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In the published version of this decision, some information has been omitted, pursuant to articles 30 and 31 of Council Regulation (EU) 2015/1589 of 13 July 2015 laying down detailed rules for the application of Article 108 of the Treaty on the Functioning of the European Union, concerning non-disclosure of information covered by professional secrecy. The omissions are shown thus […]		PUBLIC VERSION This document is made available for information purposes only.

Subject:

State Aid SA.64625 (2022/N) – Austria
State Aid SA.64642 (2022/N) – Belgium
State Aid SA.64640 (2022/N) – Czechia
State Aid SA.64633 (2022/N) – Denmark
State Aid SA.64646 (2022/N) – Estonia
State Aid SA.64632 (2022/N) – Finland
State Aid SA.64671 (2022/N) – France
State Aid SA.64647 (2022/N) – Germany
State Aid SA.64651 (2022/N) – Greece
State Aid SA.64644 (2022/N) – Italy
State Aid SA.64649 (2022/N) – Netherlands
State Aid SA.64626 (2022/N) – Poland
State Aid SA.64753 (2022/N) – Portugal
State Aid SA.64635 (2022/N) – Slovakia
State Aid SA.64624 (2022/N) – Spain

Important Project of Common European Interest on Hydrogen Technology (Hy2Tech)

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Excellencies,

PROCEDURE

(1) On 31 August, 1 September and 13 September 2021 Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Italy, the Netherlands, Poland, Portugal, Slovakia and Spain pre-notified their plans to participate in an Important Project of Common European Interest ("IPCEI")[1] on Technology for the creation of a European Hydrogen value chain ("Hy2Tech") on the basis of a common draft overall descriptive text (so-called "Chapeau" document), as well as detailed information on Hy2Tech and its components/individual projects.

(2) The European Commission (the "Commission") requested and received complementary information from all of the participating Member States listed in recital (1) (the "Member States") and the participating undertakings (the "participating undertakings") during the period between November 2021 and June 2022.

(3) The Commission services organised high-level meetings at senior administrative level in order to enhance coordination between the Member States and ensure progress.

(4) These high-level meetings took place on 29 June 2021, on 16 December 2021 and on 3 June 2022. In addition, during the pre-notification stage several meetings took place at the technical level with the Member States and the participating undertakings.

(5) The Member States notified their participation in Hy2Tech on the following dates: Austria on 13 June 2022, the Netherlands on 14 June 2022, Greece on 15 June 2022, Czechia on 16 June 2022, Belgium, Estonia, Denmark, Germany, Finland, France, Italy, Poland, Portugal, Slovakia and Spain on 17 June 2022. All of the Member States have individually notified the common Chapeau document and their planned aid measures.

(6) By letters accompanying each notification the Member States agreed to waive their rights deriving from Article 342 of the Treaty of the Functioning of the European Union ("TFEU") in conjunction with Article 3 of Regulation 1[2] and to have this Decision adopted and notified in English.

2. OBJECTIVES AND DESCRIPTION OF HY2TECH

2.1 Objectives of Hy2Tech

(7) By participating in Hy2Tech, the Member States have agreed to ensure the environmental and social sustainability of the development of hydrogen

[1] Communication from the Commission, *Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest* ("the IPCEI Communication"), OJ C528/10, 30.12.2021.

[2] Council Regulation No 1 determining the languages to be used by the European Economic Community, OJ 17, 6.10.1958, p. 385.

technologies across multiple sectors (e.g. mobility, transport and industrial sectors). This agreement, amongst other things, seeks to meet the goals of the European Clean Hydrogen Alliance and the EU's objectives in reaching its decarbonisation targets (see section 3.3.2.2).

(8) The Member States intend to grant aid to undertakings that will participate in Hy2Tech, aiming at developing an innovative and sustainable hydrogen value chain that goes substantially beyond the state-of-the-art. Hy2Tech will bring together undertakings operating at different levels of the value chain.

(9) The overall objectives of Hy2Tech are:

a. To research and develop innovative and sustainable electrolysers, fuel cells ("FC"), key enabling technologies and critical components, so as to unlock the full technological potential of the hydrogen value chain in Europe;[3]

b. To ensure the transfer of knowledge to new or improved applications as well as to new R&D&I in the different sectors and disseminate this knowledge across the hydrogen value chain by fostering collaborations between the various stakeholders;

c. To create a cost optimized hydrogen value chain in Europe through standardised, automated and robust production processes;

d. To support new jobs and growth through the development and strengthening of highly skilled staff, aiming at mitigating the social impact of the transition to clean energy;

e. To coordinate hydrogen-related activities across Europe in order to create an integrated EU Hydrogen ecosystem.

[3] For a definition of the different technical terms used throughout this decision, see Glossary in Annex II. A list of abbreviations is also presented in Annex III.

2.2 Description of Hy2Tech

(10) This section describes Hy2Tech as it has been presented by the Member States in their notification. Hy2Tech is organised along four different technology fields ("TF"):

- TF 1: Development of hydrogen generation technologies;
- TF 2: Development of FC hydrogen technologies;
- TF 3: Development of technologies for storage, transportation and distribution of hydrogen; and
- TF 4: Development of hydrogen technologies for end users.

(11) Within each of these TF, the participating undertakings will conduct both R&D&I and first industrial deployment ("FID") activities.[4]

2.2.1 Description of the TF of Hy2Tech

(12) Each TF focuses on key stages of the whole hydrogen supply chain. Along this supply chain, within and across each of the TF, the participating undertakings will collaborate in order to adequately meet Hy2Tech's objectives and overcome the challenges identified during that process (see sections 2.2.2 to 2.2.5 and 2.4.3).

2.2.2 TF 1 – Development of hydrogen generation technologies

(13) The entire hydrogen technology value chain is based on the development of hydrogen generation technologies and largely on the physical process of electrolysis. The achievement of a hydrogen market in the EU thus depends on the availability of efficient reliable, and sustainable hydrogen technologies and systems.[5]

(14) The TF 1 thus aims to develop, test and validate innovative electrolysers and components, as well as to establish different layers of integration of hydrogen technologies, for different mobility, transport and industrial applications. The activities considered in TF 1 are expected to contribute towards the following overarching objectives:

- Increasing efficiency and sustainability and reducing costs: The use of critical materials in large amounts in the electrolysis process, such as Nickel ("Ni"), Cobalt ("Co"), and Platinum-group-metals ("PGM") jeopardises the economic feasibility and sustainability of hydrogen

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4 This decision focuses on R&D&I and FID of hydrogen-related technologies and thereby does not cover the construction of infrastructure, including hydrogen refuelling stations ("HRS").

5 Hydrogen systems consist of the integration of different technologies for the generation, storage, transportation, distribution and use of hydrogen. A local hydrogen system could for instance encompass an electrolyser, a hydrogen storage tank, a hydrogen refuelling station, a methanation unit, a fleet of heavy duty vehicles ("HDV") powered by hydrogen, and a pipeline for the distribution of hydrogen.

generation. The aim of technologies falling within TF 1 is to reduce the use such critical materials, while at the same time increase the system efficiency for each electrolyser technology. Moreover, by establishing different layers of integration of hydrogen generation technologies (e.g. cells into large stacks, or electrolyser technologies with different hydrogen applications downstream), interoperability of hydrogen generation technologies with different operating modes can be achieved together with cost reductions, faster hydrogen generation capacity and scale-up;

- Increasing reliability and durability through technical progress in the electrolysis process (e.g. in stack design and heat management or in the integration of technologies) in order to increase the lifespan of the electrolyser and its components; and

- Standardisation of hydrogen generation technologies with testing and validation in order to define appropriate testing protocols to increase safety, durability and performance (addressing the aspect of upscaling and highly dynamic operation) and reduce degradation in connection with variable energy sources.

(15) In order to achieve those objectives the following stream of activities will be pursued:

- The design and development of hydrogen generation technologies (R&D&I);

- The testing, standardisation and integration of hydrogen generation technologies (R&D&I and FID); and

- The development process for pilot lines and scale-up of hydrogen generation technologies (R&D&I and FID).

(16) The main challenge in the R&D&I phase of the electrolysis process is how to replace critical materials with new materials. These materials should, on the one hand be cost-effective and durable, and on the other hand exhibit the favourable attributes, such as the catalytic properties and temperature resistance of state-of-the-art materials, like Iridium ("Ir") or Platinum ("Pt") and Co in different electrolyser technologies. In addition, the integration of hydrogen technologies (e.g. cells into stacks), is very important for future supply chain enhancement, as it enables a higher range of design and raw material attributes to be combined. This requires however extensive research in order to be implemented without losing efficiency or durability. Another challenge for each electrolyser technology (i.e. proton exchange membrane electrolysis ("PEMEL"), alkaline electrolysis ("AEL"), solid oxide electrolysis ("SOE") and anionic exchange membrane electrolysis ("AEMEL") is to increase system efficiency, which significantly impacts on the operating costs.

(17) In the FID phase, the lessons learned from the design of cell stacks and systems using pilot lines in the R&D&I phase, will be transferred into cost-effective automatised processes that can be scaled-up. Automation of cell stack manufacturing does not yet exist on an industrial scale and the challenges for carrying out such a process are significant from a technical point of view (e.g. stack assembly needs to meet specific alignment tolerances).

(18) Regarding the standardisation of hydrogen generation technologies, in both the R&D&I and FID phases, a global certification scheme does not currently exist that can guarantee electrolysers' compliance with project developers' needs. Thus, the large-scale deployment of electrolysis for hydrogen generation in a short period of time faces significant uncertainties and risks and it is necessary to define appropriate test protocols. Considerable R&D&I effort is needed to gather all of the necessary data about the different parameters of hydrogen technologies if a better understanding of the new components of the electrolysers is to be achieved. Such data gathering would facilitate the setting up of a certification scheme, against which the technologies can be tested. Such certification scheme would, in turn, assist in the integration of the different hydrogen generation technologies for mobility, transport and industrial applications.

2.2.3 TF 2 – Development of FC hydrogen technologies

(19) Hydrogen FC use the chemical energy of hydrogen to produce electricity. Thus, the FC represent a key element in the hydrogen value chain. The core characteristic of the hydrogen economy is the efficient, reliable and sustainable use of hydrogen. Therefore, the main objective of this TF is to accelerate the use of renewable hydrogen in FC in areas, such as heavy duty mobility and transport (i.e. road, railway and maritime), as well as in hard-to-electrify applications.

(20) TF 2 focuses on the development, testing, validation and system integration of FC components, as well as systems for stationary, mobility and transport applications. The activities considered in TF 2, are expected to contribute towards the following overarching objectives:

- Increasing efficiency and reducing costs: It is indispensable to increase the efficiency of FC significantly to overcome the current market barrier in competition with existing technologies. The increase in efficiency can be reached with new and optimised materials for membranes and bipolar plates ("BPP") and new catalysts;
- Adapting system behaviour for the specific application of stationary applications, mobility and transport and at the component and system level: This would require continued technical and data exchange between component and vehicle manufacturers to improve and optimize the performance, depending on the respective technical challenges;
- Ensuring the entire life cycle of materials and components, including recycling; and
- Standardisation of FC for the different use cases with testing and validation under real conditions aiming for scaling up to higher technology readiness levels ("TRL").

(21) In order to achieve those objectives the following stream of activities will be pursued:

- The design and development of FC (R&D&I);

- The integrations, testing and standardisation of fuel cell components and systems (R&D&I and FID); and
- The development process for fuel cell pilot lines and scale-up (R&D&I and FID).

(22) The challenges in both the RDI and FID phases relate to the need to meet among others certain technical (thermal and mechanical) requirements and establish higher FC temperatures in order to increase electrical production. As the current FC production is challenged by the limited process controls, the insufficient traceability of components and high scrap rates, in order to reach these specific requirements for stationary, mobility and transport applications, an innovative FC development process must be ensured (from pilot lines to scale-up). This would enable simplification and automation of subsystem quality inspection along the assembly line, as well as substantial acceleration of the time-consuming end-of-line test.

(23) Finally, in the context of recycling and in order to guarantee the entire life cycle of materials and components, recycling concepts must be established with the aim to develop sustainable raw materials.

2.2.4 TF 3 - Development for technologies for storage, transportation and distribution of hydrogen

(24) TF 3 aims to develop, test and validate technologies for hydrogen storage, transportation and distribution. This is essential for the expansion of hydrogen technologies to connect the supply with the demand side and thus, realise an economic hydrogen value chain from generation to end use. The applications in TF3 vary from stationary, mobility and transport storage systems to HRS. The activities considered in the TF aim to contribute towards the following overarching objectives:

- Reduction of costly raw materials and replacement with new innovative and sustainable materials for a more efficient and simplified hydrogen storage design and development process that will enable a recycling chain; and

- Improvement and implementation of testing, standards and monitoring procedures. The objective of the improvements envisaged in this TF is to maximise the overall system performance, by optimising the on-board storage systems and its integration within the vehicle. The standardisation of components' interfaces will facilitate their integration and interoperability and will enable easy deployment for end users. The monitoring procedures are essential to improve safety and reliability.

(25) In order to achieve those objectives, the same stream of activities as in the other TFs will be pursued:

- The design and development of technologies for hydrogen storage, transportation, distribution (R&D&I and FID);

- The testing, standardisation and integration of technologies for storage, transportation, distribution (R&D&I and FID); and

- The development process for pilot lines and scale-up of processes and technologies (FID).

(26) For non-bulk storage, transportation and distribution hydrogen technologies, the main challenge in the R&D&I and FID phase lies in the need to integrate new, compatible materials to develop innovative designs and processes that would meet all safety requirements, and to ensure adequate scale-up, while at the same time decreasing the environmental impact of these materials and processes.

(27) Furthermore, with the transformation of the energy system and the increased use of renewable energy, bulk storages for hydrogen are becoming increasingly important. Therefore, the challenge of the research work is on assessing the technical feasibility of the geological conditions that would allow for bulk storage capacities for stationary applications and facilitate hydrogen mobility and transport for heavy duty applications for instance, through HRS.

(28) Regarding the testing and standardisation of the respective technologies for transportation, distribution and non-bulk storage as well as for bulk storage, in both the R&D&I and FID phases, the challenge of the activities in this TF is to improve and explore technologies and systems for different applications (e.g. by assessing the impact of hydrogen on the materials used in underground gas storage technologies), and validate their safety and reliability.

2.2.5 TF 4 - Development of technologies for end users

(29) This TF focuses on the development of hydrogen technologies for mobility of persons (e.g. railway, buses and maritime) and transport of goods (e.g. heavy duty trucks, railway and maritime) applications. The activities considered in TF4 aim to contribute towards the following overarching objectives:

- The development and implementation of hydrogen technologies, processes and equipment (e.g. compatible vehicle architecture, components (cabin, chassis, driveline, etc.) and fabrication materials) for the specific use cases that will ensure improved lifetime, durability and safety;

- The adaptation and integration of FC systems ("FCS") for mobility and transport applications, as well as the supply of hydrogen as fuel; and

- The assessment of regulations, standards and safety issues for the use of hydrogen technologies;

(30) In order to achieve those objectives the following stream of activities will be pursued:

- The design and development of hydrogen technologies (R&D&I & FID);

- The integration, testing and standardisation of hydrogen technologies (R&D&I & FID); and

- The development process for pilot lines and scale-up of hydrogen technologies (FID).

(31) The implementation of hydrogen and hydrogen-based energy vectors (e.g. methanol, e-fuels, ammonia, etc.) as fuel sources in the mobility and transport

sectors poses significant technical challenges in the R&D&I phases. These fuel sources are different to fossil fuels and have different chemical characteristics and physical properties, which could accelerate attrition of current materials, such as metals, plastics or composites. Therefore, the activities in this phase will aim towards developing more compatible systems and components. Furthermore, key challenges include defining the best compromise between battery and FC as energy source for the road vehicles (in terms of driving and refuelling time, weight and durability) and for the railway transport (in terms of volume to weight ratios of FC, batteries and hydrogen storage, safety, management of vibration constraints, thermal control of FC and acoustic performances).

(32) In the FID phase, the newly designed compatible systems and components will need to be integrated according to the specific requirements of the end users. The main challenge lies in the design of a full-scale prototype testing phase (corresponding to TRL 7). This prototype testing phase will establish the appropriate processes of prototype homologation, as well as develop new testing and validation areas and equipment, and achieve high quality and safety standards. These steps, in turn will mitigate the risks constraints of the end users, validate the integration of the new systems and components, and enable adequate scale-up of renewable hydrogen technologies.

(33) As far as the maritime sector is concerned, the challenge in both the R&D&I and FID phases lies in determining solutions for the storage, which currently do not exist, e.g. liquid hydrogen ("LH_2"), e-ammonia and e-methanol.

2.2.6 Description of the undertakings involved in Hy2Tech

(34) Figure 1 provides an overview of the participating undertakings involved in each TF of Hy2Tech. A more detailed description of each participating undertaking's[6] individual projects falling under the different TF is provided in section 2.4.1.

[6] These undertakings will participate in Hy2Tech with separated individual projects implemented by the different legal entities, bringing the total number of individual projects to 41.

Figure 1: Overall structure of Hy2Tech

(35) The participating undertakings are briefly described below:

1. Advanced Energy Technologies Single Member SA ("Advent")

Advent (Greece) is a small and medium-sized enterprise ("SME") with experience in developing advanced materials, components and processes for energy, defence, security, and aerospace FC applications. It is a subsidiary of Advent Technologies Holdings, which develops and assembles critical components in the renewable energy sector for FC and advanced energy systems.

2. Alstom ("Alstom FR") and Alstom Ferroviaria SpA ("Alstom IT")

Both undertakings (France and Italy) develop mobility and transport solutions. Their products range from high-speed trains, metros, monorail and trams to integrated systems, customised services, infrastructure, and signalling and digital mobility and transport solutions.

3. Ansaldo Energia S.p.A. ("Ansaldo")

Ansaldo (Italy) is active in the power generation industry covering all of the activities needed to supply turnkey power plant or power equipment solutions.

4. Arkema ("Arkema")

Arkema (France) offers technological solutions to address demand for new and sustainable materials and challenges of, among others, new energies, access to water, recycling, urbanisation, a mobility and transport.

5. AVL List GmbH ("AVL")

AVL (Austria) develops, simulates and tests powertrain systems (hybrid, combustion engine, transmission, electric drive, batteries, FC and control technology) for passenger cars, commercial vehicles and off-road, as well as stationary applications to improve the fuel consumption and drivability and reduce emissions and noise.

6. B&T Composites S.A. ("B&T Composites")

B&T Composites (Greece) is an SME active in the field of composite materials for mobility, transport, and industrial applications.

7. Christof Industries Austria GmbH ("Christof Industries")

Christof Industries (Austria), a subsidiary of Christof Industries Global GmbH, operates in industrial plant construction and service. It is active in different sectors (e.g. petrochemical, paper industry, chemical industry and energy and environmental technology) and covers all services along the life cycle of a plant.

8. Daimler Truck AG ("Daimler Truck")

Daimler Truck (Germany) is a commercial vehicle manufacturer, which brings together seven vehicle brands, offering various light- and heavy duty trucks, city buses and long distance coaches.

9. De Nora Italy Hydrogen Technologies S.r.l. ("De Nora")

De Nora (Italy) is special purpose vehicle set up by Snam S.p.A and Industrie De Nora S.p.A to carry out the hydrogen project. Snam S.p.A is an energy infrastructure operator with experience in feeding hydrogen mixed with natural gas into its transmission network and in the turbine of a compressor station. Industrie De Nora S.p.A. is an international provider of sustainable electrolyser technologies and components.

10. EKPO Fuel Cell Technologies GmbH ("EKPO")

EKPO (Germany) is a joint venture between ElringKlinger and Plastic Omnium, active in FC stack and component technology. It works on the development of FC stacks for carbon-neutral mobility and transport.

11. Elcogen AS ("Elcogen")

Elcogen (Estonia) is an SME that focuses on the development of solid oxide FC ("SOFC") for energy generation and solid oxide electrolysis cell ("SOEC") for electrolysis operation and stack technology.

12. Elogen SAS ("Elogen")

Elogen (France) is a PEM electrolyser manufacturer, specialising in the design and assembly of electrolysers for producing renewable hydrogen. It develops hydrogen generators using water electrolysis, based on PEM technology.

13. Enel Green Power S.p.A. ("Enel")

Enel (Italy) develops and operates renewable energy power plants, generated by a mix of resources, including wind, solar, hydro and geothermal.

14. Faurecia ("Faurecia")

Faurecia (France) is an automotive technology undertaking developing solutions for sustainable mobility and transport. Faurecia develops ultra-low emissions solutions for internal combustion engines ("ICE"), and advanced technologies for zero-emissions FC vehicles. It also develops hydrogen storage systems.

15. Fincantieri S.p.A. ("Fincantieri")

Fincantieri (Italy) is a shipbuilding group focussing on cruise ship design and construction, high-tech shipbuilding industry sectors and mechanical and electrical component equipment and after-sales services.

16. Genvia SAS ("Genvia")

Genvia (France) is a Clean Hydrogen Technology Venture created to provide cost-effective access to high-performance electrolyser and FC technologies, supporting heavy industry, mainly in the maritime sector, to decarbonise processes and achieve emissions targets.

17. Cummins - Hydrogenics Europe NV ("Cummins")

Cummins (Belgium) designs, manufactures, distributes and services power solutions ranging from diesel, natural gas, electric and hybrid powertrains and powertrain-related components , as well as diesel and gas generator sets. After acquiring Hydrogenics in 2019, Cummins became also active in the development of water electrolysers and hydrogen generation systems for industrial, mobility and transport applications.

18. HYVIA-JV Renault-Plug Power ("HYVIA")

HYVIA (France) is owned by Renault Group and Plug Power and has activities in FC technologies for light commercial vehicles and tailored hydrogen solutions.

19. H2B2 Electrolysis Technologies ("H2B2")

H2B2 (Spain) is an SME devoted to the development of hydrogen systems based on water electrolysis.

20. Iveco Czech Republic a.s. ("Iveco CZ"), Iveco Spain ("Iveco ES") and Iveco S.p.A. ("Iveco IT")

Iveco (Czechia, Spain and Italy) is a manufacturer of light, medium and heavy commercial vehicles, city and intercity buses and coaches, minibuses, trucks, fire fighting vehicles, defence vehicles and off-road vehicles for construction and mining work, in addition to engine and powertrains for industrial and marine applications.

21. John Cockerill Hydrogen Belgium and John Cockerill Hydrogen France (together "John Cockerill")[7]

Both undertakings (Belgium and France) are active among others in energy, environment, and metals markets. In the energy market, they develop heat recovery steam generators, concentrated solar power receivers and steam generators, micro grids solutions and hydrogen electrolyser technologies.

22. McPhy ("McPhy")

McPhy (France) is a technology original equipment manufacturer ("OEM") SME providing electrolysers for mobility, transport, industrial, energy markets, and HRS.

23. NAFTA A.S. ("NAFTA")

NAFTA (Slovakia) is active in natural gas storage and underground facility development. It operates gas storage facilities, explores and produces hydrocarbons ("HC") and participates in renewable energy storage projects.

[7] John Cockerill, with the participation of its two entities in Belgium and France, submitted a single project portfolio and is thus referred to as "John Cockerill" throughout the decision. However, the financial projections (eligibility of costs and funding gap) have been notified separately by the respective Member States.

24. Nedstack fuel cell technology BV ("Nedstack")

Nedstack (The Netherlands) is a FC manufacturing SME working on composites, catalysts and polymers.

25. Neste Oyj ("Neste")

Neste (Finland) is a renewable diesel and sustainable aviation fuel producer that provides renewable and circular feedstock solutions for the polymers and chemicals industries.

26. Nordex Energy Spain, S.A.U. ("Nordex")

Nordex (Spain) offers highly efficient and competitive wind turbine systems, which enable long-term economic power generation from wind energy. Nordex also operates as a project developer for wind farms.

27. Ørsted Hydrogen Green Fuels DK A/S ("Ørsted")

Ørsted (Denmark) was established to realise the Green Fuels for Denmark (GFDK) project as a subsidiary of Ørsted A/S. The latter is active in offshore wind power, and supplies offshore and onshore wind energy and solar energy solutions. Ørsted aims to develop sustainable hydrogen fuels for mobility and transport applications ("e-fuels").

28. Plastic Omnium New Energies Wels GmbH ("Plastic Omnium AT") and Plastic Omnium New Energies ("Plastic Omnium FR")

Plastic Omnium operates in five main business areas: vehicle light-weighting exterior parts, lighting, assembly of modules, fuel tanks and after-treatment systems, and hydrogen integrated systems for mobility. Plastic Omnium New Energies designs and produces innovative hydrogen solutions for zero-emission electric mobility/transport: high-pressure vessels and full systems for hydrogen storage integration and fuel cell systems.

29. Robert Bosch AG ("Bosch AT") and Robert Bosch GmbH ("Bosch DE")

The undertakings (Austria and Germany) have activities in four business sectors: mobility and transport solutions, industrial technology, consumer goods, and energy and building technology. They also offer solutions for smart homes, Industry 4.0, and connected mobility. Bosch AT additionally develops fuel injection systems for large engines.

30. SENER Renewable Investments, S.L. ("SENER")

SENER (Spain) is an undertaking established by SENER Grupo de Ingeniería, S.A. ("SENER Group") to develop renewable investments. SENER Group is an engineering and technology group providing solutions in various sectors: infrastructure, energy, marine and aerospace sector.

31. Stargate Hydrogen Solutions OÜ ("Stargate")

Stargate (Estonia) focuses on the development and production of advanced alkaline electrolysers and offers turn-key renewable hydrogen production, storage, and dispensing solutions for large-scale industrial customers.

32. Sunfire GmbH ("Sunfire")

Sunfire (Germany) is an SME that produces industrial electrolysers and provides renewable hydrogen and e-fuels from renewable electricity, water, and CO_2 as climate-neutral substitutes for fossil energy.

33. Symbio SAS ("Symbio")

Symbio (France) develops, manufactures, and supplies hydrogen FCS and solutions for light commercial vehicles, buses, trucks, and other mobile and stationary applications.

34. Synthos Dwory 7 Ltd. ("Synthos")

Synthos (Poland) is a producer of chemical commodities that are used as raw materials and intermediate products in several industries, in particular automotive, packaging and construction.

35. 1s1 Energy Portugal Unipessoal Lda ("1s1 Energy")

1s1 Energy (Portugal) is a technology undertaking developing renewable energy products based on materials science and system engineering.

2.3 Governance of Hy2Tech

(36) For the implementation and monitoring of Hy2Tech a governance structure will be set up. This structure of Hy2Tech is summarized in the table below:

IPCEI Supervisory Board ("SB")		
Public Authority Board ("PAB")	IPCEI Facilitation Group ("FG")	Commission (guest status)
IPCEI General Assembly ("GA")		

Table 1: Hy2Tech governance structure

(37) Hy2Tech's Supervisory Board ("SB") consists of:

- The PAB, with representatives appointed by the Member States participating in Hy2Tech, each having one vote;
- Hy2Tech's FG; and
- Representatives of the Commission, as observers and advisers without voting rights, appointed by the Commission.

(38) The role of the SB will be to supervise, monitor and assure the implementation of Hy2Tech at large. This especially concerns the monitoring of the progress of the participating undertakings, as well as of Hy2Tech as a whole. The focus of the implementation is on both, technological advances and the spill-over activities to disseminate these advances, which the participating undertakings have committed to deliver. The SB will be also responsible for the annual reporting towards the Commission on the basis of the information to be provided by the FG.

(39) In principle, the SB will meet twice a year, by teleconferencing or videoconferencing. In addition, the SB may meet in extraordinary session to discuss any event relating to Hy2Tech, in particular regarding the potential entry of a new participating undertaking or the exit of an existing one.

(40) To demonstrate the effectiveness of Hy2Tech's setting and functioning, key performance indicators ("KPIs") will be agreed upon at the first meeting of the SB and monitored accordingly in the course of Hy2Tech.

(41) As regards the GA, it will be organised once a year, gathering all participating undertakings and the representatives of the Member States (and the Commission as observer). At its first meeting, within six months after the Commission's approval decision of Hy2Tech, the GA will elect the members of the FG, and it will be responsible of adopting respective decisions on any changes of the FG's composition. In particular, the GA elects the chair and the deputy of Hy2Tech and the coordinators (including their substitutes) of each TF, who will be members of the SB. It will also designate a participating undertaking, member of the FG, as key contact for the implementation of the spill-over commitments. The GA will moreover take note of any exit decision from Hy2Tech either at the next ordinary GA meeting or by written consultation, teleconferencing or videoconferencing. The decisions will be taken by a 2/3 majority. As from its second meeting onwards, the GA shall be organised alongside the annual public Hy2Tech conference.

(42) The FG is composed of the chair, the deputy of Hy2Tech, the coordinators of the TF (and their substitutes) and any additional undertaking's representatives or advisors assuming related duties. It will be in charge of the TF coordination, the annual reporting, the communication, the preparation of events, etc.). It will drive the overall progress of the TF on a non-confidential basis to establish a permanent interface between private and public stakeholders with the goal to highlight Hy2Tech's role and impact.

(43) The FG will also be responsible for organizing and fostering the collaboration and the communication within Hy2Tech and vis-à-vis third parties, which can benefit from results of Hy2Tech but are not participating undertakings. For this, the FG will implement two instruments: the annual Hy2Tech meeting and Hy2Tech website.

(44) A Hy2Tech meeting will take place once a year. The first meeting will take place at the latest one year following the Commission's decision approving Hy2Tech. The meeting will consist of a dedicated session for Member States, the Commission and the participating undertakings and a public conference open to any interested party, during which the participating undertakings will present the main results of their works.

(45) The website will host public information about Hy2Tech and the participating undertakings. Moreover, the website will serve as the dissemination and interaction channel of Hy2Tech engaging thus entities other than the participating undertakings. For this, the website will list all spill-over activities to which the participating undertakings have committed themselves (see below section 2.5). This information will be presented in form of an "Events Calendar" with the concrete dates and a brief description of the activity. The interested community will have the opportunity to register for participation at the activities

directly with the participating undertaking who will be in charge of the specific activity. The website will thus also serve as a basis for the annual reporting on the delivery of the committed activities. The FG will collect qualitative and quantitative information for each activity. It may also foresee a restricted area for the participating undertakings to organise the implementation of Hy2Tech.

(46) The members of the FG will change over time to take into consideration the end of participation of the participating undertakings according to their respective individual portfolios.

(47) As regards national governance, the individual projects of the participating undertakings are governed by funding agreements between them and their relevant funding authority within each Member State. Such funding agreements impose requirements and obligations towards the administration of any individual project according to the rules set up by the funding authority. The national funding authorities are in possession of the commitments of all participating undertakings. As such, the PAB will be responsible to monitor the completeness of the listings and announcements of the committed spill-over activities and knowledge dissemination.

2.4 Hy2Tech as an Integrated Project

(48) The Member States submit that Hy2Tech is an integrated project within the meaning of point 13 of the IPCEI Communication. Hy2Tech is based on a systemic programme aiming at the same objective laid down in the Chapeau document. The TF of the programme are not only complementary, but are mutually connected and significantly add value to each other in order to meet the objectives of each TF separately and of Hy2Tech as a whole.

(49) The sections below describe how the individual projects complementary and significantly add value within each TF and across the different TF in order to achieve the respective goals of Hy2Tech.

2.4.1 Description of the significant added value and complementarity of the individual projects within each TF for the achievement of the objective of Hy2Tech

(50) The individual projects of the participating undertakings are outlined below in the four TF. Each project is one constituent of Hy2Tech, whereas collaborations amongst the various projects aim to build up its integrated nature. The overall work plan is developed according to a circular model, which is contextualized within each TF, facilitating the generation of transnational synergies towards integrated final solutions.

(51) Hydrogen, which is mainly generated by electrolysers through water electrolysis (scope of TF 1) is fundamental to operate FC (scope of TF 2). Moreover, scaling-up the development of water electrolysis technologies, as well as optimising electrolyser operating conditions (notably pressure) is necessary to drive hydrogen costs down, and as a result, enable FC and other hydrogen based solutions becoming competitive to fossil solutions for the mobility and transport applications (TF 4). Finally, the development of technologies to upscale the necessary infrastructure for distribution and storage of hydrogen (TF 3) is essential to connect the demand side with the supply side.

2.4.1.1. Description related to the significant added value and complementarity of the individual projects for the achievement of the goals of TF 1

(52) TF 1 is divided in three main tasks and involves 20 participating undertakings, namely Advent, Ansaldo, AVL, Christof Industries, Cummins, De Nora, Elcogen, Elogen, Enel, Genvia, H2B2, John Cockerill, McPhy, Nordex, Ørsted, SENER, Stargate, Sunfire, Synthos and 1s1 Energy.

(53) Task one concerns the development of new materials and components for hydrogen electrolysers. This task includes not only the replacement/reduction of critical material, but also the design of new electrolyser cells and stacks. The R&D&I phase contains the following components:

a) Reducing/eliminating rare/expensive/environmentally critical materials (such as noble metals) and replacing them by materials well suited for recycling;

b) Improving power density, efficiency, stationary and transient performance, safety and security, durability, and reliability, as well as reduction of capital expenditure ("CAPEX") and operating expenditure ("OPEX") of hydrogen production systems;

c) Developing large stacks (increased number of cells, increased membrane active area);

d) Developing new design of electrolysis cells, stacks and systems matching certain requirements, such as high robustness, resilience against tolerances, low costs, design for recycling, etc.;

e) Achieving technical progress in stack design and heat management;

f) Solid oxide cells ("SOC"): optimization of cell microstructure for operation at higher currents with low degradation;

g) SOC: design of advanced stacks able to operate at high current density in reversible SOFC/SOEC mode;

h) Alkaline water electrolysers ("AWE"): development of a new high-pressure, high current-density AWE generation;

i) PEM electrolyser: integration of innovative and thinner membranes in stacks to reduce resistance; and,

j) Copper–chlorine ("Cu-Cl") thermochemical water splitting cycle ("TWSC"): evaluation in laboratory scale facility.

(54) In the FID phase, the participating undertakings will develop and validate innovative production processes when integrating novel and circular materials in key electrolyser components. They will furthermore ensure output quality, circularity, and energy efficiency of hydrogen generation processes.

(55) Task two focuses on the integration, testing and standardization of electrolyser technologies and contains the following components in the R&D&I phase:

a) Operating of electrolysis in intermittent mode linked to the availability of fluctuating renewable energies sources;

b) Demonstrating and testing seamless integration of the electrolyser systems with different industrial or mobility and transport applications

c) Defining of appropriate test protocols;

d) Establishing an testing infrastructure emulating different operating conditions and environments for all types of electrolysers;

e) Designing an open data hub for hydrogen containing hydrogen standards, test protocols and protocols for monitoring hydrogen systems;

f) Enable technology transfer, coordination in design and testing, and standardization in future manufacturing;

g) Developing of new verification and validation approaches for proof of concept and proof of reliability/durability of new technologies;

h) Optimal integration (regarding electric grid, gas flux/supply, heat flux, digital control) of hydrogen production systems in European networks;

i) Optimisation of the flexibility for levelised cost of hydrogen ("LCOH") minimization at variable input operation;

j) Addressing common standardization and digitalization challenges and contribute thereby efficiently to various standardization and open data initiatives; and

k) Developing a roadmap and an action plan to decrease the number of unscheduled maintenance events on electrolysis system level.

(56) Thereafter, the FID phase focuses on:

a) Developing a global certification scheme and industry test protocols for electrolysers to guarantee the compliance of electrolysers for project developers;

b) Developing a dedicated stack cost reduction programme to improve the overall stack performance; and

c) Developing in real industrial environment a testing area specifically designed for the assessment and validation of innovative key Balance of Plant ("BoP") components (reliable and non-invasive field monitoring, advanced functionalities related to Industry 4.0 and Internet of Things ("IoT"), components with less mechanical parts).

(57) Task three includes the following steps in both the R&D&I and FID phases to ensure market uptake and acceptance.

(58) For R&D&I:

a) Developing innovative and easily scalable processes;

b) Implementation of industry 4.0 concepts (e.g. digital twins, production automation trough use of robots) and AI based system'

c) Designing an experimental pilot line for SOFC and stack production;

d) Scaling up of AEM technology by development of prototypes manufacturing and testing as well as development of fabrication and assembly processes;

e) Validating processes by fabrication of pre-series units;

f) Testing product innovation by using a flexible digital factory model before the roll out;

g) Building up of automatized and standardized assembly lines;

h) Demonstrating novel electrolysis technology for accelerated market deployment;

i) Improving balance of plant components and subsystem with higher efficiency and better performance, improved durability and reliability and lower costs;

j) Developing an automated fabrication process for PEM cells and stacks of large size;

k) Simulating in a predictive way the transient behaviour of the new technologies of alkaline electrode considering durability and degradation aspects; and

l) Developing sufficiently accurate models for components and cell for the identification of limitations for the improvement of efficiency and current density in electrolysis process.

(59) For FID:

a) Achieving stable, safe and environmentally compatible processes in real environment;

b) Embedding processes in a circular economy;

c) Establishing a robust supply chain for components and subsystems;

d) Designing, constructing and operating of electrolysers pilot line production;

e) Investigating the joint development, assembly and deployment of different components of different electrolyser technologies;

f) Establishing seamless, fully digitized value/supply chain including/applying advanced digital and software technologies;

g) Minimizing energy consumption and resources of manufacturing processes of electrolysers;

h) Implementation of standards and protocols for quality, safety, and security assurance along with automated, digitized assurance systems in production processes;

i) Investigating simultaneous assembly of different stages of products (from components to electrolyser systems);

j) Establishing validation procedures to prove quality, safety, security and environmental compatibility of processes; and

k) Establishing recycling/refurbishing processes for PEM electrolysers.

Description related to the significant added value of the individual projects

1. Advent

(60) Advent will contribute to the activities of TF 1 by developing a process to produce electrolysers at large-scale. It will perform R&D&I and FID work for both electrolyser technologies, PEMEL and AEL. This dual technology approach is expected to mitigate any supply constraints and will aim to deliver renewable, pure and dry hydrogen.

2. Ansaldo

(61) The main goal of the research activities of Ansaldo is the demonstrating of relevant industrial applications for reversible SOC ("rSOC") going beyond the laboratory or R&D scale and/or co-electrolysis applications. In particular, Ansaldo aims to deploy SOE system and pilot line for 300 MW/year production capacity with increased volumetric power density (by improved electric contact stability and reduce ohmic losses) and improved safety and stability for the electrolysis process.

3. AVL

(62) AVL will contribute to TF 1 by developing a modular, highly efficient, and scalable SOEC platform for a 1 MW high temperature SOEC, based on metal-supported cells ("MSC"). In particular, the developed technology is expected to have an integrated heat reuse with an energy efficiency greater than 80 % that can be operated for more than 2000 hours of continuous operation at half degradation rate.

4. Christof Industries

(63) Christof Industries will develop during the FID a process for subsequent serial production for the new highly efficient SOEC electrolysis system based on the research and developments by AVL. Christof Industries will set up a production capacity of […]*(*)*[8] of HT-SOEC electrolysers till 2031, based on metal-supported cells using low-cost ferritic steel.

[8] **Confidential information.*

5. Cummins

(64) Cummins' project concerns the development of new stacks for PEMEL with improved performance, in particular M-type stacks (2.5 MW), L-type stacks (5 MW) and PEMEL systems in excess of 20 MW/. This is expected to improve PEMEL performance, in particular stack and system efficiency and degradation rate and support the deployment of an overall production capacity at large-scale.

6. De Nora

(65) De Nora's research activities in this TF will focus on the validation and optimisation of a new electrode pack (new anode and cathode electrodes, as well as separators and other components) for next-generation high-pressure and high-current density containerised AWE. This is expected to facilitate the design and FID of an electrolysers' large-scale production hub.

7. Elcogen

(66) Elcogen will develop a SOC with reduced amount of critical raw materials, in particular Ni and Co and with novel Strontium ("Sr")-doped ceramic substitutes (i.e. ferrites, manganites or titanates) with high catalytic activity and ionic conductivity, mechanical strength, chemical and thermal compatibility including good co-sintering properties. This is expected to facilitate operation at high current density in rSOEC and optimise manufacturing processes and stack assembly for SOE modes.

8. Elogen

(67) Elogen will contribute to TF 1 by developing a new concept of PEM stack and MEA allowing operation at increased operating temperature and current density, with higher efficiency, hydrogen production capacity, durability and reliability. In addition, Elogen will research for new catalysts with reduced PGM content on the oxygen side and without Pt on the hydrogen side. .

9. Enel

(68) Enel will launch a first-of-a-kind Innovation Test Facility. It is specifically designed for the parallel and cost effective testing and validation of several innovative hydrogen technologies, such as electrolysers, to establish proof of concept, reliability and durability under real industrial environmental conditions, using different energy sources.

10. Genvia

(69) Genvia's research will further the development of high temperature SOEC, in particular by aiming at reducing the use of critical materials and increase thereby scale and performance of the developed technologies. In addition, Genvia will develop and deploy currently non-existent digital tools supporting the full lifecycle of SOEC systems from design to client integration for their safe and cost-effective operation.

11. H2B2

(70) H2B2 will further the development of the current PEM, AEM and SOEC electrolysis technology to 5 MW units (for PEM) and 1 MW units (for AEM and SOEC). For AEM and SOEC, H2B2 will also develop new stack and BoP components. Subsequently, H2B2 is expected to scale up the three developed electrolyser technologies to a capacity of 200 MW / year.

12. John Cockerill

(71) John Cockerill will develop large alkaline electrolysers with high pressure and high current density stacks of different sizes and capacities (e.g. 5 MW […], 10 MW and 20 MW […]). This will facilitate the scale-up of the electrolysers with the aim to reach 1000 MW / year capacity by 2030.

13. McPhy

(72) McPhy will develop XL Stack and large electrolysis platforms for larger needs for industrial applications. These stacks (1-5 MW) will combine the features of high current density, high pressure and large stack size in a single unit. McPhy is expected furthermore to develop, test and subsequently up-scale its capacity for XL stacks and electrolysers.

14. Nordex

(73) Nordex will develop a pressurized alkaline electrolyser with a stack size between 2.5-10 MW, which can be adapted to variable operation with direct electrical supply from wind turbine and photovoltaics ("PV"). In particular, Nordex will design the electrolyser with the view of minimising the LCOH at variable input operation. This will aim in a different BoP and stack design, resulting from the direct connection of the wind farm and the PV plant to the electrolyser plant.

15. Ørsted

(74) Ørsted will contribute to TF 1 by deploying a 10 MW electrolyser (powered by renewable electricity from offshore wind energy) in large modules based on new developed kinetic and thermodynamic models. The large modules will be used as building block for the subsequent scale up to around 300 MW.

16. SENER

(75) SENER will develop a new generation of an AEMEL with a 5 kW capacity. This 5 kW AEMEL electrolyser will serve a building block for the development of 25 kW and 100 kW AEMEL electrolyser prototypes. In addition, SENER will further the development of AEL by increasing the alkaline stack size and the stack efficiency to subsequently achieve individual stack sizes of 10 MW.

17. Stargate

(76) Stargate will develop a high volume, high current density 1 MW AEL stack capable of operating at pressures above 20 bar. These high current density stacks will be free of PGM. Based on these developments, Stargate aims to reach a capacity to produce at large-scale PGM free and pressurised AEL.

18. Sunfire

(77) Sunfire will advance the SOEC and AEL technologies through the development of simpler cell and stack designs. For SOEC, Sunfire plans to eliminate oxygen channels in the porous anode and to replace Crofer 22 APU (a ferritic stainless steel) with MoCr steel for the coated interconnections between cells. For AEL, Sunfire will develop an automated cell frame machining. In addition, Sunfire will develop new types of components and equipment for subsequent production, leading to improved, more cost-effective AEL and SOEC at larger capacity scales. Rare and costly materials will be eliminated or substituted, and the design of the electrolysers and their components will be aligned to achieve a subsequent highly automated and cost-effective production.

19. Synthos

(78) Synthos will conduct research for subsequent further development of an unprecedented thermochemical water splitting cycle based on the Cu-Cl (TWSC and the SOE technology. Based on the results achieved, Synthos will pursue one of these two technologies for up-scaling.

20. 1s1 Energy

(79) 1s1 Energy will develop PEM electrolysers with innovative chemistries and materials for performance enhancement. In particular, 1s1 energy will develop new PEM and ionomer composition of matter incorporating tetravalent boron acid groups, new, non-PGM catalysts for the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) and new materials for the porous transport layer (PTL). With the results of this development, 1s1 Energy will develop 1 MW modules and will subsequently scale-up […].

Description related to the complementarity of the individual projects

(80) The Member States have explained that the individual projects of the undertakings participating in TF 1 are complementary, as they are all designed in a common structure and programme in order to achieve the objectives of the TF.

(81) The participating undertakings in TF 1 will collaborate aiming at the development of related technologies, namely of materials for electrolysers as well as enhanced design of electrolyser cells and stacks. After the evaluation, testing and standardization of new electrolyser technologies they prepare the market ramp-up by developing related effective manufacturing processes and test models for components and cells.

(82) The complementary character of the individual projects is further corroborated by a number of collaborations within the TF, as explained in section 2.4.3.1.

2.4.1.2 Description related to the significant added value and complementarity of the individual projects for the achievement of the goals of TF 2

(83) TF 2 is divided in four main tasks and involves 17 participating undertakings, namely Advent, Ansaldo, Alstom FR, Arkema, Bosch DE, Daimler Truck, De

Nora, EKPO, Elcogen, Fincantieri, HYVIA, Genvia, Iveco CZ, Nedstack, Plastic Omnium AT, Symbio and 1s1 Energy.

(84) Task one concerns the development and use of new materials and its components. In order to improve the performance of FC, materials constituting core elements of the stacks, the membranes, the electrodes and the BPP shall be developed and optimized. The respective R&D&I and FID phases contain the following components.

(85) For R&D&I:

a) Research for reduction/replacement of fluorine content in stack components, hence increased recyclability;

b) Making fluorine-free materials technically suitable for use in the heavy duty segment;

c) Development of high temperature PEMFC components with proton exchange groups, backbone materials, and catalyst systems that can operate at higher temperatures and have a strong durability profile;

d) Membranes: obtain specific morphology to reach the protonic conductivity that should persist higher temperatures;

e) BPP: development of polymer high-performance coatings for higher durability; and

f) Development of advanced electrodes with innovative gas diffusion layer ("GDL") and new layer fabrication techniques by determining the best structure for the gas diffusion electrode layer.

(86) For FID:

a) Evaluation of the developed materials and validation of high temperature resistance;

b) Validation of the quality of developed coatings for BPP and for membrane films in pilot lines;

c) Testing, validation, safety analyses and material characterization of the advanced FC electrodes; and

d) Demonstration and validation of new manufacturing techniques of the advanced electrodes.

(87) Task two covers the development of new FC system architecture. The respective R&D&I and FID phases contain the following components.

(88) For R&D&I:

a) Development of a novel stack concept to increase durability, longevity, gravimetric and volumetric power density and scalability;

b) Development of a novel stack concept to allow reverse operation (FC / electrolyser);

c) Development of a novel stack concept to reduce production cost;

d) New physical and control interface for simplified vehicle integration;

e) New operating strategies on FC systems and drivetrain level;

f) Co-design between FC stack provider and OEM and the adoption of systems for the different applications;

g) Development to ensure energy management between the energy sources, the FC and the battery;

h) Development of partly automated subassembly steps for cycle time reduction and development of recycling processes; and

i) Development of new, highly integrated system designs, allowing for easy integration.

(89) For FID:

a) Establishment of a recycling concept for the stacks / all possible included components;

b) Establishment of design-to-cost ("D2C") concepts for FC components;

c) Incorporation of end-of-line testing, break-in and quality control;

d) Exchange of results and improvement needs via iterative feedback loops with producers of prototypes; and

e) Establishment of digital solutions, e.g. machine learning and Industry 4.0.

(90) Task three concerns the integration, testing and standardization of FC technologies and focuses on scaling up to higher TRL of materials, components and processes.

(91) The R&D&I phase contains the following components:

a) Enable test and validation under real conditions for materials and components;

b) Development of technical standards to ensure safe and efficient on-board operation of FC systems;

c) Preparation of components and products to obtain certification and/or homologation for the targeted applications;

d) Definition and implementation of adequate testing procedures, from component to system level;

e) Adaptation of existing testing premises;

f) Development of specific test benches for testing of FCS performance at engineering centres; and

g) Implementation of a fully digitalized production process.

(92) During the FID phase, the following steps are scheduled to be implemented:

a) Integration of FC components in close cooperation with the OEM and end-users;

b) Testing of the component as twin systems on test stands as well as in test vehicles;

c) Specific test benches for testing of FCS performance at FC plant for quality checks;

d) Automatic in-line controls and digital data collection;

e) Live time testing using a digital twin concept;

f) Operation of the FC in heavy duty applications to allow feedback and improvement iterations; and

g) Studies, simulations and tests in single cylinder and multi-cylinder configuration, to validate combustion and injection management system in maritime use.

(93) Finally, in order to ensure market launch and acceptance, task four includes the following steps.

(94) During the R&D&I phase, Hy2Tech aims to develop application specific services and maintenance processes, as well as after sales processes and 3rd level support programmes and systems.

(95) The FID phase contains the following:

a) Standardized testing and characterization procedures for components and stacks;

b) Implementation of a high-quality maintenance and service process; and

c) Transform and spread truck field-testing sequentially over the growing end-user fleet.

<u>Description related to the significant added value of the individual projects</u>

1. <u>Advent</u>

(96) Advent contributes to TF 2 by developing, designing, and manufacturing fully scalable and highly efficient high temperature PEM ("HTPEM") FC for the production of power and heat reaching a capacity of 118 MW within a period of six years. In particular, Advent will develop these PEMFC incorporating innovative catalysts (e.g. consisting of non-PGM), membranes and membrane

electrode assemblies ("MEA"), gas diffusion layers, BPP being produced at very low cycle times and coatings allowing for the required longevity of FCS.

2. Ansaldo

(97) Ansaldo contributes to TF 2 by demonstrating relevant industrial applications for rSOC going beyond the laboratory or R&D scale. It aims to define the best materials and interfaces between components, in order to increase specific power in single module for easier system integration, and thereby simplify the overall design for a robust cycling operation.

3. Alstom FR

(98) Alstom will firstly develop integrated dual power packs (combination of FC and associated batteries), converters, hydrogen tanks and energy management software to be implemented on different platforms or rolling stocks and operable on different national European networks; and secondly, new tender locomotives for freight operations and new 4-axle shunting locomotives using hydrogen as a fuel.

4. Arkema

(99) Arkema contributes to TF 2 by developing and producing materials for FC stacks with fluorinated polymers for MEA and bipolar plate coatings that can provide high chemical resistance and higher operating temperature for improved efficiency. The development of this membrane, will result in a reduction in the quantity of fluorine used and will be easier to recycle.

5. Bosch DE

(100) Bosch DE contributes to TF 2 by developing stationary FCS based on the SOFC technology in a modular 10 kW+ class, aiming for an annual production capacity of FCS with a total output of 200 MW of electricity and 60 MW of additional heat over the course of its project. Bosch DE's work will cover the entire manufacturing value chain, from the core component FC and FC stack to the process of the central hotbox and the final SOFC device and entire systems.

6. Daimler Truck

(101) Daimler Truck will develop FCS with increased lifetime and durability to meet requirements for heavy duty transport and to achieve technical parity with existing diesel technology. In addition, Daimler Truck aims to reduce the Pt content of the FCS.

7. De Nora

(102) De Nora contributes to TF 2 through its research and development of new electrodes with enhanced gas diffusion and lower content of critical materials as well as components for Alkaline FC. This is expected to facilitate the design and FID of a FC large-scale production hub.

8. EKPO

(103) EKPO will develop a new generation of PEMFC stack modules for heavy duty applications with a targeted power output of more than 300 kW. The focus will be on D2C and design-for-manufacturing ("D2M") principles of the stack module. EKPO will also develop a fluorine-free stack modification, whereby the main content is the integration of the fluorine-free components, in particular the hydrocarbon catalyst coated membrane ("HC CCM"), into the technology and production processes.

9. Elcogen

(104) Elcogen contributes to TF 2 by developing a SOC with reduced amount critical raw materials, in particular Ni and Co and with novel Sr-doped ceramic substitutes (i.e. ferrites, manganites or titanates) with high catalytic activity and ionic conductivity, mechanical strength, chemical and thermal compatibility including good co-sintering properties. This is expected to facilitate operation at high current density in rSOFC and optimise manufacturing processes and stack assembly for SOFC modes.

10. Fincantieri

(105) Fincantieri will develop Hybrid Green Power Generation Systems ("HGPGS"), using hybrid propulsion systems, for maritime applications/ The HGPGS will be composed of FC based on the PEM technology with a modular approach (modules of 500 kW/each) and ICE powered with hydrogen in the range of 1-3 MW. Combining the FC with an internal combustion engine in a hybrid propulsion system will enable Fincantieri to increase the efficiency of the overall system, and thereby achieve less fuel consumption.

11. HYVIA

(106) Hyvia contributes to TF 2 by developing FC for LCVs. It will optimise the FCS by developing new membrane materials for HTPEM and integrate in-house BPP and MEA into the FC production unit. HYVIA aims to develop the first pilot fleets by optimising the integration of the 30 kW FCS into the first vehicles.

12. Genvia

(107) Genvia's research will further the development of high temperature SOFC in particular by aiming at reducing the use of critical materials and increase thereby scale and performance of the developed technologies. In addition, Genvia will develop and deploy currently non-existent digital tools supporting the full lifecycle of SOFC systems from design to client integration for their safe and cost-effective operation.

13. Iveco CZ

(108) Iveco CZ contributes to TF 2 by developing a complete FCS for FC electric coaches including stack, air supply, hydrogen supply, hydrogen and water exhaust circuit, thermal management and an electrification DC/DC inverter.

14. Nedstack

(109) Nedstack will develop and deploy roll based assembly systems for PEMFC with roll-feeding, in-line seal dispensing, adhesing and curing on FC BPP and in-line MEA assembly as well as in-line stack activation and testing concepts for stationary and maritime FC.

15. Plastic Omnium AT

(110) Plastic Omnium AT contributes to TF 2 by developing a new FC BOP system for integrating PEM FCS into the FC module. This new PEMFC system platform addresses the specific requirements of heavy duty applications. It is expected to be more efficient and better meet the requirements of the vehicle architecture than current products. Another objective is to achieve a significant cost reduction aiming to make the developed technology cost competitive with its diesel equivalents on a TCO basis.

16. Symbio

(111) Symbio will develop FC stacks with a new architecture […]. In addition, the new FC architecture is based on a brick concept […] which will allow the subsequent production of FC stacks in different modular sizes up to 300 kW.

17. 1s1 Energy

(112) 1s1 Energy contributes to TF 2 through its development of […] innovative chemistries and materials for performance enhancement. In particular, 1s1 Energy will develop new PEM and ionomer composition of matter incorporating tetravalent boron acid groups, and new, non-PGM catalysts […].

Description related to the complementarity of the individual projects

(113) Within TF 2, the participating undertakings will collaborate to develop the use of enhanced materials in FC and their components. Manifold improvements in the FC stack architecture as well as for the production process have to be developed and investigated. Evaluation, testing and standardisation activities will lead to scaling up to higher TRLs of the materials, components and processes and prepare the market launch.

(114) The complementary character of the individual projects is corroborated by a number of collaborations within the TF, as explained in section 2.4.3.1.

2.4.1.3. Description related to the complementarity and significantly added value of the individual projects for the achievement of the goals of TF 3

(115) TF 3 is divided in four main tasks and will involve nine participating undertakings, namely Arkema, B&T Composites, Daimler Truck, Enel, Faurecia, Neste, NAFTA, Ørsted and Plastic Omnium FR.

(116) Task one concerns the reduction of raw materials and the development and usage of new materials by keeping and fulfilling the high standards on safety

and reliability. The respective R&D&I and FID phases contain the following components.

(117) For R&D&I:

a) Development of thermoplastic and thermosetting composites for high pressure hydrogen tanks for mobility, transport and HRS;

b) Investigation of new technologies facilitating the manufacturing and production processes;

c) Development of piezoelectric polymer sensors for composite tank health monitoring;

d) Development of concepts for recycling carbon fibre from high pressure vessels; and

e) Development of recycling technology for thermoset pressure vessels

(118) For FID:

a) Implementation and scale-up of the production of new families of polyamide compounds materials for liners and acrylic resins for thermoplastic composites;

b) Demonstration and scale-up production of carbon fibre with lower CO_2 footprint and high performances;

c) Scale-up pilot lines for high performance polymer impregnated carbon fibre tapes for tanks fast winding;

d) Scale-up pilot lines for piezoelectric polymers; and

e) Development of concepts for facilitating the upscaling of high pressure vessels;

(119) Task two concerns the development, integration and use of new and alternative storage technologies besides high pressure gaseous tanks, and contains the following components for the R&D&I and the FID phases.

(120) For R&D&I:

a) Achievement economic and durability of solid-state storage compared with gas pressurized solutions, (i.e. increasing the storage dimension and system performance, etc.)

b) Investigation of cryogenic storage systems for heavy load application;

c) Development of methodology for geological structure assessment in terms of their suitability for hydrogen storing; and

d) Verification of the technical feasibility of underground energy storage in porous structure.

(121) The FID activities concern the scale-up of pilot lines for cryogenic hydrogen storage systems, the implementation of liquid organic hydrogen carriers ("LOHC") facilities and the pilot testing of hydrogen storing in depleted gas fields in several cycles.

(122) Task three concerns the integration and standardisation of hydrogen storage systems for the use in mobile and stationary applications and contains the following components for R&D&I and FID.

(123) For R&D&I:

a) Development of conformable and modular tank systems for on-board storage;

b) Elaboration and definition of structural health monitoring ("SHM") strategies for high pressure vessels;

c) Creation of properly designed infrastructures for the validation of new storage technologies and their integration (among them, with energy systems and with final users) at all TRL levels, both in protected and industrial environment; and

d) Exchange of knowledge allowing to define requirements for the integration and operation of hydrogen storage systems for mobile applications.

(124) For FID:

a) Definition and validation of optimal integration of storage systems to end-use technologies;

b) Optimisation of the interaction between fluctuating renewables supply and electrolyser-based hydrogen production;

c) Optimization of the hydrogen storage system operation for a peer-to-peer ("P2P") renewable and low-carbon hydrogen system; and

d) Verification and validation of component and system quality also using and integrating sensors for health monitoring.

(125) Finally task four concerns the development and upscale of specific technologies for HRS. The activities during the R&D&I phase aim to exchange new knowledge concerning the expected functionalities and parameters of the HRS. Particular consideration is given to the communication protocols between the station and the vehicle in the refuelling / charging processes, the required parameters determining the infrastructure capacity and the IT solutions supporting fleet management processes. The FID phase focuses on pressure scalable HRS compatible with the requirements of different mobile applications.

Description related to the significant added value of the individual projects

1. Arkema

(126) Arkema will develop recyclable materials for hydrogen tanks with bio-based polymers associated to carbon fibre thermoplastic composites to reduce manufacturing time and cost of high-pressure vessels. In addition, Arkema will develop a printed sensors array with a new fluorinated based piezoelectric copolymer for integrated SHM in hydrogen tanks.

2. B&T Composites

(127) B&T Composites' contribution in this TF focuses on the development of optimal light-high pressure gaseous hydrogen storage for mobile and stationary applications. In particular, B&T Composites will develop type IV and V hydrogen storage tanks through analytical and microscale modelling activities of the microstructure, stress distributions and anisotropies of the carbon fibre reinforced composites ("CFRP").

3. Daimler Truck

(128) Daimler Truck will contribute to TF 3 through its development, integration and performance testing of gaseous and liquid hydrogen storage systems for heavy duty transport applications. Storing hydrogen in liquid form has the potential to increase the range of the vehicle, save space, weight and costs compared to gaseous storage solutions or heavy high voltage batteries.

4. Enel

(129) Enel will launch a first-of-a-kind Innovation Test Facility. It is specifically designed for the parallel and cost effective testing and validation of several innovative hydrogen technologies, such as storage technologies (e.g. liquid organic carrier or metallic organic framework solutions), to establish proof of concept, reliability and durability under real industrial environmental conditions, using different energy sources.

5. Faurecia

(130) Faurecia's project aim at developing compressed and liquid hydrogen tanks for different mobility and transport applications, namely light and HDV. For compressed hydrogen tanks, Faurecia will use thermoplastic polymers for the matrix of the composite, replacing the epoxy resin of the current technology. For liquid hydrogen tanks, Faurecia will develop a double- wall insulated design to minimise the entry of heat into the fluid, especially during soak conditions, when the vehicle is not in use.

6. NAFTA

(131) NAFTA's activities will start with defining the criteria for selecting suitable geological structures for large-scale storage of hydrogen. The focus of NAFTA's project will be on the development and deployment of a pilot underground porous reservoir for storing of hydrogen in higher concentration with natural gas or in pure form enabling its transmission and distribution.

7. Neste

(132) Neste will develop carbon capture and storage ("CCS") and liquefaction technologies and design, engineer and deploy the CCS unit integration to the refinery. The captured CO_2 will be fed to the PtL production, where it will be converted with renewable hydrogen to e-fuels.

8. Ørsted

(133) Ørsted will contribute to this TF through the development and deployment of high-capacity refueling, compressing and storage technologies aiming for an efficient hydrogen distribution and the reduction of fuelling times for HDV.

9. Plastic Omnium FR

(134) Plastic Omnium FR contributes to TF 3 by developing a new compressed hydrogen tank of type 4 for on-board storage system of hydrogen in heavy and light duty vehicles. Plastic Omnium FR will develop a recyclable thermoplastic material for the composite external tank shell, enabling innovative geometrical configurations, as well as embedded sensors able to monitor the damage to the external structural layer of the tanks.

Description related to the complementarity of the individual projects

(135) The participating undertakings of TF 3 will pursue related technologies and manufacturing process for the development, integration and use of technologies for stationary and mobile storage systems aiming to fulfil all safety requirements and improve the reliability of the solutions. Further, the individual projects are expected to optimise the use and integration of storage technologies as interface of the demand and supply side to create a fully integrated hydrogen value chain.

(136) The complementary character of the individual projects is corroborated by a number of collaborations within the TF, as explained in section 2.4.3.1.

2.4.1.4 Description related to the significant added value and complementarity of the individual projects for the achievement of the goals of TF 4

(137) TF 4 is divided in five main tasks and will involve 13 participating undertakings, namely Alstom FR, Alstom IT, Bosch AT, Daimler Truck, Fincantieri, HYVIA, Iveco CZ, Iveco ES, Iveco IT, Neste, Ørsted, Plastic Omnium AT and Plastic Omnium FR.

(138) Task one concerns the investigation of regulations, standards and safety issues for the use of hydrogen technologies. The R&D&I activities concern the following:

a) Testing and validation of newly developed hydrogen systems to ensure the correct performance and approval including feedback loops, adjustment and optimization measures;

b) Study and definition of a fit-for-purpose solution for the storage of liquid hydrogen within the ship either containerized or with fixed tanks;

c) Establishment of main Class Register (such as RINA, DNV, etc.) at an early stage during the phase of vessel prototype basic design;

d) Provision of requirements for the installation on board vessels in order to facilitate OEMs to adapt their technologies to specific needs;

e) Definition of a regulatory framework or acceptance of alternative design solutions based on risk assessment;

f) Definition of a new reference standard for the use of hydrogen in railway activities meeting safety constraints; and

g) Provision of safety framework, service manuals, after crash manuals, etc.

(139) During the FID phase the individual projects will carry out demonstration activities showing simplicity of usage and safety of hydrogen vehicles.

(140) Task two concerns the development of synthetic e-fuels and hydrogen vectors and the R&D&I and FID activities will focus on the following.

(141) For R&D&I:

a) Development and optimisation of the power-to-liquid (PtL) synthesis concept for e-kerosene, completing the whole value chain from renewable electricity and CO_2 to sustainable aviation fuel;

b) Optimisation of the Fischer-Tropsch ("FT") synthesis and upgrading process train, considering also the upstream power supply, electrolysis, and carbon capture steps, for maximum cost-effectiveness and maximal yield of desired products; and

c) Development of key elements for the supply of hydrogen and refuelling station technologies to enable large-scale heavy duty application, including standardisation.

(142) For FID:

a) Upscale of large-scale hydrogen electrolysis, carbon capture, methanol synthesis and methanol-to-jet synthesis;

b) Maturation of production technology for carbon-based power-to-X ("PtX") fuels; and

c) Power-to-liquid upscaling and market development of e-fuels: established concepts and technologies for new FT-based synthetic product yield optimisation, development of value-chain and market for sustainable e-fuels, e-chemicals and plastics.

(143) Task three concerns the optimisation of power and fuel systems, with its R&D&I activities focusing on:

a) Maximisation of hydrogen quantity available on-board while maintaining payload capacity;

b) Deep re-design of structural parts of the chassis, roof and battery;

c) Management of energy on-board the vehicle (ratio of power coming from the battery vs. produced by the FC);

d) Development and testing of suitable hydrogen based power generation on board with different technologies such as PEM and SOFC;

e) Development of innovative logic for power system management;

f) Development of flexible and smart energy management system for different mobility and transport applications integrating model-based and data driven approaches;

g) Development of modular hydrogen storage systems and hydrogen handling systems applicable to maritime applications; and

h) Standardization of hydrogen storage systems for maritime applications.

(144) Task four concerns the development of new vehicle materials, systems and architectures and their integration.

(145) The R&D&I phase contains the following components:

a) Integration and development of commercially feasible zero emission vehicles and parts;

b) Development of specific alloys for mobility and transport applications:

c) Development and validation of materials that can handle hydrogen diffusion and aggressive corrosion;

d) Development of the fuel injection systems for alternative fuels;

e) Ensure specification of the system, preliminary and detailed design, prototype manufacturing, testing, validation and certification;

f) Design of efficient, affordable and ready-to-integrate powertrain components: FC, hydrogen tanks, and FC specific components, such as thermal management, blowers, hydrogen loop, fuel injection equipment;

g) Development of innovative lightweight materials for hydrogen vehicles;

h) Design of architectural solutions to achieve zero emission operations of vessels under specific conditions; and

i) Integration of new technologies (i.e. hybrid main components, auxiliaries, etc.) on-board new built ships to prove and validate fit for purpose operations of the innovative components.

(146) During the FID phase, the following will be pursued:

a) Establishing the minimum needs at system level for the vehicle design;

b) Use of quality function deployment ("QFD") - based methodologies to map each argument and each application demand and transform it into technical requirements at the vehicle level;

c) Use of "V development cycle" methodology to breakdown these requirements (at the level of systems, subsystems and components) and activate parallel developments;

d) Deployment of first industrial demonstrators for the application of hydrogen mobility and transport to medium and large vehicles (e.g. LCV/trucks/trains/ships);

e) Establishing the right processes of prototype homologation, aligned with the test and validation plans;

f) Development of prototypes and mules for data acquisition, testing and calibration of virtual models;

g) Development of prototypes to fully validate design, reliability and certify hydrogen locomotive;

h) Development of adapted and efficient processes and assembly lines to produce hydrogen-FC trucks and light commercial vehicles ("LCV") at scale with high level of quality and reliability;

i) Upscaling of hydrogen tanks and powertrain components; and

j) Validation of newly designed solutions through delivering quality testing.

(147) Finally, task five concerns the training for vehicle operation and development of vehicle maintenance strategies.

(148) The R&D&I phase will cover the following:

a) Identification of key component vulnerabilities and their lifetimes, provision of spare parts in appropriate locations to ensure timely availability, and skills to service and maintain the vehicles;

b) Development of a comprehensive maintenance strategy to optimise the vehicle availability and reliability;

c) Build or equip workshops that are capable to maintain and repair the prototype trucks; and

d) Design of a strategy involving the training and provision of appropriately skilled technicians.

(149) In the FID phase the participating undertakings will:

a) Learn to operate FC and LCV trucks;

b) Deliver a comprehensive service and maintenance capability;

c) Work with its expert conventional vehicle maintenance division to operationalise the maintenance strategy;

d) Implement monitoring and evaluation process;

e) Implement a high-quality maintenance and service process for FC electric vehicles ("FCEV");

f) Support end-user operation of the developed FCS technology; and

g) Implement process using latest cloud based technologies for remote monitoring, data collection and analysis for featuring predictive maintenance;

Description related to the significant added value of the individual projects

1. Alstom IT

(150) Alstom IT contributes to TF 4 by developing an innovative, modular solution of a novel and improved hydrogen fueled train, the Flexible hydrogen Power Car ("FHPwC"). The technology will be integrated onboard the train and will offer improved performance, enhanced flexibility in terms of components' integration, safety and reliability.

2. Alstom FR

(151) Alstom FR contributes to TF 4 by optimising the developed solutions and standardise components to meet current customer needs for the first zero-emission solution for 4-axles shunting locomotives. This includes the design and testing of reliable and competitive components for various mobility and transport applications, aiming at achieving a FC power of 1 MW and resolving shocks and vibration constraints.

3. Bosch AT

(152) Bosch AT contributes to TF 4 by developing fuel-injection equipment technologies that will cover all hydrogen base fuels (i.e. hydrogen, ammonia or methanol) and modes of usage (i.e. single and dual fuel and retrofit solutions) for large engines, ranging from 560 kW to 10 MW. The developed fuel injection system is expected to enable port fuel injection, as well as direct injection to allow the optimisation of combustion for large engines.

4. Daimler Truck

(153) Daimler Truck contributes to TF 4 by developing a new vehicle system, which integrates all components required (i.e. FC, liquid and gaseous tank systems and high voltage battery). Daimler Truck will develop a number of prototypes to be tested under real conditions, which will use liquid hydrogen aiming at achieving a range of more than 1000 km without refuelling, a speed of 89 km/h and a […].

5. Fincantieri

(154) Fincantieri will develop a Green Combined Cycle Gas Turbine fueled by Hydrogen ("G-CCGT"). It will furthermore upscale hydrogen technologies […].

The development of G-CCGT will comprise the design and implementation of a high efficiency combined cycle plant, where the latter's components and associated technologies will be integrated into an installation unit.

6. HYVIA

(155) HYVIA will develop light duty FCEV on three different platforms. In particular, HYVIA will develop a mid-power energy management system allowing the FC to power the e-motor and/or to recharge the battery, as well as a hybrid control in order to optimise performance and driving range. In addition, HYVIA will optimise the design and weight of the hydrogen power system and its integration into the FCEV with respect to safety and regulation constraints.

7. Iveco

(156) Based on its FC developments in TF 2, Iveco CZ contributes to TF 4 by developing and designing a new vehicle architecture for two types of FC coaches for inter-urban and touristic missions. Iveco CZ will integrate the powertrain components, FC, hydrogen tanks, fuel injection equipment and coach specific components, such as for thermal management into the newly developed vehicle. In addition, Iveco CZ will develop a water management system to make the coaches self-sufficient with respect to water demand. Finally, Iveco CZ will construct coach prototypes for testing purposes.

8. Iveco ES

(157) Iveco ES will develop FCEV for heavy duty use for municipal services with a new vehicle architecture integrating the FC, thermal systems with e-driven traction as well as to develop a new concept of rigid vehicle to ensure a safe design for the use of hydrogen as fuel. Iveco ES will develop pre-commercial prototypes to be tested under real conditions.

9. Iveco IT

(158) Iveco IT will develop FCEV for heavy duty transport integrating different new technologies whereby the power generation, all components and systems mechanically powered by ICE will be electrified or replaced with e-driven ones without diminishing their performance. Iveco IT will design prototypes that represent (partially and totally) the performance of the FCEV to achieve a final homologation.

10. Neste

(159) Neste will develop technologies to further improve the sustainability of advanced biofuels and to produce e-fuels via an optimised FT process. […].

11. Ørsted

(160) Ørsted contributes to TF 4 by developing technologies to produce e-fuels based on renewable electricity generated from offshore wind power, renewable hydrogen and captured CO_2. Ørsted will also develop a conversion step of e-methanol to e-kerosene through a methanol-to-jet facility, which will be integrated with the methanol and hydrogen production steps. Ørsted aims to

achieve ASTM certification for its e-kerosene. With its development of e-fuels, Ørsted contributes significantly to heavy transport decarbonisation solutions.

12. Plastic Omnium AT

(161) Based on its developments carried out in TF 2, Plastic Omnium AT contributes to TF 4 by integrating the newly developed PEM FCS in HD and commercial vehicle platforms and by optimising hard- and software interfaces and vehicle level certification as well as the calibration of the FC control unit software in different fleet application scenarios (long-haul trucking vs. customer delivery service).

13. Plastic Omnium FR

(162) Plastic Omnium FR contributes to TF 4 by developing an integrated monitoring system (embedded sensors) being able to monitor damage to the external structural layer of hydrogen tanks causing possible degradation and to predict possible failures.

Description related to the complementarity of the individual projects

(163) The participating undertakings of TF 4 will pursue related activities: investigation into regulations, standards and safety issues for the use of hydrogen technologies, development and implementation of technologies for infrastructure use, development of processes and equipment for specific applications and the adaptation and integration of FC systems for the different use cases for mobility and transport applications, and development of technologies facilitating the supply of hydrogen as fuel.

(164) The complementary character of the individual projects is corroborated by a number of collaborations within the TF, as explained in section 2.4.3.1.

2.4.2 Description related to the significant added value and complementarity between the TF for the achievement of the objective of Hy2Tech

(165) The Member States involved in Hy2Tech submit that each of the four TF significantly adds value to and is complementary with each other to meet the objectives of Hy2Tech (see recital (9)).

(166) The figure below shows a schematic representation of the complementarity between the different TF:

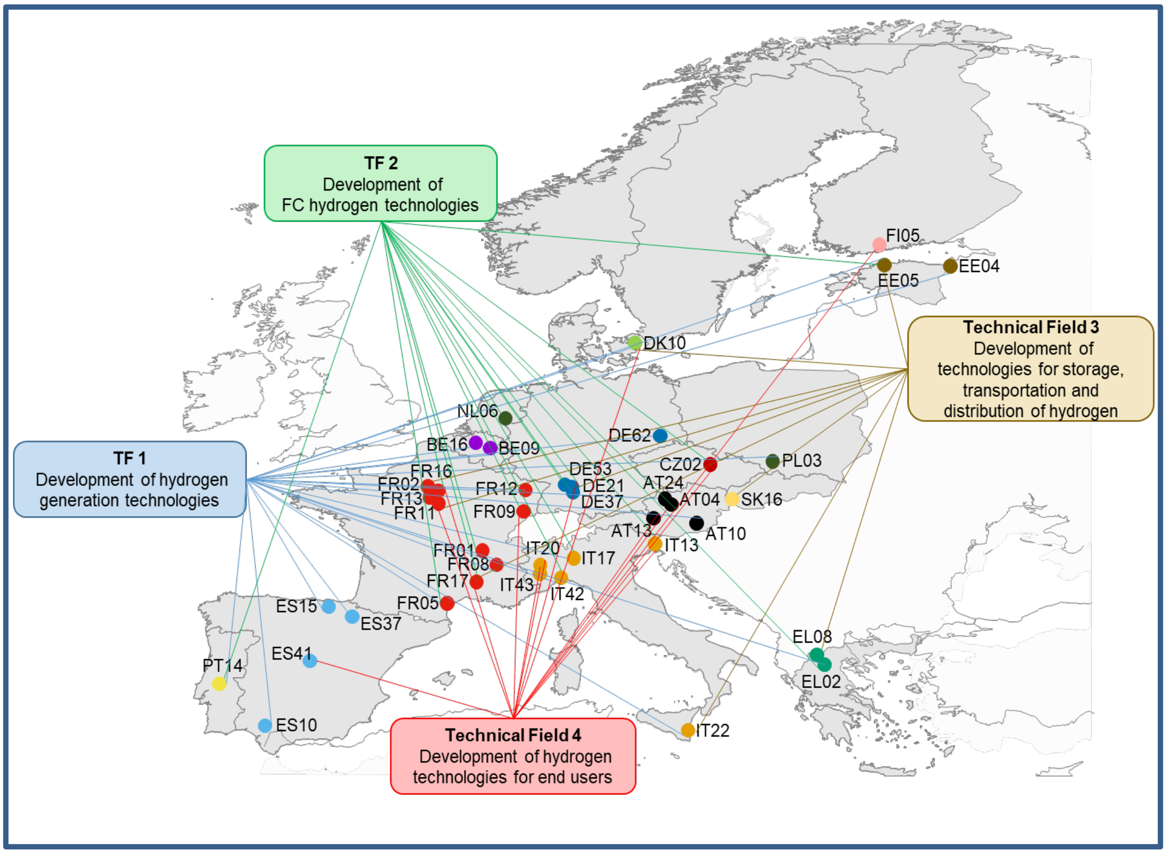

Figure 2: Schematic representation of inter- and intra-collaborations envisaged in Hy2Tech

2.4.2.1. Description related to the significant added value of TF 1 and its complementarity with other TF

(167) TF 1 significantly adds value for the completion of the other TF:

a) Significant added value of TF 1 for the completion of TF 2 and TF 3: Electrolysers are needed to produce the renewable and low-carbon hydrogen at the required purity levels needed for FC development in TF 2 and at adequate quantities for storage, transportation and distribution in TF 3. The electrolyser operating conditions (notably pressure) will also need to be optimized to improve FC total cost of ownership ("TCO").

b) Significant added value of TF 1 for the completion of TF 4: The development of the electrolyser technologies in TF 1 aims to generate adequate hydrogen with high purity content and at low cost for the mobility and transport applications in order to meet the needs of the increasing demand and protect the end users from fuel purity issues. Furthermore, the activities in TF 1 will among others focus on facilitating the manufacturing processes by using common standards and regulations in the various mobility and transport applications under TF 4.

(168) Concerning the complementarity with other TF:

a) TF 1 is complementary to TF 2 for the following main reasons: The hydrogen produced with systems developed under TF 1 is consumed by FC systems developed under TF 2. In addition, there are common specifications of hydrogen quantities and qualities, whereas the experience built up is complementary concerning codes, standards and regulations.

There is also a common approach regarding a full digital integration of the electrolysis and FC industry in a future hydrogen economy and an increased footprint of a common electrolysis and FC value/supply chain.

b) TF 1 is complementary with TF 3 for the following main reasons: The hydrogen generated under TF 1 must be stored in corresponding storage devices of various scales under TF 3. The efficiency and effectiveness of particular storage systems can be optimized considering the performance and operational characteristics of different hydrogen generation systems. For particular industrial applications, an optimal overall process efficiency can only be achieved with the use of a common approach and process design regarding hydrogen development technologies, storage and use.

c) TF 1 is complementary with TF 4 for the following main reasons: The fast ramp-up of deployment of hydrogen development systems directly depends to a large extent on the hydrogen needed for different applications. In addition, any future developments of FC systems for these applications may lead to changes of the specifications for hydrogen and/or hydrogen carriers impacting on the hydrogen development systems and their operation modes.

(169) The complementarity is evidenced in particular by the many collaborations between the different TF, as described in section 2.4.3.2.

2.4.2.2. Description related to the significant added value of TF 2 and its complementarity with other TF

(170) TF 2 significantly adds value for the completion of the other TF:

a) Significant added value of TF 2 for the completion of TF 1: Both TF have common raw material/resource management and recycling processes and common material and component development (e.g. electrodes, gas diffusion layers, membranes and catalytic coatings) particularly of the technologies used in both, electrolysis and FC operation mode (predominantly PEM and SOFC). Furthermore, they have common balance of plant development (gas and fluid management, thermal management, sensors and control, power electronics, safety system), including standardized interfaces, and common approach to scale-up technologies and processes, including automation and seamless digital process control, testing and performance environment.

b) Significant added value of TF 2 for the completion of TF 3: The optimisation of the entire hydrogen power system to be integrated into mobility, transport and industrial applications requires the joint optimisation of the size, design, and operating conditions of the FC system and the storage system (notably regarding hydrogen pressure and quality).

c) Significant added value of TF 2 for the completion of TF 4: Competitive on-board scalable FC system solutions and components are required to develop hydrogen-based mobility and transport applications under TF 4. Such solutions need to be tested and validated for each specific end use application. In addition, the integration of innovative components and the identification of safety procedures and standards are required for the different applications. This would facilitate system interconnection, standardisation and electric connection across the different applications in Europe.

(171) Concerning the complementarity to other TF:

a) TF 2 is complementary to TF 1 for the following main reasons: Given that, as mentioned under recital (170), FC and electrolysers require to a certain extent the same or similar raw materials, components and balance-of-plant sub-systems and follow common, production, assembly, recycling and standardisation processes, their interaction will offer opportunities for joint research and development or joint resource and supply chain management. This would also generate additional scale effects and accelerate cost reduction.

b) TF 2 is complementary to TF 3 for the following main reasons: Certain materials developed for FC (e.g. hydrogen compatible coatings) could be used under TF 3 for tanks and piping for gaseous, liquid or liquid organic hydrogen carrier storage and refuelling solutions. Further, both TF will benefit from collaboration on common standards and apply specific regulations to increase interoperability between systems and safety of the entire hydrogen value chain.

c) TF 2 is complementary to TF 4 for the following main reasons: The outcome of TF 2, i.e. high-performance, reliable, and competitive FC technologies, will affect the whole hydrogen value chain and unleash many opportunities for mobility and transport applications under TF 4. Moreover, standardised and open data architectures and digital interfaces will facilitate integration of the FC control system within its end-use environment, thereby supporting interoperability, as well as communication of operational data.

(172) The complementarity is evidenced in particular by the many collaborations between the different TF, as described in section 2.4.3.2.

2.4.2.3. Description related to the significant added value of TF 3 and complementarity with other TF

(173) TF 3 significantly adds value for the completion of the other TF:

a) Significant added value of TF 3 for the completion of TF 1 and TF 2: Economic, reliable, durable and safe systems for hydrogen storage at large-scale, as well as novel storage technologies (e.g. LOHC, metal organic frameworks ("MOF"), high performance polymers for liners and composites), are needed for the transportation and distribution of the hydrogen generated from electrolysis under TF 1 and for the roll out of FC under TF 2. Furthermore, specific codes, standards, regulations and testing protocols will be introduced to facilitate the interaction between the TF.

b) Significant added value of TF 3 for the completion of TF 4: Specific storage requirements (e.g. performance, yield rate, vehicle implementation and integration) are needed for the mobility and transport applications under TF 4. Storage materials would need to be available at large-scale in order to reduce the cost of hydrogen storage and secure availability for end users. The development, testing and validation of different solutions for hydrogen storage (e.g. compressed or liquid hydrogen, liquid carrier and material-based storage) is important to meet the specific needs of the mobility and transport applications. Also, the integration of innovative storage materials and the identification of safety procedures and standards under TF 3 would require specific feedback from the different mobility and transport applications under TF 4.

(174) Concerning the complementarity to other TF, the reasons mentioned in recital (173) equally apply.

(175) The complementarity is evidenced in particular by the many collaborations between the different TF, as described in section 2.4.3.2.

2.4.2.4. Description related to the significant added value of TF 4 and complementarity with other TF

(176) TF 4 significantly adds value for the completion of the other TF:

a) Significant added value of TF 4 for the completion of TF 1: The activities of the mobility and transport operators under TF 4 contain different operational requirements (e.g. hydrogen quality, temporal and local hydrogen demand, operational and control interfaces, etc.) that influence the development of technologies for hydrogen generation under TF 1. In addition, specifications for local hydrogen generation systems are needed as part of hydrogen refuelling systems for vehicles.

b) Significant added value of TF 4 for the completion of TF 2: TF 4 aims at developing hydrogen mobility and transport vehicles and end applications integrating FC technologies developed under TF 2. The requirements for mobility and transport applications are specific to each end use in terms of system architecture, hybridization, performance or durability and they are crucial for the innovations developed by TF 2 and for standardization and certification of the relevant FC technologies.

c) Significant added value of TF 4 for the completion of TF 3: TF 4 aims further to integrate the technologies developed under TF 3 for its mobility and transport applications. End-use specific TF 4 requirements in terms of storage with maximum energy density, durability, maintenance or large-scale fuelling capability are crucial for the innovations developed under TF 3 and for the standardization, safety and certification of hydrogen, gas and liquid storage system technologies.

(177) Concerning the complementarity to other TF:

a) TF 4 is complementary to TF 1 for the following reasons: Efficiently use of hydrogen is needed by developing vehicles that run on FC powered by hydrogen through electrolysis. It is also important for TF 1 activities to have an understanding of customers' requirements for hydrogen mobility and transport applications in order, for instance, to develop hydrogen technologies for renewable and synthetic fuels, to improve the reliability of electrolyser BOP, to develop competitive TCO for heavy duty mobility and transport, or to ensure safety and control for the end users. Both TF will interact in order to optimise operational performance and efficient integration of hydrogen technologies in the mobility and transport applications, maximising further the reuse of existing vehicle components and integrate them with hydrogen power systems.

b) TF 4 is also complementary to TF 2 for the following reasons: The integration of FC systems under TF 2, as well as the energy management and control systems, must be tested and validated in the mobility and transport applications under TF 4. Knowledge of FC systems' integration in the different mobility and transport applications is important and mandatory in order to develop storage technologies that would further need to meet various protocols and standards for performance and safety.

c) Finally, TF 4 is complementary to TF 3 for the following reasons: The integration of storage systems under TF 3, as well as the energy management and control systems, must be tested validated in the mobility and transport applications under TF 4. Knowledge of storage systems' integration in the different mobility and transport applications is important and mandatory in order to develop storage technologies that would further need to meet various protocols and standards for performance and safety.

(178) The complementarity is evidenced in particular by the many collaborations between the different TF, as described in section 2.4.3.2.

2.4.3. *Collaborations within Hy2Tech with respect to the relevant TF*

(179) In addition to the significant added value and complementarity of the individual projects within each TF, strong collaborations of the participating undertakings within and across the TF will exist, which, according to the Member States would not occur to this extent without Hy2Tech.

2.4.3.1. Examples of collaborations intra TF

(180) In TF 1:

- Christof Industries and SENER will collaborate to develop a supply chain for a serial production of the electrolyser systems. Christof Industries will offer collaboration in the development of technologies and components for SOEC systems, while SENER will provide its knowledge and experience in the development of technologies and components across different electrolyser technologies.

- The collaboration between AVL, Christof Industries and Synthos will enable the possibility to compare ceramic stack and metal stack SOEC systems.

- Ørsted and Elogen have agreed to collaborate with the purpose of exploring the capabilities of Elogen's PEM technology for the development and operation of Ørsted's 10 MW electrolyser.

- McPhy and Stargate will jointly work on electrodes development and testing for alkaline electrolysis, as well as for availability improvement.

They will jointly test electrodes developed by Stargate at McPhy's test facility, provided the electrodes fulfil the criteria and standards defined by McPhy.

- The collaboration between Enel and H2B2 will enable the support and verification of Enel's test facility and associate protocols and procedures, while validating H2B2's electrolyser prototypes in terms of performance, durability, reliability, RES integration and operational characteristics.

- The collaboration between AVL, Cummins, Elcogen, Elogen, Genvia, John Cockerill, McPhy and Sunfire will cover the standardisation of data protocols for electrolysers and FC and the creation of an open European hydrogen data hub.

- The collaboration of Elogen, Genvia, McPhy, Nordex and Sunfire will concern the development of a novel certification scheme to guarantee the compliance of electrolysers for the project developers. As OEM, they will guarantee the feasibility and the acceptability of the proposed standard.

(181) In TF 2:

- The collaboration between Plastic Omnium AT and EKPO targets the development of innovative end of line ("EoL") test system and process as a subsystem of a scalable and highly automated production line for FCS assembly.

- Advent will develop and design fully scalable and highly efficient HTPEMFC, and will collaborate with 1s1 Energy to evaluate the latter's PEM components.

- Nedstack and Symbio will exchange knowledge on best practices targeting carbon dioxide-footprint improvements. In doing so Symbio will bring in its learnings from the automotive PEMFC ecosystem, whereas Nedstack will do the same from its stationary and maritime background.

- Alstom FR and Fincantieri will exchange knowledge and experience to identify synergies related to high power FC suited for heavy mobility and transport applications (e.g. railway or maritime). They will define new relevant tests, qualification and validation process related to the new high power FC.

- HYVIA and Arkema will collaborate on bipolar plate (i.e. material and coating) and tank liner material and design. For instance, they will study the utilisation of high tensile strength stainless steels for high frequency stamping processes, enabling designing and producing ultra-thin BPP for application in PEMFC.

(182) In TF 3:

- The collaboration between Faurecia and Daimler Truck includes the development and upscale of integrated hydrogen storage systems, both gaseous and cryogenic, for HDV. The end result of the component/safety system and its integration into the vehicle will be achieved jointly by both undertakings and the know-how achieved will benefit both undertakings.

- Neste will collaborate with Plastic Omnium FR to develop and upscale new generation FC module and storage systems for HDV. The participating will discuss and share information on the designs of vehicles as well as on refuelling protocols, safety, education and project management.

- The collaboration of B&T Composites with Faurecia will bring together their expertise for the specification of an on-board hydrogen storage system. Optimised tank design (e.g. winding pattern, liner and boss) and expected to be developed, as a result of this collaboration.

- Arkema will collaborate with Plastic Omnium FR for the development, testing and qualification of materials for high-pressure vessels and embedded piezoelectric sensors.

(183) In TF 4:

- The collaboration between Iveco ES and Alstom IT will cover knowledge-sharing on components used and adopted in different transport modes and refuelling logistics. It will support the development of a market enabled by the creation, up-taking and diffusion of hydrogen fuelled FCEV.

- Fincantieri will collaborate with Iveco IT to foster innovative solutions and effective synergies, with particular focus on testing and validation of hybrid power units (FC and batteries) up to 300kW for automotive applications and HDV.

- Iveco CZ will collaborate with Neste to develop a complete ecosystem of FC-powered vehicles, renewable and low-carbon hydrogen and refuelling stations. In particular, the collaboration aims to cover the infrastructure and value chain for vehicles with hydrogen FC and potentially use of FCEV trucks and buses in Neste's hydrogen mobility and transport demonstration project.

- Bosch AT and Iveco ES will share their learnings and findings in hydrogen mobility and transport applications. They will develop and share safety concepts and fuel supply requirements and work on joint fuels supply/system components that support mobility and transport applications. In addition they will define a joint interface from the fuel system to the tank.

2.4.3.2. Examples of collaborations inter TF

(184) Concerning the collaborations between TF 1 and TF 2 the following examples show the complementarity of the individual projects:

- H2B2 and Elcogen will collaborate to exchange knowledge on safety, regulation and public acceptance of electrolysis technologies, in particular on the results of large SOE stack development from Elcogen.

- Neste and Ansaldo will collaborate to explore solutions in respective technology areas, such as hydrogen and syngas generation and the customisation of SOEC systems in this regard.

- Genvia will collaborate with Fincantieri to advance the SOFC technology and explore the possibility of executing a demonstration project integrating Genvia's prototype in a vessel designed by Fincantieri.

- Elogen and Symbio will work together to develop and test MEA and other components, which are both used in electrolysis stacks and in FC.

(185) As regards the collaborations between TF 1 and TF 3:

- Christof Industries will collaborate with B&T Composites for the development and implementation of a special hydrogen storage and transport solution operated by B&T Composites.

- AVL and Neste will work together for the development of the integration of electrolysers to the upstream (e.g. renewable energy systems) and downstream (refineries and PTL production) markets. In particular, the target is to collaborate on the potential utilisation of electrolysers for synthetic fuel development ("PtL").

- Enel and Stargate plan to jointly develop industrial stack testing facilities Stargate will provide the technical input and requirements gained in TF 1 and Enel will implement and run the test facility.

- The electrolyser prototypes developed by Nordex in TF 1 will be used in Enel's test facility. This test facility will cover all of the main aspects and technologies of the value chain, from hydrogen production to storage. As a result, storage developments will evaluated and improved depending on the new electrolyser technologies.

(186) Concerning the collaborations between TF 1 and TF 4:

- McPhy will collaborate with Elcogen as a supplier of the next generation SOE stack technology for the McPhy's project, to build a 20 MW electrolyser plant.

- Christof Industries will work together with Neste on the potential utilization of electrolysers for PtL. […].

- Sunfire and Daimler Truck will collaborate as follows: Sunfire aims to produce hydrogen via alkaline and SOEC electrolysis, based on renewable energy, which will then be used in Daimler Truck's test trucks.

(187) The complementarity between TF 2 and TF 1 is also evidenced by a number of envisaged collaborations:

- Bosch DE and Christof Industries will collaborate on certain technical specifications of SOFC systems, like performance data of the system, efficiency, operating requirements and outer dimensions of the SOFC stacks for a possible subsequent production partnership.

- 1s1 Energy and Advent will test innovative MEA components, which are both used in FC and electrolysis stacks. Since the same material innovations have the potential to improve both FC and electrolysis, this collaboration promotes wide diffusion of innovations across the TF.

- Arkema will supply innovative materials to be tested in the PEM applications developed by Cummins. The latter will explore options to integrate the membrane into a PEM electrolyser stack.

(188) As regards the collaborations between TF 2 and TF 3:

- Plastic Omnium AT and Plastic Omnium FR will collaborate on developing mobility and transport solutions for FC and storage technologies. The aim of Plastic Omnium AT is to develop a new generation of hydrogen FC module for HDV, while the goal of Plastic Omnium FR is to develop a new generation of hydrogen storage system for HDV.

- The cooperation of Iveco CZ and Faurecia will bring newly developed hydrogen storage tanks utilised for hydrogen powered buses. Faurecia will conduct a feasibility study based on available vehicle packaging from Iveco CZ, in order to address the maximum storage in minimal available area with optimised TCO.

- EKPO will collaborate with Neste on hydrogen safety (i.e. regulations, codes and standards) and purity for issues that span over Neste's hydrogen fuel supply scope to EKPOs' FC powertrain scope. The collaboration aims to cover the value chain for vehicles with hydrogen FC, and the technical details of the vehicles' design.

(189) Concerning the collaborations between TF 2 and TF 4:

- Fincantieri will collaborate with Bosch AT for the joint development of a fuel injection technology to be validated on Fincantieri's engine and vessel.

- EKPO will collaborate with Neste to develop sustainable FC solutions (FC system lifetime, hydrogen safety and quality, etc.) for heavy duty applications (i.e. truck, bus, railway and maritime).

- Nedstack will collaborate with Fincantieri on PEMFC system and relative components' design, testing and validation, with the benefit to contribute to the definition of the product through the exchange of experience and sharing of application requirements.

- Iveco CZ and Alstom IT will collaborate to integrate FC boost for railway applications through the joint development of secondary battery systems in order to achieve lighter and more efficient drivetrains.

(190) Collaborative projects will take place between TF 3 and TF 1. Indicatively:

- NAFTA will collaborate with Cummins to enable integration of the latter's design solution with the electrolyser technology inside the underground gas storage technology of NAFTA.

- Ørsted will collaborate with Genvia to jointly develop a pilot project for SOEC to be supplied with green electricity from an offshore wind farm off the coast of the Netherlands owned by Ørsted.

- Daimler Truck and Sunfire will jointly work on the generation of compressed hydrogen through alkaline and SOEC electrolysis and its distribution to refuelling stations.

- Ørsted and Elogen will collaborate with the purpose of exploring the capabilities of Elogen's PEM technology and its ability to scale-up in supports of Ørsted's electrolyser that is supplied with electricity by an offshore wind farm.

(191) A number of collaboration will also take place between the participating undertakings in TF 3 and those in TF 2:

- NAFTA and McPhy will collaborate to enable integration of the design solution with electrolyser technology inside the underground gas storage ("UGS") technology. The NAFTA UGS operating mode and behaviour will require testing in link with McPhy's electrolyser to make sure it fits to large quantities of hydrogen and large electrolyser.

- B&T Composites will collaborate with AVL through the development and implementation of a special hydrogen storage and transport solution for the SOEC systems of AVL. The latter will use B&T Composite's technology for a modular, highly efficient and scalable 1 MW SOEC platform.

- Sunfire and Neste will collaborate to develop new solutions for cost-effective and safe arrangements to renewable hydrogen generation at and for refineries. Neste will develop and share information, data and understanding of refinery sector safety requirements, hydrogen specifications, production system availability requirements to support the development of safe and cost-effective, new arrangements for electrolyser integration to refineries. Sunfire will use the information for their SOEC and pressurised alkaline electrolyser technology.

- Daimler Truck and Sunfire will jointly work on the production of compressed hydrogen and its distribution to the refuelling stations. Sunfire aims to produce hydrogen via alkaline and SOEC electrolysis, based on renewable energy, which will then be used in Daimler Truck's test trucks.

(192) Concerning the collaborations between TF 3 and TF 4:

- Faurecia and Bosch AT will collaborate to share knowledge regarding material requirements, safety concepts and fuels specifications. Faurecia will define the requirements from the tank side, while Bosch AT will define the system and interface requirements from fuel system side.

- B&T Composites and Bosch AT will collaborate for the supply of high pressure hydrogen storage tanks developed by B&T Composites to store the hydrogen for Bosch AT in hydrogen engines.
- Neste and Iveco IT will collaborate to share knowledge between Neste's hydrogen mobility and transport demonstration project and Iveco IT's FC vehicle developments, with the aim to harmonise the technical development roadmaps of hydrogen mobility and transport.

(193) Concerning the collaborations between TF 4 and TF 1:

- Neste will work together with AVL for the utilisation of the latter's electrolysers into Neste's synthetic fuel's development and upgrading to high quality aviation fuel and chemicals.
- John Cockerill and Bosch AT will conduct coordinated efforts on defining the optimum required hydrogen quality to protect end user from fuel purity issues. Bosch AT will define the quality of the fuel based on the properties of the fuel injection system. John Cockerill will check how the fuel requirements can be fulfilled in production and storage.
- Plastic Omnium FR will collaborate with AVL and Christof Industries to develop a hydrogen ecosystem. Plastic Omnium FR will provide specifications and requirements regarding the optimal integration of the SOEC systems developed and built by AVL and Christof Industries.

(194) As regards the collaborations between TF 4 and TF 2:

- In collaboration with Bosch DE, Bosch AT will focus on hydrogen engine in regards of safety concepts and interface to the fuel supply system. Bosch DE will focus on SOFC in regards of safety concepts and interface to the fuel supply system. It is the joint target to derive safety and interface requirements.
- Faurecia and Alstom FR will share their knowledge of the application of the hydrogen to the railway mobility and transport. Faurecia will bring its hydrogen bricks adapted to the specific use case of railway mobility and transport of Alstom FR. The latter, will integrate and test the provided bricks in its rolling-stock.
- Fincantieri and Symbio will share knowledge and technologies for the further development of PEMFC. The cooperation will take advantage of the experience of Fincantieri as system integrator and lead to the validation and development of a FC stack assembly and/or system for the maritime applications.
- Fincantieri will collaborate with Bosch DE, Elcogen and Genvia concerning pilot installations of SOFC systems on Fincantieri cruise ships. The common goal is a proper ship design/construction to define a SOFC power generation system for maritime application.

(195) There will be the following collaboration between TF 4 and TF 3:

- Iveco ES will collaborate with Plastic Omnium FR for the integration of the latter's next generation PEMFC storage system technology into Iveco ES's truck applications.

- The Faurecia and Daimler Truck collaboration includes the development and the manufacturing of integrated hydrogen storage systems, both gaseous and cryogenic, for heavy duty trucks. Faurecia will firstly carry out the development of the system considering technical requirements formerly shared by Daimler Truck. The latter will then lead the integration of the system into the vehicle.

- Iveco IT and Alstom FR will collaborate explore innovative solutions for the implementation of hydrogen technologies as propulsion leading ones. The learnings from Iveco IT will be specially exchanged with Alstom FR to increase the possible size of hydrogen tanks.

2.5 Positive spill-over effects generated by Hy2Tech

(196) The Member States submit that Hy2Tech will generate important dissemination and spill-over effects of its results across the EU (see recitals (377) to (398)). This dissemination will be made possible through:

a. The dissemination and spill-over of results that are not protected by IP rights (see recitals (198) to (209));

b. The dissemination and spill-over of results that are protected by IP right (see recitals (210) to (227)(245);

c. The dissemination and spill-over of results during the FID (see recitals (228) to (245)); and

d. The dissemination and spill-over of results to other indirect partners and to other sectors (see recitals (247) to (266)).

(197) The individual project portfolios detail that each participating undertaking commits to and will participate in dissemination and spill-over activities up until, and including, the final year of its individual project. A member of the FG will be designated as a key contact for the implementation of the dissemination and spill-over commitments.

2.5.1. Dissemination and spill-over of results that is not protected by IP rights

2.5.1.1. Overview of the dissemination and spill-over strategy of non-protected results

(198) The participating undertakings to Hy2Tech commit to disseminate knowledge and the individual project results that are not protected by IP rights to the scientific community and the industry.

(199) The table below displays the mapping of the main dissemination actions of the non-protected IP rights of Hy2Tech within the EU:

Event	**Participating undertakings**	**Scope (examples)**
Conference/Meeting/Fair	Advent, Alstom FR, B&T Composites, Bosch AT, Bosch DE, Daimler Trucks, De Nora H2B2, McPhy, NAFTA, Neste, Stargate	• Public Conference on project results • Exchange of information between all participants • International Conference
Exhibition	Arkema, B&T Composites, Bosch AT, Bosch DE, H2B2, HYVIA, NAFTA	• Exhibition, tours and expert talks for the general public
Further Public Events	Alstom FR, Arkema, B&T Composites, De Nora, Elogen, H2B2, HYVIA, Neste, Plastic Omnium FR,	• Public hearings • Quarterly discussion forum • Start-up challenges • H2 Endurance race car • Customer events • Trainings sessions • Awards • Real life experience / Short trips on hydrogen vessels • Position papers
Job Fair	Bosch AT, Cummins	• Recruitment of new employees
Kick-Off Event	AVL, Enel, H2B2, HYVIA	• Public Relations Ground-breaking ceremony • Product launch event • Launch Event
Mentoring	H2B2, John Cockerill, NAFTA, Neste	• Mentoring and co-supervising students
Open-Day/Site visits	1s1 Energy, Ansaldo, B&T Composites, Bosch AT, Bosch DE, Daimler Trucks, De Nora, EKPO, Elcogen, Elogen, Faurecia, Genvia, H2B2, HYVIA, Iveco CZ, Iveco ES, Iveco IT, McPhy, NAFTA, Neste, Plastic Omnium AT, SENER, Sunfire, Symbio, Synthos	• Tech Day for customers / IPCEI partners / press • Promotion of B&T's activities to the public • Prototype show • Virtual visitor centre • Invite local municipality, schools, undertakings and partners to road show • Event for society – such as families, citizens, local inhabitant, authorities • Long night of Science • High school events and tours
Press Release/Press Event	1s1 Energy, Alstom FR, Ansaldo, AVL, B&T Composites, Bosch AT, Bosch DE, Cummins, Daimler Trucks, De Nora, EKPO, Elcogen, Elogen, Enel, Fincantieri, H2B2, HYVIA, Iveco CZ, Iveco ES, Iveco IT, McPhy, NAFTA, Neste, Plastic Omnium AT, SENER, Symbio, Synthos	• Technology development, demonstrator release, announcement of cooperations • Inauguration ceremony • Press Conference • Yearly update on progress

Social Media	Advent, Alstom FR, B&T Composites, Bosch AT, Bosch DE, Daimler Trucks, De Nora, Faurecia, H2B2, HYVIA, McPhy, NAFTA, NedStack, Synthos	• Direct communication instruments for reaching the general public, stakeholders and industry professionals as well as increasing acceptance and stimulate interest of/for project scope • Info graphics
Website	Advent, B&T Composites, Bosch DE, Daimler Trucks, De Nora, Elcogen, Elogen, Fincantieri, H2B2, HYVIA, NAFTA, NedStack, Nordex, SENER	• Communication • Dissemination of scope, progress, technological solutions • Newsletters • Hydrogen-oriented magazines and websites
Workshop/Seminar/Summer School	Advent, Alstom IT, Ansaldo, Arkema, B&T Composites, Bosch AT, Bosch DE, Cummins, De Nora, Elogen, Enel, Fincantieri, H2B2, Iveco CZ, Iveco ES, Iveco IT, John Cockerill, NAFTA, Neste, Stargate, 1s1 Energy,	• Disseminate project results and discuss with stakeholders • Technical workshops for research organisations and academic community • Hydrogen Academy • Podcasts, Hackathons, TED Talk • Presentation of Renewable Hydrogen market to attract talent and develop sufficient skills • Masterclass • Networking Events

Table 2: Matrix of dissemination and spill-over strategy of non-IP protected results

(200) The table below details in a quantitative manner the main dissemination actions envisaged by the participating undertakings, as a result of the commitments made by the participating undertakings:

KPIs	Expected dissemination in the course of Hy2Tech (estimates per year)	Difference with "business as usual" (estimates per year)
Exhibitor at conferences (presentations, papers, exhibitor, etc.)	498	+358
Financed university chairs	38	+30
Industrial/scientific publications	270	+220
Organiser of external events	258	+213
Organiser of internal events	455	+395
Sponsorship of PhDs/MScs	335	+295

Table 3: KPIs for dissemination and spill-over knowledge

2.5.1.2. Participation in external events

(201) The participating undertakings commit to participate in conferences and public presentations in the framework of established international events listed in the table below, during which they will disseminate knowledge and the individual project results that are not protected by IP rights.

(202) These events cover a number of Member States including but not limited to the participating undertakings. They relate to a number of different sectors beyond the sector(s) where each participating undertaking operates. They are open to participants from all EU Member States and ensure wide geographic coverage, beyond the participating undertakings.

Conference Title, Location[9]	Participating undertakings	Main topics addressed (examples)
Aachen Colloquium Sustainable Mobility, Germany	AVL, Bosch AT, Daimler Truck, EKPO, Faurecia, Plastic Omnium AT, Symbio	Focus on sustainable mobility and transport solutions: • Performance of battery systems • Thermo-management in zero-emission vehicles • Life cycle assessment of zero-emission vehicles and components • Use of synthetic liquid fuels • Hydrogen combustion engines and FC • High voltage electronics.
AVERE e-mobility Conference, Belgium	HYVIA, Iveco CZ, Iveco ES, Iveco IT	The conference deals with electrification of transport.
AVL large engine Tech day, Austria	AVL, Bosch AT	General strategies on alternative fuels.
Bus World, Belgium	Iveco CZ, Symbio	Breakthroughs in the area of research and development of hydrogen buses and its components.
Clean Hydrogen Alliance conferences	Alstom FR, AVL, Bosch DE, NAFTA	Large-scale renewable and low carbon hydrogen storage in salt caverns. Topics throughout the hydrogen value chain.
Cleantech Forum	Neste, Sunfire	The conference deals with various themes along the topic of specifications of new alkaline electrolyser generation.
EU Green Week	De Nora, Genvia, Neste	Europe's largest annual environmental event. The event involves different high-level sessions on the following topics: • Health • Biodiversity • Production and Consumption • Driving change in the EU and abroad.
European Fuel Cells and Hydrogen Conference, Italy	Alstom IT, Ansaldo, AVL, De Nora, Stargate	The conference aims to discuss: • The scientific progress • The most modern applications of hydrogen and FC- based technologies.
European Fuel Cells Forum	Christof Industries, De Nora, Symbio	Presentation of: • The state-of-the-art technology addressing issues of low-temperature FC • Electrolysers including CO_2 reduction.
European Hydrogen Conference, Austria	Bosch AT, Cummins, Genvia, Iveco CZ, NAFTA, 1s1 Energy,	Latest projects, technologies, and regulations to achieve the EU's net-zero target.

9 If no location of an event is mentioned, the location is either changing each time, online or not (yet) defined, etc.

European Hydrogen Energy Conference (EHEC), Spain	Bosch DE, Cummins, Daimler Truck, De Nora, Elcogen, Enel, Faurecia, Genvia, H2B2, HYVIA, Iveco ES, Iveco IT, John Cockerill, NAFTA, Neste, Nordex, SENER, 1s1 Energy	Latest breakthroughs in the research and business sector, while presenting cutting edge hydrogen and FC science and technology.
European Hydrogen Week	Alstom FR, AVL, Bosch AT, Bosch DE, Fincantieri, Genvia, John Cockerill, Stargate	Production and use of hydrogen and hydrogen-based fuels in the different sectors of the economy and how hydrogen will play a key role in the European Green Deal.
EVER European Zero Emission Bus conference	Alstom FR, John Cockerill	The conference deals with various themes along the topics of ecological vehicles and renewable energies.
E-world energy & water, Germany	Bosch DE, John Cockerill	The conference deals with various themes along the topics of energy and digital innovation.
E-World, Germany	Cummins, NAFTA	The conference deals with various themes along the topics of climate neutrality and achievement of climate targets.
ExpoMove 21-22, Italy	Iveco ES, Iveco IT	The conference deals with various themes along the topic of environmentally friendly mobility and transport.
f-Cell, Germany	Advent, Bosch DE, Christof Industries, Daimler Truck, EKPO, Elogen, HYVIA, 1s1 Energy	Conference and meeting that provides an extensive overview for: • Relevant international markets and hydrogen industries • Technological advancements for FC technology & FC vehicles.
FDFC – International Conference on Fundamentals & Development of Fuel Cells, Germany	Alstom FR, AVL, EKPO, Plastic Omnium AT	The FDFC is an international conference with the main topics addressing: • FC and electrolysers, ranging from fundamentals of electrochemistry to systems operation.
Fuel cell conference organised by Electrochemical Society - SO-MSC Electrolyser	Alstom FR, AVL	The conference deals with various themes along the topic of SOEC.
Gastech	Cummins, Enel	The conference deals with, amongst others: • Low-carbon solutions • Power and utilities • Hydrogen.
General Maritime Hamburg Messe, Germany	Advent, Bosch AT, Fincantieri	Hydrogen production, distribution and storage for maritime applications.
Hannover Fair, Germany	Advent, Ansaldo, AVL, Bosch DE, Christof Industries, Cummins, Daimler Truck, Elcogen, Elogen, Enel, Faurecia, Fincantieri, Genvia, John	Hydrogen & FC & Batteries Expo.

	Cockerill, NedStack, Neste, Nordex, 1s1 Energy	
Hydrogen & Fuel Cells Energy Summit, Portugal	Advent, De Nora, HYVIA, John Cockerill, 1s1 Energy	The event will bring together key industry stakeholders to discuss the required economical and infrastructural innovations for a sustainable future energy carrier.
Hydrogen Days, Czech Republic	NAFTA, Sunfire	Hydrogen technology sector, electrode manufacturing processes.
Hydrogen Europe Flagship events (2022-2027) Event	Bosch DE, Stargate	Hydrogen technologies and Innovations along the entire hydrogen value chain.
Hydrogen Fuel Cells Europe, Germany	Arkema, HYVIA, John Cockerill	Materials for hydrogen mobility and transport. New polymer materials for PEM fuels cells membranes and corrosion resistant coatings for bipolar plates.
Hydrogen Online Conference	Bosch DE, H2B2	Successful deployment of hydrogen-technology.
Hydrogen Technology Conference & Expo, Germany	Advent, Ansaldo, Faurecia, Fincantieri, John Cockerill, NedStack, SENER, Symbio	Advanced technologies for the hydrogen and FC industry. Stationary & maritime PEM-FC systems.
HYvolution, France	Elogen, Faurecia, Fincantieri, Genvia, HYVIA, John Cockerill, McPhy, 1s1 Energy,	A conference for stakeholders involved in the hydrogen market covering topics: • Storage • Distribution • Value channels • Production • Gas technologies
IAA,Germany	Bosch DE, Daimler Truck, EKPO, Faurecia, HYVIA, Iveco CZ, Plastic Omnium AT, Symbio	Sharing results in the area of development of hydrogen buses/coaches vehicle construction: • Mobility and transport • Commercial vehicles • E-truck.
Inno Trans, Germany	Alstom FR, Bosch AT	Novel railway technologies including hydrogen and alternative fuel applications.
Internat. Wiener Motorensymposium, Austria	AVL, Bosch AT, Christof Industries, EKPO, Faurecia, Plastic Omnium AT, Symbio	FC technology; engine development and drivetrain technology.
International Conference on Hydrogen Production and Storage, Finland	Advent, Enel	In the fields of Hydrogen generation, storage and testing of technologies: • Recent innovations • Trends, concerns • Practical challenges encountered and solutions adopted.
Meeting of the Electrochemical Society, Sweden	De Nora, Elogen	Electrochemical energy devices: batteries, supercapacitors, FC, electrolysers.
NOW GmbH: Hydrogen and Fuel Cell Technology Supplier Marketplace, Germany	Bosch DE, Genvia, Neste	The conference deals with various themes along the topic of sector coupling, mobility and transport, electricity, heat and industry.
Smart E-Mobility Conference,	HYVIA, Iveco CZ, Iveco ES,	Provides market overview of:

Austria	Iveco IT	• The e-mobility and transport sectors • Network opportunities • Storage and charging solutions • Sharing of best practice examples.
VDMA Jahrestagung AG Brennstoffzelle, Germany	AVL, Bosch DE, EKPO, Plastic Omnium AT	Annual meeting of the working group FC of the German engineering federation.
Wind Europe annual conference, Spain	Cummins, Nordex	The conference deals with various themes including, amongst others: • Wind energy • Renewable hydrogen • Solar energy • Hybridization • Digitalization.
World Hydrogen Congress, Netherlands	Arkema, Bosch DE, Enel, Fincantieri, John Cockerill, Neste	Discussion of: • Materials for hydrogen mobility and transport • New polymer materials for PEM fuels cells membranes • Corrosion resistant coatings for bipolar plates.
World Hydrogen Summit, Netherlands	Advent, Bosch AT, Bosch DE, Daimler Truck, De Nora, Elcogen, Elogen, Genvia, HYVIA, John Cockerill, NAFTA, Nordex, Sunfire	The conference deals with various themes along the hydrogen value chain.
Zero Emission Bus conference, France	Faurecia, Iveco CZ	Development of hydrogen buses and its components taking into account: • Environmental impact improvements • Management of water produced by hydrogen FC • Recycling of hydrogen buses • Materials/components • Hydrogen2 trucks.

Table 4: Events/conferences where at least two participating undertakings will participate

2.5.1.3. Dissemination and spill-overs through the European collaborative R&D&I ecosystem

(203) The participating undertakings commit to disseminate the IP non-protected results acquired in the framework of Hy2Tech to the scientific community. In particular, the participating undertakings will collaborate with the scientific community and with indirect partners (see recitals (247) to (253)).

(204) The participating undertakings will in particular finance and/or contribute to the creation/development of university/school chairs related to technologies developed under Hy2Tech, such as new materials, cells and system designs, with a view to training future European scientists, experts, engineers, technicians and operators. The locations of the RTOs go beyond the Member States, thus providing genuine spill-over effects to e.g. Bulgaria and Romania.

(205) It is expected that the following indicative list of RTOs, will benefit from the dissemination of the results of Hy2Tech:

Institution	Participating undertakings	Scope of the Funding/Collaboration	Member State
Aalto University	Alstom IT, Ferroviaria, Neste, Symbio	Renewable hydrogen; hydrogen mobility and transport; carbon capture and storage; Power-to-liquid hybrid train based on hydrogen; FC materials and power lines devices	Finland
AIT, Austrian Institute of Technology	Plastic Omnium AT	FC and hydrogen technology and production related research and technology development projects, internships and training programmes for students	Austria
Asociación de la Industria Navarra (AIN)	Nordex	Research collaboration in electrode development	Spain
Carlos III University of Madrid	Iveco ES	Provide effective solutions to the complex technological problems related to hydrogen	Spain
CEA	Alstom FR, Elcogen, Elogen Faurecia, Genvia HYVIA, McPhy Symbio	MEA development; development of cells, stacks for SO systems; power electronics; hydrogen tanks	France
Centrale Supelec Engineering school	HYVIA, Plastic Omnium FR	Hydrogen technologies integration in engineering lectures & training	France
Centre de Recherche Metallurgique	John Cockerill	R&D collaboration on innovation on materials	Belgium
Centre for Research and Technology Hellas	B&T Composites	Modelling and life cycle analysis activities, supervision of FID activities at the Bodosakeio Hospital	Greece
CNRS	Alstom FR, Elogen, Faurecia Genvia, HYVIA Symbio	MEA optimization and recycling; hydrogen tank, fire behaviour	France
Czech Technical University in Prague (CTU)	Iveco CZ	Materials engineering and Electronics	Czechia
Ecole des Mines ParisTech	HYVIA, Symbio	System and materials development; FC thermal management optimization	France
ESTACA Engineering school	Plastic Omnium FR, HYVIA	Hydrogen technologies integration in engineering lectures & training	France
FBK- Fundation Bruno Kessler	Alstom IT, Ferroviaria	Summer School hydrogen thermodynamics, technologies, safety and applications	Italy
Forschungszentrum Jülich	AVL, Bosch DE, Christof Industries, Elcogen, Elogen	Electrolyser component testing; novel sensor concepts for robust operation and increased lifetime of SOFC systems; research on LOHC	Germany
Fraunhofer IFAMIMM	Advent, Nordex	Electrodes development and new materials	Germany

Friedrich-Alexander Universität Erlangen-Nürnberg	Bosch DE	Research on energy market design	Germany
HAN University	Nedstack	FCS production engineering.	Netherlands
Hellenic Mediterranean University	B&T Composites	Sensors for the online monitoring of the hydrogen permeability and the stress state of type V composite hydrogen vessels	Greece
Helmholtz-Institut Erlangen Nürnberg (HI ERN)	EKPO, Bosch DE	Funding of thesis on innovative Chemical hydrogen Storage and electrochemistry	Germany
HyCentA	Plastic Omnium AT	Hydrogen high-pressure equipment, metering equipment, measurement technology	Austria
Instituto Politécnico de Portalegre	1s1 Energy	Training of technicians in FID phase of the project	Portugal
IRT Jules Verne	McPhy Faurecia	Manufacturing methods; composite for hydrogen tanks.	France
IRT M2P	John Cockerill	Provision of testing facility	France
IWEN Institut für Windtechnik, Energiespeicherung und Netzintegration	Stargate	Electrolysers for offshore wind projects and green ammonia production	Germany
KIT, Karlsruhe	Bosch DE, EKPO	Production processes; SOFC single cell characterisation; development of modular and scalable production concepts and processes	Germany
KU Leuven	Symbio	FC system and materials development	Belgium
Laplace **Unité mixte de recherche depending on CNRS and INP Toulouse**	Alstom FR	FC ageing performances	France
LEC (Large Engine Competence Center)	Bosch AT	Development of combustion systems with alternative fuels	Austria
LEPMI	Symbio	FC system and materials development	France
Masaryk University Brno, Faculty of Science	NAFTA	Hydrogen microbial reactions	Czechia
Montanuniversität Leoben	AVL, Bosch AT, Christof Industries	SOEC performance improvement; cathode and anode materials; material science and manufacturing technologies; joint publications/theses	Austria
National Institute of Chemical Physics and Biophysics	Elcogen	Testing and characterisation of FC and electrolysers	Estonia
National Institute of Chemical Physics and Biophysics (NICPB)	Elcogen, Stargate	Electrode development, cell development, stack development	Estonia
NHRF (National Hellenic Research Foundation)	Advent	Developing collaborative teaching, training, mentoring, research and other support activities	Greece
Pablo de Olavide University	H2B2	Lectures and training programmes in hydrogen and FC	Spain

		technologies	
Paris Saclay University	Elogen, HYVIA	Development of innovative polymers and new catalysts; fabrication of experimental MEAs	France
Polytechnic University of Torino (PoliTO)	Alstom IT, Ferroviaria	Laboratory experiments to obtain data about the hydrogen impact on the reservoir	Italy
Pontific University of Comillas	H2B2	lectures and training programmes in hydrogen and FC technologies	Spain
Prometheus	Advent	PROMETHEUS project is an initiative of Universities, RTOs and enterprises to develop innovation solutions in the area of digital transformation related to circular economy, climate change and sustainable development	Greece, the Netherlands, Italy and Romania
RWTH Aachen University	Bosch DE, Symbio	Market potentials of SOFC	Germany
Slovak Academy of Sciences	NAFTA	R&D of metal-hydrides; R&D on hydrogen impact on the reservoir	Slovakia
Spanish National Hydrogen Center	Nordex, SENER	Research collaboration, hydrogen security and electrolyser components, and testing new developments in electrolysers' technology.	Spain
Tallinn University of Technology (Taltech)	Elcogen, Stargate	Physico-chemical characterisation of cell and stack materials and components electrode development, cell development, renewable hydrogen public acceptance, Industry 4.0 solutions	Estonia
Technical University of Denmark	AVL, Elcogen Christof Industries, Ørsted Stargate, Symbio	Optimization and testing of SOEC prototypes and scientific guidance; conducting research on various energy conversion and storage technologies	Denmark
Technical University of Košice	NAFTA	Hydrogen impact to the materials; R&D of metal-hydrides	Slovakia
TECNALIA Research and Innovation and TEKNIKER	Nordex, SENER	New developments in electrolysers technology; new materials and components for AWE	Spain
The Institute of Electrochemistry and Energy Systems - Bulgarian Academy of Sciences (IEES – BAS)	Advent	Build, develop and preserve scientific knowledge into the thematic areas of hydrogen and FC and energy materials	Bulgaria
TNO	Elcogen, Genvia NedStack	Development and modelling of cells; engine technology and autonomous driving;	Netherlands
Torvergata university of Rome	Iveco IT	Hydrogen mobility and transport	Italy
TU Clausthal	Bosch DE, NAFTA	Modelling of microbial processes; evaluation of the effects of varying fuel quality on	Germany

		SOFC systems	
TU Delft	McPhy, Symbio	Optimization of the Balance of Plant of the power systems and standardisation of the calculations to optimize the power balance of FC and batteries for each vessel and route; Requirements for on-shore or close-to-shore filling stations for the modular storage solutions	Netherlands
TU Dresden	Sunfire	Development of high temperature components; development of electrode layers	Germany
TU Munich	Symbio	Electrolyser component R&D; FC system and materials development	Germany
UAR, Upper Austrian Research	Plastic Omnium AT	FC and hydrogen technology and production related research and technology development projects, internships and training programmes for students	Austria
ÚJV Řež, a. s.	Iveco CZ	Hydrogen system management, detection system, power management, charging station for testing department	Czechia
Universidad de Oviedo	Nordex	Design of Balance of Plant, testing on BOP in variable operation on small scale unit	Spain
Universidad Politécnica de Cataluña - Barcelona	Alstom IT, Iveco ES, Ferroviaria	Hydrogen mobility and transport	Spain
Universidade do Porto	1s1 Energy	Performance testing of PEM and CCMs for FC applications.	Portugal
Universität Stuttgart	EKPO, Symbio	Funding of student's thesis on Stack design and component technology	Germany
Université de Poitiers	Arkema	Effects of hydrogen under different conditions of pressure and temperature on thermoplastic materials and composites	France
University La Sapienza Rome	Enel	Research and testing activities related to hydrogen production and storage innovative technologies; internships, training programmes and theses for students	Italy
University of Chemistry and Technology, Prague - VŠCHT	Iveco CZ	Knowledge transfer in different related subjects: chemistry; mechanical engineering and technologies; materials engineering; environmental science	Czechia
University of Genoa	Alstom IT, Ansaldo, Ferroviaria, Fincantieri, Iveco IT	rSOC design tool (Ansaldo), Hydrogen mobility and transport (Alstom IT, Ferroviaria, Fincantieri, Iveco IT)	Italy
University of Ioannina	B&T Composites	Polymeric matrices for reduction of hydrogen permeability and the non-destructive, mechanical,	Greece

		physic-chemical characterization of the modified materials	
University of Seville	H2B2	Lectures and training programmes in Hydrogen and FC technologies	Spain
University of Stuttgart	Bosch DE	Process optimisation and performance scaling of a SOFC system	Germany
University of Technology Compiegne Engineering School	Plastic Omnium FR, HYVIA	Hydrogen tanks, FC system energy management optimisation	France
University of Technology Graz	Plastic Omnium AT, Bosch AT, Christof Industries	Technology development and testing of fuel injection systems; combustion development; material science and manufacturing technologies	Austria
University of Technology of Belfort Montbéliard	Alstom FR, McPhy	Research on power to X integration and operability, on hydrogen components development, testing and qualification	France
University of Technology Vienna	Plastic Omnium AT, Bosch AT	FC and hydrogen technology and production related research and technology development projects, internships and training programmes for students.	Austria
University of the Basque Country	SENER	Collaboration in hydrogen technologies master's degree	Spain
University of Turin	Enel, Iveco IT, Symbio	Hydrogen mobility and transport	Italy
University of Western Macedonia	B&T Composites, Advent	Composite pressure vessels and mechanical evaluation of the composite structures	Greece
Unversidad Politécnica de Madrid	Iveco ES	Hydrogen mobility and transport	Spain
UPPA – Universite de Pau et Pays de l'Adour	Arkema	Thermoplastic composites mechanism for impregnation and consolidation in industrial applications	France
VTT Technical Research Center (Finland)	AVL, Christof Industries, Elcogen, Neste	Testing of SOEC prototypes and scientific guidance; Developing e-fuels based on renewable electricity and recycled carbon dioxide and upgrading e-crude to high-quality products.	Finland
Warsaw University of Technology	Synthos	Theoretical, experimental and numerical activities in hydrogen technologies	Poland
ZBT, Zentrum für BrennstoffzellenTechnik, University of Duisburg-Essen	EKPO, NedStack, Symbio	FC operation strategies / degradation; FC verification and testing solutions; development of sealing, coatings, assembly processes, system modelling & characterization solutions	Germany

Table 5: Non-exhaustive network of RTOs, benefitting from spill-over effects with participating undertakings

2.5.1.4. Dissemination and spill-overs through the participation of participating undertakings to clusters and other initiatives

(206) The results of Hy2Tech will also be disseminated through the clusters and other initiatives to which the participating undertakings are members. These include for instance, alliances, (non-profit) professional associations, industry-oriented platforms expert commissions and research consortia.

(207) Table 6 illustrates the clusters represented in Hy2Tech and the participating undertakings involved. All of the clusters are described by each participating undertaking in its respective individual project portfolio.

Hydrogen Cluster and Description	Participating undertakings
2Zero - European industry association promoting zero emission drive train solutions	EKPO, HYVIA, Faurecia
A3PS - Austrian Association for Advanced Propulsion Systems	Bosch AT, Plastic Omnium AT
Asociación Española del Hidrógeno (AeH2)	H2B2, Iveco ES, SENER
CARA - European Cluster for mobility solutions (Lyon)	Iveco CZ, Plastic Omnium FR, Symbio
ENEA Casaccia Research Center – Hydrogen Demo Valley	Ansaldo, Bosch DE, Iveco IT
European Clean Hydrogen Alliance	Alstom FR, Alstom IT, Ansaldo, B&T Composites, Bosch AT, Bosch DE, Cummins, Daimler Truck, De Nora, EKPO, Enel, Faurecia, Fincantieri, Genvia H2B2, HYVIA, Iveco CZ, Iveco ES, Iveco IT, John Cockerill, McPhy NAFTA, Neste, Plastic Omnium AT, SENER, Symbio
France Hydrogene	Arkema, Elogen, Faurecia, Iveco CZ, John Cockerill, McPhy, HYVIA, Plastic Omnium FR, Symbio
Fuel Cells and Hydrogen Joint Undertaking (Horizon 2020) Clean Hydrogen Partnership and Clean Hydrogen Joint Undertaking (Horizon Europe)	Cummins, Sunfire, Symbio
German Hydrogen and Fuel Cell Association	Bosch DE, Daimler Truck, McPhy
H2Accelerate	Iveco ES, Iveco IT
H2Haul - Hydrogen Fuel Cell Trucks for Heavy Duty Zero Emissions Logistics	Iveco ES, Iveco IT
H2IT, Italian Hydrogen and Fuel Cells	Alstom IT, De Nora, Enel, Fincantieri, McPhy

Association	
Hydrogen Council	AVL, Alstom FR, Bosch DE, Cummins, Daimler Truck, De Nora, EKPO, Elogen, Faurecia, HYVIA, McPhy, Plastic Omnium AT, Plastic Omnium FR
Hydrogen Europe Research	Fincantieri, Genvia, Plastic Omnium AT
Hydrogen Europe	Alstom FR, Alstom IT, Ansaldo, Arkema, AVL, Bosch AT, Bosch DE, B&T Composites, Cummins Daimler Truck, De Nora, EKPO, Elogen, Faurecia Fincantieri, Genvia, H2B2, HYVIA, Iveco CZ, John Cockerill, McPhy, Nedstack, Plastic Omnium AT, Plastic Omnium FR, Symbio
Hydrogen Power Storage & Solutions East Germany (HYPOS)	McPhy, Sunfire
International Energy Agency/Hydrogen Technology Collaboration Programme	Cummins, Daimler Truck, Genvia
International Gas Union	De Nora, NAFTA
Pole Vehicule du Futur	Faurecia, McPhy, Plastic Omnium FR
Renewable Hydrogen Coalition	Nordex, Sunfire
VDMA AG BZ: **Largest industry association in Europe (working group on FC)**	Bosch DE, EKPO
Waterstofnet	Cummins, HYVIA, John Cockerill

Table 6: Representation of clusters in Hy2Tech

2.5.1.5. Dissemination and spill-overs through publications in scientific journals

(208) The participating undertakings will, over the course of Hy2Tech, disseminate their research results in various scientific peer reviewed journals either Europe-wide and/or globally. The following table displays some indicative examples:

Journal Title	Scope of Journal
ACS Applied Energy Materials	Covering all aspects of materials, engineering, chemistry, physics and biology, which are relevant to energy conversion and storage.
ACS Catalysis	It is publishing original research on heterogeneous catalysis, molecular catalysis, and bio catalysis.
Advanced Industrial and Engineering Polymer Research	Polymer research and corresponding practical applications within the industry.
Advances in Industrial and Manufacturing Engineering	Industrial and manufacturing engineering.
Applied Energy	In the fields of energy conversion and conservation, use of energy resources, energy processes, environmental pollutants and sustainable

	energy systems. It is the companion title to the open access journal Advances in Applied Energy.
Chemical Engineering Journal	Chemical engineering: chemical reaction engineering, environmental chemical engineering, and materials synthesis and processing.
Chemical Engineering Research and Design	Chemical engineering: distillation and absorption; fluid flow; heat and mass transfer; materials processing and product development.
Combustion and Flame	The mission of the journal is to publish high quality work from experimental, theoretical, and computational investigations on the fundamentals of combustion phenomena and closely allied matters.
Composite science & technology	Fundamental and applied science of composites. Focus on polymeric matrix composites with reinforcements/fillers ranging from Nano- to macro-scale.
Composite structures	Disseminates knowledge between users, manufacturers, designers and researchers involved in structures or structural components manufactured using composite materials.
Current Opinion in Electrochemistry	View of experts on current advances in electrochemistry and evaluations of the most interesting papers.
ECS Transactions	Official conference proceedings publication of The Electrochemical Society.
EFC Proceedings	Aims to discuss the scientific progress and the most modern applications of hydrogen and FC-based technologies.
Electrochemica Acta	Electrochimica Acta is a peer-reviewed scientific journal covering all aspects of electrochemistry. It is the official publication of the International Society of Electrochemistry and it is published bimonthly.
Electrochemistry Communications	Covering the field of electrochemistry, providing fast dissemination of short communications, full communications and mini reviews.
Energies	Related scientific research, technology development, engineering, and the studies in policy and management.
Energy	Energy is an international, multi-disciplinary journal in energy engineering and research.
Energy and Buildings	International journal publishing articles with explicit links to energy use in buildings. About new research results and new proven practice aimed at reducing the energy needs of a building and improving indoor environment quality.
Energy conversion and management	Covers research on energy generation, utilization, conversion, storage, transmission, conservation, management, and sustainability.
Energy Technology	Covers all technical aspects of energy process engineering from different perspectives, e.g., new concepts of energy generation and conversion, design, operation, control, and optimization of processes for energy generation, etc.
Environmental Science and Technology	Covers research in environmental science and technology.
Geomechanics for Energy and the Environment	The aim of the Journal is to publish research results of the highest quality and of lasting importance on the subject of geomechanics, with the focus on applications to geological energy production and storage, and the interaction of soils and rocks with the natural and engineered environment.
Hindawi Modelling and Simulation in Engineering	It is providing a forum for the discussion of formalisms, methodologies and simulation tools which relate to the modelling and simulation of human-centred engineering systems.
Hydrogen Journal	Hydrogen science and technology open access journal.
IEEE Intelligent Transportation Systems	The design, analysis, and control of information technology as it is applied to transportation systems.
IEEE Transactions on Industrial Electronics	Applications of electronics, controls and communications, instrumentation and computational intelligence for the enhancement of industrial and manufacturing systems and processes.
International Journal of Electrical Power & Energy Systems	The scope of JEPE is focused on electrical power generation, transmission, distribution and utilization, from the viewpoints of individual power system elements and their integration, interaction and technological advancement.

International Journal of Energy and Environment	Official journal of the International Energy and Environment Foundation (IEEF). It covers all areas of energy and environment related fields that apply to the science and engineering communities.
International Journal of Hydrogen Energy	The International Journal of Hydrogen Energy is a peer-reviewed scientific journal covering all aspects of hydrogen energy, including hydrogen generation and storage.
JEC Publication	Composite materials, evaluation of energy use and emissions related to engine and vehicle technologies and fuel qualities.
Joule	Renewable energy, green chemistry, industrial chemistry, upscaling, CO_2 capture.
Journal of Advanced Transportation	Transportation science and technology that seeks to advance the efficiency, robustness, and safety of transportation systems.
Journal of Chemistry	Aspects of fundamental and applied chemistry.
Journal of Dynamic Systems, Measurement, and Control	About traditional mechanical engineering and associated interdisciplinary areas, focusing on modelling, sensing, identification, and control of dynamical systems.
Journal of Electrochemical Energy Conversion and Storage	Focuses on processes, components, devices, and systems that store and convert electrical and chemical energy.
Journal of Electrochemical Society	General electrochemistry, electrochemical energy conversion technologies and components.
Journal of Industrial and Engineering Chemistry	Industrial and engineering chemistry.
Journal of Loss Prevention in the Process Industries	The broad scope of the journal is process safety. Process safety is defined as the prevention and mitigation of process-related injuries and damage arising from process incidents involving fire, explosion and toxic release.
Journal of Manufacturing Processes	Manufacturing processes research, development and implementation.
Journal of Materials Chemistry A	Synthesis, properties, and applications of novel materials related to energy and sustainability.
Journal of Membrane Science	Publishes about membranes, membrane processes, smart membranes and membrane systems.
Journal of Power Sources	The peer-reviewed Journal of Power Sources publishes original research and reviews about the science and applications of primary and secondary batteries, FC, super capacitors and photo-electrochemical cells.
Journal of Sensors and Sensor Systems	International open-access journal dedicated to science, application, and advancement of sensors and sensors as part of measurement systems.
Journal of Sustainable Mining	This journal casts a new light on the wide range of issues surrounding mining that are impacting its sustainability. It is published quarterly.
Journal of the Electrochemical Society	Electrochemistry and solid state science and technology.
Manufacturing engineering (Vehicle construction system)	Mechanical engineering, industrial and manufacturing engineering.
Nature Catalysis	Covering all areas of catalysis, incorporating the work of scientists, engineers and industry.
Nature Energy	Research on energy, from its generation and distribution to the impacts energy technologies and policies have on societies.
Polymer Science	Polymer Science (physics, chemistry and technology).
Proceedings of the ASME	Broad range of Conference subjects that are of interest to mechanical engineers and those in related disciplines.
Proceedings of the European Electrolyser and Fuel cell Forum	Low-temperature FC, electrolysers, electrode design, cell, stack and system test, modelling. Published once per year.
Progress in Energy and Combustion Science	Publishes on all aspects of energy and combustion science.
Przemysł Chemiczny (Chemical Industry)	Published in Polish for topics concerning chemical technology and engineering.
Renewable energy	The journal seeks to promote and disseminate knowledge on the

	various topics and technologies of renewable energy systems and components.
Revista DYNA	Industrial Engineering Journal of the Spanish Council of Industrials Engineers (general engineering: management of organisations, electrical technology, mechanical, metallurgical, civil engineering and chemistry).
Salt Reviews	Salt mining with the concentration on geology, mining, industry, and the associated fields.
Solid State Ionics	FC, electrolysers, electrode design, electrochemistry, modelling, electrode fabrication, stack.
Sustainability Journal	Sustainability and management open access journal. Environmental, cultural, economic, and social sustainability of human beings.
Sustainable Energy and Fuels	Interdisciplinary research for the development of sustainable energy technologies.
Sustainable Production and Consumption	About sustainable production and consumption, publishing of interdisciplinary papers.
The Journal of Hydrogen	International, open access, peer-reviewed journal covering all aspects of hydrogen.
Transportation Research Part D: Transport and Environment	Publishes original research and review articles on the environmental impacts of transportation, policy responses to those impacts, and their implications for the design, planning, and management of transportation systems.

Table 7: Representation of scientific journals in Hy2Tech

2.5.1.6. Dissemination and spill-overs through training events

(209) The participating undertakings have committed to organise educational and academic dissemination through the dedicated training of professionals and researchers. The envisaged activities follow up on the development of the different hydrogen technologies under Hy2Tech and aim to strengthen the skills of those involved and maintain competitiveness in the hydrogen market. The training activities will cover a broad range of formats, such as regular series of lectures, technical trainings, hydrogen academies, remote online modules/e-learning platforms, exchange programmes and internships and will cover various issues, such as: PEM FCS, SOFC technology, concepts and capacities for ICE, safety functions and safety related components for drivers of EV vehicles, operation and development of vehicle maintenance strategies, software applications for hydrogen technologies, etc. Each of the training activities that a participating undertaking has committed to provide is set out in more detail in its respective individual project portfolio.

2.5.2. Dissemination and spill-over of knowledge that is protected by IP rights

(210) The participating undertakings have committed to the dissemination of their IP-protected results achieved through their individual projects under Hy2Tech. This dissemination will be carried out in different ways. As a matter of principle however, all participating undertakings will disseminate the IP-protected results of their individual projects under Hy2Tech on fair, reasonable, and non-discriminatory terms ("FRAND"). IP protected results are expected for example in the fields of new materials and microstructure, up-scaling and automation of SOEC stack development and upscaling, low-pressure hydrogen absorption storage, electrolyser numerical modelling and stack design, battery management system for hydrogen application or on PEM cell stack technology and BOS design.

(211) Indicatively, some more concrete examples are presented below.

(212) Advent is expected to generate IP-protected results from its R&D&I of process technology and architecture of PEM electrolysers and FC, and related software and hardware development that can be directly exploited. IP rights will be set up and agreed upon by all organisations involved (participating undertakings and indirect partners) through a Consortium Agreement prior to the start of the project. Advent will continuously monitor these aspects together with an IP rights office, where applicable also in conjunction with the collaborating organisations. It is further expected that during the project, Advent will create more than 50 patents, which can be licensed, related to the following innovative components/systems/processes: polymer membranes, membrane electrode assemblies, gas diffusion electrodes, BPP, FC stack design, cooling technology, FC systems, control software for scalable FC units, upscaling process of components and systems.

(213) Arkema will deploy projects concerning the development of thermoplastic resins, polyamide liners for recyclable hydrogen tanks, composite tapes and piezoelectric polymers for hydrogen tanks structural health monitoring. Arkema will provide access rights to any background and foreground IP for the execution of the project, the side ground and the protection of IP rights and confidential information before the project starts. An exploitation plan will be further detailed and updated along the project, to ensure a continuous monitoring of the key exploitable results according to principles regarding direct exploitation, indirect exploitation and license for research and educational purposes.

(214) B&T Composites will share the IP protected results beyond their usual customers, beyond the usual IP arrangements, across the specific value chain and across value chains in the whole EU. The final product will be submitted to receive ownership rights from the European Patent Office or the World Intellectual Property Organization. If a third party wishes to reproduce patented parts of the technology, this will be available with a partial ownership rights concession for a predetermined fee (partial license for exploitation).

(215) Each partner of Cummins' project will in principle be free to exploit as it wishes its results, which are protected by IP rights. Cummins will grant licenses on its foreground (i.e. the results) IP rights to third parties, which will be paid at the market price, on FRAND conditions, as a result of a negotiation between the owner of IP and the partner interested in the license.

(216) The IP protected results of De Nora's project will be disseminated though licensing agreements at FRAND terms while avoiding distorting phenomena such as discriminatory and excessive royalties. As a result, on the one hand, market players will be able to exploit the project's IP protected results related to the electrolyser pilot line upscaling and increase hence their production efficiency, whilst on the other hand, the market will reach the capacity needed to meet the growing demand of renewable and low-carbon hydrogen.

(217) Enea will undertake specific measures to enhance the transfer of the IP generated by Enea's pilot lines (including patents, know-how, engineering, etc.). This transfer will be implemented under FRAND terms. Such measures will include the creation of start-ups or spin-off undertakings in order to exploit

developed technologies filling the gap between the pilot line readiness level to concrete replication in real industrial environment (e.g. FID projects), the establishment of collaboration agreements with specific partners around clearly identified technologies/results to facilitate the transition from R&D results to FID, and the transfer of patent licenses from the RTO (ENEA) to the end users.

(218) IP protected results and patents developed within the course of HYVIA's project shall be made widely available for application domains other than terrestrial mobility and transport through FRAND licensing whenever possible, especially for start-ups and SMEs.

(219) Iveco CZ commits to a non-exclusive licensing of the IP protected results on FRAND terms. Areas of potential IP rights protection (foreground) will be in the following areas: battery and battery management system for hydrogen application, rear E-axle integration, hydrogen storage system and refuelling system, water management of water released during hydrogen consumption in FC, and new applications in body architecture.

(220) John Cockerill commits to base on FRAND terms all negotiations concerning potential licensing of its project's IP foreground results. Also, in order to ensure the largest diffusion, John Cockerill commits to non-exclusive licensing of the IP protected results. In the exceptional case of a request for an exclusive license for possible commercial exploitation, the domain and duration of the exclusivity will be limited with an obligation of exploitation of the technology/method being the object of the licensing. IP creation will cover new materials (membranes, electrodes, etc.), upscaling process, electrolyser industrial model design, utility model, software development, creation of standards, etc.

(221) For McPhy, IP protected results are expected in the following technological building blocks: electrolyser numerical modelling, electrolyser stack design and electrolyser process and drying unit. These will be the subject of patents on which FRAND licenses will be accorded for commercial exploitation beyond the water electrolysis domain.

(222) NAFTA's IP results will be protected through patents/utility models or licenses. The project's results will be more widely used by third parties at FRAND conditions as the transformation procedure undertaken by NAFTA, from natural gas storage to the storage of the gas mixture of hydrogen or hydrogen in pure form, requires research, whose results can be applicable in other EU countries with similar geological conditions.

(223) Neste expects to gain new know-how and patents from its project, which it will use as a basis of its dissemination activities to a broad audience going beyond the sector and the undertakings involved. Neste commits to the dissemination of the IP protected results at FRAND terms by establishing collaborations and partnerships that require technology contributions and knowledge sharing.

(224) Plastic Omnium AT will provide access to its hydrogen subsystem technologies and know-how to other partners (converters of conventional vehicles and OEMs for specialized vehicles). It furthermore commits to involve local SMEs and suppliers in the component and technology development process to support dissemination and specialized know-how at regional level, whereas at European level the technology transfer and dissemination will be supported by the

contracting of specific technology development projects and programmes to specialized supplier and technology providers for building up a reliable high quality value chain.

(225) SENER commits to develop IP assets, such as patents and utility models. IP creation will range from process technology, requirements relating to design, testing and operation, software and hardware development. The results giving rise to IP rights will be subject to exploitation licenses and will be shared beyond their usual customers, beyond the usual IP rights arrangements, across the specific value chain and across value chains in the whole EU. Access will be granted to third parties, by way of non-exclusive licenses at FRAND terms, as a result of negotiation with the third party interested in the license.

(226) Stargate plans to file 5 patent applications before project start and has allocated €1.1 million for IP rights during the project. A strong IP portfolio enables Stargate to license its technology to accelerate EU-wide electrolyser adoption and renewable and low-carbon hydrogen supply.

(227) Sunfire expects spill over effects through both licensing of IP rights and by exchanging know-how regarded as trade secret. With respect to licensing, Sunfire commits to licencing of IP protected results to suppliers and OEM with the intention to enable a cost reduction for sourcing of direct materials and manufacturing equipment and increasing direct material quality and ensuring availability of suitable direct materials. Further, Sunfire is open to licensing to direct competitors under FRAND terms. Sunfire is also interested in cross-licensing IP protected results to competitors, if this creates a competitive advantage and/or reduces IP risks for the parties involved. Spill over effects are expected mainly in the wider areas of manufacturing and material technology.

2.5.3. Dissemination and spill-over effects in FID

(228) The participating undertakings will use several ways for disseminating results during the FID phase. The Member States have provided information showing that the FID activities will lead to spill-over effects in downstream markets among the participating undertakings but also beyond them, involving indirect partners and the society in general. A close collaboration with RTOs and SMEs is inevitable to scale-up technologies from laboratory to industrial scale. Moreover, providing access to infrastructure facilities for, among others, testing and validation of products and services to a wide range of industrial entities is necessary to spread the results during the FID phase. Standardisation activities will also serve as means to support the exploitation and dissemination strategies.

(229) Some examples are provided below.

(230) Advent will engage not only with local academic institutions, but also with European universities and RTOs with the aim of sharing the benefits of its developed know-how for PEM electrolysers and FC. Over the courses of the project, the created research infrastructure will be made gradually available to RTOs and SMEs, with the aim to increase cooperation between different EU Member States.

(231) Alstom FR’s project in the railway sector is based on the principle of container storage. This innovative solution will imply collaborations with various

stakeholders with the aim to build standards to favour deployment of hydrogen solutions in other industrial sectors (e.g. road or maritime transport).

(232) Ansaldo will collaborate with main national, European and international standardisation and regulatory bodies in order to provide visibility of its project to a qualified audience, allow the exchange of information and knowledge, simplify processes and introduce common standards for its operations.

(233) Arkema will open its infrastructures (namely R&D centers in Lyon, Normandy and South West of France), to third parties (i.e., SMEs, RTO and start-ups) on market conditions. In addition, it will create a common lab and demonstration platform together with some RTOs and SMEs.

(234) B&T Composites will install an array of intermediate pressure hydrogen storage vessels at the Mpodosakeio Hospital of Ptolemaida for the purposes of efficiently deploying the stationary application. This specific location was selected for the initial FID stage since, as a government building, it would allow open and free access to the public, to SMEs and to RTOs. This access will enable the identification and mitigation of possible issues related to the connection of the hydrogen production unit with the hydrogen storage unit, and therefore generate spill-over effects of the relevant technical knowledge between the participants.

(235) During the FID phase Bosch AT will focus on simultaneous engineering work with industrialisation partners for the purpose of jointly developing manufacturing know-how. The results of the material research will be beneficial for the entire hydrogen value chain and technologies. For example, Bosch AT will enable suppliers to develop new coating and surface treatments and share development methods for advanced technologies.

(236) Christoph Industries will pursue the installation of a modern digital manufacturing medium batch pilot line, which can be easily transmitted and scaled up to other locations in the Union.

(237) Cummins will offer the possibility to RTOs and SMEs across Europe to rent the new PEM cell stack manufacturing and testing facilities in Belgium for a defined period of time and on FRAND terms.

(238) Daimler Truck will make all non-protected IP widely available through communication packages and supporting documentation. Training and skills development packages will also be available, whereas partnerships will be established with a range of RTOs and SMEs for project evaluation and component supply.

(239) In the project of EKPO, RTOs are expected to gain experience in basic research by supporting the undertaking in early development stages as regards process and material development.

(240) Elogen will grant its suppliers access to its assembly lines in order to gain from experience on the behaviour of their products. Joint test campaigns will be carried out to fine-tune the design of such supplied components.

(241) Faurecia will launch an open innovation lab where creativity workshops will be regularly carried out, in particular for RTOs and SMEs to boost innovation.

(242) HYVIA will provide access to its facilities through collaboration with SMEs, RTOs and start-ups, to test technical innovative solutions. HYVIA will advertise the possibility to grant access to its equipment through relevant channels, and a dedicated contact point will ensure that FRAND conditions will apply.

(243) H2B2's project results will enlarge the support to regulatory bodies in updating regulations and harmonisation of standards, test protocols and qualification programmes and enabling fast authorisation procedures for new technologies.

(244) Neste's project will support the implementation, together with partners, of a relevant certification project for renewable and low-carbon hydrogen production in compliance with relevant EU directives for renewable energy. The results of this project will enable the creation of the first EU-wide Guarantee of Origin scheme for renewable and low-carbon hydrogen.

(245) Plastic Ominum AT will share its test infrastructure by integrating suppliers, especially SMEs, in the subsystem and system validation programme and share results specific to the component delivered.

(246) Symbio is launching an incubator aiming at accelerating the development of new technologies in open innovation mode by bringing together European start-ups. The selected start-ups will receive access to Symbio R&D&I assets (e.g. laboratories, test benches, etc.) and a structured exchange with Symbio's R&D&I teams on the results of the activities under Hy2Tech.

2.5.4. *Dissemination and spill-over effects to other indirect partners and to other sectors*

(247) The participating undertakings have committed to disseminate knowledge and results arising from their individual portfolios with other undertakings, organisation and sectors outside Hy2Tech, through the involvement of its participating undertakings in collaborations with 322 indirect partners, as shown in table 5 under recital (205) and further supplemented below in recitals (250) to (253).

(248) The indirect partners are undertakings and organisations that have not submitted an individual project within Hy2Tech. Nevertheless they hold collaboration agreements with one or more participating undertakings of Hy2Tech and they can therefore benefit from the various dissemination activities (e.g. knowledge dissemination of R&D&I and FID results or open access to laboratory facilities, etc.).

(249) In addition to the RTOs already listed above in table 5, the participating undertakings commit to collaborate with several undertakings from the same or different Member State inside or outside Hy2Tech.

(250) In TF 1, 21 participating undertakings will collaborate with 239 indirect partners. The Commission refers to the following collaborations as examples: John Cockerill (Belgium/France) will collaborate with Engie (the Netherlands) for the development of a large-scale hydrogen plant simulator, including energy

management system to optimise connection between electricity supply market, off takers and equipment constraints; Stargate (Estonia) will collaborate with Duslo (Slovakia) on setting the specific parameters of alkaline electrolyser for Duslo, including possible delivery of electrolyser to Duslo during the stage of project implementation; H2B2 (Spain) will collaborate with Freudenberg (Germany) for the supply of components that will be incorporated and tested on H2B2's AEM stack development; and Genvia (France) will collaborate with BASF (Germany) for a prototype demonstration project to integrate the SOEC technology in an industrial process replacing fossil-based hydrogen by renewable hydrogen.

(251) In TF 2, 17 participating undertakings will collaborate with 138 indirect partners. For example, EKPO (Germany) will collaborate with Sintef (Norway) for the research and testing of bipolar plate coatings, MEA technology, stacks and related modeling, IP and technology know-how for optimized heavy duty cells and stacks, and support verification and modeling; Bosch DE (Germany) will collaborate with Skeleton (Estonia) on requirements for a combined design for energy storage and SOFC system; Advent (Greece) will collaborate with Everfuel (Denmark) for the development of cost efficient, large-scale, safe and sustainable hydrogen systems; and Symbio (France) will collaborate with […].

(252) In TF 3, 9 participating undertakings will collaborate with 69 indirect partners. For example, Faurecia (France) will collaborate with DAF Trucks N.V. (the Netherlands) for the design of heavy duty applications of FCEV for long haul and/or for high loads applications; Daimler Truck (Germany) will collaborate with HHLA AG (Germany) for the provision of hydrogen and FC technologies in the port of Hamburg; Arkema (France) will collaborate with Persico (Italy) for the adaptation of machines and processes and the development of new material solutions for liners, composites and sensors; and NAFTA (Slovakia) will collaborate with Polish Oil and Gas Company (Poland) to receive advice on the formula used for the cementing of the wells and to exchange results from the geochemical interaction of hydrogen in the industrial process.

(253) Finally, in TF 4, 13 participating undertakings will collaborate with 108 indirect partners. For example, Plastic Omnium AT (Austria) will collaborate with FEV (Germany) for the development of a vehicle system integrator for multiplying and adoption of the FCS technology to a wide range of applications; Iveco CZ (Czechia) will collaborate with FPT Industrial (Italy) with the objective being the power battery development and innovative evolution of standard axles to electric axles; Neste (Finland) will collaborate with Scania (Sweden) for the demonstration of the utilization of renewable hydrogen for heavy duty transportation; and Alstom FR (France) will collaborate with Acciona (Spain) for the deployment of a renewable railway system in the Canary Islands and the deployment of a renewable railway link between Zaragoza and Pau.

(254) Furthermore, Hy2Tech will have spill-over effects to other industrial sectors. Hydrogen as material and energy carrier will be urgently needed by all industries, which are currently highly dependent on energy and materials based on fossil sources. Thus, the impact of developing hydrogen technologies will be significant, allowing to increase energy efficiency and accelerate decarbonisation processes.

(255) For TF 1, hydrogen is a clean energy carrier which can be generated from electricity via electrolysis with high efficiency and can be used in various applications replacing fossil energy and energy carriers. For example, in the chemical industry, including refineries and fertiliser production plants, Stargate will develop innovative engineering solutions in addition to the undertaking's nanoceramics-enabled electrolysers, which will spillover to the following industrial production areas: hydrogen peroxide, ammonia, biofuels refining, green steel, methanol and combined heat and power.

(256) Moreover, the individual projects' results, particularly those of the R&D&I phase, will have a positive impact on other EU industrial sectors. For example, the IP developed by Sunfire in connection with the upscaling and automation of SOEC stack manufacturing may have applications in the fields of battery technology (electrodes), FC-based micro combined heat and power applications, or ceramics-based sensors. Sunfire's results could also be of interest for electronics, space and the energy sectors.

(257) Hy2Tech also foresees an increased collaboration with end users in the steel industry. For example, Arcelor Mittal France will test the developed SOEC solution of Genvia for the decarbonisation of its steel industry and Elcogen will cooperate with industries working on interconnection of steel plates in Europe. Furthermore, undertakings in the energy generation, storage and conversion industries have agreed to operate the SOEC electrolyser systems developed by AVL and Christof Industries, e.g. to balance electricity supply and demand.

(258) For TF 2, the development of FC technologies and their multiple applications particularly in the mobility and transport industries, will have an important impact on several upstream and downstream industrial sectors.

(259) In the chemical industry, the need for specialised, high performance materials will grow, since requirements for FCS to withstand thermal, mechanical, and chemical stresses will increase. Plastic Omnium AT for instance aims to support this endeavor through the development and integration of new materials (e.g. functional coatings), aimed at component level innovation in the BOP system of the technology developed in Hy2Tech.

(260) Hy2Tech will accelerate the transition to new hydrogen-based energy storage and conversion solutions for stationary applications, including in the residential housing and commercial building sector. Bosch DE for instance will work on requirements for a combined design for energy storage and SOFC systems in stationary applications.

(261) Moreover, the upscaling of pilot lines for FC during the FID phase requires high investments in machines and plants across Europe. This will create significant benefits for engineering undertakings, as well as component and machine suppliers. For example, Arkema will collaborate with several engineering undertakings in order to adapt machines and processes for the development of new material solutions for membranes and bipolar plates and also liners, composites and sensors.

(262) Hy2Tech will further generate important opportunities for undertakings active in the sectors of providing industrial development and instrumentation services during both the R&D&I phase for developing and validating the new FC

technologies and the FID phase for processing and scaling-up the technologies. This will apply to most participating undertakings in Hy2Tech.

(263) As far as the TF 3 is concerned, the development of high performance polymer and composites materials must respond to technical challenges at market affordable cost and in large-scale volumes (e.g. hydrogen compatible liners for tanks will improve barrier properties of polymers for applications, where permeability is an issue, namely in chemicals, gas and vapour installations). Faurecia and B&T Composites for instance, plan to develop new processes and technologies (e.g. composite manufacturing and recycling, large dimension composite pressure vessels, etc.) for the upscaling of storage systems and technologies that could benefit all industries that use hydrogen either for mechanical motion operation or for equipment operation.

(264) Furthermore, it is highly probable that undertakings, which are currently using natural gas for their operations, would need to diversify and commence targeting primarily the hydrogen demand. The development of UGS systems by NAFTA for example will enable high energy intensive industries, such as the steel, cement and chemical industries, to access a steady energy supply in the form of hydrogen during the whole year. NAFTA will use the R&D&I and FID results of its project at storage facilities outside Slovakia (e.g. Germany and Czechia) as spill-over in order to enable storage and transportation of hydrogen to countries with insufficient hydrogen sources and storages.

(265) The development of hydrogen storage technologies will moreover support the creation of undertakings involved in the installation of hydrogen heating or energy storage facilities from local renewable energy sources. Neste for example will cooperate with undertakings that are active in the renewable energy sector and will leverage its experience from the hydrogen sector to help develop the renewable energy sector.

(266) The development of technologies in TF 4 aim predominantly to support the establishment of commercially viable zero-emission mobility and transport. However, a positive impact is also expected to other sectors, namely railroad maintenance operators, the petrochemical industry, where renewable and low-carbon hydrogen will be introduced as a feedstock, or the sector of renewable electricity generation (i.e. PV, wind or hydro power). Ørsted for instance will ensure that the R&D&I results will be extended not only to hydrogen mobility and transport related projects, but also to multiple national or industrial research projects concerning energy related sectors (e.g. certification of methanol based aviation kerosene will be available to all industries, e.g. refineries or the steel industry, seeking methanol based synthesis routes for kerosene production).

2.6 Description of the aid measures

2.6.1. Selection of the participating undertakings in Hy2Tech

(267) The notifying Member States have submitted information on the following national procedures that were organised for the selection of Hy2Tech participants:

- In Austria, the IPCEI application process was based on an open and transparent two-stage call for interested parties. The first stage started in autumn 2020 with the participation of 50 undertakings. In autumn 2021, Austria launched the second stage targeting the most mature and promising projects for notification. Of the 20 projects that submitted proposals, four were selected as participating undertakings in Hy2Tech.

- Belgium published a national, open and transparent call for interest on March 2020. This resulted in the submission of 20 project proposals, of which two were selected for notification in Hy2Tech.

- In Czechia, the call for expression of interest was launched as a public call by the Ministry of Industry and Trade on November 2020. Eleven project proposals were presented. After detailed evaluation and several rounds of discussion with undertakings, one project was selected to be included in Hy2Tech process.

- In Denmark, an open call for expressions of interest was launched on March 2020. Ten applications were submitted and six were initially pre-selected. Denmark selected one project as participating undertaking in Hy2Tech.

- In Estonia, over 20 projects were submitted to an open call. A national evaluation committee pre-selected 11 projects for the European match-making process. Estonia finally selected three projects for Hy2Tech and, following the withdrawal of one undertaking, formally notified two projects.

- Finland organised an official national call period from 11 June 2021 to 4 July 2021. 23 projects participated in the European match-making process. At the end of the national process, three projects were preselected for IPCEI hydrogen inclusion and one project was finally formally notified as participating undertaking in Hy2Tech.

- France launched two national calls of interest on 27 January 2020 and on 18 May 2021. Approximately 80 project portfolios were submitted. 15 projects were pre-selected for direct participation and after the European match-making process and ten projects were formally notified in Hy2Tech.

- Germany launched its national call of interest on 11 January 2021. Approximately 230 project sketches were submitted. Germany pre-selected 62 projects to be introduced to the European match-making procedure and four projects were selected as participating undertakings in Hy2Tech.

- Greece launched its national call of interest on 7 April 2021. 20 projects were submitted, five were selected following an evaluation procedure by dedicated Experts Committee and, whereas eventually three projects were formally notified as participating undertakings in Hy2Tech.

- In Italy, a call for expression of interest was launched on 25 January 2019. Approximately 180 project sketches were submitted. After a national preselection, 52 projects were presented to participate in the European match-making procedure and 6 projects were formally notified in Hy2Tech.

- The Netherlands organised a national call of interest in 2020. Approximately 80 projects expressed their interests and 25 were pre-selected that best matched both the national hydrogen strategy and the criteria of the IPCEI Communication. The Netherlands eventually formally notified one project in Hy2Tech.

- Poland launched the national call of interest on 5 March 2021. 36 projects were received and nine projects were pre-selected for IPCEI Hydrogen inclusion. Poland finally selected one project for participating in Hy2Tech.

- In Portugal a call for expression of interest was opened in summer 2020. 74 expressions of interest were presented and 37 projects were pre-selected that best matched both the national hydrogen strategy and the criteria of the IPCEI Communication. Portugal eventually formally notified one project in Hy2Tech.

- In Slovakia, a call for expression of interest was launched on 23 November 2020, 32 project proposals were submitted and the national selection committee pre-selected 15. Slovakia eventually selected one project for participating in Hy2Tech.

- Spain launched three calls of interest in June and December 2020 and in May 2021. More than 500 projects were submitted as a result of all three calls. A list of candidate projects was drawn-up by the respective national authorities that led to the formal notification of four projects for Hy2Tech.

2.6.2. Total eligible costs in Hy2Tech

(268) The notifying Member States indicate that the activities performed in the framework of Hy2Tech qualify as R&D&I and FID in the meaning of points 22 to 24 of the IPCEI Communication.[10] With the exception of Iveco CZ (only R&D&I), Ørsted (only FID), Neste (only FID) and Nedstack (only FID), all individual projects consists of an R&D&I and a FID phase.

(269) On the basis of the information contained in the individual project portfolios, with the exception of the project portfolios of Ørsted, Neste and Nedstack, and as summarised in section 2.4.1, the Commission considers that the nature and scope of the R&D&I projects falling within each of the TF covered by Hy2Tech are such that those projects are of a major innovative nature or constitute an important added value in terms of R&D&I in the light of the state-of-the-art in the hydrogen sector. Furthermore, the information in the individual project portfolios, with the exception of the project portfolio of Iveco CZ, and as summarised in section 2.4.1, also demonstrates that the FID projects will allow for the development of new products or services with high R&D&I content or the deployment of a fundamentally innovative production processes, going

[10] In light of the fact that none of the individual projects falling within Hy2Tech constitute infrastructure projects in the environmental, energy, transport health or digital sectors, point 25 of the IPCEI Communication is not relevant for Hy2Tech.

beyond mere upgrades without an innovative dimension of existing facilities or the development of newer versions of existing products. Moreover, and as set out in further detail in section 3.3.1, aid granted under Hy2Tech is limited to R&D&I and FID projects and does not extend to the mass production phase of any of the products, services or processes resulting from the individual projects.

(270) The Commission, therefore, considers that Hy2Tech satisfies the specific criteria set out in section 3.2.3 of the IPCEI Communication.

(271) The notifying Member States also submit that the total Hy2Tech eligible costs[11] are approximatively EUR 9 billion.

2.6.3. Aid amounts per participating undertaking and chronology of funding per Member State

(272) The Member States have submitted the amounts of State aid under the measures that will be provided to the participating undertakings, together with the individual eligible costs and funding gaps.

(273) According to point 33 of the IPCEI Communication, the maximum permitted aid level is determined with regard to the identified funding gap in relation to the eligible costs. The amounts of State aid are capped in nominal terms by the eligible costs, which are also presented in nominal terms. If the eligible costs are lower than the funding gap (in discounted net present value ("NPV") terms), then the eligible costs determine the maximum permitted aid level. If, however, the eligible costs are higher than the funding gap, then it is the funding gap that determines the maximum permitted aid level. Member States may choose to disburse State aid in several instalments over a certain period of time, e.g. during the life span of a project. State aid payable in the future, including aid payable in several instalments, shall be discounted, after deducting subsequent revenues, to its value at the moment it is granted.

(274) The Commission has assessed the eligible costs and funding gap calculations for each individual project (see recitals (423) to (458)) and established a maximum permitted aid level for each individual project. The permitted aid level is expressed in the tables 9 to 23 as the lower of either the eligible costs (in nominal terms) or the funding gap (in discounted NPV terms). In case the notified nominal State aid amounts were higher than the permitted aid level, the Commission verified for each individual project (using the relevant weighted average cost of capital ("WACC") as the discount factor) that the discounted values of the nominal State aid amounts do not exceed the maximum permitted aid levels (see column 'State aid discounted' in tables 10, 11, 15 to 18).

[11] Eligible costs are only those costs of the individual projects, which comply with the requirements of the Annex to the IPCEI Communication. They, however, do not represent all costs required to conduct the R&D&I and FID activities concerned. The remaining portion of the costs required to conduct those activities, which are not considered eligible for public financing, will be absorbed by the participating undertakings.

Undertaking	Eligible Costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
AVL	[20-30]	- [1-10]	6
Bosch AT	[30-40]	-[10-20]	19
Christof Industries	[20-30]	-[10-20]	16
Plastic Omnium AT	[100-200]	-[90-100]	99
Sum	284	-140	140

Table 9: Austria – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)	State aid (discounted)
	Million EUR	*Million EUR*	*Million EUR*	*Million EUR*
Cummins	[100-200]	-[50-60]	26	n.a.
John Cockerill	[30-40]	-[1-10]	11	[1-10]
Sum	205	-59	37	---

Table 10: Belgium – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)	State aid (discounted)
	Million EUR	*Million EUR*	*Million EUR*	*Million EUR*
Iveco CZ	[50-60]	-[20-30]	30	[20-30]
Sum	[50-60]	-[20-30]	30	[20-30]

Table 11: Czechia – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)[12]
	Million EUR	*Million EUR*	*Million EUR*
Ørsted	[200-300]	-[200-300]	87
Sum	[200-300]	-[200-300]	87

Table 12: Denmark - State aid in million EUR

[12] The Danish authorities submit that Ørsted will proceed with the project notwithstanding the fact that the aid amount is below the project's funding gap while seeking additional sources of funding.

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
Elcogen	[20-30]	-[20-30]	17
Stargate	[50-60]	-[30-40]	29
Sum	79	-56	46

Table 13: Estonia - State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
Neste	[100-200]	-[100-200]	150
Sum	[100-200]	-[100-200]	150

Table 14: Finland – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)	State aid (discounted)
	Million EUR	*Million EUR*	*Million EUR*	*Million EUR*
Alstom	[200 - 300]	-[100 - 200]	247	[100-200]
Arkema	[100 - 200]	-[100 - 200]	101	[80-90]
Elogen	[90 -100]	-[80 - 90]	93	[60-70]
Faurecia	[200 - 300]	-[100 - 200]	213	[100 - 200]
Genvia	[500 - 600]	-[200 - 300]	279	[200-300]
HYVIA	[800 - 900]	-[100 - 200]	260	[100-200]
John Cockerill	[200 -300]	-[70 - 80]	98	[60-70]
McPhy	[100 - 200]	-[80 - 90]	123	[70-80]
Plastic Omnium FR	[100 - 200]	-[40 - 50]	79	[40-50]
Symbio	[800 - 900]	-[500 - 600]	669	[500-600]
Sum	3,474	-1,697	2,162	1,569

Table 15: France – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)	State aid (discounted)
	Million EUR	*Million EUR*	*Million EUR*	*Million EUR*
Daimler Truck	[300-400]	-[100-200]	226	[100-200]
Bosch DE	[500-600]	-[…]	161	[100-200]
EKPO	[200-300]	-[100-200]	177	[100-200]
Sunfire	[200-300]	-[100-200]	170	[100-200]
Sum	1,381	-598	734	598

Table 16: Germany – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)	State aid (discounted)
	Million EUR	*Million EUR*	*Million EUR*	*Million EUR*
Advent	[900 – 1000000]	-[500-600]	738	[500-600]
B&T Composites	[10-20]	-[10-20]	18	[10-20]
Sum	979	-572	756	572

Table 17: Greece – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)	State aid (discounted)
	Million EUR	*Million EUR*	*Million EUR*	*Million EUR*
Ansaldo	[800-900]	-[300-400]	495	[300-400]
Alstom IT	[200-300]	-[60-70]	99	[60-70]
De Nora	[90-100]	-[40-50]	63	[40-50]
Enel	[20-30]	-[30-40]	24	[20-30]
Fincantieri	[300-400]	-[200-300]	356	[200-300]
Iveco IT	[200-300]	-[30-40]	41	[30-40]
Sum	1,778	-868	1,078	861

Table 18: Italy – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
Nedstack	[20-30]	-[20-30]	22
Sum	[20-30]	-[20-30]	22

Table 19: Netherlands – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
Synthos	[20-30]	-[20-30]	24
Sum	[20-30]	-[20-30]	24

Table 20: Poland – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
1s1 Energy	[50-60]	-[30-40]	45
Sum	[50-60]	-[30-40]	45

Table 21: Portugal – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
NAFTA	[40-50]	-[30-40]	36
Sum	[40-50]	-[30-40]	36

Table 22: Slovakia – State aid in million EUR

Undertaking	Eligible costs (nominal)	Funding Gap (NPV)	State aid (nominal)
	Million EUR	*Million EUR*	*Million EUR*
Iveco ES	[50-60]	-[20-30]	27
H2B2	[30-40]	-[20-30]	25
Nordex	[40-50]	-[10-20]	12
SENER	[20-30]	-[10-20]	10
Sum	147	-74	74

Table 23: Spain– State aid in million EUR

(275) The Member States submit that the durations of the individual projects of the participating undertakings differ. The funding period (i.e. the period during which the costs, which the undertakings can claim to be eligible, should be incurred) is the following, per TF:

TF	Starting date	End date
TF 1	This TF starts at the earliest in 2021	The last eligible year during the FID phase is planned at the latest 2029.
TF 2	This TF starts at the earliest in 2021.	The last eligible year during the FID phase is planned at the latest 2028.
TF 3	This TF starts at the earliest in 2021.	The last eligible year during the FID phase is planned at the latest 2030.
TF 4	This TF starts at the earliest in 2021.	The last eligible year during the FID phase is planned at the latest 2030.

Table 24: Hy2Tech funding period

2.6.4. The aid instruments

(276) The aid to be granted by all of the Member States in Hy2Tech will take the form of direct grants. In Belgium, the Region of Wallonia will use, in addition to direct grants, repayable advances for the FID activities. In Spain and Portugal, the use a particular aid instrument has not yet been decided and may comprise a wide range of financial instruments, namely direct grant, loan or repayable advance, whereas France in certain cases could also mobilise repayable advances. In the Netherlands, the use of repayable advances may be considered a more suitable aid instrument for R&D&I/FID projects (as opposed to projects

focusing on the generation or transportation and distribution of hydrogen), given the possibility that such projects have in facilitating the generation of profits.

2.7 **Granting of the aid under the notified** measures

(277) All of the Member States in Hy2Tech have subjected the implementation of State aid to the prior approval of the Commission.

(278) The Member States have committed to suspend the award and/or payment of the notified aid if the beneficiary still has at its disposal earlier unlawful aid that was declared incompatible by a Commission Decision (either as individual aid or aid under an aid scheme having been declared incompatible), until that beneficiary has reimbursed or paid into a blocked account the total amount of unlawful and incompatible aid and the corresponding recovery interest.

(279) The Member States have further confirmed that the participating undertakings are not undertakings in difficulty as defined in the rescue and restructuring guidelines[13].

(280) Finally, the Member States have indicated that cumulation with other aid, de minimis aid[14], or EU funding will be allowed to cover the same eligible costs, as long as the total funding will not exceed the aid amount which is declared compatible with the internal market under this decision.

2.8 Transparency

(281) The Member States have in their notification committed to respect the transparency and publication requirements of points 48 and 49 of the IPCEI Communication. In particular, Member States have committed to publish in the Commission's transparency award module or on a comprehensive State aid website, at national or regional level, the full text of the individual aid granting decision and its implementing provisions or a link to it, as well as all related information as specified in point 48 of the IPCEI Communication.

2.9 Claw-back mechanism

(282) In order to further ensure that the aid is kept to the minimum necessary, the Member States have in their notification committed to introduce a claw-back mechanism, pursuant to point 36 of the IPCEI Communication. The basis for the claw-back mechanism will be ex post figures, which have been subject to annual approval by an independent auditor. For this purpose, separate analytical accounting will be required from the participating undertakings in the relevant Member State. The detailed conditions of the claw-back mechanism are explained in Annex I to this Decision.

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13 Guidelines on State aid for rescuing and restructuring non-financial undertakings in difficulty, OJ C 249, 31.7.2014, p. 1.

14 Commission Regulation (EU) No 1407/2013 of 18 December 2013 on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to de minimis aid, OJ L 352, 24.12.2013, p. 1.

(283) The claw-back mechanism for the individual projects of the participating undertakings only applies in case of a 'Surplus' including the actual State aid disbursements, as defined in Annex I to this Decision. To ensure, however, that the beneficiaries have an incentive in delivering their project in an efficient manner, a share of any potential 'Surplus' will remain with the participating undertakings.

(284) In line with previous case practice[15], the claw-back mechanism will apply at minimum to participating undertakings having a notified aid amount, per individual project, above EUR 50 million, although Member States can be more restrictive. This threshold ensures that all of the larger projects will be subjected to the mechanism and at the same time avoids imposing burdensome administrative requirements on the relatively smaller projects.[16]

(285) The Member States are required to report to the Commission the implementation of the claw-back mechanism one month after each application.

3. ASSESSMENT OF THE MEASURES

3.1. Presence of State aid pursuant to Article 107(1) TFEU

(286) According to Article 107(1) TFEU, "any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market".

(287) In order to qualify as State aid under Article 107(1) TFEU, the following cumulative conditions must be met: (i) the measure must be imputable to the State and financed through State resources; (ii) it must confer an advantage on its beneficiaries; (iii) that advantage must be selective; and (iv) the measure must distort or threaten to distort competition and affect trade between Member States.

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15 SA.55831 (2020N) - Germany - Important Project of Common European Interest on European Battery Innovation (EuBatIn), recital 316 (not yet published), and SA.54794 (2019N) – France - Important Project of Common European Interest (IPCEI) on Batteries, recital 196 (not yet published).

16 The Commission notes that the IPCEI Communication recognises that it may be appropriate to take steps to ensure that the claw-back mechanism does not result in disproportionate burdens. In this respect, footnote 30 of the IPCEI Communication, states that '[f]or projects by SMEs, no claw-back mechanism needs to be implemented unless in exceptional circumstances, in particular in consideration to the amounts of aid notified for such projects'. In Hy2Tech, notwithstanding their size, some SMEs will be undertaking large (in certain circumstances very large) projects. Given, therefore, the lack of ubiquitous correlation between the size of the undertaking and the size of the project, the Commission considers that, in the present circumstances, a claw-back mechanism which is limited by reference to the amount of the notified aid, per individual project, is more appropriate to avoid disproportionate administrative burdens than a mechanism based on the size of the relevant undertaking. Consequently, the claw-back mechanism will be implemented also for individual projects by those SMEs, where the notified aid amount is higher than EUR 50 million.

(288) The public support measures of the Member States will be financed with funds stemming from the respective State budgets. The measures therefore involve State resources and are imputable to the relevant States.

(289) The aid measures in the form of direct grants granted to the participating undertakings will relieve them from costs that they would have had to bear themselves. By contributing to the financing of their R&D&I and FID activities with funds that would not have been available under normal market conditions, the aid measures confer to the aid beneficiaries an economic advantage over their competitors. These measures are granted only to the aid beneficiaries listed in section 2.2.6 and the funding is not available to all undertakings in a comparable situation. The aid measures are therefore selective.

(290) The aid beneficiaries involved in the relevant TF described above in section 2.2, operate in different sectors along the hydrogen value chain, for example electrolyser and water electrolysis systems, FCS for mobility and transport applications and hydrogen refuelling stations, stationary FC, hydrogen fuels for mobility and transport, hydrogen power packs for rolling stocks, bus and heavy duty trucks markets, large engines for mobility/transport and pressure vessels for hydrogen storage. These are economic sectors open to intra-EU trade (both in terms of supply and demand). Therefore, the measures may affect trade between Member States.

(291) By reinforcing the aid beneficiaries' position in their respective sectors, the measures are therefore liable to distort competition by conferring beneficiaries a selective advantage as compared to their competitors.

(292) In the light of the foregoing, the Commission considers that the public resources granted to the aid beneficiaries in the form of direct grants for the R&D&I and FID activities as described within the framework of Hy2Tech qualify as State aid within the meaning of Article 107(1) TFEU.

3.2. Legality of the aid measures

(293) By notifying the measures before putting them into effect, the Member States have fulfilled their obligations under Article 108(3) TFEU.

3.3. Assessment of the aid measures

3.3.1 *Applicable legal basis for assessment*

(294) In derogation from the general prohibition of State aid laid down in Article 107(1) TFEU, aid may be declared compatible by the Commission if it can benefit from one of the derogations enumerated in Article 107(2) and (3) TFEU.

(295) According to Article 107(3)(b) TFEU, aid to promote the execution of an important project of common European interest may be considered to be compatible with the internal market.

(296) In the IPCEI Communication, the Commission has provided guidance on the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest. The criteria set out in the IPCEI Communication are applicable to this case.

(297) As Article 107(3)(b) TFEU allows the Commission to consider as compatible with the internal market aid to promote the execution of an important project of common European interest, it is appropriate to consider first whether the notified measures relate to such a project. These general eligibility criteria are assessed in section 3.3.2. Second, it needs to be considered whether the criteria for declaring the aid compatible with the internal market are met. The compatibility criteria are assessed in section 3.3.3.

3.3.2 *Eligibility criteria*

(298) In order to be eligible for aid under Article 107(3)(b) TFEU, the notified measures must involve a project. That project must be of common European interest, and it must be important. These three criteria are considered below.

3.3.2.1. Definition of a project

(299) According to point 13 of the IPCEI Communication, the Commission may consider eligible an 'integrated project', that is to say, a group of single projects inserted in a common structure, roadmap or programme aiming at the same objective and based on a coherent systemic approach. The individual components of the integrated project may relate to separate levels of the supply chain but must be complementary and significantly add value in their contribution towards the achievement of the important European objective.

(300) The Member States, as explained above in section 2.4, consider that notified Hy2Tech constitutes an integrated project. The Commission shares this conclusion for the reasons explained below.

(301) The Commission finds that Hy2Tech is designed in such a way as to contribute to a common objective, formulated by the Member States and undertakings, as described in section 2.1. As mentioned therein, the main aim of Hy2Tech is to develop an innovative and sustainable hydrogen value chain in the EU that goes substantially beyond the current global state-of-the-art and which brings together undertakings operating at different levels of the hydrogen value chain. This aim is by integrating all 41 individual projects into a common programme aiming at the same objective.

(302) The R&D&I and FID activities of the individual projects are combined in a coherent systemic approach in four TF, which constitute the individual but interlinked components of Hy2Tech.

(303) The organisation and work plan of the four TF is divided in different tasks, each of which consists of different components during both the R&D&I and the FID phases (see sections 0 to 0).

(304) As described in section 2.4 above, each individual project is complementary to the other projects and significantly adds value in its contribution for the achievement of the overall Hy2Tech's objectives. In particular, the Commission notes that:

- The different individual projects in TF 1 constitute the building blocks of the hydrogen value chain enabling the development of technologies for the design and upscale of electrolysers that are needed for the generation of renewable and low-carbon hydrogen. The hydrogen generation resulting from the activities in TF 1 will then be used at high purity content for the development of the FC in TF 2, which constitute the 'engine' that provides the power for the various mobility and transport applications under TF 4. The hydrogen must also be generated at high quantities for storage, transportation and distribution in TF 3, in order to meet the needs of the increasing demand;

- The different individual projects in TF 2 will cover activities related to the development of FC technologies using common raw materials, components and processes (e.g. recycling and standardisation processes) with those individual projects covering electrolyser activities under TF 1. They are furthermore complementary and add significant value to the activities under TF 3, given that certain materials could also be used under TF 3, whereas a joint optimisation of the different elements for both FCS and storage systems is required to achieve integration with mobility and transport applications under TF 4;

- Under TF 3, the participating undertakings will develop safe and reliable hydrogen storage systems, which are needed for the transportation and distribution of the hydrogen generated as a result of the electrolysis technologies to be developed under TF 1 and the development of FC technologies under TF 2. Furthermore, the different end-users under TF 4 would require compatible hydrogen storage solutions for their various mobility and transport applications, necessitating thus regular testing and validation; and

- The different requirements of the mobility and transport end users in TF 4 can significantly influence the development of the various hydrogen technologies to be developed in the other TF. The end users will among others provide technical expertise to the participating undertakings in the other TF for the development of the various hydrogen technologies and collaborate further with them in order to optimise operational performance and efficient integration of these technologies to the various end-use applications The activities under this TF are also complementary to all other TF, given that the requirement for safe and reliable integration of the different materials, components and systems requires the carrying out of various standardisation and certification processes.

(305) In addition, and as described in detail in section 2.4 above, the Commission observes that the individual projects of the participating undertakings and the four TF are part of a common structure and programme, having the same objective and based on a coherent systemic approach. In addition, the various TF have common objectives, as well as tasks and deliverables for the R&D&I and the FID phases. The actions required in all of the tasks included within the organisation and work plan of the four TF are considered necessary to achieve the overall objectives of Hy2Tech. As already highlighted in recital (304), the four TF and the actions required to perform the respective tasks, constitute distinct and consecutive stages of value creation along the hydrogen value chain. They each require very specific R&D&I and FID activities along the value chain, which also constitute inputs to the next level of the chain and introduce circularity.

(306) Further, in order to ensure the coherent implementation of Hy2Tech, the Member States will establish a common governance structure, as described in section 2.3, under a SB, which will have the task of reviewing the progress and the results of Hy2Tech and propose changes if necessary, giving specific attention to the benefit for the European society. The Commission will be represented in the SB as an observer.

(307) Therefore, in view of the above, the Commission concludes that the notified Hy2Tech qualifies as an integrated project in the meaning of the IPCEI Communication, as its individual projects and TF are inserted in a common structure and programme, aiming at the same objective and are based on a coherent systemic approach. Furthermore, the individual projects and TF are complementary and significantly add value in their contribution towards the achievement of the important common European objective of establishing an innovative and sustainable hydrogen value chain in the Union.

3.3.2.2.Common European Interest

(308) In order to establish that a project qualifies as being of common European interest, the IPCEI Communication sets out general cumulative criteria (section (a) below), as well as general positive indicators (section (b) below). In addition, the IPCEI Communication specifies certain criteria depending on the type of the project (section (c) below).

a) General cumulative criteria

Important contribution to the Union's objectives

(309) According to point 14 of the IPCEI Communication, the project must represent a concrete, clear and identifiable important contribution to the Union's objectives or strategies and must have a significant impact on sustainable growth, for example by being of major importance among others for the European Green Deal, the New Industrial Strategy for Europe and its update, the Next Generation EU, the new European Research Area for research and innovation, the new Circular Economy Action Plan, or the Union's objective to become climate neutral by 2050.

(310) The Commission notes the important role that the hydrogen technology industry is expected to play in reaching the decarbonisation targets of the EU. The European Climate Law[17] presents a legally binding, EU-wide, economy-wide GHG emissions reduction target by 2030 compared to 1990 of at least 55%, a target endorsed by the European Council in December 2020.[18] Further, the Commission has proposed a communication presenting its long-term vision for a

[17] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021, establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'), OJ L 243, 9.7.2021, p. 1. See also Communication from the Commission, to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Stepping up Europe's 2030 climate ambition – Investing in a climate-neutral future for the benefit of our people*, COM(2020) 562 final, 17.9.2020.

[18] European Council meeting (10-11.12.2020) – Conclusions, 11.12.2020, EUCO 22/20, point 12.

climate-neutral economy by 2050.[19] The development of clean and innovative technologies, the deployment of renewable sources of electricity and alternative sustainable fuels, the integration of low and zero-emissions mobility and transport solutions and the move towards a circular economy as a means to reduce GHG emissions, are set to be the main technological pathways to reach carbon neutrality.

(311) These initiatives will have a major impact on the uptake of renewable and low-carbon hydrogen, thus significantly contributing to the targets outlined by the Commission in the *EU Hydrogen Strategy.*[20] In the first phase, the strategic objective is to install at least 6 GW of renewable hydrogen electrolysers in the EU and the production of up to 1 million tonnes of renewable hydrogen by 2024. By 2030, the goal is to reach 40 GW of renewable hydrogen electrolysers in the EU. In the short and medium term, however, other forms of low-carbon hydrogen are needed, primarily to rapidly reduce emissions from existing hydrogen production and support the parallel and future uptake of renewable hydrogen.

(312) In the context of *EU Hydrogen Strategy*, the *European Clean Hydrogen Alliance*[21] was launched on 8 July 2020 to support the large-scale deployment of clean hydrogen technologies by 2030, by bringing together renewable and low-carbon hydrogen production, demand in industrial, mobility, transport and other sectors, and hydrogen transmission and distribution.

(313) Moreover, in its *Sustainable and Smart Mobility Strategy*, the Commission lays the foundations for how the EU transport system can achieve its green and digital transformation and become more resilient to future crises.[22] It highlights the importance of the use of hydrogen and other renewable and low-carbon fuels in building a comprehensive policy in order to stimulate demand for zero emission vehicles.

(314) Furthermore, the *Next Generation EU* stimulus package has been adopted as a temporary instrument designed to boost the recovery of Member States from the pandemic by addressing among others, climate and environmental challenges.[23] The *Resilience and Recovery Facility ("RRF")* for Europe constitutes a

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[19] 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, *A Clean Planet for all – A European strategic long-term vision for prosperous, modern, competitive and climate neutral economy*, COM(2018) 773 final, 28.11.2018.

[20] Communication from the Commission, to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *A hydrogen strategy for a climate-neutral Europe,* COM(2020)301 final, 8.7.2020.

[21] https://ec.europa.eu/growth/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance_en

[22] Communication from the Commission, to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Sustainable and Smarrt Mobility Strategy – putting European transport on track for the future,* COM(2020)789 final, 9.12.2020.

[23] 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, *Europe's moment: Repair and Prepare for the Next Generation*, COM(2020) 456 final, 27.5.2020.

centrepiece of the Next Generation EU.[24] The RRF Regulation requires each Member State to dedicate at least 37% of its recovery and resilience plan's ("RRP") total allocation to measures contributing to climate objectives. This supports the green transition by contributing to the achievement of the EU's 2030 climate targets and by complying with the target of EU climate neutrality by 2050. Particularly, the RRF supports investments in flagship areas, such as hydrogen. Hy2Tech projects will be partly funded by the RRF.

(315) In addition, on 18 May 2022, the Commission presented the *REPowerEU Plan*, in response to the hardships and global energy market disruption caused by Russia's invasion of Ukraine.[25] The measures in the *REPowerEU Plan* will particularly target energy savings, diversification of energy supplies, accelerated rollout of renewable energy and the reduction/replacement of fossil fuel consumption in industry and transport. In particular, the plan includes the implementation of a hydrogen accelerator aiming at increasing the use of renewable hydrogen in the EU up to 20 million tonnes by 2030.

(316) All of the above legislative initiatives supplement the Commission's Communication that sets out a *European Green Deal* for the EU and its citizens.[26] The aim is to transform the EU into a climate-neutral society, where there will be no net emissions of GHG by 2050 and where economic growth is decoupled from resource use.[27]

(317) The Commission considers that Hy2Tech will contribute to fulfilling the objectives laid down in the various EU initiatives mentioned above by:

- Bringing together in an integrated project 41 participating undertakings from 15 EU Member States, with more than 300 indirect partners;

- Serving, through the technological innovations proposed, all five dimensions of the EU Energy Union: i) energy security, solidarity and trust; ii) a fully integrated European energy market; iii) energy efficiency contributing to moderation and demand; iv) decarbonising the economy; and, v) research, innovation and competitiveness;

- Covering the entire hydrogen value chain with sustainable hydrogen technologies, which are critical for a successful energy and mobility transition, such as electrolysers, FC and storage facilities, and aim to strengthen the supply and demand of renewable energy;

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24 Regulation (EU) 2021/41 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility, OJ L 57, 18.2.2021, p. 17-75.

25 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, *REPowerEU*, COM(2022)230 final, 18.5.2022.

26 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, *The European Green Deal*, COM(2019) 640 final, 11.12.2019.

27 See also, Communication from the Commission, to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, COM(2020) 98 final, 11.3.2020.

- Focusing on sustainability of the hydrogen value chain, by developing critical components and enabling technologies that are necessary for the electrolysis;

- Concretely addressing the technological objectives on electrolysers, FC technology, storage systems, mobility and transport applications;

(318) Particularly, it is expected that Hy2Tech will decrease carbon-dioxide emissions substantially by substituting fossil fuel-based hydrogen or other conventional energy carriers with renewable and low-carbon hydrogen. It is also expected that the scaling up of technologies will facilitate increasing the hydrogen generation capacity and hydrogen storage, while, at the same time decreasing the EU's dependency on fossil energy imports. Indicatively, the Commission notes that the electrical efficiency of SOFC will improve by approximately 60%, the life span of PEM FCS will improve by up to 30,000 hours for mobility and transport applications, of the cumulative production capacity for all electrolysers will scale up to over 10GW/a by 2030, and, the target hydrogen storage capacity in underground porous reservoir will increase from 0.9 TWh/a in 2031to 4.3 TWh/a beyond 2050.

(319) Hy2Tech will in addition support Action 7 of the *Integrated Strategic Energy Technology ("SET") Plan,* which is the central pillar of the EU's energy and climate policy.[28] The *SET Pla*n was revised in 2015 to help realise the research and innovation priorities of the Energy Union, particularly in relation to the development of certain areas, namely 'integrating renewable technologies in the energy systems', 'reducing costs of technologies' and 'renewable fuels and bioenergy'. Hy2Tech will support the *SET Plan* by focusing on hydrogen-related technologies for the generation of renewable and low-carbon hydrogen and by reducing the cost of hydrogen materials and components.

(320) The Commission further notes that Hy2Tech will also contribute to the *EU Renewed Agenda for Research and Innovatio*n[29] and the *new ERA for Research and Innovation*[30]. In this context, Hy2Tech will:

- Host R&D activities for innovative and sustainable hydrogen related materials for mobility, transport and industrial applications to unlock the full technological potential of the hydrogen value chain in Europe;

- Contribute to the transfer of hydrogen-related knowledge to new or improved applications and different output sectors;

- Support the training of highly skilled staff; and

[28] Communication from the Commission, *Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation*, C(2015) 6317 final, 15.9.2015.

[29] 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, *A Renewed Agenda for Research and Innovation – Europe's chance to shape its future*, COM(2018) 306 final, 15.5.2018.

[30] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *A new Era for Research and Innovation*, COM(2020) 628 final, 30.9.2020.

- Help coordinate hydrogen-related activities across Europe in order to create an integrated EU hydrogen ecosystem, thus redeeming the goals of the European Hydrogen Alliance and delivering on the ambition of Hy2Tech.

(321) Particularly, it is expected that Hy2Tech will trigger R&D&I investments by the participating undertakings of up to around 13.5 billion euros, according to estimates provided by the Member States. It will comprise 72 FID activities, and the participating undertakings will directly target piloting their R&D&I results in 33 newly set-up pilot lines. Also, over 450 new collaborations between the participating undertakings and indirect partners and a total number of over 650 collaborations are expected to materialise, which would not have been realised without Hy2Tech (see table 23 in recital (365)). The dissemination of results will be realised by more than 5000 projected publications/presentations/events, and over 2000 young scientific talents will be aided, as well as additional educational training for technical workers will be offered.

(322) The Commission considers, in view of the above, that Hy2Tech will deliver on its overall objectives (see recital (9)). In addition, it will contribute significantly to fostering R&D&I, especially through the substantial investments undertaken by the participating undertakings. The numerous collaborations will further contribute to ensuring R&D&I cooperation across the EU, as well as facilitating cooperation between the industry and the RTOs.

(323) As regards the contribution of Hy2Tech to the New Industrial Strategy for Europe[31], the Commission acknowledges the importance of Hy2Tech for supporting significant investments in the EU's hydrogen value chain and that Hy2Tech is expected to contribute, according to estimates provided by the Member States, to job creation by creating approximately 20,000 direct jobs in total over its implementation.

(324) The Member States have provided estimates on the number of new direct jobs to be created annually as a result of Hy2Tech:

Member State	Jobs in TF 1	Jobs in TF 2	Jobs in TF 3	Jobs in TF 4	Total jobs
Austria	40	52	2	73	167
Belgium	70	-	-	-	70
Czechia	-	1	52	338	391
Denmark	-	-	-	99	99
Estonia	79	34	-	-	113
Finland	-	-	5	23	28
France	177	242	209	232	860
Germany	155	418	50	500	1123
Greece	67	131	4	159	361
Italy	90	44	8	443	585
Netherlands	-	67	170	50	287
Poland	15	-	1	-	16

[31] 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, *A New Industrial Strategy for Europe,* COM (2020) 102 final, 10.3.2020.

Portugal	85		-	-	85
Slovakia	-	-	11	-	11
Spain	89	-	-	201	290
Total	**867**	**989**	**512**	**2118**	**4486**

Table 25: Hy2Tech breakdown of created jobs per Member State per year.

(325) Based on the foregoing, the Commission concludes that Hy2Tech will contribute in a concrete, clear and identifiable manner to one or more Union objectives and has in particular a significant impact on sustainable growth across the EU.

Hy2Tech designed to overcome important market or systemic failures

(326) According to point 15 of the IPCEI Communication, the project must demonstrate that it is designed to overcome important market or systemic failures, preventing it from being carried out to the same extent or in the same manner in the absence of the aid, or societal challenges, which would not otherwise be adequately addressed or remedied.

(327) The Commission's assessment of important market or systematic failures has been performed by the Commission per project, focusing on identifying the existence of a market failure as such and elaborating on how each project addresses such failure specifically. This allowed the Commission to define the overarching market and systematic failures specific to Hy2Tech.

(328) First, the individual projects in Hy2Tech will contribute to addressing a market failure in the form of negative environmental externalities, by developing technologies necessary to generate, store and use renewable hydrogen more efficiently, thereby reducing GHG emissions. The underlying source of negative externalities is that undertakings do not always bear the full cost of the harm they impose on society, which leads to the use of more polluting technologies, with resulting pollutants presenting a direct or indirect health hazard to society. The role of policy intervention is to reinforce the incentives to shift towards using less polluting technologies. Absent State aid, undertakings would likely not have the incentive to invest in less polluting technologies.

(329) The individual projects under Hy2Tech will address negative environmental externalities for instance by:

a) Developing technologies allowing for the production of hydrogen with reduced or without GHG emissions, applying a life cycle assessment to focus on the impact of any activities on the environment over the full manufacturing value chain, from extraction of minerals to recycling;

b) Developing high-efficient breakthrough technologies that will increase the performance of electrolysers;

c) Upscaling mass production of electrolysers, which will enable the industrial production of renewable hydrogen to replace fossil-based hydrogen; and

d) Substituting of traditional ICE by vehicles equipped with FCS, thereby contributing to the transformation in the EU automotive industry.

(330) Second, the individual projects in Hy2Tech are expected to address positive externalities of innovation efforts, not fully internalised by the beneficiaries, through dissemination of knowledge and results to other market participants, including those beyond the beneficiaries' own sectors of activities. In other words, undertakings may share the stock of knowledge with other undertakings without being directly compensated for it. This is further reinforced in the case of commitments to disseminate knowledge and results. In the presence of positive externalities, the social rate of return on the R&D&I investment made by undertakings is higher than the undertakings' private return from the R&D&I investment.

(331) Where individual projects may provide benefits to society that are not fully captured by the undertakings, the undertakings' private rate of return may not be sufficiently attractive for each project to be funded fully privately, even though the overall benefits of that project justify the investment from a societal perspective. This leads to the underinvestment (or underproduction) in renewable energy technologies, from the social perspective, which justifies the need for State intervention. State aid may complete this gap, and ensure a level of investments in renewable hydrogen technologies closer to the socially optimal.

(332) Projects under Hy2Tech will address such positive externalities, for example by:

a) Generating benefits from innovation efforts going beyond undertaking-specific benefits by creating jobs and training opportunities along the different levels of the hydrogen value chain and, thereby, Stimulating regional employment not only in undertakings that indirectly benefit from the renewable hydrogen market, such as suppliers, but also in the local economy more generally;

b) Improving economic activity by creating a new market and promoting the auxiliary industry associated with the hydrogen market; and

c) Supporting further innovations beyond hydrogen storage (e.g., reservoirs for the storage of CO_2 or synthetic methane production) through the data collected and methodologies developed in the individual projects and in particular considering the commitment undertaken by the aid beneficiaries to disseminate knowledge and results.

(333) Third, the integrated, coordinated and simultaneous nature of the individual projects in Hy2Tech is expected to address coordination problems in the development and adoption of new hydrogen technologies, by aligning the incentives of multiple actors along a value chain, enabling thereby undertaking invest simultaneously in Hy2Tech.

(334) When the profitability of various projects is interdependent, multiple actors may end up underinvesting, if they are not able to coordinate and invest simultaneously. This is for instance the case for the development of new hydrogen technologies that require complementary components or infrastructure and inter-industry cooperation. The integrated, coordinated and simultaneous nature of Hy2Tech allows the market failure to be addressed.

(335) Hy2Tech will address such coordination problems, which include for example:

a) Coordination problems relating to investing and ramping up of production: Unclear market conditions on the supply-side as well as on the demand-side may prevent large-scale development of hydrogen technologies ('chicken-egg-problem'). The coordinated approach followed in the framework of Hy2Tech will create an opportunity for multiple actors on the demand- and supply-side to simultaneously invest and ramp up production capacities in order to commercialise new technologies in hydrogen generation. This includes integrated planning, common technical and safety standards for interoperability, and a joint and coordinated approach of relevant stakeholders; and

b) Coordination problems between the different levels of the hydrogen supply chain (e.g. generation, distribution, logistics, refuelling and end use): Hy2Tech brings together market participants from all levels of the hydrogen supply chain in an integrated project with a single and coordinated focus and plan of action, creating benefits for society as a whole by developing hydrogen technologies that would not be realised through multiple independent and fragmented smaller projects.

(336) Fourth, the individual projects in Hy2Tech are expected to address the problem of asymmetric information on innovative hydrogen projects and their prospects, showing the willingness of Member States to support hydrogen related projects.

(337) The presence of asymmetric information may lead to a situation where innovators may face difficulties convincing investors of the prospects of their projects, thereby increasing the cost of or even limiting access to capital to fund the projects. The Commission's assessment of Hy2Tech relies on a transparent, public, open process of individual project selection together with the explicit joint commitment by Member States across the EU to contribute to projects in Hy2Tech. This specifically contributes to addressing this market failure by reducing information asymmetry and providing regulatory certainty.

(338) Hy2Tech seeks to address problems with respect to asymmetric information in the following way:

a) The residual risks pertaining to the hydrogen technology itself and the fragmented set of information around its specific deployment for heavy duty applications may limit access to capital as compared to other more mature technologies. Hy2Tech will help overcome this through the creation of a value chain that kick-starts the market. Once this has been achieved, investors are expected to be less reluctant to invest in similar renewable and low carbon hydrogen production technologies; and

b) Given the high cost and the irreversibility of an investment in a large-scale electrolyser system, undertakings potentially willing to adopt this technology remain reluctant to invest in an unproven technology. However, technology suppliers need to demonstrate the viability of their disruptive innovations before being able to sell their product in high volumes. Therefore, the development of potentially superior yet unproven technologies can be trapped into a dead end because of the asymmetry of information between technology suppliers and their potential customers.

Hy2Tech will help overcome this by providing State aid necessary to trigger investments in innovative technologies.

Member States involved

(339) The IPCEI Communication, point 16, requires that at least four Member State must ordinarily be involved. Hy2Tech involves 15 Member States: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Netherland, Poland, Portugal, Slovakia and Spain, and thus satisfied point 16 of the IPCEI Communication.

Open procedure for Member States

(340) On 17 December 2020, 22 Member States plus Norway signed a joint manifesto in which they committed to launch IPCEI on hydrogen[32]. The signatory Member States invited all other interested EU and EFTA Member States to join this initiative, which is open to countries willing to participate in the construction of IPCEI on hydrogen.

Positive spill-over effects generated by Hy2Tech

(341) As required by points 16 and 18 of the IPCEI Communication, an IPCEI must benefit the European economy or society via positive spill-over effects. According to the IPCEI Communication, "the benefits of the project must be clearly defined in a concrete and identifiable manner" and "the benefits of the project must not be limited to the undertakings or to the sector concerned but must be of wider relevance and application to the economy or society in the Union through positive spill-over effects (such as having systemic effects on multiple levels of the value chain, or up- or downstream markets, or having alternative uses in other sectors or modal shift) which are clearly defined in a concrete and identifiable manner."

(342) The IPCEI Communication requires for spill-over effects to be identified at all of the following levels: beyond the Member States ("economy or society in the Union"); beyond the aid beneficiaries ("not be limited to the undertakings"); beyond the sector(s) in which the aid beneficiaries are active ("[…] or to the sector concerned").

(343) In view of the commitments for spill-overs as submitted by the Member States for each individual project, the Commission observes that different dissemination levels, ranging from awareness to exploitation, are proposed to ensure the translation of developments and outputs into new findings and market opportunities. The objective is to reach a wide range of potential users and uses amongst research, social, investment and policy makers.

[32] https://www.bmwk.de/Redaktion/DE/Downloads/M-O/manifesto-for-development-of-european-hydrogen-technologies-systems-value-chain.pdf?__blob=publicationFile&v=8. Although Norway does not participate in Hy2Tech, certain participating undertakings have committed to establish collaborations with Norwegian companies and RTOs, which are considered indirect partners in Hy2Tech.

(344) As regards spill-over effects for non-IP protected results of R&D&I and FID activities, the Member States have provided an extensive list of activities (described in section 2.5.1) illustrating that the effects of Hy2Tech are not limited to the participating undertakings, but will be disseminated to the whole scientific community and be of wider relevance and application to different economic sectors. For example, the Commission recognises that involvement in conferences and events as speaker, contributor, or participant will contribute to the dissemination of the knowledge, skills and results in the sense that attendance to these events is typical of all key actors (undertakings, RTOs, universities, etc.) of the hydrogen value chain, as they provide an excellent opportunity to exchange on the specific results produced by each individual project and the technological advancements achieved (see section 2.5.1.2). Moreover, the establishment of collaborations with numerous and various indirect partners (see recitals (247) to (266)), as well as the close communication and connection to clusters, professional trade associations and other intermediary bodies will enhance the dissemination effort (see section 2.5.1.4).

(345) The Commission also notes the significant effort undertaken by the participating undertakings in spreading and sharing knowledge and results by publications in peer-reviewed journals (see section 2.5.1.5) and in increasing links with the academic world, including through direct collaborations for the implementation of Hy2Tech, but also through a significant sponsorship of PhD and MSc degrees and university chairs related to technologies developed under Hy2Tech (see recital (200) and (204)-(205)). This is particularly important to ensure that the knowledge and individual project's results of Hy2Tech are transmitted to the next generations and that the future workforce can acquire the skills and knowledge that will be needed in the future. This is furthermore, corroborated by the commitments undertaken by all participating undertakings to provide training activities in collaboration with RTOs and universities, targeting professional and researchers (see recital (209)).

(346) As regards spill-over effects for IP-protected results of R&D&I (see section 2.5.2), the Commission considers that the Member States have shown adequately the dissemination activities and the commitments undertaken by the participating undertakings to spread those results as widely as possible to interested parties, e.g. SMEs or RTOs, the scientific community and across economic sectors through non-exclusive licensing based on FRAND conditions, without jeopardising the objectives of Hy2Tech. Thus, the IP-protected results will not only benefit the participating undertakings, but will go beyond the undertakings generating those results during Hy2Tech.

(347) In line with the commitments provided by each participating undertaking (cf. recital (210), the setting of the licence fees will be fixed in the respective cooperation contracts between the participating undertakings and the interested parties. This dissemination will provide interested parties with the possibility to reap the benefits of the R&D&I and FID activities undertaken by Hy2Tech across the TF. Through access on FRAND terms to IP-protected results of R&D&I stemming from individual projects falling within Hy2Tech, it can be expected that interested parties will be able to exploit the results of Hy2Tech in different applications, in up- or downstream markets, increasing therefore their technological expertise and their own research activities, improving their own

equipment, materials and processes and having the opportunity to develop new products or establish new collaborations.

(348) As far as particular spill-over effects of FID activities are concerned, the Commission considers that, on the basis of the information provided by the Member States (described in section 2.5.3), the FID activities across the four TF is expected to lead to significant spill-over effects in downstream markets. Hy2Tech will enable the participating undertakings to develop new product applications and designs and acquire specific skills and know-how, which can be used in cooperation with third parties within or outside Hy2Tech. Hy2Tech will also provide access to next generation hydrogen-related technologies and know-how to other interested large undertakings, as well as to SMEs and RTOs that want to develop new knowledge and applications considering the entire lifecycle of these materials. These parties should benefit from early access to the latest technologies available and may thus be able to reduce their development time.

(349) In this regard, the Commission notes that some of the participating undertakings have committed to granting access to R&D&I lab production lines for SMEs (including start-ups) and RTOs that do not have the capability to build up their own lab system (see section 2.5.3, for example recitals (233), (237), (241)), in order to carry out further material, component, cell, process or equipment research and testing. These facilities are in principle planned to function as start-up incubators for knowledge-based ventures in areas related to hydrogen technologies and systems, for different applications within the hydrogen value chain, creating as a result spill-over effects in the downstream markets.

(350) As a result of the above, the benefits of Hy2Tech are not limited to the participating undertakings, but extend to the EU economy and society. Hy2Tech will benefit various other sectors in markets that are not directly targeted by the activities covered by Hy2Tech (see recitals (254) to (266)). Through providing feedback to the disseminated knowledge and results of Hy2Tech, undertakings in other economic sectors are expected to benefit in order to improve their own equipment, materials and processes, develop new product applications and designs and acquire specific skills and know-how.

(351) Based on the description of the positive spill-over effects generated by Hy2Tech as presented in section 2.5, the Commission considers that the benefits of Hy2Tech are clearly defined in a concrete and identifiable manner and the Member States have adequately shown how Hy2Tech benefits interested parties beyond those directly involved in Hy2Tech and beyond the sectors concerned. In addition, the Commission notes that at both integrated and national governance levels Hy2Tech will monitor the correct implementation of the committed dissemination activities and spill-overs of the participating undertakings (see recitals (41) and (47)) in compliance with the provisions of the IPCEI Communication and the national funding agreements.

(352) Therefore, in view of the above the Commission considers that this eligibility condition is satisfied, in accordance with point 18 of the IPCEI Communication.

Co-financing by the aid beneficiaries

(353) As required by point 19 of the IPCEI Communication, the project must involve important co-financing by the beneficiaries. The Commission estimates that the cash flow needs for the implementation of the beneficiaries' projects are approximately EUR 8.8 billion in total, which is significantly higher than the total aid to be granted by the Member States.

'Do no significant harm' ("DNSH") principle

(354) According to point 20 of the IPCEI Communication "Member States must provide evidence as to whether the project complies with the principle of 'do no significant harm' within the meaning of Article 17 of Regulation (EU) 2020/852, or other comparable methodologies.[33] In the overall balancing of the positive effects of the aid against its negative effects on competition and trade, the Commission will consider compliance with this principle as an important factor in its assessment. In general, investments that do significant harm to environmental objectives within the meaning of Article 17 of Regulation (EU) 2020/852 are unlikely to have sufficient positive effects to outweigh their negative effects on competition and trade".

(355) Article 17 of the Taxonomy Regulation defines what constitutes 'significant harm' for the six environmental objectives covered by the Taxonomy Regulation:

1. An activity is considered to do significant harm to *climate change mitigation* if it leads to significant GHG emissions;

2. An activity is considered to do significant harm to *climate change adaptation* if it leads to an increased adverse impact of the current climate and the expected future climate, on the activity itself or on people, nature or assets;

3. An activity is considered to do significant harm to the *sustainable use and protection of water and marine resources* if it is detrimental to the good status or the good ecological potential of bodies of water, including surface water and groundwater, or to the good environmental status of marine waters;

4. An activity is considered to do significant harm to the *circular economy*, including waste prevention and recycling, if it leads to significant inefficiencies in the use of materials or in the direct or indirect use of natural resources, or if it significantly increases the generation, incineration or disposal of waste, or if the long-term disposal of waste may cause significant and long-term environmental harm;

[33] Regulation (EU) 2020/852 of the European Parliament and the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investments (the "Taxonomy Regulation"), OJ L 198, 22.6.2020, p. 13.

5. An activity is considered to do significant harm to *pollution prevention and control* if it leads to a significant increase in emissions of pollutants into air, water or land; and

6. An activity is considered to do significant harm to the *protection and restoration of biodiversity and ecosystems* if it is significantly detrimental to the good condition and resilience of ecosystems, or detrimental to the conservation status of habitats and species, including those of Union interest.

(356) In order to check compliance with point 20 of the IPCEI Communication, the Commission required that the Member States provide evidence that justifies compliance of the individual projects with the above-mentioned six environmental objectives of the Taxonomy Regulation.

(357) Furthermore, footnote 20 of the IPCEI Communication states: "For measures which are identical to measures within the Recovery and Resilience Plans [("RRP")] as approved by the Council, their compliance with the 'Do no significant harm' principle is considered fulfilled as this has already been verified". In this context, the Commission required from the Member States to indicate whether their notified project(s) is/are part of a measure included in the national RRP approved by the Council and provide the necessary documentation.

(358) The Commission therefore, firstly verified that the documentation submitted by the Member States shows that a certain number of individual projects were falling under the scope of national RRP already approved by the Council, namely the projects of AVL, Bosch AT, Christof Industries and Plastic Omnium AT from Austria, Cummins and John Cockerill from Belgium, H2B2, Iveco ES, Nordex and SENER from Spain, Neste from Finland, Alstom IT, Ansaldo, De Nora, Enel, Fincantieri and Iveco IT from Italy, 1s1 Energy from Portugal and NAFTA from Slovakia. The Commission assessed that these projects correspond to the measures in the approved RRP.[34]

(359) Secondly, the Commission assessed the environmental impact of all of the individual projects on the six environmental objectives set out in Article 9 of the Taxonomy Regulation and finds the following:

1. The Member States have shown that all individual projects within Hy2Tech contribute substantially (and thereby fulfil the required standards to do no significant harm) to the *climate change mitigation* objective by:

   a. Relating to the development of equipment for the production of electricity-based hydrogen or equipment for the use of hydrogen; or

   b. Relating to the production of hydrogen leading to at least life-cycle GHG emissions savings of 70% for hydrogen or hydrogen-based

[34] For the methodology used by the Commission to assess compliance with the DNSH principle in the context of the RRF, see Commission Notice, Technical Guidance on the application of 'do no significant harm' under the Recovery and Resilience Facility Regulation ("Technical Guidance to the RRF"), OJ C 58, 18.2.2021, p.1.

synthetic fuels relative to a fossil fuel comparator of 94 g CO_2eq/MJ; or

c. Relating to hydrogen storage facilities; or

d. Relating to the development of zero emission transport vehicles, rolling stock and vessels.

2. Concerning climate change adaptation, the Commission finds that no negative effects are foreseeable. Renewable and low-carbon hydrogen technologies along the entire value chain represent an essential step towards climate neutrality of many sectors, especially in transport and industry. They enable the transition to a climate-neutral energy system. The individual projects and the Hy2Tech as a whole do not lead to an increased adverse impact on the current or on the expected future climate, on the activities themselves or on people, nature or assets. The Commission has verified that the engineering design processes of all of the individual projects consider different climate hazards when designing and building new assets in order to ensure that the assets are resilient throughout their expected lifespan.

3. Concerning the sustainable use and protection of water and marine resources, the Member States have demonstrated that the individual projects will not be located in protected areas; they will be subject to an environmental impact assessment, where required by EU and national environmental legislation. Moreover, they will not cause significant harm to water resources, as they generally do not involve the use of process water. When they involve the use of process water, measures will be put in place to reduce impact on water bodies, in particular by the use rainwater and closed water circuits, where the process water is reused.

4. Member States have also shown that the projects under Hy2Tech will contribute to the *circular economy* and thereby fulfill the required standards to prevent significant harm by developing equipment that can easily be repaired and/or recycled. The Commission in this context observes that one of the main objectives of Hy2Tech is to reduce or replace the use of critical materials. In certain projects, the participating undertakings aim at developing technological solutions that do not involve the use of critical materials. Finally, as far as PEM technology is concerned, several projects specifically aim at researching and developing membranes without PFSA.

5. The Commission verified that the development of hydrogen technologies and systems under Hy2Tech does not lead to a significant increase of *pollution to air, water or land*. Instead, the use of hydrogen, as opposed to fossil fuels or feedstock, will lead to a decrease of such pollution. For instance, appliances that require cooling (e.g. furnace type) will be equipped with a closed cooling circuit, to keep water consumption low. The Commission further notes that when the undertakings involve the use of process water for their projects, measures will be put in place to reduce pollutants into the water, in particular by the use of rainwater and closed water circuits, enabling process water to be reused. Additional measures will also be implemented to collect rainwater and drain it in less polluted

soil areas, and process the collection of used water in closed reservoirs. Where soil pollution linked to the use of chemicals has to be controlled, operating instructions, installed retention tanks and kits in the event of a spill will be installed. Systems with flue gas cleaning (prevention of environmental pollution) will be used and monitored, where relevant.

6. Finally, the Commission considers that it is unlikely that the activities carried out under Hy2Tech will have a significant negative impact on the *protection and restoration of biodiversity and ecosystems*. Certain projects will work on programmes related to eco-design and life-cycle analysis and a biodiversity diagnosis will need to be done for new sites with the requirement that no impact is found. The individual projects will be continuously subject to national environmental inspections.

(360) In view of the above, the Commission concludes that the Member States have sufficiently demonstrated compliance with point 20, including footnote 20, of the IPCEI Communication.

Conclusion

(361) Based on all of the above considerations, the Commission considers that the general cumulative criteria for eligibility of the notified Hy2Tech for aid under Article 107(3)(b) TFEU are met.

b) General positive indicators

Involvement of the Commission in the design of Hy2Tech

(362) The Commission facilitated the emergence of Hy2Tech and helped enhance coordination between Member States in the project by having organised during the period January 2021 to August 2021 several technical meetings with open invitations for all Member States interested in participating in Hy2Tech. This is consistent with point 21(a) of the IPCEI Communication.

Governance

(363) As described in detail above under section 2.3, the governance structure of Hy2Tech involves the Commission through participation into the SB. This is consistent with point 21(c) of the IPCEI Communication

Important collaborative interactions

(364) The Member States provided detailed information (see section 2.4.3) describing how each individual project creates important collaborative interactions in terms of the number of partners, involvement of undertakings participating in the same and different TF and the involvement of undertakings of different sizes.

(365) The Commission takes note of the number of collaborations within each and across the different TF, as illustrated in table 26 and considers that such collaborations are in line with point 21(d) of the IPCEI Communication.

TF	Number of indirect collaborations	Number of direct collaborations intra TF	Direct collaborations inter TF	
			Technology Field	Number of collaborations
TF 1	168	32	TF 2	12
			TF 3	12
			TF 4	20
TF 2	132	21	TF 3	18
			TF 4	28
TF 3	70	10	TF 4	25
TF 4	100	27	-	-
Total	**470**	**90**		**115**

Table 26: Summary of the different inter and intra TF collaborations

Co-funding or co-financing by a Union fund

(366) The Commission acknowledges that some Member States (namely, Austria, Belgium, Estonia, Greece, Finland, Italy, Poland, Portugal and Spain) will be using for all of their projects co-funding or co-financing from the European Regional Development Fund, the Just Transition Fund, the Innovation Fund and the RRF. The inclusion of co-funding or co-financing of individual projects within Hy2Tech is consistent with point 21(e) of the IPCEI Communication.

Significant strategic dependency

(367) The Commission acknowledges Hy2Tech's furthering of the EU's policy to decrease its dependency on fossil energy imports and provide energy security (see recitals (315) to (318)). This is consistent with point 21(g) of the IPCEI Communication.

(368) In view of all of the foregoing, the Commission considers that on grounds of section 3.2.2 of the IPCEI Communication, five general positive indicators, in accordance with point 21 of the IPCEI Communication are met.

c) Specific criteria and parameters of assessment of the innovative nature

(369) Point 22 of the IPCEI Communication provides that R&D&I projects must be of a major innovative nature or constitute an important added value in terms of R&D&I in the light of the state of the art in the sector concerned. According to point 23 of the IPCEI Communication, projects comprising of industrial deployment must allow for the development of a new product or service with high research and innovation content and/or the deployment of a fundamentally innovative production process. Regular upgrades without an innovative dimension of existing facilities and the development of newer versions of existing products do not qualify as IPCEI.

(370) Further, point 24 of the IPCEI Communication defines the FID phase as the upscaling of pilot facilities, demonstration plants or of the first-in-kind equipment and facilities covering the steps subsequent to the pilot line including the testing phase and bringing batch production to scale, but no mass production or commercial activities.

(371) In general, the Commission verified at the level of individual aid beneficiaries and per project that each aid beneficiary has a well-defined and documented research programme regarding the innovations brought forward. The

Commission conducted a technical assessment of each individual project portfolio to determine whether the projects that contain R&D&I/FID phases comply with the innovativeness requirements as laid out in the IPCEI Communication. Whenever possible, as a first point of reference for the current state-of-the-art, the Strategic Research and Innovation Agenda ("SRIA") document of the Clean Hydrogen Joint Undertakings[35] was utilised along with any other reference document available, such as peer review papers and available project deliverables. Individual projects were deemed to have shown innovation in line with the SRIA document, if they could demonstrate at least one of the following general advances that are relevant for both R&D&I and FID:

- Technical performance beyond that of the current state-of-the-art technology at global scale;
- Deployment of a technology at a scale that clearly goes well beyond the current state-of-the-art at global scale; and
- Innovative applications or innovativeness of overall processes/approaches.

(372) In particular, the innovative nature of each individual project portfolio during the R&D&I and the FID phases was analysed taking into account the following specific principles and parameters.

(373) For the R&D&I phase:

- State-of-the-art: the Commission has compared all product and process innovations of each participating undertaking against the state-of-the-art on the market at global scale;
- Innovation: as regards the technical assessment of the innovative nature of the different projects, the Commission examined whether each project portfolio set specific targets for achieving the innovation required for the R&D&I activities proposed; whether those activities and targets go beyond the state-of-the-art; which are the innovations brought forward; and what are the benefits and expected results stemming from these innovations;
- Technical process/approach: the participating undertakings were asked to provide a clear description of the technical process/approach needed to reach the innovation targets. The Commission assessed in this context the type of technology used, the challenges encountered by each participating undertaking (see sections 0 to 0) and the means chosen to overcome those challenges; and
- Collaborations: the Commission assessed the various collaborations envisaged within and across the four TF. By examining the share of responsibilities within those collaborations, the Commission was enabled

35 This document is prepared in collaboration with Hydrogen Europe and the JRC: https://www.clean-hydrogen.europa.eu/system/files/2022-02/Clean%20Hydrogen%20JU%20SRIA%20-%20approved%20by%20GB%20-%20clean%20for%20publication%20%28ID%2013246486%29.pdf

to quantify the distribution of tasks and budget across the different activities.

(374) For the FID phase:

- Member States described the testing, sampling and upscaling processes implemented by each participating undertaking during the FID phase and explained how they differed from mass production and normal commercial activities. The Commission examined whether the FID phase contains important R&D&I activities, going beyond the above mentioned processes (i.e. testing, sampling and upscaling) but instead including an optimisation of innovation developed in the R&D&I phase; and

- The Commission further assessed the duration of the FID phase of each individual project portfolio, the criteria determining its start (i.e. at which point the undertaking starts using its pilot and industrial lines) and end period (i.e. at which point the undertaking produces samples, as well as the liability and return conditions applying to feedback sales and sales during the FID) and the scale of the FID (e.g. whether the FID phase envisaged by the individual project portfolios is disproportionate in terms of size in comparison to the number of samples /tests projected). Whenever possible, this information has been cross-examined and compared with information provided by participating undertakings active in the same sector.

(375) Specifically for hydrogen storage technologies and for hydrogen technologies for mobility, transport and subsequent industrial applications, the innovativeness of R&D&I and FID related actions was assessed as follows:

<u>Hydrogen Storage technologies</u>:

- Innovative nature and scale of the storage facility – depleted gas field, porous reservoirs, salt caverns, etc.;

- Definition of suitable innovative reservoir and tank materials and components for hydrogen storage technology and distribution;

- Hydrogen storage in new geological formations with increased maximum admissible hydrogen concentration; and

- Novel technologies offering manufacturing solutions targeting Industry 4.0 standards, in particular automation of manufacturing methods currently carried out manually, as well as digitalisation of manufacturing (digital twin, AI-based work flows, automated quality control and quality assurance).

<u>Hydrogen technologies for mobility, transport and subsequent industrial applications</u>:

- Development of first-of-a-kind components (e.g. injection systems) or systems (e.g. engines) targeting propulsion systems using hydrogen or hydrogen-derived fuels;

- Scale of deployment and management of transport systems and transport infrastructure based on hydrogen technologies;
- Deployment and development of first-of-a-kind refuelling protocols and refuelling solutions increasing reliability, safety and volume of supply;
- Scale of carbon capture and utilisation technology and/or downstream chemical and industrial processes;
- Product selectivity at scale for chemical and industrial processes downstream of carbon capture processes;
- Scale of deployed electrolyser (MW) on industrial premises;
- Innovative combination of specific technological options for hydrogen generation (e.g.: electrolyser technology, or thermochemical cycles, carbon capture technology (e.g. nature of CCS solutions at scale) and carbon sourcing (source for carbon-containing emissions); and
- Innovative deployment of a 'technical twin' solution for specific industrial processes and management of operations for targeted industrial processes.

(376) Based on the information provided by the notifying Member States and following an assessment against the relevant factors listed above, the Commission considers that the R&D&I and FID activities carried out in each TF aim to l advance the relevant technology substantially beyond current the state-of-the-art. The main general innovations and key expected results that the Commission identified as part of its assessment are described below.

<u>Major innovative nature and expected results</u>

(377) The Commission considers that the Member States have demonstrated the innovativeness of Hy2Tech including both R&D&I and FID activities, in all areas of the hydrogen technologies value chain that are specifically targeted by Hy2Tech.

(378) In TF 1, the focus will be on the development of hydrogen generation technologies. The main general innovations, as listed in table 27, consist of the following:

- Improving the cells and stack performance in terms of durability, lifetime, efficiency, and overall cost reduction. This requires the development of advanced materials, optimised microstructures and innovative manufacturing processes for the next generation core hydrogen products (i.e. cells, catalysts, membranes, ionomers, MEAs, electrode materials, stacks and BOP). This process will enable the adoption of wider hydrogen technologies through scaled-up and cost-effective production of cells and stacks, with further integration in various hydrogen systems;
- The development of high-fidelity numerical models and digital twins for electrolysis systems and electrolysers manufacturing plants are expected to provide adequate control systems for electrolyser integration within renewable power plants, as well as with industrial systems coping with

variable energy generation (e.g. PV, wind or hydro). This development is needed in order to increase the hydrogen system performance, flexibility and base load behaviour, due to temperature and pressure management optimisation and reduction of start-up time;

- Although the variety of renewable sources seems to be well developed, R&D&I is necessary to develop new hydrogen technologies that overcome the intermittence of renewable energy sources and enable continuous generation of large volumes of renewable and low-carbon hydrogen. For this purpose, advanced large-size base-load, cost-effective and long-life cycle electrolysers will be developed; and

- Different electrolyser system platforms with different key innovations will be developed. These include reversible systems, advanced control (i.e. predictive maintenance), systems to directly couple with wind turbines, or renewable plants (mainly mix of wind farms and PV plants), large electrolysis systems designed for direct coupling to the electric grid, systems with the possibility to operate in co-electrolysis mode to produce syngas as base for synthetic fuel and systems that integrate electrolysers and wind turbines, or PV solar cells (also with the potential of co-generation of heat and electricity via electrolysis using the renewable electricity generated).

(379) Regarding the processes for the development of hydrogen technologies the main general innovations consists of the following:

- Hydrogen stacks and systems will be scaled-up with innovative Industry 4.0 approaches, which will enable close monitoring of the stack and system performance. New electrolysis stack and system architectures for large-scale installations will be developed, including integrated testing platforms that are needed to evaluate the electrolysers' performance and robustness in a fully operational environment; and

- Joint innovative laboratory facilities will be built enabling validation and testing of technology components and systems. These facilities will enable multiple testing of innovative technologies and they will be open to technology developers and end users.

(380) The key expected results of the TF 1's R&D&I and FID activities and the corresponding contribution of the participating undertakings are the following:

Expected results	Participating undertakings
R&D&I activities	
Reduction/elimination of rare / expensive / environmentally critical materials (such as noble metals) and replacement by materials well suited for recycling and a circular economy.	Advent, Cummins, Elcogen, Elogen, Genvia, H2B2, McPhy, SENER, Stargate, Sunfire, 1s1 Energy
New design of electrolysis cells, stacks and systems matching the requirements of high robustness, resilience against tolerances, low costs, design for recycling, etc.	Advent, Ansaldo, AVL, Christof Industries, Cummins, De Nora, Elcogen, Elogen, Genvia, H2B2, John Cockerill, McPhy, Nordex, SENER, Stargate, Sunfire, 1s1 Energy
Demonstration of novel electrolysis technology for accelerated market deployment.	Advent, AVL, Christof Industries, Cummins, De Nora, Elcogen, Elogen, Enel, Genvia, H2B2, McPhy, Nordex, SENER, Stargate, Sunfire,
BOP (including, hydrogen production systems as well as entire renewable plants) components and subsystem of higher efficiency and better performance, improved durability and reliability and lower costs.	Advent, Ansaldo, AVL, Christof Industries, Cummins, De Nora, Elcogen, Elogen, Enel, Genvia, H2B2, John Cockerill, McPhy, Nordex, Stargate, Sunfire, Synthos, 1s1 Energy
Improvement of power density, efficiency, stationary and transient performance, safety and security, durability, and reliability as well as reduction of CAPEX and OPEX of hydrogen generation systems.	Advent, AVL, Christof Industries, Cummins, De Nora, Genvia, Elogen, Enel, H2B2, John Cockerill, McPhy, SENER, Nordex, Stargate, Sunfire, 1s1 Energy
Optimal integration (regarding electric grid, gas flux/supply, heat flux, digital control) of hydrogen generation systems in European networks.	Ansaldo, Cummins, De Nora, Enel, Genvia, John Cockerill, McPhy, Nordex, Stargate, Sunfire
Development and testing environment for components, prototype systems and plants for performance verification and validation with special focus high flexibility regarding system requirements and operating conditions of different sectors.	Advent, AVL, Christof Industries, Cummins, Enel, Genvia, H2B2, John Cockerill, Nordex
Development of advanced control and algorithm (i.e. digital twin) to improve maintenance and durability of electrolysers systems.	Cummins, De Nora, Genvia, H2B2, McPhy, Nordex, SENER, Stargate, Sunfire, 1s1 Energy
Collaboration between TF 1 electrolyser OEMs on standardisation, certification & harmonisation of data protocols.	AVL, Cummins, Elcogen, Elogen, Genvia, John Cockerill, McPhy
FID activities	
Continuous improvement of components and systems during scale-up based on large-scale technologies	Advent, Ansaldo, AVL, Christof Industries, Cummins, Elcogen, Elogen, Enel, Genvia, H2B2, John Cockerill, McPhy, Nordex, SENER, Stargate, Sunfire, Synthos, 1s1

	Energy
Upscaling of components and systems, including improvement and automation of manufacturing processes, minimization of consumption of energy and resources.	Advent, Ansaldo, AVL, Christof Industries, Cummins, De Nora, Elcogen, Elogen, Genvia, H2B2, John Cockerill, Ørsted, SENER, Stargate, Sunfire, Synthos, 1s1 Energy
Establishment of a seamless, fully digitised value/supply chain, applying advanced digital and software technologies.	Advent, Ansaldo, Cummins, De Nora, Elcogen, Elogen, Genvia, John Cockerill, SENER, Stargate, 1s1 Energy
Standards and protocols for quality, safety, and security assurance along with automated, digitised assurance systems to be implemented in the production processes.	Advent, Ansaldo, AVL, Christof Industries, Cummins, De Nora, Elcogen, Elogen, Genvia, H2B2, John Cockerill, McPhy, Nordex, SENER, Stargate, Sunfire, 1s1 Energy
Pilot development of components and systems; verification and validation of product and process quality at industrial scale and in real environment.	Advent, Ansaldo, AVL, Christof Industries, De Nora, Elogen, Enel, Genvia, H2B2, John Cockerill, McPhy, Nordex, SENER, Stargate, Sunfire, Synthos, 1s1 Energy

Table 27: Expected results from innovation - TF 1

(381) The focus of TF 2 will be on the development of FC technologies and processes, as well as on the development of associated technologies. Hy2Tech seeks to develop multiple FC technologies, such as PEMFC, the alkaline FC ("AFC") and SOFC, and associated technologies, namely batteries, power electronics and hydrogen combustion systems (e.g. ICE and turbines).

(382) Concerning FC technologies and processes, the main innovations expected to result from Hy2Tech consist of the following:

- The core developments within the component level for PEMFC are: innovative catalyst (e.g. consisting of non-PGM), membranes and MEA (e.g. reducing the fluorine content or avoiding the use of perfluorinated polymers, being operable at higher temperatures or being highly recyclable), gas diffusion layers, BPP being produced at very low cycle times, and coatings allowing for the required longevity of FCS;

- The results achieved at component level will enable the required innovations at stack level in terms of durability, longevity, gravimetric and volumetric power density, modularity, scalability, efficiency, and cost. The development of innovative FC stacks, regardless of the technology, involves the development of new architectures and the application of D2C, D2M and design-to-recycling principles, as well as the development of specific operating strategies (e.g. for low temperature ("LT") PEMFC, operating temperatures around 100 °C);

- In the context of SOFC, the main innovation driver is the general improvement of the electrical efficiency (> 60%) and overall efficiency with heat extraction (up to 90%). At component level, key innovation drivers are material and structural developments, targeting the lowering of operating temperatures or the reduction/avoidance of critical raw materials (e.g. Co and Ni). The innovation at component level will also allow for the development of hydrogen systems capable of running on a broad variety of gaseous and liquid fuels (e.g. methane, methanol, ammonia, hydrogen or even natural gas or biogas), most of which are available as power-to-x products produced from renewable and low-carbon hydrogen. Therefore, the SOFC will be an important component of a decentralised European energy supply and a contributor to the lowering of GHG emissions;

- Concerning AFC, the core developments will be on advanced gas diffusion electrodes and catalysts for enabling increased efficiency and long operating life. Furthermore, recycling processes will be developed for material recovery in line with a circular economy approach;

- Standardised testing procedures will also be considered as key innovations that will enable validation at all levels of the value chain, thus allowing for further accelerated realisation of industrial development plans; and

- In addition to innovations in the technologies for generation of hydrogen, digital innovations (such as, IoT, digital twins of components, stacks and systems, predictive maintenance and control, as well as simulations and other AI supported environments) will facilitate substantial improvements in the production line, as well as during operations. New scaling concepts (e.g. virtual power plant) and new business models (e.g. pay per kW) will be introduced. Digital innovation will enable the development of open standards and interfaces to support the integration of the FC in various applications, as well as the implementation of an open European hydrogen data hub.

(383) Hydrogen FC lack power density and the ability to recuperate energy, i.e. they cannot be recharged if excess energy is instantly available. Therefore, a secondary energy source in form of associated technologies is needed. These associated technologies face comparable challenges, such as lacking longevity (e.g. batteries <3000 cycles), low power (e.g. batteries: <1 kW/kg), low degree of maturity (FC boost), reliance on critical raw materials (e.g. batteries: Co, Ni and natural graphite), and cost (FC boost: 500€/kWh). Furthermore, direct current power converters ("DC-DC") along with new energy management systems have to be tailored to the operation of FCS, and hence achieve an improved energy efficiency and reduced weight and noise level.

(384) The key expected results of the TF 2's R&D&I and FID activities and the corresponding contribution of the participating undertakings are the following:

Expected results	Participating undertakings
R&D&I activities	
Reduction / elimination of rare / expensive / environmentally critical materials.	Advent, ALSTOM FR, Bosch DE, EKPO, Elcogen, Genvia, HYVIA, Iveco CZ, Symbio, 1s1 Energy,
Higher operating temperature in low temperature LT PEMFC, in order to simplify system cooling, leading to a reduction/replacement of fluorine content in stack components, hence to increased recyclability.	ALSTOM FR, Arkema, EKPO, HYVIA, Plastic Omnium AT, Symbio, 1s1 Energy
Establishment of recycling concepts.	Advent, Arkema, Bosch DE, Daimler Truck, EKPO, Elcogen, Genvia, HYVIA, Iveco CZ, Nedstack, Plastic Omnium AT, Symbio, 1s1 Energy
Innovative stack components with improved longevity, production cost and high conductivity.	Advent, Arkema, Bosch DE, Daimler Truck, De Nora, EKPO, Elcogen, Genvia, HYVIA, Iveco CZ, Nedstack, Plastic Omnium AT, Symbio, 1s1 Energy,
Novel stack concepts achieving an increased durability, longevity, gravimetric and volumetric power density, scalability and efficiency.	Advent, Ansaldo, Bosch DE, Daimler Truck, De Nora, EKPO, Elcogen, Fincantieri, Genvia, HYVIA, Iveco CZ, Plastic Omnium AT, Symbio, 1s1 Energy,
Novel stack concepts allowing reverse operation (FC / electrolyser) and multifuel operation.	Advent, Ansaldo, Bosch DE, Elcogen, Iveco CZ, Genvia, Symbio, 1s1 Energy,
Establishment of a European supplier base for innovative BoP components.	Advent, Ansaldo, Bosch DE, Daimler Truck, De Nora, Elcogen, Fincantieri, Genvia, HYVIA, Iveco CZ, EKPO, Plastic Omnium AT, Symbio
Standardized testing and characterization procedures for components and stacks, as well as availability of testing environments for components, stacks and systems.	Advent, Bosch DE, Daimler Truck, EKPO, Elcogen, Fincantieri, Genvia, Iveco CZ, NedStack, Plastic Omnium AT, Symbio, 1s1 Energy,
Integration of digitalization concepts (e.g. IoT and digital twin) into systems to enable new business models.	Advent, Ansaldo, Bosch DE, EKPO, Genvia, Iveco CZ, Plastic Omnium AT, Symbio
New, highly integrated system designs, allowing for easy integration.	Advent, Alstom FR, Ansaldo, Bosch DE, Daimler Truck, De Nora, Elcogen, Fincantieri, Genvia, HYVIA,Iveco CZ, Plastic Omnium AT, Symbio
Development and integration of novel supporting technologies that are necessary for the improved operation of FCS.	Alstom FR, Bosch DE, Plastic Omnium AT, Symbio
Innovative BOP system specifically designed for	Daimler Truck, Plastic Omnium AT,

heavy duty applications.	Symbio
Real-world performance and lifetime testing of next generation FCS technology platform in heavy duty applications, such as long-haul trucking, distribution & collection of goods.	Alstom FR, Daimler Truck, EKPO, Plastic Omnium AT
Development of technologies to facilitate the upscaling process, including innovative end-of-line testing for factorial reduced cycle times and increased product quality.	Arkema, Bosch DE, De Nora, EKPO, Elcogen, Advent, Genvia, HYVIA, Nedstack, Plastic Omnium AT, Symbio
FCS optimised for typical HDV applications with zero CO_2 emissions.	Bosch DE, Plastic Omnium AT, Symbio
FID activities	
Established design-to-cost concepts for FC components, stacks and systems, hence substantially reduced production costs.	Alstom FR, Advent, Ansaldo, Bosch DE, Daimler Truck, De Nora, EKPO, Elcogen, Genvia, HYVIA, Nedstack, Plastic Omnium AT, Symbio
Pilot production of components and systems; verification and validation of product and process quality.	Advent, Alstom FR, Ansaldo, Arkema, Bosch DE, De Nora, EKPO, Elcogen, Fincantieri, Genvia, HYVIA, NedStack, Plastic Omnium AT, Symbio
Implementation of digitalization concepts (e.g. Industry 4.0 and digital twin) for improved production processes.	Advent, Ansaldo, Bosch DE, De Nora, EKPO, Elcogen, Genvia, HYVIA, Symbio
Production capacity available for associated technologies	Advent, Arkema, Bosch DE, Genvia, NedStack, Symbio
Maintenance and service process based on digital and cloud based services for optimised fleet utilisation, energy efficiency, availability and costs.	Bosch DE, Daimler Truck, EKPO, Genvia, HYVIA, Plastic Omnium AT
Commissioning and calibration of flexible and scalable production process for next generation heavy duty FCS products	EKPO, Nedstack, Plastic Omnium AT, Symbio

Table 28: Expected results from innovation - TF 2

(385) TF 3 will focus on the development of technologies for storage (e.g. UGS, compressed storage systems and pressure vessels), transportation and distribution of hydrogen, including refuelling.

(386) Based on the current state-of-the-art there are limited opportunities for UGS of hydrogen in porous structures, such as depleted gas fields. The storage of hydrogen in depleted gas fields currently amounts to 10% of hydrogen in the mixture with natural gas. Moreover, for a gaseous hydrogen truck system, the refuelling time is typically above 20-30 min. The innovative activities therefore will focus on:

- Increasing hydrogen concentration and reducing the refuelling time to below 15 minutes for a hydrogen truck;
- Establishing a methodology to assess the geological structure for the storing of hydrogen;
- Design of blending/deblending technology for hydrogen purification from natural gas;
- New test facilities will be built enabling validation and testing of technology components and systems. These facilities will allow multiple testing of innovative technologies and they will be open to technology developers and end users;
- Development of electro-chemical and thermo-chemical compression systems for hydrogen handling;
- Using existing or new porous gas fields for storing of hydrogen in pure form or in the mixture with natural gas in higher concentration to ensure secure supply of energy in the distribution system;
- Real storing of hydrogen in the mixture or in pure form in porous type of underground storage; and
- Creation and verification of models simulating the hydrogen behaviour in the reservoir.

(387) The current state-of-the-art compressed hydrogen storage systems are costly at 1000 € / 1 kg stored hydrogen. In these storage systems, the pressure vessel is a type IV pressure vessel comprising a thermoplastic liner encapsulated by a carbon-fibre composite structure. The gravimetric efficiency of a 700 bar hydrogen storage system is typically limited to 0.04 kg hydrogen / kg of system. Systems to detect the structural damage on such vessels exist only at laboratory scale. The main general innovations consists of the following:

- Improved performance in terms of weight and material savings;
- Embedded sensors and monitoring strategy for enhance safety of pressure tanks;
- Optimized design of the storage system regarding performance and cost;
- Computer-aided engineering ("CAE") tools optimization for a lean design of the storage system;
- Design to cost with a competitive TCO for the end users;
- Enhanced Performance of materials (e.g. resin, carbon fibre, etc.) with high sensitivity and thermal stability up to 130°C;
- High safety & savings due to close monitoring of tank through production to end-of-life; and

- Optimisation of materials used for manufacturing Type IV and V hydrogen storage tanks, with integrated optical fibre sensors for online monitoring of hydrogen permeability and tanks' stresses.

(388) The current state-of-the-art pressure vessels are made of an epoxy resin. The manufacturing process of these vessels typically requires a long curing time, and the resulting thermoset composite structure is not recyclable. In terms of recycling, the process exists at laboratory scale but requires high volumes of energy and is not cost competitive. The main general innovations consists in the following:

- Novel bio-based thermoplastic materials with high performance for high pressure vessels;
- New high temperature thermoplastic composites tapes for high performance and high rate winding of large high-pressure vessels;
- Developing thermoplastic recyclable material solutions for high pressure vessels. The life cycle of these materials would be further improved through the use of bio-based polymers like Rilsan® PA 11 synthetised from castor oil;
- Proven recyclability through compounding and depolymerisation;
- Recycling process for thermoset composites; and
- New thermoset resins with optimised curing time.

(389) According to the current state-of-the-art the processes for gaseous hydrogen storage technology generate approximately 1000 parts/year. This is driven by the slow manufacturing time for a hydrogen pressure vessel and the significant time needed to test the vessel at the end of the production line. The main general innovations consists of the following:

- Novel manufacturing and testing concepts for composite pressure vessels;
- Development of a LOHC reactor technology to optimise the energy required for the reactor technology;
- Development of new and innovative processes for cryogenic storage systems;
- Development of a novel high rate production line for thermoplastic composite tapes;
- Deployment of high performance polymer impregnated carbon fibre tapes for tank fast winding; and
- Development of new and optimised processes for thermoset composite pressure vessels including end of line testing and embedding sensors.

(390) The key expected results of the TF 3's R&D&I and FID activities and the corresponding contribution of the participating undertakings are the following:

Expected results	Participating undertakings
R&D&I activities	
Thermoplastic and thermosetting composites for high pressure hydrogen tanks for mobility, transport and HRS.	Arkema, B&T Composites, Daimler Truck, Faurecia, Plastic Omnium FR
Piezoelectric polymer sensors for composite tank health monitoring.	Arkema, Plastic Omnium FR
Conformable and modular tank systems for on-board storage.	Arkema, B&T Composites, Faurecia, Plastic Omnium FR
Concepts for recycling carbon fibre from high pressure vessels.	Arkema, B&T Composites, Faurecia, Plastic Omnium FR
Structural health monitoring strategies for high pressure vessels.	Arkema, B&T Composites, Faurecia, Plastic Omnium FR
Maximisation of heat recovery for LOHC and metal hydride solutions.	Enel
Achievement economic and durability of solid-state storage compared with gas pressurized solutions, (i.e. increasing the storage dimension and system performance, etc.)	Enel
Cryogenic storage systems for heavy duty applications.	Daimler Truck, Faurecia
Lower cost carbon fibre with high performances.	B&T Composites, Daimler Truck, Faurecia
Recycling technology for thermoset pressure vessels.	Daimler Truck, Plastic Omnium FR
Validation of new storage technologies in properly designed facilities.	B&T Composites, Enel
Development of hydrogen storage solutions for HRS.	Arkema, B&T Composites, Faurecia
Exchange of new knowledge allowing to define the expected functionalities and parameters of refuelling / charging stations.	Daimler Truck
FID activities	
Implementing a hydrogen heavy duty truck fleet demonstration project in collaboration with OEM and logistics undertakings.	B&T Composites, Daimler Truck, Faurecia, Neste, Ørsted, Plastic Omnium FR
Deploying hydrogen heavy duty inland waterway vessels / ships.	Faurecia, Plastic Omnium FR
Bringing hydrogen as fuel to multiple sectors (e.g. mining, forest and agriculture).	B&T Composites, Faurecia, Neste, Plastic Omnium FR
Large-scale production of new families of polyamide compounds materials for liners and acrylic resins for thermoplastic composites.	Arkema, Plastic Omnium FR
Large-scale production of carbon fibre with lower CO_2 footprint and high performance.	Faurecia
Upscaling of pilot lines for high performance polymer impregnated carbon fibre tapes for tanks fast winding.	Arkema

Upscaling of pilot lines for piezoelectric polymer.	Arkema
Sensors for health monitoring.	Arkema
Upscaling of high pressure vessels.	Arkema, B&T Composites, Faurecia, Plastic Omnium FR
Upscaling of pilot lines for cryogenic hydrogen storage systems.	Arkema, Faurecia
Optimisation of the interaction between fluctuating renewables supply and electrolyser-based hydrogen production.	B&T Composites, Enel, Ørsted
Optimisation of the hydrogen storage system operation for a P2P renewable and low-carbon hydrogen system.	NAFTA
Pilot verification and validation of the quality of components and systems.	B&T Composites, Enel
Definition and validation of optimal integration of renewable and low-carbon hydrogen technologies and renewable plants	Enel, Ørsted
Deployment of high-capacity refueling, compressing and storage technologies for mobility and transport applications.	Ørsted
Implementation of LOHC facilities.	Enel
Solid state storage systems production.	Enel
Implementation of underground facilities for bulk hydrogen storage.	NAFTA
Deployment of technologies to separate hydrogen from natural gas.	NAFTA

Table 29: Expected results from innovation - TF 3

(391) TF 4 will focus on the development of hydrogen technologies for mobility and transport applications.

(392) For large engine systems, the state-of-the-art is injection and admission systems for gas, diesel and gasoline engines, whereas technologies for injecting alternative fuels barely exists. Some concepts for injection systems are available but they do not cover all types of fuels and engine sizes in one platform. For hydrogen, methanol and ammonia for instance, there are currently no industrial solutions for 4-stroke ICE.

(393) The fuel injection system required for the use of alternative fuels shall enable port fuel injection, as well as direct injection to allow combustion optimisation of large engines. Efficiency and emission targets, as well as a lifetime goal of 20,000 h must be reached. In order to achieve these targets, alternative fuels will require new combustion systems for the development of compatible injection systems. The main general innovations consists of the following:

- Flexible concepts in terms of performance, pressure ranges, injection quantities, lubricity, viscosity, density and corrosiveness of the fuel;
- Portfolio of new materials and processing technology; and

- Validate newly designed solutions through delivering quality testing results of testing.

(394) For railway freight applications, there are currently no zero-emissions solutions available on the market worldwide. In order to meet the market needs for zero-emissions, the main general innovations will focus on:

- Total traction power at wheel rim: power available for traction from battery and FC;
- Autonomy: volume of hydrogen stored has to be in line with the targeted performances for the different applications;
- Refuelling time: time necessary to refill or replace energy storage; and
- Shock, vibration, thermal and aeraulic functions: FC and battery constraints shall be validated.

(395) The deployment of FC technology for zero-emissions LCVs will require innovative activities in order to achieve certain KPIs, in respect of driving range, refuelling time, durability, weight and packaging, TCO and on-board energy management system. Current deployments of FC for LCVs have so far been limited to range-extender models, where a low power FC is used to extend the operating range of a battery EV. The necessary R&D&I activities will not focus only on the core FC technology (under TF 2), but also on key auxiliaries that are necessary on-board the vehicle, namely, air compressors, hydrogen storage tanks, power electronics and system integration.

(396) In the case of combined cycle gas turbines for maritime applications the global state-of-the-art for the use of hydrogen-based solution is limited to a number of prototypical applications mainly based on FC technology. The regulatory framework is still under development and there are currently no ships on the market equipped with hydrogen power generation in large sizes (MW). The new hydrogen technologies shall address certain KPIs in respect of durability, compactness and compatibility with maritime conditions (e.g. saline air, temperature, shock, rolling and vibration) and they shall be designed and developed taking into account the limited space and volume, as well as safety issue, in particular in the case of passenger ships. Therefore, the focus of this TF in this respect in order to achieve the above KPIs is to develop HGPGS that can include combined cycle gas turbines with FC, ICE or batteries.

(397) The key expected results of the TF 4's R&D&I and FID activities and the corresponding contribution of the participating undertakings are the following:

Expected results	Participating undertakings
Key elements and components for the supply of hydrogen (e.g. loading station, transport trailers) and refuelling station technologies to enable large-scale heavy duty application.	Daimler Truck, Iveco ES, Plastic Omnium FR
Design of efficient, affordable and ready-to-integrate powertrain components: FC, hydrogen tanks, and FC specific	Alstom FR, Alstom IT, Bosch AT, HYVIA, Iveco CZ, Iveco

components: thermal management, blowers, hydrogen loop, fuel injection equipment, etc.	ES, NedStack, Plastic Omnium AT, Plastic Omnium FR
Design of efficient, affordable and ready-to-integrate powertrain components based on ICE hydrogen.	Bosch AT, Fincantieri, Iveco CZ, Plastic Omnium FR
Setting of a new reference standard for the use of hydrogen in railway activities, especially meeting safety constraints.	Alstom FR, Alstom IT, Bosch AT, Plastic Omnium FR
Available fuel injection technology for alternative CO_2-neutral fuels (e.g. hydrogen, ammonia and methanol).	Bosch AT, Iveco CZ
Introduce to the market at full-scale different types of vehicles fuelled with hydrogen (i.e. busses, heavy trucks, light commercial vehicles, municipal vehicles, maritime cruise ships, barges for inland waterway and trains).	Alstom FR, Alstom IT, Bosch AT, Daimler Truck, HYVIA, Iveco CZ, Plastic Omnium AT, Plastic Omnium FR
Development of a modular and scalable hydrogen platform.	Alstom IT, HYVIA, Plastic Omnium FR
Definition of the perimeter and characteristics of systems to be integrated within the FCE vehicles (e.g. fuel cell, hydrogen fuel systems, thermal systems, e-driven traction, etc.).	Alstom IT, Daimler Truck, HYVIA, Iveco CZ, Iveco ES, Iveco IT, Nedstack, Plastic Omnium AT, Plastic Omnium FR
Unified pressure system for trucks and buses.	Iveco CZ, Iveco ES
Innovative lightweight materials for hydrogen vehicles.	HYVIA, Iveco CZ, Plastic Omnium FR
Develop green cruise vessels integrating hydrogen-based technologies.	Bosch AT, Fincantieri, Nedstack, Plastic Omnium FR
Provide mobility and transport fleet operators with a complete turnkey hydrogen solution at competitive TCO.	Alstom IT, HYVIA, Iveco CZ, Iveco ES, Iveco IT, Plastic Omnium AT, Plastic Omnium FR
Improvement in energy efficiency and lifespan of components, subsystems, vehicle systems and integrated logistics applications.	Alstom IT, Bosch AT, Daimler Truck, HYVIA, Iveco CZ, Plastic Omnium FR
Innovative logic for power system management.	Fincantieri, Iveco CZ
Innovative EMS and safety systems for FC mobility and transport.	Alstom FR, Alastom IT, Fincantieri, HYVIA, Plastic Omnium AT, Plastic Omnium FR
Safety rules, processes, service manuals, after crash manuals, etc.	Alstom FR, Alstom IT, Bosch AT, Daimler Truck, HYVIA, Iveco ES, Plastic Omnium AT, Plastic Omnium FR

Effective vehicles with respect to power efficiency.	Alstom FR, Alstom IT, Bosch AT, Iveco CZ, Iveco ES, Plastic Omnium AT
Designing architectural solutions to achieve zero emission operations of ships under specific conditions.	Bosch AT, Fincantieri
Increased overall energy efficiency of power generation systems by implementing dedicated heat recovery systems for combined cycles gas turbine for maritime applications.	Fincantieri
Modular hydrogen storage and handling systems for maritime applications	Plastic Omnium FR
Development of an ICE fuelled with hydrogen for maritime operations.	Bosch AT, Fincantieri
Integrating the new technologies (i.e. hybrid main components, auxiliaries, etc.) on-board new built ships to prove and validate fit- for-purpose operations.	Bosch AT, Fincantieri, Plastic Omnium FR
Standardization of hydrogen storage systems for (inland) shipping applications.	Plastic Omnium FR
Innovative safety systems for FC trains, enabling the highest safety standards.	Alstom FR, Alstom IT
Flexible and smart energy management system developed for different mobility and transport applications integrating model-based and data driven approaches.	Alstom IT, Iveco CZ, Plastic Omnium AT
Demonstrate innovative technical solutions for hydrogen railway mobility and transport that will enable different mission profiles, including bi-modal use on electrified lines	Alstom FR, Alstom IT, Bosch AT
Innovative BOP system specifically designed for heavy duty applications.	Plastic Omnium AT
Testing of next generation FCS technology platform in heavy duty applications.	Daimler Truck, Iveco ES, Plastic Omnium AT
FID activities	
Develop adapted and efficient processes and assembly lines to produce hydrogen FC trucks and LCVs.	Daimler Truck, HYVIA, Iveco ES
Upscaling of hydrogen technologies for the development of a HGPGS.	Fincantieri
Installation of combined cycle gas turbine package on specific ship types.	Fincantieri
Competitive and locally integrated hydrogen components.	Bosch AT, HYVIA
Upscaling of technologies for the production of hydrogen tanks and powertrain components with effective and scalable production processes.	Alstom IT, Bosch AT, Plastic Omnium AT, Plastic Omnium FR
Hydrogen-powered railway demonstrator offering sustainable means of transport to regions with inadequate electrification infrastructure.	Alstom FR, Alstom IT, Plastic Omnium FR
Large-scale demonstration of integrated PtX fuel production facilities producing (in addition to hydrogen for heavy duty road transportation) e-fuels for maritime and aviation.	Neste, Ørsted, Plastic Omnium FR
Operation and safety competence for carbon capture and storage operations in refinery settings.	Neste
PtL plant: develop and optimise the PtL synthesis concept for e-kerosene, completing the full value chain from renewable	Neste, Ørsted

electricity and CO_2 to sustainable aviation fuel.	
Heating integration for all different components and the district heating networks.	Ørsted
Development of the PtL synthesis and upgrading process trains, considering further the upstream power supply, the electrolysis as well as the carbon capture steps.	Neste, Ørsted
Maintenance and service process based on digital and cloud based services for optimised fleet utilization, energy efficiency, availability and costs.	Daimler Truck, HYVIA, Plastic Omnium AT
Commissioning and calibration of flexible and scalable production process for next generation heavy duty FCS.	Iveco ES, Plastic Omnium AT
Deployment of FCEV tractor units with 600 - 800 km driving range.	Ørsted
Evaluation of performance of FCEV and hydrogen-ICE HDV in daily operation at customers.	Iveco IT, Plastic Omnium AT
Developing new solutions for integrating the electrolyser into refining, renewable fuel and intermediate chemical production.	Neste

Table 30: Expected results from innovation - TF 4

(398) Based on the above, the Commission considers that content of the R&D&I and FID projects that will be performed within Hy2Tech satisfy the specific criteria set out in points 22 to 24 of the IPCEI Communication.

3.3.2.3.Importance of Hy2Tech

(399) According to section 3.3 of the IPCEI Communication, in order to qualify as an IPCEI, a project must be important quantitatively or qualitatively. As demonstrated below, Hy2Tech is particularly large in size and scope and implies a very considerable level of technological and financial risk.

(400) The Commission considers Hy2Tech to be an important project meeting the quantitative and qualitative requirements set out in section 3 of the IPCEI Communication, based on the following:

- Hy2Tech represents an important contribution to Union's objectives (see recitals (309) to (325));
- Hy2Tech is designed to overcome important market or systemic failures (see recitals (326) to (338));
- A high number of Member States are involved (see recital (339));
- Open procedure for Member States to participate in Hy2Tech (see recital (340));
- Hy2Tech generates positive spill-over effects (see recitals (341) to (352));
- Hy2Tech involves important co-financing by the beneficiaries (see recital (353));
- Hy2Tech complies with the DNSH principle (see recitals (354) to (360));

- Involvement of the Commission in the design of Hy2Tech (see recital (362));
- A governance structure is set (see recital (363);
- Hy2Tech involves important collaborative interactions (see recitals (364) to (365));
- Hy2Tech involves co funding or co-financing from a Union fund (see recital (366));
- Hy2Tech addresses a significant strategic dependency (recital (367)); and
- The innovative character of all of the hydrogen technologies involved in the relevant TF (see recitals (377) to (397)).

(401) In addition, the Commission acknowledges the considerable level of technological, economic and financial risks and other risks for both R&D&I and FID activities entailed in Hy2Tech.

(402) Regarding the technological risks, numerous projects under Hy2Tech will be confronted with a number of technological hazards that could lead to an unacceptable failure in performance, cost and sustainability. As different hydrogen applications require different purities, the development of hydrogen technologies should match these requirements. Considering however the complexities inherent in performing R&D&I in the hydrogen sector, damages to devices and processes using hydrogen during the implementation of the multiple hydrogen technologies are highly probable. Dealing with this challenge can further lead to significant delays, thereby jeopardising the success of the each individual project and Hy2Tech as a whole.

(403) In particular, the hydrogen technologies addressed in Hy2Tech are currently at an early stage of their development and they will require further validation and upscaling, in order to meet the needs of mobility, transport and industrial applications. In addition, a number of the materials, (sub-) components, and auxiliary systems required for the successful implementation of hydrogen projects are either do not yet exist or have not yet been optimised, or they are only available at lab or demonstrator scale. It is therefore likely that that delays will occur during the R&D&I phase, especially in cases of high-volume production requirements.

(404) During the FID Phase, Hy2Tech is confronted with the risk of deploying technologies that are not compatible with qualitative requirements of equipment and infrastructure currently available on the market. For instance, the purity demands for the different hydrogen applications vary widely; certain types of FC (e.g. LT-PEM mainly used in transport applications) require very high purity hydrogen, while other applications are much more tolerant.

(405) The technological risks also extend to the field of safety regulations. The handling of hydrogen requires multiple safety precautions. For example, hydrogen equipment requires a multitude of sensing and emergency shut off technical features, adding more complexity to the technical layout. Hydrogen technologies need to comply with established safety and standardisation rules

that need to be verified by the responsible authorities. Potential disagreements over the technical layout can lead to delays and additional costs.

(406) The deployment of hydrogen also faces economic and financial risks, considering that the amounts involved in Hy2Tech are significant while the hydrogen market is still uncertain. This uncertainty derives from the assumption that the participating undertakings may introduce their products on the market with a delay or the cost of competitive hydrogen technologies may decrease quicker than anticipated, thereby posing a significant economic risk to the innovative application of Hy2Tech hydrogen technologies.

(407) The participating undertakings furthermore will face strategic and organisational risks. The implementation period of Hy2Tech and of the individual projects will be lengthy, and numerous changes of the projects' operating conditions are very likely to occur. The planned collaborations and synergies between multiple different stakeholders from various sectors, are expected to entail challenges. For instance, RTOs engaged in the development of certain building blocks of hydrogen technologies will need to cooperate with undertakings to achieve common scientific and technological objectives. In addition, the different contributors to Hy2Tech will have to align their development schedules to reach the same level of maturity at the same time, in order to fit with customers' demand requirements. Any delay therefore will jeopardize the effective implementation of Hy2Tech.

(408) Finally, the supply risks of Hy2Tech will be significant given that the necessary technologies required to establish a hydrogen economy can only be developed optimally, if sufficient amounts of certain critical raw materials (e.g. Ir, Scandium ("Sc") or Yttrium ("Y")) are available. Any shortage in supply of such critical elements will inevitably and materially hinder the development of hydrogen technologies of Hy2Tech.

3.3.2.4.Conclusion on the eligibility of Hy2Tech

(409) In view of the above, the Commission concludes that the eligibility criteria of the IPCEI Communication are met by Hy2Tech.

3.3.3 *Compatibility criteria*

(410) When assessing the compatibility with the internal market of aid to promote the execution of an IPCEI on the basis of Article 107(3)(b) TFEU, the point 27 of the IPCEI Communication requires the Commission to take into account a number of criteria, as elaborated below. Moreover, point 28 of the IPCEI Communication also requires that the Commission carries out a balancing test to assess whether the expected positive effects outweigh the possible negative effects.

(411) Having regard to the conclusion that, for the reasons set out in section 3.3.2 above, Hy2Tech fulfils the eligibility criteria set out in section 3 of the IPCEI Communication, and the Commission considers that the presence of a market failure or important systemic failure can be presumed for the individual components of Hy2Tech, in line with point 29 of the IPCEI Communication.

(412) The Commission analysed the compatibility criteria at the level of individual aid beneficiaries and per project.[36]

3.3.3.1. Necessity and proportionality of aid

Necessity of aid

(413) According to point 30 of the IPCEI Communication, the aid must not subsidise the costs of a project that an undertaking would anyhow incur and must not compensate for the normal business risk of an economic activity. Without the aid, Hy2Tech's realisation should be impossible, or it should be realised in a smaller size or scope or in a different manner that would significantly restrict its expected benefits. The application for aid must precede the starts of the works, which is either the start of construction works on the investment or the first firm commitment to order equipment or other commitment that makes the investment irreversible, whichever is the first in time. According to point 31 of the IPCEI Communication, the Member State should provide the Commission with adequate information concerning the aided project, as well as a comprehensive description of the counterfactual scenario, which corresponds to the situation where no aid is awarded by any Member State.

(414) The Commission has verified that all undertakings have submitted their applications for aid to the relevant Member States before the start of their work on their individual projects included in Hy2Tech, therefore the formal incentive effect criterion, as required by the IPCEI Communication (footnote 26) has been met.

(415) The Member States have submitted information demonstrating that the aid has a substantive incentive effect for all aid beneficiaries, i.e. that the aid will induce the beneficiaries to change their behaviour by enabling them to engage in their individual projects in their full ambitious scope and in the time span as notified. More specifically, this is demonstrated by the counterfactual scenarios for each of the aid beneficiaries. For the undertakings with a clearly defined and sufficiently predictable counterfactual scenario, the Commission compared the NPVs of the aided and alternative projects, in line with point 32 IPCEI Communication. Furthermore, the Commission verified that the aid is kept to the minimum necessary to ensure the implementation of Hy2Tech (see recitals (422) to (458)).

(416) The Member States affirm that, absent Hy2Tech public financing, each of the aid beneficiaries has demonstrated that it either: (i) would not undertake their individual projects and, for example, would continue buying inputs from external suppliers rather than developing innovative inputs itself, or, (ii) if the beneficiaries would develop their own inputs, they would not undertake them rapidly enough, or they would carry out activities with a significantly lower level of ambition. Consequently, absent the aid measures, the aid beneficiaries would instead either refrain from developing the new products that they have committed to under Hy2Tech or they would not conduct the R&D&I to introduce the different fundamental innovations covered by Hy2Tech.

[36] Such individual projects can be composed of an R&D&I part and a FID part.

(417) The Member States have underlined that absent the aid, the development of a competitive, innovative and sustainable ecosystem would not take place. The innovations both in terms of performance and sustainability, would not be made available to European consumers, as each participating undertaking would have focussed on its own programme.

(418) In view of the above, the Commission notes that the information provided by the Member States shows that in the absence of aid, the participating undertakings would not undertake their individual projects under Hy2Tech. Indeed, there is no evidence showing that the participating undertakings had considered such projects in their internal decision-making at the time of taking the decision to apply for the public support. Further, an analysis of the factual and counterfactual scenarios in the context of the funding gap (as discussed in recitals (446) to (448)), shows that undertakings would not have had a financial incentive to implement their projects in the absence of aid. Thus the absence of aid would jeopardise the materialisation of Hy2Tech.

(419) The Member States submit (also where the aid would not cover the full funding gap (see recital (272)) that the aid helps to induce the change of the aid beneficiaries' behaviour in the light of further strategic and security considerations (for example development of key enabling technologies to facilitate flexibility to the energy system, balancing supply and demand of electricity, strategic energy security considerations, etc.). Also, in its assessment of the eligible costs, the Commission verified that the list of submitted costs would not include costs that an undertaking would anyhow incur, such as costs linked to already existing laboratories in which research would have been conducted anyhow and the undertaking would have had to support those facility and personnel costs even without Hy2Tech.

(420) In view of the above, the Commission considers that the Member States have sufficiently demonstrated that the aid measures do not subsidise the costs of the projects that the participating undertakings would anyhow incur and do not compensate for their normal business risks.

(421) Considering the fact that the aid measures enable the participating undertakings to pursue ambitious projects, which would not have been pursued in the absence of Hy2Tech, the Commission concludes therefore that the notified aid measures are necessary to induce the change of the behaviour of the aid beneficiaries.

Proportionality of the aid

(422) According to point 32 of the IPCEI Communication, in the absence of an alternative project, the Commission will verify that the aid amount does not exceed the minimum necessary for the aided project to be sufficiently profitable, e.g. by making it possible to achieve an internal rate of return ("IRR") corresponding to the sector or firm specific benchmark or hurdle rate. According to point 33 of the IPCEI Communication, the maximum aid level should be determined with regard to the identified funding gap and to the eligible costs. The aid could reach up to 100% of the eligible costs, provided that the aid amount does not exceed the funding gap.

(423) The Member States have submitted, for all participating undertakings, detailed calculations of the eligible costs for their IPCEI specific R&D&I and FID

projects and funding gap calculations. The contents of the undertakings' individual R&D&I and FID projects falling within the scope of Hy2Tech are detailed in the individual project portfolios. In particular, the individual project portfolios set out how R&D&I activities are to be performed, the relevant technology risks and challenges, the state-of-the-art in the sector concerned, the market failures to be addressed and the various spill-over activities committed. In addition, the individual project portfolios explain how these R&D&I activities bring about important added value in going substantially beyond the global state-of-the-art, are of major innovative nature, how the FID allows for the development of new products with high R&D&I content and/or fundamentally innovative production processes and contains a very important R&D&I component. They also detail the eligible costs for the R&D&I and FID projects.

Assessment of eligible costs

(424) In its assessment of the eligibility of the costs, for the individual R&D&I projects, the Commission verified individually for all aid beneficiaries that their projects contain R&D&I activities of major innovative nature, going substantially beyond the global state-of-the-art in the sector concerned. This verification was based on the nature of the activities to be performed, the technology challenges and risks to be overcome within each TF and the duration of each activity, as demonstrated by each undertaking (see section 3.3.2 above).

(425) The Commission consistently verified for all TF and individual projects that a high innovation level is to be reached, and that the activities are not limited to a merely allow for an incremental evolution of the technologies existing and embedded in hydrogen products already existing on the market (see recitals (377) to (398)). Moreover, the Member States have verified that the related R&D&I costs of each aid beneficiary comply with the Annex on eligible costs to the IPCEI Communication. The Commission confirms that these costs fall within the categories listed in points (a) to (h) as set out in the Annex to the IPCEI Communication. In line with points (b) and (c), if instruments and equipment or buildings, infrastructure and land are not to be used during the full life for Hy2Tech, the Commission has verified that only the depreciation costs corresponding to the life of Hy2Tech are considered for the calculation of the eligible costs. The Commission has also required that the aid beneficiaries demonstrate that the depreciation periods used corresponded to good accounting practice.

(426) For the individual FID projects, the Commission verified, in order to determine whether they qualify as FID under the IPCEI Communication, that the FID activities:

a. Concern “the development of a new product or service with high research and innovation content and/or the deployment of a fundamentally innovative production process”[37];

[37] Point 23 of the IPCEI Communication, first sentence.

b. Do not relate to “regular upgrades without an innovative dimension of existing facilities and the development of newer versions of existing products”[38];

c. Consist in “the upscaling of pilot facilities, or [to] the first-in-kind equipment and facilities which cover the steps subsequent to the pilot line including the testing phase and bring batch production to scale;

d. Do not correspond to mass production nor to commercial activities”[39];

e. Relates to the capital and operating expenditures ("CAPEX" and "OPEX"), as long as the industrial deployment follows on from an R&D&I activity and itself contains a very important R&D&I component, which constitutes an integral and necessary element for the successful implementation of the project”[40].

(427) Having regard to the specificities of the hydrogen value chain concerned and the participating undertakings’ individual FID projects contained in Hy2Tech, the Commission has assessed the eligibility of FID costs for each aid beneficiary according to the above criteria, as follows.

(428) The Commission’s assessment took into account, for each FID project specifically, the integration of the hydrogen technologies in systems and processes, their compatibility with the end-use applications, the technological complexity and performance going substantially beyond the global state-of-the-art hydrogen technologies and systems, the applications addressed and their specific constraints in particular in terms of safety and reliability. When assessing the setting up of processes (e.g. innovative process to integrate critical materials in electrolyser components or environmental compatibility of the electrolysis process, etc.), activities were only considered eligible where they relate to the introduction of processes that transfer the R&D&I performed before FID and are critical for the functionality of the resulting product. These activities were assessed against the most up-to-date publicly available information related to the different Hy2Tech technologies and systems (including scientific and technical literature journals, corporate technical scientific publications, patents, etc.).

(429) The Commission finds for all aid beneficiaries, for each FID project, that it concerns either a new product with high R&D&I content or a fundamentally innovative production process or both (see recitals (377) to (398)).

(430) The Commission further finds for all aid beneficiaries, for each FID project the following: the FID concerns technologies with high R&D&I content or fundamentally innovative nature. These highly innovative technologies are a

38 Point 23 of the IPCEI Communication, second sentence.

39 Point 24 of the IPCEI Communication.

40 Point (g) in the Annex to the IPCEI Communication. The wording of the IPCEI Communication implies that the very important R&D&I component that needs to be embedded in the FID costs in order for these to be eligible constitutes a limit both in scope and time ("as long as") on the eligible FID costs.

result from a preceding R&D&I activity, but they still require additional important R&D&I to be carried out, even after the R&D&I phase. As such, the FID of these specific technologies contains an additional important R&D&I component on its own (quantitatively or qualitatively), which is indispensable for the successful FID of the technologies.

(431) In relation to the very important R&D&I component, the Commission finds that all of the beneficiaries have provided an adequate demonstration of the very important (in quantitative and/or qualitative terms) R&D&I activities in their FID, which constitutes an integral and necessary element for the successful implementation of their individual projects. In particular, the Commission verified that each FID project demonstrated that the planned important R&D&I during the FID is necessary to solve outstanding technological roadblocks, among others in terms of hydrogen technologies integration, design stability, cost-effective automatized processes, testing and validation, safety and reliability of materials and components, in the context of the complex technologies and large number of processes involved, is demonstrated. In particular, the assessment of the very important R&D&I component in the FID of each aid beneficiary took into account the following elements.

(432) In its assessment, the Commission verified, on the basis of the parameters established in recitals (426) and (428), that the FID is not a mere regular upgrade, without an innovative dimension, of existing facilities, or a development of newer versions of existing products or technologies. Mere engineering work accompanying normal activities of FID does not constitute eligible costs for the required R&D&I in FID.

(433) In its assessment, the Commission further considered that where FID costs and the embedded R&D&I do not relate to the highly/fundamentally innovative technologies the beneficiary is developing, these are not eligible. Where the R&D&I in FID does not take place before the end of FID (end date in line with the IPCEI Communication), the FID costs are not eligible. The Commission has verified that such R&D&I costs are excluded from the eligible costs represented in tables 9 to 23 above.

(434) The Commission moreover verified that the FID as described by the Member States for the different aid beneficiaries does not cover mass production or commercial activities.

(435) In this connection, the Commission first examined whether the different beneficiaries established KPIs (e.g. quality of product, durability, compatibility, energy consumption, safety, environmental impact, etc.) for identifying the moment in time that they reach a stabilised mass production. Any costs relating to production occurring after the KPIs have been met cannot be included in eligible FID costs. The Commission verified that they were not included in the eligible costs represented in tables 9 to 23 above.

(436) Furthermore, the Commission verified that the activities taking place during the FID phases notified by the Member States for the different participating undertakings correspond indeed to FID activities and not mass production or commercial activities. Thus, in addition to verifying that the FID phases are accompanied by a significant R&D&I effort until the end of FID, the Commission also verified that the activities undertaken during these periods do

not correspond to commercial activities both in quantitative and qualitative terms.

(437) In performing this verification, the Commission identified a FID phase as corresponding to a phase in which the undertaking starts to test the production of its new product or the new production method outside the lab and the pilot line. Undertakings provide pre-commercial samples to selected potential customers to verify the quality of the sample and how it can be integrated in the potential customers' activities. Typically, at that moment, new issues will appear and the sample-product might need to be changed or the production process might need to be modified or further developed. During the FID, numerous trial runs and a critical number of testing scenarios will be performed at different days and shifts to validate the production process with many idle moments in between. This validation process is specific to the developed hydrogen technology, aiming to enable the preparation of a subsequent stable process that would facilitate the transition to mass production after the end of the FID phase (see recital (374)).

(438) In addition, as the activities supported under Hy2Tech involve substantial innovations, the FID activities (including testing, sampling and upscaling) continue to involve an important R&D&I effort until the end of FID, which the Commission has verified, as indicated under recital (431). During the ramp-up period, given that the production processes are put in place for the first time complications are expected and adjustments will in any event be needed to remedy the situation, potentially requiring that part of the production process to be redesigned.

(439) Even during the upscaling, potential customers expect the delivery of sample-products of a sufficiently high quality to be used for their own needs and requirements. In the FID phase, this cannot be achieved at arms' length. Customers will be particularly keen to require extensive liabilities from new entrants. Those quality assurances imply for the undertakings additional quality control, screening and sorting processes, which are not needed once the production process has stabilised and would also not be sustainable under normal commercial conditions (because they are too costly). During the FID phase, customers reserve the right to reject or return shipments not only in the event of a quality issue but also in cases that customer applications show technical problems or the market introduction is postponed, in particular from new entrants.

(440) The Commission verified that the planned FID activities included by Member States in the eligible costs calculations presented in tables 9 to 23 above: a) correspond only to the testing, sampling and upscaling activities described in recitals (437) to (439), b) include only activities that still require significant R&D&I effort, c) correspond only to a limited output volume, and d) when a small volume of sales is planned, those sales occur under extended liability conditions. Conversely, the Commission verified that sales occurring after product qualification and years for which high volumes of sales were already planned were not included in the FID and excluded from the eligible cost

calculations summarised in tables 9 to 23 above, given that such sales would point to commercial activities.[41]

(441) The Commission's assessment confirms that the notified FID phases of all aid beneficiaries comply with the requirement of the IPCEI Communication not to cover either mass production or commercial activities and that the costs summarised in tables 9 to 23 for the FID phase of each beneficiary relate to FID within the meaning of the IPCEI Communication.

(442) With regard to the eligible FID costs, the Commission also verified that for cost items that are depreciated during several years, only depreciation costs until the end of the FID phase are included in the eligible costs. The Commission further required the aid beneficiaries to demonstrate that the depreciation periods used correspond to good accounting practice.

(443) With regard to the operating costs, which should be limited both in scope and in time to the R&D&I that the FID entails according to the Annex to the IPCEI Communication, the Commission examined thoroughly the costs information provided by the Member States and considers the requirement to have been fulfilled, because it has found that the operating costs constitute an integral and necessary part for the implementation of the individual projects

(444) The Commission moreover reviewed the FID cost information provided by the Member States and summarised in tables 9 to 23 above and considers that they fulfil the conditions set out in the Annex to the IPCEI Communication.

(445) Based on the above, the Commission finds that the costs notified by the Member States in relation to all aid beneficiaries constitute eligible costs for Hy2Tech and fulfil the requirements of the Annex to the IPCEI Communication.

Assessment of funding gaps

(446) The Commission reviewed in detail the funding gap calculations provided by The Member States for each aid beneficiary and verified the main assumptions in those calculations, as explained below.

(447) The funding gap is equal to the difference between the NPV of the IPCEI project (or factual scenario) and the NPV of the counterfactual scenario (or the scenario where no State aid is provided). The NPV is the sum of the discounted future inflows and outflows of cash generated by an investment over its lifetime, thus also including the financial streams related to the mass production following from Hy2Tech. The cash flows are discounted at the WACC.

(448) The Commission assessed the funding gap of each project at the level of each beneficiary. This assessment entailed:

[41] According to footnote 24 of the IPCEI, "[l]imited sales, when necessary in the specific sector, related to the testing phase, including sample or feedback or certification sales, are excluded from the notion of 'commercial activities'".

a) First, ensuring that every project calculated the funding gap as the difference between the NPV of their IPCEI project and the NPV of their counterfactual scenario; and

b) Second, reviewing and verifying the funding gap assumptions.

(449) Regarding the funding gap calculation, the Commission verified that each project provided a realistic factual scenario, as well as a realistic counterfactual scenario, this being essential to the correct calculation of the funding gap. For the counterfactual scenario, the Commission observes that the participating undertakings have reported the following options, in the absence of Hy2Tech:

a) They would undertake a project different, but comparable to the project under Hy2Tech (e.g. delayed, smaller, etc.); or

b) They would undertake no alternative project.

(450) Regarding the funding gap assumptions, the Commission reviewed and verified them both for the factual and counterfactual scenarios. Particular scrutiny was applied to the revenues, terminal value and WACC assumptions.

(451) First, the Commission assessed and ensured that the projections of each individual project include all of the revenues expected to be generated from their respective investments. To this end, the Commission verified that the revenue streams:

a) Are comprehensive and thus in line with the technical characteristics of each of the individual projects;

b) Accrue over the entire mass production phase and span over the expected life-cycle of the respective hydrogen technology; and

c) Lead to a profit margin in line with the market during the mass production phase.

(452) Second, the Commission verified and ensured that each individual project's projections include a terminal value that captures any remaining expected market value of the project after the end of the projections.

(453) Third, the Commission verified that each individual project's WACC:

a) Corresponds to each undertaking's internal WACC. Deviations from this rule were assessed on a case-by-case basis.

b) Is calculated by applying the formula below:

$$WACC = \frac{E}{D+E} * \left(r_f + \beta * ERP\right) + \frac{D}{D+E} * (r_f + DP) * (1 - T),$$

where: E = equity, D = debt, r_f = risk-free rate, β = equity beta, ERP = equity risk premium, DP = debt premium and T = tax rate, and all of the parameters in the formula above, together with their sources and the methodology to determine them are provided.

c) Is in line with external benchmarks. To this aim, the Commission has identified benchmarks for the WACC's parameters based on publicly available data, with the aim of assessing the plausibility of these WACCs.[42]

(454) Having verified compliance with each of the above elements for each of the individual projects, the Commission concludes that all participating undertakings have calculated their funding gap in line with the IPCEI Communication and guidance provided.

(455) The Commission observes that both the eligible costs and the funding gaps have been calculated in line with the IPCEI Communication, and that the notified aid amounts do not exceed the minimum between the funding gap and the eligible costs (as reported in section 2.6.3).

(456) Furthermore, the claw-back mechanism described above in section 2.9 provides further reassurance of compliance with the proportionality requirement.

(457) In addition, where the notified aid may be cumulated with aid under other measures, Member States have put in place mechanisms to make sure that irrespective of the source of the funding (local, regional, federal, EU), the total support will not exceed the notified and approved aid amount under this decision.

(458) Therefore, the Commission considers that the aid to be granted by the notifying Member States is proportionate.

3.3.3.2. Prevention of undue distortions of competition and balancing test

Appropriateness

(459) According to point 42 of the IPCEI Communication, the Member State should provide evidence that the proposed aid measure constitutes the appropriate policy instrument to address the objective of the project.

(460) The Member States submit that State aid is the appropriate policy instrument to support Hy2Tech. In their view, due to the exceptional size of Hy2Tech and the synergies it requires from the various partners, it could not be achieved and such technological breakthroughs could not be created without the support of the Member States involved in the financing of Hy2Tech. Alternatively, the participating undertakings would have focused on their own programmes to the detriment of innovations whose spill-over effects largely benefit the EU ecosystem.

(461) The Member States further argue that the payment of direct grants constitutes the appropriate instrument in view of the high risk of Hy2Tech in financial and technological terms and the low expected profitability induced by the relevant spill-overs. It is considered further that the use of direct grants limits the

[42] The benchmarks identified by the Commission reflect the country and industry risks of the individual projects.

potential financial losses in case of project failure. Also, Member States submit that direct grants address the coordination problems and encourage the participating undertakings to commit to their projects for the achievement of common objectives.

(462) The Commission shares the views of the Member States that given the level of ambitions pursued by Hy2Tech, its size and numerous collaborative interactions that it will induce, the public support through the notified State aid measures constitutes the appropriate policy instrument to address the objectives of Hy2Tech. Given the level of risk and uncertainty (see recitals (401) to (408)), the Commission considers the use of direct grants for the R&D&I phase to be appropriate. The Commission also considers that the FID phase will equally entail a relatively high level of risk and uncertainty and therefore finds appropriate the use of direct grants.

(463) The Commission further considers that any potential use of repayable advances or loans also constitutes appropriate policy instruments for Hy2Tech, given that each individual project can become profitable and thereby generate income for the State. As a result, these policy instruments are amongst the least distortive.

(464) The Commission further notes that all larger aided individual projects will be subject to a claw-back mechanism that will further ensure the appropriateness of the aid measure.

<u>Identification of the potential risks of distortions of competition</u>

(465) According to point 43 of the IPCEI Communication, aid can be declared compatible if the negative effects of the aid in terms of distortions of competition and impact on trade between Member States are limited and outweighed by the positive effects in terms of contribution to the objective of common European interest. The assessment of the potential negative effects of the aid under the IPCEI Communication needs to consider, in particular, the effects on competition between undertakings in the markets concerned, as well as risks of market foreclosure and dominance (points 44 and 45 of the IPCEI Communication).

(466) The Member States provided detailed information and reasoning on the absence of undue distortions to competition in relation to each individual project under the Hy2Tech. In particular, the Member States argue that the European markets impacted by Hy2Tech are either non-existent (as they are yet to be developed) or are in the very early stage of their development. This is reflected by the fact that most of the participating undertakings of Hy2Tech are not currently active in the markets in which they intend to develop their products as a result of the discussed aid measures. In the few cases of participating undertakings already active in these markets, they do not raise concerns of undue distortions of competition in the technologies that constitute the object of Hy2Tech. The Member States also argue that the current and expected market shares of the participating undertakings already active in markets impacted by Hy2Tech are not material. The Member States in their submissions also indicate that there will be no risk of foreclosure and overcapacity as a consequence of Hy2Tech.

(467) The Commission's analysis of undue distortions to competition is specific to the particular case at hand. The assessment of potential distortions to competition

was carried out taking into account the particularities of the sectors and TF concerned (as described in recital (470)) and participating undertakings involved. The assessment of the potential negative effects of the aid under the IPCEI Communication needs to consider, in particular, the effects on competition between undertakings in the concerned product markets, as well as risks of market foreclosure and dominance.

(468) The assessment of distortions to competition has followed a consistent approach across all projects, while each project was assessed individually in detail by the Commission. Hy2Tech involves a large number of undertakings, each with a current or future presence in a wide range of product and service markets concerned along the hydrogen production value chain. For this reason, in this particular case, the Commission adopted a two-step approach, as described below, in order to identify potential significant competition distortions that might result from the aid measures.

(469) First, the Commission screened projects based on the position of the participating undertakings in the markets affected by Hy2Tech. In particular, the Commission screened participating undertakings based on a uniformly available metric on European production (the "PRODCOM" statistics on the production of manufactured goods collected by the EU Member States). The Commission requested and received data on the aid beneficiaries' past production (2016-2020) values by 8-digit PRODCOM classification for the products categories related to the aided project in Hy2Tech. Based on this information, the Commission assessed the share of European production of the respective undertakings involved in the project, a proxy to horizontal market shares.

(470) This first screening step of the assessment was further developed by adapting it, when necessary, to the particularities of the sectors concerned and participating undertakings involved. In particular, the assessment considered the “type” of project as reflected by the technical field it addressed. This allowed defining and focusing the assessment to be tailored to the markets actually affected by the aid measure:

a) For TF 1 `Development of hydrogen generation technologies’, the Commission requested and received additional data on the aid beneficiaries’ past (2017-2021) and expected (2022-2026) market shares at EU-level for the market for electrolysers, also distinguishing between their different categories. Importantly, as many aid beneficiaries were not yet active in the field of hydrogen generation technologies, this approach allowed to capture also their expected future market positions to be captured. For each of these markets, the Commission requested and received information on the aid beneficiaries’ five main EU-competitors;

b) For TF 2 `Development of FC technologies’ and TF 3 `Development of technologies for storage, transportation and distribution of hydrogen’, the assessment was based on PRODCOM values, which proved to be well-fit for purpose; and

c) The competition assessment has shown that the potential of distortions of competition was highest for projects under the technological field TF 4 `Development of hydrogen technologies for end users’, e.g. undertakings developing technologies for the market for trucks or rolling stock. Indeed, projects under technological field TF4 concern the development of hydrogen technologies for end use applications, where the latter are markets where undertakings are already active in. Accordingly, in this preliminary screening, the Commission requested and received data on the aid beneficiaries' past market shares (2016-2020) at a broader 4 digit NACE Rev. 2 level (statistical classification of economic activities in the European Community) corresponding to the end-use activities of the aid beneficiaries involved in the respective projects, as well its main European competitors active in these categories. Consequently, the Commission followed a conservative approach in assessing proxies to horizontal market shares of undertakings, as it has undertaken its assessment both at both broader (4 digit NACE Rev. 2 level) and narrower (PRODCOM) industry classifications.

(471) For those undertakings/projects raising potential concerns based on their position in the markets affected by State aid to Hy2Tech, the Commission further assessed whether other competitors active in the European markets, who may or may not have benefitted from IPCEI support, could be in any way foreclosed by the undertakings benefitting from aid under the IPCEI. The Commission has also undertaken the assessment of potential risk of overcapacity. The Commission’s assessment has shown that the aid granted under the Hy2Tech is limited in scope in relation to the current economic activity of the undertakings and the overall hydrogen based economic activities.

(472) Second, the Commission reviewed the more detailed information provided for each participating undertaking by the relative Member State and carried out an overall assessment of competition distortions based on that information.

(473) Following the assessment described above, the Commission has undertaken a balancing test to assess whether the expected positive effects of the aid outweigh its possible negative effects. The positive effects of the aid considered in the balancing test included concrete contributions of projects under Hy2Tech to addressing well-defined market failures (see recitals (307) to (323)) as well as the objective of the common European interest (see recitals (307) to (323)). Furthermore, the potential negative effects in terms of foreclosure are likely to be mitigated by the participating undertakings’ commitments to disseminate R&D&I results (see recitals (339) to (350) and to unconditionally license IP-protected results of the funded projects based on FRAND conditions (see recitals (344) and (345)). Moreover, in view of the fact that the hydrogen sector remains nascent and is expected to expand significantly, the Commission considers that the risks of Hy2Tech giving rise to concerns based on overcapacity are limited.

(474) The analysis of the detailed information available to the Commission, therefore, leads to the conclusion that the risks of foreclosure, dominance and overcapacity are likely to be outweighed by the positive effects of Hy2Tech.

3.3.3.3. Transparency

(475) The transparency requirement, specified in section 4.3 of the IPCEI Communication, is fulfilled (see recital (281) above).

3.3.4. *Conclusion on compatibility*

(476) Based on the assessment under the IPCEI Communication, the Commission concludes that the notified aid measures are compatible with the internal market pursuant to Article 107(3)(b) TFEU.

3.3.5. *Reporting obligation*

(477) According to point 52 of the IPCEI Communication the execution of the project must be subject to regular reporting.

(478) As notified by the Member States, the annual execution of Hy2Tech activities will be subject to reporting by the participating undertakings and the Member States. This reporting is three-fold:

a) First, the participating undertakings will report annually the execution of their activities, as regards the technical advancements, the individually committed spill-overs and the compliance with the DNSH principle to the national funding authorities and any other complementary activities with other EU initiatives, for example, the Clean Hydrogen Joint Undertaking or the Horizon Europe programme. The reporting period will ideally reflect the Member States' annual reporting obligation towards the Commission;

b) Second, the Member States will provide a summary report (of the undertakings' execution of their activities) annually to the Commission. In accordance with the Member States' notifications, a template will be created by the FG during its first meeting and evaluated by the Commission. The reporting will be scheduled based on the annual FG meetings. A detailed description on the reporting mechanisms will be published after the initial FG meeting, as well as the respective reporting period; and

c) Thirdly, the SB, which has the role of supervising the monitoring and implementation of Hy2Tech as a whole (see recital (38)), will report annually to the Commission on the progress of Hy2Tech (including through KPIs). The reporting period shall ideally follow the reporting of the Member States to the Commission.

(479) Further, the concerned Member States have agreed to report annually to the Commission the application of the claw-back mechanism (see Annex I).

(480) The Commission therefore considers that the reporting obligation on the execution of Hy2Tech is fulfilled.

4. CONCLUSION

(481) In view of the above and in light of the Member States' notifications, the Commission has decided:

- not to raise objections to the aid on the grounds that it is compatible with the internal market pursuant to Article 107(3)(b) TFEU.

If this letter contains confidential information which should not be disclosed to third parties, please inform the Commission within twenty working days of the date of receipt. If the Commission does not receive a reasoned request by that deadline, you will be deemed to agree to the disclosure to third parties and to the publication of the full text of the letter in the authentic language on the Internet site: http://ec.europa.eu/competition/elojade/isef/index.cfm.

Your request should be sent electronically to the following address:

European Commission,
Directorate-General Competition
State Aid Greffe
B-1049 Brussels
Stateaidgreffe@ec.europa.eu

Yours faithfully,

For the Commission
Margrethe VESTAGER
Executive Vice-President

ANNEX I

CLAW-BACK MECHANISM

The aid is capped in nominal terms by the notified and actual eligible costs. Member States will also ensure that the discounted value in 2022 terms of the aid (using the notified WACC as a discount factor) will not exceed the notified funding gap.

The claw-back mechanism will apply to those aid beneficiaries having a notified aid amount, per Member State, above EUR 50 million[43] in total in that Member State[44].

The basis for the claw-back mechanism (at project level) will be *ex post* figures, which have been subject to annual approval by an independent auditor. For this purpose, separate analytical accounting will be required from the aid beneficiaries in the relevant Member State.

Letter of credit

Starting as from 30 July 2028 and then, every five years, until an "End date"[45] to be determined depending on the durations of the projects a test will be run ("the test-run") and the following $Surplus_i$ for year i (i=2027, 2032…) will be computed as the sum (positive or negative) of:

(a) the net present value discounted in year "i" (using the notified WACC as a discounting factor[46]) of the actual *ex post* audited post-tax cash flows (including Capex, excluding State aid payments and financing cash flows) from 2022 to year "i"; and

(b) the net present value discounted in year "i" (using the notified WACC as a discounting factor) of the actual aid disbursements from 2022 to year "i".

[43] This threshold of EUR 50 million of aid amount is to be understood in discounted terms in 2022 value terms when notified by the relevant Member State or in nominal terms in the absence of the former. If the aid eventually disbursed to the aid beneficiary is lower than the notified aid amount and lower than EUR 50 million (in discounted terms, in 2022 value terms), the aid beneficiary's individual project will be relieved from this claw-back mechanism. In such case, the Member State disbursing the aid commits to inform the Commission of the occurrence of a lower than notified aid amount and of the inapplicability of the claw-back mechanism within 2 months after final disbursement of the aid.

[44] Clearly identifiable beneficiary projects which are determined as unsuccessful by both the undertaking and the Member State (i.e. commercially non-viable) and are terminated before the End date, will not be subject to the claw-back clause.

[45] The End date (only for the purposes of this claw-back mechanism) is set at the year corresponding to the end of FID + 5 years, or of R&D&I + 5 years for those projects with no FID. In the case of multiple FID stages within the same project, 5 years should be added from the end of the latest of those FID stages. In case of delays in implementing the project compared to the timeline forecasted in the notification, the relevant end of FID will be the actual one, as verified by the relevant Member State.

[46] This means that for instance, for the test-run in 2029, a cash flow in 2022 will be multiplied by (1+WACC)^(6).

The $Surplus_i$, if it is positive, will be multiplied by an allocation ratio "$Share_{State}$", equal to the lesser between 60% or the net disbursed State aid from 2022 to year "i" divided by the verified eligible costs from 2022 to year "i" (both expressed in nominal terms and relating to the applicable project).

This claw-back mechanism only applies in case of positive net present values of cash flows after taking into account the actual State aid disbursements. No surplus can be generated by projects with negative net present value after State aid.

A letter of credit (by a reputable financial institution having investment grade rating from a first-rank rating agency) should cover the repayment obligation at the End date by the aid beneficiary, from the first test-run (that is, mid-2028).

The secured amount guaranteed by the above-mentioned letter of credit should be at least equal to an amount ensuring that the two following principles are fulfilled:

1) The secured amount must never be negative (initial balance equal to zero);

2) The secured amount must, after each test-run, correspond to the lower of the following, if positive:

   - $Surplus_i$, multiplied by $Share_{State}$ (computed at that test-run) and

   - The sum of the actual State aid disbursements between 2022 and that test-run expressed in terms of the year "i" of the test-period. For all of the disbursements before that test-run, the discount factor will be the EU reference rate applicable to the Member State concerned according to the Commission's communication on setting the reference and discount rates[47] applicable at year "i", increased by 100 basis points between the corresponding disbursement and year "i".[48]

An amount equal to the final secured Amount, after the last application at the End date, will be transferred to the Member State.

The application of the claw-back mechanism will be reported by the relevant Member State to the Commission within 1 month following completion of each test-run and after the End date (e.g. first reporting on application of the claw-back mechanism in July 2028).

Account with annual transfers

Alternatively, the Member State, instead of the letter of credit system described above, may opt for an account-based system. This system will apply exclusively if the two following conditions are both met: a) the account to be used for the purpose of applying the claw-back mechanism is not under the control of the aid beneficiary; and b)

[47] OJ C 14, 19.01.2008, p.6.

[48] NB: Written in the form of a formula, this means that after each test run, a transfer from the undertaking to the Account (respectively from the Account to the undertaking) takes place so that the overall balance of the Account reaches the following

$MAX(0; MIN(Surplus_i;$ State Aidproject (in NPV 2022 terms, multiplied by [1+$BaseRate_j$ + 1.0%]^(i-2022))) computations and transfers to/from the account by the aid beneficiary must take place once every year[49] until the End date.

The balance of that account should never be negative and no transfer by the Member State to the account shall take place at any time.

This account-based system must not be more favourable from the aid beneficiary perspective than the letter of credit system[50] and should ensure comparable results[51].

The annual application of the claw-back mechanism will be reported by the relevant Member State to the Commission within 1 month following completion of each test-run (e.g. for projects starting in 2023, first reporting on application of the claw-back mechanism in July 2024 and thereafter every July until the final application after the End date).

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[49] Not later than in the first six months of the year following the year of implementation the project (e.g. for a project starting in 2023, by end June 2024 at the latest).

[50] Excluding the specific administrative costs of a letter of credit, as well as fees and deposit interests related to an account.

[51] The competent services of the Commission will provide to the Member States a template in Excel format to assist them in the implementation of this claw-back mechanism, including in the form of an account-based system. This template should allow for comparable results of the account-based system with the "letter of credit" system when discounting both the final payment in the "letter of credit" system and the annual transfers to/from the account with the WACC.

ANNEX II

GLOSSARY[52]

Acrylic resin	Acrylic resins typically are copolymers of acrylic or methacrylate esters and a hydroxyl-functionalized acrylic ester.
Alkaline fuel cell (AFC)	An alkaline fuel cell (AFC) is a FC that employs an alkaline electrolyte.
Alkaline water electrolyser (AWE)	An alkaline water electrolyser (AWE) is a water electrolyser using alkaline solution as electrolyte. This is also sometime referred to as AEL or AE (alkaline electrolyser).
Ammonia (NH_3)	Ammonia is a compound of nitrogen and hydrogen with the formula NH_3. Ammonia is a colourless gas with a distinct pungent smell.
Anion exchange membrane (AEM)	An anion exchange membrane (AEM) is a polymer based membrane with anion conductivity, which acts as an electrolyte and a separator between anode and cathode.
Anode	An anode is by convention, the cell electrode at which an oxidation reaction occurs. At the anode, electrons are produced in a galvanic cell or extracted in an electrolytic cell. The concepts of "anode" and "cathode" are related only to the direction of electron flow, not to the polarity of the electrodes.
Artificial intelligence (AI)	Artificial intelligence (AI) is intelligence demonstrated by machines, as opposed to the natural intelligence displayed by animals including humans.
Ash fouling	Ash fouling is the deposition of ash on the heat transfer surface in coal-fired power plant utility boilers. The effect of ash fouling is a reduction of heat absorption and a loss in thermal efficiency.
Balance of Plant (BoP)	Balance of plant (BoP) is an arrangement of all supporting and auxiliary components and devices needed for fluid, thermal and electrical management of the system and its safe and reliable operation whether locally or remotely.
Biobased Polyamide	Bio-based polyamides are a new class of bioplastics that are derived from renewable resources such as natural fats and oils.
Bipolar plate (BPP)	A bipolar plate (BPP) is an electrically conductive and gas-tight plate separating individual cells in a single cell or stack, acting as a reagent flow distributor and current distributor and providing mechanical support for the electrodes or membrane electrode assembly.
Boil-off of hydrogen	When using cryogenic hydrogen (liquid hydrogen) boil-off is the process when ambient temperature causes the liquid hydrogen to heat up and form its gaseous state.
Capital expenditure (CAPEX)	Capital expenditure (CAPEX) is an expenditure on acquisitions of, or improvements to, assets. Based upon accounting standards and organisation policy, CAPEX usually relates to relatively large (material)

[52] This Glossary is included merely as an aid to the reader for the purpose of this decision. The nomenclature and the respective definitions included are not legally binding.

	expenditure, which has benefits that are expected to last for more than 12 months.
Carbon capture and storage (CCS)	Carbon capture and storage (CCS) is the process of capturing carbon dioxide (CO_2) before it enters the atmosphere, transporting it and storing it.
Carbon fibre (CF)	Carbon fibres are fibres of about 5 to 10 micrometers in diameter and composed mostly of carbon atoms. Carbon fibres have several advantages: high stiffness, high tensile strength, high strength to weight ratio, high chemical resistance, high temperature tolerance and low thermal expansion.
Carbon-composite	Carbon composites are composed of carbon fibres and a matrix consisting of special resin systems or thermoplastics. Mutual interactions between the two components give the overall material higher-quality properties than either of the two components alone.
Carbon-fibre-reinforced polymers (CFRP)	Carbon-fibre-reinforced polymers (CFRP), also known as carbon fibre, carbon composites are extremely strong and light fibre-reinforced plastics that contain carbon fibres. CFRPs are commonly used wherever high strength-to-weight ratio and stiffness (rigidity) are required.
Castor oil	Castor oil is a vegetable oil pressed from castor beans.
Catalyst coated membrane (CCM)	A catalyst coated membrane (CCM) is a specific configuration of a membrane electrode assembly (MEA) where the catalyst layer (CL) is coated directly onto the membrane to form the reaction zone of the electrode
Cell	A single cell is the basic unit of a FC or electrolysis stack.
Combined cycle gas turbine	A combined-cycle power system typically uses a gas turbine to drive an electrical generator, and recovers waste heat from the turbine exhaust to generate steam. The steam from waste heat is run through a steam turbine to provide supplemental electricity.
Combined heat and power	Combined heat and power (CHP) or cogeneration is the use of a heat engine or power station to generate electricity and useful heat at the same time. Combined heat and power plants recover otherwise wasted thermal energy for heating.
Computer-aided design (CAD)	Computer-aided design (CAD) is the use of computers to aid in the creation, modification, analysis, or optimization of a design.
Computer-aided engineering (CAE)	Computer-aided engineering (CAE) is the broad usage of computer software to aid in engineering analysis tasks.
Cryogenic	Cryogenic conditions are conditions involving very low temperatures in the vicinity of the normal boiling point
Cryogenic Storage System	A cryogenic storage system uses low temperature (cryogenic) liquids such as liquid air or liquid hydrogen to store energy.
Cu-Cl thermochemical water splitting cycle (Cu–Cl TWSC)	The copper–chlorine thermochemical water-splitting cycle (Cu–Cl TWSC) is a four-step thermochemical cycle for the production of hydrogen. The Cu–Cl TWSC is a hybrid process that employs both thermochemical and electrolysis steps.
Current densities	Current density or electric current density is defined as the amount of

	electric current flowing through a unit cross-sectional area.
Dark doldrums	Dark doldrums or dark wind lull, known in meteorological literature as anticyclonic gloom is a term used in the renewable energy sector to describe a period of time in which little to no energy can be generated with the use of wind and solar power.
Design-to-cost (D2C)	The Design-to-Cost (D2C) method aims to secure an undertaking's profit and cost targets over an entire product life cycle, starting with early product development. Minimising overall costs is an equally important development goal alongside functionality, feasibility, quality and adherence to deadlines.
Design-to-manufacturing-concept (D2M)	Design for Manufacturing is the process of designing parts, components or products for ease of manufacturing with an end goal of making a better product at a lower cost.
Diaphragm	Diaphragms are like membranes; a specific form of electrochemical separators.
Digital twin	Digital twins are virtual images of products, machines, processes or even entire production plants that contain all relevant data and simulation models.
Dimensionally Stable Anodes (DSA)	Dimensionally Stable Anodes (DSA), also called Mixed metal oxide (MMO) electrodes are devices with high conductivity and corrosion resistance for use as anodes in electrolysis.
Direct current converter DC-DC power converter	A DC-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another.
Disruptive technology	Disruptive technologies, often also called disruptive innovations, are technologies/innovations that replace the successful series of an already existing technology, product or service or drive it completely out of the market and make the investments of the previously dominant market participants obsolete. This occurs because the disruptive technology has attributes which are considerably superior to the incumbent technology.
E-crude	E-crude is a preliminary stage in the synthesis process of synthetic fuels.
E-fuels	Electrofuels, also known as e-fuels or synthetic fuels, are a type of drop-in replacement fuel. They are manufactured using captured carbon dioxide or carbon monoxide, together with hydrogen.
Elastomer	An elastomer is a polymer with viscoelasticity (i.e., both viscosity and elasticity). Elastomers are dimensionally stable but elastically deformable plastics. The plastics can deform elastically under tensile and compressive stress, but then return to their original, undeformed shape.
Electrochemical compression system	An electrochemical compression system is a hydrogen compressor where hydrogen is supplied to the anode, and compressed hydrogen is collected at the cathode.
Electrochemical separator	An electrochemical separator in an electrochemical cell, is a device made of insulating material permeable to the ions of the electrolyte and prohibiting totally or partially the mixing of the substances on both sides.
Electrolyser	An electrolyser is an electrochemical device that converts water/steam and/or CO2 to hydrogen and oxygen by electrolysis reaction.

Electrolyte	An electrolyte is a medium containing ions that is electrically conducting through the movement of ions. This includes most soluble salts, acids, and bases dissolved in a polar solvent, such as water.
Embritlement	Embrittlement is a significant decrease of ductility of a material, which makes the material brittle. Embrittlement is used to describe any phenomena where the environment compromises a stressed material's mechanical performance.
E-methanol	E-Methanol is a type of synthetic fuel or e-fuel.
End of life (EoL)	End of life (EoL) is a life cycle stage of a product such as a device, equipment or system starting when it is removed from its intended use phase. The phrase "removed from its intended use" does not necessarily mean "dismantled". In fact, the product can either be reused/recovered or disposed of, possibly after dismantling and further recycling processes.
E-powertrain	The e-Powertrain powers the central drive unit and removes the need for an internal combustion engine. The key components of an e-Powertrain are the inverter, high-power electric motor, reduction drive and power delivery module.
Fischer-Tropsch	The Fischer–Tropsch process is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen (water gas) into liquid hydrocarbons.
Flue gas	Flue gas is the gas exiting to the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases from a fireplace, oven, furnace, boiler or steam generator.
Fluorinated polymers	Fluorinated polymers are fluorocarbon-based polymers with multiple carbon–fluorine bonds. They are characterized by a high resistance to solvents, acids, and bases.
Fly ash	Fly ash is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases.
Front-end engineering design	Front-End Engineering Design (FEED), is an engineering design approach used to control project expenses and thoroughly plan a project before a fix bid quote is submitted.
Fuel cell (FC)	electrochemical device that converts the chemical energy of a fuel and an oxidant to electrical energy (DC power), heat and other reaction products
Fuel cell boost	A FC boost is created by coupling FC with high-power energy storage components.
Fuel Cell Power Module (FCPM)	A FC power module is a system that generates electricity from hydrogen in vehicles and is essentially used in commercial vehicles.
Fuel cell power system (FCS)	A FC power system (FCS) is a generator system that uses one or more fuel cell modules to generate electric power and heat. FCSs typically contain the following subsystems: FC stack, air processing system, fuel processing system, thermal management, water management, and their control system.
Gas Diffusion Electrodes (GDE)	A gas diffusion electrode (GDE) is a type of electrode specifically designed for gaseous reactants or products or both. A gas diffusion electrode usually comprises one or more porous layers, like the gas diffusion layer and the catalyst layer. Gas diffusion electrodes can be gas

	diffusion anodes or gas diffusion cathodes.
Gas diffusion layers (GDL)	Gas diffusion layers (GDL) are gas diffusion layer base material for FC. GDL are commercially available in various forms such as carbon paper or woven carbon fabrics. A GDL should allow the flow of reactant gases H_2, air/oxygen and product gases to pass through it.
Gas separator	A gas separator is a pressure vessel used for separating gaseous and liquid components.
Geological structure assessment	A geological structure assessment uses geophysical methods (e.g. 2-D resistivity, seismic refraction and ground magnetic) for subsurface investigations of geological structures.
Graphene	Graphene is an allotrope of carbon consisting of a single layer of atoms arranged in a two-dimensional honeycomb lattice nanostructure.
Graphene nanoplatelet	Graphene nanoplatelets are nanoparticles consisting of short stacks of graphene sheets having a platelet shape
Gravimetric power density	Gravimetric power density, sometimes referred to as specific energy, is the available energy per unit mass of a substance. Gravimetric power density is typically expressed in Watt-hours per kilogram (Wh/kg), or Megajoules per kilogram (MJ/kg).
Greenhouse gas (GHG)	natural or anthropogenic gaseous constituent of the atmosphere that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds
Hard-to-electrify application	Hard to electrify applications are applications for which for technical or economic reasons, a switch to electricity (directly or indirectly e.g. via electrochemical storage) as an energy source is not viable while maintaining scope, quality or quantity of the applications' result. This can be the case for long distance aviation and shipping or for high temperature industry processes.
Heat flux	Heat flux is the thermal intensity, indicated by the rate at which heat crosses a given surface per unit area of that surface
High temperature proton exchange membrane fuel cell (HTPEM)	A high temperature proton exchange membrane FC (HTPEM) is a proton exchange membrane FC operating at temperatures above 100 °C
Hotbox	A hotbox is a component of an SOFC.
Hydrocarbon	A hydrocarbon is an organic compound consisting exclusively of the elements of carbon and hydrogen.
Hydrogen permeability	hydrogen permeability is the rate of diffusion of hydrogen through a membrane or other porous material
Industry 4.0	Industry 4.0 refers to the intelligent networking of machines and processes for industry with the help of information and communication technology.
Internal combustion engines (ICE)	An internal combustion engine is a heat engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal

	combustion engine, the expansion of the high temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. This force moves the component over a distance, transforming chemical energy into kinetic energy which is used to propel, move or power whatever the engine is attached to.
Internet-of-Things (IoT)	The Internet of things (IoT) describes physical objects with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks.
Key performance indicator (KPI)	A key performance indicator (KPI) is a type of performance measurement. KPIs evaluate the success of an organization or of a particular activity (such as projects, programmes, products and other initiatives) in which it engages.
Laser welding	Laser welding is a welding technique used to join pieces of metal or thermoplastics through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates.
Levelised cost of energy (LCOE)	Levelised cost of energy (LCOE) is a way of comparing the cost of energy stemming from different sources given the wide range of energy and power technologies available for energy generation whether renewable or non-renewable. LCOE should consider all CAPEX direct and indirect and all operational expenditure (OPEX) (i.e. labour, maintenance, materials, overheads, utilities, etc) fixed and variable including taxes, fees and charges as may be applicable in a given situation.
Levelised cost of hydrogen (LCOH)	Levelised cost of hydrogen (LCOH) is a way of comparing the cost of hydrogen stemming from the use of different electrolysis technologies whether already available, suggested and in actual use. LCOH should consider all CAPEX direct and indirect and all OPEX (i.e. labour, maintenance, materials, overheads, utilities, etc) fixed and variable including taxes, fees and charges as may be applicable in a given situation.
Life cycle assessment (LCA)	Life cycle assessment (LCA) is a method of measuring and evaluating the environmental impacts associated with a product, system or activity, by describing and assessing the energy and materials used and released to the environment over the life cycle
Liquified hydrogen (LH_2)	Hydrogen liquefies at a temperature of -253 °C. Liquid hydrogen is also referred to as cryogenic hydrogen.
Liquefied natural gas (LNG)	Liquefied natural gas (LNG) is natural gas (predominantly methane) that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport.
Liquid organic hydrogen carriers (LOHC)	Liquid organic hydrogen carriers (LOHC) are organic compounds that can absorb and release hydrogen through chemical reactions. LOHCs can therefore be used as storage media for hydrogen.
Load	A load can be a device, system or process that consumes electrical energy
Low temperature electrolyser	Low temperature electrolysis technologies can be roughly divided according to the type of electrolyte which can be an alkaline liquid electrolyte (AWE) or a cationic (PEM) or anionic exchange polymer

	membrane (AEM).
Low-carbon hydrogen	For the purpose of this decision, low-carbon hydrogen means hydrogen the energy content of which is derived from non-renewable sources, which meets a greenhouse gas emission reduction threshold of 70%.
Manufacturing 4.0	Manufacturing 4.0 refers to the term Industry 4.0.
Manufacturing readiness level (MRL)	The manufacturing readiness level (MRL) quantitative measures on an integer scale from 1 (basic: implications identified) to 10 (most mature: full operation demonstrated) for assessing the maturity of a manufacturing process or a given technology, component, product or system from a manufacturing perspective as well as the capabilities of possible suppliers and potential contractors including the identification of associated risks.
Matrix material fracture toughness	Fracture toughness is the critical stress intensity factor of a sharp crack where propagation of the crack suddenly becomes rapid and unlimited.
Membrane electrode assembly (MEA)	A MEA is a component of a PEMEC or an anion exchange membrane electrolysis cell (AEMEC) consisting of an electrolyte membrane with catalyst layers on either side.
Metal creep	In materials science, creep (sometimes called cold flow) is the tendency of a solid material to move slowly or deform permanently under the influence of persistent mechanical stresses.
Metal organic framework (MOF)	Metal–organic frameworks (MOFs) are a class of compounds consisting of metal ions or clusters coordinated to organic ligands to form one-, two-, or three-dimensional structures. They are a subclass of coordination polymers, with the special feature that they are often porous.
Methanol (MeOH)	Methanol, also known as methyl alcohol is a chemical and the simplest alcohol
Molten carbonate fuel cell (MCFC)	MCFC is a FC that employs molten carbonate electrolyte.
NOx	Nitrogen oxide may refer to a binary compound of oxygen and nitrogen, or a mixture of such compounds
Operation & maitenance (O&M) cost	O&M costs are costs incurred in operating and managing the facility, as well as labour, material and other related costs to maintain the facility or its parts in a condition in which it can perform its required functions
Operational expenditure (OPEX)	OPEX are recurrent expenditures required to provide a service or product
Original equipment manufacturer (OEM)	An OEM is a person or an undertaking having design responsibility for the equipment or for parts of it.
Peer-To-Peer (P2P)	P2P in computing or networking is a distributed application architecture that partitions tasks or workloads between peers. In this context it is about P2P hydrogen systems, where renewable generation and hydrogen production are the two peers in the system.
Perfluorosulfonic acid (PFSA) structure	The PFSA membranes are characterized by high mechanical stability, excellent chemical inertness, good thermal stability, and high proton conductivity.

Phosphoric acid fuel cell (PAFC)	PAFC is a FC that uses an aqueous solution of phosphoric acid (H3PO4) as the electrolyte.
Photovoltaic (PV)	PV is the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry.
Piezoelectricity	Piezoelectricity is the electric charge that accumulates in certain solid materials in response to applied mechanical stress.
Platinum group metal (PGM)	PGM consists of six noble metal elements: iridium, osmium, palladium, platinum, rhodium and ruthenium.
Polyamide 11 (PA 11) or Nylon 11	PA 11 is a polyamide, bioplastic and a member of the nylon family of polymers produced by the polymerization of 11-aminoundecanoic acid. It is applied in the fields of oil and gas, aerospace, automotive, textiles, electronics and sports equipment, frequently in tubing, wire sheathing, and metal coatings.
Power-to-liquid (PtL)	PtL is a technology which transforms renewable energy (electricity and/or heat) into the form of liquid fuels.
Power-to-X (PtX)	PtX is a technology which converts electric power - typically surplus electric power generated from renewable energy sources during periods when generation exceeds load - to another form of energy (such as hydrogen, methane or methanol) for storage and re-conversion to electric power, to an alternative form of energy (such as gas or synthetic fuel), or to another useful product (such as ammonia or other chemical feedstocks).
Pressure swing adsorption (PSA)	Pressure swing adsorption (PSA) is a method of separating gases using the physical adsorption of one gas at high pressure and releasing it at low pressure.
Proton exchange membrane (PEM)	A PEM is a polymer based membrane with cation (proton) conductivity which acts as an electrolyte and a separator between anode and cathode.
Proton exchange membrane electrolysis (PEMEL)	A PEMEL is a electrolysis that employs a proton exchange membrane as electrolyte.
Proton exchange membrane fuel cell (PEMFC)	A PEMFC is a FC that employs a polymer membrane with (proton) ion exchange capability as the electrolyte.
QFD-based methodologies	Quality function deployment (QFD) is a method to help transform the voice of the customer into engineering characteristics for a product. It combines quality assurance and quality control points with function deployment used in value engineering.
Ramp-up phase of production	The term ramp-up refers to when an undertaking substantially increases its output in response to increased demand or an expected increase in the near term.
Refuse-derived fuel (RDF)	RDF is a fuel produced from various types of waste such as municipal solid waste, industrial waste or commercial waste.
Regulations, codes, and standards (RCS)	The development and use of harmonised performance-based standards for appliances and systems, together with their safety in energy and aim can facilitate access to the market and can serve as mandatory references

	in regulatory documents at EU level.
Reliability Availability Maintainability and Safety (RAMS)	RAMS refers to Reliability, Availability and Maintainability Study which is a decision making tool used to identify how to increase the availability of the system, and thus increase the overall profit as well as reducing the life cycle costs.
Renewable Energy source (RES)	RES is a energy source which is not depleted by extraction as it is naturally replenished at a rate faster than it is extracted
Renewable hydrogen	For the purpose of this decision, renewable hydrogen is hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources. The full life-cycle greenhouse gas emissions of the production of renewable hydrogen are close to zero. Renewable hydrogen may also be produced through the reforming of biogas (instead of natural gas) or biochemical conversion of biomass, if in compliance with sustainability requirements.
Reversible solid oxide cell (rSOC)	rSOC is a SOC which can function both in FC (SOFC) mode and in electrolysis (SOEC) mode.
Six-Sigma	Six Sigma is a systematic procedure for process optimisation and can be counted among the methods of quality management as well as seen as an actual quality objective from the perspective of statistics.
Smart Energy Management System	Smart Energy Management helps to save energy in conversion, storage, distribution and consumption units by strategically influencing user behaviour and energy flows through the intelligent interaction of sensors, actuators, controllers and user interfaces.
Solar thermochemical water-splitting cycles (TWSCs) / Water thermolysis	Solar TWSC uses high temperatures from concentrated solar power and chemical reactions to produce hydrogen and oxygen from water.
Solid oxide cell (SOC)	A SOC is an electrochemical cell composed of three functional elements, positive electrode, electrolyte, negative electrode (PEN) based on ceramic oxide materials.
Solid oxide electrolyser (SOE)	SOC-based electrolyser used in high temperature electrolysis (also SOEL)
Solid oxide electrolysis cell (SOEC)	A SOEC is a SOC operated in electrolysis mode, i. e. reversed FC mode.
Solid oxide fuel cell (SOFC)	A SOFC is a FC that uses an ion-conducting oxide as the electrolyte
Stack	A FC stack is a cell stack that usually consists of bipolar plates, membrane electrode assemblies (MEAs), seals as well as end plates and the bracing system.
Stationary Storage systems	A stationary energy storage system can store energy and release it in the form of electricity when it is needed. In most cases, it will include an array of batteries, an electronic control system, inverter and thermal management system within an enclosure. Unlike a FC that generates electricity without the need for charging, energy storage systems need to be charged to provide electricity when needed.

Synfuel or synthetic fuel	Synthetic fuel or synfuel is a liquid fuel, or sometimes gaseous fuel, obtained from syngas, a mixture of carbon monoxide and hydrogen, in which the syngas was derived from gasification of solid feedstocks
System gravimetric efficiency	The system gravimetric efficiency includes the weight of a vessel as well as the storage material.
Technology readiness level (TRL)	TRL is a method for estimating through assessment of the maturity of an evolving technology prior to using this technology in a product or system according to an integer scale from 1 (basic) to 9 (most mature: system proven and market ready)
Thermoplastic composites	Thermoplastic composites have evolved from structural polymer composites. When heated, they soften and can be remolded without degradation. When they cool, they solidify into the finished shape
Thermoplastic liners	A thermoplastic lining is a thin layer of material composed of plastic polymer that is often affixed to the inner surface of a metallic vessel or pipe. The thermoplastic lining serves as a protective coating against corrosion and erosion from wear and tear.
Total cost of ownership (TCO)	TCO is a monetary (economic value) estimate designed to help consumers and businesss to assess and account the full cost directly and indirectly related to a product, service or system as an investment over the whole life cycle of such product, service or system
Type IV vessels	Type IV vessels are made of all carbon fibre, with an inner liner of polyamide or polyethylene plastic.
Type V vessels	Type V vessels are all-composite, linerless pressure vessels that provide the best pressure vessel efficiency of any composite pressure vessel.
Underground gas storage (UGS)	Underground Gas Storage facilities (UGS) are depleted oil or natural gas fields, aquifers, mines, and salt caverns that have the geological properties to store natural gas over long periods. These facilities differ from other types of gas storage (e.g. liquefied or compressed natural gas) since they use an existing geological underground formation for storage.
UV polymerisation	UV polymerisation is a UV-activated process of reacting monomer molecules together in a chemical reaction to form polymer chains or three-dimensional networks.
V development cycle	The V-Model demonstrates the relationships between each phase of the development life cycle and its associated phase of testing.
Virtual power plant (VPP)	A VPP is a cloud-based distributed power plant that aggregates the capacities of heterogeneous distributed energy resources for the purposes of enhancing power generation, as well as trading or selling power on the electricity market.
Volatile Organic Compounds (VOC)	VOC are organic chemicals that have a high vapour pressure at room temperature.
Watt (W)	Watt (joules per second) is a unit of power or radiant flux.

ANNEX III

LIST OF ABBREVIATIONS

Abbreviation	Meaning
AEL	Alkaline electrolysis
AEM	Anionic Exchange Membrane
AI	Artificial Intelligence
BOP	Balance of Plant
CAPEX	Capital Expenditure
CHP	Combined heat and power
Co	Cobalt
D2C	Design-to-cost
D2M	Design-to-manufacturing
DCDC	Direct current converter
EOL	End Of Life
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicles
FCS	Fuel Cell System
GDE	Gas diffusion electrode
GDL	Gas diffusion layer
GWe	Giga Watt equivalent
ICE	Internal Combustion Engine
HD	Heavy Duty
HRS	Hydrogen refuelling station
HTPEM	High temperature proton exchange membrane
HTPEMFC	High temperature proton exchange membrane fuel cell
KPI	Key Performance Indicator

LD	Light Duty
LH_2	Liquid hydrogen
LOHC	Liquid Organic Hydrogen Carrier
LTPEM	Low temperature proton exchange membrane
LTPEMFC	Low temperature proton exchange membrane fuel cell
MEA	Membrane electrode assembly
MW	Mega Watt
Ni	Nickel
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditures
PEM	Proton exchange membrane
PEM EL	Proton Exchange Membrane Electrolysis
PEMFC	Polymer Electrolyte Membrane Fuel Cell
PEMWE	Polymer Electrolyte Membrane Water Electrolyser
PGM	Platinum Group Metals
ppm	parts per million
Pt	Platinum
PTL	Porous transport layer
rSOC	Reversible Solid Oxide Cell
SOC	Solid Oxide Cell
SOE	Solid Oxide Electrolyser
SOEC	Solid Oxide Electrolysis Cell
SOFC	Solid Oxide Fuel Cell
SOFC	Solid Oxide Fuel Cell
TCO	Total Cost of Ownership