



ANNEX to GB decision no FCH-GB-2019-14.

FUEL CELLS and HYDROGEN 2 JOINT UNDERTAKING (FCH 2 JU)

2020

ANNUAL WORK PLAN and BUDGET

NOTICE

Please note that until the UK leaves the EU, EU law continues to apply to and within the UK, when it comes to rights and obligations; this includes the eligibility of UK legal entities to fully participate and receive funding in Horizon 2020 actions such as those called for in this work plan. Please be aware however that the eligibility criteria must be complied with for the entire duration of the grant. If the UK withdraws from the EU during the grant period without concluding an agreement with the EU ensuring in particular that British applicants continue to be eligible, they will no longer be eligible to receive EU funding and their participation may be terminated on the basis of Article 50 of the grant agreement.

In accordance with the Statutes of the FCH 2 JU annexed to Council Regulation (EU) No 559/2014 and with Article 31 of the Financial Rules of the FCH 2 JU.

The annual work plan will be made publicly available after its adoption by the Governing Board.

TABLE OF CONTENT

2.INTRODUCTION	4
3.ANNUAL WORK PLAN YEAR 2020	7
3.1 Executive Summary.....	7
3.2 Operations	8
Objectives & indicators - Risks & mitigations	8
Scientific priorities & challenges	11
List of actions	14
A. Call for proposals 2020	14
B. Collaboration with JRC – Rolling Plan 2020	82
C. Regulations, Codes and Standards Strategy Coordination (RCS SC) Group	88
D. European Hydrogen Safety Panel (EHSP).....	89
E. Knowledge management. Dissemination and communication on projects results	91
F. Support to policies and funding/financial engineering	94
G. International Cooperation	99
H. Public Procurements	101
Conditions for the Call.....	102
3.3 Call management rules	105
3.4 Support to Operations	108
COMMUNICATION AND OUTREACH ACTIVITIES	108
Procurement and contracts	112
IT and logistics	113
JU Executive Team – HR matters.....	114
Administrative budget and finance	116
Data protection	116
3.5 Governance.....	118
3.6 Internal Control framework	120
Financial procedures	120
Ex-ante and ex-post controls.....	120
Audits	122
4. BUDGET YEAR 2020	123
4.1 Budget information.....	123
4.2 Staff Establishment Plan and Organisation Chart	129
5. LIST OF ACRONYMS	131
6. ANNEX: HORIZON 2020 INDICATORS FOR JOINT UNDERTAKINGS	134

TABLE I: Horizon 2020 Key Performance Indicators common to all JUs	135
TABLE II: Indicators for monitoring Horizon 2020 Cross-Cutting Issues common to all JUs	139
TABLE III: Key Performance Indicators specific to FCH 2 JU	144

2. INTRODUCTION

This document establishes the seventh Annual Work Plan (AWP) of the Fuel Cell and Hydrogen 2 Joint Undertaking (FCH 2 JU), outlining the scope and details of its operational and horizontal activities for the year 2020.

FCH 2 JU is a public-private partnership focusing on the objective of accelerating the commercialization of fuel cell and hydrogen technologies. FCH 2 JU was setup, within the Horizon 2020 Framework programme, as a Joint Undertaking by Council Regulation N° 559/2014¹. Its aim is to contribute to the Union's wider competitiveness goals and leverage private investment by means of an industry-led implementation structure.

Conscious of its dependence on energy resources imports, largely from unstable countries, the EU has set targets to reduce the related risks. This is voiced in the European Commission's (EC) 2014 Energy Security Strategy², which puts the focus on the need for improved energy efficiency but also on the necessity to increase EU's own energy production, to diversify supply sources and routes, to consolidate its internal energy system and to protect its critical infrastructure.

At international level, during Paris climate conference (COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to 2°C “...and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius”.

Underpinning this, the 2015 Communication from the European Commission³ on ‘A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy’ contains among all lines of action the energy security, solidarity and trust, energy efficiency, decarbonizing the economy and research, innovation and competitiveness.

In November 2016, the EC adopted the “Clean Energy for All Europeans Package”⁴, which included revised legislative proposals covering energy efficiency, energy performance in buildings, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union. In addition, the European Commission Staff Working Document (SWD) on Energy storage published as part of the "Second Report on the State of the Energy Union" on 01 February 2017⁵, outlines the role of energy storage in relation to electricity, presents the advantages of different technologies and innovative solutions in different contexts, and discusses further possible policy approaches. It is acknowledged that energy storage, including hydrogen storage based solutions, has not yet developed its full potential in the energy markets. Developing affordable and integrated energy storage solutions is highlighted as a priority to facilitate and enable the transition to a low carbon energy system based largely on renewables.

On 8th November 2017, the European Commission has also proposed to update the EU Gas Directive⁶, in order to ensure that all major gas pipelines entering EU territory comply with EU rules, are operated with the same levels of transparency, are accessible to other operators, and are operated in an efficient way. The proposal aims to improve the functioning of the EU internal gas market, increase competition between suppliers, and boost Europe's energy security. The role of hydrogen is also mentioned as one of the solutions to decarbonise the EU gas network and increase security of supply.

On the same date of 8th November 2017, the European Commission has adopted and published the so-called ‘Clean Mobility package’ which takes action to reinforce EU's global leadership in clean vehicles by proposing new targets for the EU fleet wide average CO2 emissions of new passenger cars and vans to help accelerate the transition to low- and zero emission vehicles. As part of the package,

¹ OJ L 169/108 of 7.6.2014

² European Energy Security Strategy. {SWD(2014) 330 final}

³ COM(2015)80, Energy Union Package

⁴ Clean Energy for All Europeans Package: <https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition>

⁵ https://ec.europa.eu/energy/sites/ener/files/documents/swd2017_61_document_travail_service_part1_v6.pdf

⁶ https://ec.europa.eu/info/news/commission-proposes-update-gas-directive-2017-nov-08_en

an action plan and investment solutions for the trans-European deployment of Alternative Fuels Infrastructure was proposed, which includes hydrogen as one of the clean fuel for transport. The aim is to increase the level of ambition of national plans, to increase investment, and improve consumer acceptance. In addition, proposal was made to amend the Clean Vehicles Directive to promote clean mobility solutions in public procurement tenders and thereby provide a solid boost to the demand and to the further deployment of clean mobility solutions, including fuel cells vehicles.

Furthermore, in 2018 there was a global agreement for the first time within International Maritime Organisation, IMO on targets to reduce the GHG emissions of the maritime transport by a minimum of 50% by 2050 and phase-out completely before the end of the century. This represents a substantial challenge and the possibility of using fuel cells, together with hydrogen or other zero carbon fuels, as a very promising energy source for large-scale shipping is increasingly being considered.

On 18 September 2018 the use of hydrogen as a future-oriented energy form was among the items on the agenda of the informal meeting of EU energy ministers⁷. *"The Austrian Presidency of the Council of the European Union proposed a Hydrogen Initiative that many member states approved of and signed"*, said Elisabeth Köstinger, chair of the EU energy minister meetings. *"Under this initiative, the signatory states commit themselves to continue research and investment in the production and use of hydrogen as a future-oriented technology"*, Elisabeth Köstinger added. EU Commissioner Miguel Arias Cañete also welcomed the initiative of the Austrian Presidency of the Council of the European Union: *"Green hydrogen offers significant potential for the decarbonisation of the European economy. The Commission warmly welcomes the Hydrogen Initiative as it will further harness the innovative drive across the EU."*

European Commission has published the 2050 Long-term Strategy⁸ in November 2018 that calls for a calls for a climate-neutral Europe by 2050 (COM (2018) 773). The strategy shows how Europe can lead the way to climate neutrality by investing into realistic technological solutions, empowering citizens, and aligning action in key areas such as industrial policy, finance, or research – while ensuring social fairness for a just transition. *'The eight scenarios build upon no regret policies such as strong usage of renewable energy and energy efficiency. Five of them look at different technologies and actions which foster the move towards a net-zero greenhouse gas economy. They vary the intensity of application of electrification, hydrogen and e-fuels (i.e. power-to-X) as well as end user energy efficiency and the role of a circular economy, as actions to reduce emissions'*. In all these pathways electricity consumption increases, but notable differences exist. *'Pathways that focus more on electrification in end-use sectors see also need for high deployment of storage (6 times today's levels) to deal with variability in the electricity system; but pathways which deploy more hydrogen require more electricity to produce the hydrogen in the first place'*. It also concludes that *'Pathways more reliant on carbon-free energy carriers require less transformation and investment in the end-use sector, but also the highest investment needs in the energy supply sectors'* and in consequence *'further significant steps in research and development are needed in production of decarbonised fuels as well as the vehicle technologies such as batteries fuel cells and hydrogen gas engines'* but also that *'EU research should focus on transformational carbon-neutral solutions in areas such as electrification (renewables, smart networks and batteries), hydrogen and fuel cells, energy storage'*.

In line with its ultimate long-term strategy and following the political agreement reached by the Parliament and the Council in June 2018, the revised Renewables Energy Directive (RED II)⁹ establishes a binding EU target of at least 32% for 2030 with a review for increasing this figure in 2023. In this context, it calls to Member States to establish a methodology for guarantees of origin of renewable gases (including hydrogen) and consequently certification system.

⁷ <https://www.eu2018.at/latest-news/news/09-18-Informal-meeting-of-energy-ministers.html>

⁸ <https://ec.europa.eu/clima/policies/strategies/2050>

⁹ https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

In December 2018, Member States have also submitted their draft integrated National Climate and Energy Plans (NECPs)¹⁰ for the period 2021-2030. Several of them have already made ambitious plans based on (renewable) hydrogen to decarbonise entire economy. The final plans must be submitted by the end of 2019.

In June 2019, the Common rules for the internal market for electricity Directive¹¹ entered into force. They establish common rules for the generation, transmission, distribution, energy storage (including hydrogen) and supply of electricity, together with consumer protection provisions, with a view to creating truly integrated competitive, consumer centred, flexible, fair and transparent electricity markets in the Union. Within the same package, entered into force the Regulation (EU) 2019/943 on the internal market for electricity¹² that *'sets fundamental principles for well-functioning, integrated electricity markets, which allow all resource providers and electricity customers non-discriminatory market access, empower consumers, ensure competitiveness on the global market as well as demand response, energy storage and energy efficiency, and facilitate aggregation of distributed demand and supply, and enable market and sectoral integration and market-based remuneration of electricity generated from renewable sources'*.

In line with all the policy developments described above, it is crucial that the FCH 2 JU continues to develop technology solutions that will help materialise the benefits of hydrogen and fuel cell technologies in support of the high level EU policy agenda. The present Annual Work Plan 2020 of the Fuel Cells and Hydrogen 2 Joint Undertaking proposes a list of research and demonstration activities in line with the above-mentioned EU-wide objectives and with all the FCH 2 JU objectives as listed in Council Regulation 559/2014 of 6 May 2014:

1. Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies;
2. Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs;
3. Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using fuel cell system can compete with the alternatives for electricity production available on the market;
4. Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources;
5. Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements.

¹⁰ <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans>

¹¹ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944&from=EN>

¹² <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN>

3. ANNUAL WORK PLAN YEAR 2020

3.1 Executive Summary

The Annual Work Plan 2020 for the FCH 2 JU continues the work initiated in previous years concerning the development of a research and innovation programme aligned with the objectives set in Council Regulation 559/2014 of 6 May 2014.

During 2020, a call for proposals with an indicative budget of EUR 93 million will be launched in January 2020 (see chapter 3.2, Conditions for the Call), addressing key challenges as identified by the stakeholders in the Joint Undertaking. These challenges encompass different areas of research and innovation for each of the Transport and Energy pillars, as well as Overarching and Crosscutting activities. A total of 24 topics will be part of the call for proposals, including 8 for Transport, 9 for Energy, 2 for Overarching and 5 for Cross-Cutting. They will be grouped into 9 Innovation Actions (IA), 14 Research and Innovation Actions (RIA) and 1 Coordination and Support Action (CSA).

The Call for Proposals will be subject to independent evaluation and will follow the H2020 rules on calls for proposals. Upon selection, the Partners (the 'consortium') will sign a Grant Agreement with the JU.

In addition, work will continue on the different operational activities along the call and to ensure that the support activities to operations provided by the Programme Office facilitates the proper management of H2020 and FP7 funds, according to the principles laid out in the financial guidelines.

Communication and outreach activities will ensure that stakeholders are duly informed about the activities and results of the FCH 2 JU, raising the FCH 2 JU Programme's profile and highlighting technology potential and market readiness.

3.2 Operations

Objectives & indicators - Risks & mitigations

Techno-economic objectives

The techno-economic objectives laid out in the Multi-Annual Work Plan (MAWP) 2014-2020¹³ are addressed in this AWP through the call topics. The correspondence of topics into the techno-operational objectives is shown below:

Objective	Topic
Techno-economic objective 1: reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels competitive with conventional technologies	<p>FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures</p> <p>FCH-01-2-2020: Durability-Lifetime of stacks for Heavy Duty trucks</p> <p>FCH-01-3-2020: Liquid Hydrogen on-board storage tanks</p> <p>FCH-01-4-2020: Standard Sized FC module for Heavy Duty applications</p> <p>FCH-01-5-2020: Demonstration of FC Coaches for regional passenger transport</p> <p>FCH-01-6-2020: Demonstration of liquid hydrogen as a fuel for segments of the waterborne sector</p> <p>FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework</p> <p>FCH-01-8-2019: Scale-up and demonstration of innovative hydrogen compressor technology for full-scale hydrogen refuelling station</p>
Techno-economic objective 2: increase the electrical efficiency and the durability of the different fuel cells used for CHP and power only production, while reducing costs, to levels competitive with conventional technologies	<p>FCH-02-4-2020: Flexi-fuel stationary SOFC</p> <p>FCH-02-9-2020: Fuel cell for prime power in data-centres</p>
Techno-economic objective 3: increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system is competitive with the alternatives available in the marketplace	<p>FCH-02-2-2020: Highly efficient hydrogen production using solid oxide electrolysis integrated with renewable heat and power</p> <p>FCH-02-3-2020: Diagnostics and Control of SOE</p> <p>FCH-02-8-2020: Demonstration of large-scale co-electrolysis for the Industrial Power-to-X market</p>
Techno-economic objective 4: demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium	<p>FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology</p> <p>FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores</p> <p>FCH-02-6-2019: Electrolyser module for offshore production of renewable hydrogen</p>

¹³ <http://www.fch.europa.eu/page/multi-annual-work-plan>

for electricity produced from renewable energy sources	<p>FCH-02-7-2020: Cyclic testing of renewable hydrogen storage in a small salt cavern</p> <p>FCH-03-2-2020: Decarbonising islands using renewable energies and hydrogen - H2 Islands</p>
Techno-economic objective 5: reduce the use of the EU defined "Critical raw materials", for example via low platinum resources, and through recycling or reducing or avoiding the use of rare earth elements	<p>FCH-04-3-2020: Development of eco-design guidelines for FCH products</p> <p>FCH-04-4-2019: Development and validation of existing and novel recycling technologies for key FCH products</p> <p>FCH-04-5-2020: Guidelines for Life Cycle Sustainability Assessment (LCSA) of fuel cell and hydrogen systems</p>

Two topics are addressing techno-economic objectives related to both transport and energy pillars (so called '**overarching activities**') while also addressing mainly the 'cross-sectorial' aspects of the Techno-economic objective 4:

- FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation;
- FCH-03-2-2020: Decarbonising islands using renewable energies and hydrogen - H2 Islands.

While two topics are addressing **crosscutting issues (mainly techno-administrative aspects and pre-normative/contribution to standards aspects)**, related to all techno-economic objectives:

- FCH-04-1-2020: Overcoming technical and administrative barriers to deployment of multi-fuel hydrogen refuelling stations (HRS);
- FCH-04-2-2020: PNR on hydrogen-based fuels solutions for passenger ships.

Key Performance Indicators (KPIs):

FCH 2 JU follows the objectives and technical targets defined in the MAWP. These are integrated in the call topics.

A list of indicators (see Annex) was developed by the European Commission services; the indicators are grouped into 3 categories as follows:

- Horizon 2020 Key Performance Indicators¹⁴ common to all JUs;
- Indicators for monitoring H2020 Cross-Cutting Issues¹⁵ common to all JUs;
- Key Performance Indicators specific to FCH 2 JU;

Risk Assessment

In the annual risk assessment exercise, conducted in October 2019, the following significant risks & responses to those risks in terms of action plans were identified:

	Risk Identified	Action Plan
MEDIUM	Due to BREXIT, participation of UK entities in the programme (representing significant part of FCH 2 JU funding) during projects execution can be adversely affected, including fluctuations of project budgets, and commitments from the UK based companies.	Follow up closely on the developments; maintain active dialogue with the EC. Contingency plans are in place for continuation of the projects, even in case of no agreement for BREXIT is reached.

¹⁴ Based on Annex II - Council Decision 2013/743/EU

¹⁵ Based on Annex III - Council Decision 2013/743/EU

MEDIUM	<p>Representative error rate may increase due to the simplified ex-ante controls under H2020 agreed horizontally for the Research family.</p> <p>Consequently, there is a risk of obtaining a qualified opinion and of not getting the discharge from the European Parliament due to fact that the Court of Auditors' threshold for representative error rate stays at the level of 2%.</p>	<p>Annual analytical risk – assessment at the beneficiary level and subsequent introduction of the targeted ex-ante controls for the projects / beneficiaries with higher identified inherent risk.</p> <p>Application of the feedback from ex-post audits and lessons learnt on ex-ante controls, e.g. from accompanying auditors in the missions for FCH audits.</p> <p>Continuation of interactive financial webinars for complex projects or where there are numerous newcomers in the consortia in the first 12 months of the project duration.</p>
MEDIUM	<p>The transition to the new EU Internal Data Protection Regulation (EUDPR).</p> <p>In case if roles, responsibilities and processes of staff working with personal data are unclear or not defined or do not match the new data protection regulation, this may lead to personal data not being properly managed and to litigation and sanctions.</p>	<p>Ensure that responsibilities and processes of staff working with personal data are clear and fully in accordance with the processes under the new data protection regulation (for example privacy by design and privacy by default).</p> <p>Continuous dialogue with CIC with whom the FCH has a "joint ownership" of part of the processed personal data.</p> <p>The implementation steps for the Data Protection Action Plan for transition to EUDPR for 2019 included the set-up of several additional internal processes and tools which would bring additional safeguards as of the date when they will come into production.</p> <p>Further training/awareness sessions for staff</p> <p>Newly developed tools and applications, including third-party services are to be reviewed for the compliance with the EUDPR already at their design stage.</p>
MEDIUM	<p>The general increase in the FCH digital footprint (e.g. progressive transfer and management of information in the Cloud, and use of online tools), coupled with an increase in "cyber-attacks" worldwide, are raising the possibility of suffering "cyber-attacks" trying to gain access to FCH 2 JUs' restricted/sensitive information.</p>	<p>Mitigating actions include raising awareness of staff and mechanisms to prevent attacks including the following:</p> <ul style="list-style-type: none"> - Improved ex-ante and ex-post security systems controls for automated attacks - Further training and tests of the BCP

The FCH 2 JU monitors closely the fulfilment of the action plan and reports on it in its Annual Activity Report.

Scientific priorities & challenges

In order to achieve its objectives, the FCH 2 JU should provide financial support mainly in the form of grants to participants following open and competitive calls for proposals.

The 2020 Call for Proposals is the result of a joint effort by the major stakeholders, namely Hydrogen Europe, Hydrogen Europe Research and the European Commission. It represents a set of prioritised actions, consistent with the objectives of the FCH 2 JU, and is divided primarily into the Pillars identified in the MAWP: Transport, Energy and Crosscutting activities. In addition, Overarching activities, combining the entire supply chain from production of hydrogen all the way to its use in different applications and addressing the sectoral integration aspect for H2 Islands, but also breakthrough research on new materials for both energy and transport applications were identified as priority for this year.

The emphasis given to different actions in different pillars reflects the industry and research partners' assessment of the state of the technological maturity of the applications and their estimated importance to achieve critical objectives of the FCH 2 JU.

In line with the activities started already in 2017, the FCH 2 JU will continue to work to reinforce the European supply chain of critical key components by e.g. a higher range of common/standardised parts to be produced in EU and H2020 Associated Countries, and to enable start investments in production facilities for further ramp-up in these markets.

International collaboration with countries under International Partnership of Hydrogen into the Economy (IPHE)¹⁶ is encouraged for all topics of the call. Collaboration with developing world countries supported by the Climate Technology Centre & Network (CTCN) under the UN Environment Programme¹⁷ is also encouraged. In particular, cooperation within RENEWABLE AND CLEAN HYDROGEN INNOVATION CHALLENGE¹⁸ under Mission Innovation (Accelerating the Clean Energy Revolution) is foreseen (see section 3.2.G below).

In addition, further openness towards markets in the EU13 countries should be continued and integration of participants from those countries in consortia is highly encouraged.

For proper technology monitoring and progress against state-of-art, but also to identify how each of the projects contribute to reaching the targets and indicators set by the MAWP, supported projects will report on an annual basis in the FCH 2 JU secure online data collection platform (TRUST), according to template questionnaire(s) relevant to the project content (and the technology development and TRL). This should be integrated as specific annual deliverable in the grant agreement. The template questionnaires can be consulted online (<http://www.fch.europa.eu/projects/knowledge-management>), subject to modifications due to technology development and/or change in projects portfolio.

For all topics and related successful projects, any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN.

For all Innovation Actions, the Safety Planning Guidance document developed by the EHSP¹⁹ should be followed and accordingly a 'draft safety plan' should be proposed as part of the proposal (to be further updated during project implementation and reviewed by the EHSP).

For all topics, activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should

¹⁶ <https://www.iphe.net/>

¹⁷ <https://www.ctc-n.org/>

¹⁸ <http://mission-innovation.net/our-work/innovation-challenges/hydrogen-challenge/>

¹⁹ <https://www.fch.europa.eu/page/european-hydrogen-safety-panel>

adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

1. Transport related activities:

While expected that vehicle architectures will change significantly in the next few years due to mainly increase of electro mobility but also autonomous driving, it would be extremely beneficial if hydrogen drive and battery systems could share the same vehicle architecture. The integration of both energy systems in the same car body would enable economies of scale, simplify and reduce engineering and manufacturing processes and allow flexible production, which could buffer demand fluctuations. In that respect, FCH 2 JU is looking to support disruptive solutions for tank concepts, in order to be able to integrate hydrogen drive systems into after-2020 future vehicles e.g. high-pressure hydrogen storage vessels (which used to have cylindrical geometries in conventional pressure vessels) into a rectangular shape for battery spaces.

Hydrogen is considered to play an essential role in future zero-emissions Heavy Duty mobility. There is a growing consensus that (long haul) heavy duty transport and stationary will be the key market for hydrogen fuel cells from the mid-2020s onwards. In addition, this transport sector struggles with the electrification of their portfolio.

In this respect, the FCH 2 JU is looking in 2020 to support a series of topics for heavy-duty transport applications: improving the durability of fuel stacks for heavy duty applications (up to 1,000 km driving range per day of vehicles more than 12t, with power output from 150 to 350 kW and ranges from 12,000 to 100,000 km/year); looking for innovative on-board storage solutions based on liquid hydrogen (LH2) that can ensure storage of around 100 kgH₂ (ensuring the required 100,100 km/year); and ultimately building a standard-sized FC module for heavy duty applications among all fuel-cells manufacturers, while securing the EU supply-chain.

In addition, demonstration in the field of such heavy-duty applications is proposed to be supported this year, such as FC Coaches for regional passenger transport, waterborne/shipping applications based on liquid hydrogen and different prototypes for fuel cells trains (e.g. multiple units, shunters or mainline locomotives).

Finally, to complement all development and demonstration activities for heavy-duty applications, the related infrastructure should also be developed. In this regards, in 2020 FCH 2 JU is looking to support innovative compression technologies which can ensure the minimum of 200 kg H₂/day.

2. Energy related activities:

Hydrogen is a flexible energy carrier that can be produced from any energy source, and which can be converted into various energy forms. The main challenges with hydrogen use are related to its storage during large periods of time and capacity, and transportation on long distance.

In that respect, FCH 2 JU is looking to support in 2020 different solutions for transportation of hydrogen on long distances such as Liquid Organic Hydrogen Carriers (LOHC) and their technical and energetic performance of the catalysts that ensure high efficiency of loading/unloading processes. In addition, is looking to increase the knowledge in EU on seasonal storage of hydrogen underground (either in depleted gas fields or in salt caverns), which has the potential to be the most cost efficient, environmentally friendly, and suitable for storing large amounts (e.g. more than 200 GWh per salt cavern or over 1,000 GWh in a gas field).

In working to prove that hydrogen is the best solution for integrating renewable electricity into the EU energy networks, further development is necessary on electrolyzers; in that respect, in 2020 FCH 2 JU continues to support development of high-temperature electrolysis (Solide-Oxide Electrolysis, SOE) in particular further understanding of degradation mechanisms and use of diagnostics and control methods to improve it. Moreover, FCH 2 JU is looking to support the novel solution of integrating also the renewable heat (from Concentrated Solar Panel, CSP) with the renewable electricity, while producing hydrogen.

Ultimately, in 2020 FCH 2 JU intends to look at new sector markets and demonstrate again the hydrogen technologies solutions such in integrating the renewable electricity from large-scale offshore wind and potentially floating solar PV or in using the co-electrolysis for the Industrial Power-to-X market (to supply green syngas at a competitive cost and in the MW range in order to be relevant to the industrial applications that will still rely on carbon in the future).

As regards the FC-CHP solutions, in 2020 the FCH 2 JU looks at supporting innovative business models for using fuel cells in data-centers (expected to use up to 4% of world's energy consumption in the next few years while required by the city centers to reduce and avoid emissions like NO_x, SO_x, particulate matter and noise, to protect the health of their inhabitants); fuel cells can adequately address all these challenges as they can provide high power density within buildings or on roof tops and highly reliable power supply at acceptable cost levels.

Moreover, taking advantage of the development on natural gas fed SOFC and of the high number of units already installed, FCH 2 JU is looking to support the adaptation of existing SOFC systems design made for natural gas to varying mixtures, with the aim of developing the next generation of "flexifuel" fuel cell systems; this should develop and demonstrate in a relevant environment a stationary solid oxide fuel cell system capable to operate under variable fuel mixtures with high electrical efficiency, high heat quality, long lifetime and able to reach the cost level of conventional fuel cell systems.

3. Overarching activities:

Green hydrogen is crucial to meet the CO₂ reduction objectives of both the industry (e.g. e-chemicals etc.) and in the transportation sector (e.g. fuel cell cars, e-fuels). In this context, the demand of high-quality hydrogen regarding dryness, purity and pressure is steadily increasing. In this context, the FCH 2 JU is looking in 2020 to develop new materials (Proton Conducting Ceramic Cells, PCC) as a promising alternative way to compress and purify hydrogen for both energy and transport applications.

Hydrogen and its associated technologies have the potential to support islands in addressing a number of challenges related to energy. Building on the successful experience of previous year (Hydrogen Valleys in the FCH 2 JU call 2019), the FCH 2 JU intends in 2020 to similarly prove solutions of hydrogen for sectoral integration in another type of defined geographical areas (islands) where several hydrogen applications are integrated within an FCH ecosystem.

4. Cross-Cutting activities:

The focus in 2020 of these activities is on sustainability aspects, with several topics addressing Life Cycle Assessment (LCA) aspects but also eco-design solutions for FCH technologies and ultimately recycling (including reduction of dependency on critical raw materials).

In addition, FCH 2 JU intends to build on previous projects and explore the necessary steps (and overcome the main technological and administrative barriers) to be followed to deploy multi-fuel hydrogen refuelling stations (HRS).

Finally, as regards contribution to standards, FCH 2 JU is continuing activities to contribute to the development of a goal-based regulatory framework on the use of hydrogen and hydrogen-based alternative fuels for waterborne transport, by developing the necessary pre-normative research based on the 'alternative design approach' required by the IMO).

List of actions

For the implementation of the Work Plan, the following actions will be taken in 2020:

A. Call for proposals 2020

Topic descriptions are detailed starting from the next page.

TRANSPORT PILLAR

FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures

Specific Challenge

It is expected that vehicle architectures will change significantly in the next few years due to major trends in the automotive industry: the increase of electro mobility based on battery technology, which demands flat design spaces in car underbodies and the increasing technology readiness level of autonomous driving, which causes significant vehicle transformations including use of car interiors. Passengers will require space for free movement, which implies among other changes, body structures without central tunnel.

Today gasoline and diesel vehicles share the same installation spaces. Similarly, it would be extremely beneficial if hydrogen drive and battery systems could also share the same vehicle architecture. The integration of both energy systems in the same car body would enable economies of scale, simplify and reduce engineering and manufacturing processes and allow flexible production, which could buffer demand fluctuations. Due to the expected above changes in future car bodies, installation spaces designated for the integration of energy storage cannot be used efficiently with conventional type IV hydrogen cylinders tanks.

The major challenge today is the integration of hydrogen storage systems that fulfil customers' autonomy range expectations. Development of novel and innovative tank concepts is therefore necessary, in order to be able to integrate hydrogen drive systems into after-2020 future vehicles. The main challenge consists of packaging high pressure hydrogen storage vessels (which used to have cylindrical geometries in conventional pressure vessels) into a rectangular shape for battery spaces while complying with current type-approval regulations EC 79/2009²⁰ and UNECE Regulation No.134²¹. Finding a tank design concept while fulfilling requirements for certification as well as realizing a high storage volume for acceptable vehicle ranges is one of the main obstacles.

Scope

The core goal of this project is the development and validation of an innovative hydrogen 70 MPa tank system in a conformable shape that can be integrated in light-duty vehicles with flat architectures, unsuitable for conventional cylindrical Type IV (Composite Overwrapped Pressure Vessel, COPV) tanks.

The new storage system concept should take into account especially industrial manufacturability, mechanical safety, low permeation, fire resistance, low costs, high gravimetric and volumetric efficiency, and meet type approval requirements. It should also be compatible with SAE J2601²² and allow fast refueling according to SAE J2601 refueling protocols.

It is expected that the new storage system would need to fit into a design space of 1800 x 1300 x 140 mm³. The geometry and concept of the tank system is however not defined yet. The system can consist of one or more separate vessels that are linked in order to form the tank system.

The project should address the analysis, simulation, hardware validation and the Computer-Aided Design, CAD-based vehicle integration of the chosen concept.

It is expected that at least 10 prototypes will be built-up and major performance tests will be conducted in order to validate the concept according to current type-approval regulations. If a concept is chosen such that it shows a tank system consisting of several identical vessels linked to form the tank system, one prototype means one vessel; a vessel defines a closed containment with a separate valve.

The following tests are expected to be performed:

²⁰ <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:035:0032:0046:en:PDF>

²¹ https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.129.01.0043.01.ENG

²² https://www.sae.org/standards/content/j2601_201003/

- Non-destructive geometric/gravimetric characterization (on at least 2 prototypes);
- Burst pressure (on at least 3 prototypes);
- Pressure cycle tests (on at least 3 prototypes);
- Permeation (on at least 1 prototype);
- Fire resistance (on at least 2 prototypes);

The project should contribute to safety and type-approval standards for conformable hydrogen vessels (especially critical tests like drop and impact test).

TRL at the start of the project: 2 and TRL at the end of the project: 4.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

The consortium should consider collaborating with the European Commission's Joint Research Centre (JRC) and using its High Pressure Gas Tank Testing Facility (GASTEF) for conducting hydrogen cycle tests to complement the performance tests requested above.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 2 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years

Expected impact

The project should represent a new approach of mobile hydrogen storage in the EU and, if successful, will generate a true breakthrough, opening the door of the FCEV technology for all types of future vehicle concepts. A prototype would then need to be developed and built within the envelope of the installation space, and the project should result in:

- Prototypes designed for storing hydrogen gas at a nominal working pressure of 70 MPa;
- Developing an understanding for main requirements in future design space;
- Understanding of manufacturing hurdles and solutions;
- Demonstration that future fuel cell electric vehicles can share vehicle architectures with battery electric vehicles;
- Better understanding for temperature changes inside the pressure vessels with new geometries due to hydrogen fueling and defueling;
- Necessary steps for certification and standardization of investigated pressure vessel geometries should be shown (especially critical tests like drop and impact test).

The project should measure its impact through the following KPIs:

- Volumetric efficiency (according to the FCH 2 JU target for 2024):
 - o Within the H2 tank system > 0.033 kg H2/L system;
 - o Within the estimated design space (1800 x 1300 x 140 mm³) > 45 % (stored H2 volume within design space volume);
- Gravimetric efficiency (according to the FCH 2 JU target for 2024) > 5.7 %;

- Costs for tank system < 400€/kg H₂;
- Permeation < 46 cm³/h/l at 55 °C (according to UNECE Regulation No.134);
- No leakage or burst of the vessel may occur under an engulfing fire affecting the whole tank at a temperature higher than 590 °C for a duration of at least 10 minutes, according to UNECE Regulation No.134;
- Burst pressure > 157.5 MPa (according to UNECE Regulation No.134);
- Hydraulic pressure cycle test: no leakage before 11,000 cycles and no burst before 22,000 cycles at 87.5 MPa (according to UNECE Regulation No.134).

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

FCH-01-2-2020: Durability-Lifetime of stacks for Heavy Duty trucks

Specific Challenge

Fuel cell powered heavy-duty vehicles (HDVs) hold great promise for deployment at global scale. However, for HDVs, and more specifically trucks, we face new challenges compared to Light Duty Vehicles (LDVs), especially with respect to durability and robustness. While 6,000 h lifetime is sufficient for LDVs, heavy-duty trucks will require at least five times longer. Therefore, core stack components particularly Membrane Electrode Assemblies (MEAs) need to be specifically developed in line with the specific heavy-duty truck requirements, while complying with prevailing cost targets. This improvement of the components is an essential step in order to confirm performance and durability for any full-scale stack and system design.

Increased understanding of degradation phenomena at stack level remains a major challenge to overcome in order to achieve the durability required for HD trucks. Very long lifetime is required along with high autonomy, combined with aggressive road duty cycles for some applications. Technical targets will be to further develop and apply advanced methods to properly investigate degradation of performance and the causes of these losses for the first step and, to identify, develop, realise and validate improved MEA formulations in stacks in a second step. The final outcome should thus allow significantly increased stack lifetime whilst enhancing performance and reducing cost.

Scope

The global scope is to enable in the short-term (<5 years) the deployment of competitive HD trucks based on EU fuel cell technology. The main objectives will be firstly, to clarify the durability and degradation issues of heavy duty stack components for SoA technologies (to ensure that studies are based on the most relevant up-to-date parameters, components and operating conditions for the selected applications) and, secondly, to propose and validate more durable stacks based on re-designed MEAs.

The project should rate and rank the most critical degradation mechanisms, looking for specific phenomena or stressors in stacks for heavy-duty (HD) trucks. This may be achieved using aged MEA components reflecting actual ageing from real HD operation either by collecting aged samples as well as the corresponding ageing data from field tests or actual trucks when available or mainly by performing ageing tests in labs on short stacks following realistic load profiles (full power, range extender, hybridization cases, or accelerated test), validated regarding actual, in-service drive cycles using HD-specific stack components. Applications data to be considered are: 1,000 km driving range per day; HD vehicles of classes from >12t; with power output from 150 to 350 kW and ranges from 12,000 to 100,000 km/year.

The methodology should include a broad range of investigations, with method development as needed for local in-situ measurements or ex-situ analysis, such as advanced electrochemical, physical, chemical and structural analyses, aiming to relate degradation phenomena to operating modes and conditions, quantify and correlate component degradation to performance losses. The second and major phase should be to use the results from the understanding phase to propose the best-suited mitigation strategies for the degradation mechanisms identified, concentrating the efforts on MEAs and MEA components (materials, formulations, processing), ensuring that the PGM-loading meets the target. Due to the longer lifetime required, the PGM loading target may be higher compared to LDV; hence research on how to achieve on the long term a high power density to PGM loading ratio would be of particular interest. In order to validate the proposed improvements in durability within a restricted timeframe, alternative methodologies should be proposed, such as strategies based on accelerated stress tests.

Modelling could be used to go further in the interpretation, or to simulate ageing for various MEA compositions and help defining the better trends for components formulation and stack operation. Several aspects should be covered by the project to develop disruptive MEAs and MEA components, for example by modifications of the component properties (membranes, ionomer, catalysts, gas diffusion layers) and preferably by looking for more effective utilisation of the MEAs by tuned

formulations (optimised interfaces, flow-field-adapted or graded electrodes). A focus on improved durability should be the priority, while maintaining low cost and avoiding negative impact on performance. The assessment of the developments should be conducted following specified relevant protocols in representative full-size single cells and preferably stacks.

A stack performance and durability test protocol recognised by the OEMs and in-line with EU standardisation activities (in collaboration with the European Commission's Joint Research Centre (JRC) testing harmonization activities) should be applied (including minimum duration required). This validation should be done at a representative scale, at least in a short-stack of minimum 10 cells or 1 kW, with a statistically significant number of MEAs, and an MEA active area of at least 150 cm², preferably conforming with the full-power stack design. The impact on system cost over the lifetime should be assessed based on these final validation results.

The project should build on the results of previous supported projects²³ dedicated to relevant applications such as GiantLeap (addressing advanced online diagnostic, prognostic and control systems), ID FAST (addressing investigation of ageing causes and AST methodology applied on LDV), Revive (developing garbage trucks) or H2HAUL (developing FC heavy duty trucks) as well as national actions, in order to get relevant data on FC operation and degradation or aged components as starting points.

Consortia should prove their access to SoA stack designs and include the capability to assemble stacks, by involving at least two stack providers. The hardware should be available for the implementation and the test of both performance and durability of reference and developed MEAs. Project consortia should include the capability to manufacture MEAs at the SoA level to ensure correct implementation and assessment of improvements of MEA materials or components.

TRL at start of the project: 2 and TRL at the end of the project: 4.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN.

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 3.5 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years

Expected impact

The final outcome should validate the solutions developed showing clear added-value in stack durability whilst maintaining the initial performance at least as high as that achieved by the selected reference (to be defined at the beginning of the project and consistent with the current SoA, to avoid artificial improvements by using a weak starting point).

Other expected impacts should include:

²³ <https://www.fch.europa.eu/page/fch-ju-projects>

- Durable cost-effective performing technical solutions for PEMFC stacks' core components allowing to support the future implementation of European technologies in HDV systems;
- Recommendations at system level, including hybridization as appropriate, for an optimized management of the full power chain allowing to improve FC durability consistently with the targeted KPIs;
- Contribution to the targets set by the Multi-Annual Work Plan and its addendum for 2024²⁴ on LDVs, particularly on stack power density (increase in kW/kg and kW/L vs. SoA) and indirectly on PEMFC system cost through stack components (reduction in €/kW vs. SoA) for heavy duty transport applications;
- Technological solutions whose economic and environmental aspects can be easily transferred to other fields compared to HDV, such as other transport or stationary applications;
- Possible contribution to RCS with regards to fuel cell testing and durability assessment.

In particular, the main targeted KPIs to be considered for the investigations are the following:

- Power density > 1.2 W/cm² at 0,675 V/cell;
- PGM loading < 0.3 g/kW;
- System durability: 30,000 projected hours with less than 10% performance loss at nominal power.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

²⁴ <https://www.fch.europa.eu/page/multi-annual-work-plan>

FCH-01-3-2020: Liquid Hydrogen on-board storage tanks

Specific Challenge

Commercial trucks, that are responsible for a quarter of road transport CO₂ emissions, are particularly sensitive to H₂ storage system density. The length and height of road vehicles in EU are limited to 16.5m and 4m, respectively. As a consequence, truck manufacturers have to choose between less payload (since a bulky H₂ takes valuable space away from the cargo) and less range when designing H₂ vehicles. The range limitation is less critical for fleet trucks with short routes: 350 bar H₂ storage seems to be sufficient for municipal vehicles, buses and even parcel delivery trucks. For trucking applications with larger payload and less dense HRS network, for instance regional and long haul, other solutions need to be investigated. Pressures of 500 to 700 bar indeed offer more volumetric capacity (more than 20 to 45% over 350 bar) but these solutions are costly and bring in hurdles on the infrastructure where large capacities need to be dispensed rapidly, while controlling the inlet temperature and allowing high station demand ("back-to-back").

350/700 bar storage requires compression and high-pressure storage at the hydrogen station, which takes footprint and important CAPEX/OPEX. Those will not be needed for LH₂ on-board, which require solely a LH₂ tank and a transfer pump in addition to dispenser(s), allowing to save costs on the whole H₂ chain. No industrial actors or consortia have started to develop consistently such technology in the world. Actors of the EU industry are currently well positioned and by pursuing this activity, have the potential to become world leaders.

Storing LH₂ (Liquid Hydrogen) on-board offers unprecedented storage density (two times more compared to 700 bar) while greatly improving the cost and complexity of high-throughput gaseous H₂ refuelling stations. Even though on-board LH₂ storage has been disregarded for light-duty vehicles (see the example of BMW 7 Hydrogen mini-series in 2005-2007²⁵), its relevance for applications that require larger capacities (40 to more than 100kg H₂) and that experience much more utilization (more than 100,000 km/year) deserve to be carefully evaluated.

LH₂ tanks have been used as stationary storage in industrial facilities, and of course in various space programs, for half a century. However, no on-board LH₂ storage for transportation vehicles exists today. The on-board environment has very unique challenges for LH₂: insulation optimization vs. gravimetric, functional, mechanical and safety requirements, fluid regulations for various modes (acceleration, parking refuelling etc.), compliance with stringent regulations and end-user interface.

Scope

The objective is to evaluate the feasibility of using LH₂ for heavy-duty vehicles through a design study followed by a demonstration test bench. The first phase of this effort will consist of mechanical and fluid design. This will include an investigation from the end-user perspective, by simulating real-life utilization (H₂ extraction, driving, parking and refuelling) and making sure that the state-of-charge, the actual boil-off and the refuelling are compatible with the expectations. A few configurations will be used as benchmark: rail mounting, behind cab, and within frame. The overall shape of the storage system is important, and advanced storage solutions to optimize the energy density (through e.g. a single vacuum jacket with multiple cylinders) should be investigated. The mechanical design should meet all requirements typical of the trucking industry in terms of durability, exposure to harsh environments, vibrations, accelerations, safeties. Pressure in the LH₂ storage tank should be compatible with the pressure at which the fuel cell typically operates. Alternatively, mitigation strategies should be proposed.

The nominal target capacity considered in the scope of this topic is 40-100 kg LH₂, with gravimetric and volumetric (usable) system densities of 10% wt H₂ and 45 g H₂/L for a 24 to 72 hour-dormancy, boil-off rates < 5%/day and compatibility with fuelling rates of up to 10 kg/min.

²⁵ For reference, estimated performances for the BMW 7 LH₂ storage system are 9% wtH₂ and 40 gH₂/L for a capacity of 8 kg H₂

All the activities should consider the current EC79/2009²⁶ (liquid hydrogen storage systems) and other relevant standards. Refuelling technologies are not within the scope of this topic, although the prototype should be compatible with an efficient refuelling process. The consortium should establish links with ongoing projects dedicated to relevant applications such as H2HAUL²⁷ and future project under ongoing FCH 2 JU call 2019 “Topic FCH-04-2-2019: Refuelling Protocols for Medium and Heavy-Duty Vehicles”.

TRL at start of the project: 4 and TRL at the end of the project: 5.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarned database, HELLEN.

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 2 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years

Expected impact

The much greater intrinsic energy density of LH2 (70 g/L) compared to 350 bar (24 g/L) and 700 bar (40 g/L) enables to increase dramatically the autonomy of the vehicle, and come closer to LNG truck autonomy; also reducing the overall number of hydrogen stations needed, and hence the average hydrogen cost at the pump.

The following KPIs should be reached by the end of the project:

- CAPEX storage tank: €320/kg H2;
- Volumetric capacity at tank system level: 0.045kg/L²⁸;
- Gravimetric capacity at tank system level: 10% (H2/(H2+tank system)).

In addition, although not addressed in this topic, it should contribute to pave the way towards the following KPIs on the infrastructure side as LH2 on-board storage solutions mature: station energy consumption of 0.05kWh/kg and CAPEX HRS: 2M€ @2t/day.

This project should represent the first step towards large adoption of the on-board LH2 technology and the creation of related standardized refuelling protocols. By enabling longer haul applications and cheaper cost of hydrogen at the pump, the LH2 on-board technology should enable larger scale deployments of hydrogen trucks than with state of the art storage methods, thus proving as unavoidable for zero emission heavy-duty transportation.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

FCH-01-4-2020: Standard Sized FC module for Heavy Duty applications

Specific Challenge

Hydrogen is considered to play an essential role in future zero-emissions Heavy Duty (HD) mobility. There is a growing consensus that (long haul) HD transport and HD stationary will be the key market for hydrogen Fuel Cells (FC) from the mid-2020s onwards. In addition, this transport sector struggles with the electrification of their portfolio. A large element is considered to be the consequence of the

²⁶ <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:035:0032:0046:en:PDF>

²⁷ <https://www.h2haul.eu/>

²⁸ Please note that the current status for the volumetric capacity at tank system level is 0.02 and 0.027 kg/l, for 350 and 700 bar, respectively.

impact on the production and supply chain, and the workshop and parts organisation. The complexity of the system as such is seen as too large of an obstacle.

Hydrogen has proven to be a serious alternative for (large) batteries, but TCO has to be reduced in order to reach a competitive level. Standard sized sub-systems are considered to be an important part of reaching this level of competitiveness. Standard sizes will improve reliability, parts availability, competition in the supply chain and above all a critical mass. These elements will also substantially lower the threshold for OEM's and end users to adopt hydrogen as alternative for batteries.

The next step is real-world operation with heavy duty applications such as buses, trucks, trains, and ships in daily operation, all based upon the same technology and using the same supply chain to create a critical mass. Instead of demonstrating the technology, it is paramount to make FC applications economically feasible, by reaching 'economy of scale'. This means FC system prices per kW and hydrogen prices per kg have to be reduced significantly by 3 to 5 times vs current levels. These figures are based on different TCO calculations (Euro/km or Euro/kg) which include all parameters (like operation and maintenance, lifetime etc.). To achieve 'economy of scale' with FC systems, they have to be standard sized and multi-purpose (not dedicated to only bus, truck or stationary). A standard size will be of benefit for the FC system supplier as well as for the FC system user. 'Economy of Scale' and 'Fair Competition' are the keywords for making hydrogen mobility economically feasible. In line with this, the challenge for this topic is based on three principles:

- Hydrogen FC + BoP within a standard sized module (AA-Battery principle);
- Hydrogen-Electric mobility for HD (> 3.5 ton) and long haul transport (off-road, rail, water). HD requires efficient, flexible, available, reliable, durable, robust and widely serviceable solutions (according to the defined KPI's);
- Hydrogen-Electric mobility TCO comparable (max +30%) with non-zero emission HD TCO.

Scope

The standard for the size, connections, Application Programming Interface(API) protocol and general test procedures of this FC module "frame" should be defined. Depending on the different HD market legislations, different options on the FC module "cover" could be implemented. This definition should be done no later than the end of project month 12 with an associated go/no-go decision gate on the following development to which at least 7 FC suppliers should commit to make their FC conform to this standard as part of this go/no go decision milestone:

- At least 7 FC suppliers and 3 OEMs from at least two different HDV application sectors should participate in the standard definition process;
- The FC module should be around 30 to 100 kW net (max 1 stack power is 100-125 kW gross);
- The FC module should be specified so that it can be scaled up (as LEGO) to a minimum power level of 1 MW;
- The FC module should include at least the FC stack, the air supply system and the cooling/heating system without radiator;
- The maximum 3 standard mechanical size(s) should be equivalent to the common battery pack systems or the available space in the different HD applications. This should be done to make switching between full electric and FC applications more modular and cost effective;
- A minimum of 7 FC suppliers develop, build and commit their standard sized FC + BoP module according to the agreed standard (although FC stack development might be part of project, will not be considered within the scope of the topic and therefore not supported by funding).

These FCs should be tested by an independent organisation according to an agreed protocol; the FC modules should be validated, according to an agreed test protocol, as whole FC module to make technical comparison between the different FC module suppliers easier for the different HD customers, without infringing the FC module supplier's Intellectual Property (IP). The testing should be done on an independent reference test device.

The scope should also include some essential and critical aspects:

- To define and specify together with the FC system suppliers and HD customers an International Standard module size, connections, API, test protocols and requirements for different HD applications;
- To define possible approaches on how to operate the modular systems in series/parallel up to a minimum of 1MW;
- To build standard sized FC modules from at least seven different FC suppliers (minimum five of them should be from EU);
- To develop and build a FC system reference test device for these modules, for testing on location and dynamically, by an independent organisation;
- To test the FC module(s) on the independent reference test device to get comparable/reproducible results and test the module also for durability purposes.

The ultimate goal is to go from relatively small FC suppliers, each with their own specific customers/markets to a global FC module market with a larger choice of different suppliers for a wide range of new HD applications. This 'Standard sized FC-module' will also lower the threshold for industries that have not yet considered hydrogen as an energy source (due to scale, limited R&D budgets etc.). The FC system should evolve from a High-Tech experimental product today to a common easy to integrate energy module in a wide range of HD applications tomorrow.

TRL at start of the project: 5 and TRL at the end of the project: 6-7.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The maximum FCH 2 JU contribution that may be requested is EUR 7.5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

Expected duration: 3 years

Expected impact

The aim of the topic is to create a plug-and-play FC module that can take the 'Hydrogen Economy' out of the vicious circle and into 'Economy of Scale'. Some overall expected impacts could be:

- Economy of Scale (Scale and BoP) and Fair Competition (by reducing TCO);
- Expected increase in sales, markets and applications including easier logistics for parts and services;
- A standard sized module which will further optimize (simplify) the FC system design and manufacturability; investments in developments and automated production can be justified;
- Future technology improvements can be made and easily integrated without big changes on the application side (size and interfacing);
- The user application can be designed to the needed power by adding extra FC modules and without to be bounded to a specific FC system supplier;
- The FC module specifications can be described using agreed and validated test protocols;
- The FC module can be used as H2-Range Extender or as H2-Hybrid now or later as upgrade;
- When more than 1 FC module is used, availability through redundancy can be achieved; the plug-and-play requirement should reduce the operational downtime to a minimum by swapping units; specialists repair can be centralized.

As the maximum 3 standard size(s) and connections are to be defined:

- The FC module supplier and the HD customers can independently from each other develop their Zero Emission product/application;
- The HD customers can freely and easily switch between the FC module suppliers;
- No FC module supplier should need to share any of their IP; all the IP is inside their FC module:
 - Inside the module the FC system supplier will use its own IP while outside it is a standard sized plug-and-play module;
 - New developments and optimisation of the FC module can be done within these agreed specifications without changing the HD application itself.

Standard sized modules will contribute by the fact that developments will shift from technology into applications (based on modules and high volumes) and thus should accelerate the use of hydrogen, resulting also in the needed reduction of costs. The end goal is to make hydrogen for Heavy Duty applications economical viable without funding's in the next 5-10 years.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018-2020 which apply mutatis mutandis.

FCH-01-5-2020: Demonstration of FC Coaches for regional passenger transport

Specific Challenge

For intercity and long-distance transport of passengers, coaches are used normally. About 20% of all registered buses for public transport are coaches, fuelled primarily by diesel (Euro II to Euro VI²⁹). Electrification for these vehicles is not equally advanced in comparison to urban city buses, due to challenges in meeting driving range requirements. In comparison to FC city buses, which have been demonstrated for more than a decade, FC coaches are expected to drive longer distances, typically 400-800 km/day and faster, typically 80-100 km/h on highways. There are very few stops on the route, which results in limited recuperation of breaking energy. Coaches often have a higher energy consumption, due to higher weight and auxiliary systems such as air conditioning. The FC Coach also encounters space constraints for the drive line and hydrogen storage components, since the coaches often carry luggage as well. Learnings and experiences from the FC city buses can be utilized, but the completely different driving pattern, power demand and space constraints require an entirely new FC system design to be validated.

Scope

The scope of this topic is to demonstrate first-prototype FC coaches in EU. By utilizing the extensive knowledge of the FC city bus demonstration projects, the FC coach concept should be designed in consideration of the coach specific operational requirements, with special focus on weight and space optimized design of the coach specific hybrid power system (fuel cells, batteries) and the H2 storage tanks.

This topic will address two very different coach segments: long distance coaches and intercity transport coaches, characterized however by similar performance requirements, such as long route distances, high average speeds and high payload and seating capacity requirements. The FC coaches should be of vehicle classes³⁰: M3 Class II – destined for regional passenger transport and/or intercity scheduled passenger transport and/or M3 Class III – destined for long distance travel with seated passengers used for tourist coaches enabling long distance travel in EU.

The project should aim at demonstrating at least 6 FC Coaches in the two coach segments (inter-city and long-distance passenger transport) which should fulfil the following requirements:

- The FC coach should integrate a fuel cell system of min. 100 kW (net power) or 100% of the energy consumption should come from hydrogen. Other intermediate solutions could be tested during the project but the consortium should demonstrate how they will reach this objective in the long term;
- The fuel cell modules should prove durability of at least 25,000h. At the end of the demonstration phase a monthly availability > 85% of the operation time (excluding preventive maintenance time) should be demonstrated;
- The FC coach should demonstrate driving speed up to 100 km/h;
- Vehicle range should follow intercity/long-distance end user's needs (minimum 400 km between refuelling) and standard comfort requirements equal to diesel buses;
- For standardization reasons, the hydrogen tanks should be based on existing standard H2 storage solutions ;
- Vehicle weight and size should not grow beyond the current state of the art or beyond current certification limits;
- Hydrogen fuel consumption should be less than 10kg/100km according to the Vehicle Energy Consumption Calculation Tool (VECTO)³¹ mission profile driving cycle;

²⁹ https://ec.europa.eu/growth/sectors/automotive/environment-protection/emissions_en

³⁰ <https://www.eafo.eu/knowledge-center/european-vehicle-categories>

³¹ https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en

- The FC coaches should be operated for minimum two years, and minimum of 80,000 km per coach per year with a minimum daily travel distance of 100 km for the M3 Class III type bus;
- Fully developing the necessary supply chain with focus on a healthy and diversified EU value chains (e.g. drivetrain, FC stacks and systems, tanks among others) and second sources for related services, including availability of trained personnel, spare parts etc. in order to bring this technology on a parity with conventional technologies;

The activities of the project should at least include:

- Optimization of driveline for fuel efficiency and operating range; optimize hybrid FC + battery design, given absence of (frequent) stop-and-go, i.e. limitations of brake energy recuperation;
- Optimization of fuel economy, given the different duty cycle (maximum speed, average speed, relative (in)sensitivity to topography, climate and load variations); optimize performance, output of fuel cell and traction battery for best fuel efficiency and cost;
- Optimize space utilization in relation to the location of H₂ tanks, given the required operating range(s), considering both passenger and luggage bays minimum volume(s) requirements;
- H₂ refuelling plan and operating range requirements, i.e. refuelling options and time, based on the use case and range requirements;
- Safety assessments, given the location of the drive components and the storage tanks, with the objective to meet or exceed existing safety standards;
- Establishment of new hydrogen refuelling stations, HRS is not considered in scope of the topic; upgrade of existing stations is however considered to be as part of the scope.

TRL at start of the project: 6 and TRL at the end of the project: 8.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

"CertifHy Green H₂" guarantees of origin should be used through the CertifHy platform³² to ensure that the hydrogen produced and dispensed at the HRS is of renewable nature.

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

Expected duration: 5 years

Expected impact

The project should contribute to introduce a new technology into the existing business model on FC coaches and the expected impacts could include:

- Extend electrification of public transport for two major coach transport segments;
- Help reach critical mass by making existing H₂ refuelling network more viable;
- Allow FC coaches to enter city boundaries and inner city low/zero emission zones;

³² <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

- Ensure EU competitiveness and EU industrial leadership on developing zero-emission transportation solutions and support the European value chain for fuel cell systems;
- Improvement of fuel cell and fuel cell system efficiency and power train components, like DC/DC Conversion, Power Inverters and E-Drives;
- Advances in fuel cell hybridization strategies to improve on-board energy management and power performance;
- Advances in drive profile and route recognition to optimize energy management strategies on-board the vehicle;
- Advance in service and maintenance strategies and workshop facilities;
- Advances in predictive maintenance strategies;
- Support economy of scale and cross platform synergies for components and sub-systems between different heavy-duty transport vehicles;
- Standardized interfaces between fuel cell system, tank system and vehicle (e.g. communication, fluids, voltage levels) and vehicle communication system.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018-2020 which apply mutatis mutandis.

Specific Challenge

Shipping contributes significantly to local air pollution in major harbour areas and around 3% of global CO₂ emissions. Shipping is bound to grow together with global trade and against other sectors decarbonising more quickly. The International Maritime Organisation (IMO) has found that GHG emissions from ships have already increased by 70% since 1990³³ and the European Commission strategy³⁴ estimates that without action the global share of shipping's GHG emissions may reach 17% by 2050. IMO has set a 50% reduction target for emissions related to maritime transport by 2050 compared to 2008, and an ambition of full decarbonization by 2100. In this context, the shipping market is forced to identify more sustainable fuels on the route to full decarbonisation and adopt new technologies for on-board energy conversion for all its fields (cargo, passenger ferries, cruise, service/supply vessels...).

Hydrogen as a fuel can enable zero-emission shipping in both GHG and pollutant emissions. However, the volumetric energy density of gaseous hydrogen is a limiting factor in terms of range which is critical for several types of ships. Hydrogen in its liquid form at approx. 20Kelvin (LH2) is a promising solution to address this issue but little knowledge related to the handling and use of LH2 within the shipping sector exists today due to a lack of demonstration projects. In turn, it hampers the progression of its inclusion in relevant regulations. Similarly, managing LH2 within a port environment (where industrial clusters users of hydrogen are often found) is yet to be demonstrated, with its subsequent learnings.

There are currently several challenges associated with using liquid hydrogen as a fuel in shipping:

- The total system's energy and power density as well as redundancy should be adequately secured for the specific applications;
- Not sufficiently mature/developed regulations, codes and standards (RCS), apply currently to hydrogen-related technologies in maritime environment. The time-consuming and ship type specific Alternative Design process may exhibit an unavoidable challenge, as IMO rules are not yet in place;
- Market deployment, cost reduction strategies (including maintenance for marine environments) leading to viable business models need to be developed;
- The public domain needs to be addressed, ensuring the acceptance of these new propulsion systems by the shipping industry and public.

Scope

The scope of this topic is to develop a prototype of a maritime power system operating on LH2 including bunkering concept with the potential for scaling-up (for larger amount of stored energy in adequacy with a 20 MW system, preferably fuel cell based), ensuring minimisation of hydrogen loss/leakage/boil-off. The system should be capable to deliver to the ship propulsion and/or on-board energy needs. The prototype's scalability needs to be proven ensuring the capability to completely replace prevailing ship propulsion systems.

A reference ship should be selected for the ship's operational profile, the power/energy requirements and volume/weight constraints defined. A type of ship within an early adopters' segment of maritime transport preferably with potential for extensive use and widespread deployment is recommended, to secure the overall impact of the effort.

The proposals should address the following technical components/issues of the prototype system:

- LH2 fuel supply/bunkering infrastructure;
- LH2 storage and distribution in a ship, with a minimum of 1.5 tons of tank capacity;

³³ <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx>

³⁴ https://ec.europa.eu/clima/policies/transport/shipping_en

- A power system of minimum 2 MW output, preferably based on fuel cell technology; other conventional technology solutions (such as combustion engines) could be offered, but their development is not considered within the scope of the topic and therefore not supported by funding;
- Evaluate the technical feasibility and the benefit of cogeneration to provide additionally heat to the ship and, if possible tri-generation including cooling;
- Identify best configuration of electrical architecture for an optimal integration (e.g. AC/DC grids, power management system, batteries, etc...), allowing for hybridizing potential with different combination of fuel cells, batteries, super cap, or combustion engines if desired;
- The performance, durability and efficiency of the prototype system should be demonstrated according to the operational profiles defined by the reference ship. The project should include an operational/testing period of at least 12 months (including both winter and summer season) and a minimum of 3,000 operational hours. Bunkering to sustain the normal operational profile of the system should be considered;
- Scalability to suit larger 20 MW applications should be proven at design phase including definition and design of physical on-board integration and interconnection with other main ship's systems (e.g. fuel, electric, thermal) for the 20 MW scale system with corresponding energy storage requirements.

In addition, the project should address the regulatory, economic and societal issues such as:

- Address and contribute to develop regulations, codes and standards (RCS) needed for shipping application, including the safety issues related to H2 fuelling protocols/bunkering and the H2 fuel storage;
- Establish/include a ship design where storage of LH2 is fully integrated into the ship, in order to pave the way for more integrated solutions and contribute to the establishment and further development of maritime rules and guidelines for selected H2 powered vessel design(s) in line with class/flag/port approval requirements;
- Assess and propose suitable business models, to foster further commercialisation of technical hydrogen solutions both on board the vessel and bunkering/refuelling;
- Quantify the potential for cost reductions as the hydrogen technologies mature and define the necessary roadmap;
- Assess the advantages of using hydrogen systems in combination with the liquid hydrogen (LH2) in terms of emission reduction during operation, noise reduction, availability and reliability;
- Discuss /share experiences with the shipping industry to contribute to raise awareness of the potential of hydrogen-based technology, and accelerate the development of LH2 for different types of ships;
- Define training requirements for operator and crews.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The project should closely follow the developments in the IGF Code Correspondence Group at the IMO³⁵, works of the European Sustainable Shipping Forum (Sub-group on alternative fuels)³⁶ and relevant work of the certification bodies.

Finally, the following activities should be also included:

- Validate in laboratory system components' performance, durability and efficiency for use profiles defined by reference ship application;
- Evaluate ship's performance through two dimensions Least Cost Path (LCP) Analysis: horizontally i.e. spanning the entire lifecycle of the ship and vertically i.e. assessing the overall impact of fuel chain (production, distribution and utilization) for prototype while the LH2 market matures;
- Evaluate the economics of the proposed solution and lay out a pathway towards a positive business case through the entire value chain;
- Define a go-to market strategy supported by marine industry and ships operators;
- Address project's activities complementing the projects funded under the following calls:
 - Horizon 2020: LC-MG-1.8-2019, "Retrofit Solutions and Next Generation Propulsion for Waterborne Transport"³⁷;
 - FCH-01-2-2019 "Scaling up and demonstration of a multi-MW Fuel Cell system for shipping"³⁸.

TRL at start of the project: 5 and TRL at the end of the project: 7.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

"CertifHy Green H₂" guarantees of origin should be used through the CertifHy platform³⁹ to ensure that the hydrogen produced and used is of renewable nature.

The maximum FCH 2 JU contribution that may be requested is EUR 8 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

Expected duration: 5 years (including 12 months of ship operation, all seasons included).

Expected impact

As the aim of this topic is to develop and demonstrate a prototype of a large hydrogen system capable of providing large autonomy under usual maritime operational conditions, it should prove that the developed technology is viable on-board a given vessel and that the scalability is possible for providing full propulsion and auxiliary loads for ships.

The expected impact should include:

³⁵ <http://www.imo.org/en/MediaCentre/PressBriefings/Pages/28-CCC1IGF.aspx#.XclUo1dKg2w>

³⁶ <https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=2869>

³⁷ <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-mg-1-8-2019>

³⁸ <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/fch-01-2-2019>

³⁹ <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

- Validating that the power system may reach a durability of 25,000 h (by applying AST protocols);
- Demonstrating the relevance of LH2 as a solution to decarbonise relevant segments of the shipping sector;
- Approval of specific ship type following the Alternative Design process, thereby facilitating faster deployment of more ships of same type;
- Ensuring that appropriate training processes are in place to safely manage LH2 both in a port environment and on a ship;
- Demonstrating an availability of 97 % for the entire prototype system during operation;
- Improving environmental performance of waterborne transport towards achieving a goal of low-to-zero-emission;
- Increasing EU's competitive lead in green shipping technology;
- Fostering further development of regulations, codes and standards for maritime hydrogen applications;
- The proposed solution, when implemented in a vessel, should be able to reduce the CO₂ and NO_x emissions by 90%, compared to incumbent technologies (i.e., heavy fuel oil converted in combustion engines), in a tank to wake perspective.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018-2020 which apply mutatis mutandis.

FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework

Specific Challenge

Rail line electrification is in general limited due to economic feasibility. Today, half of EU's rail lines are not electrified and are operated by diesel trains which generate substantial air pollution and noise. In some cases, diesel trains can also operate on electrified portions of partially electrified lines. Such trains include regional passenger trains, shunting or main line locomotives.

In recent years, some FCH passenger train prototypes have been developed and tested. The interest of many Public Transport Authorities (PTAs), both in EU and abroad for this technology has led to orders being placed in Austria and Germany for small fleets of vehicles to be put into service in 2021 – 2023. Several different OEMs are therefore committed to deliver FCH powered trains and intend to enter the market. As outlined in the common FCH 2 JU & S2R JU study on "Use of Fuel Cells and Hydrogen in the Railway Environment"⁴⁰, FC technology provides a flexible, zero-emission and potentially cost-competitive solution to replace diesel trains while FCH trains perform to the rail system specifications as well as the diesel technology can. The most mature FCH application, i.e. Multiple Units, has the potential to become cost competitive with diesel-powered trains in the short term (can potentially replace 30 % of diesel volumes as the most market-ready application by 2030), followed by the Shunters and Mainline Locomotives which still need further technology development. Therefore, FCH technology needs to take a systemic approach to the rail environment and engage simultaneously on different fronts for accelerated deployment.

Despite this increasing interest, many challenges remain for fuel cell trains to be considered a competitive alternative to diesel trains, which should be addressed by this topic:

- The regulatory environment for trains remains fragmented, including both European (Technical Specifications for Interoperability) and national (NNTR – Notified National Technical Rules) technical requirements while today several types of trains are required to address the complete European market. It is estimated that FCH powered trains will face the same market fragmentation which could lead to high fixed costs for each first project in a new normative environment for all types of application;
- Specific standards need to be established with railway safety agencies, operators, rolling stock manufacturers and fuel cell manufacturers on safety, installation and performance testing (as usually done in IEC TC105⁴¹) in order to facilitate commercialization across European countries and homologation by the European Union Agency for Railways (ERA)⁴²;
- Deployment of traditional line electrification programs is still ongoing. These costly investments, while taking decades to materialize, question also the long-term residual value of train fleets that do not use overhead line electrification. Therefore, bi-mode capability (hydrogen + catenary) could improve marketability and residual value of FCH trains;
- FCH train cost competitiveness against diesel train could be increased by improving the on-board components and sub-systems (improving the train autonomy and its cost).

Scope

The topic aims to support the development of a fuel cell powered train prototype that addresses one of the three railway segments identified by the above-mentioned study: regional passenger trains, shunting or main line locomotives. The project should therefore support:

1. The design and manufacture of an innovative prototype:
 - Using FCH traction only or combining FCH traction and electric pantograph;

⁴⁰ <https://www.fch.europa.eu/publications/use-fuel-cells-and-hydrogen-railway-environment>

⁴¹ https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1309,25

⁴² <https://www.era.europa.eu/>

- Both compressed hydrogen on-board storage solutions (e.g. at 350 or 700 bars) or liquid hydrogen should be explored and considered in scope of the topic;
 - Test, validate and carry out the homologation (at EU level, covering at least three Member States) of such a prototype; the testing duration and testing environment should progress the technology to reach TRL7;
 - The operational performance of the prototype (autonomy, fuelling downtime) should be competitive with existing diesel-based designs;
2. Propose a normative framework for the placement on the market of trains using FCH propulsion:
- Identify the gaps in the current applicable regulatory and voluntary framework (TSI and EN);
 - Propose modifications of relevant standards and TSIs to enable obtaining authorization to place on the market of FCH and FCH bi-mode trains, to be submitted to CEN, CENELEC and the European Union Agency for Railways.

The project should deliver an innovative prototype and therefore go beyond those currently in operation/testing.

Only the design and engineering of the prototype are considered within the scope of the topic, including the building of the fuel cell based power train and hydrogen storage. Other activities, (e.g. train development etc) might be part of the project but shall not be considered within the scope of the topic.

The project should consider developing the necessary supply chain with focus on a healthy and diversified EU value chains (e.g. drivetrain, FC stacks and systems, tanks among others) and second sources for related services, including availability of trained personnel, spare parts etc. in order to bring this technology on a parity with conventional technologies.

TRL at start of the project: 4-5 and TRL at the end of the project: 7.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

"CertifHy Green H₂" guarantees of origin should be used through the CertifHy platform⁴³ to ensure that the hydrogen produced and dispensed at the HRS is of renewable nature.

The maximum FCH 2 JU contribution that may be requested is EUR 10 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

Expected duration: 4 years

Expected impact

Due to the openness of the topic to various type of applications, KPIs can be different depending on the selected application. Proposals should therefore demonstrate ambitious goals aligned with the technical KPIs included in the FCH 2 JU MAWP and in particular its Addendum⁴⁴, while also making

⁴³ <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

⁴⁴ <https://www.fch.europa.eu/page/multi-annual-work-plan>

reference to the common JUs study on “Use of Fuel Cells and Hydrogen in the Railway Environment” to define further specific targets. Project proposals should also address the market size addressed by the prototype, based on the 2018 edition of the UNIFE World Rail Market Study⁴⁵ as part of the potential impact.

In addition, the following impact is expected:

- Demonstration of the competitiveness of trains using a FCH based traction versus existing diesel designs in the selected railway application;
- Knowledge and feedback (regulatory, safety procedure, FCH technologies) should be transferable to all use cases for FCH propulsion in the rail sector;
- Appropriate awareness level of this technology by all the relevant stakeholders according with the chosen application.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018-2020 which apply mutatis mutandis.

⁴⁵ <http://unife.org/publication-press/wrms.html>

FCH-01-8-2019: Scale-up and demonstration of innovative hydrogen compressor technology for full-scale hydrogen refuelling station

Specific Challenge

Hydrogen compression remains a major bottleneck in the development of the refuelling infrastructure for H₂ mobility. The need for reliable and low-cost compression solutions are considered therefore strategically important as the economy prepares for large scale deployment of hydrogen technologies, including heavy-duty applications. Currently used piston or membrane compressors are noisy, require high maintenance, have substantial downtime and have a large footprint.

In the frame of already supported FCH 2 JU projects⁴⁶ (PHAEDRUS, Don Quichote, H₂Ref, COSMHYC XL), innovative compression solutions have been identified and technologies were advanced to TRL 5. These include electrochemical and metal hydride compressors, as well as a combination of conventional and innovative compression technologies into integrated solutions. There is a need now to test these concepts on reliability in a full-size scale HRS. Scale up to economically viable level as measured in total cost of ownership, hydrogen quality in compliance with fuel cell grade hydrogen purity and convincing demonstration of these technologies are the challenges to meet in order for them to become ready for market entry.

Alternative hydrogen compressor technologies could remove the typical disadvantages of current mechanical compressors like high maintenance/down time, therefore high operational cost and high noise levels. Innovative H₂ compressor technology development could reduce the HRS cost and footprint while increasing its reliability.

Scope

This topic calls for a scale up through standardization of design, allowing easy maintenance, demonstration and proof of sufficient availability and lifetime of an innovative, low noise compressor system applied in a hydrogen refuelling station with a renewable hydrogen source that can be built close to residential areas, ready for market entry towards the end of the project.

The project should develop an end-user specification of the innovative compressor system designed for HRS followed by construction, commissioning, qualification and certification - therefore resulting in a demonstration of a more than 200 kg H₂/day standardized, containerized hydrogen compressor system in a hydrogen refuelling station;. This could be based on one single innovative hydrogen compression technology or on a combination of innovative compression technology with a conventional compression technology, for the purpose of reliability and reduced investment and operating cost.

It is expected at least 1 year of testing under real operating conditions, serving a fleet of passenger vehicles, refuelling at 700bar at a designed compressor system scale of minimum 200 kg H₂/day.

The project should explicitly identify and motivate the selected site in EU where the H₂ compressor technology will be applied for refueling.

The project may have limited focus (and related limited funding) on activities regarding the construction of a new HRS or the adaptation of an existing HRS.

Techno-economic analysis throughout and at the end of the project should assess market readiness and show the feasibility of future scale up of the new developed compressor technology to a level of 2,000 kg H₂/day, including ambitious KPI targets for CAPEX, maintenance and efficiency. Lifetime assessment through accelerated stress testing and theoretical model extrapolation is expected to allow for lifetime indication of the compressor technology.

The project should include an assessment of the output hydrogen purity, proving that the innovative compressor technology does not introduce impurities harmful to any fuel cell, maintaining 99.999%

⁴⁶ <https://www.fch.europa.eu/page/fch-ju-projects>

hydrogen purity, or perform a risk assessment on hydrogen purity, aiming for SAE J2719/ISO 14687-2/3 (5N) standard for fuel cell grade hydrogen.

TRL at start of the project: 5 and TRL at the end of the project: 7.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

“CertifHy Green H₂” guarantees of origin should be used through the CertifHy platform⁴⁷ to ensure that the hydrogen produced and dispensed at the HRS is of renewable nature.

The maximum FCH 2 JU contribution that may be requested is EUR 3 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

Expected duration: 3 years

Expected impact

Innovative H₂ compressor technology development should demonstrate how will reduce the HRS cost and footprint while increasing its reliability for a cost-effective compression towards the 2024 targets.

The improvements of the innovative hydrogen compressor technology as demonstrated in a full-scale HRS, should have the following expected impacts:

- System scale: >200 kg H₂/day with proof of feasibility of scale-up to 2,000 kg H₂/day;
- Pressure range from <6 bar to 950 bar output pressure;
- Energy demand: <6 kWh/kg H₂ (from very low pressure to 950 bar) and <4 kWh/kg H₂ (typical storage pressure 50-100 to 950 bar);
- Availability compressor system >98%;
- Extrapolated lifetime: >20,000 hrs at a refuelling frequency of 30 person-vehicles per day;
- Degradation of the compressor flow rate at constant energy demand of less than 1% per year;
- Demonstration of future compressor CAPEX <1000 EUR/(kg H₂/day) for small series compressor production at a projected scale of 2,000 kg H₂/day;
- 30% reduction of Total Cost of Ownership (TCO) compared to conventional mechanical compression technology;
- Compliance with SAE-J2601 standard⁴⁸ on refuelling (time) and with refuelling profiles as defined in the H₂ Mobility program/projects⁴⁹ and any protocols that will be defined in due time, included those to be developed for heavy-duty trucks by the future project under ongoing H2020-JTI-FCH-2019-1 call.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018-2020 which apply mutatis mutandis.

⁴⁷ <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

⁴⁸ https://www.sae.org/standards/content/j2601_201003/

⁴⁹ <https://www.fch.europa.eu/page/transport#H2ME> // <https://www.fch.europa.eu/page/transport#H2ME%202>

FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology

Specific Challenge

Hydrogen is a flexible energy carrier that can be produced from any energy source, and which can be converted into various energy forms. The main challenges with hydrogen use are related to its storage during large periods of time and capacity, and transportation on long distance. Moreover, due to its low volumetric energy density, hydrogen requires costly steps of compression or liquefaction; while boil-off limits the use of liquid H₂ during large scale of time.

Liquid Organic Hydrogen Carriers (LOHCs) based on organic compounds hold the promises for long time and high capacity energy storage, cost-effective long-distance energy transport and, in a long-term perspective, they might be directly used as a fuel for mobile applications. Due to the chemical binding of hydrogen to the liquid carrier, hydrogen can be stored and transported at ambient temperature and pressure in a safe way. Some carrier substances are also fully compatible with existing liquid fuel infrastructure.

Capacities of renewables and electricity costs are extremely heterogeneous in EU. It will not be possible to produce low carbon hydrogen nationally or locally at adequate costs. Just as fossil fuels are being imported and exported across borders today, sites with high renewable potential and low costs of decarbonized electricity should be used for hydrogen production in the long-term perspective. In doing so, storage and transportation of hydrogen at scale is the missing link on the targeted road to a low carbon hydrogen economy. This is where the LOHC approach can play a key role.

Technical feasibility of LOHC has been demonstrated in several projects up to a capacity of 240 kg H₂/day. Nevertheless, this technology shows its advantages solely when applied at larger scales. From today's perspective, the main bottleneck is however its economic viability. In order to overcome this, three routes should be pursued: 1) utilize the economics of scale, 2) optimize the interface to existing large-scale hydrogen generation technologies (e.g. electrolyzers, SMR with CCS) and hydrogen consumers (e.g. hydrogen refuelling stations) and 3) redesign of the process technology by merging of sub-components. Central point for all three procedures is the technical and energetic performance of the catalysts.

Scope

The scope of this topic is to reduce the system costs of the LOHC technology by developing improved catalysts or novel catalytic system architecture. This would allow, among others, the reduction of energy intensity during loading/unloading processes, a higher cycle efficiency and increased lifetime. To reach this scope, three approaches are expected:

- Decrease the PGM (Platinum Group Metal) loading, as upscaling of the technology will reduce the specific costs of the unit, but the use of PGM will keep this technology costly. To overcome this, an increase of the catalytic activity in both hydrogenation and dehydrogenation reaction or the partial/total substitution of PGM catalyst/critical raw materials is expected to reduce the specific PGM demand;
- Increase the catalytic selectivity and specificity as a reduction of the pre- and post-conditioning of hydrogen before and after the hydrogenation / dehydrogenation process can tremendously reduce the costs of the technology. The selectivity of the catalyst for hydrogenation reaction should be adjusted to the properties of the inlet hydrogen stream from electrolyser (or Steam Methane Reformer). In case of dehydrogenation, the used catalyst should be optimized to avoid unwished side-reactions and release hydrogen with a high purity e.g. for fuel cell applications;
- Increase space-time-yield by coating surfaces with catalyst as merging the catalyst, the catalyst support and the heat exchanger into one single unit could achieve an increase of

efficiency and cost reduction. Concepts involving new component architecture, new materials, and new manufacturing processes should be developed and demonstrated.

It is expected that at least 2 solutions and 3 approaches are proposed by the project.

The topic is open to all kind of LOHC concepts as long as the carrier has the general capability to be used for hydrogen logistics in terms of efficiency, regulatory and safety issues. Substances with low cyclability, high toxicity or low availability should not be considered.

The project should address at least the following key issues:

- Evaluation of the catalyst performance compared to state-of-the-art experimentally in a demo unit >10 kW;
- Evaluation of the catalyst lifetime and maintenance experimentally in continuous operation of at least 200 h;
- Reduction of the energy required in the dehydrogenation to < 6 kWh/kg H₂;
- Assessment of the catalyst synthesis route regarding the environmental footprint (e.g. with respect to abandoning/elimination of critical raw materials);
- Identify the pathways for upscaling of catalyst production and determination of the marginal costs for annual catalyst demand >1,000 t;
- Technology comparison with other hydrogen logistic concepts e.g. GH₂, LH₂, shipping or pipeline, based on Total Cost of Ownership (TCO) calculations and Life Cycle Analysis (LCA), avoiding duplications with already funded initiatives or projects i.e. HySTOC⁵⁰.

The project consortium should include at least one industrial partner willing to exploit the results.

TRL at start of the project: 2 and TRL at the end of the project: 4.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

The project will be required to contribute towards the activities of the Hydrogen Innovation Challenge (as detailed under point G. International cooperation). Cooperation with non-EU/Associated country member of this challenge is encouraged (see chapter 3.3 for the list of eligible countries).

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 2.5 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years

Expected impact

The improved catalysts and/or novel catalytic structures is expected to open the way for wider impact of LOHC technology. This should be the significant step to provide cost-efficient systems based on LOHC technology that finally will enable upscaling and process intensification. Catalytic improvements (material, integration, comprehension) will also contribute to the development of other technologies (Fuel Cell, Electrolysers) applications.

The expected impact with validated results in a complete LOHC system should include:

- Increased technology competitiveness by novel processes/materials/concept with improved techno-economic efficiency while at least maintaining energy demand for dehydrogenation compared to state of the art practice (≤ 10 kWh/kg H₂ thermal energy);

⁵⁰ <http://www.hystoc.eu/>

- Increased kinetics in dehydrogenation ($> 3 \text{ g H}_2/\text{g catalyst}/\text{min}$) by maintaining high grade of conversion ($>90\%$) at high selectivity ($>99.8\%$);
- Improved stability/robustness of the system with loss of performances $< 0.01\%/\text{cycle}$;
- Gravimetric capacity at tank system level $>5.0 \text{ \% wt}$;
- Volumetric energy density $>1.6 \text{ MWh}/\text{m}^3$ (based on LHV H_2);
- Catalyst compatibility in hydrogenation with H_2 from mixed gas streams (impurities up to 20%);
- Better catalyst comprehension that will have an interest in fuel cell or electrolyzers.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

FCH-02-2-2020: Highly efficient hydrogen production using solid oxide electrolysis integrated with renewable heat and power

Specific Challenge

Increasing penetration of intermittent Renewable Energy Sources (RES) on the grid requires large energy storage capacity. According to the analysis of CertifHy⁵¹, EU's demand for hydrogen in 2030 will reach 10 million tonnes, of which 17.3 % should be produced by renewable sources to fulfil the goals for the energy transition. A large share of this green hydrogen will be produced by electrolysis in areas of low electricity prices associated to renewable power from photovoltaic or wind. High-temperature steam electrolysis exhibits the highest electrical efficiency among existing water electrolysis technologies for hydrogen production with the potential of further enhancing efficiency when high-temperature heat is used for supplying steam. Therefore, it has also the potential for producing renewable hydrogen very cost –efficiently.

Solid Oxide Electrolysis (SOE) technology has already been developed to TRL 7 including the coupling with industrial waste heat. Most of the applications rely on steady state operation of the SOE process. However, in the cases where the electrolyser is placed in the area of inexpensive electricity generation, e.g. by photovoltaics, such heat is not available all the time or not available at all. The obvious conclusion is to consider renewable heat since concentrated solar power systems are available at medium – big scales, economic and efficient in areas where photovoltaic electricity is inexpensive.

The challenge is to leverage the SOE's efficiency by integrating renewable heat to produce renewable hydrogen with the highest efficiency among all water electrolysis technologies. As a result, renewable hydrogen will be efficiently produced in large amounts at places where both solar heat and renewable power are available. A specific challenge is given by the need of optimising the coupling of high-temperature steam electrolysis with two intermittent sources: renewable electricity and high temperature solar heat.

Dedicated solar steam generators with steam storage and handling are necessary to buffer the intermittent nature of solar heat and avoid thermal cycling of the SOE in variable operation. Furthermore, an optimized heat integrated system concept is necessary. Still due to the dynamic operation during start up and shut down cycles, steam temperatures will vary. This will demand for a SOE core technology robust enough to cope with temperature transients and gradients. This requires detailed investigation of operational models optimized for such a combination. The focus is on performance and durability of SOE in a relevant testing environment, given the fluctuations of renewable energy sources. The challenge includes understanding how fluctuating operating conditions affect the SOE core, the identification of operational strategies that are safe for the SOE, and which implications are expected on system efficiency and economics considering the production of hydrogen.

Scope

SOE technology on cell, stack and system levels has been developed in various FCH 2 JU projects such as SOPHIA, Eco, SelySos and HELMETH⁵². Additionally, scale-up of high temperature electrolysers into the MW industrial-scale with integration of the waste heat in the process has already started (projects GrinHy and GrinHy 2.0).

Thermal integration of heat into SOE by using solar heat from Concentrated Solar Plants (CSP) or from power-to-heat (PtH) systems has only been a subject in the project SOPHIA so far. It was demonstrated that coupling of a SOE with CSP power plant can reduce the electricity demand of the SOE from the grid to less than 5% of the annual operating time, and can achieve a higher energetic efficiency and sustainability index compared to a photovoltaic system.

⁵¹ <https://www.fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

⁵² <https://www.fch.europa.eu/page/fch-ju-projects>

In a wider context, the project should couple high-temperature electrolysis with solar heat or power-to-heat sources at different levels from stack box to multi-kW scale and larger system level to investigate operational behaviour in detail. This should result in the identification and provision of practical technical solutions resulting from the specific operating conditions given by the coupling with intermittent RES for electric power and heat.

The project should cover the following topics:

- Build-up of a stack box and a system with power capacity higher than 20kW_{el}, including a SOE system, a solar steam source, or other renewable heat sources;
- Investigation of the dynamics of the heat and electricity supply and the reactions of the SOE, under typical cycling conditions (e.g. day-night). System design should focus on solutions to maintain the SOE core warm during night. The sensitivity of SOE towards steam temperature variations caused by solar radiation volatility and / or upon dynamic operation should be investigated. A strategy should be formulated for buffering the fluctuation of heat and electricity and safe operation regimes for the SOE core also by modifying SOE stack and/or module design;
- The specific operating conditions for the proposed solution should be specified (e.g. steam temperature) and determined versus the specific technology scale (e.g. number of stacks) clarifying the upscaling potential and conditions;
- Perform a concept design study for a heat Integrated SOE system scale-up towards units of 100 MW_{el} with heat supply from a large-scale renewable heat source such as a CSP plant and electricity from renewables.

TRL at start of the project: 3 and TRL at the end of the project: 5.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN.

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell or electrolyser components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 2.5 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 4 years

Expected impact

Integration of renewable heat will lower the cost of hydrogen produced by high-temperature solid oxide electrolyzers at places without cheap steam sources. It will support the deployment of hydrogen use for lowering the carbon footprint. The project should therefore have the following impacts:

- Demonstrate $\geq 98\%$ availability and the production of hydrogen by operation of $> 1,000$ h with production loss $< 1.2\%/kh$;
- The SOE with renewable heat integration shall demonstrate electrical efficiency $\geq 85\%$ based on LHV and specific energy consumption of < 39 kWh/kg H₂ in a market-representative relevant environment;
- Make SOE technology a suitable path for cheap green hydrogen production in places where both renewable heat and electricity are available and without a waste steam supply (e.g. from industry);
- Efficient operation strategy of SOE coupled with two RES (electricity and heat) for facilitating RES integration in the grid and grid balancing.

The successful achievement of the project should:

- Set the ground for efficient concepts of hydrogen production from renewable sources directed to sector coupling between electric and gas grids, involving SOE;
- Unlock new market opportunities that shall act as an additional driver for scaling-up the European SOE technology and contribute to further reduce CAPEX;
- It is expected that the deployment of RES, particularly solar thermal solutions, will leverage from the results of the project.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

Specific Challenge

High temperature Solid Oxide Electrolysers (SOE) are the most promising solution for efficient and cost-effective hydrogen production and storage/re-use of intermittent electricity from renewable sources. The integration of SOE stacks with balance of plant components proved the successful use of these systems, however, coupling with real intermittent renewable energy sources (RES) is still a big challenge. Due to the intermittent nature of RES, using them to power SOE systems is expected to require substantial transient operation capability from the SOEs, which can induce high stress onto the stack and system as compared to steady state operation, resulting in thermal issues and degradation worsening.

As compared to other electrolysis technologies, SOE offers two specificities. The first one is the reversible operation (rSOC), meaning the possibility to operate in electrolysis mode to produce hydrogen when an excess of intermittent renewable energy is available, and in fuel cell mode to produce electricity from hydrogen previously produced when electricity available stands below the demand. Depending on the use case, a large number of cycles between electrolysis and fuel cell mode will have to be performed over the lifetime of the rSOC system (at least one per day). The time to switch from one mode to the other can be in the range of 20 minutes or below. It has been found recently in ongoing EU/FCH 2 JU projects that such an operation can induce accelerated degradation compared to stationary SOFC or SOE operation. So far, the exact mechanism behind this acceleration is not well understood. The second specificity of SOE is its ability to electrolyse not only steam but also CO₂, and as a consequence the possibility to co-electrolyse steam and CO₂ to produce syngas (H₂+CO mixture), which can subsequently be used for the production of synthesis molecules (gaseous or liquid). As compared to pure SOE operation, the co-electrolysis (so-called co-SOE) can induce additional degradation due to the presence of carbon, in addition to the dynamic and transient operation also needed for this technology.

Consequently, careful and coordinated control actions during transient manoeuvres, which may occur when coupling (co-)SOEs with RES or rSOC operation are therefore needed. It is key to first identify the specific consequences of dynamic operation at stack and system level, and then to develop methods to detect and finally counteract related issues with simple and cost-efficient methods. Subsequently, BoP control actions are to be developed to i) guarantee smooth transient operations during mode shift operations and ii) select proper working points to optimize performance, keeping durability and availability in the planned maintenance timeframe.

Scope

Several previous monitoring, diagnostic and control projects were performed in the field of SOFC in the last years e.g. DESIGN, DIAMOND and INSIGHT⁵³. They developed and validated monitoring and diagnostic techniques ranging from processing conventional signals to advanced techniques like Electrochemical Impedance Spectroscopy (EIS), with both conventional sinewave excitation and PRBS (pseudorandom binary sequence signal) and Total Harmonic Distortion (THD), and diagnostic algorithms for Detection and Isolation of faults (FDI). In order to embed in a real SOFC system, the developed monitoring, diagnostic and lifetime tools described above, specific hardware has been developed.

The topic aims at developing the same approach on SOE (possibly including co-SOE) and/or rSOC stacks and systems, with the aim to increase lifetime of stack and availability of systems operated dynamically. To establish the ranges of dynamic operation (frequency, amplitude and occurrence of reactant, power and heat ratios involved) the most promising process chains should be considered, as determined e.g. in the H2020 project BALANCE⁵⁴ or motivated by recorded industrial assessment.

The project should cover the following:

⁵³ <https://www.fch.europa.eu/page/fch-ju-projects>

⁵⁴ <https://cordis.europa.eu/project/rcn/206760/factsheet/en>

- Enhance the understanding of (co-)SOE and/or rSOC stack degradation mechanisms in representative operating conditions of intermittent electricity supply and/or rSOC cycles using both experimental and modelling approaches;
- Assess system capabilities:
 - For rSOC operation to switch from one mode to the other with the appropriate dynamics (time scale, hydrogen or syngas production volume, electricity - and possibly heat) production, etc.);
 - For (co-)SOE operation to cope with fluctuating electricity input in terms of thermal management (time scale, hydrogen or syngas production volume, down-stream processes, etc.);
- Identify suitable stack and system level monitoring parameters which indicate a possible critical state of the (co-)SOE and/or rSOC stack/module within the system, using advanced monitoring techniques like EIS (electrochemical impedance spectroscopy) and using both sinusoidal and PRBS (pseudo random binary signal) stimuli) complemented by THD (total harmonic distortion) and/or DRT (distribution of relaxation time) analysis in addition to conventional signals (temperature, pressure, flow rate etc.);
- Develop the algorithms able to perform the diagnostics and to determine the remaining useful lifetime depending on the state of health of the stack/module;
- Develop the hardware for the implementation of these advanced Monitoring, Diagnostic and Lifetime tools, able to interact with the power electronics of the system to apply counteractions;
- Develop control devices and strategies to keep performance, and improve durability and availability of stacks and systems;
- Demonstrate the diagnostic approach and the developed hardware for monitoring and lifetime prediction, and to validate the control strategy and devices in a relevant environment with (co-SOE) and/or rSOC stacks or stack modules;
- Develop a physical product, embedding the software tools, evaluate the TCO (total cost of ownership) of this product and propose routes for exploitation of the solutions developed

Taking advantage of previous SOFC projects in this research area, the project should start with TRL 4 and conclude at TRL 6.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarned database, HELLEN.

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell or electrolyser components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The FCH 2 JU considers that proposals requesting a contribution of EUR 2.5 million would allow the specific challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years.

Expected impact

Development of a monitoring and diagnostic tool, also able to evaluate remaining useful lifetime and to propose counteractions to the (co-)SOEC or rSOC stack/system. This will contribute to improve the durability, reliability and availability of those systems, thus reducing their TCO and accelerating their market penetration. The most relevant degradation mechanisms in (co-)SOE or rSOC stacks/systems for specific market segments will be identified and analysed with respect to impact on lifetime, such as fatal impact or slow decrease of performances.

Monitoring parameters will be determined that reveal the State-of-Health of (co-)SOE and/or rSOC stacks regarding those identified critical mechanisms.

Counter measures to prevent fatal (co-)SOE or rSOC stack failure should be proposed, including possible regular treatments that prevent or slow-down long-term degradation, with a target of (co-) SOE and/or rSOC stack lifetime increase by 5%, allowing to reach a production loss rate of 1.2%/1,000h and an availability increase by 3% to reach a value of 98% (in agreement with the MAWP target in 2024⁵⁵).

It should be demonstrated that the added cost of this monitoring/diagnostics approach does not increase the overall system manufacturing costs by more than 3%, and contribute to achieve the reduction of the operation and maintenance cost by 10%, to reach a value of €120/(kg/d)/y in agreement with the MAWP target in 2024.

A physical product, embedding the software tools should be developed. An evaluation of the TCO (total cost of ownership) should be done, to assess the benefit of installing such a tool in SOE systems, with a target to improve the TCO of a SOE of 15%, thanks to the increase of the maintenance interval and the minimization of the stack replacement as compared to a system not equipped with this tool. Accordingly, an exploitation roadmap should be defined at the end of the project.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁵⁵ <https://www.fch.europa.eu/page/multi-annual-work-plan>

FCH-02-4-2020: Flexi-fuel stationary SOFC

Specific Challenge

Solid Oxide Fuel Cell (SOFC) technology is mainly considered for stationary applications. The number of units installed is growing continuously around the world, for a wide range of power (kW to MW). One of its main advantages is that it can be easily fed by different fuels, not only pure hydrogen as it is the case with other fuel cell technologies. Currently, the reference fuel is natural gas abundantly available throughout EU at low cost. Fuel cells operated with natural gas from the grid reduce already significantly the amount of CO₂ generated compared to other conventional heat and power generation systems thanks to their higher efficiency, however not entirely.

In order to reach the target of greenhouse gases emissions reduction set by the EU, a reduction of the carbon footprint of the fuel has to be considered, for example by using renewable gases like biogas or hydrogen. In addition, in order to promote the storage of intermittent renewable energies through the power-to-gas concept, blending hydrogen with natural gas into the existing natural gas network is expected, though several questions remain open like the maximum admissible percentage of H₂ in the natural gas and the seasonal variability of the content. The challenge is to have SOFCs able to operate under variable fuel mixtures whilst maintaining acceptable levels of performance.

Scope

The project should develop and demonstrate in a relevant environment a stationary solid oxide fuel cell system capable to operate under variable fuel mixtures with high electrical efficiency, high heat quality, long lifetime and able to reach the cost level of conventional fuel cell systems.

The project should evaluate the operation of stationary SOFCs designed for conventional natural gas over a wide range of gas compositions including H₂ mixture in natural gas from zero to 100% and additions of biogas in the gas grid.

In order to take advantage of the long and costly development done so far on natural gas fed SOFC and of the high number of units already installed, it is expected that the project focuses on the adaptation of existing SOFC systems design made for natural gas to varying mixtures, with the aim of developing the next generation of “flexifuel” fuel cell systems.

The project consortium should include at least 2 SOFC system manufacturers based in EU or H2020 Associated Country.

The project should:

- Evaluate experimentally at lab scale on stack and system level, how the change of fuel can modify the performance and the durability of the fuel cell, taking in particular into account the thermal management, which will be more complex and might affect SOFC lifetime;
- Implement required BoP components allowing the operation window from zero to 100% H₂ in natural gas and with additions of purified biogas (CH₄ and CO₂, no pollutants);
- Define and validate an operation strategy adapted for a flexifuel operation;
- Demonstrate in relevant environment conditions and at system level, for at least 9 months, the operation in such flexifuel operating conditions; it should involve change of fuel (from 100% natural gas or biogas (potentially varying composition of biogas) to 100% H₂, going through different levels of H₂ admixtures in natural gas/biogas;
- Address safety and certification aspects in a suitable manner taking into account all relevant directives and regulations. These activities should take into account other FCH 2 JU projects working in this area. The project should bring the fuel cell system developed as close as possible to certification considering the applicable legal basis.

TRL at start of project: 4 and TRL at the end of the project: 6.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 2.5 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 4 years

Expected impact

Flexifuel operation of SOFC systems should target to cover long-term EU policy perspectives. Consequently, the project is expected to have the following impacts:

- Demonstration of long-term operation (> 6000 h) at stack level with degradation rate below 1%/1000h in the operation window from 0 to 100% H₂ in natural gas, thus proving the tolerance of H₂ content in natural gas up to 100%;
- Demonstrate that BoP components are compatible for this wide range of gas composition, by qualifying them for the 0-100% H₂ in natural gas range in laboratory and by integrating them in SOFC systems;
- BoP components allowing to reach the CAPEX targeted by the 2024 MAWP values⁵⁶;
- Demonstrate the operation at system level in relevant environment, with an electrical efficiency >48% LHV for the whole operation window from 0 to 100% H₂ in natural gas, a behaviour and a degradation rate similar to natural gas fed SOFC systems, and with availability >90% over the operating duration (9 months minimum);
- Confirmation that flexifuel operation mode allow to reach the lifetime and efficiencies targeted by the 2024 MAWP values, thus demonstrating that SOFC systems are fully hydrogen ready;
- Decrease of CO₂ emissions of SOFC by at least 40% during operation as compared to a standard natural gas fuel cell fed system;
- Demonstrate that the primary energy reduction through cogeneration is available also to pure hydrogen networks

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁵⁶ <https://www.fch.europa.eu/page/multi-annual-work-plan>

FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores

Specific Challenge

The increasing contribution of variable renewable energy (VRE) in the electricity grid is creating a substantial temporal mismatch between supply and demand. To balance this daily to seasonal mismatch it is necessary to have a large facility for storing and withdrawing VRE. Underground storage of gas molecules is cost efficient, environmentally friendly, and suitable for storing large amounts (e.g. more than 200 GWh per salt cavern or over 1,000 GWh in a gas field). The combination of VRE, electrolyzers and geological storage can therefore provide a means for capturing and holding renewable energy at an unprecedented scale for satisfying time-varying energy demands. When moving towards a fully renewable system, very large volumes of hydrogen storage will be needed and the rates of energy transfer in/out the store will vary substantially across the day/year, with associated variations in pressure level. It is therefore important to understand whether EU can find a suitable storage option using its depleted gas or oil fields and other geological stores in a time-varying cyclic manner to buffer the future energy system with renewable energy.

Although pure hydrogen storage in salt caverns is practiced in some locations, hydrogen storage in depleted gas or oil fields has not been done anywhere in the world – only few attempts to inject hydrogen up to a certain percentage. Lab and field trials have shown that hydrogen can yield geochemical and microbiological reactions in the subsurface. Also, hydrogen has different mobility, dissolution and diffusion characteristics, when compared with natural gas. Some preliminary studies are indeed promising regarding the possibility of using the depleted fields for hydrogen storage, but further research and experimentation is required.

Scope

The main objectives of this topic are to research the feasibility of implementing large-scale storage of renewable hydrogen in depleted gas fields and other types of geological store, and to undertake a techno-economic assessment of how the underground storage of renewable hydrogen could facilitate achieving a zero-emissions energy system in EU by 2050.

Suitable geological stores should be identified and classified, together with information concerning nearby connecting infrastructure and wind/solar farms. The outstanding feasibility questions should be defined, and a research plan of laboratory and possibly field tests and literature surveys implemented to cover all questions concerning geological, microbiological, engineering and economic factors. The analysis should help clarify whether most of the hydrogen can be recovered, or if a significant percentage would be lost due to dissolution, diffusion, viscous fingering, chemical reactions or leakage.

Cyclability and longevity aspects of such stores should also be addressed. The geographical distribution across EU of all suitable types of geological store and their potential hydrogen capacities should be also identified.

A comprehensive techno-economic analysis of the considered approach should be undertaken, building on the findings of the HyUnder project⁵⁷, to examine the potential for its widespread implementation across the period 2025-2050. This should include (onshore and offshore) mapping of the proximity of suitable underground stores with existing and future wind/solar farms, modelling the production of renewable hydrogen, associated gas compression and hydrogen pipeline networks to transfer hydrogen to/from the stores, and identifying the profiles and amounts of renewable energy that can be buffered by such storage facilities to meet time-varying energy demands across all end use sectors. The developed model should identify how to match renewable supply with energy demand at all times by appropriately sizing and operating the technologies involved in producing, storing, distributing and using renewable hydrogen. Future scenarios should be formulated or existing

⁵⁷ <https://www.fch.europa.eu/page/cross-cutting-issues-0#HyUnder>

scenarios/roadmaps should be reviewed for the EU to establish the considered approach at a prodigious scale by 2050.

In addition, the techno-economic feasibility of implementing hydrogen storage in preferred locations should be assessed to a level sufficient to support a decision whether or not to proceed to field pilot demonstration. This will provide substantial insights into the suitability for implementing such storage across EU and enable the development of positive business cases for adoption.

The project consortium should involve geologists to undertake expert analyses of underground storage opportunities for a wide range of sites across EU, both offshore and onshore.

TRL at start of the project: 3 and TRL at the end of the project: 5.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

“CertifHy Green H₂” guarantees of origin should be used through the CertifHy platform⁵⁸ to ensure that the hydrogen produced and injected underground is of renewable nature.

The maximum FCH 2 JU contribution that may be requested is EUR 2.5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

Expected duration: 2 years

Expected impact

The project should:

- Establish the geochemical, mineralogical and microbiological reactions occurring in geological stores in the presence of hydrogen;
- Improve understanding of the scalability of the demonstrated approach if replicated across Europe and the associated requirement for hydrogen infrastructure and renewable power sources;
- Provide a detailed techno-economic assessment of future scenarios for the EU to achieve widespread deployment of underground renewable hydrogen storage by 2050;
- Provide insights concerning the value chain and which parts need further study or development to establish positive business cases (covering technology development/selection, operation, location, system integration and other aspects).

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁵⁸ <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

FCH-02-6-2019: Electrolyser module for offshore production of renewable hydrogen

Specific Challenge

The foreseen magnitude of renewable electricity (RE) production requires the development of large-scale offshore wind and potentially floating solar PV. Significant challenges lie ahead regarding the implementation of such renewable electricity generation, especially because of the required investments in electricity infrastructure to transport peak RE production to shore and the increasing variability due to the substantial temporal mismatch between supply and demand.

The offshore conversion of renewable electricity to renewable hydrogen by electrolysis overcomes several of these challenges, as hydrogen transportation and storage can be done at large scale and relatively low cost. Many offshore oil and gas assets in the North Sea and elsewhere will also soon be out of purpose because EU's natural gas sources are declining, so re-purposing these for renewable hydrogen production and transport to shore may accelerate and de-risk the implementation of an offshore energy system.

The foremost technical challenge for producing renewable hydrogen offshore is the development of an electrolyser module which is compatible with that environment, while being sufficiently compact to achieve very high rates of hydrogen production per platform or per wind turbine, and able to survive long term when connected directly to an intermittent variable renewable power supply. Different specific conditions, including the marine environment, stringent safety requirements, commercial terms of existing delivery contracts and the difficult accessibility make it very challenging.

Scope

This topic aims to develop and test an offshore electrolyser module of >1MW at an onshore, seafront location. The electrolyser should form one component of a proposed multi-module design solution for a stand-alone offshore renewable hydrogen production facility, in order to facilitate a subsequent demonstration programme at scale. All factors pertaining to the exacting offshore environment should be considered (including the electrolyser's requirement to desalinate and purify sea water, operating in a high salinity environment, pressurizing the hydrogen output to enable it's transfer by pipeline to shore, surviving periods of zero renewable power input, transportation to site, commissioning, ease of operation and maintenance).

Laboratory tests should already verify that the developed electrolyser will still reach the MAWP Addendum 2024 KPIs for hydrogen production⁵⁹. This should be followed by a field test programme of at least 12 months, with operating conditions reflecting the variability and capacity factor of the renewable power input. The test programme should be sufficiently comprehensive and qualified to clarify what performance to expect from offshore renewable hydrogen production (in terms of efficiency, degradation, maintenance cost etc.) and to convince stakeholders that a multi-module facility based on the developed electrolyser module could subsequently be installed offshore. Hydrogen should preferably be injected in a Hydrogen or Natural gas grid.

Permitting and regulatory approval should be sought for the developed electrolyser module and certification obtained before completion of the project. A techno economic assessment of installing and operating offshore electrolyser facilities should be undertaken, with consideration given to transferring hydrogen or hydrogen admixtures to shore, and candidate business cases identified.

The consortium should include the offshore energy sector, an electrolyser manufacturer and a systems engineering company or a qualified competence center with strong links to hydrogen safety expertise. The consortium should possess the necessary contractual and commercial expertise to analyse the market for hydrogen if the considered offshore hydrogen approach is widely applied.

TRL at start of the project: 3 and TRL at end of project: 6.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-

⁵⁹ <https://www.fch.europa.eu/page/multi-annual-work-plan>

H2SAFETY@ec.europa.eu , which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell or electrolyser components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

"CertifHy Green H₂" guarantees of origin should be used through the CertifHy platform⁶⁰ to ensure that the hydrogen produced is of renewable nature.

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

The grid connection, building, desalination and purification as well as the electricity for the commissioning phase are within the scope of the topic. The electricity used during demonstration/business operation shall not be considered in the scope of the topic.

Expected duration: 4 years

Expected impact

The project should:

- Deliver a certified electrolyser as a basic module ready for replication and deployment in an offshore environment;
- Demonstrate the first worldwide field test of an offshore electrolyser;
- Determine the long-term performance of offshore power-to-gas in terms of efficiency, system balancing, performance degradation, operational cost aligned with MAWP Addendum 2024 KPIs;
- Evaluate the operational, inspection and maintenance requirements of the offshore electrolyser and BoP;
- Act as a stepping stone for deploying future offshore electrolysers which are directly connected to both offshore wind-farms and existing or new dedicated pipelines for transferring RH ashore;
- Improve understanding of the technical, economic, regulatory and operational benefits and hurdles of re-using existing natural gas assets for transition to hydrogen;
- Help to prepare natural gas consumers for the hydrogen economy, at minimum cost and environmental impact.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁶⁰ <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

FCH-02-7-2020: Cyclic testing of renewable hydrogen storage in a small salt cavern

Specific Challenge

The combination of variable renewable energy, electrolyzers and geological stores can provide a means for capturing and holding renewable energy at scale. A fully renewable system in EU will require very large volumes of hydrogen storage and the ability to transfer hydrogen in/out of the stores at various rates across the day/year, with associated variations in pressure level. Considering this challenge, it is important to understand whether geological stores can be used in a time-varying cyclic manner to accept high charge and discharge rates, together with any impacts on the gas transportation system or downstream applications.

Hydrogen storage in salt caverns is well established, but salt caverns have not been subjected to time-varying rates of hydrogen input and output to reflect the variable profiles of renewable power and hydrogen/energy demand (as will be required if they are to act as a dynamic buffering option to enable sector coupling and a more resilient energy system).

Scope

The main objective of this topic is to examine the feasibility of cycling a salt cavern, fed by an electrolyser that follows an intermittent renewable power profile while hydrogen is discharged from the cavern to cover a specific hydrogen demand. This should provide a better understanding of how to integrate and balance intermittent renewables in the EU energy system. The results should offer sufficient learnings for decisions on scaling-up large underground storage of renewable hydrogen.

A suitable salt cavern should be identified for undertaking a pilot scale demonstration involving a MW scale electrolyser and essential infrastructure equipment. The size of the cavern, the electrolyser and the profile of hydrogen demand should be such that over the duration of the project the cavern will be cycled a few hundred times, e.g. at least daily cycling.

The transient performance of the system should be assessed in a temporally precise manner when it is subjected to a variety of relevant renewable input and hydrogen/energy demand profiles. The electrolyser response times should be compliant with providing grid services in future balancing markets, as may be required to achieve a fully renewable energy system. Through an extensive test and demonstration programme, the project should establish the technical (geological, geochemical, microbiological) and economic capabilities and limitations of salt caverns to act like a 'lung' for the energy system (absorbing variable renewable energy and discharging hydrogen as required to match supply and demand across very different periods and response times).

For this demonstration pilot, preferably hydrogen produced directly from renewable sources should be used for providing the working volume, while the cushion gas may come from other sources. "CertifHy Green H₂" guarantees of origin should be used through the CertifHy platform⁶¹.

The application model to be considered in the project should be parameterised (e.g. the fuel utilization factor with respect to the overall amount of pressurized fuel stored in the cavern), in order to identify positive business cases and the highest replication potential of the pilot case in caverns of various size. To achieve a deep understanding of how the project could be scaled up and applied across the EU energy system, it should study a real case of sector coupling by considering one or a combination of the following options: hydrogen consumption by the industrial sector, hydrogen mobility, injection into the gas grid (of hydrogen or synthetic methane) and stationary power generation.

It is expected that the replicability and scalability of the project would be fundamental to facilitating further deployments of renewable hydrogen storage underground in salt caverns. The project should therefore liaise with relevant bodies and other projects to share and disseminate learnings including RCS issues.

TRL at start of the project: 5 and TRL at the end of the project: 7.

⁶¹ <https://fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

The project consortium should involve geologists to undertake expert analyses for any structural, geochemical or other effects that the cycling of the cavern with hydrogen could lead to.

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

The grid connection, building and the electricity for the commissioning phase are within the scope of the topic. The electricity used during demonstration/business operation shall not be considered in the scope of the topic.

Expected duration: 3 years

Expected impact

The project should:

- Demonstrate the cyclic operation of a salt cavern when subjected to hydrogen input variations that respect typical variations in renewable power generation and energy demand (e.g. hydrogen consumption by industry, hydrogen mobility, heat or power generation), as well as the possible impact in the gas transportation system;
- Establish the technical feasibility of safe and effective underground storage of renewable hydrogen by considering the possible geological and environmental issues, and the operational, inspection and maintenance requirements (e.g. the range of pressure levels required, degradation, humidity levels, etc.);
- Evaluate the scalability of renewable hydrogen storage for large scale replication and propose the engineering of specific solutions;
- Clarify issues relating to hydrogen purity and composition after the injection/extraction processes, the geological and the environmental impacts, pressure level variations and the level of measurement/instrumentation required among other issues;
- Aim to reach the 2020 H2 storage MAWP target of System CAPEX of €450/kg of H2 stored or an additional cost to H2 released of €1/kg.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

Specific Challenge

In order to fight climate change, the need to reduce the emission of greenhouse gases will force the chemical industry to find alternate paths to the conventional fossil carbon sources. A significant number of existing and future value chains require carbon monoxide (CO) in addition to hydrogen. Even at high rates of direct electrification scenarios that include the use of biomass, there is still a demand for carbon (C). At EU level, this is in the range of millions of tons/year⁶² (corresponding to GWs of energy demand if derived from CO₂) due to following reasons:

- Carbon (C) is a building block in basic chemicals such as aviation fuels and alloys and is responsible for 20% of crude oil usage in the EU. It can hardly be replaced by direct electrification or pure hydrogen;
- CO has a stronger binding enthalpy to oxygen (O₂). Redox processes, e.g. ore reduction, can run at lower temperatures (and therefore fewer complex materials) with CO than with pure H₂.

Carbon is either part of a product directly from crude oil or derived from fossil syngas (H₂ + CO). Similarly to hydrogen, most of the syngas nowadays is produced by steam methane reformers (SMR) which emit more than 6 kg of CO₂ per kg of syngas. Industrial Power-to-X Plants require quantities of syngas in scales of minimum 20 MW while the standard scale will be more than 100MW.

The general challenge is to supply green syngas at a competitive cost and in the MW range in order to be relevant to the industrial applications that will still rely on carbon in the future.

High temperature steam electrolysis based on Solid Oxide Cell (SOC) technology can perform the co-electrolysis of CO₂ to CO along with hydrogen production. This directly creates syngas (H₂ + CO) at high system efficiencies of 80% (LHV SynGas/kWh AC) and high conversion rates (>80%), already demonstrated at low TRL by previous FCH 2 JU projects and national projects (e.g. Kopernikus⁶³ or ECo⁶⁴).

The specific challenge is to scale up to the MW range and advance it to a TRL that is relevant for industrial syngas consumers while getting the cost of green syngas close to the steam reformer level.

Scope

This topic calls for the development, manufacturing, commissioning and operation of an industrial size co-electrolysis system, based on SOC technology. This should be demonstrated in an industrial environment with the following goals:

- Fully equipped system including CO₂, steam, electricity supply and the conditioning of all feed and product streams (especially the cleaning of CO₂ from contaminants) as well as the compression of the syngas to the pressure required by the consumer;
- Net output of at least 80 kg pure (2 H₂:CO) syngas/h, used to substitute fossil-based syngas, which corresponds to approximately 700 kWAc;
- Demonstration for two years with an expected production of 500-900 tons of syngas at >95% availability. Part load operation to handle flexible loads is also expected and the demonstration should be concluded without the need for a stack replacement;
- The power consumption at Beginning-of-Life (BOL) should be less than 8.5 kWh AC/kg of syngas and the production loss rate should be less than 1.2%/kh;
- Stack box reference tests should be performed in order to analyse root causes of degradation. Degradation caused on stack and system level should be separately investigated. Consequences of gas flow and temperature inhomogeneity as well as impacts from critical operating conditions should be analysed;

⁶²https://cefic.org/app/uploads/2018/12/Cefic_FactsAnd_Figures_2018_Industrial_BROCHURE_TRADE.pdf

⁶³ <https://www.kopernikus-projekte.de/en/projects/power2x>

⁶⁴ <http://www.eco-soec-project.eu/>

- It should be able to demonstrate a pathway that achieves a CAPEX of less than €480/kg/day and operation and maintenance cost of less than €24/kg/day by 2024. Recommendations on how to reach these targets should be given;
- CO₂ and steam should be sourced from existing streams, while electricity should be sourced renewably by a direct connection to a renewable power source or through a contractual relationship (e.g. PPA). “CertifHy Green H₂” guarantees of origin should be used through the CertifHy platform;
- The co-electrolyser should be benchmarked against the operational range of the fossil source process (SMR). This benchmarking should be done with respect to the H₂:CO ratio as well as part load capability (from min to max in <5 minutes for grid services);
- All data derived from the operation and the market such as feed stream purchasing, product sales and additional income streams should be used to create a techno-economic analysis. It is expected that an LCA will be conducted and that the GHG mitigation potential and Total Cost of Ownership (TCO) will be calculated in order to derive a business model that encourages the use of co-electrolysis over fossil sources. Recommendations for adaptations in the relevant legal frameworks should be made.

The values above are expressed for the standard syngas composition of 2H₂:CO. Different use cases might require different stoichiometry, e.g. higher CO content. For those cases, equivalent targets should be developed and proposed by the applicants.

The consortium should include the co-electrolysis system manufacturer and the industrial syngas consumer.

TRL at start: 5 and TRL at the end of the project: 7

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell or electrolyser components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

Expected duration: 4 years

Expected impact

The project is expected to demonstrate a path forward to the reduction of carbon-emissions from the chemical industry in EU. The most important impact is the industrial operation of the world's largest co-electrolyser, which will be perceived as “MW scale” in comparison to legacy water electrolysis, although it may take in less than one MW electric power due to its high efficiency.

Due to the scale-up factor it is expected that industrial components will be used offering a reduction in the overall costs of a co-electrolysis system.

A very important impact is the increased trustworthiness for this technology by achieving the following goals:

- At least 12,000 operational hours with less than 1.2%/kh production loss rate;
- Electricity consumption at rated capacity and at beginning of life (BOL) that will be less than 8.5 kWh AC/kg of syngas without compression. This equals to about 80%

electrical efficiency (LHV SynGas/kWh AC), which is below the MAWP target of 2024⁶⁵ for pure steam electrolysis since co-electrolysis is more complex;

- Availability of 95% which is 3% less than the 98% MAWP target for 2024 for this new technology for the same reason as above;
- An expected capital cost reduction to €480/kg/day and operation and maintenance cost reduction to less than €24/kg/day;
- A detailed degradation analysis and the identification of measures to lower degradation in the future;
- The project is expected to demonstrate the scale up of SOC co-electrolysis which will be necessary in order to decarbonise chemical feedstock;
- The project is expected to produce high quality data for LCA, GHG mitigation potential and TCO calculations. Additionally, a business model is expected as well as recommendations for adaptations of the relevant regulatory framework. The above should enable the replication of such business propositions following the completion of the project.

With the successful completion of such a project, co-electrolysis shall show its potential to largely contribute to sectoral integration as well as grid balancing by utilizing existing infrastructure and by enlarging the reach of green hydrogen to industrial areas that are today only accessible for fossil syngas or fossil hydrocarbons.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁶⁵ <https://www.fch.europa.eu/page/multi-annual-work-plan>

FCH-02-9-2020: Fuel cell for prime power in data-centres

Specific Challenge

Pushed by the major trend of digitalization and the internet of things, the market demands more and more highly reliable, continuous power supply (prime power) for data-centres. It is expected that data-centres will use up to 4% of world's energy consumption in the next few years. Most of the visible hyper scale data-centres (100 MW) are nowadays built in cold remote areas in proximity of renewable energy sources, primary wind and hydro power and where free cooling is available.

The more numerous but more discrete smaller "edge data centres", situated close to the end-user, have also experienced a strong growth in cities and urban areas. Much smaller in scale, they offer an increased service level to the end-users expecting very fast data response time where every millisecond counts in customer experience. The power density of the data-servers has more than doubled over the last few years, allowing to increase the data treatment capacity within the same space, while the availability of electric power is becoming increasingly a constraint in those areas. Often it is simply not possible to increase the power supply in cities like London and Frankfurt, as the power distribution infrastructure is already extensively loaded.

The challenge is to overcome the constraints in the existing electrical infrastructure without increasing local emissions using solutions that are efficient from an energy and an economic point of view. This creates an opportunity for distributed generation. In addition, city centres often practice stringent policies to reduce and avoid emissions like NO_x, SO_x, particulate matter and noise, to protect the health of their inhabitants. This limits the use of power generation using combustion engines. Fuel cell generators can adequately address all these challenges as they can provide high power density within buildings or on roof tops and highly reliable power supply at acceptable cost levels.

An appropriate overall data-centre architecture is required to address all aspects simultaneously, particularly the redundancy to provide high reliability and availability.

Furthermore, edge data-centres are often located in large commercial buildings like banks and insurance buildings, hotels and hospitals, offering the opportunity for the use of the by-product heat. This can be realised either within the building itself or by providing the heat to a nearby district heating system. An appropriate thermal design provides the opportunity to reach higher total efficiencies relative to other conventional technologies at the same scale.

Scope

The project aims at demonstrating a highly reliable power supply to data-centres within urban areas where grid power supply is limited due to infrastructure constraints and where combustion-based combined heat and power (CHP) is not admissible due to emissions regulation.

The project will develop a building integrated solution using fuel cells that are adapted and suited to the requirements for strong load modulation, electrical integration/connection to the data centre and heat recovery for use in the building or a district heating network.

The solutions developed in the project should:

- Provide an appropriate data-centre electricity supply architecture based on fuel cells modules to provide a 99.999% availability to the data-centre;
- Supply at least 50 kWe of power to the data centre. The architecture developed should be modular, easily scalable to other system capacities and able to provide the five 9 (99.999%) availability;
- Demonstrate the solution developed in an operational environment (real data centre) for at least 8,000 hours;
- Provide overall solutions that cope with the strongly varying load of data-centres;
- Address service and maintenance requirements of both fuel cell modules and data servers in a coordinated manner to optimise the overall operating costs of the data-

centre. This includes minimisation of system footprint and accessibility for maintenance;

- Consider the suitability of using the heat generated from the fuel cell and data-centre server either to supply the building needs or to a nearby district heating system.

Projects should identify and/or develop business models aiming to foster the replication of the solutions developed in the project in other data centres.

The consortium is expected to include at least a system supplier based in the EU or H2020 Associated Country with proven track record of units running in the field and a data-centre infrastructure provider. Activities should build on the experiences and achievements of earlier projects and bring further cost reductions as a means to improve and strengthen the competitiveness of the EU fuel cell supplier industry.

TRL at start of the project: 5 (for the electrical architecture) to 6 (for the fuel cell) and TRL at the end of the project: 7.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

Activities developing test protocols and procedures for the performance and durability assessment of fuel cell components should foresee a collaboration mechanism with JRC (see section 3.2.B "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published FCH 2 JU harmonized testing protocols to benchmark performance and quantify progress at programme level.

The maximum FCH 2 JU contribution that may be requested is EUR 2.5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contribution above this amount will not be evaluated.

Expected duration: 3 years

Expected impact

- Provision of solutions to supply the energy requirements of data centres located in urban areas that are reliable, modular, highly efficient and compatible with the requirements of the most stringent local air quality regulations;
- Cost-effective solution to overcome constraints in the existing electrical infrastructure of city centres and urban areas without increasing local emissions;
- Opening of new markets for EU suppliers including export opportunities for overseas markets. The project should provide business models for fuel cell and data centre providers planning to roll-out and implement the solutions developed in the project at scale;
- After an initial deployment phase in electricity constraint areas, it is expected that the use cases will expand more generally throughout urban areas and that the resulting products are compatible with increasing amounts of hydrogen within the existing gas infrastructure.

The solutions developed should achieve the following KPIs:

- Fuel cell system cost <€5,500/kWe;
- Fuel cell system volume <225 l/kWe;
- Single system availability of at least 98%;
- Overall availability of power supply to data-centre at least 99.999%;
- Electrical efficiency > 50% (methane LHV) and >45% (H2 LHV).

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

OVERARCHING ACTIVITIES

FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation

Specific Challenge

Green hydrogen is crucial to meet the CO₂ reduction objectives of the industry (e.g. e-chemicals etc.) and in the transportation sector (e.g. fuel cell cars, e-fuels). In this context, the demand of high-quality hydrogen regarding dryness, purity and pressure is steadily increasing. Although conventional methods like mechanical compressors, zeolites, and thermal drying cycles to clean, dry and compress hydrogen are economic and reliable at large scales, they have not been optimised to the scale of decentralised hydrogen production such as electrolysis. Commonly several conventional processing steps are simply put in series in a non-integrated way, resulting in high equipment and maintenance costs, significant energy and limited reliability.

Electrochemical hydrogen pumping for drying, purification and compression presents a radically different approach to fulfil the high-quality requirements of fuel cell applications in various fields, including mobility, Power-to-X and to Power-to-Power. The most advanced technology in this field is based on symmetric high temperature Polymer Electrolyte Membrane, however only marginal progress has been achieved over the last decade and the commercial maturity is yet to be reached.

Proton conducting Ceramic Cells (PCC) represent a promising alternative way to compress and purify hydrogen. They can extract hydrogen from low pressure levels, low concentrations or mixed with pollutants like CO in a single step to more practical pressure levels and adequate levels of purity. PCCs operate in a temperature range of 400°C – 700°C and allow seamless heat integration options. The use of noble metals is avoided, as these cells are based on inexpensive and abundantly available materials. Therefore, the technology is extremely attractive for an efficient thermal integration when coupled with other chemical processes (e.g. steam biogas reforming, methanation etc.). In combination with reversible Solid Oxide Cells, they open the door to exceed 50% round-trip efficiency for power-to-power applications that can offer a significant contribution to seasonal energy storage. PCCs are however at an early stage of development. The current challenge is to overcome the limited understanding at the materials level and the lack of optimized stack / reactor designs for energetically integrated downstream processing of hydrogen.

Scope

Based on the challenge of PCC based technologies for efficient green hydrogen processing and handling both in terms of materials, performance, cell and reactor, this topic calls for an integrated approach of material science, reactor design and multiscale modelling. It is expected to reach a significant performance enhancement on materials (increased current density and mechanical integrity, reduced over-potentials), and at the elaboration of a proof of concept reactor design taking into account the physical, mechanical and chemical properties of materials.

Most national and EU projects have focused so far on the development of PCCs for use as fuel cells or electrolyzers. Planar cell-based technologies have been investigated in EFFIPRO⁶⁶ and METPROCELL⁶⁷ projects and tubular cell-based technologies devoted to high-pressure electrolysis in the FCH 2 JU ELECTRA and GAMER projects⁶⁸, the latter focusing on 10 kW prototype demonstrations.

The main objective of the topic is to go beyond the above state-of-the-art, arriving to a laboratory scale validation and a PCC technology system operated in different conditions. Among the different testing conditions, mechanical stability, electric conductivity and high proton throughput should be tested in different operation modes.

The project should therefore cover the following aspects:

⁶⁶ <https://cordis.europa.eu/project/rcn/89271/brief/en>

⁶⁷ <https://cordis.europa.eu/project/rcn/101146/factsheet/en>

⁶⁸ <https://www.fch.europa.eu/page/fch-ju-projects>

- Qualification of novel materials (electrodes, electrolyte, robust mechanical substrates, sealants, current collectors and interconnects) suitable for stable operation under pressure and purity gradients;
- Development of cell or reactor components and included in at least two architectures (e.g. robust composite and/or graded electrodes with high electro-catalytic activities, thin film electrolyte with high crystallinity). The applied manufacturing processes should be industrially scalable;
- Multi-scale modelling from the meso-scale up to the single unit level, to enhance the performance of specific materials and to support the development of manufacturing processes towards improved stack / reactor design. The model should be validated by relevant experimental data;
- The proposed materials and cells should be implemented in short stacks and/or mini-reactors (with at least 5 repeating units scaled at industrially-relevant size; i.e. 80-100 cm² per repeat unit). The short stacks and mini reactors should be tested in a configuration allowing pumping of hydrogen, monitoring the hydrogen production, purity and pressure levels;
- Insight on the correlation of performance and degradation mechanisms should be gained, including on/off cycles and dynamic operation. This should be the base for designing various PCC electrochemical reactors, enabling process intensification (e.g. shifting chemical equilibria) and electro-synthesis reactors to increase efficiency of overall chemicals and/or green fuel production with low or no CO₂ footprint;
- A comprehensive assessment of the environmental impact through life cycle assessment, comparing the proposed solution with conventional purification and compression technologies, should be also performed. This should provide a full techno-economical comparison;
- As an option, the reversible operation between electrolysis and fuel cell modes in a PCC cell should be considered too;
- As another option, the design and validation of a short stack and/or mini reactor in green fuels synthesis (e.g. CO₂ reduction, direct electro-synthesis of hydrocarbons) might be included.

The project should bring together the research on proton ceramic conducting materials with the further exploitation of materials of interest for the industry in the next scaling up of the technology.

The consortium should therefore include both academia and industry and should ideally leverage international collaborations. The project should build on existing know-how on cells and stack manufacturing and synergies to other electroceramic processes should be sought.

TRL at start: 2 and TRL at the end of the project: 4

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 3 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years

Expected impact

The project results are expected to unlock a path towards commercially viable technology based on PCC technology for dry, pure and pressurized hydrogen extraction from various gaseous streams (any type of electrolyzers, biological processes, gasification processes) at a small to medium scale. Single

step delivery of pressurized hydrogen will allow efficient integration in the process chain to reduce the overall cost for using hydrogen as energy vector. This will enable the EU players to take a strategic worldwide lead position in PCC technologies.

Insight on the correlation of performance and degradation mechanisms should be gained, including on/off cycles and dynamic operation. This will be the base for designing various PCC electrochemical reactors, enabling process intensification (shifting chemical equilibria) and electro-synthesis reactors to increase efficiency of overall chemicals and/or green fuel production with low or no CO₂ footprint.

To leverage the impact of the proposed solutions, following KPIs should therefore be reached:

- ASR of cells/stacks: < 1 ohmcm² at 650°C, Faradaic efficiency > 95 %;
- Validation of the durability of cells for at least 3,000 hours and validation of short stacks/mini reactors in selected applications for at least 1,000 hours of operation;
- Processing of hydrogen with a production loss rate of less than 1.2 %/1,000 hours;
- Cell and stack architectures allowing for a pressure ratio across a single membrane (H₂ partial pressure increase) of at least 5 and/or cell and stack design extracting hydrogen from concentrations as low as 10 hPa (e.g. 1% H₂ admixture in CH₄), to offer an economic option for H₂ distribution in the existing natural gas infrastructure (reverse step of H₂ admixing).

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

Specific Challenge

Islands and island regions are confronted with a number of energy challenges due to their specific geographic and climatic conditions. In addition, islands' economy is often largely based on tourism, which results in unbalanced seasonal energy demand, which puts a strain on natural resources and infrastructures. At the same time, these challenges represent great opportunities for EU Islands and island communities to showcase innovative solutions for the clean energy transition. Against this backdrop the European Commission, together with 14 Member States, signed the "Political Declaration on Clean Energy For EU Islands"⁶⁹ under the Maltese Presidency.

Hydrogen and its associated technologies have the potential to support islands in addressing a number of challenges related to energy. Previous years' initiatives, as Hydrogen Valleys in the FCH 2 JU call 2019, were focused on defined geographical areas where several hydrogen applications were integrated within an FCH ecosystem. Although some experiences with islands and hydrogen technologies exist (e.g. BIG HIT and REMOTE projects⁷⁰), it is necessary to widen the scope to larger community islands as they face particular challenges, including fuel import dependency, high electricity costs, limitations in terms of energy production and energy interconnections, and imbalances on all time scales from minutes to seasons due to tourism relevance.

The development of hydrogen economies in these singular locations will also help boosting the reindustrialization and generating new low carbon economies and sustainable tourism based on green hydrogen as a singular EU flagship initiative.

Scope

The project should cover the following main objectives:

- Showcase the ability of hydrogen and its associated technologies to decarbonize islands in EU and worldwide through this renewable hydrogen flagship project. For this reason, the project should be implemented in a location with high communication visibility;
- Cover the complete value chain of H2 from production to distribution, storage and end-use in order to decarbonize islands with restricted connections and indigenous energy sources and with significant fluctuations in seasonal energy demand. The proposed solution should provide energy flexibility and improve the island's system resilience through the use of renewable hydrogen, acting as a buffer;
- Demonstrate how hydrogen enables sector coupling and allows large integration of renewable energy on the selected island;
- Develop and promote the use of renewable hydrogen, energy efficiency and sectoral integration in applications related to intensive tourism such as hotels infrastructure (e.g. power, heat, cooling), general services, airports, ports, buses, ferries, renting fleets etc.;
- Promote the economic growth of EU islands in new technologies and areas (e.g. reindustrialization of remote areas based on hydrogen technologies);
- All hydrogen should be produced from renewable energy capacity installed on the island. This hydrogen production should be included in the "CertifHy Green H2" guarantees of origin scheme. "CertifHy Green H2" guarantees of origin should be issued and cancelled through the CertifHy platform⁷¹ to show that the hydrogen production and consumption is of renewable nature.

The project should therefore cover the following:

- Renewable energy integration and green H2 production;

⁶⁹ <https://ec.europa.eu/energy/en/news/clean-energy-eu-islands-launched-malta>

⁷⁰ <https://www.fch.europa.eu/page/fch-ju-projects>

⁷¹ <https://www.fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market>

- Hydrogen transport, storage and distribution, including the possibility of gas grid injection or other options;
- Sector coupling to manage in the most efficient way seasonal energy and H2 production/demand balancing;
- Promotion of a renewable H2 ecosystem in the island, as a new economical vector and as mechanism of creating value for the island population.
- All final consumption sectors can be considered for the use of renewable hydrogen, with a clear focus on:
- - Energy sector: Possible applications on heat and power for commercial/residential buildings (e.g. hotels), service sector and industry using FC-based CHP units, fuel cell powered gen-sets, backup-power systems, and electric supply of critical infrastructure. Gas grid injection, in blending mixtures and its impact assessment in order to promote the progressive decarbonisation of the gas grid should also fall under this sector; using renewable H2 as feedstock in industrial applications;
 - Transport sector: Possible applications of buses, coaches, cars (private/captive fleets), delivery vans, trucks, special vehicles, trains, waterborne and airborne applications, maritime sector or material handling vehicles.

At least two FCH applications from both energy and transport sectors should be part of the project. The volume of renewable hydrogen produced for the different applications should be consistent with the seasonal imbalances in the island and with the amount of investment considered. For the expected size of the project, at least 300 tons H2/year should be produced and consumed on the island. As a renewable energy island flagship project, in line with the EU Clean Energy for Islands initiative⁷², it is preferable that up to 70% of funding would support the energy sector activities, involving a complete solution of hydrogen generation, storage, distribution and/or energy applications (e.g. power to gas or power to power applications).

Projects are highly encouraged to select island locations that promote the visibility and increase the impact of the hydrogen technologies. Projects based on islands connected to centralized or mainland's areas are possible too.

The replicability and scalability of the project is fundamental to facilitate further deployments of H2 economies in other islands. The proposals should therefore address efforts to provide learnings on how to best scale-up and transfer FCH solutions investigated within the selected H2 island to other interested areas and islands. For this reason, a clear communication and dissemination strategy and a plan to engage with and foster replication in other islands should be addressed by the project. This should comprise also RCS issues. These activities should be framed and aligned with the European Union Clean energy for EU islands initiative⁷³ and other similar initiatives supported by EU to accelerate the introduction of clean technologies in islands.

To increase impact beyond the demonstration part of the project, the consortium should develop a long-term vision (roadmap) on the local/regional H2 economy plans on the island towards 2050.

In addition and in view of expected important involvement from industrial stakeholders and/or end-users such as public authorities, consortia are encouraged to identify and secure additional funding sources. Commitment of public authorities (Member States, Regions and Cities) is considered necessary and should be evidenced in the proposal at least in the form of letter of Interests (LOIs). The proposal should therefore include a financing scheme describing the business model, including

⁷² <https://ec.europa.eu/energy/en/topics/renewable-energy/initiatives-and-events/clean-energy-eu-islands>

⁷³ idem

envisaged sources of co-funding/co-financing and in line with state-aid rules. . The funding requested shall be consistent with the economical gap to incumbent technologies.

The TRL of the applications in the project should be at least 6 at the beginning of the project while the overall concept should target a TRL 8 at the end of the project.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu , which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN. A draft safety plan at project level should be provided in the proposal and further updated during project implementation (deliverable to be reviewed by the European Hydrogen Safety Panel (EHSP)).

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The maximum FCH 2 JU contribution that may be requested is EUR 10 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

Expected duration: 5 years (including at least 2 years of operation per application).

Expected impact

Depending on the chosen applications, KPIs should be defined and aligned with the Multi Annual Working Plan (MAWP) 2024 targets⁷⁴. The project should also address the techno-economic objectives as defined in the MAWP and in particular:

- Showcase the versatility of hydrogen in the frame of the clean energy transition and as an enabler to sectoral integration within the island geographical area;
- Show evidences of the GHG reduction potential in the islands and identify the contribution of such concept in the EU 2030 GHG reduction targets;
- Showcase an unprecedented scale of H2 Islands' concept in the EU, and demonstrate the sustainability of the solutions proposed and of the business model associated;
- Demonstrate the replicability of the solutions proposed to other islands in EU and worldwide;
- Promote 'green tourism' concept by providing green energy supplies and balancing seasonal imbalances;
- Develop synergies and promote further development of different hydrogen technologies;
- Demonstrate the role of electrolysis for grid balancing and for improving capacity factor of variable RES (sector coupling and sector integration);
- Promote and facilitate the re-industrialization of sectors based on high carbon emissions;
- Promote progressive decarbonisation of the transport and energy sectors and related infrastructure ;
- Identify potential barriers, including RCS to creating a viable business model for implementing such a Hydrogen Island across other islands in EU and recommend possible solutions;
- Create close links between all parties (including technology providers, owners, operators, end-users, local authorities) with long-term ambitions and strategies;
- Develop public awareness and acceptance of hydrogen technologies and create a ground for hydrogen specific skills development.

⁷⁴ <https://fch.europa.eu/page/multi-annual-work-plan>

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

CROSS-CUTTING ACTIVITIES

FCH-04-1-2020: Overcoming technical and administrative barriers to deployment of multi-fuel hydrogen refuelling stations (HRS)

Specific Challenge

The development of a widely available hydrogen vehicle refuelling infrastructure across EU will need hydrogen to be able to be dispensed in a straight-forward manner alongside other conventional and alternative fuels. Whilst the Directive 2014/94/EU on the Deployment of Alternative Fuels Infrastructure (AFID)⁷⁵ introduces interoperability requirements for individual alternative fuels, and, in the future, requirements on the number of distances between refuelling/recharging points, it will not necessarily enable this infrastructure to be provided in a multi-fuel/multi-energy forecourt.

Currently the approach taken to co-location of hydrogen and other fuels is left to be defined on a national basis. This can have a variation of effects: in some cases is straight-forward to co-locate hydrogen with other fuels and integrate hydrogen into a conventional forecourt, in others the provision of hydrogen can be subject to not insignificant minimum separation distances from other fuels, with a hydrogen dispenser needing to be either on an 'island' on its own or located away from the forecourt (or even not be permitted at all).

The definition of safety recommendations for including hydrogen in a multi-fuel configuration requires zoning and risk assessment. Furthermore, the different approaches to zoning taken around EU can make it difficult for a standard dispenser product to be designed/manufactured/installed without significant additional justification, or alterations to the design (even though the dispensers typically use components that barely differ). One key missing element to enable standardised zoning and risk assessment is the characterization of the leaks that can be anticipated from hydrogen dispensing technologies and their effects (fire, explosion).

To address this gap, experimental data from engineering research on H₂ leaks for HRS is necessary, including analysis of their effects and the reliability of the safety barriers typically employed in hydrogen dispenser design and installation.

Scope

The main aim of this topic is to provide guidance to assist the deployment of gaseous hydrogen dispensing in a multi-fuel environment across EU, overcoming the technical and administrative barriers consistently by using a clear, transparent and scientifically sound methodology. The work should therefore tackle at least the following objectives:

1. Detailed investigation of current status:

A comprehensive review of existing (i) permitting requirements (and where applicable public guidance) and (ii) risk assessment (including, for example hazardous areas and safety distances) methodologies used across EU for hydrogen in multi-fuel refuelling stations. This should also include and complete safety requirements established already by FCH 2 JU projects⁷⁶ such as HyLaw, H2ME, HyFive etc. and from other relevant stakeholders groupings, such as the Sector Forum Gas Infrastructure WG Mobility (SFGI WG Mobility)⁷⁷. The project should therefore go beyond these activities and perform more detailed investigations into the approaches taken for hydrogen dispensers in different EU countries, for both light duty and heavy-duty road vehicles.

The full scope of requirements should be covered, including zoning, risk assessment with accidental scenarios and leak sizes, and the relevant parts of permitting. The project should identify and critically assess relevant documentation (e.g. safety studies) which have contributed to the installation of HRS or development of normative rules. This should include investigating whether or not there is a route

⁷⁵ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094>

⁷⁶ <https://www.fch.europa.eu/page/fch-ju-projects>

⁷⁷ <https://www.cen.eu/work/areas/energy/Gas/Pages/default.aspx>

to a common approach that can be justified to regulators and other relevant authorizing parties across EU, in order to simplify the installation of hydrogen dispensers, particularly in cases where these are co-located with other fuels and often subject to authorization processes that differ from stand-alone stations.

2. Practical research to address gaps in current understanding:

The principal scope of the experimental campaign should be the hydrogen dispensing system. Taking into consideration the identified approaches for risk assessment, the project should perform an experimental research campaign for the characterization of potential hydrogen leaks that contribute to risk assessment for a hydrogen dispensing system (leak sizes, likelihood, suitability of control measures etc.). The project should undertake a theoretical and experimental research focused on the characterization of hydrogen leaks with their potential (leak size, likelihood and leak rate) and their effects (explosion, fire). Generic types of equipment (non-standardised and if available, standardised fuelling components/systems) used in dispenser systems should be considered. A wide practical testing campaign shall be performed on such components to determine and justify hole size assumptions used in hazardous area or separation distance calculations. The first step includes tests on critical HRS equipment in order to determine the frequency of leak and the size of the leak with test cycles. In the same philosophy, the critical safety barriers could be tested in order to determine their reliability. The second step should include a quantification of the scenarios generated by these leaks: probability of the event (with the previous data) and the effects (with dispersion study by computational tools). The consequences of expected usage scenarios, for example, temperature and pressure cycles, aging, improper use, impacts for leaks of other fuels, etc. should be considered within this research.

3. Generate best practice guidance:

Using the findings from the points above, develop best practice guidelines that can be utilised as common approach to risk assessments (e.g. related to zoning, separation distances etc.) addressing the permitting requirements as well as safe designs for hydrogen refuelling stations in a multi-fuel context. The effect of proximity to the other components of the refuelling station (e.g. storage tanks, compressors, etc.) should also be considered in this part.

This guidance should be prepared in a manner that can be applied throughout EU to help the development of national guidance/requirements where applicable and in a consistent manner. It should support the development of common assumptions for hazardous area classification for hydrogen dispensers across EU. The data collected should enable the development of the minimum requirements in standards (and regulations and codes if appropriate) such that they offer an improved reliability to those currently used, and an appropriate level of safety for customers using the stations without excessive costs or other issues relating to unnecessarily conservative estimates. Guidance documents should be developed for performing example zoning/risk assessments for both (a) hydrogen-only dispenser and (b) the additional hazards from collocating hydrogen equipment with other fuel dispensing equipment in a multi-fuel context.

4. Engagement with permitting authorities and standards developing organisations (SDOs):

The consortium should build a network of public authorities and use existing networks or forums, such as HySafe⁷⁸ to foster engagement, knowledge and experience sharing. By engaging with a network of public authorities, the consortium should share the relevant materials developed within the project to support the drafting of guidelines for HRS developers.

Finally, it should foster exchanges of best practices with Mission Innovation IC-8 (and IPHE countries). All Member States and EEA countries should, at least be invited to join a network of public authorities. SDOs should also be engaged to foster better uptake of the project results.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-

⁷⁸ <http://www.hysafe.org/>

H2SAFETY@ec.europa.eu , which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The FCH 2 JU considers that proposals requesting a contribution from the EU of EUR 2 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years

Expected impact

The project should produce:

- (i) A compilation of permitting requirements and best practices for risk assessment methodologies currently used for HRS across EU and a list of PNR gaps identified in previous relevant projects;
- (ii) Experimental and theoretical data supporting the knowledge gaps associated to risk assessment for hydrogen dispensers in a multi-fuel environment, reported publicly in manner that supports regulatory compliance and regulatory development;
- (iii) Best practice guidance on what constitutes safe designs for hydrogen refuelling stations in multi-fuel contexts, based on scientifically derived, clear, consensus driven guidance, that can be published for instance through CEN/CENELEC⁷⁹, or other routes as appropriate, backed up by the results of the experimental and theoretical research performed within the project;
- (iv) A network of public authorities which has contributed to all stages of implementation of the project and which serve as the target group for the results experimental and analytical data.

The results of the project should enable public authorities across EU to develop rules based on scientific evidence and common, agreed assumptions for hazardous area classification for hydrogen dispensers. It will vastly simplify the process of designing and permitting standardised hydrogen dispensers which will lead to greater degree of harmonisation of requirements for the permitting of hydrogen dispensing alongside other fuels, thus (i) reducing cost and (ii) ensuring that hydrogen dispensing can be co-located with other fuels safely.

The inclusion and involvement of a network of national authorities is essential for ensuring take-up of results and maximising the impact of the project.

The elimination of legal and regulatory barriers will reduce costs (financial, human resources and actual time) for economic operators and public authorities and speed up the large-scale commercial deployment of key hydrogen applications in numbers that will allow them to have a meaningful contribution to the European Union's energy, environmental and climate policy goals.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁷⁹ <https://www.cencenelec.eu/Pages/default.aspx>

Specific Challenge

In April 2018, the International Maritime Organisation, IMO adopted an initial strategy on reduction of GHG emissions from ships (overall fleet target $\geq 50\%$ CO₂ reduction by 2050 compared to 2008)⁸⁰. Alternative fuels and FC technologies can help meet these environmental and climate goals but require short and medium-term measures to become sustainable, viable and safe solutions. H₂ and FC technologies are not covered nor supported by existing regulations applicable to the maritime sector, undermining the willingness of actors (in particular ship-builders and owners) to invest and develop solutions based on these technologies.

The current IMO International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels, IGF Code⁸¹ covers primarily LNG. It is nevertheless of outmost importance for the shipbuilding industry to have provisions for the introduction of other low-flashpoint fuels used by fuel cell power generation systems. Although the IGF Code itself provides general indications for a goal-oriented approach on such installations to introduce novel technologies, designers and operators can only rely upon a performance-based technology qualification process, supplemented by complex safety assessment methodologies.

Since a regulatory framework applicable to hydrogen fuelled ships is not yet available, the only approach is given by IMO generic 'Alternative Design' process whereby safety, reliability and dependability of the systems is to be proven equivalent to that of traditional fuels and power generation systems. Extensive formal safety assessment methodologies should be carried out and national flag administrations require specific and agreed regulatory framework to approve such installations.

To draft a dedicated chapter in the IGF Code, IMO member states would need to gather theoretical guidance, feedback from existing applications, best practices, reference from other industrial sectors, available technologies, safety procedures in design and operation, human element aspects, etc. This would smooth and speed up the development of a comprehensive set of international regulation.

Scope

The project will contribute to the development of a goal-based regulatory framework on the use of hydrogen and hydrogen-based alternative fuels for waterborne transport. It will identify and ensure the correct management of risks in all design and operational aspects. It will establish the relevant objectives and the functional requirements for the use of hydrogen, consistent with the provisions of SOLAS chapter II-2⁸² for the fuel system components, installation and energy converters.

The scope of the project should therefore include:

- A review of the current regulatory framework, identifying obstacles and barriers, needs, challenges etc.;
- Technical knowledge to support the discussions for the development of a coherent regulatory framework for risk assessment and risk management of gaseous and liquid hydrogen (GH₂ and LH₂) and hydrogen-based alternative fuels on ships;
- A roadmap to add GH₂, LH₂ and hydrogen-based alternative fuels to the IGF Code in practical consistent manner e.g. referring to fuels already addressed by the Code.

With reference to the above roadmap, all the following points should be addressed from a regulatory point of view:

- Ship design and arrangements for the use of GH₂, LH₂ or other H₂-based fuels;

⁸⁰ <http://www.imo.org/en/MediaCentre/HotTopics/GHG/Pages/default.aspx>

⁸¹ <http://www.imo.org/en/OurWork/Safety/SafetyTopics/Pages/IGF-Code.aspx>

⁸² <http://www.imo.org/en/OurWork/Safety/FireProtection/Pages/Prevention.aspx>

- Bunkering procedures and logistic interface at port;
- Fuel storage and distribution to systems on-board;
- Materials, components and general piping design for H₂ containment and handling;
- H₂ power generation and management systems;
- Active and passive safety systems for fire and explosion prevention, including ventilation and exhaust systems, integrated automation, safety monitoring and control systems;
- Operational best practices, condition-based monitoring and maintenance.

As regards the technical knowledge the project should also:

- Define and validate the most appropriate science-based safety engineering and Computer Fluid Dynamics (CFD) models to support designers in minimising risk in early design stage;
- Draft guidelines for the integration of fuel cell power generation systems in the ship network;
- Define requirements for the ship interactions at port (bunkering, refilling etc.).

Materials and components for the containment and distribution of hydrogen-rich fuels on-board should be carefully selected, analysed and tested to ensure the expected performance in the wide range of operational pressures and temperatures. To carry out these R&D activities, a strong partnership with all stakeholders is recommended: shipbuilders, ship designers, technology providers, research centres, ship operators, classification societies, experts in the production/handling /transport/bunkering of hydrogen, local authorities.

Such teamwork among all stakeholders is necessary to pave the way for a seamless cooperation at IMO level. To finalize the provisions of a dedicated chapter of the IGF Code dedicated to hydrogen, the proposal should:

- Establish a cooperation with IMO and other relevant organizations (ISO-TC197⁸³, IEC TC 105⁸⁴) to facilitate the discussion and the uptake of the necessary provisions;
- Seek feedback from existing applications, best practices, reference from other industrial sectors, available technologies, safety procedures in design and operation, human element aspects etc.

It is expected that the project will setup an international advisory board to support the R&D activities and the continuation of the activities afterwards, interacting with the IMO throughout the process.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.

The FCH 2 JU considers that the proposals requesting a contribution of EUR 2.5 million, including the analysis and testing of the materials, would allow the specific challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of supplementing proposals, requesting other amounts.

⁸³ <https://www.iso.org/committee/54560.html>

⁸⁴ https://www.iec.ch/dyn/www/f?p=103:7:0:::FSP_ORG_ID,FSP_LANG_ID:1309,25

Expected duration: 4 years.

Expected impact

The project is expected to deliver:

- Unique experimental data concerning the interaction of hydrogen with maritime infrastructure (materials, ships, bunkering installations and harbours) to support further development and validation of relevant physics models, simulation and risk assessment tools;
- Review of existing standards against new and missing knowledge to suggest the implementation and modification of international standards;
- Guidelines for safe design for the new IGF chapter on hydrogen based on the experimental results and simulations, implementation and operations of H₂-fueled ships which would support the authorization process of National Administrations;
- Commonly agreed, scientifically based recommendations for the update of relevant RCS will lead to a more harmonised normative landscape and level up the safety culture in general;
- A boost in the entry into the market of commercial passenger ships based on hydrogen and fuel cells, and in the scaling-up of hydrogen technologies.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

FCH-04-3-2020: Development of eco-design guidelines for FCH products

Specific Challenge

The path towards a well-established hydrogen economy requires the deployment of sustainable FCH systems. Moreover, such an economy should contribute to the circularity concept. Furthermore, considering that the transition to such an economy will require significant investments, it is important that FCH projects are considered sustainable investments, as specific budgets and funds have been dedicated to investments classified as such. Although FCH technologies are already both explicitly and implicitly mentioned in the Taxonomy Technical Report on sustainable investments⁸⁵, the acceptance of FCH technologies as sustainable investment would greatly benefit from factual support.

Within this context, it is of paramount importance to screen and develop eco-efficient actions for the (re)design of FCH products (design for excellence, DfX). For instance, actions regarding the use of secondary raw materials in stack components that include critical raw materials should consider not only FCH products' manufacture but also end-of-life (EoL), paying special attention to the quality of the recovered materials (PGMs, ionomer, carbon, etc.). Hence, a holistic approach needs to be followed in order to propose, screen and prioritise actions that minimise the environmental impact of FCH products along their life cycle from the design phase until EoL, without jeopardising (but promoting) their economic feasibility.

This need for the thorough integration of environmental traits into the design of FCH products calls for the development of tailor-made eco-design guidelines, thereby filling the current gap for this type of reference documentation.

Furthermore, this topic addresses the challenge of generating a scientific basis that facilitates the future standardisation of the manufacture of key FCH products' components, with emphasis on design solutions that allow an effective implementation of EoL technologies as well as an automatic and non-destructive disassembly of FCH products (design for recycling).

In this sense, according to the EU action plan for the circular economy⁸⁶, only high quality recycling can ensure the recovery of critical raw materials and it will be essential to improve the recyclability of electronic devices through product design.

Scope

The objective of this topic is to develop eco-design guidelines that include well-defined solutions for FCH products under the DfX paradigm, where X represents several features such as manufacture, assembly, cost, dismantling, recycling, reuse, etc. Projects proposed under this topic should take into consideration good practices and frameworks from more mature sectors (e.g. catalytic converters at the automotive industry, primary and secondary batteries etc.) as well as the outcomes of the project HyTechCycling (e.g. review on RCS and EoL technologies and strategies)⁸⁷.

The focus of this topic should be at least on two key FCH products (PEM fuel cells and electrolyzers, alkaline water electrolyzers, solid oxide fuel cells...). The integration of the environmental dimension into the design of these FCH products should pursue the minimisation of the current product's environmental impacts (carbon footprint, energy footprint, abiotic depletion, human toxicity etc.) throughout its whole value chain, conceiving, appraising and prioritising potential actions for its enhancement.

The guidelines should focus on the identification of these actions for the target products, with advances in the product design methodology while integrating environmental aspects in such a way that they can be updated according to future progress in the field of life cycle assessment of FCH systems. The prioritised solutions should be feasible for wide implementation across EU in the

⁸⁵ Prepared by the Technical Expert Group on sustainable finance in June 2019

(https://ec.europa.eu/info/publications/sustainable-finance-teg-taxonomy_en)

⁸⁶ <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN>

⁸⁷ <https://www.fch.europa.eu/page/cross-cutting#HYTECHCYCLING>

medium term, thereby effectively contributing to the eco-design of FCH products. As an additional step within the well-established eco-design methodology, the impact reductions of the eco-designed FCH products should be appraised and benchmarked to check the suitability of the prioritised solutions. According to the focus on the product, the collaboration with industry stakeholders as well as the establishment of an Advisory Board is considered important to both retrieve a complete set of data and propose, screen and prioritise eco-design actions. Since the environmental results should be interpreted in combination with other aspects, especially economic indicators, the use of the standardised methodology of eco-efficiency assessment is recommended. Besides, the project approach should take into account the EU Taxonomy framework⁸⁸, as an integral part of sustainable economic development to support economic growth while reducing pressures on the environment and taking into account social and governance aspects.

For a reduced set of prioritised eco-design actions within the guidelines (at least one per FCH product addressed), it should be checked how the different actors involved could benefit from the eco-design process, including EoL recovery and recycling. It is expected that the consortium includes experts in the field of design of FCH products, eco-design, and industry actors relevant to the prioritised eco-design solutions.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

Cross-collaboration with the project to be funded under topic FCH-04-5-2020: Guidelines for Life Cycle Sustainability Assessment (LCSA) of fuel cell and hydrogen systems should be sought especially on common approaches to sustainability issues and their impact on future eco-design of products. Furthermore, the extent to which eco-design actions would contribute to FCH products being more comprehensively included in the taxonomy on sustainable investments should be considered.

The FCH 2 JU considers that proposals requesting a contribution of EUR 1 million would allow the specific challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years.

Expected impact

The main outcome of the project should be the delivery of eco-design guidelines for FCH products (one eco-design guideline per involved FCH product, with a minimum of 2 guidelines).

Overall, the project should therefore contribute to:

- The availability of eco-design guidelines not only for their straightforward use for the FCH products involved in the project, but also for their supporting use as reference documentation for subsequent protocols and/or standards;
- Developing FCH devices designed to allow their easy dismantling and disassembly;
- Reducing the use of the critical materials listed by the European Commission present in the FCH products involved in the project through substitution, otherwise by resorting to recycling strategies;
- Consolidating FCH products as sustainable energy solutions through increased circularity and sound eco-efficiency reporting of every eco-design action and solution addressed in the project. In this regard, cumulative cost and environmental reductions above 3% and 10% are targeted for the eco-designed products, with eco-efficiency improvements above 10%.

⁸⁸ https://ec.europa.eu/info/publications/sustainable-finance-teg-taxonomy_en

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

FCH-04-4-2019: Development and validation of existing and novel recycling technologies for key FCH products

Specific Challenge

Previous research initiatives, such as HyTechCycling project^{89,90} have identified the current absence of viable and up-scalable recycling technologies for fuel cells products as a possible bottleneck to future mass deployment of the technology. The recovery and reuse of these and other materials can contribute to reducing the overall system costs. On top of that, critical raw materials can also represent bottlenecks in the supply chains due to low availability. This is valid in first instance for the platinum group metals (PGM) used as electro-catalysts in the fuel cell and electrolyser stack, but also for the raw earth metals of the high temperature stacks. Additional potentially critical materials can be identified in the ionomer used in the membrane and the printed circuit boards used in the balance-of-plant components.

On top of these economic consideration, and even more importantly, the sustainability aspects of the whole value chains has to be considered. Since a major increment of fuel cells and hydrogen devices is expected in the next few years (20-40 GW of electrolysis together with about 10,000 units of FCs are expected to be installed in EU by 2030), suitable recycling technologies have to be available to enable the development of a hydrogen circular economy.

There is currently no process to recycle some key components of FCH devices (e.g. the materials of solid oxide devices, PGM of electrolyzers), while for other devices available recovery processes already used in other sectors need important modifications to be applied to fuel cells technologies (e.g. the recovery of Pt from catalytic converters). Therefore, the design and development of suitable end of life strategies and recycling technologies should be addressed.

Scope

The overall objective of this topic is to develop and validate materials recovery and recycling technologies for key FCH products in order to reduce the costs of FCH devices, optimise the recovery of critical materials and facilitate a well-established hydrogen economy.

To this end, various physical, chemical and thermal processes should be identified, assessed and ranked to optimise the overall materials recovery. A whole Life Cycle approach needs to be undertaken in order to truly characterise the Life cycle Sustainability Impact of the proposed solutions. This should initially be studied on an environmental (LCA) and later on an economic (LCC) basis. In addition, quality analysis methods for secondary product (material) should be recommended at the end of the recovery process, aiming at labelling the recovered material suitable to be (1) reused in a new FCH product with a similar value to the original one (closed-loop recycling) or (2) reused in another sector requiring lower-value applications (open-loop recycling).

The proposal should address at least the following objectives:

- Adaptation and validation in a relevant environment of processes already existing in conventional recycling and recovery centres to make them suitable to fuel cell and hydrogen commercial systems, including key materials such as the PGMs;
- Selection and validation in a relevant environment of at least two novel recycling techniques for key materials contained in to fuel cell and hydrogen commercial products, such as PEMFC/PEMWE, AWE and SOFC; the focus should be on the recovery of precious metals used in the stacks as catalysts, pre-customer scraps etc.;
- Validation of the suitability of the material(s) recovered for their reintroduction in the supply chain of different FCH systems and/or different industrial sectors. The validation should include the testing of secondary raw materials in a laboratory-scale environment to demonstrate the absence of impact in the performance of the FCH

⁸⁹ HyTechCycling, Grant No. 700190, D 2.2 – Existing end-of-life technologies applicable to FCH products, 2016

⁹⁰ HyTechCycling, Grant No. 700190, D 3.1 – New end of life technologies applicable to FCH products, 2018

system using the recovered material, while ensuring the quality standards of industry in open and/or close-loops recycling applications;

- A comprehensive environmental-economic analysis of the considered strategy should be undertaken, to examine the potential for its widespread implementation in EU across the period 2025-2050. Analysing/proposing B2B recycling arrangements for each PGM and other critical raw materials, and the efficiency of recovery of each for a few subcategories of FC application and electrolyser application is suggested.

The processes developed shall aim at the following targets: manufacturing of new stacks should include min. 30% of recycled critical raw materials, 95% of Pt and 70% of ionomer, recovered over all potential streams (pre-customer scraps and end-of-life products).

It is expected that OEMs relevant to the selected technologies will be part of the proposal, to guarantee the required industrial know-how and to provide the real-life aged components and samples necessary to validate the recovery and recycling process. The proposal should also involve recovery and recycling companies and experts in the field of feasibility assessment from a life-cycle perspective, and the consortium should include industrial companies capable of scaling up the outcomes of the proposal.

To demonstrate the reproducibility of the methodology, a minimum of two recycling processes for 2 different FCH products' materials should be validated in the relevant environment. Technical training focused on recycling and dismantling FCH technologies should be developed and provided to the recycling company. The teaching material should be made publicly available.

The validation of the recovery and recycling process should be carried in an operational environment and in coordination and agreement with the EU recycling community, to assess and confirm its robustness.

TRL at start of the project: 3 and TRL at the end of the project: 5.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEARNed database, HELLEN.

The FCH 2 JU considers that proposals requesting a contribution of EUR 1.5 million would allow the specific challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3 years.

Expected impact

The expected impacts are:

- Development and optimisation of a recovery and recycling processes as critical component of a circular economy approach to the whole to fuel cell and hydrogen technology chain;
- These processes can act as basis for further development to other products;
- Reduction of the overall costs of fuel cells and hydrogen products;
- Reduction of EU dependences on critical raw materials.

Type of action: Research and Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

FCH-04-5-2020: Guidelines for Life Cycle Sustainability Assessment (LCSA) of fuel cell and hydrogen systems

Specific Challenge

The ambition of the FCH 2 JU is to develop clean, efficient and affordable solutions that fully demonstrate the potential of hydrogen as an energy carrier and of fuel cells as energy convertor. The provision of clean, efficient and affordable solutions calls for a holistic assessment of the systems from a sustainable development point of view. A methodological framework is therefore needed that takes a comprehensive set of aspects into account in a standardised way.

Besides, the methodological framework needs to go beyond the outcomes provided by the FC-HyGuide guidance documents⁹¹ already established by the FCH 2 JU projects “HyGuide” and “H2FC-LCA” in 2011 regarding the Life Cycle Assessment (LCA) of fuel cell and hydrogen (FCH) systems. For instance, the guidelines provided in these documents need to be checked for relevance and appropriateness regarding scope. To demonstrate environmental, economic and social trade-offs of alternative FCH systems, valid and fair comparisons with competing products should be conducted following a consistent, harmonised methodological approach. To facilitate such comparisons, high-quality information on the materials, energy and other resources needed for the manufacturing, operation and end-of-life of these systems need to be available as well.

When dealing with these challenges, contributions not only from previous projects such as FC-HyGuide but also from international platforms such as the International Energy Agency Hydrogen Task 36⁹² should be considered in order to facilitate the future standardisation of the methodological framework by providing robust and comprehensive guidelines for the Life Cycle Sustainability Assessment (LCSA) of FCH systems.

Scope

The overall goal of this topic is to establish a methodological framework stating requirements and providing guidance on how to conduct an LCSA of FCH technologies and applications providing a framework for a fair comparison against competing technical solutions. To this end, the proposal should address the following activities:

- Identification of development needs concerning the FC-HyGuide guidance documents based on experience made with applying these guidance documents in projects funded through the FCH JU or the FCH 2 JU⁹³, such as projects ene.field and HyTechCycling, and taking into account relevant examples of LCAs (potentially also including economic and social dimensions) that did not follow these guidelines;
- Updating those guidance documents according to these development needs and following ISO standards 14040 and 14044 including their amendments and the ILCD handbook; thereby also new technologies and new fields of application and the potential comparison of these systems with competing technical solutions should be taken into account; this includes prospective methods to allow a fair comparison between rather mature technologies and those for which progress in their development is fast;
- Extending the assessment framework to include social and economic indicators, including the criticality of raw materials. Recommendations regarding the environmental, economic and social impact assessment methods to be used should draw on current best practice and recommendations from the JRC;
- Collecting robust and up-to-date environmental, social and economic life cycle inventory data on selected FCH systems and a set of prioritised competing technical

⁹¹ <http://www.fc-hyguide.eu/>

⁹² http://ieahydrogen.org/pdfs/IEA-HIA_Task36_final-report_Jan2019_wCover.aspx

⁹³ <https://www.fch.europa.eu/page/fch-ju-projects>

solutions. The data should be made publicly available, for example through the EU platform on life cycle assessment hosted by the JRC⁹⁴. A third-party review of the data should be conducted;

- Demonstrating the practicability and implications of the developed guidelines in at least one test application case for FCs and one for H2 production systems. A third-party review of the guidelines should be conducted.

The project should contribute towards the activities of Mission Innovation - Hydrogen Innovation Challenge. Cooperation with entities from Hydrogen Innovation Challenge member countries, which are neither EU Member States nor Horizon 2020 Associated countries, is encouraged (see chapter 3.3 for the list of countries eligible for funding, and point G. International Cooperation).

The FCH 2 JU considers that proposals requesting a contribution of EUR 2 million would allow the specific challenges to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected duration: 3.5 years (including the development, application and internal/external verification of methodology and data).

Expected impact

The project should establish guidance regarding life cycle sustainability assessment of FCH systems from an environmental, economic and social perspective. Therefore the expected impacts should include:

- Providing a robust framework for a transparent, harmonised and up-to-date LCSA of FCH systems as well as for a fair comparison between competing technical solutions. This framework also allows assessing consistently the extent to which production costs of FCH systems are expected to be reduced;
- Proposing a material criticality indicator, to be assessed based on life cycle inventory data;
- Facilitating the sustainability benchmarking of FCH systems against competing technical solutions by publicly providing high-quality data, including data on specific materials (e.g. ceramics in solid-oxide cells, carbon fibres) and their costs, data on processes (e.g. auxiliary materials and energy demand), recycling scenarios, economic performance and social aspects of the FCH systems and their alternatives. This includes prospective methods as regards cost and technical performance developments;
- Supporting the International “Mission Innovation” initiative as regards the development of clean(er) energy;
- Facilitating the spread of the knowledge e.g. integrating the data and guidance documents from the project into one or two already existing platforms (e.g. a dedicated webpage on LCA hosted by the FCH 2 JU, yet to be established).

Type of action: Coordination and Support Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018– 2020 which apply mutatis mutandis.

⁹⁴ <https://eplca.jrc.ec.europa.eu/>

B. Collaboration with JRC – Rolling Plan 2020

The JRC undertakes high quality research in the field of fuel cells and hydrogen that is of considerable relevance to the implementation of the FCH 2 JU activities. During the FP7 period, cooperation between the JRC and FCH JU was structured under a Framework Agreement that covered support activities that JRC provided in-kind to FCH JU, as well as possible funded JRC participation to FCH JU projects.

For the Horizon 2020 period, a Framework Contract between FCH 2 JU and JRC was approved by the Governing Board on 23/12/2015 and signed by both parties on 18/02/2016. Contrary to the situation under FP7, involvement of JRC in FCH 2 JU funded projects outside the Horizon 2020 Rules for Participation is not possible. The scope of the Framework Contract therefore covers the activities that JRC will provide at the level of the FCH 2 JU programme free of charge and against payment from the FCH 2 JU operational budget. In line with the JRC mission, these support activities will primarily contribute to formulation and implementation of the FCH 2 JU strategy and activities in the areas of RCS, safety, technology monitoring and assessment. In addition, the Programme Office may call upon JRC to perform testing as a service to FCH 2 JU, providing added value to programme objectives by complementing activities of FCH 2 JU funded projects.

For the year 2020, a maximum budget of EUR 1 million from the FCH 2 JU operational budget is foreseen.

The JRC support activities to the FCH 2 JU programme covered by the Framework Contract are discussed and agreed on an annual basis between the JRC and the Program Office, with involvement of representatives of Hydrogen Europe and Hydrogen Europe Research.

The annual Rolling Plan 2020 (based on the similar plans approved and executed from 2016 onwards), constitutes part of this work-plan and describes the annual activities and their related deliverables provided by JRC to FCH 2 JU (heading B of Article 2 in the Framework Contract) against payment. Additional activities which JRC performs without payment (heading A in Article 2) are not listed in this document.

B.1 JRC support to RCS strategy

Section 4.1 of the MAWP requires the set-up and operation of a Regulations, Codes and Standards (RCS) Strategy Coordination (RCS SC) group led by industry, and specifies that "... JRC will assist the RCS Group and the PO in their RCS task". In 2020 JRC will continue in its role as coordinator of the group⁹⁵, supporting the secretariat and chair. JRC will also deliver data and gap analysis as performed for the past 4 years. The JRC will participate to international standardisation bodies upon request of RCS SC to ensure that European strategic priorities and/or results generated within FCH 2 JU projects are considered. Among the set of activities identified in Section 4.1 of the MAWP, JRC will deliver the following contributions to the RCS strategy coordination:

Annual deliverables:

- B.1.1 Updated mapping of programme PNR progress and its link to the international and European standardisation activities (November 2020)*
- B.1.2 Support to the organisation of a workshop with FCH 2 JU demonstration projects regarding their findings and recommendations on PNR and RCS priorities (t.b.d. 2020)*
- B.1.3 Annual report on RCS SCG activities, as input to the Annual Activity Report (December 2020)*

B.2. JRC support to testing protocols harmonisation

To provide inter-project comparable results and to facilitate assessment of technology progress without compromising on IPR issues, FCH 2 JU formed working groups lead by JRC, aiming at harmonisation of the various testing protocols and procedures. The harmonised tests should be consented to by industry and enable a consistent performance assessment. They are not expected to

⁹⁵ Decision taken at the RCS SC meeting of 28th September 2017

replace already existing or future specific tests developed for specific designs, but rather to be used on a voluntary basis.

The first harmonisation working group which started the activity in 2015, focussed on automotive applications. In 2016, it published the required testing protocols. Since then, a more ambitious goal was pursued, aiming at the development of reference test cell hardware for PEM fuel cells, to be used in conjunction with the aforementioned protocols. In the period 2017-2018, JRC has designed and manufactured the ZEROVCELL, a single cell test hardware aiming at minimising the effect of the testing device on the overall test results. This is achieved by ensuring, as far as possible, that the active area of a MEA experiences the same uniform operating conditions along all flow channels. As in the case of the harmonised testing protocols, the ZEROVCELL has the prime objective to allow for a reliable comparison of performance and durability assessment results obtained by different test centres. Since 2019, JRC has extensively tested the hardware, and has made the design of the ZEROVCELL hardware available to relevant European projects and stakeholders. JRC also provides technical support and assistance to individual users on request. In addition, upon request and within the limits of its own resources, JRC foresees validation testing for performance assessment and harmonised testing protocols and procedures as part of the testing harmonisation multi-annual plan.

The activities of this first year of the ZEROVCELL hardware, including feedback from users, will be collated in a report for the FCH2JU.

The JRC activities in the frame of the FCH 2 JU working group on test harmonisation for low temperature water electrolysis (LTWE) applications will deliver all the expected tests protocols and procedures reports by the end of 2019. Recently, JRC and FCH 2 JU have agreed to undertake a similar harmonisation effort dedicated to high temperature electrolysis (HTE). This will be carried out in collaboration with the recently established HTE harmonisation working group to which the relevant projects are invited to contribute. This is work which will take place over a multiannual period, and foresees the preparation of a terminology document on HTE in energy storage applications during 2020. The work on HTE terminology has been agreed upon by the stakeholders and the JRC will compile the draft report based on the input collected from the working group. The final multiannual results of this harmonisation activity, in particular the HTE terminology document and the LTWE testing protocols, will be utilised for standardisation and their implementation to further standardise hydrogen technologies at ISO TC 197 and IEC TC105, as appropriate. All work will take recent and ongoing standardisation efforts, such as those regarding reversible fuel cells, into account.

B.2.1 Support provided to the FCH community for the use of JRC ZEROVCELL single cell test hardware for PEM fuel cells (including feedback from users)

Annual activity report (4Q 2020)

B.2.2 High temperature electrolysis (HTE) terminology document

Draft for public stakeholder consultation (Q3 2020)

Final report (Q4 2020)

B.3 JRC contribution to programme monitoring and assessment

Technology benchmarking. In 2019, the JRC has begun a historical analysis of the performance of selected FCH 2 JU projects against the overall Programme Targets, using, wherever possible, quantitative values and Key Performance Indicators (KPI) for assessment. The purpose of this exercise is to see how the programme has enhanced the state of the art for selected technologies and to identify potential gaps for their future development. This work is to continue in 2020 for other technologies, following the 2019 reports on electrolysis and stationary fuel cells. To allow for an assessment of European achievement against the international state-of-the-art, so-called 'reference data' also needs to be collected. In the past few years, JRC has delivered the reference data related to some priority technologies. In 2020, JRC will support the update of information on the international state-of-the-art for selected technologies, as well as gather new information, as requested, taking into account other ongoing efforts. JRC will also provide input to the FCH 2 JU towards the setting of

appropriate KPIs for applications and technologies that do not have targets yet, and contribute to the development of a dedicated methodology. In addition, the JRC will track the evolution of selected key performance technological indicators throughout the running time of the FCH 2 JU programme.

B.3.1 Support to knowledge management through technology monitoring and assessment of the FCH 2 JU project portfolio. Historical analysis report on selected technology. (December 2020)

B.3.2 Reporting on international technology status upon request, according to the agreed priority ranking. (December 2020)

Support to Programme Monitoring and Assessment by means of JRC tools: JRC.I.3 will develop and adapt to the needs of the FCH 2 JU two JRC general monitoring and analysis tools.

- The Europe Media Monitor (EMM) is a system for monitoring open source news information. The main purpose of EMM is to provide monitoring of a large set of electronic media, reducing the information flow to manageable proportions by clustering related news and categorising articles to derive further metadata. In 2018, JRC has tailored its generic EMM tool to the FCH 2 JU needs, by defining categories and developing ad-hoc filters. This customised EMM system is hosted and maintained at JRC Data Centre in Ispra and enables a custom newsletter template and an interface to provide data to the FCH 2 JU Web Portal that sends content to the list of FCH subscribers.

In 2019, system validation has been completed and used. FCH 2 JU accessed the EMM platform to create and improve categories to improve the quality of the media coverage.

During 2019, the new interface between the EMM system and the new FCHJU web portal has been handed over to a new IT team coordinated by FCH 2 JU and will be finalized in 2020.

During 2020, the existing installation of the EMM platform customized for FCH-JU will be maintained, regularly updated and improved. Categories and filters defined in the system will be monitored and EMM will continue to provide assistance and training sessions to FCH 2 JU to further customize the system, to tailor it to the needs of the FCH-JU.

EMM will deliver ad hoc periodic media monitoring selections and ad hoc statistics based on EMM media coverage.

- The JRC Tools for Innovation Monitoring (TIM) is a tool gathering scientific literature, patent data, news articles and data from R&D projects funded by the EU, aiming at monitoring and analyzing thematic or technological areas, tracking currently used or emerging technologies. The JRC is developing a FCH 2 JU-specific version of TIM to provide the FCH 2 JU with a system customised with features related specifically to its programme, such as tagging functions of FCH beneficiaries. The existing four technology fields (alkaline electrolyzers/FC, H₂ production methods, polymer electrolyte membrane FC/electrolyzers and solid oxide FC/electrolyzers) will be further enhanced, with the additional provision of some data cleaning, in order to maximize accuracy of publishable results. A possible new technology field is currently being considered by FCH (Transport applications). Content delivery will proceed based on requests of the FCH 2 JU. A feasibility study has been further proposed by TIM, which could potentially give indications of patent publications undisclosed by FCH beneficiaries, or indirectly emanating from previous FCH funding. This would require an analysis of each of the technology fields created, by combining the existing semantic capabilities of TIM with research into the actual patents that are flagged by TIM as potentially relevant.

B.3.3 Customized FCH media monitoring system European Media Monitor FCH EMM (December 2020)

B.3.4 Maintenance, operation and extension of FCH Technology Innovation Monitoring System FCH TIM (December 2020)

Programme Annual Review: as in previous years, JRC will perform a full programme review cycle for the year 2020, in the form of a report.

B.3.5 Update of methodology for the Programme Review, if needed, submitted for approval by PO (April 2020). This will consider the lessons learned from the 2019 PRD.

B.3.6 Draft report delivered before the Programme Review Days (PRD) 2020 (October 2020)

B.3.7 Final JRC report delivered for finalization & publication by PO (February 2021)

Sustainability aspects: one of the overarching objectives of the FCH 2 JU, as laid down in the MAWP, is to reduce the use of EU-defined 'critical raw materials'. More generally, this objective relates to the development of a circular economy. As a tool to support progress in this area, the FCH 2 JU has defined a Life-Cycle Assessment (LCA) methodology which is to be applied to its projects and products⁹⁶. LCA is part of the FCH 2 JU strategy: *"it is expected that LCAs will be performed at both project and programme levels. The resulting Life Cycle Inventory (LCI) data sets will form a database, published as part of the ILCD Data Network, and maintained by the industry partners of the FCH 2 JU. The FCH 2 JU shall also establish an international exchange, thus providing for a globally consistent framework."*

In 2018, JRC has provided an inventory and gap analysis of the work performed in the various projects to the FCH 2 JU, focussing on LCA methodology. Based on the outcome of this analysis, a workshop was held in 2019, and a number of recommendations were given by the experts, e.g. the need for a harmonisation effort in the approach to LCA. In 2020, the JRC will continue to assess the LCA deliverables of all ongoing projects and report to the FCH 2 JU. JRC will also support the FCH 2 JU in developing a strategy for data collection from projects and population of a LCI database with FCH technology data. JRC will also perform a literature-based gap analysis on available LCA work regarding the use of hydrogen in transport applications.

B.3.8 Report on LCA activities of the JRC (December 2020)

B.4 JRC contribution to safety, and safety awareness

In the frame of the FCH 2 JU strategy on safety aspects at programme level, the restricted access database Hydrogen Events and Lesson LEarNed (HELLEN) is a multi-purpose tool for a repository of safety information generated by projects, for lessons learned and safety improvement recommendations. In 2016, the structure and interface of the database was revamped, and in 2017 the modus operandi and the communication channels with the projects were agreed and designed. All the events (i.e. incidents or accidents) that occur during the execution of any FCH 2 JU Project have to be reported to HELLEN. Access to HELLEN is limited only to selected staff of the FCH 2 JU and to the JRC-HIAD team.

In 2018, the FCH 2 JU launched the European Hydrogen Safety Panel (EHSP) initiative with the mission to assist the FCH 2 JU in assuring that hydrogen safety is adequately managed, both at programme and at project level. This also included the assessment and lessons learned from HIAD 2.0 (i.e. the public available version of the Hydrogen Incident and Accident Database).

JRC is supporting the EHSP in their work as requested by FCH 2 JU. During 2018, the EHSP tasks have encompassed the analysis of safety data and events contained in HIAD 2.0 operated by JRC and supported by the FCH 2 JU. In close collaboration with JRC, the EHSP members have systematically reviewed more than 250 events and the lessons learned which stemmed from this assessment were summarized in a report. This provides a clear view about the current situation regarding the Hydrogen Safety Reference Database, and indicates the foundations for future research in this field. In 2019, efforts have begun to enlarge the HIAD 2.0 database by entering additional events from other safety databases, which will considerably increase the number of events included in the database by the end of the year. In 2020, it is planned to continue enlarging and populating the HIAD 2.0 database. The EHSP, supported by the JRC, will analyse the enlarged HIAD 2.0 database to summarize the lessons learnt, and start a statistical evaluation of the accumulated data. JRC will also contribute to the annual identification and ranking of safety research priorities. This task, focussing specifically on pre-normative research, will result in a report summarizing and making sense of various information sources (studies, scientific publications, conferences and workshops). It aims to support the setting of annual priorities in the field.

⁹⁶ See project FC-HyGuide

B.4.1 HELLEN operation: HELLEN population with the events delivered by projects and annual report⁹⁷ (December 2020)

B.4.2 Contribution to the EHSP activities, in particular for WP3, in the field of hydrogen safety, including co-writing of relevant reports (continuous).

B5. JRC support to FCH Smart Specialisation.

No particular/dedicated activities foreseen in 2020.

B.6 JRC testing activities in support to programme implementation.

This deliverable consists of providing testing services by means of JRC reference facilities and reference hardware, mainly to implement the harmonisation efforts mentioned in subsection B.2 above and to guarantee programme-level harmonisation of performance assessment. The type and the quantity of the testing service will depend on the execution of AWP's and PO requests. In the previous three years this deliverable was not activated, however, this year testing activities are foreseen, following requests from projects. These testing activities are particularly relevant for low temperature and high temperature electrolysis harmonisation and standardisation.

⁹⁷ This also includes assessment of HELLEN functions and (if needed) an improvement plan for the following year.

Enclosure I – Resources required for the support at programme level

(THESE ARE VALUES REFLECTING APPROXIMATELY THE TRUE FIGURES FROM THE COST EVALUATION FORM OF THE FRAMEWORK CONTRACT)

Deliverable number	Deliverable title	Effort [PM]	Costs [k€]
B.1	Support to formulation and implementation of RCS strategy (RCS SC group)	6	-
B.2	Direct contribution to implementing RCS strategy (Harmonisation)	6	-
B.3	Contribution to programme monitoring and assessment	28	-
B.4	Support to safety aspects	6	-
B.6	Testing in support to specific activities of the FCH 2 JU programme	Max 6	-
	Manpower Totals [PM]	52	
			Overview indicative costs (with overhead)
			[k€]
Manpower		600.0	
Missions		40.0	
Consumables		50.0	
Hardware (EMM/TIM)		20.0	
Subcontract (for maintenance of databases B.4)		15.0	
Subcontract (for TIM and EMM, deliverables B.3.3 and B3.4)		205.0	
Total indicative cost for 2020		930.0	
<i>Max amount per year</i>		<i>1000</i>	

Costs includes overhead costs = 25%

JRC will report on a regular basis (every month) on deliverables progress and meet the Programme Office every three months.

C. Regulations, Codes and Standards Strategy Coordination (RCS SC) Group

The establishment and implementation of a multi-annual Regulations, Codes and Standards strategy is crucial for the market deployment of FCH systems. The development of common regulations and codes, the harmonisation of standards, also carrying out PNR to address RCS knowledge gaps at EU (and worldwide) level is recognised as something that would greatly facilitate the commercialization of FCH products. Inconsistent and conflicting regulations and standards will hinder the development of FCH technologies through lack of confidence from stakeholders (customers, authorities) and impair the reduction of costs linked to experience gained and economies of scale.

The overall goal of the RCS Strategy is to enable the development and application of any necessary safety and harmonized performance-based standards for FCH appliances and systems for energy and transport applications so that these standards can be translated into legislation.

The RCS Strategy therefore aims to facilitate activities which will enable EU-based industry interests to be met, e.g. establishing compliance/certification criteria within the EC and United Nations (UN) regulatory framework; developing international and EU standards that provide the technical requirements to achieve safety and build confidence; as well as to guide authorities and other stakeholders in their application.

The FCH 2 JU tackles RCS-related issues mainly through the Crosscutting activities and for the RCS Strategy, an industry-led RCS SC Group was created in 2015 with the aim of addressing the needs of the European FCH sector.

The RCS SC Group⁹⁸, consisting of representatives of organisations in the Hydrogen Europe and Hydrogen Europe Research groupings, supported by the European Commission's Joint Research Centre (JRC) and the FCH 2 JU Programme Office (PO), coordinates the strategy on RCS. The four main tasks of the RCS SC Group are to:

1. Identify and prioritise RCS needs of strategic importance for the EU, through following RCS developments, and updating and prioritizing RCS needs of the sector through a continuous global watch function;
2. Identify PNR activities to support the RCS priorities, tailor PNR and other RCS-related activities in the FCH 2 JU programme to ensure that safety issues and needs for standardization and regulation are appropriately addressed and validated;
3. Transfer and ensure application of the projects' PNR results into RCS development;
4. Define a strategy to pursue the priority RCS issues.

The activities include interfacing with regulatory bodies (e.g. EC, UN), and international organizations for standardization (e.g. ISO, IEC, CEN, CENELEC) for development/amendment of international standards and regulations. To progress these tasks, through its members, the SCG interacts with standardisation and regulatory bodies particularly by introducing European interests into these bodies, and coordinating the attendance of European representatives.

Since 2016, the RCS SC Group has identified and prioritised the main RCS needs of strategic importance for the EU and based on them, has provided recommendations of topics to be considered for incorporation into the Annual Work Plans. Meanwhile, a strategy implementation plan has been developed and adopted to further define the tasks of the RCS SC Group.

In 2020 the RCS SC Group will continue these activities, as laid out in its annual work plan.

⁹⁸ <https://www.fch.europa.eu/page/rcs-strategy-coordination-group>

D. European Hydrogen Safety Panel (EHSP)

Hydrogen technologies are undergoing rapid expansion across multiple applications. This is a result of the credibility hydrogen has built as a flexible, reliable and safe technology. The safety to date has been achieved through an evolving “state-of-the-art”, identifying, understanding and solving scientific and engineering challenges in keeping with the development and growth of these technologies.

Hydrogen technologies are now at a critical stage with massive growth predicted, and in some cases, already observed. Nevertheless, there are some critical “warning signs” with serious hydrogen incidents in 2019: in the USA, in Europe in Norway, and an incident leading to two fatalities and several injuries in Korea. These incidents have all occurred in applications that could be considered as past (or current) phase of hydrogen applications, rather than the new phase of expansion that is happening today.

The FCH 2 JU launched the European Hydrogen Safety Panel (EHSP) initiative⁹⁹ in 2017. The mission of the EHSP is to assist the FCH 2 JU both at programme and at project level in assuring that hydrogen safety is adequately managed, and to promote and disseminate H2 safety culture within and outside of the FCH 2 JU programme. The EHSP is composed of a multidisciplinary pool of experts (16 experts in 2019) grouped in small ad-hoc working groups (task forces) according to the tasks to be performed and to expertise. Collectively, the members of the EHSP have all necessary scientific competencies and expertise covering the technical domain needed to make science-based recommendations.

The EHSP is currently working as a cohesive unit producing important outputs. At the project level, a Safety Planning guidance document¹⁰⁰ for Hydrogen and Fuel Cell Projects document has been released and has started to be applied in ongoing projects. The objective is to provide a guidance reference for avoiding risks in hydrogen research and innovation projects. Besides, a template for the FCH 2 JU projects has been issued to help researchers in ensuring the incorporation of the state-of-the-art in hydrogen safety. At the programme level, the EHSP has developed a working roadmap for the panel with a broader and cross-cutting dimension focused on the FCH 2 JU programme itself and how safety aspects can be enhanced within the entire programme. Moreover, in close collaboration with JRC, the EHSP members have systematically reviewed more than 250 events from HIAD 2.0 (Hydrogen Incidents and Accidents Database) and the lessons learned stemmed from this assessment have been released in a public report¹⁰¹, as learning from others and referring to best practice is an essential element of a high-level safety culture.

In terms of the future role of the EHSP, it is proposed that EHSP prioritises the following themes for its activities in 2020:

Awareness: Increased awareness of the hazards associated with hydrogen energy systems, and the measures required to reduce the inherent risk of such systems to a tolerable level. This includes increased understanding of concepts such as hazards and risk, and the importance of assessing the knowledge available for risk assessments, as well as quantifying the inherent uncertainty in risk assessments, especially for emerging technologies.

Foresight: Understanding developing and future technologies in terms of innovation, implementation, operation and safety. Evidence suggests progress will be rapid and it is essential that safety does not become a barrier nor undermine the future of hydrogen technologies. By working closely with the FCH 2 JU and its full spectrum of stakeholders the EHSP will be able to maximise the effectiveness and impact of the state of the art to anticipate safety challenges and solutions.

Collaboration: As already illustrated for the state-of-the-art to date, collaboration is essential. To maximise safety and development of the future state-of-the-art this collaboration must continue. Strategies to reinforce the impact of collaboration with stakeholders are being deployed. For example,

⁹⁹ <https://www.fch.europa.eu/page/european-hydrogen-safety-panel>

¹⁰⁰

https://www.fch.europa.eu/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects_Release1p31_2019_0705.pdf

¹⁰¹ <https://www.fch.europa.eu/sites/default/files/Assessment%20and%20lessons%20learnt%20from%20HIAD%202.0.pdf>

further discussions are foreseen with the Hydrogen Safety Panel in the USA (US HSP) in view of seeking the cooperation of both safety panels.

Public outreach: Sharing lessons learnt and formulating recommendations, knowledge and best practice for safety is clearly an important part of improving the state-of-the-art in hydrogen safety and accidents. However, in light of the recent incidents mentioned above, an argument can be made that with the rapid expansion of hydrogen systems and infrastructure, this activity needs even greater attention. It is imperative to ensure that such incidents are prevented, or at least that the consequences are reduced as far as possible through inherently safe or robust design and appropriate mitigating measures. Lessons learnt from accidents should be properly analysed and made available for all relevant stakeholders. With the widespread use of hydrogen in society, a growing fraction of the general population will be exposed to potential hazards. As such, the risk picture is about to change dramatically, as the technology is transferred from highly trained and knowledgeable experts in controlled industrial environments to the general public. The EHSP can play an important role in this transition.

Exploitation: Funding from FCH 2 JU and other sources internationally have resulted in achievements in a number of areas related to hydrogen safety. It is important to analyse the progress and identify knowledge that can inform quantitative risk analysis (QRA) and industrial practice. The EHSP is the ideal platform to guide and direct the international community to the exploitable outcome from previous achievements.

E. Knowledge management. Dissemination and communication on projects results

Knowledge Management:

Technology and programme monitoring will continue with the annual data collection exercise from projects, in the internally developed data collection platform TRUST (Technology Reporting Using Structured Templates)¹⁰². Following its successful development and use and while considering data generated the year(s) before (e.g. for 2019 data from 2018 were requested), projects will be invited similarly to provide their data in 2020 concerning results generated in 2019. Data collected, will allow to benchmark project progress against State of the Art (SoA) and FCH 2 JU targets as defined in the MAWP 2014-2020 (and its Addendum)¹⁰³ and related AWP. In addition, the annual iterations of the data collection exercise will enable the development of a time-dependent database of FCH 2 JU project results.

In that respect, each project active in the year 2019 (previous year to the exercise) will be asked to complete one or several questionnaires concerning the data obtained within the activities foreseen in the description of action/work. The questionnaires are assigned to the projects according to the type of technologies concerned and the activities carried out. In 2019, 23 different questionnaires were used (so called “templates”)¹⁰⁴. Within each questionnaire, several parameters either descriptive or operational should be filled and each of them can individually be tagged as public or confidential. The FCH 2 JU is committed to respect data confidentiality (according to the conditions setup by the Grant Agreement) and will only use them in the respect of this attribute: confidential data will not be disclosed as such, but only in aggregated form (following a clean-room approach), and in a manner that ensures anonymity of their origin.

Progress and findings that can be shown will be made public (normally associated to the Programme Review exercise – see below). This year further developments will take place on the TRUST tool to offer efficient use of the tool and the database. Developments will improve the interface of the tool as well as functions related to input and export of data/databases. Recommendations for further improvements derive from the feedback collected from the FCH 2 JU project beneficiaries who experienced the tool and the FCH 2 JU programme office. Furthermore, additional templates will be developed to cover new applications related to heavy-duty applications (trucks, maritime) and liquid hydrogen.

In parallel to this, JRC (see section B above) will support the PO by updating international state-of-the-art, SoA figures with the so called ‘reference data’ for the various technologies, in order to allow a benchmarking of the FCH 2 JU activities and results of its projects within the global setting. This year, JRC will further expand their research on defining targets for new fuel cell and hydrogen applications that do not have targets yet as defined in the latest AWP call topics.

Continuing the developments on TIM (Tools for Innovation Monitoring) tool, JRC delivered an additional dataset “Non-Electrolysis Production methods” in 2019 on top of the: Polymer Exchange Membrane (PEM), Solid Oxide (SO) and Alkaline datasets produced in 2018. In addition, further improvements were performed and electrolysis and fuel cell applications were differentiated under the aforementioned technologies. FCH 2 JU created a dedicated webpage¹⁰⁵ to host the TIM tool and will further update it based on the latest developments. FCH 2 JU will continue cooperation with JRC for further adaptation, maintenance and operation of the tool.

The internal database containing overall plans and deployments in EU, will continue to be maintained and updated by the FCH 2 JU. This database is fed with information from projects and from general/specific press concerning plans and deployments of FCH technologies, such as electrolyzers, vehicles, hydrogen refuelling stations and stationary units, including detailed information on country,

¹⁰² https://www.fch.europa.eu/sites/default/files/documents/TRUST_ExplanationFile_Draft_2019%20%28ID%205709356%29%20%28ID%205833842%29.pdf

¹⁰³ <https://www.fch.europa.eu/page/multi-annual-work-plan>

¹⁰⁴ <https://www.fch.europa.eu/projects/knowledge-management>

¹⁰⁵ <https://www.fch.europa.eu/page/tools-innovation-monitoring-tim>

size, technology etc. Information for other parts of the world may also be included for benchmarking. In particular, for cars, this should be complemented with reference to fuel cell car deployment figures (passenger car data only) from the European Automobile Manufacturers Association (ACEA) recorded on a quarterly basis, as obtained from ACEA directly. Vehicle sales figures are also captured every 6 months from the vehicle manufacturers themselves.

The development of the European Media Monitoring (EMM)¹⁰⁶ for FCH technologies with support of JRC (mainly for communication purposes), should provide a more comprehensive press screening mechanism and allow a more thorough capture of the relevant information in the future.

These data will be harmonised and then transferred, if needed to the '*Fuel cells and hydrogen market and policy observatory*', which will eventually become the main reference point for data related to the FCH sector; the Fuel Cells and Hydrogen Observatory started its operation at the end of 2018 and it is expected to become publically available through a dedicated website in April 2020. The observatory will gather data in the following domains: technology and markets, socio-economic, policy & regulation, codes and standards (RCS), financial support and incentives. The observatory shall present the data in a user friendly way so that policy-makers, general audience as well as FCH stakeholders can easily retrieve information of their interest reinforcing the role of the FCH 2 JU as a reference source of fuel cells and hydrogen related information.

Dissemination and communication on projects results:

The FCH 2 JU is part of the Horizon 2020 Dissemination and Exploitation Network (D&E-Net) which is established under the H2020 Strategy for common dissemination and exploitation of research and innovation data and results for the remaining period of 2018-2020. In 2019 the D&E-Net activities mainly involved the participation of FCH 2 JU in the main working group and in six subgroups established by the European Commission DG RTD: (1) D&E practices across the R&I family & capacity building, (2) Data sharing and visualisation, (3) Activating multipliers & synergies, (4) Virtual marketplace & go-to-market tool, (5) Strengthening policy feedback, (6) Exploitation and impact in FPs. FCH 2 JU is planning to continue its active contribution to these working groups or their successors as well as to new ones such as the Data & Results user group. Additionally, FCH 2 JU will contribute to the IRIS initiative concerning text mining for EU policy purposes of project documents (proposals, grant agreements, amendments, reports, deliverables, etc).

In close relationship with daily knowledge management activities, relevant actions will continue as part of the European Commission initiatives in the field, such as invitation and encouragement of projects to participate in the new European Dissemination and Exploitation (D&E) Booster¹⁰⁷ and the Intellectual Property Booster (IP Booster)¹⁰⁸. FCH 2 JU projects will resume in the Horizon Results Platform where projects can present their results and eventually establish fruitful partnerships.

The service of SSERR (Support Services for Exploitation of Research Results), which benefited more than 20 FCH 2 JU beneficiaries and projects through training and coaching on exploitation aspects has now closed, succeeded by the aforementioned D&E Booster.

In 2018, the FCH 2 JU began its participation in the Innovation radar and by the end of 2019 the exercise will have been conducted for 27 projects. The Innovation Radar exercise has so far been conducted in project mid-term and final reviews where a dedicated expert is mandated to identify potential innovations and is required fill out a questionnaire with the aim of providing information in a structured and quantified way. Furthermore, the identified innovations/innovators will be supported for further exploitation and dissemination of their results. One concrete example of this is the Innovation Awards that are organized by the FCH2 JU during the Programme Review Days. There the top-ranking innovations that have been filtered from the Innovation Radar are presented to the public allowing them to vote for the best one.

¹⁰⁶ <https://ec.europa.eu/jrc/en/scientific-tool/europe-media-monitor-newsbrief>

¹⁰⁷ https://ec.europa.eu/research/participants/data/ref/h2020/other/comm/190906_d-e-booster_en.pdf

¹⁰⁸ <http://ipbooster.meta-group.com/Download/IPBooster/flyer.pdf>

Continuing the good experience and practice so far, the 10th annual Programme Review Days will be organised in autumn 2020 (Q4 of 2020). The review will be carried out with the support of JRC and will be reflected in the Annual Programme Review Report (see section B above). Initiated in 2011, this annual exercise, managed by the FCH 2 JU initially with the input of independent experts and lately JRC, provides feedback on the progress of the portfolio of FCH 2 JU funded projects identifying key achievements but also potential areas to be addressed or reinforced in subsequent years. The exercise also provides an excellent visibility platform for projects and technological developments achieved in the sector, as well as networking and pitching opportunities for project participants (please section F below).

F. Support to policies and funding/financial engineering

Support and input to EU policies:

The FCH 2 JU is contributing to the activities of a number of services in the European Commission (EC). Contributions vary in content and format, but they all share the common goal of providing fact-based information on the state-of-the-art of fuel cells and hydrogen technologies and their contribution to the EU initiatives and policies especially in the energy, transport and industry sectors as well as to competitiveness and growth.

In practical terms, this means taking part in a number of technical groups organised by the EC and other international bodies, active participation in the meetings, providing written technical input and ensuring that fuel cells and hydrogen technologies are properly represented. It includes also feedback from projects and studies to the EC in contribution to relevant energy, transport and clean air policy files.

The FCH 2 JU is actively following and contributing as necessary to the European Strategic Energy Technology Plan (SET-Plan)¹⁰⁹ activities, in particular Action 5 “Energy Efficiency in Buildings”, Action 6 “Energy Efficiency for Industry” and Action 8 on “Renewable Fuels”. The FCH 2 JU is also taking part as an observer in several of the sub-groups of the ART Fuels Forum¹¹⁰ established under the project “Support for alternative and renewable liquid and gaseous fuels forum (policy and market issues)”.

In 2019 the FCH 2 JU published a tender and signed a contract for a study on ‘Opportunities arising from the inclusion of Hydrogen Energy Technologies in the National Energy & Climate Plans (NECPs)’. This study aims to identify such opportunities and inform the teams of national experts working on the finalisation of the NECPs. Final versions of the NECPs shall be submitted by the end of 2019. By then the study will have interacted through the submission of drafts fiches for each Member State (MS). The final fiches will be ready in early 2020, enabling MS to integrate their findings for the 1st revision of the NECPs, in 2 years’ time. The undertaking of this study also helps in establishing closer links with DG ENER services dealing with the NECPs.

In 2019 the Strategic Transport Research and Innovation Agenda (STRIA) managed by DG RTD and DG MOVE started its activities to update the roadmap dedicated to alternative fuels. Most notably the roadmap has been updated with the inclusion of a chapter dedicated to fuel cells and hydrogen technologies. The FCH 2 JU followed the works of the EC by attending meetings and providing feedback on the draft roadmap with the aim of providing technical information.

In 2019 the FCH 2 JU launched a tender for the preparation of an ‘Observatory’ dedicated to fuel cells and hydrogen technologies. The aim of the Observatory is to become the reference point for all parties interested in knowing more about these technologies. When completed, the Observatory will include information on technology deployment, policies, training and education as well as financing. This portal will become a precious tool for all policy makers and other stakeholders interested in the use of fuel cells and hydrogen technologies as a decarbonisation solution primarily in the energy and transport sectors.

Worth mentioning is the on-going collaboration with DG MOVE, DG RTD, JRC and EMSA¹¹¹ on regulatory aspects (safety, standardisation, regulation) related to hydrogen as a maritime fuel. In addition, the FCH 2 JU participates to the International Energy Agency’s Hydrogen Implementing Agreement (IEA HIA) Task 39 “Hydrogen in maritime transport” and together with US Department of Energy, it has organised a technical workshop on “H2 at Ports” in San Francisco involving EU, US and Japan, with the participation of DG MOVE. The publication of a complementary topic between FCH 2 JU and DG RTD (H2020) on fuel cells ships supports and accelerates the policy effort to decarbonise the sector via demonstration projects. The planned participation to ESSF (European Sustainable Shipping Forum) and to the project from the topic “Structuring R&I towards zero emission

¹⁰⁹ <https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan>

¹¹⁰ <http://artfuelsforum.eu/>

¹¹¹ European Maritime Safety Agency (<http://www.emsa.europa.eu/>)

waterborne transport” (H2020) by the hydrogen stakeholders is an additional contribution to policy. For fluvial navigation, exchanges between NOW (Germany) and FCH 2 JU with CESNI (Comité européen pour l’élaboration de standards dans le domaine de la navigation intérieure) on two pusher boats is promoting the use of clean fuel in rivers. During 2019 the FCH 2 JU has continued exchanging with DG ENV, in particular about the potential role of hydrogen gensets in reducing air pollution and emissions. Exchanges will continue as deemed relevant.

The FCH 2 JU will continue in 2020 to collaborate closely with the EC representatives in the steering committees of a number international agreements/associations, including the International Energy Agency (IEA) under the Hydrogen Implementing Agreement¹¹² (IEA Hydrogen) and Advanced Fuel Cell Implementing Agreement. In addition synergies will continue to be explored with the Climate Technology Centre & Network (CTCN)¹¹³, which is the implementing body to the COP¹¹⁴, making sure developing countries adopt the right climate technologies to reach the 2°C target.

During 2019 the FCH 2 JU has continued working closely with DG GROW. The FCH 2 JU studies “Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies” and “Hydrogen Roadmap Europe”¹¹⁵ were key to inform the early stages of the work led by DG GROW on the selection of “hydrogen technologies and systems” as an EC’s Key Strategic Value Chains for the EU industrial policy¹¹⁶. This evidence based policy-input approach has led to recognising the contribution that the FCH sector can have in economic growth, jobs and competitiveness in the EU. As a result an Important Project of Common Interest (IPCEI) on Hydrogen is currently being prepared¹¹⁷.

To foster the adoption of FCH solutions in Islands, the FCH 2 JU presented the portfolio of readily available solutions to the “Clean energy for EU islands initiative”¹¹⁸. In view of the support to a ‘Hydrogen Island’ in the current call the exchanges and collaboration with this initiative will be strengthened.

The FCH 2 JU also continued to work on developing a Guarantee of Origin (GO) Scheme for Green and Low-Carbon Hydrogen, an effort that started back in 2014 with the first “CertifHy” project¹¹⁹. In its continuation, in CertifHy2, the work involved gaining practical experience with an operational pilot to identify and address practical issues raised by the implementation of the GO scheme that was designed as part of CertifHy1 and to ensure compatibility with evolving EU legislation. A highly inclusive Stakeholder Platform was set-up and governed the project. About 70,000 GOs were issued from the four pilot production plants and several thousand of them were bought and used by entities such as Transport for London and H2 MOBILITY Deutschland to prove the renewable nature of their hydrogen products to their customers.

The work above is planned to continue through a new procurement in an effort to accelerate the establishment of harmonised and mutually recognised Guarantees of Origin Schemes for renewable and non-renewable hydrogen across Members States, by sharing the lessons learned from the CertifHy GO pilot scheme operation while ensuring compliance to article 19 of the RED II.

Within the RED II, there are also some instances where hydrogen has the opportunity to contribute to the renewable energy targets, such as those under articles 25, 27, 28, 29 and 30. Therefore, another objective of this procurement will be to support the design of a RED II compliant Voluntary Scheme, with the aim to get it recognized by the EC, for demonstrating compliance with targets on the share of renewables in transport or heating & cooling, following the specific requirements that are applicable in each case.

¹¹² <http://ieahydrogen.org/>

¹¹³ <https://www.ctc-n.org/>

¹¹⁴ <http://unfccc.int/bodies/body/6383.php>

¹¹⁵ <https://www.fch.europa.eu/publications/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition>

¹¹⁶ https://ec.europa.eu/growth/content/hydrogen-climate-action_en

¹¹⁷ <https://www.hydrogen4climateaction.eu/>

¹¹⁸ <https://ec.europa.eu/energy/en/topics/renewable-energy/initiatives-and-events/clean-energy-eu-islands#content-heading-0>

¹¹⁹ <https://www.certifhy.eu/>

The FCH 2 JU will remain proactive in taking up opportunities for collaboration with other JUs, EU agencies, initiatives and actions with the potential for synergy with its research agenda. Examples of these collaborations are the common study with S2R¹²⁰ to identify where fuel cell technologies best fit in the rail sector, the linked project JIVE-MERLHIN on the deployment of fuel cell buses with CEF, the link between projects Life'N Grab Hy (Interreg), HECTOR (Interreg), and REVIVE (FCH 2 JU) on the deployment of fuel cells garbage trucks, the link between projects FLAGSHIPS with HySeas III (H2020) on hydrogen fuel cells ships, or the complementary programs and recently launched common study with CleanSky2 for the use of fuel cells in the aeronautic sector. More recently, the FCH 2 JU also launched a study on “European business cases for fuel cells and hydrogen trucks and technology development roadmap” where both a coalition of stakeholders and the active involvement of other MS funding agencies is thought, ensuring a robust analysis. The study is expected to identify R&I gaps as well as to draw conclusions useful for objective policy feedback.

Exchanges of the FCH 2 JU extend also to the Executive Agencies in charge of managing other parts of Horizon 2020 in areas relevant to fuel cells and hydrogen technologies. On the energy sector the FCH 2 JU and INEA have continued exploring potential synergies and areas of collaboration, especially on fuel cells for stationary applications and hydrogen production and storage. On the transport sector, the FCH 2 JU continues collaborating with INEA¹²¹ (under both H2020 and CEF¹²² programmes) on activities related to fuel cell buses and Hydrogen Refuelling Stations (HRS). The FCH 2 JU has also liaised closely with the EASME¹²³. The FCH 2 JU is exploring synergies with the EASME BUILD UP Skills initiative¹²⁴ to support the training of installers and white collar workers for small fuel cell heat and power systems. Also during 2020, the FCH 2 JU intends to capitalise on the City and Island facilities that the EASME and INEA will be managing. These facilities are expected to offer lump sum funding and other forms of assistance to support cities, communities and islands to prepare investments in sustainable energy¹²⁵.

The FCH 2 JU will continue to collaborate with executive agencies and other JUs (under the leadership of the policy DGs in the EC) in view of improving the exchange of information and generating synergies between different initiatives, thus reducing the risk of duplication within areas that are of common interest.

The FCH 2 JU in transport and energy have continued exchanging with the European Defence Agency¹²⁶ (EDA). The FCH 2 JU will explore how this collaboration with EDA can continue during the next Phase of the Consultation Forum for Sustainable Energy in the Defence and Security Sectors, which brings together European Ministries of Defence.

The above are just examples of some of the activities the FCH 2 JU is involved. In 2020 the FCH 2 JU Programme Office will continue to reinforce the collaboration with policy makers in the European Commission.

Funding and Financial Engineering:

Funding/financial engineering activities have been integrated into the Programme Office in order to work closely with the Industry, Academia and Research, the European Commission, Member States, Regions and Cities, other EU bodies and Financial Institutions to create synergies between different funding and financing sources. By combining or opening access to new funding streams for the projects, it is expected that both the time to market of R&D supported under FCH 2 JU operations and its cost premium compared with incumbent technologies will be reduced. The aim is to accelerate the

¹²⁰ Shift2Rail (<https://shift2rail.org/>)

¹²¹ Innovation & Networks Energy Agency (<https://ec.europa.eu/inea/en/welcome-to-innovation-networks-executive-agency>)

¹²² Connecting Europe Facility (CEF)

¹²³ Executive Agency for SMEs (EASME)

¹²⁴ <https://www.buildup.eu/en/skills/about-build-skills>

¹²⁵ <https://ec.europa.eu/easme/en/news/eu-support-announced-creation-two-large-scale-facilities-help-cities-and-islands-kick-start>

¹²⁶ European Defence Agency (<https://www.eda.europa.eu/>)

market introduction and deployment of the technologies stemming from the projects that FCH 2 JU supports.

To better exploit synergies among funding programmes the FCH 2 JU is providing advice and support to prospective or past beneficiaries of FCH 2 JU projects in order to combine funding from various programmes and optimise structured finance operations.

Acknowledging that in terms of funding structure there is no one-size-fits-all approach, the FCH 2 JU has launched a dedicated webpage on Funding and Financing¹²⁷ to harmonise and aggregate the sources of information and lessons learnt. It includes the lessons learnt from already supported projects benefiting from the combination of funds, highlighting specific requirements that potential beneficiaries must address to ensure EU funds' blending is fully compatibility with EU rules (e.g. compliance with the non-cumulative principle and the co-financing principle). The site is set to be further consolidated in 2020 to become a repository of IT tools¹²⁸ and studies that (1) raise awareness on the technology, (2) provide clarity on the viability of investments and (3) reveal the funding and financing available to support the deployment of FCH technologies. The webpage is now an entry door for new project promoters but also a market enabler for beneficiaries of the FCH 2 JU calls, providing them with the guidance and initial support towards materialisation of investments.

Following the completion and conclusions of the study "Fuel Cells and Hydrogen for Green Energy in European Cities and Regions"¹²⁹ in 2018, the FCH 2 JU has implemented a number of measures to address the gaps identified, including:

- Smart Specialisation Platform – Leveraging on the existing network and capacity building generated under the FCH Regions initiative, the FCH 2 JU has facilitated and supported a group of four co-leading Regions from the Netherlands, France (2) and Spain, to set up a new thematic interregional partnership on Fuel Cells and Hydrogen within the Industrial Modernisation Smart Specialisation Strategies (S3) Platform. The so-called European Hydrogen Valleys Partnership (EHV-S3P)¹³⁰ aims at enhancing the role of green hydrogen in the European energy transition process. It shall support regions in their efforts to raise the technological and commercial readiness of FCH applications, facilitate match-making and co-investment between European regions also leveraging on EU Funds' blending opportunities, strengthen the value chain for FCH technologies via interregional cooperation. The partnership shall become an active stakeholder on EU policy making on hydrogen, towards the decarbonisation of the EU's economy with a bottom-up approach (from local regions to the EU). The EHV-S3P was approved by DG GROW during the first half of 2019 and has already delivered two workshops gathering a large community of Regions in the EU;
- Project Development Assistance (PDA) – Launch of a pilot PDA facility to help develop detailed project planning in regions and cities with a lower maturity level and a special attention to Central and Eastern Europe. The aim is to work on project concepts and move them from their current stages to implementation;
- H2 Valley topic under the AWP2019 - The inclusion of a topic in the AWP2019 (topic FCH-03-1-2019) for an H2 Valley topic - The FCH Regions Initiative managed to attract extensive support from local and regional governments across Europe. Over 90 separate regional and municipal public authorities from 22 countries representing about one quarter of Europe's population, surface area and GDP, have committed to the goals of this Initiative. The surveys undertaken assessed project implementation intentions in excess of EUR 1.8 billion over the next 5 years. Out of the 36 responses, 24 participating regions and cities have expressed an ambition to become an "H2 Valley" in the future, with ten regions pursuing concrete plans for implementation in the years ahead. Regions with ambitions to become H2 Valleys are mainly

¹²⁷ <http://www.fch.europa.eu/page/funding-financing>

¹²⁸ E.g. "funding and financing navigation tool", "mobility business case tool"

¹²⁹ More information at <http://www.fch.europa.eu/page/about-regions>

¹³⁰ <https://s3platform.jrc.ec.europa.eu/hydrogen-valleys>

in countries that already have substantial experience in FCH deployments, in particular the UK, Belgium, the Netherlands, Germany and France. In view of showcasing a large demonstration (flagship) project with hydrogen as the energy carrier for various types of usages (transport, power, heat and industry) the FCH 2 JU has included a topic in the 2019 call for proposals to develop Hydrogen Valleys (topic FCH-03-1-2019). The topic worth EUR 20 million was fit for the most mature project intentions with typically investment volumes ranging from EUR 50 million to as much as EUR 400 million.

The Regions and Cities Initiative bottom-up approach has encouraged local and regional governments to include fuel cells and hydrogen within their regional priorities when managing certain European Structural and Investment Funds (ESIF). It is thus necessary to establish strong links and relationships with countries and regions managing EU Funds and/or having budget leeway to support FCH technologies. To this end, other MS specialised funding agencies have taken up this challenge, seeing the advantages of the different supporting mechanisms tested by the FCH 2 JU regarding regions and cities at different stages of project development and have since then been following similar strategies. This is the case of NOW's HyLand – Hydrogen Regions in Germany – in which funding for regions and municipalities ranges from support for awareness campaigns or the initial organisation of actors' involvement (HyStarter), creating integrated concepts and in-depth analyses (HyExperts), to taking the step of being able to procure actual applications and implementing those concepts (HyPerformer).

The FCH 2 JU will also continue to work together with the EIB and the industry in view of facilitating access to Financial Instruments like the InnovFin EDP or others being used for de-risking projects having access to the European Fund for Strategic Investments (EFSI).

As the momentum around Hydrogen is growing, it is essential that the investors and finance community becomes fully aware of the state-of-the-art in terms of FCH technology solutions (through the results of FCH 2 JU projects and studies), their market readiness, the benefits they bring and the impacts they may achieve through the provision of private sector funding and financing support (across the spectrum of new entrants, start-ups, SMEs and established firms in the FCH marketplace). The FCH 2 JU will continue to raise awareness of projects' results within the finance community. It will therefore address the private sector funding and financing challenge that acts as a market barrier for deployment of FCH technologies and wider FCH integrated solutions. To this end, the FCH 2 JU has partnered with Tech Tour to deliver the 2019 Tech Tour Energy Transition (TTET) in Rotterdam (27-28 November). This Venture Capital event has taken the hydrogen sector as a central piece of the energy transition by dedicating one of its six panels to this topic, with five companies from the FCH 2 JU hydrogen and fuel cells ecosystem getting the chance to pitch in front of prestigious Venture Capital investors. Leveraging on last year's successful experience during the PRD2018, the FCH 2 JU again joined hands with DG RTD and their Support Services for Exploitation of Research Results (SSERR), offering training to the five companies selected to pitch at the TTET. In addition, hydrogen was the subject of one of the Investment Outlook panels of the TTET. Also, a full day side event on super-scaling up of hydrogen companies was organised one day after. It is expected that these events are replicated in the near future, leading to a regular Venture Capital (and Finance) Club dedicated to hydrogen and fuel cells technologies.

G. International Cooperation

The importance of international cooperation in science and technology is explicitly recognized in the European Union's Innovation Union flagship initiative and the Horizon 2020 programme. This is described in the communication entitled "Enhancing and focusing EU international cooperation in research and innovation: a strategic approach"¹³¹. Following this principle, in order to align with, facilitate and accelerate worldwide market introduction of fuel cell and hydrogen technologies the FCH 2 JU continuously tries to identify priority areas, at policy and technology level, where coordinated and collaborative international activities are of interest.

As the deployment of fuel cells and hydrogen technology is carried out globally and key stakeholders of the FCH 2 JU are involved in these developments, establishment of links with other major FCH related programmes globally is deemed important. This is particularly valid during 2019 in areas of cross cutting nature such as regulatory and policy frameworks (for example issues with harmonisation of regulations for maritime applications), codes, standards (for example pre-normative research on refueling protocols or impact of hydrogen admixtures in the natural gas networks), safety or education (for example training of responders). These areas play a very important role in early market activation and where intellectual property rights are less of an issue.

On a more general level, the relevant international activities of interest include in particular those carried out by the International Energy Agency (IEA) under the Hydrogen Implementing Agreement (IEA Hydrogen)¹³², Advanced Fuel Cell Implementing Agreement and the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)¹³³. The FCH 2 JU will hence continue in 2020 to collaborate closely with the EC representatives in the steering committees of these international agreements/associations, in particular within the working-groups on power-to-X, maritime applications and recently launched working group on modelling of the IEA.

Synergies will continue to be explored with the Climate Technology Centre & Network (CTCN)¹³⁴, which is the implementing body to the COP¹³⁵, making sure developing countries adopt the right climate technologies to reach the 2°C target.

Following the launch in May 2018 (Malmö, Sweden) of a new Hydrogen Innovation Challenge¹³⁶ to accelerate the development of technologies needed for a global hydrogen market, FCH 2 JU will foster the collaboration and support to the Mission Innovation¹³⁷ activities, especially through projects collaboration with similar worldwide activities. Within this context, European Commission (as co-leader of this Hydrogen Innovation Challenge) pushes the acceleration of hydrogen innovation and this work-plan includes a number of specific actions, which directly target an increased international cooperation of EU Member States and Associated Countries in the context of Mission Innovation.

In recognition of this committed collaboration within Mission Innovation, proposals are expected to contribute towards the objectives and activities of the Hydrogen Innovation Challenge by promoting international collaboration beyond EU Member States and H2020 Associated Countries.

Consortia are strongly encouraged to include legal entities established in the countries members/participant¹³⁸ in the Hydrogen Innovation Challenge under the following topics, without prejudice to the countries eligible for funding set out in section 3.3 (Call management rules – Countries eligible for funding):

FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures

¹³¹ COM(2012)497

¹³² <http://ieahydrogen.org/>

¹³³ <http://www.iphe.net/>

¹³⁴ <https://www.ctc-n.org/>

¹³⁵ <http://unfccc.int/bodies/body/6383.php>

¹³⁶ <http://mission-innovation.net/our-work/innovation-challenges/hydrogen-challenge/>

¹³⁷ <http://mission-innovation.net/about/>

¹³⁸ For the list of countries which are members/participant to Hydrogen Innovation Challenge, please see: <http://mission-innovation.net/our-work/innovation-challenges/>

FCH-01-2-2020: Durability-Lifetime of stacks for Heavy Duty trucks

FCH-01-6-2020: Demonstration of liquid hydrogen as a fuel for segments of the waterborne sector

FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology

FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation

FCH-03-2-2020: Decarbonising islands using renewable energies and hydrogen - H2 Islands

FCH-04-1-2020: Overcoming technical and administrative barriers to deployment of multi-fuel hydrogen refuelling stations (HRS)

FCH-04-2-2020: PNR on hydrogen-based fuels solutions for passenger ships

FCH-04-3-2020: Development of eco-design guidelines for FCH products

FCH-04-4-2020: Development and validation of existing and novel recycling technologies for key FCH products

FCH-04-5-2020: Guidelines for Life Cycle Sustainability Assessment (LCSA) of fuel cell and hydrogen systems

Following increasing importance of hydrogen on the International Agendas (e.g. G20, Clean Energy Ministerial, H2 Ministerial etc.) and related initiatives, the role of the FCH 2 JU has become increasingly important internationally and therefore will be further clarified and reinforced during 2020.

H. Public Procurements

In 2020, the FCH 2 Joint Undertaking will carry out a number of activities financed via calls for tenders (i.e. public procurement) financed by the operational budget for an indicative amount of **EUR 0.5 million**. Recourse to existing Framework Contracts will be envisaged where possible. The procurement activities are covering subjects of a strategic nature for the FCH 2 JU, providing input to R&I priority setting and supporting further financing, deployment and commercialisation of green hydrogen and fuel cells.

For each of the procurements, detailed Terms of Reference will be drafted with European Commission participation. The following indicative list of procurements is currently foreseen:

Subject (Indicative title)	Indicative budget (EUR)	Expected type of procedure	Schedule Indicative
<i>Study on use of hydrogen and fuel cells for aircraft propulsion (joint study with CleanSky 2 JU)</i>	300,000	Open procedure	Procedure ongoing and led by Cleansky 2 JU ¹³⁹
<i>Study on the impact of deployment BEV and FCEV infrastructures (detailed analysis of the best mix between battery charging points and HRSs infrastructures, to avoid redundancies or not relevant allocations and allowing a massive electric vehicle for every type of usage)</i>	200,000	Open procedure	Q2 2020

The final budgets awarded to actions implemented through procurement procedures may vary by up to 20% of the total value of the indicative budget.

For procurements covering support activities please refer to “Procurement and contracts” under section 3.4.

¹³⁹ Based on a Memorandum of Understanding for collaboration and synergies between FCH 2 JU and Cleansky 2 JU (<https://www.cleansky.eu/calls-for-tenders>)

Conditions for the Call

Call identifier: **H2020-JTI-FCH-2020-1**

Total budget¹⁴⁰: EUR million 93

Estimated opening date¹⁴¹: **14 January 2020**

Estimated deadline¹⁴²: **21 April 2020**

Indicative budgets:

Topic	Type of action	Indicative budget (million EUR)
1. TRANSPORT PILLAR		
FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures	Research and Innovation Action	2
FCH-01-2-2020: Durability-Lifetime of stacks for Heavy Duty trucks	Research and Innovation Action	3.5
FCH-01-3-2020: Liquid Hydrogen on-board storage tanks	Research and Innovation Action	2
FCH-01-4-2020: Standard Sized FC module for Heavy Duty applications	Innovation Action	7.5
FCH-01-5-2020: Demonstration of FC Coaches for regional passenger transport	Innovation Action	5
FCH-01-6-2020: Demonstration of liquid hydrogen as a fuel for segments of the waterborne sector	Innovation Action	8
FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework	Innovation Action	10
FCH-01-8-2020: Scale-up and demonstration of innovative hydrogen compressor technology for full-scale hydrogen refuelling station	Innovation Action	3
2. ENERGY PILLAR		
FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology	Research and Innovation Action	2.5

¹⁴⁰ The final budgets awarded to actions implemented through the Call for Proposals may vary by up to 20% of the total value of the indicative budget for each action.

¹⁴¹ The Executive Director may decide to open the call up to one month prior to or after the envisaged date of opening.

¹⁴² The Executive Director may delay the deadline by up to two months. The deadline is at 17.00.00 Brussels local time.

FCH-02-2-2020: Highly efficient hydrogen production using solid oxide electrolysis integrated with renewable heat and power	Research and Innovation Action	2.5
FCH-02-3-2020: Diagnostics and Control of SOE	Research and Innovation Action	2.5
FCH-02-4-2020: Flexi-fuel stationary SOFC	Research and Innovation Action	2.5
FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores	Research and Innovation Action	2.5
FCH-02-6-2020: Electrolyser module for offshore production of renewable hydrogen	Research and Innovation Action	5
FCH-02-7-2020: Cyclic testing of renewable hydrogen storage in a small salt cavern	Innovation Action	5
FCH-02-8-2020: Demonstration of large-scale co-electrolysis for the Industrial Power-to-X market	Innovation Action	5
FCH-02-9-2020: Fuel cell for prime power in data-centres	Innovation Action	2.5
3. OVERARCHING ACTIVITIES		
HT proton conducting ceramic materials for highly efficient and flexible operation	Research and Innovation Action	3
Decarbonising islands using renewable energies and hydrogen - H2 Islands	Innovation Action	10
4. CROSS-CUTTING ACTIVITIES		
FCH-04-1-2020: Overcoming technical and administrative barriers to deployment of multi-fuel hydrogen refuelling stations (HRS)	Research and Innovation Action	2
FCH-04-2-2020: PNR on hydrogen-based fuels solutions for passenger ships	Research and Innovation Action	2.5
FCH-04-3-2020: Development of eco-design guidelines for FCH products	Research and Innovation Action	1

FCH-04-4-2020: Development and validation of existing and novel recycling technologies for key FCH products	Research and Innovation Action	1.5
FCH-04-5-2020: Guidelines for Life Cycle Sustainability Assessment (LCSA) of fuel cell and hydrogen systems	Coordination and Support Action	2
Total		93

Through their participation in projects funded under this call and in accordance with point (b) of Article 13(3) of the FCH 2 JU Statutes, it is estimated that an additional 20 million EUR in-kind contributions will be provided by the constituent entities of the Members, other than the Union or their affiliated entities participating in the indirect actions published in this call.

In accordance with Article 4 (2)(b) of Council Regulation (EU) No 559/2014 the estimated value of the costs incurred by the constituent entities of the Members other than the Union or their affiliated entities them in implementing additional activities outside the work plan of the FCH 2 Joint Undertaking contributing to the objectives of the FCH Joint Technology Initiative (referred to as In-Kind in Additional Activities (IKAA)) is set out in the 2020 Additional Activities Plan, subject of a separate document to be submitted to the FCH 2 JU GB for approval.

Indicative timetable for evaluation and grant agreement signature:

Information on the outcome of the evaluation: Maximum 5 months from the date for submission;

Indicative date for the signing of grant agreements: Maximum 8 months from the date for submission.

Consortium agreement: Members of consortium are required to conclude a consortium agreement, in principle prior to the signature of the grant agreement.

Proposals are required to provide a draft plan for exploitation and dissemination of results.

3.3 Call management rules

The call will be managed according to and the proposals should comply with the Call conditions above (chapter 3.2) and with the General Annexes to the Horizon 2020 Work Programme 2018–2020¹⁴³ that shall apply *mutatis mutandis* to the call covered in this Work Plan (with the exceptions introduced below). There is no derogation from the H2020 Rules for Participation.

Countries eligible for funding: The list of countries eligible for funding is described in Part A of the General Annexes to the Horizon 2020 Work Programme 2018–2020 which shall apply *mutatis mutandis* to the actions covered in this Work Plan.

Eligibility and admissibility conditions: The conditions are described in parts B and C of the General Annexes to the Horizon 2020 Work Programme 2018–2020 which shall apply *mutatis mutandis* to the actions covered in this Work Plan.

For some actions, an **additional eligibility criterion** has been introduced to limit the FCH 2 JU requested contribution mostly for actions performed at high TRL level, including demonstration in real operation environment and with important involvement from industrial stakeholders and/or end-users such as public authorities. Such actions are expected to leverage co-funding as commitment from stakeholders. It is of added value that such leverage is shown through the private investment in these specific topics. Therefore, proposals requesting contributions above the amounts specified per each topic below will not be evaluated.

FCH-01-4-2020: Standard Sized FC module for Heavy Duty applications

The maximum FCH 2 JU contribution that may be requested is EUR 7.5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-01-5-2020: Demonstration of FC Coaches for regional passenger transport

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-01-6-2020: Demonstration of liquid hydrogen as a fuel for segments of the waterborne sector

The maximum FCH 2 JU contribution that may be requested is EUR 8 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework

The maximum FCH 2 JU contribution that may be requested is EUR 10 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-01-8-2020: Scale-up and demonstration of innovative hydrogen compressor technology for full-scale hydrogen refuelling station

The maximum FCH 2 JU contribution that may be requested is EUR 3 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores

The maximum FCH 2 JU contribution that may be requested is EUR 2.5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-02-6-2020: Electrolyser module for offshore production of renewable hydrogen

¹⁴³ http://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-ga_en.pdf

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-02-7-2020: Cyclic testing of renewable hydrogen storage in a small salt cavern

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-02-8-2020: Demonstration of large-scale co-electrolysis for the Industrial Power-to-X market

The maximum FCH 2 JU contribution that may be requested is EUR 5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-02-9-2020: Fuel cell for prime power in data-centres

The maximum FCH 2 JU contribution that may be requested is EUR 2.5 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

FCH-03-2-2020: Decarbonising islands using renewable energies and hydrogen - H2 Islands

The maximum FCH 2 JU contribution that may be requested is EUR 10 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

Other conditions: For all actions of the call, the FCH 2 JU will activate the option for EU grants indicated under Article 30.3 of the Model Grant Agreement, regarding the FCH 2 JU's right to object to transfers or licensing of results.

Types of Action: The definitions of the types of actions, specific provisions and funding rates are described in Part D of the General Annexes to the Horizon 2020 Work Programme 2018–2020 which shall apply *mutatis mutandis* to the actions covered in this Work Plan.

Technology Readiness Levels (TRL): The definitions for technology readiness levels are provided in Part G of the General Annexes to the Horizon 2020 Work Programme 2018–2020.

Evaluation procedure: The entire evaluation procedure including criteria, scoring and threshold(s) but also the procedure for setting a priority order for proposals with the same score are described in part H of the General Annexes to the Horizon 2020 Work Programme 2018–2020 which shall apply *mutatis mutandis* to the actions covered in this Work Plan ¹⁴⁴.

Grants will be awarded to proposals according to the ranking list. However, in order to ensure a balanced portfolio of supported actions, at least the highest-ranked proposal per topic will be funded provided that it attains all thresholds.

Budget flexibility is described in Part I of the General Annexes to the Horizon 2020 Work Programme 2018–2020 which shall apply *mutatis mutandis* to the actions covered in this Work Plan.

In order to optimise the use of possible leftover call budget (or in case any additional budget becomes available), notwithstanding the provisions of Parts I and H of the General Annexes to the Horizon 2020 Work Programme 2018–2020 which apply *mutatis mutandis* to the actions covered in this Work Plan, the following criteria shall be used, in the following order of priority, if sufficient additional budget is available:

1. Selecting at least the highest ranked proposals per topic remaining on the ranking lists below. These have been considered strategically important by the FCH 2 JU Governing Board in view of future development of hydrogen solutions and next generation of products through complementary approaches at low-TRL:

FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures,

FCH-01-2-2020: Durability-Lifetime of stacks for Heavy Duty trucks,

¹⁴⁴ The full evaluation procedure is described in the relevant **H2020 guide for participants** as published on the Funding and Tender Opportunities Portal: http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/pse/h2020-guide-pse_en.pdf

FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework,

FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology,

FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores,

FCH-02-6-2019: Electrolyser module for offshore production of renewable hydrogen,

FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation

2. Selecting the proposal(s) having the highest total score among the next proposals from all ranked lists (and repeating this until the budget is spent);
Where there are two or more proposals from different ranked lists having equal total score, the proposal having the highest score in “Excellence” shall be selected (and repeating this until the budget is spent); if still equal, the proposal having highest score in ‘Impact’ shall be selected;
3. Selecting the proposal(s) from the ranked list(s) having the highest oversubscription.

As a general approach, complementarity between approaches/solutions of different proposals in the same ranked list should be sought; this should be checked by experts evaluating the proposals.

As regards **open access to research data**, part L of the General Annexes to the Horizon 2020 Work Programme 2018–2020 shall apply *mutatis mutandis* to the actions covered in this Work Plan.

3.4 Support to Operations

COMMUNICATION AND OUTREACH ACTIVITIES

Overview

2020 is a crucial year, during which the future of the FCH 2 JU will be decided (mainly on the possible impact of its past and future activities) and the last call for proposals will be launched.

Especially when communicating about its impact, there is a need to communicate the FCH 2 JU's core messages with even more clarity, focusing on concrete actions and results that are important for all its stakeholders.

We will therefore provide state of the art communication products and services to accompany the crucial period of the run up to the new partnership announcements and beyond.

During the past years, FCH 2 JU has built up its communication around the programme success stories, to demonstrate the benefit of the instrument and the impact of its results. This approach will continue as it proved to be extremely valuable. The stories about the technology, the journey and the successes are a powerful tool; however, their outreach can be improved by reaching out to new target groups and by enhanced cross-promotion.

As usual, communication activities will continue to support the priorities identified in the current AWP and will ensure that all stakeholders will be duly informed about the activities and results of the FCH 2 JU.

As the growing momentum created throughout 2018 and 2019 for the FCH technology is continuing, with different initiatives taking place at both regional and international level, it is essential to highlight and raise awareness about the market readiness of the technology.

In addition, we will continue to create synergies with the projects communication to strengthen the impact and increase outreach.

Communication objectives

The main objective in the area of communication will be to demonstrate the EU added value of FCH 2 JU in particular how the programme delivers results that have a strong impact and translate into concrete benefits for EU citizens.

- Highlight the programme's relevance, impact and contribution to related EU policy;
- Showcase the programme achievements progress and benefits in several areas;
- Mobilise strongly committed applicants for the last call for proposals;
- Increase communication synergies with other programmes and instruments;
- Highlight technology potential and market readiness ;
- Leverage project communication and promote successful projects' outcomes;
- Communicate the benefits of the technology with real-life examples and projects' results;
- Increase public awareness of the FCH 2 JU and of fuel cells and hydrogen technologies beyond the programme stakeholders, reaching out to new audiences.

Target audiences

- Policy-makers: EU Institutions (European Commission, European Parliament, Committee of the Regions, Council of the EU), individual Member States (relevant representatives of governments and permanent representations), municipalities and regional authorities;
- FCH stakeholders (Governance: European Commission, Hydrogen Europe, Hydrogen Europe Research, National Contact Points, technical experts, associations etc.);
- FCH 2 JU current beneficiaries;
- FCH 2 JU potential beneficiaries;

- Financial actors;
- General public;
- Decision supporters/multipliers (Civil society, Associations, NGOs).

Main communication themes

Throughout all communications, we need to deliver clear and consistent messages that resonate with all audiences, from policymakers to the wider public and raise awareness and excitement around fuel cells and hydrogen.

Communication themes will include, amongst others:

- #Clean Hydrogen (to have a continuity with the proposed future name of the partnership);
- Projects' results and success stories: concrete benefits for the EU citizens, socio-economic benefits, benefits and involvement of Small and Medium Enterprises etc.;
- Innovative concepts i.e. the Hydrogen valley, other flagship projects in key areas (heavy duty transport, shipping industry, Hydrogen islands etc.);
- Successful collaboration between the EU research and industry, to deliver green/renewable transport and energy: a long-standing cooperation that bears fruit;
- Growing momentum for the FCH technology – scaling up;
- Market readiness of the technology and the need to support the development of the market conditions;
- Specific, target messages for both transport and energy sectors.

*The activities outlined below will form the basis for the **annual communication plan 2020**.*

Communication and outreach activities

Success stories

FCH 2 JU will continue to develop success stories while adapting them to different audiences and channels and back up FCH 2 JU's key messages. We will continue to maintain close contacts with ongoing projects to gather and promote their latest news and results. In order to amplify the reach of project success stories and results, we will continue to work in close collaboration with the communication unit of the European Commission's Directorate-General for Research and Innovation, responsible for services such as the Horizon Magazine and the webpage for EU research success stories.

Awareness-raising campaign

Building on the BTL ('below-the-line') advertising campaigns launched in 2018 and 2019 to promote both the technology and the FCH 2 JU partnership/programme, we will continue to promote the programme messages to a wider audience in Brussels' main transportation hubs such as metro, train stations and airport.

Media relations

The following activities will continue throughout 2020 in order to develop media outreach:

- Publication of news articles and op-eds in both specialised and general publications (online and print);
- Development of a press and social media strategy around relevant initiatives/events;
- Further developing the media contacts database;
- Media Monitoring tool through the European Media Monitoring (EMM) for FCH technologies (developed with the support of JRC);
- Paid advertising will be used only in combination with earned media and as part of wider campaigns;
- Development and implementation of press & media relations, to include the public procurement of media and press agency services and of media monitoring services;

- The development of short promotional videos to tell the success stories about the programme through its projects.

Website

As the main communication tool of the programme, the website <https://www.fch.europa.eu/> is in need of continuous updating and editing. New developments are needed to improve user friendliness and allow for a better presentation of the information, in line with recent trends. These will be addressed throughout the year, according to resources.

FCH 2 JU Flash news

These are distributed around important announcements, articles, events to the FCH 2 JU Community registered on the website.

e-Newsletter

Programme highlights are distributed to a subscribers database through a monthly external e-newsletter, which will complement the existing news-alert system. New subscribers will be targeted actively, via social media and during events (while ensuring compliance with GDPR rules).

Social media

In 2020 FCH 2 JU will continue to develop its brand on social media, especially Twitter and LinkedIn with specific campaigns around key events such as the Stakeholders Forum. This will include developing engaging content with strong visuals and using promoted/sponsored tweets at key moments of the year.

By creating an editorial calendar around the main events and initiatives, social media will be more coordinated and pro-active.

The FCH 2 JU twitter account is one of the main tools for distributing content to a wider audience. Communication activities will continue leveraging this channel to relay news information, drive traffic to the FCH 2 JU website and reach out to new audiences.

In addition, LinkedIn will continue to support communication targeting the professional community interested in both technical and general information, while the YouTube channel will support the distribution of the programme and project videos.

Events

The (co)organisation and sponsorship of targeted events will continue to build FCH 2 JU's corporate reputation in line with its mission and objectives.

A detailed events calendar will be developed and updated throughout the year. Below are the events identified at the date of AWP 2020 preparation:

- Launch of the FCH 2 JU call for proposals 2020 – January 2020, Brussels;
- Joint JUs breakfast: possibly 21/22 January 2020 in EP Brussels (TBC);
- Joint exhibition in the EP in Strasbourg: 9-13 March 2020 in Strasbourg (TBC);
- HyVolution: 04 - 05 February 2020, Paris;
- Hannover Messe: 20 - 24 April 2020, Hannover;
- Hydrogen event under the Croatian EU Presidency, 20-27 April 2020, Split (TBC);
- TRA2020: 27–30 April 2020, Helsinki;
- The EU Sustainable Energy Week (EUSEW): June 2020, Brussels;
- Stakeholder Forum (SF) and Programme Review Days (PRD): November 2020, Brussels;
- Awards 2020: November 2020, Brussels; the Awards Ceremony is a novel initiative of the programme which aims to celebrate the efforts of its most successful and innovative projects. 2020 should see a special edition of the awards that will look back at the most important projects and results in the programme life.

Visual Identity

The FCH 2 JU visual identity has been reinforced lately throughout all communication channels, both print and online. We will continue to incorporate the EU funding reference and logo throughout all the programme communications as well as in the communication of the project beneficiaries. [The dedicated webpage](#) on communication and dissemination activities contains important information on this topic. The visual identity will be revised in the context of a possible Clean Hydrogen Partnership.

Collaboration with the European Commission and EU agencies

Collaboration with EC communication services and other relevant DGs entails:

- Organisation of and participation in joint events such as Open Doors Day, Research and Innovation Days, EUSEW, TRA2020, SET PLAN, Transport and Energy Horizon Info Days;
- Meetings of the Joint Communication Taskforce;
- Participation in the Communication Correspondents (COCO , former CRIG) group;
- Contributions to the EC websites and publications (including Horizon Europe, CORDIS etc.);
- Cross-communication and contribution to campaigns in line with the FCH 2 JU's objectives.

External communication support

The FCH 2 JU will contract external services providing web design and development support, event organisation, proofreading and editorial tasks, media relations and the design and production of promotional material, as appropriate. Participation in communication framework contracts will be assessed according to the needs and context.

Procurement and contracts

Besides procurement funded by the operational budget as described in section 3.2.H above, FCH 2 JU allocates part of the administrative budget to procure the necessary services and supplies needed to support its operations and infrastructures.

With a view to make tendering and contract management as effective and cost-efficient as possible, FCH 2 JU has a policy to join inter-institutional tenders either launched by the EC or in agreement with other Joint Undertakings.

In order to maximize efficiency gains, FCH 2 JU already started using eProcurement solutions in 2019, namely eTendering (for preparing and managing a call for tenders) and eSubmission (for receiving and opening tenders), whereas as since 2018 it is making use of eInvoices (for the electronic reception of commercial invoices). In addition, contract management reporting has become more efficient with the use of ABAC LCK.

The focus in 2020 will be to further simplify the management of procurement requests by using the Public Procurement Management Tool (PPMT), developed by the JRC. In addition, FCH 2 JU will continue following closely on developments on eProcurement so that the Programme Office is ready to implement the soonest possible corporate solutions offered by the EC.

FCH 2 JU is expected to be invited in the following procedures in 2020:

- INAS II for internet access
- Office Automation for IT specialists and in Project Management
- Conferencing services
- Mobile Telephony Services
- Office furniture
- Production of promotional material
- Audiovisual and conference services

In addition, FCH 2 JU may launch the following procedures:

Subject	Indicative budget (€)	Expected type of procedure	Indicative launch date
Review and re-design of the FCH 2 JU website	139,000	negotiated	Q3
Leasing of hydrogen powered cars	60,000	negotiated	Q3
Renting a mobile HRS unit for the test drives of the hydrogen cars in the context of the Transport Research Arena (TRA) event in Helsinki	60,000	negotiated	Q1
Acquisition of a collaborative platform that will enable the storage, organization, sharing and access of information among FCH 2 JU users	60,000	negotiated	Q2
Development and maintenance of the HRS availability platform	200,000	open	Q1

IT and logistics

The FCH 2 JU strategic objective in the field of IT is to deliver applications and infrastructure to support the implementation of the business objectives. The priority objectives are to ensure a stable and secure IT system, provide IT support to staff in the use of IT applications and equipment and to cooperate with the other JUs to ensure synergy and efficient use of resources.

In 2020 special focus will be put on the following:

1) Infrastructure and office automation:

FCH shares IT infrastructure, related IT operations and office automation support with other JUs that are also located in the same premises. In the context of the common infrastructure, the following activities are foreseen:

- Follow-up of the infrastructure-as-a-service (IaaS) solution transferred to the inter-agency framework contracts available to the JU, together with the lead on the Framework Contract for common IT services, to ensure a continuous maintenance of the common infrastructure and networks as well as end-user office-automation support covering incidents, service requests and improvements;
- Depending on the availability of Microsoft products compliant to the EUDPR, FCH 2 will proceed to the deployment of Microsoft Office 365 (O365) as Software-as-a-service solution (SaaS). It will provide new functional applications to end users allowing better collaboration and flexibility in the daily work, either through O365 or acquisition of software (see section on procurement and contracts);
- In the context of the Future Office Automation Environment (FOAE), FCH 2 JU will explore the possibility to complement or replace the classic phones with new, more secure and less expensive Unified Communication and Collaboration (UCC) service;
- Following the preparation made in 2019 together with the other JUs FCH 2 JU will upgrade the internal telecommunication network, with special focus put on the Wi-Fi capacity;
- Concerning enhancement of the applications regarding performance, usability and user interface we will focus on the reinforcement of teleworking capabilities using the windows VPN solution available with windows 10 to improve the end-user experience, and the possibility to join the Connected Commission platform to collaborate between EC and FCH staff.

2) Information systems for operational and administrative activities:

- Completion of the enhancement of the FCH 2 JU website aiming to facilitate the dissemination of results related to studies and project related information's;
- In 2019 all the necessary IT changes took place within FCH2 JU in order to support the transition for the implementation of the EC application SYSPER (for personnel management). In 2020, FCH2 JU will therefore start the effective progressive use of the application along roadmap for production;
- After the deployment of SYSPER FCH 2 JU will prepare for the adoption of MiPS (Mission Processing System) as IT application for the management of mission approval workflows and the reimbursement of costs incurred by mission performers;
- FCH 2 JU will also further assess the SYSTAL tool for recruitments adopted by a number of EU agencies and consider its acquisition together with the other JUs;

- In the context of compliance with EUDPR and following the acquisition of a privacy management tool in 2019, FCH 2 JU will ensure its complete implementation in 2020; it will also monitor the electronic central register of records of processing activities to be published on its website;
- Regarding software applications, the FCH2 JU will continue to adopt more common EU systems. Amongst them the e-procurement platform provided by DIGIT for the management will be implemented for a paperless procurement cycle that simplifies manual interactions, saves time and reduces payment delays;
- Following the business continuity plan and disaster recovery plan established in 2018, a secondary telecommunication link was established in 2019 to access the EC application services. The plans and the new line will be subject to a full test in 2020.

In addition, **logistical support** is provided in the context of General Administration. It encompasses the management of supply and maintenance of equipment namely stationery, goods and services for administration and includes monitoring of services provided in particular through the OIB, the translation centre and the publication office.

JU Executive Team – HR matters

JU Executive Team

The Executive Director is the legal representative of the FCH 2 JU and the chief executive responsible for the day-to-day management. He is supported by the Programme Office (PO), composed of temporary and contract agents.

The PO implements all the decisions adopted by the GB; provides support in managing an appropriate accounting system; manages the calls for proposals; provides to the Members and the other bodies of the FCH 2 JU all relevant information and support necessary for them to perform their duties as well as responding to their specific requests; acts as the secretariat of the bodies of the FCH 2 JU and provides support to any advisory group set up by the GB.

In 2020, in the context of the discussions and preparation of a possible Clean Hydrogen Partnership an analysis will be carried out on the future needs in terms of organisation and resources necessary to implement the new mandate and achieve the objectives.

HR matters

The priority objectives in the field of Human Resources are to ensure that the Staff Establishment Plan is filled, to ensure an efficient management of staff resources and to ensure an optimal working environment.

This is achieved mainly through efficient selection procedures, staff performance appraisals and reclassifications, learning and development opportunities, promotion of open communication and inter-JU cooperation.

In 2020 special focus will be put on the following:

- Organise a selection procedure to fill the vacant position for a communication officer following the reallocation of resources decided by the Executive Director and agreed by the Governing Board;
- Continue to implement the learning and development plan to ensure adaptation of staff skills and competences to efficiently implement the Programme office mission and tasks, organise in-house common learning events to further foster common working methods, and knowledge-sharing, enhanced use of tools and improved communication;
- Update procedures as necessary to ensure alignment to the legal framework;

- Most implementing rules of the revised staff regulations have now been adopted; a few new or revised rules are expected and will be applied by analogy or adopted by the FCH 2 JU Governing Board;
- Conduct a staff survey;
- Organise a teambuilding activity to promote team spirit and increased team collaboration;
- Carry out the appraisal and reclassification exercises;
- Pursue the traineeship programme by giving opportunities to new trainees to acquire experience at the FCH 2 JU;
- Following the preliminary phase in 2019, FCH 2 JU will enter the project phase of SYSPER in 2020 with implementation of the various modules of this HR IT tool between January and December.

Administrative budget and finance

The main objective for Finance and Budget is to ensure a sound financial management of the Programme Office resources.

This is mainly achieved through the alignment of planned activities with budgeted resources, the establishment of commitments for respecting legal obligations, the payment execution for goods and services delivered, the management of subsidies and revenues and the monitoring of the budget execution.

In 2020 activities will focus on the following:

- Ensure efficient budget forecast and maintaining a high level of accuracy in budgetary forecasting; to this perspective the spending pace of the grants with the highest budget will be closely monitored and checked against the forecast that their consortia has been provided;
- Subject to the form of the future partnership and the legislation, FCH will prepare its multiannual budget under Horizon Europe as well as the contribution agreement (with the European Commission) and the Financing Agreements with the members other than the Union.
- Prepare 2021 budget in liaison with DG RTD and DG BUDG;
- Report on 2019 budget execution and financial management;
- Prepare monthly reports containing key elements to budget execution and sound financial management (payment delays, budget execution, state of play for procurement procedures);
- Ensure transactions are financially and procedurally correct, that is, in conformity with the contracts and respecting the Financial Regulations and other relevant rules in operations; timely handling of all types of transactions.

These activities will be monitored through targeted KPIs, such as budget execution and Time-To-Pay.

Data protection

The new data protection legislation regarding the processing of personal data by the Union institutions, bodies, offices and agencies¹⁴⁵ is applicable as of December 2018. The FCH 2 JU, under the supervision and guidance of the Data Protection Officer (DPO), will continue to ensure an effective application of the data protection legal framework, encompassing all the legislative changes as well as the guidance documentation issued on this matter by the European Data Protection Supervisor.

In 2020, the following actions will be taken:

- Continued update of the data protection framework with any other measures required by the current legislation to complement the update of the data protection framework undertaken during the year 2019 including support for the implementation of the privacy management tool contracted in 2019;
- Publication on the FCH 2 JU website of an electronic central register of records of processing activities;
- Continued awareness raising for staff in internal meetings with regard to the rights and obligation of data subjects pursuant to Regulation 1725/2018 through , bi-annual sessions to be organised by the DPO;
- General and ad-hoc advice to the controller in fulfilling its obligations;
- The DPO will provide support for the preparation of any new records and corresponding privacy statements, for any new processing operations, as well as for the migration from notifications to records, within the meaning of article 31 of Regulation 1725/2018, ;
- Continue to participate in the data protection working groups of the EU institutions and bodies for maintaining up-to-date the necessary documentation relating to data protection in the

¹⁴⁵ OJ L 295, 21.11.2018, p. 39–98. Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC

framework of Horizon 2020, as well as for establishing an agreement on joint controllership in accordance with article 28 of Regulation 1725/2018 and for the process for elimination of data and retention safeguards;

- Ensure follow-up with guidelines provided by the EDPS, the European Data Protection Board, CJEU decisions affecting the field of data protection in the context of FCH 2 JU's activities.

3.5 Governance

The **Governing Board (GB)** is the main decision-making body of the FCH 2 JU. It shall have overall responsibility for the strategic orientation and the operations of the FCH 2 JU and shall supervise the implementation of its activities in accordance with Article 7 of the Statutes. The GB is composed of 3 representatives of the European Commission on behalf of the EU, 6 representatives of the Industry Grouping (Hydrogen Europe) and 1 representative of the Research Grouping (Hydrogen Europe Research). The GB is planning to hold three meetings during 2020.

The indicative key decisions of the GB in the year 2020 are listed below:

Key decisions in 2020 – timetable	
Approve the AAR 2019 and adopt its assessment	Q2
Deliver an opinion on the Final Accounts 2019	Q2
Approve the independent assessment of the level of in-kind contributions (related to FP7) as at 31 December 2019	Q2
Adopt the Annual Work Plan and Budget for 2021 including the staff establishment plan	Q4
Approve the Additional Activities plan for 2021	Q4
Elect new Chair and Vice-Chair	Q4

The **States Representatives Group (SRG)** is an advisory body to the GB. It consists of one representative of each Member State and of each country associated to the Horizon 2020 Framework Programme. The SRG shall be consulted and, in particular review information and provide opinions on the following matters: (a) programme progress in the FCH 2 JU and achievement of its targets; (b) updating of strategic orientation; (c) links to the Horizon 2020; (d) annual work plans; (e) involvement of SMEs. The GB shall inform without undue delay the SRG of the follow up it has given to recommendations or proposals provided by the SRG, including the reasoning if they are not followed up. The Chairperson of the SRG shall have the right to attend the meetings of the GB and take part of its deliberations but without voting rights.

The SRG will hold at least two meetings in 2020, in Q2 (tentatively around May) and Q4 (in November around the Stakeholder Forum). Issues that are likely to be covered include:

- Input to AWP2021 (depending on a last call under H2020 in case of leftover budget);
- Follow up on the measures to enhance SRG involvement (such as country fiches, info days, outcome of best practices survey);
- Further discussions on role of Members States/SRG under a possible Clean Hydrogen Europe partnership

The **Scientific Committee (SC)** is an advisory body to the GB and shall consist of no more than 9 members. The members shall reflect a balanced representation of worldwide-recognized expertise from academia, industry and regulatory bodies. The SC role is to provide (a) advice on scientific priorities to be addressed in the annual work plans; (b) advice on scientific achievements described in the Annual Activity Report. The Chairperson of the SC shall have the right to attend the meetings of the GB and take part of its deliberations, but without voting rights. The SC will hold at least two meetings in 2020.

The **Stakeholder Forum (SF)** is an advisory body to the GB. It is an important communication channel to ensure transparency and openness of the FCH 2 JU programme. It provides an overview of the major developments in the past year and seeks to outline a vision for the way the sector will unfold in the coming years. It shall be convened once a year and shall be open to all public and private stakeholders, international interest groups from Member States, Associated Countries as well as from other countries. The SF shall be informed of the activities of the FCH 2 JU and shall be invited to provide comments. The next edition of the SF will take place in Q4 2020 (see also communication section above).

3.6 Internal Control framework

FCH 2 JU revised Internal Control Framework was adopted by the GB in August 2018¹⁴⁶, whereas an assessment of the level of implementation of Internal Control Framework was completed in December 2018¹⁴⁷.

The priority objective remains to implement and maintain an effective internal control system so that reasonable assurance can be given that (1) resources assigned to the activities are used according to the principles of sound financial management and (2) the control procedures in place give the necessary guarantees concerning the legality and regularity of transactions.

For this purpose, particular emphasis will be given to the assessment of efficiency of internal control measures.

An assessment in internal control systems revealed where focus should be placed in 2020:

- ✓ Regarding the **control environment component**:
 - 1) An awareness session on integrity and ethics will be organised by the confidential counsellor in Q1 2020.
 - 2) The common business continuity plan will be tested in practice in the first half of 2020.
- ✓ Regarding the **component of the risk assessment**:
 - 1) The methodology for conducting the annual risk assessment exercise will be revised with a view to maximize staff engagement
 - 2) Staff will be encouraged through annual reminders to regularly attend relevant trainings on ethics and integrity as well as fraud prevention.
- ✓ Regarding the **information and communication component**:
 - 1) An awareness session on the revised Internal Control Framework will be presented to the staff in the 1st half of the year.
 - 2) A comprehensive reassessment of the effective implementation of control procedures will be carried out by Q3 2020.
 - 3) A set of Internal Control Monitoring Criteria will be developed in the 1st half of the year with the aim to facilitate the consistent and effective implementation of the revised ICF.

Financial procedures

Financial procedures guide FCH 2 JU operations and lay out how the JU uses and manages its funds and resources.

In 2020, focus will be in implementing the revised FCH 2 JU Financial Rules following their expected adoption by the end of 2019.

Ex-ante and ex-post controls

Ex-ante controls are essential to prevent errors and avoid the need for ex-post corrective actions. In accordance with Article 74 of the Financial Regulation 2018/1046¹⁴⁸, “each operation shall be subject at least to an ex ante control relating to the operational and financial aspects of the operation, on the basis of a multiannual control strategy which takes risk into account.”. Therefore, the main objective of ex ante controls is to ascertain that the principle of sound financial management has been applied.

An ex-ante control can take the form of checking grant agreements, initiating, checking and verifying invoices and cost claims, carrying out desk reviews (performed by FCH 2 JU project, finance and legal officers); mid-term reviews carried out by external experts and ad-hoc technical reviews (when deemed necessary).

¹⁴⁶ Ares(2018)4420458

¹⁴⁷ Ares(2018)6591876

¹⁴⁸ OJ L193, 30.7.2018 p.66

FCH 2 JU has developed elaborated procedures defining the controls to be performed by project and finance officers for every cost claim, invoice, commitment and payment taking into account risk-based and cost-effectiveness considerations.

In 2020, specific attention will be put to the following elements of ex-ante control:

- Increased financial checks during the Grant Agreement Preparation (GAP) phase;
- Participation of project and finance officers at H2020 project kick-off meetings in order to clearly communicate the financial reporting requirements;
- Setting-up webinars with consortia to clarify financial issues before claiming costs;
- Targeted workshops and reviews for beneficiaries and projects with higher identified inherent risk, especially for smaller SMEs;
- Participation of the finance officers to audits launched by CAS with the aim to identify potential risks as well as for training purposes;
- Application of the feedback from ex-post audits and lessons learnt on ex-ante controls, e.g. identification and red-flags for most frequent H2020 errors identified by ex-post audits.

Ex-post controls are defined as the controls executed to verify financial and operational aspects of finalised budgetary transactions in accordance with Article 19 of FCH 2 JU Financial Rules. The main objectives of the ex-post controls are to ensure that legality, regularity and sound financial management (economy, efficiency and effectiveness) have been respected and to provide the basis for corrective and recovery activities, if necessary. FCH 2 JU ex post controls of FCH grants include financial audits. The complete lifecycle of FCH-FP7 audits is managed and monitored by FCH 2 JU and audits are carried out by external audit firms. For FCH- H2020 grants, the ex-post audits are monitored by the Common Audit Service (CAS – Unit B2) of the Common Implementation Centre (CIC), in close cooperation with the FCH 2 JU, except for implementation which remains fully with the FCH 2 JU. CAS may also outsource the audit work to external audit firms for the FCH-H2020 grants.

In 2020, focus will be put on the following:

- Monitoring and closure of remaining financial audits of FCH-FP7 grants which were launched in 2017 - 2019;
- In cooperation with CAS, launching of new H2020 audits in two rounds: early in 2020 based on analytical risk-profile review of the main beneficiaries and later in 2020 based on the JUs' random sampling methodology to cover annual targets as per Annex 1 of the H2020 ex-post audit strategy;
- In cooperation with CAS, and in line with H2020 Working Arrangements, ensure monitoring of timely completion of the H2020 audits;
- Contribute, in cooperation with the CAS, to developments of the Horizon Europe programme, based on experience and lessons learnt from H2020;

FCH 2 JU implements the common Research **Anti-Fraud Strategy**. In March 2019, the **Common Implementation Centre (CIC)** adopted the revised Research Family Anti-Fraud Strategy (RAFS 2019) and the associated action plan (replacing RAFS 2015 and its action plan). The implementation of the action plan is monitored through regular meetings of the Fraud and irregularity Committee (FAIR) to which the FCH 2 JU takes part. Furthermore for areas of expenditure other than grants, the FCH 2 JU applies 'mutatis mutandis' by analogy the anti-fraud strategy of DG R&I. This is relevant in particular for expert management, procurement and internal fraud and the risk analysis lead to the conclusion that the residual risks (after mitigating actions) are low.

In 2020, FCH 2 JU will:

- continue to apply harmonized preventive measures for fraud detection, e.g. via enhanced-monitoring tool available as a new feature in Sygma-Compass workflow;

- participate in the pilot for anti-plagiarism check of project deliverables
- participate to FAIR meetings organized by DG R&I;
- continue awareness raising actions among staff about ethical rules through information or reminders and encourage participation in ethics trainings ;

Audits

Internal audits are carried out by the **Internal Audit Service of the European Commission (IAS)** in liaison with Internal Control and Audit Manager.

In 2020, focus will be put on the following:

- Coordination of the new annual IAS audit under a new strategic internal audit plan (fieldwork estimated to take place in Q1 – Q2 of 2020);

As regards **ECA audits**, the FCH 2 JU will:

- Liaise with an independent auditor (contracted in 2018 based on the results of the reopening of competition under EC (DG BUDG) FWC) to audit FCH 2 JU accounts as required by the FCH 2 JU Financial Rules);
- Follow up and implement the recommendations made in ECA reports on the FCH 2 JU annual accounts;
- Provide the necessary information and support for ECA audit on 2019 and 2020 accounts;
- Join the ECA team in their field missions for FCH 2 JU projects selected (on a sample basis) for an ex-post financial audits.

4. BUDGET YEAR 2020

4.1 Budget information

The draft budget 2020 is in line with the preliminary budget presented in the Fiche Financière and with the draft budget sent to GB members on 1 February 2019. The following changes are noted:

1) Due to the impact from the adjustment of the EFTA contribution from 2.38 % (initial assumption in the Fiche Financière) to 2.41 % (confirmed EFTA rate for 2020), there is an increase of:

i) EUR 1,396 in administrative commitment appropriations. It is noted that operational commitment appropriations to be asked in 2020 will not be impacted. The amount included in the draft budget sent to GB members in February 2019 is the balance between the amount as in the Council Regulation establishing FCH 2 JU (EUR 665 M) and what the EC has committed for FCH operational budget until 2019 included. Due to its nature, this amount is fixed and not dependent on any EFTA adjustment.

ii) EUR 23,697 in payment appropriations (EUR 22,301 for operational expenditure of H2020 and EUR 1,396 for administrative expenditure).

3) Reactivation of EUR 304,655 of unused commitment appropriations from administrative costs, coming from year 2019, stemming from de-commitments and appropriations that will not be committed

4) Reactivation in operational commitment appropriations of EUR 12,773,671 as follows:

- ✓ EUR 11,600,255.62 from H2020 unused appropriations in 2019 stemming mainly from the outcome of the call 2019 evaluations. A small amount also comes from public procurements that resulted in awarding contracts with amount less than the one included in the AWP 2019.
- ✓ EUR 41,388.57 from H2020 recoveries cashed in 2019
- ✓ EUR 1,132,026.51 from H2020 decommitments done in 2019. They refer to 1 project from call 2014 that was terminated (HY4ALL) and the amounts reserved for the annual working plan of JRC for 2018 and the work of the European Hydrogen Safety Panel in 2018.

It is noted that the budget of the FCH 2 JU shall be adapted to take into account the amount of the Union contribution as laid down in the budget of the Union.

The estimated revenue of FCH 2 JU for the year 2020 include contributions to the administrative costs from Hydrogen Europe and Hydrogen Europe Research as well as the contribution of the Union for administrative costs and operational activities. Amounts are expressed in euros.

Title Chapter Article Item	Heading	Budget 2018 CA (executed)	Budget 2018 PA (executed)	Budget 2019 (as at 08/10/2019) CA	Budget 2019 (as at 08/10/2019) PA	Budget 2020 CA	Budget 2020 PA	Remarks
20	SUBSIDIES AND REVENUES							
2001	European Commission subsidy for operational expenditure (7th Framework Programme)	0	15,586,390		4,750,000		3,935,268	Council Regulation 559/2014 of 6 May 2014 on the establishment of the Fuel Cells and Hydrogen 2 Joint Undertaking
2002	European Commission subsidy for administrative expenditure	2,341,923	2,341,923	2,684,775	2,684,775	2,381,733	2,381,733	Council Regulation 559/2014 of 6 May 2014 on the establishment of the Fuel Cells and Hydrogen 2 Joint Undertaking includes EFTA (2.33% in 2018, 2.38% in 2019 and 2.41% in 2020)
2003	Hydrogen Europe contribution for administrative expenditure	2,014,054	2,014,054	2,308,907	2,308,907	2,048,290	2,048,290	Council Regulation 559/2014 of 6 May 2014 on the establishment of the Fuel Cells and Hydrogen 2 Joint Undertaking
2004	Hydrogen Europe Research contribution for administrative expenditure	327,869	327,869	375,869	375,869	333,443	333,443	Council Regulation 559/2014 of 6 May 2014 on the establishment of the Fuel Cells and Hydrogen 2 Joint Undertaking
2005	European Commission subsidy for operational expenditure (Horizon 2020)	75,099,696	82,096,147	81,723,069	105,618,082	81,510,246	76,127,865	Council Regulation 559/2014 of 6 May 2014 on the establishment of the Fuel Cells and Hydrogen 2 Joint Undertaking includes EFTA (2.33% in 2018, 2.38% in 2019 and 2.41% in 2020)
2006	JTI revenues	2,265,498	2,265,498					Interest, income from liquidated damages & others
	Total title subsidies and revenues	82,049,040	104,631,881	87,092,620	115,737,633	86,273,712	84,826,599	
30	REACTIVATIONS							
3010	C2 reactivation of appropriations for administrative expenditure (2016)	734,699	734,699					FCH 2 JU Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative costs
3011	C2 reactivation of appropriations for operational expenditure (2016)	1,847,044	0					FCH 2 JU Financial rules article 6 - de-committed CA for operational activities re-entered to be used for operational activities
3012	C2 reactivation of appropriations for administrative expenditure (2017)	243,355	1,043,471	269,954	269,954			FCH 2 JU Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative costs
3013	C2 reactivation of appropriations for operational expenditure (2017)	640,499	20,126,737					FCH 2 JU Financial rules article 6 - de-committed CA for operational activities re-entered to be used for operational activities
3014	C2 reactivation of appropriations for administrative expenditure (2018)				814,345	662,380	662,380	FCH 2 JU Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative costs
3015	C2 reactivation of appropriations for operational expenditure (2018)			3,529,221	7,695,259	263,606	10,829,662	FCH 2 JU Financial rules article 6 - de-committed CA for operational activities re-entered to be used for operational activities
3016	C2 reactivation of appropriations for administrative expenditure (2019)					304,655	304,655	FCH 2 JU Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative costs
3017	C2 reactivation of appropriations for operational expenditure (2019)					12,773,671		FCH 2 JU Financial rules article 6 - de-committed CA for operational activities re-entered to be used for operational activities
	Total title reactivations	3,465,597	21,904,907	3,799,175	8,779,558	14,004,311	11,796,696	
	TOTAL REVENUES	85,514,638	126,536,788	90,891,795	124,517,191	100,278,023	96,623,295	

The FCH 2 JU 2020 budget amounts to a total of EUR 100,278,023 in CA and EUR 96,623,295 in PA with the following breakdown:

Title Chapter Article Item	Heading	Executed 2018		Financial year 2019 (as at 08/10/2019)		Financial year 2020		Ratio 2018/2020	Ratio 2018/2020	Comments
		Commitment appropriations (committed)	Payment appropriations (paid)	Commitment appropriations (CA)	Payment appropriations (PA)	Commitment appropriations (CA)	Payment appropriations (PA)	Commitment appropriations (CA)	Payment appropriations (PA)	
1	STAFF EXPENDITURE									
1 1	STAFF IN ACTIVE EMPLOYMENT	3,031,153	2,936,862	3,218,000	3,353,241	3,556,000	3,556,000	85%	83%	Salaries for temporary staff and contract agents, family allowances, expatriation and foreign residence allowances, unemployment insurance, insurance against accidents and occupational disease, annual travel costs; Interim staff and trainees; SNE allowances Installation allowance and daily subsistence and removal costs for staff arriving/departing Cost of PMO provisions
1 2	EXPENDITURE RELATED TO RECRUITMENT	18,102	19,839	107,000	107,000	5,000	5,000	362%	397%	Miscellaneous expenditure on staff recruitment: installation and travel expenses
1 3	MISSIONS AND TRAVEL	137,700	155,380	175,000	176,467	175,000	175,000	79%	89%	Mission expenses
1 4	SOCIOMEDICAL INFRASTRUCTURE AND TRAINING	38,533	46,837	42,000	44,809	44,500	44,500	87%	105%	Training, medical service and mobility costs
1 5	ENTERTAINMENT AND REPRESENTATION EXPENSES	3,568	4,989	5,600	5,600	5,600	5,600	64%	89%	Representation and receptions
	TOTAL TITLE 1	3,229,056	3,163,907	3,547,600	3,687,118	3,786,100	3,786,100	85%	84%	
2	BUILDING, EQUIPMENT AND MISCELLANEOUS EXPENDITURE									
2 0	INVESTMENTS IN IMMOVABLE PROPERTY RENTAL OF BUILDINGS AND ASSOCIATED COSTS	325,060	300,704	360,000	391,227	370,000	370,000	88%	81%	Rent, works, insurance, common charges (water/gas/electricity), maintenance, security and surveillance
2 1	INFORMATION TECHNOLOGY	328,482	206,340	282,000	491,647	372,000	372,000	88%	55%	IT purchases, software licences, software development
2 2	MOVABLE PROPERTY AND ASSOCIATED COSTS	12,593	12,593	5,000	5,000	5,000	5,000	252%	252%	Purchases and rental of office equipment, maintenance and repair
2 3	CURRENT ADMINISTRATIVE EXPENDITURE	5,328	4,635	10,000	11,201	11,000	11,000	48%	42%	Office supplies, library, translation service, bank charges and miscellaneous office expenditure
2 4	CORRESPONDENCE, POSTAGE AND TELECOMMUNICATIONS	10,650	9,271	13,000	20,359	13,000	13,000	82%	71%	Telephones, video conferences and postal services
2 5	EXPENDITURE ON FORMAL AND OTHER MEETINGS	76,895	77,656	90,000	92,711	90,000	90,000	85%	86%	Official meetings such as SRG, Scientific Committee, Governing Board
2 6	COMMUNICATION COSTS	445,620	528,358	583,705	822,541	500,000	500,000	89%	106%	External communication and events
2 7	SERVICE CONTRACTS	371,993	336,885	344,000	504,913	222,000	222,000	168%	152%	Studies and audits
2 8	EXPERT CONTRACTS AND MEETINGS	338,499	357,517	404,200	427,134	361,400	361,400	94%	99%	Costs related to expert contracts (evaluations, mid-term reviews)
	TOTAL TITLE 2	1,915,120	1,833,960	2,091,905	2,766,732	1,944,400	1,944,400	98%	94%	
	TOTAL TITLE 1+2 (ADMINISTRATIVE EXPENDITURE)	5,144,175	4,997,867	5,639,505	6,453,850	5,730,500	5,730,500	90%	87%	
3	OPERATIONAL EXPENDITURE									
3 0 0 1	Implementing the research agenda of FCH Joint Undertaking: 7th Framework Programme (FP7)	86,953	21,430,496	-	9,825,755		4,337,752	N/A	110%	This appropriation shall cover the operational costs of the JU regarding FP7 grants (pre-financings, interim and final payments) and studies.
3 0 0 2	Implementing the research agenda of FCH Joint Undertaking: Horizon 2020	74,545,919	78,639,310	85,252,290	108,237,586	94,547,523	86,555,043	79%	91%	This appropriation shall cover the operational costs of the JU regarding H2020 grants (pre-financings, interim and final payments), studies and JRC contribution.
	TOTAL TITLE 3 (OPERATIONAL EXPENDITURE)	74,632,872	100,069,805	85,252,290	118,063,341	94,547,523	90,892,795	79%	110%	
	TOTAL EXPENDITURE	79,777,047	105,067,672	90,891,795	124,517,191	100,278,023	96,623,295	80%	109%	

Revenues

As per article 13.2 of the Statutes annexed to the Council Regulation No 559/2014 of 06/05/2014, the Union shall contribute 50%, the Industry Grouping 43% and the Research Grouping 7% to the administrative budget.

The 2020 administrative budget is complemented by additional EUR 967,034 from 2018 and 2019 unused administrative appropriations.

Operational expenses are entirely covered by the EC subsidy.

Expenditure

Overall the administrative budget (Titles 1 and 2) will show a marginal increase by 1.6% (EUR 90,995) compared to 2019.

In more details:

Title 1 – Staff

Title 1 (staff costs) represents 66% of the administrative costs in the 2020 budget. It mainly covers salaries (94% of the Title 1 amount) whereas other budget lines cover missions, training & socio-medical costs, recruitment costs and representation expenses.

Title 1 will show an increase by 10.5% (EUR 238,500) compared to 2019 costs. This is due to:

- An increase by EUR 338,000 in staff in active employment. Considerable part of this increase is due to the reallocation of costs of SNEs and entitlements upon recruitment (in total an estimate of EUR 130,000) that until 2019 were included in the budget line 1200 (recruitment related expenditure). The provision for 2020 includes 1 SNE as of the beginning of the year and an additional one as of April 2020 whereas the adjusted provision for 2019 includes the effective recruitment of 1 SNE as of October 2019. In addition, 2020 budget provides for 3 interims, as opposed to 2 in 2019.
For reasons of harmonisation of reporting among JUs, ECA proposed the reallocation of these costs.
The remaining amount is the impact of the step and career advancements and the indexation assumed at 2%.
- An increase by EUR 2,500 (6%) compared to 2019 for sociomedical infrastructure and training, following adjustments in prices of the SLA with DG HR which covers most of these services.

On the other side, the following budget lines will show decrease compared to 2019:

- Expenditure related to recruitment (-EUR 102,000) due to the reclassification of these costs as explained above.

Title 2 – Infrastructure

Title 2 represents 34 % of the administrative costs in 2020. Title 2 will show a 7.1% decrease (EUR 147,505) compared to the 2019 budget. This is due to:

- A significant decrease by more than 1/3 (EUR 122,000) of the service contracts budget, as no FP7 audits are foreseen for 2020. In addition, the provision for H2020 audits is decreased to a reserve of 180,000. It should be noted that this is an estimate as there is no information from Common Audit Service (CAS) on when they will start charging FCH 2 JU.
- Decrease by 11% (EUR 42,800) of the experts budget line due to less mid-term reviews expected compared to 2019.
- Decrease by 14% (EUR 83,705) in communication budget line since the provisions for 2020 do not include various sponsorships as in 2019. This budget is restored to the level of previous years.

On the other side:

- IT costs will show an increase by 90,000 due to additional software to be procured and EC corporate solutions that will be acquired as explained in the sub-sections of procurement and contracts and IT and logistics.
- Costs related to building will be increased due to the charges for additional building projects within the White Atrium and due to indexation.

Title 3 – Operational

Commitment appropriations correspond to H2020 programme and will be increased by 11%. They will include new commitment appropriations of EUR 81,510,246 and re-activations as detailed under the 1st bullet point of “Budget Information” amounting to EUR 13,037,277. The appropriations will cover the call 2020, procurement plan as detailed in section 3.2 of the document, the annual contribution to JRC and the works of the European Hydrogen Safety Panel.

Payment appropriations correspond to estimated needs to cover:

- Payment appropriations under FP7 projects for EUR 4,337,752, which constitutes a significant decrease by 56% compared to 2019 level since only 2 projects are expected to be paid in 2020.
- Payment appropriations under H2020 projects for EUR 86,555,043, decreased by 20% compared to the 2019 level as it is assumed –based on historical trends- that the pre-financing for call 2020 will be split between 2020 and 2021. The 2020 payment appropriations will cover mainly interim and final payments of H2020 projects, the majority of the pre-financing for call 2020, the payments in line with the JRC agreed rolling plan and payments of studies procured under the operational budget as described in section 3.2 (H).

Summary Statement of Schedule of Payments

The FCH 2 JU Schedule of payments represents a summary statement of the schedule of payments due in subsequent financial years (2019-2022 and following years) to meet budget commitments entered into earlier financial years (before 2019) as well as in 2019 and 2020.

SUMMARY SCHEDULE OF PAYMENTS (Operational)

2018 Outturn		2019 Budget		2020 Budget		Difference (2020/2018)	
Committed	Paid	CA	PA	CA	PA	CA	PA
74,632,872	100,069,805	85,252,290	118,063,341	94,547,523	90,892,795	11%	-23%

DETAILS OF PAYMENT SCHEDULE (Operational)

FP7 Payments

Commitments		2019	2020	2021	2022	Outstanding amount	Total
Pre-2014 commitments still outstanding (RAL)	39,091,253	5,125,784	4,337,752	3,487,285	2,999,997	23,140,435	39,091,253
TOTAL	39,091,253	5,125,784	4,337,752	3,487,285	2,999,997	23,140,435	39,091,253

H2020 Payments

Commitments		2019	2020	2021	2022	Outstanding amount	Total
Pre-2019 commitments still outstanding (RAL)	148,587,234	20,843,791	41,270,862	38,524,610	15,842,927	32,105,044	148,587,234
2019 commitment appropriations still outstanding (RAL)	73,192,700	36,968,920	1,822,540	8,986,386	5,606,611	19,808,243	73,192,700
2020 commitment appropriations	94,547,523		43,461,641	13,946,873	11,395,781	25,743,228	94,547,523
TOTAL	316,327,457	57,812,711	86,555,043	61,457,869	32,845,320	77,656,514	316,327,457

State of play on 09/10/2019: RAL refers to open commitments on 09/10 - payments for 2019 refer to foreseen payments from 10/10/2019 until the end of the year

FP7: payments in 2020 include the payments initially foreseen and included as payment appropriations (PA) in the budget

H2020:

- 1) Pre-2019 RAL includes also a RAL on global commitment for call 2018, where 1 Grant Agreement is not signed yet
- 2) From the available 2019 commitment appropriations, an amount of 2,400,000 will still have to be committed for the studies in AWP 2019

4.2 Staff Establishment Plan and Organisation Chart

The JU team of statutory staff consists of 27 positions (24 TA and 3 CA).

In addition, staff resources include 2 Seconded National Experts (SNE).

The 2020 Staff Establishment Plan is shown below:

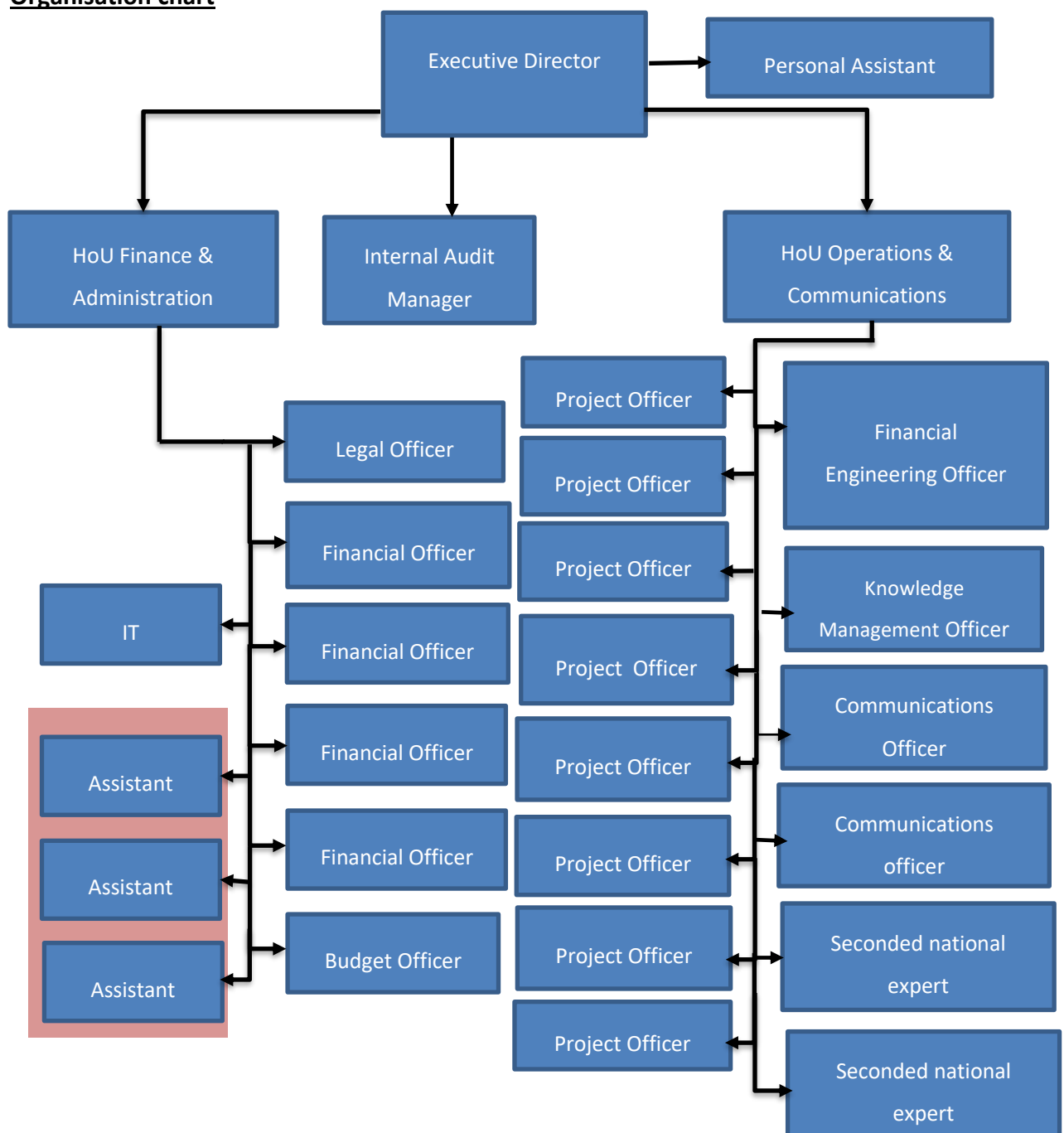
Grade	2019 budget	2019 filled	2020 budget
AD 14	1	1	1
AD 13	-	-	-
AD 12	-	-	-
AD 11	2	2	2
AD 10	-	-	-
AD 9	2	2	4
AD 8	6	6	4
AD 7	-	-	1
AD 6	4	4	3
AD 5	0	0	0
Total AD¹⁴⁹	15	15	15
AST 9	-	-	1
AST 8	2	2	1
AST 7	1	1	1
AST 6	1	1	1
AST 5	1	1	1
AST 4	4	4	4
Total AST¹⁵⁰	9	9	9

¹⁴⁹ AD stands for Administrator

¹⁵⁰ AST stands for Assistant

Function Group IV	1	1	1
Function Group III	1	1	1
Function Group II	1	1	1
Total Contract Agents	3	3	3
Total Seconded National Experts	2	1	2

Organisation chart



5. LIST OF ACRONYMS

Term	Definition
AAR	Annual Activity Report
ASR	Area Specific Resistance
AWP	Annual Work Plan
BoP	Balance of Plant
CA	Contract Agent (HR); Commitment Appropriations (Budget)
CAPEX	Capital Expenditure
CAS	Common Audit Service
CHP	Combined Heat Power
CEF	Connecting Europe Facility funding instrument
CIC	Common Implementation Centre (former CSC)
COCO	Communication Correspondents
COP	Conference of the Parties (yearly conferences in the framework of the United Nations Framework Convention on Climate Change)
COPV	Composite Overwrapped Pressure Vessel
CORDIS	Community Research and Development Information Service
CRIG	Communication Research and Innovation Group
CSP	Concentrated Solar Panel
CSC	Common Support Centre
CTCN	Climate Technology Centre & Network
DG BUDG	Directorate-General for Budget
DG GROW	Directorate-General for Internal Market
DG HR	Directorate-General for Human Resources and Security
DG MOVE	Directorate-General for Mobility and Transport
DG RTD; DG R&I	Directorate-General for Research and Innovation
DIGIT	Directorate-General for Informatics
DPO	Data Protection Officer
ED	Executive Director
EC	European Commission
ECA	European Court of Auditors
EHSP	European Hydrogen Safety Panel
EMM	European Media Monitoring
EMSA	European Maritime Safety Agency
EFTA	European Free Trade Area
EU	European Union
EUDPR	EU Internal Data Protection Regulation
EUSEW	EU Sustainable Energy Week
FAIR	Fraud And Irregularity Committee of DG RTD
FCEV	Fuel Cell Electric Vehicle
FCH 2 JU	The Fuel Cells and Hydrogen 2 Joint Undertaking: name used to refer to the legal entity established as the public & private partnership.

FP7	EU's Seventh Framework Programme for Research and Technological Development (2007 - 2013)
GB	Governing Board
GHG	Greenhouse Gases
H2020	Horizon 2020 – EU's Framework Programme for Research and Innovation programme (2014 - 2020)
HDV	Heavy-duty vehicles
HE	Hydrogen Europe
HELLEN	Hydrogen Event and Lessons LEarNed database
HER	Hydrogen Europe Research
HIAD	Hydrogen Incident and Accident Database
HRS	Hydrogen Refuelling Station
HTE	High Temperature Electrolysis
IAS	Internal Audit Service
ICF	Internal Control Framework
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IGF	International code for ships fuelled by gases or other low-flashpoint fuels
IMO	International Maritime Organisation
IPHE	International Partnership for Hydrogen into the Economy
ISO	International Standards Organization
JRC	Joint Research Centre of the European Commission
KPI	Key Performance Indicator
LCA	Life-Cycle Assessment
LDV	Light Duty Vehicles
LH2	Liquid Hydrogen
LHV	Lower Heating Value
LOHC	Liquid Organic Hydrogen Carriers
LTWE	Low Temperature Water Electrolysis
MAWP	Multi-Annual Work Plan
MEA	Membrane Electrode Assembly
MW	Megawatt
NECPs	National Energy and Climate Plans
NG	Natural Gas
NGO	Non-governmental organisation
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
PEM/PEMFC	Proton Exchange Membrane Fuel Cell
PGM	Platinum-Group metals
PA	Payment Appropriations
PCC	Proton Conducting Ceramic Cells
PO	FCH 2 JU Programme Office
PPP	Public Private Partnership
PRD	Programme Review Days
PNR	Pre-normative Research

RCS	Regulations, Codes and Standards
rSOC	Reversible Solid Oxide Cell
R&D; R&I	Research and Development; Research and Innovation
SAE	Society of Automotive Engineers association and standards developing organisation
SDOs	Standards developing Organisations
SET-plan	Strategic Energy Technology plan
SME	Small and Medium Enterprises
SMR	Steam Methane Reformers
SoA	State of the Art
SOC/SOFC	Solid Oxide (Fuel) Cell
SOE	Solid Oxide Electrolysis
SRG	States Representative Group, advisory body of the FCH 2 JU gathering representatives from Member States and Associated Countries
SWD	Staff Working Document of the European Commission
TA	Temporary Agent
TCO	Total Cost of Ownership
TIM	Tools for Innovation Monitoring
TRA2020	Transport Research Arena 2020
TRL	Technology Readiness Level
TRUST	Technology Reporting Using Structured Templates (Data collection platform)
UN	United Nations
VRE	Variable Renewable Energy

6. Annex: Horizon 2020 INDICATORS FOR JOINT UNDERTAKINGS

- Table I shows the Horizon 2020 KPIs which apply to JUs, both under Industrial Leadership and Societal Challenges (Horizon 2020 Key Performance Indicators (Annex II - Council Decision 2013/743/EU)).
- Table II presents all indicators for monitoring of cross-cutting issues which apply to JUs (Annex III - Council Decision 2013/743/EU).
- In tables I and II, the numbers attributed to the indicators correspond with those in the Horizon 2020 indicators approved by the RTD Director-General and agreed by all the Research family DGs (according to Annexes II and III - Council Decision 2013/743/EU). The missing numbers correspond to KPIs not applicable to the JUs.
- KPIs and Indicators that correspond to those approved by the RTD Director-General are presented with a white background in the tables. They are aligned to what has been discussed between the Common Support Centre and the JUs. KPIs and monitoring indicators in tables I and II, which do not correspond to those approved by the RTD Director-General, are presented with a green background in the tables.
- Table III presents the KPI specific for FCH 2 JU.

TABLE I: Horizon 2020 Key Performance Indicators¹⁵¹ common to all JUs

		Key Performance Indicator	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Baseline at the Start of Horizon 2020 (latest available)	Target at the End of Horizon 2020	Automated
INDUSTRIAL LEADERSHIP	12	SME - Share of participating SMEs introducing innovations new to the company or the market (covering the period of the project plus three years);	Based on Community Innovation Survey (?). Number and % of participating SMEs that have introduced innovations to the company or to the market;	Number of SMEs that have introduced innovations;	HORIZON 2020 beneficiaries through project reporting	n.a. [<u>new approach</u> under Horizon 2020]	50%	Yes
	13	SME - Growth and job creation in participating SMEs	Turnover of company, number of employees	Turnover of company, number of employees;	Horizon 2020 beneficiaries through project reporting	n.a. [<u>new approach</u> under Horizon 2020]	To be developed based on FP7 ex-post evaluation and /or first Horizon 2020 project results	Yes
SOCIETAL CHALLENGES	14	Publications in peer-reviewed high impact journals	The percentage of papers published in the top 10% impact ranked journals by subject category.	Publications from relevant funded projects (DOI: Digital Object Identifiers); Journal impact benchmark (ranking) data to be collected by commercially available bibliometric databases.	Horizon 2020 beneficiaries through project reporting; Responsible Directorate/Service (via access to appropriate bibliometric databases)	n.a. [<u>new approach</u> under Horizon 2020]	[<u>On average, 20 publications per €10 million funding (for all societal challenges)</u>]	Yes

¹⁵¹ (based on Annex II to Council Decision 2013/743/EU)

		Key Performance Indicator	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Baseline at the Start of Horizon 2020 (latest available)	Target at the End of Horizon 2020	Automated
	15	Patent applications and patents awarded in the area of the JTI	Number of patent applications by theme; Number of awarded patents by theme	Patent application number	Horizon 2020 beneficiaries through project reporting; Responsible Directorate/Service (via worldwide search engines such as ESPACENET, WOPI)	n.a. [new approach under Horizon 2020]	On average, 2 per €10 million funding (2014 - 2020) RTD A6	Yes
	16	Number of prototypes testing activities and clinical trials ¹⁵²	Number of prototypes, testing (feasibility/demo) activities, clinical trials	Reports on prototypes, and testing activities, clinical trials	Horizon 2020 beneficiaries through project reporting	n.a. [new approach under Horizon 2020]	[To be developed on the basis of first Horizon 2020 results]	Yes
	17	Number of joint public-private publications in projects	Number and share of joint public-private publications out of all relevant publications.	Properly flagged publications data (DOI) from relevant funded projects	Horizon 2020 beneficiaries through project reporting; Responsible Directorate/Service (via DOI and manual data input-flags)	n.a. [new approach under H202]	[To be developed on the basis of first Horizon 2020 results]	Yes
	18*	New products, processes, and methods launched into the market	Number of projects with new innovative products, processes, and methods,	Project count and drop down list allowing to choose the type processes, products, methods,	Horizon 2020 beneficiaries through project reporting	n.a. [new approach under Horizon 2020]	[To be developed on the basis of first Horizon 2020 results]	Yes

¹⁵² Clinical trials are IMI specific

		Key Performance Indicator	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Baseline at the Start of Horizon 2020 (latest available)	Target at the End of Horizon 2020	Automated
EVALUATION	NA	Time to inform (TTI) <u>all applicants</u> of the outcome of the evaluation of their application from the final date for submission of completed proposals	To provide applicants with high quality and timely evaluation results and feedback after each evaluation step by implementing and monitoring a high scientific level peer reviewed process	Number and % of information letters sent to applicants within target Average TTI (calendar days) Maximum TTI (calendar days)	Joint Undertaking	FP7 latest know results?	153 calendar days	Yes
	NA	Redress after evaluations	To provide applicants with high quality and timely evaluation results and feedback after each evaluation step by implementing and monitoring a high scientific level peer reviewed process	Number of redresses requested	Joint Undertaking	FP7 latest know results?		
GRANTS	NA	Time to grant (TTG) measured (average) from call deadline to signature of grants	To minimise the duration of the granting process aiming at ensuring a prompt implementation of the Grant Agreements through a simple and transparent grant preparation process	Number and % of grants signed within target Average TTG in calendar days Maximum TTG in calendar days	Joint Undertaking	n.a. [new approach under Horizon 2020]	TTG < 243 days (as %of GAs signed)	Yes
	NA	Time to sign (TTS) grant agreements from the date of informing successful applicants (information letters)		Number and % of grants signed within target Average TTG in calendar days Maximum TTG in calendar days	Joint Undertaking	n.a. [new approach under Horizon 2020]	TTS 92 calendar days	Yes

		Key Performance Indicator	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Baseline at the Start of Horizon 2020 (latest available)	Target at the End of Horizon 2020	Automated
PAYMENTS	NA	Time to pay (TTP) (% made on time) -pre-financing - interim payment -final payment	To optimize the payments circuits, both operational and administrative, including payments to experts	Average number of days for Grants pre-financing, interim payments and final payments; Average number of days for administrative payments; Number of experts appointed	Joint Undertaking	FP7 latest know results?	-pre-financing (30 days) - interim payment (90 days) -final payment ((90days)	Yes
HR	NA	Vacancy rate (%)		% of post filled in, composition of the JU staff ¹⁵³	Joint Undertaking	n.a. [new approach under Horizon 2020]		
JU EFFICIENCY	NA	Budget implementation/execution: 1. % CA to total budget 2. % PA to total budget	Realistic yearly budget proposal, possibility to monitor and report on its execution, both in commitment (CA) and payments (PA), in line with sound financial management principle	% of CA and PA	Joint Undertaking		100% in CA and PA	Yes
	NA	Administrative Budget: Number and % of total of late payments	Realistic yearly budget proposal, possibility to monitor and report on its execution in line with sound financial management principle	Number of delayed payments % of delayed payments (of the total)	Joint Undertaking			Yes

NOTES:

18* This indicator is not a legally compulsory one, but it covers several additional specific indicators requested for more societal challenges by the services in charge.

¹⁵³ Additional indicators can be proposed/discussed with R.1 and/or DG HR

TABLE II: Indicators for monitoring Horizon 2020 Cross-Cutting Issues¹⁵⁴ common to all JUs

	Cross-cutting issue	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Data to be Provided in/to	Direct Contribution to ERA	Automated
2	Widening the participation	2.1 Total number of participations by EU-28 Member State	Nationality of Horizon 2020 applicants & beneficiaries (number of)	Horizon 2020 applicants & beneficiaries at the submission and grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
		2.2 Total amount of EU financial contribution by EU-28 Member State (EUR millions)	Nationality of Horizon 2020 beneficiaries and corresponding EU financial contribution	Horizon 2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
NA		Total number of participations by Associated Countries	Nationality of Horizon 2020 applicants & beneficiaries (number of)	Horizon 2020 applicants & beneficiaries at the submission and grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
NA		Total amount of EU financial contribution by Associated Country (EUR millions)	Nationality of Horizon 2020 beneficiaries and corresponding EU financial contribution	Horizon 2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
3	SMEs participation	3.1 Share of EU financial contribution going to SMEs (Enabling & industrial tech and Part III of Horizon 2020)	Number of Horizon 2020 beneficiaries flagged as SME; % of EU contribution going to beneficiaries flagged as SME	Horizon 2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report		Yes
6	Gender	6.1 Percentage of women participants in Horizon 2020 projects	Gender of participants in Horizon 2020 projects	Horizon 2020 Beneficiaries through project reporting	JU AAR	YES	Yes

¹⁵⁴ (based on Annex III to Council Decision 2013/743/EU)

	Cross-cutting issue	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Data to be Provided in/to	Direct Contribution to ERA	Automated
		6.2 Percentage of women project coordinators in Horizon 2020	Gender of MSC fellows, ERC principle investigators and scientific coordinators in other Horizon 2020 activities	Horizon 2020 beneficiaries at the grant agreement signature stage	JU AAR	YES	Yes
		6.3 Percentage of women in EC advisory groups, expert groups, evaluation panels, individual experts, etc.	Gender of memberships in advisory groups, panels, etc.	Compiled by Responsible Directorate/Service/Joint Undertaking based on existing administrative data made available by the CSC	JU AAR	YES	
7	International cooperation	7.1 Share of third-country participants in Horizon 2020	Nationality of Horizon 2020 beneficiaries	Horizon 2020 beneficiaries at the grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
		7.2 Percentage of EU financial contribution attributed to third country participants	Nationality of Horizon 2020 beneficiaries and corresponding EU financial contribution	Horizon 2020 beneficiaries at the grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
9	Bridging from discovery to market ¹⁵⁵	9.1 Share of projects and EU financial contribution allocated to Innovation Actions (IAs)	Number of IA proposals and projects properly flagged in the WP; follow up at grant level.	Project Office – at GA signature stage he/she will be required to flag on SYGMA. Responsible Directorate/Service (WP coordinator)/Joint Undertaking - via tool CCM2	JU AAR RTD Monitoring Report		Yes
		9.2 Within the innovation actions, share of EU financial contribution focussed on demonstration and first-of-a-kind activities	Topics properly flagged in the WP; follow-up at grant level	Responsible Directorate/Service (WP coordinator)/Joint Undertaking - via tool CCM2	JU AAR RTD Monitoring Report		Yes

¹⁵⁵ This indicator (9.2) is initially intended to monitor the Digital Agenda (its applicability could be only partial)

	Cross-cutting issue	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Data to be Provided in/to	Direct Contribution to ERA	Automated
NA		Scale of impact of projects (High Technology Readiness Level)	Number of projects addressing TRL ¹⁵⁶ between ...(4-6, 5-7)?	Joint Undertaking	JU AAR RTD Monitoring Report		
11	Private sector participation	11.1 Percentage of Horizon 2020 beneficiaries from the private for profit sector	Number of and % of the total Horizon 2020 beneficiaries classified by type of activity and legal status	Horizon 2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report		Yes
		11.2 Share of EU financial contribution going to private for profit entities (Enabling & industrial tech and Part III of Horizon 2020)	Horizon 2020 beneficiaries classified by type of activity; corresponding EU contribution	Horizon 2020 beneficiaries at grant agreement signature stage	JU AAR RTD Monitoring Report		Yes
12	Funding for PPPs	12.1 EU financial contribution for PPP (Art 187)	EU contribution to PPP (Art 187)	Responsible Directorate/Service/	JU AAR		Yes
		12.2 PPPs leverage: total amount of funds leveraged through Art. 187 initiatives, including additional activities, divided by the EU contribution	Total funding made by private actors involved in PPPs - in-kind contribution already committed by private members in project selected for funding - additional activities (i.e. research expenditures/investment of industry in the sector, compared to previous year)	Joint Undertaking Services	JU AAR RTD Monitoring Report JU annual accounts (part of)		

¹⁵⁶ TRL: Technology Readiness Level

	Cross-cutting issue	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Data to be Provided in/to	Direct Contribution to ERA	Automated
13	Communication and dissemination	13.3 Dissemination and outreach activities other than peer-reviewed publications - [Conferences, workshops, press releases, publications, flyers, exhibitions, trainings, social media, web-sites, communication campaigns (e.g. radio, TV)]	A drop down list allows to choose the type of dissemination activity. Number of events, funding amount and number of persons reached thanks to the dissemination activities	Horizon 2020 Beneficiaries through project reporting	JU AAR RTD Monitoring Report	YES	Yes
14	Participation patterns of independent experts	14.2 Proposal evaluators by country	Nationality of proposal evaluators	Responsible Directorate/Service/Joint Undertaking in charge with the management of proposal evaluation	JU AAR		
		14.3 Proposal evaluators by organisations' type of activity	Type of activity of evaluators' organisations	Responsible Directorate/Service/Joint Undertaking in charge with the management of proposal evaluation	JU AAR	YES	
NA	Participation of RTOs and Universities	Participation of RTO ¹⁵⁷ s and Universities in PPPs (Art 187 initiatives)	Number of participations of RTOs to funded projects and % of the total Number of participations of Universities to funded projects and % of the total % of budget allocated to RTOs and to Universities	Horizon 2020 beneficiaries at the grant agreement signature stage	JU AAR RTD Monitoring Report	YES	Yes
NA	Ethics	The objective is ensuring that research projects funded are compliant with provisions on ethics efficiently	% of proposals not granted because non-compliance with ethical rules/proposals invited to grant (target 0%); time to ethics clearance (target 45 days) ¹⁵⁸	Responsible Directorate/Service/Joint Undertaking	JU AAR RTD Monitoring Report		

¹⁵⁷ RTO: Research and Technology Organisation

¹⁵⁸ Data relates to pre-granting ethics review. This time span runs in parallel to granting process.

	Cross-cutting issue	Definition/Responding to Question	Type of Data Required	Data to be Provided by	Data to be Provided in/to	Direct Contribution to ERA	Automated
NA	Audit	Error rate	% of common representative error; % residual error	CAS	JU AAR RTD Monitoring Report		Yes
NA		Implementation of ex-post audit results	Number of cases implemented; in total €million; 'of cases implemented/total cases	CAS	JU AAR RTD Monitoring Report		Yes

Notes:

* Horizon 2020 applicants - all those who submitted Horizon 2020 proposals

* Horizon 2020 beneficiaries - all those who have signed a Horizon 2020 Grant Agreement

*Responsible Directorate - DG RTD Directorates and R&I DGs family in charge with management of Horizon 2020 activities

*Services -Executive Agencies and other external bodies in charge with Horizon 2020 activities

*Project officer - is in charge of managing Horizon 2020 projects in Responsible Directorate/Service including Executive Agencies

TABLE III: Key Performance Indicators specific to FCH 2 JU

Key Performance Indicator	Objective	Data to be Provided by	Baseline at the Start of Horizon 2020	Target at the End of Horizon 2020	Automated
Share of the fund allocated to the following research activities: - renewable energy - end user energy-efficiency - smart grids - storage		JU	Result of FP7		
Demonstrator projects hosted in MSs and regions benefiting from EU structural funds		JU	Result of FP7		