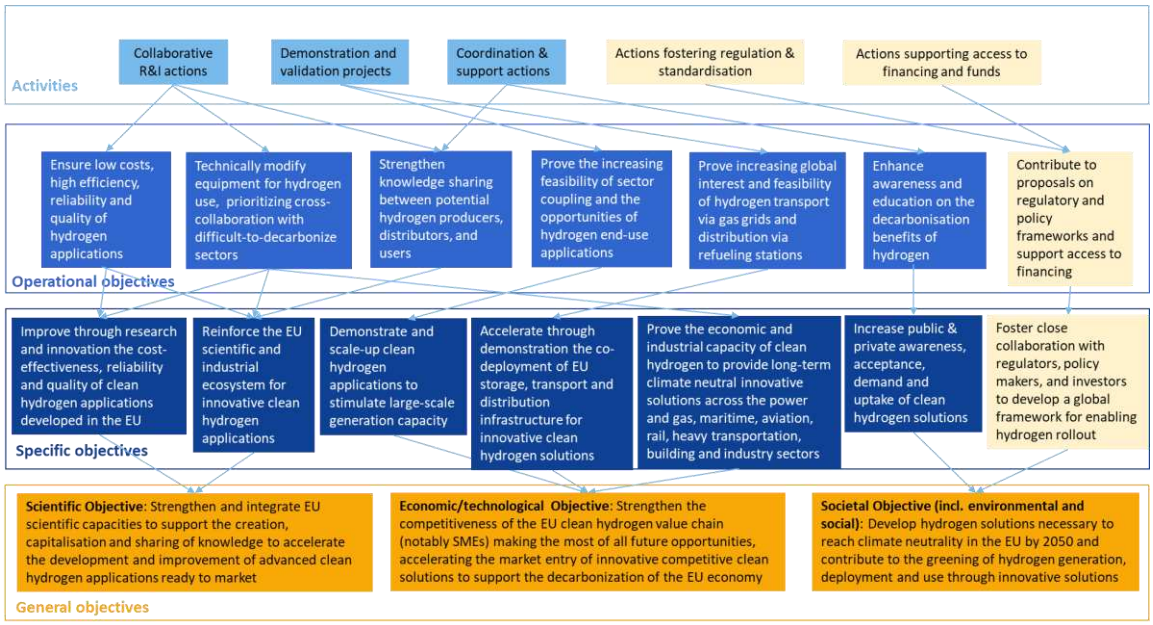
7.2. Objectives and corresponding monitoring indicators

7.2.1. Operational objectives

Several operational objectives have been identified which would enable the partnership to achieve its specific objectives, as shown in Figure 10 below.

The figure also lists a range of actions and activities, going beyond R&I 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 of a programme of research and innovation activities, including those related to market, regulatory or policy uptake."

Figure 10: Operational objectives of the initiative



7.2.2. Monitoring indicators

In addition to Key Impact Pathways indicators set centrally in the Regulation of Horizon Europe, additional monitoring indicators have been identified to enable the tracking of progress of the partnership towards meeting its objectives. These are shown in Table 9.

Table 9: 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 times that journal citations generated by the partnership are cited in the global literature	Number of publications registered by the clean hydrogen industry and research organisation located in Europe Number of staff transferring between research-based institutions & industry
Technological / economic impact	Number of projects involving organisations outside the hydrogen industry Number of projects with a documented strategy identifying the potential application of results to	Number of projects leading to validated demonstration of clean hydrogen applications Number of clean hydrogen pilots demonstrating readiness	Number of patents registered by the clean hydrogen industry and research organisation located in Europe Number of projects conducting market uptake Time for clean hydrogen pilots demonstrating readiness for market

	defined market needs Number of projects resulting in increasing clean hydrogen application's TRLs Number of individuals working on projects initiated by the partnership	for market uptake Number of years for programmed projects to reach TRL 8 Number of mature clean hydrogen applications Number of occupied and advertised jobs in clean hydrogen	uptake Value of exports generated by the European hydrogen sector Direct and indirect employment generated by the European clean hydrogen economy Costs of clean hydrogen production Costs of clean hydrogen distribution Price of hydrogen based solutions compared to alternatives
Societal impact Incl. Environmental 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) Number of projects focussing on hard to decarbonise sectors	Changes in local outdoor air pollution Changes in public acceptance of clean hydrogen solutions Evolution in CO_2, emissions reduction in relevant sectors

7.2.3. Evaluation framework

The evaluation of the Partnership will be done in full accordance with the provisions laid out in Horizon Europe Regulation Article 47 and Annex III, with external interim and ex-post evaluations feeding into the overall Horizon Europe evaluations. As set in the criteria for European Partnerships, the evaluations will include an assessment of the most effective policy intervention mode for any future action; and the positioning of any possible renewal of the Partnership in the overall European Partnerships landscape and its policy priorities. In the absence of renewal, appropriate measures will be developed to ensure phasing-out of Framework Programme funding according to conditions and timeline agreed with the legally committed partners ex-ante.