

Clean Hydrogen JOINT UNDERTAKING (Clean Hydrogen JU)

WORK PROGRAMME 2022



In accordance with the Council Regulation (EU) 2021/2085 and with Article 33 of the Financial Rules of the Clean Hydrogen Joint Undertaking.

The work programme is made publicly available after its adoption by the Governing Board.

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Acronyms and abbreviations

2Zero	Towards Zero Emission Road Transport Partnership
A/C	Aircraft
AC	Alternating Current
AEL	Alkaline Electrolysis
AEMEL	Anion Exchange Membrane
AEMEL	Anion Exchange Membrane Electrolysis
AFIR	Alternative Fuels Infrastructure Regulation
AIP	Approval in Principle
AIT	Auto Ignition
AWP	Annual Work Programme
B2B	Business-to-Business
B4P	Built4People European Partnership
BEV	Battery Electric Vehicles
BoP	Balance of Plant
CAPEX	Capital Up-front Expenditure (Investment)
CEF	Connecting Europe Facility
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CFD	Computational Fluid Dynamics
CINEA	European Climate Infrastructure and Environment Executive Agency
Co	Cobalt
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
CRM	Critical Raw Materials
CSA	Coordination and Support Actions
CTCN	Climate Technology Centre & Network, under the UN Environment Programme
D&E	Dissemination and Exploitation
DC	Direct Current
DNI	Direct Normal Irradiance
EC	European Commission, sometimes also shortened to just Commission
EoL	End of Life
ED	Executive Director
EDA	European Defence Agency

EHS&CP	European Hydrogen Sustainability and Circularity Panel
EHSP	European Hydrogen Safety Panel
EIB	European Investment Bank
EIC	European Innovation Council
EL	Electrolyser
EPC	Engineering, Procurement, and Construction
ERA	European Research Area
ERDF	European Regional Development Fund
ETS	Emission trading system (also seen as EU ETS)
EU	European Union
EU ETS	EU Emission Trading System
EURAMET	European Association of National Metrology Institutes
FP	European Union's Framework Programmes for research and technological development. FP7 refers to the seventh programme (period 2007-2013), H2020 to the eighth (period 2014-2020), while Horizon Europe to the ninth (period 2021-2027).
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicle
FCH	Fuel Cell and Hydrogen
FCH (2) JU	Fuel Cells and Hydrogen Joint Undertaking. FCH 2 JU (2014-2020/Horizon 2020) succeeded FCH JU (2008-2014/FP 7) ¹
FCHO	Fuel Cell and Hydrogen Observatory, https://fchobservatory.eu/
FWC	Framework Contract
GB	Governing Board
GDL	Gas Diffusion Layer
GH ₂	Gaseous Hydrogen
GHG	Greenhouse Gases
GO	Guarantees of Origin
GT	Gas Turbine
GW	Gigawatt; GW _e refers to GW electric.
H ₂	Hydrogen
H2020	Horizon 2020
H ₂ O	Water
H ₂ S	Hydrogen Sulfide
H ₂ V	Hydrogen Valley Platform

¹ FCH JU was replaced by FCH 2 JU, which has taken over all rights and obligations of its predecessor. FCH 2 JU is now in turn replaced by the Clean Hydrogen Joint Undertaking.

HAZ	Heat Affected Zones
HD	Heavy-Duty
HDV	Heavy-Duty Vehicles
HELLEN	Hydrogen Events and Lesson LEarNed
HER	Hydrogen Evolution Reaction
HHV	Higher Heating Value
HIAD	Hydrogen Safety Reference Database
HOR	Hydrogen Oxidation Reaction
HRS	Hydrogen Refuelling Station
HTCP	Hydrogen Technology Collaboration Programme
HTE	High-Temperature Water Electrolysis
HTSE	High-Temperature Steam Electrolysis
IA	Innovation Actions
IACS	International Association of Classification Societies
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IMO	International Maritime Organisation
IPCEI	Important Projects of Common European Interest
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IPR	Intellectual Property Rights
IRENA	International Renewable Energy Agency
ISO	International Organisation for Standardisation
IT	Information Technology
JRC	Joint Research Centre of the European Commission
JU	Joint Undertaking. For the scope of this document, when used as standalone, this acronym is used specifically to refer to the Clean Hydrogen Joint Undertaking. In all other instances or when not obvious the name Clean Hydrogen JU is used.
kft	Kilofoot
kg	Kilogramme
KPI	Key Performance Indicator
kW	Kilowatt; kW _{th} refers to kW thermal.
kWh	Kilowatt-hour; kWh _e refers to kWh electric, while kWh _{th} to kWh thermal.
LAP	Legal and Administrative Processes

LCA	Life-Cycle Assessment
LCSA	Life-Cycle Sustainability Assessment
LCI	Life Cycle Inventory
LCOH	Levelised Cost of Hydrogen
LDV	Light Duty Vehicles
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
LH ₂	Liquid Hydrogen
LHV	Lower Heating Value
LIN	Liquid Inert Nitrogen
LNG	Liquefied Natural Gas
LOHC	Liquid Organic Hydrogen Carrier
LOI	Letters of Intent
LT-WE	Low Temperature Water Electrolysers
m ² , m ³	Square Meters, Cubic Meters
MEA	Membrane Electrode Assembly
MGA	Model Grant Agreement
MPL	Micro Porous Layer
MRL	Manufacturing Readiness Level
Mt	Million Tonnes
MTBF	Mean Time Between Failures
MW	Megawatt. MW _e refers to MW electric.
N ₂	Nitrogen
NDT	Non-Destructive Testing
Ni	Nikel
NO _x	Nitrogen Oxides
NG	Natural Gas
NGO	Non-Governmental Organisations
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OER	Oxygen Evolution Reaction
OPEX	Operational Expenditure
P4P	Processes 4 Planet Partnership
PBI	Polybenzimidazole
PCCEL	Proton Conducting Ceramic

PCCEL	Proton Conducting Ceramic Electrolysis
PDA	Project Development Assistance
PEM	Proton Exchange Membrane
PEMEL	Proton Exchange Membrane Electrolysis
PEMFC	Proton Exchange Membrane Fuel Cell
PFAS	Per- and Polyfluoroalkyl Substances
PGM	Platinum Group Metals
PNR	Pre-Normative Research
PO	JU Programme Office
PPA	Power Purchase Agreement
Pt	Platinum
RA	Risk Assessment
R&I	Research and Innovation
R&D	Research and Development
RCS	Regulations, Codes and Standards
RCS SC	Regulations, Codes and Standards Strategy Coordination
RED	Renewable Energy Directive
RES	Renewable Energy Sources
RIA	Research and Innovation Actions
RFNBO	Renewable Fuels of Non-Biological Origin
RRF	Recovery and Resilience Facility
rSOC	Reversible Solid Oxide Systems
RTO	Research and Technology Organisations
SBA	Single Basic Act; referring to the regulation establishing the Joint Undertakings under Horizon Europe.
SET-Plan	Strategic Energy Technology Plan
SG	Stakeholder Group
SHM	Structural Health Monitoring
SME	Small and Medium-sized Enterprise
SoA	State-of-the-Art
SOC	Solid Oxide Cells
SOE	Solid Oxide Electrolyser
SOEL	Solid Oxide Electrolysis (Cells)
SOFC	Solid Oxide Fuel Cell
SRI	Strategic and Comprehensive Innovation Roadmap
SRIA	Strategic Research and Innovation Agenda for 2021-2027 of the Clean

Hydrogen Joint Undertaking (previously MAWP Multi-Annual Work Programme).

SRIA-HE/HER Strategic Research and Innovation Agenda for 2021-2027 of Hydrogen Europe and Hydrogen Europe Research

SRG State Representative Group

t Tonne

T&D Transportation and Distribution

TC Technical Committee

TCO Total Cost of Ownership

TEN Trans-European Network. TEN-E refers to Electricity, while TEN-T to Transport.

TIM Tools for Innovation Monitoring

TPD Tonnes per Day

TRL Technology Readiness Level

UAV Unmanned Aerial Vehicle

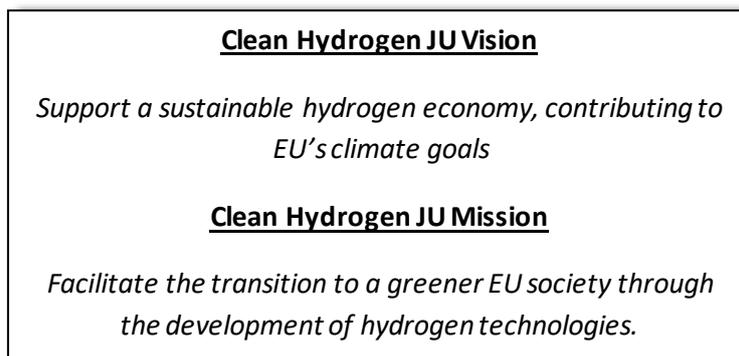
US, USA United States of America

ZE Zero Emission

ZEWT Zero Emission Waterborne Transport Partnership

1 Introduction

1.1 Mission statement of Clean Hydrogen JU



This document represents the **Annual Work Programme for 2022 of the Clean Hydrogen Joint Undertaking** (hereafter also Clean Hydrogen JU²), outlining the scope and details of its activities for the year 2022. It constitutes an amended version of the Annual Work Plan 2022 of the Fuel Cells and Hydrogen Joint Undertaking adopted on 30th of November 2021 and re-adopted on 17th of December 2021.

The overall goal of the Clean Hydrogen JU is to support research and innovation (R&I) activities in the Union in clean hydrogen solutions and technologies, under EU's new funding programme for research and innovation, Horizon Europe, established by the Horizon Europe Regulation³, and in synergy with other EU initiatives and programmes. The Clean Hydrogen JU is the continuation of the successful Fuel Cell and Hydrogen Joint Undertakings (FCH JU and FCH 2 JU), under FP7 and Horizon 2020 (H2020) respectively.

The Clean Hydrogen JU will contribute to the European climate neutrality goal by producing noticeable, quantifiable results towards the development and scaling up of hydrogen applications. This will help develop a number of hydrogen technologies, which are currently either not competitive or have a low technology readiness level but are expected to contribute to the 2030 energy and climate targets and most importantly make possible climate neutrality by 2050.

The research and innovation activities of the Clean Hydrogen JU will address areas related primarily to the production of clean hydrogen, as well as the distribution, storage and end use applications of low carbon hydrogen in hard to abate sectors. They will be guided to a large extent by EU's Hydrogen Strategy and the policy developments in this context, contributing to its implementation.

In particular the Clean Hydrogen JU will aim to accelerate the development and deployment of the European value chain for safe and sustainable clean hydrogen technologies, strengthening its competitiveness and with a view to supporting notably small and medium enterprises (SMEs), accelerating the market entry of innovative competitive clean solutions. The final goal is to contribute to a sustainable, decarbonised and fully integrated EU energy system, and to the EU's Hydrogen Strategy, playing an important role in the implementation of its roadmap towards climate neutrality.

To this end, cross-cutting aspects such as safety, circularity and sustainability will be

² For purposes of communication with the public, often the name Clean Hydrogen Partnership is also used instead of the legal name of the JU. In the present document only the legal name is used.

³ Regulation (EU) 2021/695 establishing Horizon Europe – the Framework Programme for Research and Innovation, OJ L 170, 12.5.2021, p. 1–68.

embedded throughout the entire Clean Hydrogen JU Programme, guiding and underpinning the activities undertaken within. Concerning circularity and sustainability aspects, in particular, it is foreseen that activities will not only address these aspects as part of the “post-development” assessment, but also for orientating and/or looking for solutions and/or taking decisions (e.g. materials selection) to develop a product, technology and/or a value chain in a more sustainable and circular manner. In this sense, “Safety and circularity by design” will become essential aspects across the Clean Hydrogen JU Programme.

1.2 Background and link with the Strategic Research and Innovation Agenda

This document establishes the first Annual Work Programme (AWP) of the Clean Hydrogen Joint Undertaking (Clean Hydrogen JU), outlining the scope and details of its activities for the year 2022. The Clean Hydrogen JU is a unique public-private partnership supporting research and innovation in hydrogen technologies in Europe. In November 2021 the Clean Hydrogen JU was set up, within the Horizon Europe, as a Joint Undertaking by the Council Regulation establishing the Joint Undertakings under Horizon Europe⁴ (also referred to as Single Basic Act – SBA). Its aim is to contribute to the Union's wider competitiveness goals and leverage private investment by means of an industry-led implementation structure.

Recent economic analyses indicate that hydrogen can play a critical role in filling the gap between electrification and the hard-to-abate sectors, such as high temperature heat applications in industry and heavy-duty transport. Hydrogen can be used as a feedstock, a fuel, an energy carrier and an energy storage medium, and thus has many possible applications across industry, transport, power and buildings sectors. Most importantly, when produced sustainably, it does not emit CO₂ emissions. It is therefore an important part of the overall solution to meet the 2050 climate neutrality goal of the European Green Deal.

In July 2020 the Commission adopted the Energy System Integration⁵ and Hydrogen Strategies⁶. Together they aim to address a vision on how to accelerate the transition towards a more integrated and clean energy system, in support of a climate neutral economy. The Energy System Integration Strategy addresses the planning and operation of the energy system “as a whole”, across multiple energy carriers, infrastructures, and consumption sectors. The Strategy sets out 38 actions to implement the necessary reforms, including the promotion of renewable and low-carbon fuels, including hydrogen, for sectors that are hard to decarbonise.

The Hydrogen Strategy aims to create an enabling environment to scale up renewable and low carbon hydrogen supply and demand for a climate-neutral economy. Building on the Commission's New Industrial Strategy for Europe⁷ and the Recovery Plan for Europe⁸, the Strategy sets out a vision of how the EU can turn hydrogen into a viable solution to decarbonise different sectors over time. It also tries to address the issue that the majority of hydrogen production is today fossil-based, as low-carbon hydrogen is not yet cost-competitive. To achieve this, the strategy outlines a number of key actions and presents three strategic phases in the timeline up to 2050. Most notably, it sets the ambitious goal of installing at least 6 GW of renewable hydrogen electrolyzers in the EU by 2024 and 40 GW

⁴ Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC) No 219/2007, (EU) No 557/2014, (EU) No 558/2014, (EU) No 559/2014, (EU) No 560/2014, (EU) No 561/2014 and (EU) No 642/2014. OJ L 427/17 of 30.11.2021

⁵ Strategy for Energy System Integration. COM(2020) 299 final.

⁶ A Hydrogen Strategy for a climate neutral Europe. COM(2020) 301 final.

⁷ New Industrial Strategy for Europe. COM(2020) 102 final.

⁸ Europe's moment: Repair and Prepare for the Next Generation. COM(2020) 456 final.

of renewable hydrogen electrolyzers by 2030.

On 11 December 2020, the Council adopted conclusions on steps to be taken towards creating a hydrogen market for Europe.⁹ The conclusions gave political guidance to the implementation of the EU Hydrogen Strategy presented by the European Commission on 8 July 2020. In its conclusions, the Council recognised the important role of hydrogen, especially from renewable sources, and the need for the hydrogen market to be significantly scaled up, asking the Commission to further elaborate and implement the EU Hydrogen Strategy. The pathway towards the roadmap's objectives should use joint programmes, be cost-efficient and prioritise energy efficiency and electrification from renewable sources. The Council also sees the need to develop an ambitious hydrogen roadmap and strategy for climate neutrality in the end-use sectors, which makes use of flexible policies.

On 19 May 2021, the European Parliament also adopted a resolution¹⁰ on the European Strategy for Hydrogen. The Member of the Parliament requested for incentives to encourage demand and to create a European hydrogen market and fast deployment of hydrogen infrastructure. They also emphasised the need to phase out fossil-based hydrogen as soon as possible, while certification should be applied to all hydrogen imports, similar to EU-produced hydrogen. Finally, they requested to assess the possibility of repurposing existing gas pipelines for the transport and underground storage of hydrogen.

On 28 June 2021 the first ever Climate Law for Europe¹¹ was adopted, writing into law the goals set out in the European Green Deal. The first European Climate Law sets the goal of climate-neutrality by 2050 and includes a binding EU climate target for reducing net greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990, significantly increasing the previous 2030 target of 40% agreed a few years back in 2014.

To achieve these ambitious goals, the European Commission adopted on 14 July 2021 the 'Fit for 55' package¹² of policy proposals to make the EU's climate, energy, land use, transport and taxation policies fit for this target. It is a broad package, containing 13 different proposals approaching the goal of emission reductions from many different angles, with both targeted and horizontal policy measures. Increasing renewable energy, energy efficiency and member states' non-ETS targets, while strengthening the EU emission trading system (EU ETS), including creating a new ETS for buildings and road transport. Restructuring energy taxation in Europe – including the introduction of a carbon border adjustment mechanism -, but also revising the CO₂ emission standards for new cars. Accelerating the development of alternative fuel infrastructure, while at the same time promoting the use of sustainable fuels in Aviation and Maritime. Creating a social climate fund and acknowledging the importance of forests and land use in achieving our climate goals. Its proposals will be complemented in Q4 2021 with the Hydrogen and Gas markets Decarbonisation Package¹³ and in Q4 2022 with the CO₂ Standards on Heavy-Duty Vehicles¹⁴.

As the first step in the implementation of the EU Hydrogen Strategy, the 'Fit for 55' package contains a number of measures aiming to promote the production and use of hydrogen and hydrogen-based fuels in the different sectors of the economy. The revised Renewable

⁹ European Council conclusions, 10-11 December 2020.

¹⁰ European Parliament resolution of 19 May 2021 on a European Strategy for Hydrogen (2020/2242(INI))

¹¹ Regulation (EU) 2021/1119 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law').

¹² 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, COM(2021) 550, July 2021.

¹³ The combined evaluation roadmap and inception impact assessment of the initiative can be found [here](#). This initiative aims to address a number of issues associated with gas markets and networks, including hydrogen.

¹⁴ Announced on August 2021, timeline can be found [here](#).

Energy Directive¹⁵ proposes the extension of the EU-wide certification system for renewable fuels to include hydrogen¹⁶, as well as targets for transport¹⁷ and industry¹⁸ that include renewable hydrogen consumption. Additional financial incentives for hydrogen are foreseen by the revision of the EU ETS proposal,¹⁹ which shall extend to maritime, establish emissions trading for transport and buildings; and include electrolytic hydrogen under ETS, thus making low carbon hydrogen eligible for free allowances. Further incentives shall be given through the preferential taxes for the use of low carbon hydrogen, foreseen in the revision of the Energy Taxation Directive.²⁰ Hydrogen is promoted specifically in the transport sector by three additional targeted proposals: the more stringent CO₂ standards for Cars and Vans;²¹ the revision of the Alternative Fuel Infrastructure Regulation²², requiring one hydrogen refuelling station available every 150 km along the TEN-T core network and in every urban nodes by 2030; and the FuelEU Maritime proposal²³ promoting strongly low carbon hydrogen and hydrogen-based fuels (including methanol and ammonia).

The 'Fit-for-55' package is complemented by the proposals for the new Gas Markets Decarbonisation package²⁴, released on 15 December 2021, aiming to enable the decarbonising of the gas networks and revise the EU gas rules to facilitate the market entry for renewable and low-carbon gases, mainly biomethane and hydrogen, and remove any undue regulatory barriers. The revised gas markets and hydrogen regulation²⁵ and directive²⁶ aims to establish a market for hydrogen, create the right environment for investment, and enable the development of dedicated infrastructure, including for trade with third countries: market rules in two phases similar to the existing ones for natural gas, new governance structure in the form of the European Network of Network Operators for Hydrogen, removal of tariffs for cross-border interconnections and lowering tariffs at injection points, introduction of a certification system for low-carbon gases, consumer empowerment and protection etc. This is to ensure that the gas market framework is in line with the Fit for 55 ambition.

In line with all the policy developments described above, it is crucial that the Clean Hydrogen JU continues to support its existing projects and develop technology solutions that will help materialise the benefits of hydrogen technologies in support of the high-level EU policy agenda.

To achieve this, the Strategic Research and Innovation Agenda (SRIA) of the Clean Hydrogen JU describes an extensive number of research and innovation activities, covering the areas of renewable hydrogen production, as well as hydrogen transmission, distribution and storage, alongside selected fuel cell end-use technologies. Several scientific challenges,

¹⁵ Proposal for a Directive as regards the promotion of energy from renewable sources. COM (2021) 557 final.

¹⁶ Renewable Fuels of Non-Biological (RFNBO) now include renewable hydrogen.

¹⁷ at least 2.6% share of RFNBO in the energy supplied to the transport sector

¹⁸ 50% of the hydrogen used for final energy and non-energy purposes should come from RFNBO

¹⁹ Establishing a system for greenhouse gas emission allowance trading with the Union. COM (2021) 551 final.

²⁰ Restructuring the Union framework for taxation of energy products and electricity, COM (2021) 563 final.

²¹ Strengthening the CO₂ emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition. COM (2021) 556 final.

²² Regulation on the deployment of alternative fuels infrastructure. COM (2021) 559 final.

²³ Regulation on the use of renewable and low-carbon fuels in maritime transport. COM (2021) 562 final.

²⁴ New EU framework to decarbonise gas markets, promote hydrogen and reduce methane emissions (https://ec.europa.eu/commission/presscorner/detail/en/ip_21_6682)

²⁵ Regulation on the internal markets for renewable and natural gases and for hydrogen (recast). COM/2021/804 final (<https://ec.europa.eu/energy/sites/default/files/proposal-revised-gas-markets-and-hydrogen-regulation.pdf>)

²⁶ Directive on common rules for the internal markets in renewable and natural gases and in hydrogen. COM/2021/803 final (<https://ec.europa.eu/energy/sites/default/files/proposal-revised-gas-markets-and-hydrogen-directive.pdf>)

priorities and objectives have been identified, which are described in detail in Section 1.3 and are addressed by the research and innovation actions listed in the SRIA.

In parallel, the SRIA foresees parallel activities, aiming to support the research and innovation agenda and reinforce it, including:

- Seeking synergies with other partnerships and programmes;
- Facilitating the market uptake of hydrogen via a number of Task Forces and Panels²⁷;
- Enlarging the knowledge base around hydrogen via the knowledge management activities;
- Building awareness and acceptance of the hydrogen technologies, through communication activities, but also the dissemination and exploitation of project results;
- Supporting the European Commission in the implementation of its international cooperation agenda in research and innovation.

The present Annual Work Programme 2022 of the Clean Hydrogen Joint Undertaking consists of the first implementation step of the SRIA. It includes a Call for Proposals, along the lines of the research and innovation actions listed in the SRIA, with an overall indicative budget of EUR 300 million. In parallel specific actions are foreseen in the context of the parallel activities described in the SRIA, while at the same time the continuation of all on-going activities of the Clean Hydrogen JU predecessor (FCH 2 JU).

1.3 Strategy for the implementation of the programme

1.3.1 Implementation Strategy

The Clean Hydrogen JU has been set up to achieve a number of objectives described in the European legislation or its SRIA:

- The objectives of the Horizon Europe Programme, as described in Article 3 of the Horizon Europe Regulation, including contributing to the Union policy objectives;
- The objectives set out in the SBA establishing the Clean Hydrogen JU, both common for all Joint Undertakings and the specific ones for the Clean Hydrogen JU, as described in Articles 3 to 5 and 73-74 of the SBA;
- The research objectives set out in the SRIA per research area.

In general, the Clean Hydrogen JU aims to accelerate the development and deployment of the European value chain for safe and sustainable clean hydrogen technologies, strengthening its competitiveness and with a view to supporting notably SMEs, accelerating the market entry of innovative competitive clean solutions. The final goal is to contribute to a sustainable, decarbonised and fully integrated EU energy system, and to the EU's Hydrogen Strategy, playing an important role in the implementation of its roadmap towards climate neutrality.

In order to prepare the implementation strategy of the Programme, the Clean Hydrogen JU prepared a Strategy Map²⁸ to map this large number of (often high level) objectives to more

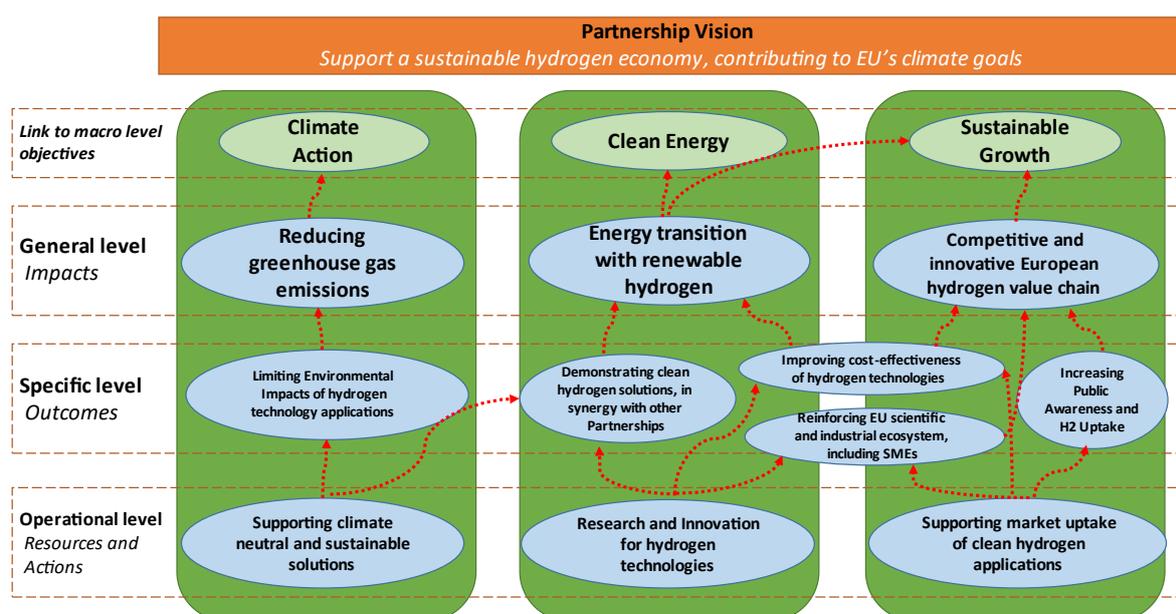
²⁷ Regulations, Codes and Standards Strategy Coordination Task Force, the European Hydrogen Safety Panel and the Sustainability and Circularity Panel.

²⁸ See Section 7 of the Clean Hydrogen JU SRIA.

specific ones. This facilitated the identification of the necessary actions over the lifetime of the JU, necessary to meet its objectives. The Strategy Map links the resources of the JU and the actions taken (operational objectives / indicators) towards concrete outcomes (specific objectives / indicators) and directly to one (or more) of the general objectives and intended impacts of the Clean Hydrogen JU, which would contribute in turn to one or more high-level objectives of the Union. Figure 1 below presents the JU's strategy map, linking actions with expected outcomes and intended impacts.

It needs to be emphasised that the Strategy Map does not aim to replace the legal objectives of the JU, as reflected in the SBA and the Horizon Europe Regulation, but helps to restructure and further specify them, in order to be able to better define the implementation strategy for the Programme and set up relevant indicators for its monitoring framework, while avoiding overlaps among the objectives and making more obvious the interlinkages between them.

Figure 1 Strategy Map of the Clean Hydrogen Joint Undertaking



Considering the different levels of objectives and the high level of ambition associated with the hydrogen sector, a gradual implementation was deemed more appropriate. Therefore, the Programme will be mainly implemented through open and competitive annual Calls for Proposals²⁹, providing financial support mainly in the form of grants to participants. The planned research and innovation actions are described in Section 1.3.2. The topics of each Call will be determined on an annual basis through extensive consultation between the three members of the JU³⁰ and with the support of the Programme Office. The progress of the Programme, as observed via the monitoring framework of the JU, will be a useful input in these discussions, indicating whether more action is needed in certain area.

Moreover, the Clean Hydrogen JU will undertake in parallel a number of complementary activities, aiming to support the market uptake of hydrogen applications and reinforce the EU scientific and industrial ecosystem. In addition, these activities will address the specific tasks

²⁹ In 2022, the Clean Hydrogen Joint Undertaking will also carry out a number of operational activities via calls for tenders, see section 2.2.4 of this document for additional information.

³⁰ The three members of the JU are the European Commission, Hydrogen Europe and Hydrogen Europe Research.

assigned in the SBA to the Joint Undertaking, its Governing Board and its Executive Director, with the exception of grants. These activities are described in Section 1.3.3.

1.3.2 Planned research and innovation actions

The key component in the implementation of the Programme is the annual Call for Proposals, covering a number of the research and innovation actions described in the SRIA. The selection of the actions and the description of the topics comes from a joint effort and intensive interaction between the major stakeholders, namely Hydrogen Europe, Hydrogen Europe Research and the European Commission. They represent a set of prioritised actions, consistent with the objectives of the Clean Hydrogen JU, and is divided primarily into the Pillars identified in the SRIA:

- Pillar 1: Renewable Hydrogen Production
- Pillar 2: Hydrogen storage and distribution
- Pillar 3: Hydrogen end uses
 - Pillar 3.1: Transport applications
 - Pillar 3.2: Clean heat and power

In addition to working within each of these pillars, mass deployment requires support and coordination action. They are thus complemented by four additional horizontal and cross-cutting activities, necessary as follows:

- Horizontal Activity 1: Cross-cutting activities
- Horizontal Activity 2: Hydrogen Valleys
- Horizontal Activity 3: Hydrogen Supply Chains
- Horizontal Activity 4: Strategic Research Challenges

In the SRIA, for each Pillar and Horizontal Activity, specific objectives are described, accompanied by a number of actions³¹ aiming to contribute towards their achievement. These actions comprise of long-term, breakthrough-oriented research, applied research and technology development, demonstrations and supporting actions, including strategic studies, pre-normative actions and technology assessment.

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 Clean Hydrogen JU.

The main scientific priorities and challenges for the different pillars and activities are as follows:

Scientific priorities and challenges: Renewable Hydrogen production

Most of the hydrogen that is currently being produced in the EU and worldwide is produced from fossil fuels – either by steam reforming of natural gas or gasification of coal. Renewable hydrogen needs to become cost-competitive and its technologies need to be scaled up in a fashion similar to renewable technologies during the last decade. For transport, this would

³¹ The actions proposed for all the pillars are based on the final draft of the SRIA-HE/HER. These should be considered indicative, especially considering the dynamic and fast-growing field of research and development in hydrogen technologies, which may very likely shift the priorities over the next few years.

require a cost around 5 €/kg at the pump to achieve cost parity with diesel fuel³². For Industry, renewable hydrogen costs must reach levels between 2-3 €/kg as a feedstock³³, in order to achieve parity with fossil-based inputs, once the cost of carbon is included in the feedstock cost.

To reach this objective, further improvements are required especially in cost reduction and efficiency increase for a variety of renewable hydrogen production routes, the main workhorse being electrolysis, supported by other routes exploiting direct sunlight such as thermal dissociation of water using concentrated solar energy or through photocatalysis, biomass/biogas or other biological routes.

Water electrolysis will be the main technology supported, covering high TRL types - Alkaline Electrolysis (AEL), Proton Exchange Membrane Electrolysis (PEMEL), Solid Oxide Electrolysis (SOEL) - and less mature types - Anion Exchange Membrane Electrolysis (AEMEL) and Proton Conducting Ceramic Electrolysis (PCCEL). The topic of pyrolysis and carbon black production is outside the scope of the Clean Hydrogen JU and will be covered through the synergies with Processes 4 Planet Partnership (P4P).

Scientific priorities and challenges: Hydrogen storage and distribution

As explicitly mentioned in the EU Hydrogen Strategy, it is essential that hydrogen becomes an intrinsic part of an integrated energy system. In order for this to happen, hydrogen will have to be used for daily and/or seasonal storage providing buffering functions thereby enhancing security of supply in the medium term. The strategy also calls for an EU-wide logistical infrastructure that needs to be developed to transport hydrogen from areas with large renewable potential to demand centres across Europe.

For distances compatible with the European territory, compressed and liquefied hydrogen solutions, and especially compressed hydrogen pipelines, offer lower costs than chemical carriers do. The repurposing of existing natural gas pipelines for hydrogen use is expected to significantly lower the delivery cost, making the pipeline option even more competitive in the future. By contrast, chemical carriers become more competitive the longer the delivery distance (due to their lower transport costs) and thus can more easily be traded in the global hydrogen markets.

In line with the above, a pluralistic approach with respect to the technologies that will be investigated and supported is envisaged, to have a complete set of technologies that can serve as building blocks of the EU-wide logistical infrastructure.

Scientific priorities and challenges: Hydrogen end uses - transport

Transport is a key area of economic growth in our society, responsible for around 30% of EU total CO₂ emissions. The European Green Deal has set the ambition for at least 90% reduction in transport emissions by 2050 to be consistent with climate neutrality. Hence, there is a need to urgently take measures to decarbonise the transport sector. Regulatory aspects will define the speed of adoption of new zero emissions transport means. The 'Fit for 55' package proposes a number of policy measures that promote the use of hydrogen as a low carbon fuel in the transport sector.

The technology developments so far are not sufficient to meet the ambitious emission reductions in transport. The required solutions can be based on the transfer of technical knowledge already gained in fuel cell (FC) light duty vehicles (LDV) and FC buses, while

³² See Figure 15 in Strategic Research and Innovation Agenda, final draft October 2020, Hydrogen Europe and Hydrogen Europe Research

³³ Green Hydrogen Cost Reduction: Scaling up electrolyzers to meet the 1.5°C climate Goal, IRENA 2020

cost reductions and higher efficiencies can be achieved by scaling and by process integration, improving the competitiveness of these technologies with a roll down effect, e.g. by platform approaches of FC modules across sectors.

A number of technology routes still need further improvements, especially in the context of reducing costs and increasing durability, in order to make them competitive with incumbent technologies. These include:

- Improvement of main technology building blocks that can be applied across a range of different transport applications, notably fuel cell stacks and hydrogen tanks;
- Adapting fuel cell systems from other vehicles (urban buses / cars) for long distance coaches and heavy-duty vehicles;
- Producing components for rail freight and shunting locomotive applications;
- Adapting FC components to waterborne transport, and developing next generations based on learnings from first demonstrations;
- Developing tanks and FC technologies specifically adapted for aviation.

It should be also stressed that, especially in the case of hydrogen-based transportation, the competitiveness of hydrogen technologies is dependent on research and innovation breakthroughs, on production volumes of vehicles and components and on the price and availability of hydrogen as a fuel. Therefore, actions aimed at stimulating a broad rollout of FC vehicles around Europe are equally important to research and innovation actions, in particular for hard to abate sectors, in order to drive the Total Cost of Ownership (TCO) of the FC vehicles down. This is particularly true, for example, for the road heavy-duty transport segment where the TCO is extremely relevant for final users and ultimately for the market uptake. Monitoring of the FC trucks TCO and comparison with battery-powered trucks electrified trucks and others decarbonisation technologies will be needed. Addressing all of these aspects simultaneously is necessary to allow for hydrogen transport applications to enter mass market.

Scientific priorities and challenges: Hydrogen end uses - clean heat and power

Hydrogen offers a unique chance to decarbonise the power generation and heating sectors reliably and independently from weather or seasonal conditions.

The overall goal of this pillar is to support European supply chain actors to develop a portfolio of solutions providing clean, renewable and flexible heat and power generation for all end users' needs and across all system sizes; from domestic systems all the way to large-scale power generation plants. Preferential support will be for solutions running on 100% hydrogen. However, there is still room to support solutions running on a hydrogen mixture in the gas grid (up to 20% within the context of the activities included in this support area) during the transition phase³⁴.

For gas turbines, in order to enable a smooth transition and assure backward compatibility with conventional fuels during the transition, support for actions running with different hydrogen admixtures are likely to be required to facilitate the development process and to achieve the final goal of 100% hydrogen turbines.

³⁴ According to the "Hydrogen strategy for a climate-neutral Europe", the blending of hydrogen in the natural gas network at a limited percentage may enable decentralised renewable hydrogen production in local networks in a transitional phase.

Scientific priorities and challenges: Cross-Cutting activities

Mass-market commercialisation of hydrogen-based technologies presents a number of systemic (or horizontal) challenges that need to be addressed to effectively kick-start a hydrogen ecosystem of significant scale throughout the EU in the coming decade.

Cross-cutting activities are structured around three focus areas: (i) Sustainability; (ii) Education and public awareness; and (iii) Safety, pre-normative research and regulations, codes and standards.

As hydrogen-based technologies become a market value proposition, strengthening the focus on environmental and sustainability aspects (such as water resources for electrolysis, critical raw materials use along hydrogen value chains and pollutant emissions) is required in the framework of the transition to a circular economy. Furthermore, continuous education and training are fundamental to safeguard existing expertise and to prepare a well-educated workforce needed for a competitive hydrogen market, while underpinning the jobs and value creation in a knowledge-based society in Europe. Public awareness activities are essential for increasing social acceptance and trust in hydrogen-based technologies throughout Europe but in particular, for bridging the potential lack of knowledge or mistrust of key stakeholders directly involved in the first phases of mass deployment in Europe. Moreover, for a safe deployment of clean hydrogen technologies in Europe, safety-related aspects are of paramount relevance. As the technologies will shift from the industrial domain to the public domain, strengthening hydrogen safety will become one of the priorities of the Clean Hydrogen JU Programme. Besides, a suitable regulatory framework for hydrogen-based technologies is necessary for an EU-wide deployment of clean hydrogen technologies. To this end, pre-normative research activities and desk research activities are fundamental for supporting regulations, codes and standards (RCS) development.

Scientific priorities and challenges: Hydrogen Valleys

Since 2014, FCH JU has pursued the concept of hydrogen territories, which have evolved into the most recent concept of Hydrogen Valleys. A Hydrogen Valley is '*a defined geographical area, city, region or industrial area where several hydrogen applications are combined together and integrated within an FCH ecosystem*'. The idea is to demonstrate how all the different parts of the use of hydrogen as an energy vector fit together in an integrated system approach. This concept has gained momentum and is now one of the main priorities of industry and the European Commission (EC) for scaling-up hydrogen deployments and creating interconnected hydrogen ecosystems across Europe.

A Hydrogen Valley should not only demonstrate how hydrogen technologies work in synergy, but it should also work complementary with (or reuse of) other elements: renewable production, gas infrastructure, electricity grid, batteries, etc.

A key objective is to demonstrate the notion of "system efficiency and resilience": it is not only the energy efficiency of a single application that matters but the overall energy and economic efficiency and resilience of the integrated system.

Scientific priorities and challenges: Hydrogen Supply Chains

Hydrogen technologies and systems have been recently identified by the European Commission as an emerging and strategic value chain for Europe.³⁵ A strong and sustainable European supply chain of hydrogen technologies will avoid that the manufacturing capacity becomes a limiting factor to technology uptake, improve the

³⁵ Strengthening Strategic Value Chains for a future-ready EU Industry, EC, 2019.

competitiveness and innovation of industries, support the decarbonisation of the economy and reduce dependence on fossil fuels, critical raw materials (CRM) and components imports.

The SRIA foresees a set of actions aiming at strengthening the overall supply chain of hydrogen technologies, from processing the raw materials into specialised materials (e.g. electro-catalysts), production of components and sub-system to system integration. The supply chain is complemented by the wider view of the value chain approach vis-à-vis creation of jobs, added value to economy and industry competitiveness.

Scientific priorities and challenges: Strategic Research Challenges

To ensure a continuous generation of early stage research knowledge, the above actions will be supplemented by multidisciplinary investigations, gathering expertise at different technology scale (materials, component, cell, stack and system). All the generated knowledge needs also to be combined in such a way to allow further comprehensive interpretations. The usual superposition of 3-year research projects does not really appear to be the optimum option to ensure a continuum in early-stage research knowledge. The proposed approach considers gathering, with a long-term vision and covering the whole Clean Hydrogen JU activities, the needed capabilities and expertise from European Research and Technology Organisations (RTO).

Based on the early-stage research actions mentioned in the different previous roadmaps, the following strategic research challenges appear the most relevant:

- Low or free platinum group metal (PGM) catalysts (including bioinspired catalysts), reducing critical (raw) materials use in electrolyzers and fuel cells, and safe and sustainable use of all material, including developing of perfluorosulfonic acid (PFAS)-free ionomers and membranes;
- Advanced materials for hydrogen storage (e.g. carbon fibres, H₂ carriers);
- Advanced understanding of the performance / durability mechanisms of electrolyzers and fuel cells.

1.3.3 Other activities

Although the financial support to research and innovation actions is the main tool of the JU to achieve its objectives, it is not sufficient. A number of additional activities are necessary to fulfil its objectives in relation, for example, to developing synergies with other partnerships and programmes, strengthening scientific excellence and its links to innovation and increasing public awareness.

For this reason, the SBA³⁶ includes a number of tasks that the JU, its Governing Board and its Executive Director should carry out, which were then translated into specific activities in the SRIA.

Activities related to Synergies

The overall principle is that the JU activities shall be implemented in synergy with other Union programmes while aiming for maximal administrative simplification.

In line with the SBA, the JU will develop close cooperation and ensure coordination with other European partnerships, including by dedicating, where appropriate, a part of the joint undertaking's budget to joint calls.

³⁶ See Articles 5(2), 17 (2), 19(4), 74, 82 and 83 of the SBA.

Moreover, it will seek and maximise synergies with and, where appropriate, possibilities for further funding from relevant activities and programmes at Union, national and regional level, in particular with those supporting the deployment and uptake of innovative solutions, training, education and regional development, such as Cohesion Policy Funds, or the national Recovery and Resilience Plans.

Activities related to Regulations, Codes and Standards

The Clean Hydrogen JU will contribute to supporting the implementation of hydrogen-specific regulatory and enabling frameworks by a strategic and coordinated approach to RCS issues within the Programme, which will mostly be implemented through Pre-Normative Research (PNR) activities. To this end, PNR activities will encompass research activities and desk research activities in view of supporting RCS developments.

Moreover, an RCS Strategy Coordination (RCS SC) Task Force composed of the Commission, Hydrogen Europe and Hydrogen Europe Research, and the Clean Hydrogen JU Programme Office (PO) will be set up to better coordinate these activities. Altogether, the RCS SC Task Force will contribute to coordinating and establishing an approach to enhance European participation and contribution in international and European RCS bodies while contributing to lay down a regulatory friction-less hydrogen market in Europe and beyond if possible.

Activities related to European Hydrogen Safety

Independently of the research and innovation actions addressing hydrogen safety issues, the Clean Hydrogen JU will retain and further reinforce the European Hydrogen Safety Panel (EHSP), aiming to support the development and deployment of inherently safer hydrogen systems and infrastructure.

The mission of the EHSP in the Programme will be twofold:

- Assist the Clean Hydrogen JU at both programme and project levels, in assuring that hydrogen safety is adequately addressed and managed;
- To promote and disseminate hydrogen safety knowledge and culture within and outside of the Programme.

Activities related to European Hydrogen Sustainability and Circularity

The research and innovation actions under the Cross-cutting and the Hydrogen Supply Chain will play a key role in providing the methodological foundation to strengthen the sustainability and circularity of these technologies and their industrial value chains in Europe. Nevertheless, the transition towards a fully-fledged sustainable and circular hydrogen economy requires an integrated approach beyond these activities.

To this end, the Clean Hydrogen JU will set up a European Hydrogen Sustainability and Circularity Panel (EHS&CP) at the Programme level which will act as a focal point or “advisor” to the Programme in these matters in an independent, coordinated and consolidated way.

The EHS&CP will assist the Clean Hydrogen JU in assuring that sustainability and circularity aspects are adequately addressed and managed at both programme and project levels, encompassing environmental, social and economic aspects as a whole. Moreover, it will promote and disseminate knowledge and a more sustainable and circular culture within and beyond the Programme.

Activities related to knowledge management

The main goals of the Clean Hydrogen JU knowledge activities will be to support the collection and diffusion of high-quality new knowledge and support evidence-based implementation of Union policies.

It will monitor progress towards the achievement of the objectives of the Clean Hydrogen JU and its technology key performance indicators (KPIs), while strengthening the knowledge capacity of hydrogen value chain actors through data collection and knowledge collection.

Moreover, it will contribute to developing a more effective science-policy interface, fostering open science by ensuring better use of results and to addressing policy needs, as well as to promoting faster exploitation, dissemination and uptake of results.

Activities related to SMEs

The Clean Hydrogen JU will continue to rely on the innovativeness of SMEs. To do this, it will need to deal with two of the largest obstacles that SMEs must overcome, the need to raise financing, especially in the early stages of growth, and to kick-start sales and thereby gain valuable field experience.

In order to address the specific limitations and risks of SMEs, the Clean Hydrogen JU will continue to explore ways to open access to the necessary manufacturing and process capabilities through partnership schemes and education initiatives. It will help raise awareness of projects' results within the finance community, while at the same time trying to address the private sector funding and financing challenge that acts as a market barrier for deployment of hydrogen technologies and wider hydrogen integrated solutions.

Activities related to international cooperation

The Clean Hydrogen JU will build on the actions undertaken by its predecessor and expand them accordingly, in order to support the European Commission in the implementation of its international cooperation agenda in research and innovation.

Its activities will include strengthening the links with the major deployment programmes globally, continue providing technical support to the European Commission on its international activities in relation to hydrogen research and innovation, most notably in relation to the International Partnership for Hydrogen and fuel cells in the Economy (IPHE), the Clean Energy Ministerial Hydrogen Initiative, Mission Innovation 2.0 and Hydrogen Energy Ministerial. Similarly, the Clean Hydrogen JU PO will continue to support JRC by contributing to the Commission activities for the International Energy Agency (IEA) Hydrogen Technology Collaboration Programme (HTCP) executive committee.

Activities related to Communication

The JU will undertake a number of communication activities with the objective to promote the development of the hydrogen technologies sector, build public awareness and acceptance of the hydrogen technologies and ensure communication towards and between stakeholders.

Among them, it will convene, subject to approval by the Governing Board, an annual European Clean Hydrogen partnership forum. The forum will include an independent scientific advisory workshop, aiming to gather independent opinions and advice of the wider scientific community on the Strategic Research and Innovation Agenda, work programmes and developments in adjacent sectors.

2 Work Programme 2022

2.1 Executive summary 2022 and message from the Executive Director

2.1.1 Message from the Executive Director



Dear Readers,

I am proud to present to you the first Work Programme of the Clean Hydrogen JU, which will take over all the activities of its predecessor FCH JU.

The new JU, building on the great experience and good collaboration between the industrial, research and public sectors, aims to contribute to EU's ambitious climate and energy goals for 2030 and 2050 by supporting clean hydrogen technologies and allowing them to take a central place in the climate neutral economy of the future. By scaling-up clean hydrogen technologies and expanding their applications, we can set the foundations for a competitive and innovative European hydrogen value chain.

In close collaboration with other partnerships and in synergy with other EU, national and regional research funding programmes, we will strengthen and integrate Union scientific capacity to accelerate the development and improvement of advanced clean hydrogen applications ready for market, across energy, transport, building and industrial end-uses.

To achieve these ambitious objectives, the EU will support the Clean Hydrogen JU with €1 billion euro for the period 2021-2027, complemented by at least an equivalent amount of private investment from the private members of the JU. It will fund a large number of research & innovation activities, focusing the renewable hydrogen production, as well as hydrogen transmission, distribution and storage, alongside selected fuel cell end-use technologies in hard to abate sectors (industry and heavy transport).

As a first step, we will kick off the year with a Call for Proposals with an overall indicative budget of 300 million euros, covering a wide spectrum of research and innovation activities. At the same time, we will continue with many other complementary activities aiming to support the market uptake of clean hydrogen applications and reinforce the EU scientific and industrial ecosystem. All of these activities are described in detail in the next pages.

Enjoy the read!

A handwritten signature in blue ink, which appears to be 'Bart Biebuyck'. The signature is stylized and somewhat abstract, with several loops and flourishes.

Bart BIEBUYCK

Executive Director

Clean Hydrogen Partnership

2.1.2 Executive Summary

The first Annual Work Programme 2022 for the Clean Hydrogen JU will build on the previous work of its predecessor, FCH 2 JU, aligning it with the SRIA and its implementation strategy described in Section 1.3.1.

As the Clean Hydrogen JU was launched in the end of November 2021, it was not possible to launch a separate Call for Proposals that year. In 2022 one Call for Proposals with two deadlines for an indicative total budget of 300.5 million euros are foreseen. The Call addresses key challenges as identified by the stakeholders in the Clean Hydrogen JU. These challenges encompass different areas of research and innovation with direct and quantified impact towards the achievement of the objectives of the Clean Hydrogen JU in general and to each of the Pillars in particular. A total of 41 topics will be part of the call for proposals, including 10 for Renewable Hydrogen Production, 11 for Hydrogen Storage and distribution, 8 for transport and 4 for heat and power. In addition, 5 projects will support Cross-cutting issues. This call will also support 2 Hydrogen Valleys and 1 Strategic Research Challenge. They will be grouped into 10 Innovation Actions (IA), 29 Research and Innovation Actions (RIA) and 2 Coordination and Support Action (CSA). Six of the Innovation Actions considered of strategic importance and are selected as flagship projects. Synergies with other European partnerships and programmes as well as with Member States and regional programmes are at the core of a number of topics.

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

The Clean Hydrogen JU will continue to contribute towards the implementation of EU Policies through different means. It will continue following and contributing as necessary to the European Strategic Energy Technology Plan (SET-Plan)³⁷ activities, as well as support transport policies. On the latter, a study supported by the Clean Hydrogen JU on "Impact of Deployment of Battery Electric Vehicles (BEV) and Fuel Cells Electric Vehicles (FCEV) Infrastructure" should be finalised, while another on "Hydrogen in Ports and Industrial Coastal Areas" began early 2022. Moreover, the JU will examine its role in relation to the Alternative Fuels Infrastructure Regulation (AFIR) implementation. The CertifHy3 project aims at facilitating the creation of an EU-wide system of guarantees of origin for hydrogen. Finally, it remains ready to support the European Commission by cooperating with the European Clean Hydrogen Alliance.³⁸

As part of the on-going framework contract with JRC, the annual Rolling Plan 2022 was agreed in 2021 and will be implemented in 2022. It consists of the annual activities and their related deliverables provided by JRC, which include the support to the regulations, codes and standards strategy and its implementation, its contribution to the Programme monitoring and assessment, the assessment of sustainability of hydrogen and fuel cells and the JRC contribution to safety, and safety awareness. As the framework contract will end in 2022, the Clean Hydrogen JU intends to sign a new framework contract with JRC in 2022 in the context of the current one, to ensure the continuity of services provided by JRC.

In terms of knowledge management, it will continue with the annual data collection exercise from its projects and the publication of the Programme Review Report, with the aim to gradually extend it to other hydrogen projects funded by other partnerships or EU, national or regional funds. A procurement is foreseen for the continuation of the Fuel Cell and

³⁷ <https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan>

³⁸ https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

Hydrogen Observatory platform, providing data and up to date information for the entire hydrogen sector, with the current contract ending in April 2022. The continuous demand for more information and knowledge services may require a new platform, combining all platforms supported currently by the JU but with additional capabilities; the need will be examined in 2022 and the necessary steps will be taken. In terms of feedback to policy, the JU will continue contributing to the activities of the European Commission services as necessary.

Building already on experiences (and success stories) from the previous JUs, synergies have become a central piece of the 2021-2027 multi-annual financial framework. In 2022 we will further develop our structured cooperation with relevant European partnerships, EU agencies and other EU funding programmes, including those managed by national or regional Managing Authorities. Several procurements in 2022 have synergies in their scope and cooperation with other funding sources will be sought specially for the flagship topics (see further details in chapter on synergies later).

The regulations, codes and standards issues will continue to be addressed by the RCS SC group. In 2022, the RCS SC Group will continue with its main tasks, as laid out in its annual work plan, while redefining its structure/scope within the Clean Hydrogen JU.

Similarly, the European Hydrogen Safety Panel will also continue its activities, performing safety plan reviews, updating its guidance documents, providing guidance in developing areas (e.g. heavy transport), performing public outreach and continuing with its data collection and assessment activities.

Considering the importance of strengthening the sustainability and circularity of hydrogen technologies, the Clean Hydrogen JU will set up EHS&CP at the Programme level. Its mission will be to assure these aspects are adequately addressed at Programme level, while also promote and disseminate the relevant knowledge and culture within and beyond the Programme.

The Clean Hydrogen JU will continue supporting the European Commission in its international cooperation activities. It will continue its work in relation to the harmonisation of the regulatory and policy frameworks, as well as safety and education. Moreover, it will continue its involvement in the IEA HTCP following a number of working groups. Finally, it will continue supporting the Hydrogen Valleys platform through a public procurement published on 10/12/2021,³⁹ while contributing also towards the other activities of Clean Hydrogen Mission under MI2.0.

Communication and outreach activities will ensure that stakeholders are duly informed about the Clean Hydrogen JU and ensure continuity in the transition from the FCH 2 JU, including getting the public accustomed to the new visual identity of the JU. The two new Calls will be strongly promoted to ensure high participation, while emphasis will also be given to an increased outreach effort to the general public with intensified awareness campaigns. A public procurement launched in 2021 for a Public Opinion Survey, to be signed in 2022, with the aim to gain insights into perceptions on the use of fuel cells and hydrogen technologies relating to a number of aspects will help further guide communication activities in the future.

As part of the knowledge management activities, but also in the context of the Project Management workflow, the Programme Office will continue its activities in dissemination and exploitation of project results. It will continue participating in the Innovation Radar, while will also promote other tools supporting further exploitation and dissemination.

³⁹ <https://etendering.ted.europa.eu/cft/cft-display.html?cftId=9670>

As an EU body, the Clean Hydrogen Joint Undertaking will secure sound financial management of all its activities in accordance with the principles of the Internal Control Framework and with the Financial Rules of the Clean Hydrogen JU⁴⁰. In continuation of the work undertaken in previous years in the FCH 2 JU, corporate processes and procedures will be adapted to the provisions set forth in the Single Basic Act, and new ICT systems will be deployed over the year 2022, to support both operational and administrative activities. This includes in particular the set-up with the other joint undertakings of common back-office arrangements, which are expected to be operational by the end of 2022. The Clean Hydrogen JU will closely monitor the implementation of its budget and its Staff Establishment Plan and will continue its close cooperation with the other Joint Undertakings in matters of common interest.

⁴⁰ The Financial Rules of the Clean Hydrogen JU were adopted on 17 December 2021 through Governing Board decision reference CleanHydrogen-GB-2021-03

2.2 Operational activities of Clean Hydrogen JU for 2022

2.2.1 Objectives, Indicators and Risks

2.2.1.1 Objectives

The operational activities of the Clean Hydrogen JU aim to implement its Strategy Map, as described in Section 1.3.1, thus contributing to its objectives. The links between the specific operational activities with the Strategy Map are presented in Annex 4.2.

2.2.1.2 Key Performance Indicators

The Clean Hydrogen JU has established a monitoring framework to track the progress towards its objectives as set out in the SBA and the Horizon Europe Regulation, as well as its contribution towards the priorities of the Union and the SRIA.⁴¹

The JU will monitor a number of Key Performance Indicators as described in Section 7 of its SRIA. These indicators can be grouped in the following categories:

- Horizon Europe KPIs,⁴² defined in the Horizon Europe Regulation as Key Impact Pathways and applicable for the whole Horizon Europe Programme;
- Common JU Indicators, as defined in the monitoring framework⁴³ developed by the Expert Group set up to support the strategic coordination process of the European R&I partnerships;
- Clean Hydrogen JU KPIs, defined by the Clean Hydrogen JU⁴⁴ for the purpose of monitoring the progress towards the objectives of the Strategy Map and its relevant targets;
- Technology KPIs, defined by the Clean Hydrogen JU⁴⁵ to monitor technology progress and innovation of its projects towards the R&I priorities defined in the SRIA.

The third category of these KPIs, the ones specific for the Clean Hydrogen JU present in Table 1 below, are the ones that are used to evaluate the performance of the JU as an entity and provide quantifiable means to measure any associated risks towards the achievement of its objectives.

⁴¹ Articles 5.2(h), 17.2(a), 19.4(f)/(g)/(o), 36, 74(a) and 171 of the SBA.

⁴² HE Regulation Art 50(1) & SBA Art 171(2)(a-c-d-e)

⁴³ A robust and harmonised framework for reporting and monitoring European Partnerships in Horizon Europe, 2021, RTD, <https://europa.eu/!b3TBfW>.

⁴⁴ Annex I of the SRIA

⁴⁵ Annexes II-VI of the SRIA.

Table 1 Clean Hydrogen JU KPIs, monitoring the progress towards the objectives of the Strategy Map

Strategy Map Objective	KPI Name	Unit of measurement	Baseline	Target 2023	Target 2025	Target 2027	Ambition >2027
Resources (input), processes and activities							
Supporting sustainable solutions	1. Supporting sustainable solutions	% of budget	2.5	20	35	50	
R&I for hydrogen technologies	2. Early research projects	% of budget	10	10	10	10	
	3. Demonstration projects	# of projects	43	20	40	60	
Supporting market uptake of clean hydrogen applications	4. Education and training	# of projects	4	2	4	6	
	5. Monitoring technology progress	<i>Qualitative indicator</i>	N/A	N/A	N/A	N/A	
	6. Supporting EC in H2 market uptake	<i>Qualitative indicator</i>	N/A	N/A	N/A	N/A	
Outcomes							
Limiting environmental impacts	7. Environmental impact and sustainability	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	
Improving cost-effectiveness	8. Capital cost of hydrogen applications	€/kW	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	<i>TBD⁴⁶</i>	
Synergies with other partnerships	9. Research and Innovation Synergies	# of projects	5	5	10	20	
Increasing Public Awareness	10. Public perception of hydrogen	<i>Qualitative indicator</i>	N/A	N/A	N/A	N/A	
Reinforcing EU scientific and industrial ecosystem, including SMEs	11. Total persons trained	# of persons	4,163	1,000	3,000	6,000	
	12. Patents and publications	# of patents / publications	12 / 289	17 / 350	20 / 400	25 / 450	
	13. Promoting cross-sectoral solutions	# of projects	15	10	15	25	
Impacts							
Reducing GHG emissions	14. Expected avoided emissions	Mt of CO2-eq	<i>TBD⁴⁶</i>	N/A	N/A	N/A	<i>TBD⁴⁶</i> (2030/2050)
Energy transition with renewable hydrogen	15. Deployment of electrolyzers	Gigawatt	1	4	6	10	40 (2030)
	16. Market uptake of clean hydrogen	Mt of clean hydrogen consumed	0.155	0.7	1	2	10 (2030)
Competitive and innovative European hydrogen value chain	17. Total cost of hydrogen at end-use	€/kg	8	6.5	5.5	4.5	3 (2030)
	18. Size of private hydrogen sector	<i>Qualitative indicator</i>	N/A	N/A	N/A	N/A	

⁴⁶ KPIs, including baseline and targets values, will be added as soon as the methodology/definition is determined. The methodology will be published on the website of the Clean Hydrogen Partnership.

2.2.1.3 Risk Assessment

The risk assessment methodology aims to identify the main risks in achieving the objectives of the JU, as represented by its Strategy Map, analyse them and determine action plans on how they should be managed.

In the annual risk assessment exercise, conducted between October 2021 and January 2022, the following significant risks & responses to those risks in terms of action plans were identified (only medium or high risks are presented):

Table 2 Annual Risk Assessment

Risk Level	Objective	Indicators	Risk Identified	Action Plan
HIGH	All objectives	All indicators	<p>Risk of meeting H2020 and Horizon Europe objectives due to insufficient manpower, as in the upcoming years, the programme office will be running two framework programmes simultaneously, H2020 in the peak of implementation, Horizon Europe with increased 50% of the budget (approx. one third to be committed in the first year), with only two additional FTEs for 2022 - 2027.</p> <p>Risk of unclear arrangements of the common back office planned to be in place in 2023 which can result in resources inefficiencies, double work or even staff leaving.</p> <p>(e.g. DG BUDG has already resigned from the role of the accountant of the Clean Hydrogen JU for 2022.)</p>	<p>Use of service contracts for support activities, increased coordination and efficiency gains through synergies with other joint undertakings.</p> <p>Discussion with the GB on the adequacy of the current staff establishment plan supported with a real workload analysis for the entire organisation.</p> <p>Together with other joint undertakings, Clean Hydrogen JU will participate in a common study for the back office arrangements with an external provider to assess efficiencies and potential gains of the planned back office arrangements.</p>
MEDIUM	Supporting market uptake of clean hydrogen applications	Indicator 5 (Table 1)	<p>Risk that Clean Hydrogen JU is unable to manage and to report on EU hydrogen research in accordance with its mandate.</p>	<p>A continuous expansion of the data sources will be sought, including collaboration with entities that can contribute to this e.g. via exchange of information and administrative agreements.</p> <p>The contracts for the FCHO and H2V will be expanded, with more data being collected.</p> <p>Moreover, it will be investigated how to better organise the collected data and ensure their consistency, improve their visualisation and their accessibility by the stakeholders or the public in general, possibly by having one single platform hosting all the different individual platforms supported by the JU, with additional capabilities as necessary.</p>

Risk Level	Objective	Indicators	Risk Identified	Action Plan
MEDIUM	Financial reporting objectives	Representative error rate	<p>Due to limitation of H2020 and Horizon Europe ex-ante controls (trust-based approach with minimum amount of default checks in H2020), representative error rate for Clean Hydrogen JU may increase.</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 a residual representative error rate stays at the level of 2%.</p> <p>(NB: H2020 ex-ante control strategy envisaged level of the residual error rate in the range between 2-5%. Horizon Europe audit strategy has not been defined yet.)</p>	<p>Clean Hydrogen JU has introduced an 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, in line with the internal risk monitoring guidance.</p> <p>Clean Hydrogen JU continues to apply feedback from ex-post audits and lessons learnt on ex-ante controls.</p> <p>Continuation of the financial webinars for beneficiaries with higher inherent and control risks. Follow up action after the webinars via reinforced monitoring.</p> <p>Clean Hydrogen JU will explore the possibility of adding lump sum payments in the future.</p>
MEDIUM	Synergies with other partnerships	Indicator 9 (Table 1)	<p>Risk of missing synergies with other partnerships and other EC programmes or MS/regional funds for hydrogen technologies due to insufficient coordination.</p>	<p>The programme office considers it is in its mandate to coordinate the synergy efforts required by the SBA, building on the extensive experience in implementing such synergies in the existing FCH JU.</p> <p>Forthcoming Stakeholder group should be the required structure for the Clean Hydrogen partnership, to propose and follow-up on synergies with the Programme Office in an effective manner.</p>

2.2.2 Scientific priorities, challenges and expected impacts

Throughout its duration the Clean Hydrogen JU will provide financial support mainly in the form of grants to participants following open and competitive calls for proposals. The Awarded Grants are the main instrument of the Clean Hydrogen JU to implement the actions (Grants) that are needed to reach the SRIA objectives.

In line with the structure of the SRIA, topics in the Call for Proposal are clustered according to Pillars (scientific priorities). Topics under a specific pillar contribute mainly to the objectives of that particular Pillar. Sometimes a topic can contribute to the objectives of several pillars.

In line with the philosophy of Horizon Europe, the topics in this Call for Proposals have been written following an impact driven approach and in line with the standard structure proposed under Horizon Europe. In this regard, each of the topics include a section on expected outcomes and another one on the scope.

To maximise the impacts that can be achieved by each of the topics, the 'expected outcome' section for all topics includes:

- The outcomes that are expected to be reached as a consequence of the achievements of a particular project
- The SRIA objectives that for a specific Pillar are addressed by each of the topics. This is complemented by the inclusion of Programme KPIs⁴⁷ that each of the topics should reach.

The above structure is aligned with the monitoring strategy of the Clean Hydrogen partnership. It will allow a streamlined approach to monitor how the Grants that will be supported contribute to advancing towards the achievements of the Clean Hydrogen Partnership goals.

In 2022 the Call of the JU will contribute to the objectives of the Clean Hydrogen partnership as described below - more detailed information how each of the topics contribute to achieving the objectives of each Pillar is included in the Annexes.

Scientific priority – Renewable Hydrogen production

Renewable hydrogen needs to become cost-competitive and related technologies need to become more reliable and scaled up. To reach this objective, further improvements are required especially in cost reduction, reliability and increase of efficiency for a variety of renewable hydrogen production routes.

On scalability in 2022 Clean Hydrogen JU will support new electrolyser designs for advanced and scalable manufacturing of electrolysers. In addition, industry driven research is proposed to support the development of larger cells and stack with the ultimate objective to build single stacks of 10 MW capacity. To improve the economics of delivering pressurised hydrogen support will be provided to the development of both low and high temperature electrolysers able to produce hydrogen at high pressure as well as in improving electrolysis manufacturing processes.

Concerning alternative to electrolysis hydrogen production technologies, support will be provided in boosting the efficiency of solar thermochemical water splitting.

In 2022 there will be support to three innovation actions. One of the topics calls for the

⁴⁷ Detailed information on the objectives and KPIs available in the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

demonstration of the complete value chain of off-grid hydrogen production, storage and end-use installations at MW scale capitalising on the opportunities for renewable hydrogen production independently of the electricity grid and its levies. The other two topics relate to flagship⁴⁸ projects. The first one should demonstrate in an operational industrial environment improved electrolysis technology at a scale of >25MW, configured to provide the necessary reliability of supply at the lowest possible cost of bulk renewable hydrogen to one or more hydrogen users, possibly using the oxygen as well. This action is expected to pave the way for further large-scale integration of electrolyser systems in industrial applications in the framework of fully commercial operations and is a topic that could lead to synergies with the P4P Partnership. The second flagship should demonstrate at multi-MW scale (>5MW) the technical and economic feasibility of offshore renewable hydrogen production, in the context of the EU Strategy on Offshore Renewable Energy⁴⁹.

Scientific priority - Hydrogen Storage and distribution

As explicitly mentioned in the EU Hydrogen Strategy, it is essential that hydrogen becomes an intrinsic part of an integrated energy system. In order for this to happen, hydrogen will have to be used for daily and/or seasonal storage providing buffering functions thereby enhancing security of supply in the medium term. The strategy also calls for an EU-wide logistical infrastructure that needs to be developed to transport hydrogen from areas with large renewable potential to demand centres across Europe. Significant work is still needed to have a complete set of technologies that can serve as building blocks of the EU-wide logistical infrastructure.

In 2022 Clean Hydrogen JU will support the injection of hydrogen into the distribution level of the natural gas by studying the effects of various natural gas/hydrogen blends and looking at the effects of having 100% hydrogen. It also plans to support the development of novel sensor systems for in order to have appropriate leak detection devices for various applications ensuring the safety of hydrogen technology use.

With respect to hydrogen carriers, support will be provided to the development of improved dehydrogenation technologies for both liquid organic hydrogen carriers (LOHCs) and ammonia, aiming at higher efficiencies and lower costs.

On the topic of liquid hydrogen in 2022 Clean Hydrogen JU will support the development of an improved liquefaction prototype aiming at improved efficiencies and costs while targeting a scalability of 100 tonnes per day (TPD). In addition, it will support the development of a large liquid hydrogen containment unit for shipping which will be tested in a scaled-down prototype with a capacity of 10 tonnes.

Continuing on the distribution of hydrogen, the Clean Hydrogen JU will support the development of compressed gas tube trailers with increased capacity with the target of having a tube trailer of 1.2 tonne capacity as an end result of the project.

It has also become very clear through various demonstration projects that a critical component in the hydrogen infrastructure is the compression system. Hence in 2022 Clean Hydrogen JU will support the scale-up of a novel compression system targeting better availabilities, lower cost and improved efficiency.

Finally, on the topic of Hydrogen Refuelling Stations in 2022 the Clean Hydrogen JU will support the development of refuelling protocols as well as improved components in order to

⁴⁸ For definition of flagship see section 5.3 of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

⁴⁹ An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future. COM(2020) 741 final.

address the requirements of heavy-duty applications. On top of this it will support the improvement of quality assurance mechanisms for Hydrogen Refuelling Stations to ensure a high-level of customer satisfaction.

Scientific priority - Hydrogen end uses - transport

Looking at fuel cells and hydrogen mobility solutions, despite recent leaps forward these need to reach an even greater level of maturity. A number of specific applications need further improvements, especially in the context of reducing costs and increasing performance and durability, in order to make them competitive with incumbent technologies.

Building on the activities and results of FCH 2 JU, in 2022 Clean Hydrogen JU will support research and development (R&D) for innovative membrane electrode assemblies (MEA) and proton exchange membrane fuel cell (PEMFC) stacks for heavy-duty vehicles. Also for heavy-duty one topic will support the development and integration of an improved liquid hydrogen (LH₂) vessel in road long distance heavy-duty vehicles.

In order to support and accelerate the wide roll out of hydrogen mobility options in 2022, support will be provided to two ambitious and necessary flagship⁵⁰ projects. The first one will lead to the deployment a minimum of 150 heavy-duty vehicles (trucks) across along the TEN-T corridors. This topic is calling for at least 3 original equipment manufacturers (OEM) and 6 operators to engage in this action. For waterborne applications the focus is on inland waterway vessels. The support will be provided for the deployment of a first of its kind sizeable fleet of at least 5 inland vessels with fuel power above 500kW and preferably at 1 MW scale. For the refuelling infrastructure in these two projects synergies with CEF Transport programme are foreseen.

Aeronautics is one of the EU's key high-tech sectors on the global market. With world leading aircraft companies and expertise in fuel cell technologies, Europe could play a vital role in driving the transformation of aviation to reduce emissions. To this end in 2022 Clean Hydrogen JU will provide support to the development and optimisation of dedicated fuel cells for aviation. In addition, support will be provided for the development of specific cryogenic and lightweight storage system for aviation.

Scientific priority - Hydrogen end uses - clean heat and power

Hydrogen offers a unique chance to decarbonise the power generation and heating sectors reliably and independently from weather or seasonal conditions. The main goal of the Clean Hydrogen JU in this pillar is to support European industry to develop a portfolio of cost-competitive solutions providing clean, renewable and flexible heat and power generation for all end users' needs and across all system sizes; from domestic systems all the way to large-scale power generation plants. For stationary fuel cells after successful demonstration of the performance of fuel cell driven devices the automation of their production is the next necessary step for their broad deployment. In 2022 it is expected to support the design and industrial deployment of innovative manufacturing processes for solid oxide fuel cells systems and components with automation/equipment manufacturer/s at the core. This should contribute to reaching stack manufacturing costs for solid oxide technology of ≤800 €/kW at annual production volume of single manufacturing line of at least 100 MW.

With the decarbonisation targets ahead in mind the focus of the Clean Hydrogen JU is to prepare and demonstrate the next generation of fuel cells for stationary applications able to run under 100% hydrogen and other hydrogen-rich fuels whilst keeping high performance. In

⁵⁰ For definition of flagship see section 5.3 of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

2022 the Clean Hydrogen JU proposes to support the development and validation of ammonia fuel cell solutions. It is also proposed to support the development and validation of reversible Solid Oxide Cell systems able to operate with 100% hydrogen but also with mixtures of hydrogen and natural gas. Such systems should be able to produce renewable hydrogen production and its injection in the gas or hydrogen grid at a distributed level, offering new business models for hydrogen supply for gas and energy companies. System roundtrip efficiency of at least 38% when operating with hydrogen is targeted.

Finally, to support the decarbonisation of power and heat supply with gas turbines it is necessary to fuel switch to hydrogen. In this regards, Clean Hydrogen JU will support in 2022 the Clean Hydrogen JU support the development and demonstration of gas turbines able to run on higher admixtures of hydrogen, up to 100% whilst keeping low NO_x emissions, high efficiencies and flexible operation

Scientific priority - Cross-Cutting activities

As markets for hydrogen and fuel cell technologies develop and become more widely adopted in the market it becomes crucial to raise public awareness, trust and acceptance in hydrogen technology and hydrogen-based products and their system benefits. The challenge resides in understanding reactions and attitudes towards FCH technologies among citizens, consumers, and stakeholders in Europe. In 2022, the Clean Hydrogen JU will support a topic aiming to address this challenge.

It will also support two topics with the objective of increasing the level of safety of hydrogen technologies and applications. One topic will look at the safety aspects of handling liquid hydrogen in public areas and another will look at the impact of injecting hydrogen on gas Transportation and Distribution (T&D) network components and on all end-users connected to the gas infrastructure. Both of these topics will contribute to the development of RCS with a focus on standards.

In addition, building on results from previous and ongoing projects, in 2022 Clean Hydrogen JU will support a topic aiming to validate technical and metrological requirements for measuring devices used in the gas distribution and transmission networks. These activities are expected to result, among others, in the definition of hydrogen limits and tolerances for currently used measuring devices.

Scientific priority - Hydrogen Valleys

Building on the successful experience of previous years (Hydrogen Valleys in the FCH 2 JU Call 2019 and Hydrogen Islands in the FCH 2 JU Call 2020), the Clean Hydrogen JU proposes to support a flagship⁵¹ Hydrogen Valley of a scale significantly larger to what has been supported to date. In this year topic the ambition is to support the deployment of a large-scale hydrogen valley (at least 5,000 tonnes / year) with interlinkages to other places of hydrogen production and/or consumptions outside its boundaries. In addition, the Clean Hydrogen JU proposes to support a smaller scale project (at least 500 tonnes / year) in areas of Europe with no or limited presence of H₂ Valleys such as in Central and Eastern European Countries.

Scientific priority - Hydrogen Supply Chains

Europe will have to expand considerably the hydrogen production capacity to reach the industrial-scale applications and meet the EU hydrogen strategy targets. For doing so, the hydrogen industrialisation has to rely on a robust and sustainable domestic supply chain.

⁵¹ For definition of flagship see section 5.3 of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

This area of the SRIA aims to support strengthening the Europe's supply chain of hydrogen technologies.

Building on previous studies in 2022 Clean Hydrogen JU will support a study to reassess the current status of the hydrogen supply chain, update the EU/global manufacturers list, identify potential gaps in the domestic supply and determine any future bottlenecks according to relevant deployment scenarios. The study should also capture the socio-economic aspects (e.g. competitive advances, skill, jobs, etc.) through a value chain analysis and provide recommendations how to support from a technological point of view the increase of their production capacity in Europe.

Scientific priority - Strategic Research Challenges

The activities in this area of the SRIA aim to ensure a continuous generation of early -stage research knowledge in different disciplines. In 2022 the Clean Hydrogen JU will support a topic to address one of the Strategic Research Challenges⁵² included in SRIA: the sustainability and criticality of electrolyser and fuel cell materials by the development of technical advancements in (i) replacement of the critical (raw) materials including those of environmental concerns (e.g. polyfluorinated ionomers) (ii) reduction in the amount of CRM used and (iii) developing breakthrough high-efficient recycling approaches for materials critical for fuel cells and electrolysers, including novel means of dissociating and separating components.

International collaboration

Finally, to foster cooperation with Africa, Clean Hydrogen JU will support a topic aiming to create enabling conditions for the development of renewable hydrogen technology and market that would contribute to the social, economic and environmental transition of the African continent. This should lead to the preparation of a strategic and comprehensive innovation roadmap to technology development and market introduction in the context of African national and continental industrial strategy and energy infrastructures. Mutual benefits to stakeholders, citizens and policies of both African Union and European Union should be identified as a result.

The correspondence of topics into the different scientific priorities is shown below.

⁵² For definition of Strategic Research Challenges see section 3.9 of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

Table 3 Correspondence of topics into the different scientific priorities according to the Call deadline

	Deadline (31 May 2022)	Deadline (20 September 2022)
Renewable Hydrogen	<p>HORIZON-JTI-CLEANH2-2022-01-01: Development and validation of pressurised high temperature steam electrolysis stacks (Solid Oxide Electrolysis)</p> <p>HORIZON-JTI-CLEANH2-2022-01-02: Development and validation of pressurised high temperature steam electrolysis stacks (Proton Conducting Ceramic Electrolysis)</p> <p>HORIZON-JTI-CLEANH2-2022-01-03: Development of low temperature water electrolyzers for highly pressurised hydrogen production</p> <p>HORIZON-JTI-CLEANH2-2022 -01-06: Efficiency boost of solar thermochemical water splitting</p> <p>HORIZON-JTI-CLEANH2-2022 -01-07: Bringing green hydrogen MW scale off grid installations closer to technical and financial maturity</p> <p>HORIZON-JTI-CLEANH2-2022 -01-09: Scaling-up technologies for SOEL</p>	<p>HORIZON-JTI-CLEANH2-2022 -01-04: Design for advanced and scalable manufacturing of electrolyzers</p> <p>HORIZON-JTI-CLEANH2-2022 -01-05: Scaling up of cells and stacks for large electrolyzers</p> <p>HORIZON-JTI-CLEANH2-2022 -01-08: Integration of multi-MW electrolyzers in industrial applications</p> <p>HORIZON-JTI-CLEANH2-2022 -01-10: Demonstrating offshore production of green hydrogen</p>
Hydrogen storage and distribution	<p>HORIZON-JTI-CLEANH2-2022 -02-02: Hydrogen and H2NG leak detection for continuous monitoring and safe operation of HRS and future hydrogen/H2NG networks</p> <p>HORIZON-JTI-CLEANH2-2022 -02-03: Validation of a high-performance hydrogen liquefier</p> <p>HORIZON-JTI-CLEANH2-2022 -02-07: Increased hydrogen capacity of GH2 road trailers</p> <p>HORIZON-JTI-CLEANH2-2022-02-08: Development of novel or hybrid concepts for reliable, high capacity and energy-efficient H2 compression systems</p> <p>HORIZON-JTI-CLEANH2-2022 -02-09: Sampling methodology and quality assessment of HRS at real-world scale</p> <p>HORIZON-JTI-CLEANH2-2022 -02-10: Implementing new/optimised refuelling protocols and components for high flow HRS</p>	<p>HORIZON-JTI-CLEANH2-2022 -02-01: Compatibility of Distribution non-steel metallic gas grid materials with hydrogen</p> <p>HORIZON-JTI-CLEANH2-2022 -02-04: Ammonia to Green Hydrogen: efficient system for ammonia cracking for application to long distance transportations</p> <p>HORIZON-JTI-CLEANH2-2022 -02-05: Efficient system for dehydrogenation of liquid organic hydrogen carriers for application to long distance transportations</p> <p>HORIZON-JTI-CLEANH2-2022 -02-06: Development of large scale LH2 containment for shipping</p> <p>HORIZON-JTI-CLEANH2-2022 -02-11: Development and demonstration of mobile and stationary compressed hydrogen refuelling solutions for application in inland shipping and short-distance maritime operations</p>

	Deadline (31 May 2022)	Deadline (20 September 2022)
Hydrogen end uses: transport applications	<p>HORIZON-JTI-CLEANH2-2022 -03-02: Innovative and optimised MEA components towards next generation of improved PEMFC stacks for heavy-duty vehicles</p> <p>HORIZON-JTI-CLEANH2-2022 -03-03: Large scale demonstration of European H2 Heavy-Duty Vehicle along the TEN-T corridors</p> <p>HORIZON-JTI-CLEANH2-2022 -03-04: LH2 tanks for heavy-duty vehicles</p> <p>HORIZON-JTI-CLEANH2-2022 -03-05: Large scale demonstration of hydrogen fuel cell propelled inland waterway vessels</p> <p>HORIZON-JTI-CLEANH2-2022-03-06: Development and optimisation of a dedicated Fuel Cells for Aviation: from dedicated stack (100s kW) up to full system (MWs)</p> <p>HORIZON-JTI-CLEANH2-2022-03-07: Development of specific aviation cryogenic storage system with a gauging, fuel metering, heat management and monitoring system</p> <p>HORIZON-JTI-CLEANH2-2022-03-08: Development and optimisation of a dedicated Fuel Cells for Aviation: disruptive next-gen high temperature Fuel Cells technology for future aviation</p>	<p>HORIZON-JTI-CLEANH2-2022 -03-01: Development and optimisation of reliable and versatile PEMFC stacks for high power range applications</p>
Hydrogen end uses: clean heat and power	<p>HORIZON-JTI-CLEANH2-2022 -04-02: Ammonia powered fuel cell system focusing on superior efficiency, durable operation and design optimisation</p> <p>HORIZON-JTI-CLEANH2-2022 -04-03: Reversible SOC system development, operation and energy system (grid) integration</p> <p>HORIZON-JTI-CLEANH2-2022 -04-04: Dry Low NO_x combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications</p>	<p>HORIZON-JTI-CLEANH2-2022 -04-01: Design and industrial deployment of innovative manufacturing processes for fuel cells and fuel cell components</p>
Cross-cutting Issues	<p>HORIZON-JTI-CLEANH2-2022 -05-02: Safety of cryogenic hydrogen transfer technologies in public areas for mobile application</p> <p>HORIZON-JTI-CLEANH2-2022 -05-04: Development of validated test methods and requirements for measuring devices intended for measuring NG/H2 mixtures</p> <p>HORIZON-JTI-CLEANH2-2022 -05-05; Research & Innovation co-operation with Africa on hydrogen</p>	<p>HORIZON-JTI-CLEANH2-2022 -05-01: Public understanding of hydrogen and fuel cell technologies</p> <p>HORIZON-JTI-CLEANH2-2022 -05-03: Safe hydrogen injection management at network-wide level: towards European gas sector transition</p>

Deadline (31 May 2022)		Deadline (20 September 2022)
Hydrogen Valleys		HORIZON-JTI-CLEANH2-2022 -06-01: H2 Valley (large-scale) HORIZON-JTI-CLEANH2-2022 -06-02: H2 Valley (small-scale)
Strategic Research Challenges	HORIZON-JTI-CLEANH2-2022 -07-01: Addressing the sustainability and criticality of electrolyser and fuel cell materials	

2.2.3 Call for Proposals

2.2.3.1 Call

The AWP 2022 includes one Call for Proposals with two deadlines as follows:

Call Identifier	Budget (EUR mill)	Publication ⁵³	Deadline
HORIZON-JTI-CLEANH2-2022			
HORIZON-JTI-CLEANH2-2022-1	179.50	01 March 2022	31 May 2022
HORIZON-JTI-CLEANH2-2022-2	121.00	01 March 2022	20 September 2022
Overall indicative budget	300.50		

Proposals are invited against the following topic(s):

Topic descriptions are detailed starting from the next page.

⁵³ The Executive Director may decide to open the call up to one month prior to or after the envisaged date of publication.

RENEWABLE HYDROGEN PRODUCTION

HORIZON-JTI-CLEANH2-2022-01-01: Development and validation of pressurised high temperature steam electrolysis stacks (Solid Oxide Electrolysis)

Specific conditions	
<i>Expected EU contribution per project</i>	The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.5 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project. See General Annex B.

Expected outcome

Hydrogen is stored, transported or used pressurised with variable pressures depending on user cases (e.g. between 7 and 70 bar for various industrial applications and grid injection, up to 200 bar for filling gas cylinders, as well as up to 350 and 700 bar in refuelling stations). Hydrogen compression requires energy, which negatively affects overall process efficiency and hydrogen molecule final cost. Pressurised electrolysis therefore has the potential to provide an efficient solution for delivery of pressurised hydrogen at reduced cost. It also enables a low emissions form of hydrogen production, including down to zero emissions if powered solely by renewables.

It is expected that this topic will provide breakthrough and game changing technologies for energy efficient pressurised hydrogen production using solid oxide electrolyzers (SOEL) and contributing to the overall objective of the SRIA of the Clean Hydrogen JU, namely the hydrogen production cost of 3 €/kg by 2030.

The project outcomes will pave the way for the deployment of pressurised hydrogen production units using SOEL to accelerate uptake in one or more applications (e.g. injection into the gas grid, onsite production at hydrogen refuelling stations (HRS), feedstock for industry, such as steel plants, refineries, chemical plants).

The project results are expected to contribute to all of the following expected outcomes:

- Contributions to demonstration on stack level for a pressurised steam electrolysis solutions by 2025;
- Contributing to European leadership for renewable hydrogen production based on SOEL;
- Solutions for pressurised hydrogen production should vary from 5 bar to several hundreds. They will open new production of hydrogen for target applications that will be opened up (e.g., gas grid injection, HRS) at scale of minimum 10 kW operated in a laboratory or simulated environment for at least 2,000 hours;
- Contributing to defining use cases showing the applications and the benefits of the

novel technology.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Reduction of CAPEX 2,000 €/kg/d and OPEX 130 € (kg/d)/y (of the overall system costs when also taking into account compression);
- Ensure circularity by design for materials and for production processes, minimising the life-cycle environmental footprint of electrolysers;
- Electricity consumption at nominal capacity of 39 kWh/kgH₂;
- Heat demand at nominal capacity of 9 kWh/kgH₂ by 2024;
- Stack current density 0.85 A/cm²;
- Stack pressure of at least 5 bar.

Scope

Solid Oxide Electrolysis (SOEL) operating at 650-850°C, can be improved with pressurised operation. The integration of SOE stacks with balance of plant components proved the successful use of these systems at now significant scale (> 700 kW) and the road is paved towards MW scale thanks to a modular approach simplifying the scale-up step. However, these systems are designed for operating efficiently and durably at atmospheric pressure. There have been previous FCH JU projects⁵⁴ dedicated to pressurised High-Temperature Steam Electrolysis (HTSE) at small scale for SOE. Pressurised operation has been validated up to 30 bar at cell scale, and up to 15 bar at stack scale embedded in a pressure vessel⁵⁵. These previous activities highlighted the need for more research efforts directed to the optimisation of components, cells and stacks to improve current density and stability in pressurised operation for SOEL technologies. Furthermore, additional efforts should focus on system integration and on defining optimal boundary operations for dedicated user cases in order to maximise the efficiency of the integrated scenarios (e.g. taking into account thermal integration and possible side stream products). This opens for the development of novel and/or improved systems concepts, where the benefits of pressurised electrolysis should be leveraged for deployment in large-scale centralised systems with economies of scale, hydrogen distribution to end uses, as well as distributed systems located at demand centres.

Proposals for this topic should set out a credible pathway to contribute to the development and validation of pressurised SOEL with technological breakthroughs aiming at designing and operating a stack at an optimal pressure with eventual assistance of a downstream compression process to reach higher delivery pressure. Electrochemical compression in the stack can also be considered. To tackle these challenges, the proposals should focus on system and stack design, as well as fabrication, assembly and testing of stack in the conditions suitable for the relevant business cases as follows:

- System design should be defined based on optimal integration of SOEL in selected application(s) taking into account the operating limits of the SOEL. This activity will entail defining the optimal operating pressure of the stack and system to balance electricity consumption and heat demand at nominal capacity;

⁵⁴ https://www.clean-hydrogen.europa.eu/projects-repository_en

⁵⁵ SOPHIA and HELMETH projects: https://www.clean-hydrogen.europa.eu/projects-repository_en

- A techno-economic evaluation of the SOEL integrated in given application(s) will provide Levelised Cost of Hydrogen (LCOH) of the pressurised SOEL system taking into account economy of scale and will be used to evaluate the impacts of the various modes of operation (e.g. atmospheric SOEL + pressurisation afterwards, pressurised SOEL, and combination of modes). Comparing the technology with e.g. other alkaline and PEM electrolysers, operating in pressurised mode using similar boundary limits will also provide insights into relevant business models. The proposals will furthermore aim at reaching the capital costs below 2,000 €/kg/d. The project should also compare the efficiency gains between pressurised electrolyser and unpressurised with compressor for various system sizes;
- Stack designed for high current density (SOEL: 0.85 A/cm²) should be successfully operated over one long term test of at least 2,000 hours and 4,000 hours of aggregated testing time in relevant pressurised operating conditions at a minimum of 5 bar and conforming to the envisaged use case;
- Degradation mechanisms and boundary operation of the stack and its components should be identified with respect to pressure, temperature, load, in stationary and transient conditions;
- Modelling should be used to support the development of cells and/or stacks.
- The stack(s) should be tested at scale of minimum 10 kW; the considered pressure will be selected in relation to the targeted use case (s) to minimise energy loss;
- The stack should be operated in representative conditions to evaluate its, as well as its durability during a 2,000 hours long term test. This should include some pressurisation/depressurisation cycles;
- The applicants should provide thorough analysis of safety aspects, such as safety shut-off, and focus on establishing smooth operation modes including pressurisation and depressurisation.

Consortia are expected to build on the expertise from the European research and industrial community to ensure broad impact by addressing several of the aforementioned items.

Proposals are expected to address sustainability and circularity aspects.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁵⁶ to benchmark performance and quantify progress at programme level.

⁵⁶ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-02: Development and validation of pressurised high temperature steam electrolysis stacks (Proton Conducting Ceramic Electrolysis)

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.5 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project See General Annex B.

Expected outcome

Hydrogen is stored, transported or used pressurised with variable pressures depending on user cases, e.g., between 7 and 70 bar for various industrial applications and grid injection, up to 200 bar for filling gas cylinders, as well as up to 350 and 700 bar in refuelling stations. Hydrogen compression requires energy, which negatively affects overall process efficiency and hydrogen molecule final cost. Pressurised electrolysis therefore has the potential to provide an efficient solution for delivery of pressurised hydrogen at reduced cost. It also enables a low emissions form of hydrogen production, including down to zero emissions if powered solely by renewables.

It is expected that this topic will provide breakthrough and game changing technologies for energy efficient pressurised hydrogen production using Proton Conducting Ceramic Electrolysis (PCCEL) and contributing to the overall objective of the SRIA of the Clean Hydrogen JU, namely the hydrogen production cost of 3 €/kg by 2030.

The project outcomes will pave the way for the deployment of pressurised hydrogen production units based on proton conducting electrolyte to accelerate uptake in one or more applications (for example: injection into the gas grid, onsite production at HRS, feedstock for industry, such as steel plants, refineries, chemical plants).

The project results are expected to contribute to all of the following expected outcomes:

- Contributions to demonstration on stack level for a pressurised steam electrolysis solutions by 2025;
- Contributing to European leadership for renewable hydrogen production based on PCCEL;
- Solutions for pressurised hydrogen production will open new target applications (e.g. gas grid injection, HRS) contributing to defining user cases and showing the applications and benefits of the novel technologies

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Reduction of CAPEX 2,000 €/(kg/d) and OPEX 130 €/(kg/d)/y (of the overall system costs when also taking into account compression).
- Ensure circularity by design for materials and for production processes, minimising the life-cycle environmental footprint of electrolyzers;
- Achieving a current density of 0.5 A/cm²;
- Achieving a pressure at stack level of at least 5 bar;
- Faradaic efficiency above 90% at operational pressure and temperature.

Scope

For High Temperature Steam Electrolysis (HTSE), the Protonic Conducting Ceramic Electrolysis (PCCEL) operating at 500-700 °C can be a promising solution. PCCEL technology has emerged over the past decade with strong development in materials and cells research, while activities towards stack and system development have been marginal. There have been previous FCH JU projects dedicated to pressurised HTSE at small scale for PCCEL. For instance, pressurised PCCEL electrolysis cells with tubular geometry are showing high Faradaic efficiency (> 90%) and stable performance at 600°C up to 3 bar. These previous activities highlighted the needs for more research efforts directed to the optimisation of components, cells and stacks to improve current density and stability in pressurised operation for both technologies. Furthermore, additional efforts should focus on system integration and on defining optimal boundary operations for dedicated user cases in order to maximise the efficiency of the integrated scenarios (e.g. taking into account thermal integration and possible side stream products). This opens for the development of novel and/or improved systems concepts, where the benefits of pressurised electrolysis should be leveraged for deployment in large-scale centralised systems with economies of scale, hydrogen distribution to end uses, as well as distributed systems located at demand centres.

Proposals for this topic should set out a credible pathway to contribute to the development and validation of pressurised PCCEL with technological breakthroughs aiming at designing and operating a stack at an optimal pressure with eventual assistance of a downstream compression process to reach higher delivery pressure. Electrochemical compression in the stack can also be considered. To tackle these challenges, the proposals should focus on system and stack design, as well as fabrication, assembly and testing of stack in the conditions suitable for the relevant business cases as follows:

- System design should be defined based on an optimal integration of the PCCEL in selected application(s) while taking into account the operating limits of the PCCEL. This activity will entail defining optimal operating pressure of the stack and system to balance electricity consumption and heat demand at nominal capacity;
- A techno-economic evaluation of the PCCEL integrated in given application(s) will provide the Levelised Cost of Hydrogen (LCOH) of the pressurised PCCEL system taking into account economy of scale and will be used to evaluate the impacts of the various modes of operation. (e.g. atmospheric PCCEL + pressurisation afterwards, pressurised PCCEL, electrochemical compression in the PCCEL, and combination of modes) Comparing the technology with e.g. other alkaline and PEM electrolyzers, operating in pressurised mode using similar boundary limits should also provide insights into relevant business models. The proposals should furthermore aim at reaching the capital costs below 2,000 €/(kg/d);

- The project should also compare the efficiency gains between pressurised electrolyser and unpressurised with compressor for various system sizes and propose the most efficient solution;
- A stack designed for high current density (0.5 A/cm²), should be successfully operated over one long term test of at least 2,000 hrs and 4,000 hours of aggregated testing time in relevant pressurised operating conditions at a minimum pressure of 5 bar and conforming to the envisaged use case;
- Degradation mechanisms and boundary operation of the stack and its components should be identified and measured with respect to pressure, temperature, load, in stationary and transient conditions;
- Modelling should be used to support the development of cells and/or stacks;
- The stack(s) should be tested at scale of minimum 5 kW; the considered pressure will be selected in relation to the targeted use case (s) to minimise energy loss;
- The stack should be operated in representative conditions to evaluate its efficiency, as well as its durability during a 2,000 hours long term test. This should include pressurisation/depressurisation cycles;
- The applicants should provide thorough analysis of safety aspects, such as safety shut-off, and focus on establishing smooth operation modes including pressurisation and depressurisation.

Consortia are expected to build on the expertise from the European research and industrial community to ensure broad impact by addressing several of the aforementioned items.

Proposals should demonstrate how they go beyond the ambition of WINNER and GAMER projects⁵⁷ and be complementary to them.

Proposals are expected to address sustainability and circularity aspects.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁵⁸ to benchmark performance and quantify progress at programme level.

⁵⁷ https://www.clean-hydrogen.europa.eu/projects-repository_en

⁵⁸ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-03: Development of low temperature water electrolyzers for highly pressurised hydrogen production

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 5.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 2 and achieve TRL 5 by the end of the project See General Annex B.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches, grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds.

Expected Outcome

The current generation of Low Temperature Water Electrolyzers (LT-WE) are demonstrated on a large scale and are ready for mass production. However, to reduce the Levelised Cost of Hydrogen (LCOH) and to make renewable hydrogen competitive with hydrogen from fossil sources, continuous improvements to LT-WE systems that avoid energy and cost intensive downstream mechanical compression processes, especially in the first stages, are required. Therefore, to maintain and accelerate the European leadership position in water electrolysis technology and innovation in the whole supply chain, new research and innovation (in parallel to upscaling) are crucial in the electrolyser stack design as whole and the different critical components including Balance of Plant (BoP).

Low temperature water electrolyzers are expected to produce hydrogen at high pressure (from 50 to 80 bar), accelerating the adoption in several applications such as gas grid injection, as well as utilisation in the chemical industry and at hydrogen refuelling stations (HRS), circumventing the initial compression stages.

Project results are expected to contribute to all of the following expected outcomes:

- Contributing to keep European leadership for pressurised hydrogen production including innovative embedded compression approaches based on: Alkaline (AEL) or Proton Exchange Membrane (PEMEL) or Anionic Exchange Membrane (AEMEL) Electrolyser systems;
- Contributions to full scale demonstrators by 2027;
- New business models for end use applications such as hydrogen injection in the existing gas grid and utilisation in the chemical industry;

- A boost for future dedicated transmission gas network and methanol ammonia production while strengthening EU supply chain and HRS developers.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Improving efficiency by 2-4% (lower heating value, LHV) compared to the use of a mechanical compressor 0.5kWh for mechanical compression of 1kg H₂ from 30 to 80 bar;
- Increase system and components reliability and significantly reduce compression energy needs resulting in an overall lower levelised cost of hydrogen (LCOH) below 3 €/kg once integrated in the multi-MW electrolyser platform assuming 40 €/MWh and 4,000 full load hours operation;
- Demonstrate the value of electrolysers for the power system through their ability to allow higher integration of renewables.

Research findings and outcomes at stack and balance of plant level will contribute to speed up the reduction of the levelised cost of hydrogen. Proposals should investigate the high-pressure effects on the overall electrolysis process, since the increase of gas solubility might reduce the dynamic operating range while increase the corrosion/degradation of the materials.

Some of the barriers to be addressed are in line to novel design concepts and compatible materials while finding some high-pressure specific components might be challenging.

Research will contribute to a faster achievement towards the 2024 KPIs of the Clean Hydrogen JU SRIA, whilst allowing electrolysers to a fully integrated operation with renewable energy sources (RES) and direct gas grid connection and limiting the use of critical raw materials and precious metals as oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) catalysts or replace them completely with other (more) available metals.

The project results will also contribute to speed up the achievement of some of the key 2024 KPIs of the Clean Hydrogen JU SRIA for LT-WE according to the following figures for each technology:

- AEL, Electricity consumption @ nominal capacity (kWh/kg) 49, Degradation (%/1,000 hrs) 0.11, Minimum pressurisation levels (bar) 50, Minimum stack size (kW) 50;
- PEMEL, Electricity consumption @ nominal capacity (kWh/kg) 52, Degradation (%/1,000 hrs) 0.15, Minimum pressurisation levels (bar) 80, Minimum stack size (kW) 50;
- AEMEL, Electricity consumption @ nominal capacity (kWh/kg) 53, Degradation (%/1,000 hrs) 0.9, Minimum pressurisation levels (bar) 50, Minimum stack size (kW) 25.

Due to the higher pressure, the temperature may also be raised to above 100°C, which will in turn drastically reduce the H₂ production energy consumption contributing to reduction in overall hydrogen production costs.

Scope

High-pressure electrolyzers should be compatible with direct injection into chemical industry and gas networks both onshore and offshore as the avoidance of mechanical compressors are of crucial importance to reduce the LCOH and improve the availability of systems. The developed electrolyzers may reach low LCOH for both centralised and decentralised applications due to the unique modular approach.

The scope of this project is to develop the next generation of water electrolyzers (PEMEL or AEMEL) operating below 150 °C for pressurised hydrogen production at the pressure of minimum 50 bar for AEL and AEMEL and 80 bar for PEMEL further advancing innovations developed in projects⁵⁹ like NEPTUNE and PRETZEL.

To this extent, breakthroughs in materials science of cell components should encompass advances in the cell design, cell architecture and BoP modules. This requires a completely new design enabling: low energy consumption and low degradation rates while contributing to reduce the hydrogen production costs.

Novel stack concepts should be designed, whilst innovations in BoP (e.g., integration of innovative compression solutions with electrolyser stacks), advanced materials with longer term durability and components (membranes/diaphragms, porous transport layers, bipolar plates, catalysts) developed and integrated into a short-stack prototype.

Targeted prototype scale and cell size should be appropriate for targeted application but a scale of minimum 50 kW for AEL and PEMEL and 25 kW for AEMEL, including larger cell areas than SoA, should be addressed.

Proposals should demonstrate how the concepts developed will be validated in a laboratory (TRL4) but should also include testing in relevant environment (TRL5) to pave the way for end-use applications (e.g. technology could be tested for injection in transmission natural gas grid). This includes the validation at the single cell and stack levels, testing the components at nominal, steady state and dynamic conditions and identifying a best candidate solution.

Operations at elevated pressures should be validated under various operating conditions (understood as directly scalable to multi-MW electrolyzers) in order to develop new control strategies and to optimise operation at high-pressure and evaluate the effect of pressure in the case of hot starts and cold starts.

Proposals should investigate the high-pressure effects on the overall electrolysis process, both with respect to the effect of increased gas solubility, bubble-formation and the effect on electrode overpotentials and ohmic losses as well as the associated increase in gas cross-over at elevated pressures.

Optimal stack and cell design in terms of structure and geometry (e.g. spacing distances within the cell) should be within the scope of proposals.

Research on corrosion effects on the cells and/or lifetime prediction model and mitigation strategies should be conducted in order to maintain lifetime and degradation.

Proposals are expected to address sustainability and circularity aspects.

⁵⁹ https://www.clean-hydrogen.europa.eu/projects-repository_en

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁶⁰ to benchmark performance and quantify progress at programme level.

⁶⁰ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-04: Design for advanced and scalable manufacturing of electrolyzers

Specific conditions	
<i>Expected contribution per project</i>	<i>EU per</i> The JU estimates that an EU contribution of around EUR 2.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 4.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Manufacturing Readiness Level</i>	Activities are expected to start at MRL 4 and achieve MRL 5 by the end of the project See Call management and general conditions section.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches, grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds

Expected Outcome

The huge leap expected in the evolution of water electrolyser technology can be performed only by reaching significant technical and economic targets. The European Hydrogen strategy targets 6 GW installed electrolyser capacity by 2024 ramping up to 40 GW electrolyser capacity by 2030. To achieve such targets, both products and production processes should undergo a significant enhancement, by means of strong cost reduction program, as well as improved automation and technologies. Such upgrades can be applied to the several steps of manufacturing, starting from the single electrolyser cell to the stack assembly. Therefore, it is necessary that the whole manufacturing chain is involved in this cost reduction/performance improvement of the electrolyser stacks required to produce enough renewable hydrogen to fulfil the EU targets, similarly to the on-going manufacturing development of fuel cells (e.g. slot die coating for Catalyst Coated Membrane, plasma spray, roll-to-roll coaters).

The project should aim to find the best compromise between CAPEX and OPEX⁶¹ costs to minimise the cost of produced hydrogen, also considering the output pressure.

At the end of the project the achievement of the target figures described in detail above should be demonstrated. The outcome should be a novel component(s) or manufacturing process(es) integrated in a demonstrator stack. The scalability of the final demonstrator and the cost targets of hydrogen should be clearly proven with a business plan.

Project results are expected to contribute to all the following expected outcomes:

⁶¹ O&M costs

- Improving efficiency by 2-4% LHV compared to the use of the present state of the art solutions;
- Increase system reliability and significantly reduce manufacturing costs resulting in an overall lower CAPEX and reaching a projected levelised cost of hydrogen (LCOH) below 3 €/kg assuming 40 €/MWh and 4,000 full load hours operation @, after the scaling up of the foreseen manufacturing techniques;
- Demonstrate the value of advanced manufacturing techniques to reduce manufacturing times enhancing printing or assembly tolerances versus the state of the art.

To address the above-mentioned cost system targets, the project is focusing on stack/components manufacturing and should at least reach the 2024 KPIs stack targets (degradation, current density, limited use of Critical Raw Materials) included in the Clean Hydrogen JU SRIA. Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA as summarised below.

- AEL Degradation (%/1,000 hrs) 0.11, Current density (A/cm²) 0.7, Use of CRMs as catalysts (Mg/W) 0.3;
- PEMEL Degradation (%/1,000 hrs) 0.15, Current density (A/cm²) 2.4, Use of CRMs as catalysts (Mg/W) 1.25;
- AEMEL Degradation (%/1,000 hrs) 0.9, Current density (A/cm²) 0.6, Use of CRMs as catalysts (Mg/W) 0.4;
- SOEL Degradation (%/1,000 hrs) 1, Current density (A/cm²) 0.85.

European R&D institutions and hydrogen-related companies should join their efforts to reach the following targets provided by the system costs Key Performance Indicators (KPIs), which have been set for all the major electrolysis processes (Alkaline Electrolysis (AEL), Proton Exchange Membrane Electrolysis (PEMEL), Solid Oxide Electrolysis (SOEL), Anion Exchange Membrane Electrolysis (AEMEL):

- The capital costs per system, calculated on 100MW production volume for a single company, are expected to drop well below 1,000 €/kW for all technologies (AEL capital costs should decrease at least to 480 €/kW, aiming at 400 €/kW; PEMEL capital costs should decrease at least to 700 €/kW, aiming at 500 €/kW; SOEL capital costs should at least be below 1,000 €/kW, aiming at 700 €/kW; AEMEL should aim to 300 €/kW);
- The operational and maintenance costs (O&M) should also be reduced, by means of an increased reliability of the stack and the application of advanced monitoring systems, i.e. predictive maintenance (AEL O&M costs should decrease at least below 50 €/(kg/d)/yr; PEMEL O&M costs should decrease at least to 30 €/(kg/d)/yr, aiming to 20 €/(kg/d)/yr; SOEL O&M cost should decrease at least to 130 €/(kg/d)/yr, aiming to 45 €/(kg/d)/yr; AEMEL O&M cost should aim to 20 €/(kg/d)/yr).

Scope

Proposals should aim to significant and innovative improvements of the manufacturing processes to achieve the expected KPI targets. The changes can involve both the manufacturing of components of the single unit (e.g. innovative materials and processes)

and the assembly of a whole stack (e.g. automation). Integrated quality control and monitoring systems are also included.

The following items are in scope of this topic and should lead to cost reduction and cell/stack reliability improvement. Scalability should be considered for each of the research paths to be followed in the project. The project should consider the re-use and recycling of the electrolyzers and their components at their end of life. Proposals should address at least 3 of the topics below:

- Alternatives and/or novel processes should be identified, allowing improved conduction coatings with impact on Platinum group metals (PGM) content. Catalysts should be reduced in water electrolyzers, since they are both very expensive and CRMs;
- Exploration of new surface coating technologies and advanced manufacturing processes (e.g., 3D printing) for more efficient mass production, which can allow higher current density and process efficiency;
- Improvement of manufacturing throughput, feature control, and scale for electrolyser bipolar plates to be coupled with a reduction of the processing cost through cost-effective and mass production-friendly processing techniques, including forming, punching, cleaning, coating and other processes;
- Reduction of the manufacturing steps and transportation costs required to fabricate porous transport layers/gas diffusion layers;
- Improvement of the level of automation of the cell stacks assembly thanks to the development of robotics tooling and automated inspection;
- Test and development of scalable predictive maintenance devices which can greatly reduce the O&M costs of the electrolyser stack;
- Include process design to leverage the recyclability of the materials at the end of life and the utilisation of recycled materials in novel manufacturing on a circularity approach.

Consortia should include at least one electrolyser OEM, one actor from the manufacturing sector and at least one SME.

Consortia are encouraged to consider some of the best practices from the fuel cell manufacturing sector not yet adopted in the electrolyser manufacturing and that could be beneficial to it. In addition, consortia are encouraged to explore synergies and cooperation with Made in Europe partnership (Cluster 7).

Proposals are expected to address sustainability and circularity aspects. In particular, circularity and sustainability by design concepts should be holistically considered towards the whole technology chain.

HORIZON-JTI-CLEANH2-2022-01-05: Scaling up of cells and stacks for large electrolyzers

Specific conditions	
<i>Expected EU contribution per project</i>	The JU estimates that an EU contribution of around EUR 6.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 6.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project. See General Annex B.

Expected Outcome

This topic concerns the research and development of much larger cells and stacks for water electrolyzers than the current State of the Art (SoA). By upscaling electrolyser cells and stacks, economies of scale can be realised in manufacturing and more compact installations can be achieved when integrating electrolyzers into industrial chemical processes, thermal processes and hydrogen hubs. Achieving all of the 2024 KPI targets stated in the SRIA of the Clean Hydrogen JU for low-temperature electrolyzers will ease the adoption of renewable hydrogen by existing industrial processes and facilitate the introduction of renewable hydrogen production at scale. Furthermore, the research findings and outcomes at cell, stack and balance of plant level are expected to advance the subsequent deployment of large electrolyzers to help satisfy the 2030 target of 40 GW renewable hydrogen electrolyzers included in the European Hydrogen Strategy⁶² and contribute to speeding up the achievement of key 2030 KPIs specified in the Clean Hydrogen JU SRIA.

Project results are expected to contribute to all of the following expected outcomes:

- Innovations will be delivered with respect to the design and construction of electrolyser cells and stacks, which have considerably larger active areas and operate at higher current densities than the existing SoA;
- The performances of a number of prototype test stacks based on these cells will be assessed in order to establish the viability of building a single stack of nominally 10 MW capacity. This will fill a knowledge gap concerning the feasibility of large cells and stacks and prepare the way for subsequently demonstrating a 10MW electrolyser module (including appropriate balance of plant);
- A techno-economic evaluation should be undertaken of electrolyser systems, of approximately 50-1,000MW scale, comprising assemblies of this electrolyser module for use in identified industrial processes and other large-scale applications.

⁶² https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

Project results are expected to help maintain European leadership in the field of electrolysis and contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Develop larger area cells/stacks components with adequate manufacturing quality for high power systems;
- Improve cell design for high performance and increase cell/stack robustness;
- demonstrate that electrolysis technology, when deployed at scale, has the potential to meet cost and performance KPIs;
- reducing electrolyser CAPEX and OPEX;
- Increasing current density;
- Increasing the scale of deployment.

In particular, the developed electrolyser stacks should conform with the 2024 KPI targets of the Clean Hydrogen JU SRIA, corresponding to the type of low-temperature electrolyser technology that is being developed, as per the list below.

- AEL, Electricity consumption @ nominal capacity (kWh/kg) 49, CAPEX €/(kg/d) 1,000, OPEX €/(kg/d)/y 43, Current density (A/cm²)0.7, Use of critical raw materials as catalysts (mg/W) 0.3;
- PEMEL, Electricity consumption @ nominal capacity (kWh/kg) 52, CAPEX €/(kg/d) 1,550, OPEX €/(kg/d)/y 30, Current density (A/cm²)2.4, Use of critical raw materials as catalysts (mg/W) 1.25.

Scope

The application of electrolysers to industrial clusters and hydrogen hubs in order to achieve substantial CO₂ savings is inhibited by the present capacities of electrolyser stacks. Hydrogen production could be achieved more cost effectively if larger electrolyser cells and stacks were available. When compared with the current SoA, the development of an electrolyser module of about 10MW, if feasible, would be a considerable step-forward (where a module comprises the least number of stacks and preferably only one stack). However, there are several R&I challenges which first need to be overcome to realise this. Proposals are expected to address the following:

- Scale-up of cell active areas by a factor of at least two, operating at higher current densities and increasing the number of cells per stack, while ensuring durability and performance (mechanically, electrically and in terms of heat and mass transfer) for the envisaged balanced pressure or differential pressure stack;
- Ensure the catalyst and electrode production techniques achieve uniform performance for the required cell areas;
- Develop appropriate production methods and supply chains for larger cell plates and electrodes;
- Establish any technical limits that may restrict the achievable cell size, current density or stack size for a large electrolyser;
- Establish the extent of cost reductions, relative to a SoA stack, when innovating larger cells and stack;
- Ensure a good match between the design of the stack assembly and the power supply unit to minimise energy losses and the overall cost of the electrolyser

module;

- Appropriately scale-up of the balance-of-plant while ensuring a compact design for the electrolyser module;
- Minimise weight and footprint to ensure ease of handling and shipping;
- Maximise the overall cost reduction potential by minimising parts count and value engineering;
- Build and test several short stacks, based on large cells, in order to establish the feasibility of subsequently building an electrolyser module of 10MW capacity comprising preferably a single stack;
- Identifying any optimal sizes for larger cells and stacks from scientific, engineering, logistics and economic perspectives.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁶³ to benchmark performance and quantify progress at programme level.

⁶³ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-06: Efficiency boost of solar thermochemical water splitting

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 4.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 4.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 4 and achieve TRL 6 by the end of the project. See General Annex B.

Expected Outcome

In order to ramp up renewable hydrogen production in the future, a suitable portfolio of diverse technologies is needed to serve the expected growing demand for different applications and markets. Since hydrogen technologies will be deployed on a broad range of markets and scales, abundant and cheap renewable energy resources need to be used. Solar energy has by far the highest potential of all options. In this context, solar thermochemical cycles may contribute to complement the electrochemical solar hydrogen production. Proposals under this topic aim to bring thermochemical cycles to the next stage of maturity.

Project results are expected to contribute to all of the following expected outcomes:

- Diversify the portfolio of technologies for the generation of renewable hydrogen;
- Mitigate mid-to-long term risks of renewable hydrogen availability shortage through diversifying the technology options;
- Enable solar thermochemical cycles as a viable and competitive hydrogen production technology;
- Foster awareness and acceptance of renewable hydrogen production technologies.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRJA:

- Reaching solar-to-hydrogen energy conversion efficiencies higher than 10% (daily average based on higher heating value (HHV) and direct normal irradiance (DNI));
- Ensuring hydrogen production cost < 5 €/kg for a scaled plant in multi-MW size;
- Improving the efficiency of processes: average hydrogen production rates higher than 0.75 kg/year per m² land area used (equivalent of 2.16 kg/day/m² (receiver area) for a solar concentration factor of about 1,000);
- Reducing CAPEX and OPEX: System capital cost in k€/kg/day (15.19 by 2024 and 7.41 by 2030); System operational cost in €/kg (0.59 by 2024 and 0.30 by 2030);
- Provide a technology with robust materials and all components scalable to multi-

MW-scale.

Scope

Thermochemical cycles can directly convert heat into chemical energy by a series of chemical reactions. The direct application of solar heat in water-splitting thermochemical cycles for renewable hydrogen production allows operating at relatively moderate to upper temperatures, reducing electricity consumption and also reducing production cost. Main technical challenges to be addressed are increasing the solar-to-hydrogen efficiency through process intensification, especially through highly efficient internal heat transfer and recovery as well as the scalability of the reactor concept to achieve high energy conversion efficiencies and high throughput. Two stages of development are foreseen for thermochemical cycles and for achievement of the indicated targets and KPIs.

The most promising and advanced solar thermal and hybrid water-splitting processes are those based on metal oxide cycles or on sulphur cycles (thermal and hybrid ones), where prototypes of core components and core production chain elements have been developed and tested at solar towers. Those cycles are attractive since they involve only few chemical steps with low complexity, leading to high reversibility and potentially high cycle efficiency.

One of the central measures to reach intermediate targets in terms of efficiency and cost is the improvement of heat management. It is necessary to recover and reuse a significant portion of the high temperature heat in order to increase the process efficiencies thus making the systems more attractive for commercial use. Several approaches for such heat recovery systems are currently under consideration and development. Proposals should demonstrate how they intend to address this.

Proposals should also address the heat recuperation from solid and gas phase by enhancing heat and mass transfer especially in the reactor using suitably structured porous materials and also in other units of the process via the usage of suitable heat transfer media such as gases or particles.

Proposals should demonstrate on-sun operation of a prototype plant system (including key components) in a relevant environment (typically between 50 and 300 kW) for at least 6 months operation time (net operation time; only day time operation) reaching average hydrogen production rates higher than 0.75 kg/year per m² land area used (equivalent of 2.16 kg/day/m² (receiver area) for a solar concentration factor of about 1,000).

Proposals should develop smart operation and control strategies as well as pathways to scale the technology to the multi-MW scale using modelling and simulation of the plant and key components.

To tackle the above, proposals should consider the following:

- improvement of heat management via efficient heat recovery systems;
- improvement of coupling the process to a concentrating solar energy source (“solar interface”);
- shaping the solar field towards the needs of a chemical process;
- wherever possible, the coupling to heat storage;
- integration of smart control procedures as a central measure to incorporate aspects on digitalisation of the energy system;
- explore suitable options for decreasing the production cost through hybrid renewable supply;

- develop suitable 3-dimensional structuring of key materials, like redox materials, to achieve high production rates and high reactor efficiencies through optimal heat and mass transfer in the reactor;
- ensure stability and performance of key components and related properties of their constituent functional materials;
- consider the circular economy aspects such as the recycling/regeneration of the materials and low content of Critical Raw Materials;
- optimised fluids handling, including the minimisation of inert gas consumption, the efficiency of gas separation operations, and auxiliary power needs;
- describe and validate upscaling strategies of the process and all major components.

Proposals are encouraged to seek collaboration with the existing or upcoming projects of the European Innovation Council (EIC) Pathfinder Challenge on novel routes to green hydrogen production⁶⁴. In particular, applicants should consider building on the breakthrough technologies and advance thermochemical processes developed in these projects.

Proposals are expected to address sustainability and circularity aspects.

⁶⁴ https://eic.ec.europa.eu/eic-funding-opportunities/calls-proposals/eic-pathfinder-challenge-novel-routes-green-hydrogen_en

HORIZON-JTI-CLEANH2-2022-01-07: Bringing renewable hydrogen MW scale off grid installations closer to technical and financial maturity

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of maximum EUR 9.00 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 9.00 million.
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected achieve TRL 7 by the end of the project. See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility condition</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The maximum Clean Hydrogen JU contribution that may be requested is EUR 9.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): electrolyser and other hydrogen related equipment essential for implementation of the project, (e.g. compression of hydrogen, storage and any essential end-use technology) costs may exceptionally be declared as full capitalised costs.

Expected Outcome

Off-grid locations offer an attractive opportunity to incorporate new Renewable Energy Sources (RES) into the energy system without requiring an electricity grid infrastructure to connect the electrolyser system; and in addition grid fees are avoided. Such locations can be remote areas where the grid cannot be easily deployed, or places where the grid is weak, or it is already saturated with renewable sources. The hydrogen produced in these locations is unquestionably renewable hydrogen and would allow demonstrating its use for seasonal energy storage and industry uses. Furthermore, the development and improvement of such renewables and hydrogen integrated systems can play an important role for energy communities and distributed energy models, not only inside the EU but also in locations with relevant renewable energy production capacity and limited grid

development, such as Northern Africa. There are two main barriers to overcome in an off-grid hydrogen production site, (i.e. cost and efficient energy management), and projects at the scale of several MW are now required to tackle these barriers.

Projects are expected to contribute to all of the following expected outcomes:

- Installation of electrolyzers to decarbonise existing hydrogen production in locations where the electricity grid is unavailable, weak or saturated;
- Allowing increased amounts of renewable generation through optimised integration between RES, electrolyzers and large-scale hydrogen storage improving flexibility, efficiency and cost.
- Showcase the role of electrolysis in locations with insufficient infrastructure for connecting electrolyzers to the grid, where RES feed-in or electrolyser connections are limited by grid capacity constraints, or where grid fees are an economic barrier;
- Understanding the complexities of design, commissioning, and operation of MW size projects in off-grid environments with the aim to reduce technical and financial risks of similar projects;
- Direct coupling of large-scale renewable and hydrogen production installations involving optimisation of overall system conversion efficiency. Investigation of potential changes in renewable technologies as well as hydrogen technologies;
- Obtaining a representative comparison in cost and hydrogen production and storage of off-grid vs on-grid electrolysis, also considering scenarios where hydrogen is transported (either on-shore, or also to or from off-shore) instead of electricity to hydrogen consumption points;
- Identification of the optimal balance between RES power installed, stack power, H₂ production and storage;
- Showcase the versatility of hydrogen as an efficient energy storage tool for balancing production/demand applied to different end uses cases;
- Stimulation of the development of new Renewable Energy Supply (RES) in local "renewable hydrogen valleys" where local produced energy is also used locally;
- Determining the opportunities and restrictions of off-grid electrolysis, including the impact of the absence of grid- and transport fees while adding hydrogen storage costs;
- Increasing awareness and support for local renewable hydrogen production and consumption, including models to increase share benefits of local RES with the local community;
- Identification of appropriate business models for reducing costs and accelerating the transition to decarbonisation for various sectors;
- Learnings on off-grid renewable hydrogen generation at large scale in areas with existing gas infrastructure e.g. pipelines and to underground storage, islands and remote areas, and an assessment of the time-varying interactions between hydrogen production, storage and end use;
- To become the seed of an "off-grid" hydrogen valley.

Project results are expected to contribute to all of the following objectives of the Clean

Hydrogen JU SRIA:

- MW scale direct coupling to renewable generation (both on- and off-grid) including offshore hydrogen production, aiming at identifying the best system configuration to reach competitiveness.

Project results will also contribute to speed up the achievement of some of the KPIs of the Clean Hydrogen JU for LT-WE according to the following figures for each technology:

- AEL, Hot idle ramp time (sec) 30, Cold start ramp time (sec) 900, electricity consumption @ nominal capacity (kWh/kg) 49, Degradation (%/1,000h) 0.11, Current density (A/cm²) 0.7, Use of critical raw materials as catalysts (mg/W) 0.3;
- PEMEL, Hot idle ramp time (sec) 1, Cold start ramp time (sec) 10, electricity consumption @ nominal capacity (kWh/kg) 52, Degradation (%/1,000h) 0.15, Current density (A/cm²) 2.4, Use of critical raw materials as catalysts (mg/W) 1.25.

Scope

The main objective of this topic is to demonstrate the complete value chain of off-grid hydrogen production, storage and end-use installations at MW scale.

In regions of high renewable resource where the electricity grid is either heavily utilised or non-existent, off-grid hydrogen production provides the only opportunity for harnessing renewable energy at scale. Off-grid electrolyzers should be designed to be coupled directly to variable solar/wind power sources and survive periods of zero power generation and poor weather, without recourse to the electricity grid. In this way they can access renewable electricity at least cost, by avoiding the usual fees and tariffs that are imposed for grid connection by grid operators, electricity suppliers and regulators. The combination of high renewable resource and low-cost electricity suggests that hydrogen could be produced at low cost, provided that suitable off-grid electrolyzers are developed.

The electrolyser function cannot rely on a stable energy source (AC grid); it has to perform across the whole range of operation with high flexibility and use advanced control systems to efficiently utilise the time-varying renewable electricity input. The electrolyser system needs to include some energy storage (eg. by incorporating batteries, hydrogen storage and fuel cells) to ensure that the electrolyser is always protected during dormant periods (especially freezing weather conditions) and is ready to operate as soon as the renewable generation begins. More development is needed to achieve better ratios of BoP/stack power at all ranges of operation, looking for improvement in the electricity consumption of components (intensity) during operation, in order to realise cost-effective and efficient off grid electrolyser solutions. Also, further development is needed to find optimised and cost-efficient system architectures for the coupling between RES and the system. Direct connection of the RES source to the stack (DC/DC) has been satisfactorily demonstrated for units at 50 kW scale in a strict off-grid environment (TRL 6), obtaining 97% of efficiency across the whole range of operation, which makes the scale up to MW scale feasible by adapting the design to cope with higher input voltages and currents. Modifications to be applied to renewables technologies in terms of DC/DC conversion are also conceivable, and suitable ways to include batteries and supercapacitors for safe stand-alone operation can be explored.

To optimise the efficiency, cost reduction, flexibility, and reliability (security of supply) of the whole value chain adding hydrogen storage (or hydrogen transport in comparison to

electricity transport), it is essential to support the role of electrolysis in off-grid configuration. In this respect, optimisation of the control strategy and alignment with the storage system specifics (and other components of the value chain) to improve overall system efficiency and lifetime for the complete facility has to be taken into consideration. Projects should provide a preliminary analysis for relevant geographical regions, including country-specific challenges, a sustainability assessment for the environmental impact, social acceptance, as well as economic feasibility.

The participation of inter- and trans-disciplinary consortia combining expertise and capacity covering both renewables and hydrogen technologies from public authorities, industrial stakeholders, infrastructure providers, knowledge institutions, planners, entrepreneurs, societal actors and citizens is advised to address the challenges.

In addition, proposals should address the following aspects:

- As the aim of the topic is to cover the whole value chain and depending on the application the cost of certain components may be more relevant than others, the following ranges are to be considered. Size of electrolysis system: 3 to 5 MW. Minimum size of hydrogen storage: 4 tonnes;
- Proposals should be oriented to optimise the performance of the system, with particular attention paid to the effects on electrolyser's efficiency and degradation rate on hydrogen production, as well as to power conversion, system control and other critical parameters. The KPI values as indicated above should be achieved at the end of the project, with the exception of the capital cost KPI. It is recognised that the cost of a MW scale off-grid electrolyser system may be significantly different to that of a grid-connected electrolyser of the same size;
- Proposals should secure downstream use, and it should include integration with enough storage to match discontinuous generation with hydrogen end uses. The end use of the hydrogen should be included and clarified in the proposal including a viable business case. All decisions relating to pressurised or atmospheric electrolyser operation, the use of compressors, and the amount and type of hydrogen storage should be justified;
- Proposals should also build upon knowledge and experience from relevant previously funded FCH JU projects⁶⁵, like ELY4OFF and REMOTE;
- Proposals should consider periods for scheduled maintenances of the system and estimate the performance of the system on that period;
- Strict off-grid conditions are desirable, although connection to the grid for testing, control and safety reasons can be foreseen;
- The system (demonstrator) developed by the project should operate for at least one complete year. This includes the complete value chain covering off-grid hydrogen production, storage, and end use.

Costs of equipment besides the electrolyser can be considered eligible as long as proposals demonstrate that they are essential for implementation of the project, e.g. compression of hydrogen, storage and any essential end-use technology. Costs related to the development of renewable energy technologies specifically designed for off-grid hydrogen production, e.g. a hydrogen producing wind turbine, would also be considered

⁶⁵ https://www.clean-hydrogen.europa.eu/projects-repository_en

eligible.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is produced. In this respect consortium may seek out the issuance and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the issuance and cancellation of non-governmental certificates (e.g CertifHy⁶⁶).

Activities developing test protocols and procedures for the performance and durability assessment of electrolyzers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁶⁷ to benchmark performance and quantify progress at programme level.

⁶⁶ <https://www.certifyhy.eu/>

⁶⁷ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-08: Integration of multi-MW electrolysers in industrial applications

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 18.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 18.00 million.
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 6 and achieve TRL 8 by the end of the project. See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): electrolyser, its BoP and any other hydrogen related equipment essential for the implementation of the project (e.g. hydrogen storage) costs, may exceptionally be declared as full capitalised costs.

Expected Outcome

This flagship⁶⁸ project is expected to pave the way for further large-scale integration of electrolyser systems in industrial applications in the framework of fully commercial operations. The project should demonstrate in an operational industrial environment improved electrolysis technology at a scale of >25MW, configured to provide the necessary reliability of supply at the lowest possible cost of bulk renewable hydrogen to one or more hydrogen users. It will prove the integration of multi-MW state of the art electrolysers into industrial applications, showing decreased costs for both CAPEX and OPEX, increased operational reliability, improved integration both within the industrial process plant and with an associated renewable energy power plant/power purchase agreement (PPA) (as per regulatory requirements) to ensure high reliability. SRIA KPIs for 2024 for the relevant

⁶⁸ For definition of flagship see section 5.3. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

technology should be met.

Moreover, the project shall prove important technological advancement compared to the Djewels⁶⁹ project, as well as the three projects that have been selected in the context of the Green Deal call on the 100 MW electrolyzers⁷⁰ under Horizon 2020.

Project results are expected to contribute but are not limited to the following expected outcomes:

- Emphasise innovation aspects that demonstrate how electrolyser technology goes beyond the current state of the art, while ensuring replicability and wide commercial impact following the implementation of the project;
- Demonstrate reliable operation of large-scale electrolysis and the use of the produced hydrogen in an application valorising the renewable character of the produced hydrogen according to final user's requirements;
- Gain operational experience, including safety and regulatory framework, of the contractual and hardware arrangements required to distribute and supply hydrogen to the specific industrial environment;
- Perform techno-economic analysis of the performance of these systems showcasing the business case of the proposed solution;
- Technically assess the operation of the electrolyser in the industrial environment regarding contractual and hardware arrangements and suggest best practices;
- Evaluate the life cycle environmental performance of the system (including water usage) in alignment with the applicable regulation, defining renewable hydrogen with attention to the CO₂ intensity of the hydrogen produced, which should include an understanding of the CO₂ footprint impact in the addressed hydrogen end-user markets;
- Identify the value and size of the markets addressed and the possibility of indirectly affecting additional relevant markets;
- Assess the legislative and RCS implications of these systems and any issues identified in obtaining consents to operate the system;
- Make recommendations for policy makers and regulators on measures helping to maximise the value of renewable energy and stimulate the market for renewables-electrolyser systems.

Project results are expected to contribute to all of the following objectives of the JU as reflected in the SRIA:

- AEL, Electricity consumption @ nominal capacity (kWh/kg) 49, Capital cost €/kg/d) 1,000, O&M cost €/kg/d/y 43, Degradation (%/1,000h) 0.11, Current density (A/cm²) 0.7, Use of critical raw materials as catalysts (mg/W) 0.3;
- PEMEL, Electricity consumption @ nominal capacity (kWh/kg) 52, Capital cost €/kg/d) 1,550, O&M cost €/kg/d/y 30, Degradation (%/1,000h) 0.15, Current density (A/cm²) 2.4, Use of critical raw materials as catalysts (mg/W) 1.25.

⁶⁹ https://www.clean-hydrogen.europa.eu/projects-repository_en

⁷⁰ <https://cordis.europa.eu/search?q=contenttype%3D%27project%27%20AND%20programme%2Fcode%3D%27LC-GD-2-2-2020%27&p=1&num=10&srt=project/contentUpdateDate:decreasing>

Scope

The project should aim at demonstrating electrolyser technologies beyond actual state-of-the-art producing hydrogen reliably under favourable economic conditions and rationale use of water in a specific industrial application to be chosen by the proposers.

The scope of the project is to demonstrate the integration of a large-scale electrolyser of minimum 25 MW. Technical requirements in terms of purity and pressure shall be designed to fulfil the industrial requirements. At least 2 years of operation are expected. Hydrogen production should be >1,500 tonne/yr and the facility should be working more than 3,200 equivalent hours/yr at full load.

Proposal should address innovation aspects that ensure the project goes beyond the state of the art. Examples of innovations could include, but are not limited to:

- Possibly supply hydrogen to two separate users, each with their own operational requirements and managing electrolyser output both in terms of generation and storage in order to maximise the efficiency of the setup;
- Use oxygen and/or waste heat from the electrolyser for other processes at the industrial site, or from the industrial process to the electrolyser in case of SOEL;
- Concepts related to the circular economy (e.g.: water utilisation, re-use of CO₂ at the site);
- Provision of grid services that help the economics of the installation;
- Footprint reduction, for example integrating hardware vertically instead of horizontally, or minimising the footprint of the electrolyser with a single balance of plant including all required utilities such as water purification, power rectification with appropriate grid interfaces and hydrogen purification, process cooling, etc;

Given that the topic leaves the possibility open for addressing a broad scope of industrial applications, it will be up to the proposal to clearly specify these innovation aspects and avoid any duplication of previous industrial electrolyser applications. In this regard, proper reference and complementarity to previously funded projects by the FCH JU (e.g. Refhyne, H2Future, Djewels, Multiplhy, MegaSyn) and the Green Deal 100MW electrolyser projects should be included, if applicable;

Proposals should also:

- Satisfy industrial requirements for round-the-clock operation using an otherwise (a priori) intermittent source of primary renewable energy;
- demonstrate the economic benefits/enablers of the project for the selected applications. The consortium should demonstrate/investigate a sustainable long term business case for industrial customers who value the renewable character of the hydrogen. This should include a study on the impact of using renewable hydrogen on the final cost of the product and a market evaluation to understand how much premium the end customers are willing to pay for a renewable product;
- Provide the operating scenarios, the expected annual production, the use(s) foreseen and a detailed business case analysis. The electrolyser and downstream systems should be installed and operated for a minimum period of two years within the duration of the project; assurances for operation thereafter should be provided at the proposal stage;

- Include a plan for use of the installation after the project;
- Disseminate the technical and economic benefits, notably (but not only) to the communities of the relevant Horizon Europe private-public partnerships;
- Describe how learnings will be communicated and dissemination will occur beyond the consortium, including those regions in Europe where large scale electrolysis has not yet been demonstrated;
- Support the development of the EU value chain and competitiveness of EU industry for electrolysers, including main components, cells and stacks.

The power connection costs, building costs and the electricity costs for the commissioning phase are eligible for funding. Electricity costs during demonstration / business operation are not eligible. The results of a techno-economic assessment should be reported after each year of operation, including information on the individual cost and revenue streams related to the electrolyser.

The project shall include a clear go/no-go decision point (milestone) ahead of entering the deployment phase. Before this go/no go decision point, the project shall deliver the following: detailed engineering plans, a complete business and implementation plan and all the required permits for the deployment of the project. The project proposal is expected to clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these.⁷¹

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

Applicants are encouraged to seek collaboration with existing projects of the Horizon Europe Process4Planet and Clean Steel partnerships or future topics concerning innovative industrial processes, that could make use of the hydrogen produced by the electrolyser.

Proposals are expected to address sustainability and circularity aspects.

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is produced. In this respect consortium may seek out the issuance and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the issuance and cancellation of non-governmental certificates (e.g CertifHy⁷²).

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁷³ to benchmark performance and quantify progress at programme level.

⁷¹ independent experts will assess all deliverables and will give advice on the go/no go decision.

⁷² <https://www.certify.eu>

⁷³ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-09: Scaling-up technologies for SOEL

Specific conditions		
<i>Expected contribution per project</i>	<i>EU</i>	The JU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>		The total indicative budget for the topic is EUR 6.00 million
<i>Type of Action</i>		Research and Innovation Action
<i>Technology Readiness Level</i>		Activities are expected to start at TRL 4 and achieve TRL 6 by the end of the project See General Annex B.
<i>Procedure</i>		The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches , grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds

Expected Outcome

To decarbonise industries, but also as an energy vector, hydrogen can play a major role, but its production needs to be scaled up in the GW scale.

High Temperature Steam Electrolysis (HTSE) technology using Solid Oxide Electrolysis Cells (SOEL), thanks to its high efficiency, has the potential to become a game changer technology for the massive production of hydrogen at low cost. However, its maturity remains one step behind alkaline and Proton Exchange Membrane (PEM) water electrolysis. Currently, the largest demonstration unit installed has a power of 720 kW (GrinHy 2.0 project), while there is a plan to install and operate in the frame of MULTIPLHY⁷⁴ project a unit of 2.4 MW by the end of 2022. In contrast, units of MWs or tens of MW are already installed or planned to operate shortly for the two other electrolysis technologies. In addition, the unit size of SOEL cells, stacks, and modules remains small, as compared to other electrolysis technologies, which might not be optimal from both a technical and economical point of view in order to address a massive hydrogen production market with multi-MW units. Indeed, small cells and stacks require the assembly and integration of a large number of stacks to reach the high power targeted, which makes system integration more complex.

For SOEL to reach this scale, increasing the size of the cell, stack and module size, as well as the current density and lifetime, can be undertaken to accelerate the accomplishment of the targeted footprint and CAPEX and possibly OPEX goals.

The expected outcome of the present topic is to move forward the maturity of the technology by:

- Developing and validating upscaled cells, larger stacks, and their assembly into

⁷⁴ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

enlarged modules;

- Designing the integration of these enlarged pieces into a multi-MW scale electrolysis unit;
- Enabling hydrogen production costs of < 3 €/kg for such a multi-MW scale plant by 2030, jointly establishing relevant business models;
- Paving the way for the deployment of large-scale hydrogen production units.

Project results are expected to contribute to the following expected outcomes:

- Contributions to at least two full scale demonstrators (MW) for SOEL technology by 2027;
- Maintain European leadership on SOEL technologies that will be applicable for massive hydrogen production;
- Solutions for enlarged cells, stacks and modules demonstrated and validated in relevant environments;
- New business models for SOEL technology based on upscaled components;
- Breakthrough and game changing technologies for SOEL upscaled components;
- Foster the replication of the solutions developed in the project as demonstration units;
- Strengthen the European value chain on cells, stacks, modules and systems by encouraging vertical partnerships;
- New products addressing/targeting massive hydrogen production.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Reducing electrolyser CAPEX to 2,000 €/(kg/d) and OPEX to 130 €/(kg/d)/y by 2024;
- Decreasing footprint to 150 m²/MW or less, this being considered as an average specific space requirement of a MW system comprising all auxiliary systems;
- The performance and lifetime for enlarged cells and stack should present performance and lifetime not below that of the reference cells and stack. Current density should be at least 0.85 A/cm² and degradation at thermoneutral voltage at or below 1%/1,000 hours;
- Reaching an electricity consumption at nominal capacity of 39 kWh/kg H₂ produced;
- Ensure circularity by design for materials and for production processes, minimising the life-cycle environmental footprint of electrolyzers;

Scope

The proposal should focus on the scalability of cells, stacks and modules, namely in terms of design, cells and stack manufacture and their assembly into modules as well as on operation in environment suitable for the selected applications and business cases as follows:

- Identify the optimal sizes for larger cells and stacks from both techno-economical and practical point of view. Pinpoint any technical limits that may restrict the achievable size and the extent of cost reductions when innovating larger cells and stacks;
- Identify the optimal stack assembly layout into modules of > 250 kW capacity, as well as the assembly of such modules into multi-MW units;
- Based on this work, perform a thorough techno-economic analysis considering economies of scale and scalability of manufacturing processes to show that project developments allow reaching the CAPEX and OPEX KPI targets included above in order to pave the way to reach a Levelised Cost of Hydrogen (LCOH) of 3 €/kg, or under, by 2030;
- Operate successfully the cells of the optimal defined size or arrangement in the repeat unit as estimated by the action indicated above for high current density and low degradation as set out in the KPI targets included above, over 2,000 hours in relevant operating conditions;
- Validate, in terms of performance and durability over 2000h, stacks or assemblies of stacks in series to increase the power at the optimal defined size;
- Demonstrate appropriate production methods and supply chains for larger cells and stacks;
- Build a downscaled module of at least 80 kW of power. Upstream and downstream BoP components in relation to the targeted use case(s) should be included to minimise energy losses and the overall cost of the electrolyser module;
- Operate this 80-kW system in representative conditions to evaluate its efficiency (including stack and BoP components), as well as its durability for at least 2,000 h.

Proposals are expected to address sustainability and circularity aspects.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁷⁵ to benchmark performance and quantify progress at programme level.

⁷⁵ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-01-10: Demonstrating offshore production of renewable hydrogen

Specific conditions	
<i>Expected contribution per project</i>	<i>EU per</i> The JU estimates that an EU contribution of around EUR 20.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 20.00 million
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 5 and achieve TRL 7 by the end of the project See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): electrolyser, its BOP and any other hydrogen related equipment essential for implementation of the project (e.g. offshore infrastructure, renewable electricity supply infrastructure, storages, pipelines and other auxiliaries required to convey and utilise the hydrogen), costs may exceptionally be declared as full capitalised costs.

Expected Outcome

The European Commission’s “Strategy to Harness the Potential of Offshore Renewable Energy for a Climate Neutral Future”⁷⁶ expects renewable energy projects to become increasingly important in most sea basins in Europe, including innovative projects such as offshore hydrogen production. Hydrogen may be produced offshore by achieving an association between wind turbines and electrolysers by various approaches. These include retrofitting an electrolyser to an existing oil & gas platform, building a renewable hydrogen production hub on a man-made island, building a new platform close to a wind farm, or integrating the electrolyser and wind turbine into one offshore assembly. The electricity may

⁷⁶ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0741&from=EN>

be supplied via a private wire, a grid connection, or off-grid. Moreover, offshore produced hydrogen may be exported via existing repurposed or new pipelines (gas blended or pure hydrogen) or by dedicated ships; and a platform may be used for grid balancing and for refuelling ships offshore.

This topic calls for a flagship project demonstration at multi-MW scale, >5MW, of the feasibility of offshore renewable hydrogen production. This may be achieved by either re-using existing offshore electricity/oil/gas infrastructure or using new infrastructure, to export energy as hydrogen rather than electricity and so support the greater integration of renewable power sources into the energy system. It is expected that the electrolyser operation will closely follow the wind power generation profile. This will be one of the first worldwide demonstrations of an offshore multi-MW system integration for renewable hydrogen production and export/use.

Project results are expected to contribute to all of the following outcomes:

- Achievement of a step change regarding experience with the additional safety aspects of hydrogen production offshore and export/use, de-risking future projects and investments;
- Determination of the long-term performance of an offshore electrolyser in terms of integration capabilities, efficiencies, systems balancing, performance degradation, corrosion management and operational costs;
- Evaluation and demonstration of operational, inspection and maintenance requirements of offshore electrolysis process;
- Building upon existing experience and research into suitable offshore renewable hydrogen infrastructures and expanding this knowledge;
- Enabling further roll-out of offshore renewable hydrogen production and export/use;
- Acting as a stepping stone for dedicated offshore electrolysis coupled with windfarms, transporting renewable energy as renewable hydrogen, or the offshore use of renewable hydrogen;
- Provide relevant experience to retrofitting existing electricity/oil/gas offshore infrastructure demonstrating their feasibility and cost competitiveness in the long run.

Proposals should aim to improve understanding of the technical, economic, regulatory and operational benefits and hurdles of producing and exporting offshore renewable hydrogen with direct connection to offshore windfarms.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- AEL, Electricity consumption @ nominal capacity(kWh/kg) 49, Degradation (%/1,000h) 0.11, Hot idle ramp time (sec) 30, Cold start ramp time (sec) 900;
- PEMEL, Electricity consumption @ nominal capacity(kWh/kg) 52, Degradation (%/1,000h) 0.15, Hot idle ramp time (sec) 1, Cold start ramp time (sec) 10.

Scope

This Innovation Action flagship⁷⁷ topic will aim to demonstrate offshore production and export/use of hydrogen as a first multi-MW step towards large-scale offshore renewable hydrogen production. The scope covers process design, engineering, construction, procurement, integration with offshore infrastructure and operation of a >5MW electrolysis system at an offshore setting. This can include the supply of renewable electricity, water at the required specification as well as cooling, drying, compression, storages, pipelines and other auxiliaries required to convey and utilise the hydrogen. Accordingly, the project will incur substantial integration costs, both upstream and downstream of the electrolyser, in addition to the costs of the offshore electrolyser itself.

Proposals should address the following:

- Deployment of a system that is designed to be remotely controlled, monitored and autonomously operated to minimise operational costs, while also allowing ready access for essential maintenance purposes;
- Evaluation of the operational, inspection and maintenance requirements of offshore electrolysis systems;
- Operation of the offshore electrolyser and hydrogen export/storage/use for two complete seasonal cycles (24 months). Projects should record all relevant operating data (e.g.: electricity input, hydrogen production and export, system degradation, system fault/trips and root cause analysis) to allow the feasibility of offshore renewable electrolysis to be fully assessed;
- Determination of the performance of the offshore electrolyser in terms of efficiency, performance degradation, operational and maintenance costs;
- If relevant to the electrolyser site, an assessment of economic impact of re-using existing offshore infrastructure compared with developing new offshore infrastructure. KPIs regarding accommodation ratios (MW/m²), cost of installed production (€/MW), etc, shall be defined as appropriate in the proposals to build the assessment;
- A techno-economic comparison of the chosen approach to offshore hydrogen production and transport by pipeline with an otherwise similar approach on land that is based on onshore wind power;
- Assessment of the efficient use of the available renewable energy and of the best control strategies to optimise the plant performances based on the measured process operation data. For this purpose, proposals shall define KPIs regarding availability, efficiency, LCOH, etc;
- Assessment of the environmental impact in terms of avoided CO₂ emissions resulting from the utilisation of the renewable hydrogen produced offshore. A preliminary estimation of the CO₂ avoided emission is expected already in the proposal;
- Describe how learnings will be communicated and dissemination will occur beyond the consortium, including regions in Europe with significant potential for offshore renewable hydrogen production.

⁷⁷ For definition of flagship see section 5.3. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

The offshore conditions, stringent safety requirements, securing a renewable electricity supply, EPC requirements, and the difficult accessibility makes this call very challenging compared with land-based deployments of electrolyzers in the electricity grid. Hence to address adequately the challenges of this project, the consortium should assess:

- Technical and specific hydrogen expertise for the design, provision, integration, safety and operation of the offshore electrolysis process devices and associated hydrogen export/use
- The necessary contractual and commercial expertise to market the hydrogen;
- The end-use of the produced and exported hydrogen;
- The potential sustainability of the deployed renewable production plant beyond the demonstration phase;
- Obtaining the necessary permitting and regulatory approvals as required for the timeframe of the project;
- Legal, safety and regulatory expertise related.

Proposals are expected to demonstrate important additional technological advancement compared to the FCH JU project OYSTER⁷⁸.

This topic encourages the deployment of sustainable transportation of hydrogen methods by soliciting the planning of «medium range and backbone transmission infrastructures» in line with the “Hydrogen Strategy for a Climate Neutral Europe⁷⁹”. In addition, it is important that the offshore production of hydrogen conforms with Europe’s general commitment to achieving and maintaining clean and healthy oceans by addressing the operation, recyclability, recovery and re-use of offshore electrolyzers⁸⁰.

The following costs are considered to be eligible for funding: the design, development, procurement, integration and installation of the offshore electrolyser and its water supply; the electrolyser’s electricity connection; the auxiliary systems (including hydrogen storage and export infrastructure); the commissioning, operation and maintenance of the deployed system for the demonstration phase. Costs associated with offshore infrastructure acquisition or retrofitting, buying electricity and electricity grid levies for the demonstration phase are not eligible.

Applicants should be able to demonstrate the compatibility of their proposal with a wider perimeter, such as renewable electricity production, export/use means and/or platform infrastructure. Additional funding streams and match funding are encouraged.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

Proposals should provide a preliminary draft on ‘hydrogen safety planning and management’ at the project level, which will be further updated during project implementation.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is produced. In this respect consortium may seek out the issuance and subsequent cancellation of GOs from the relevant Member State issuing

⁷⁸ https://www.clean-hydrogen.europa.eu/projects-repository_en

⁷⁹ https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

⁸⁰ https://ec.europa.eu/oceans-and-fisheries/ocean/clean-and-healthy-oceans_en#ecl-inpage-101

body and if that is not yet available the consortium may proceed with the issuance and cancellation of non-governmental certificates (e.g CertifHy⁸¹).

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols⁸² to benchmark performance and quantify progress at programme level.

⁸¹ <https://www.certify.eu/>

⁸² https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HYDROGEN STORAGE AND DISTRIBUTION

HORIZON-JTI-CLEANH2-2022-02-01: Compatibility of Distribution non-steel metallic gas grid materials with hydrogen

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.5 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project. See General Annex B.

Expected Outcome

In its strategic vision for a climate-neutral EU (to meet the carbon neutrality in 2050) presented by the European Commission on 28th November 2018, the share of hydrogen in Europe's energy mix is projected to grow from the current less than 2% to 13-14% by 2050. In order for hydrogen to claim such position in the energy mix and as explicitly mentioned in the EU Hydrogen Strategy⁸³, it is essential that hydrogen becomes an intrinsic part of an integrated energy system. Hydrogen will have to be used for daily or seasonal storage providing buffering functions thereby enhancing security of supply in the medium term. The strategy also calls for an EU-wide logistical infrastructure that needs to be developed in order to transport hydrogen from areas with large renewable potential to demand centres across Europe. Consequently, a pan-European grid will have to be established.

To do so there is significant energy system benefit in using existing natural gas assets across Europe, as they have large seasonal storage potential and can also readily manage large swings in daily demand. To supply this hydrogen, European gas grid operators aim to increase the content of hydrogen blends into natural gas from in existing gas grids (including transmission and distribution gas networks but also by extension their connections to hydrogen production facilities and new end users). In parallel, European gas grid operators also work on repurposing existing assets to transport 100% hydrogen.

Considering these challenges, project results are expected to contribute to all of the following expected outcomes:

- De-risking of business case for repurposing of existing European gas grids for hydrogen and enabling expansion of new dedicated infrastructures for pure hydrogen;
- Increased operator, regulator, authorities, and end user confidence in safety of repurposed gas grids by consolidated and exhaustive scientific data;
- Making available harmonised guidelines to assess the hydrogen effect on metallic materials present in the gas grids to get a complete view of network

⁸³ https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

compatibility. These guidelines would provide inputs to pre-normative actions conducted through European organisations and enable a seamless interconnection between gas grids.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Development of technologies and materials to facilitate the transportation of hydrogen via the natural gas grid.
- Enable through research and demonstration activities the transportation of hydrogen through the natural gas grid either by blending or via repurposing to 100% hydrogen.

Scope

Former public bibliographic results and testing programs (e.g. NaturalHY⁸⁴, HYready⁸⁵, MultiHy⁸⁶ or Higgs⁸⁷ projects) have identified an embrittlement effect on steel grid materials used for pipes or network equipment, directly linked to the partial pressure of hydrogen (commonly expressed in terms of percentage of hydrogen in the total volume of gas at a specific pressure). However, this embrittlement effect on the various metallic materials used on the gas distribution networks (steel, but also cast iron, copper, lead...) has not been documented to date, as most existing testing programs have investigated non-metallic materials only. Therefore, there is a strong need to document the effect of hydrogen on metallic materials at low pressure, taking into account the great diversity of existing networks across the European Union, in terms of material grades used, building protocols (e.g. welds) or day-to-day current and future operational parameters (e.g. pressure level).

All types of metallic materials (steel, cast iron, copper, brass, lead, aluminium) or operational parameters representative of the functioning of the distribution networks have not been fully studied. All gas grids characteristics and load case scenarios should be covered to better assess the lifespan of existing infrastructure.

Currently different standards can be used for the design of metallic components (ISO 11114-4, ASME B31.12) or to assess their mechanical properties in the presence of hydrogen (ANSI/CSA CHMC 1, ASTM G142). This wide range of standards and the lack of commonly agreed mechanical guidelines are slowing down the definition of harmonised criteria to assess hydrogen-readiness of European gas networks.

Proposals should therefore focus on all non-steel metallic materials constitutive of Distribution networks (such as cast iron, copper, brass, lead, aluminium etc.).

In particular proposals should:

- Deliver a preliminary inventory of non-steel metallic materials constitutive of the European distribution natural gas grid and deliver a priority ranking analysis to evaluate the most cost-efficient strategy (adaptation or replacement) for each of them;
- Propose a testing approach covering most relevant non-steel metallic grades (cast iron, copper, brass, lead, aluminium) constitutive of European distribution natural

⁸⁴ <https://cordis.europa.eu/project/id/502661/es>

⁸⁵ <https://www.gerg.eu/project/hydrogen/>

⁸⁶ <https://cordis.europa.eu/project/id/263335>

⁸⁷ https://www.clean-hydrogen.europa.eu/projects-repository_en

gas grids and their different operating conditions (maximum pressure, pressure cycling, etc.). Proposals should cover an extensive range of natural gas/hydrogen blends with a focus on hydrogen contents up to 20%, and 100%. This approach should combine mechanical tests and modelling, e.g. using first principles calculations or fracture mechanics method of hydrogen interaction with the materials. A preliminary bibliographic review should be conducted to identify the gap analysis at the start of the action, taking into account existing results from former and other ongoing projects;

- Propose harmonised protocols and run material tests to measure the mechanical properties affected by the presence of hydrogen and critical for its integration into networks (should include e.g. crack propagation, fatigue, toughness, and impacts on welds and heat affected zones (HAZ)) and impact of chemical composition for grid components. The protocols should be made available to the public and should ensure that all results are comparable between the different testing laboratories involved. It should also, serve as a standardised reference guideline for future investigations.

Following the testing activities proposals should make available a database of gas grid metallic materials' behaviour in the presence of hydrogen associated with network operating conditions, assessing the compatibility of vintage and new gas pipes. There should also be a plan that ensures the that the database is updated after the project is finished with future testing results.

Projects should also identify acceptance criteria including the allowed size of defects, depending on the pressure and hydrogen concentration.

Proposals should ensure regular knowledge sharing with other topics devoted to hydrogen injection into gas grids that will require those tests' results, and especially HORIZON-JTI-CLEANH2-2022-02-02, HORIZON-JTI-CLEANH2-2022-05-03 and HORIZON-JTI-CLEANH2-2022-05-04.

At least two different research institutions should be included in the consortium in order to ensure the comparability of the testing results.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

HORIZON-JTI-CLEANH2-2022-02-02: Hydrogen and Hydrogen/Natural gas mixture leak detection system for continuous monitoring and safe operation of HRS and future Hydrogen/Natural gas mixture networks

Specific conditions	
<i>Expected contribution per project</i> EU per	The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.5 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project See General Annex B.

Expected Outcome

The growing attention on methane emissions is also triggering a debate around the safety of hydrogen. Although different in nature, the two issues are frequently associated with each other in the public debate. During a recent event organised by the US-based Environmental Defence Fund, the topic of hydrogen leakage and related GHG emissions took up a prominent place in the discussion with members of the European Parliament and Commission officials. According to the participants, the discussion and the lessons learned about methane emission can be applied to the subject of hydrogen leakage. Even though hydrogen in itself is not a GHG, by depleting hydroxyl radicals (OH), thus increasing the atmospheric lifetime of methane as well as by influencing tropospheric ozone formation, the total GWP of hydrogen over 100 years can be estimated at 5.888. As hydrogen leakage, during storage and transportation, is potentially the largest source of anthropogenic hydrogen emissions, minimising hydrogen leakage rates is therefore key to ensure climate sustainability of the developing hydrogen economy. Furthermore, as around 60% of hydrogen's global warming potential results from changes in methane concentration, tackling hydrogen leakage would be complementary to the EU Methane Strategy⁸⁹ and the Proposal for a Regulation to reduce Methane emissions of December 2021⁹⁰ as well as to the recent Global Methane Pledge⁹¹. As hydrogen has a very broad flammability range - a 4 percent to 74 percent concentration in air – leakage detection and prevention is also crucial from safety point of view, especially inside confined spaces.

Safety requirements of natural gas (NG), mixed NG/H₂ and pure hydrogen transport require robust yet innovative solutions for sensor-based leak detection monitoring throughout Europe. In addition, leaks at HRS level became one the main concerns to operate safely and economically the retail business.

The sensor technology development in this field should address the development, testing and validation of new detection techniques and tools for measurement by continuous monitoring of pure hydrogen and mixed methane-hydrogen emissions.

⁸⁸ https://www.geos.ed.ac.uk/~dstevens/publications/derwent_cc01.pdf

⁸⁹ https://ec.europa.eu/energy/sites/default/files/eu_methane_strategy.pdf

⁹⁰ https://eur-lex.europa.eu/resource.html?uri=cellar:06d0c90a-5d91-11ec-9c6c-01aa75ed71a1.0001.02/DOC_1&format=PDF

⁹¹ <https://www.globalmethanepledge.org/>

This will enable safer storage, transport (in NG Grid or trailers) and distribution of gaseous hydrogen. The approach to solve these safety issues may vary due to different demands at different sites, both enclosed and open air, and will depend on variable configuration of the network / distribution, different gas pressure ranges and hydrogen concentration, and possible interference from other components like the NG/H₂ mixture.

Current technologies for continuous leak detection monitoring are not satisfactory and should meet the industry & public area requirements.

Project results are expected to contribute to all of the following expected outcomes:

- The development of leak detection system that can classify leak types and leak sources according to risk, location, impact, consideration of severity, probability and predictability arising from sensors for leak detection and system integrity including predictive maintenance, odourised molecules and airborne technologies which will detect hydrogen leakage remotely (such as Raman LiDAR for hydrogen pipelines).
- To ensure safe operation of hydrogen infrastructure (e.g. HRS, filling centres, gas grids, compressor housings)
- Improvement of Leak detection time/rate and detection accuracy of the system
- Improvement in the productivity and cost effectiveness of the sensor device. While some leak categories may require continuous monitoring, for other leaks periodic measurements by mobile sensors or multiplexed arrangements may be more cost-effective. Continuous monitoring solutions can detect and report leaks in real-time and trigger early warning systems which helps to reduce risk for both humans and materials, especially in densely populated areas or densely built industry parks and refineries.

Project results are expected to contribute to all of the following objectives of the JU as reflected in the SRIA of the Clean Hydrogen JU:

- Increase the level of safety of hydrogen technologies and applications
- Enable through research and demonstration activities the transportation of hydrogen through the natural gas grid either by blending or via repurposing to 100% hydrogen.

The project is also expected to achieve the following technical KPIs:

- Concentration measurement accuracy for safe operation in terms of explosion limit, 1% lower explosive limit (LEL). This means that the sensor should be able to detect 0.04% of H₂ in air;
- A minimum detection sensitivity of $\pm 0.18\%$ by volume of hydrogen in air (a good practice is to set the detectors to alarm at 0.4% hydrogen by volume in air, which is 10% of the lower flammability limit (LFL);
- A maximum response time of 1 sec at a concentration of 0.4% by volume (more than 10% LFL), while keeping in mind that sensor performance can vary from one application to another, this is extremely important for system designed to monitor hydrogen concentrations in rooms or areas (e.g. turbomachinery package enclosure) with high temperature environments in presence of hot surfaces with temperatures above auto-ignition (AIT).

Scope

The proposed research is expected to focus on developing and validating reliable leak sensing services and leak detection sensor technologies for hydrogen and NG/H₂ mixtures. The proposed research work should start at TRL 3 and end at TRL 5 or higher.

New and optimised leak detection sensors and tools should be developed in order to enable safer storage, transport and distribution of hydrogen. Leak detection technologies may include the development of new or optimisation of existing portable and fixed sensors (ideally with remote access) with various technical approaches (e.g. acoustic, laser scanning, optical fibre sensors, infrared if NG/H₂ mix considered, odourised molecules, strain gauge). Optimisation of existing hydrogen emission detection systems in terms of measuring range, tolerance, temperature measuring range, pressure range, response and recovery time⁹², and to lower the costs for investments, compression/operations and maintenance should also be considered.

Besides the technical KPIs that were already mentioned in the expected outcome section other key elements for leak detection monitoring are outlined below:

- Leak detection devices should identify the origin or the leak (e.g. acoustic detection) to allow the commissioning & operating team to fix the issue;
- The leak detection system should warn personnel with visual and audible warnings when the environment is becoming unsafe; remote notification should be preferred.

The proposed technology should be suitable for continuous leak detection monitoring or/and periodic maintenance. Certain leak categories may be addressed by periodic measurement while other leak detection solutions may require interconnected mobile sensors or multiplexed arrangements.

Technologies related to hydrogen detection are based on the effects induced by the interaction of hydrogen with a selected sensing material. For example these effects can span catalytic, thermal conductivity, electrical and electrochemical, mechanical optical and acoustic properties. The scope of the topic is completely open to any kind of sensing technology.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

⁹² Understood as time between two measurements.

HORIZON-JTI-CLEANH2-2022-02-03: Validation of a high-performance hydrogen liquefier prototype

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 5 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3-4 and achieve TRL 5 by the end of the project See General Annex B.

Expected Outcome

Hydrogen is liquefied by reducing its temperature to -253°C which increases its volumetric energy density (cryo-compressed form of hydrogen is recommended as well). This makes it possible to transport hydrogen and store it in large quantities enabling the transport of hydrogen by road/ship from centralised/decentralised production unit to customers or even direct use of liquid hydrogen for on-board storage in the frame of heavy-duty mobility.

Hydrogen liquefaction is an energy intensive process and current liquefaction plants rely on technologies and materials that need energy efficiency improvement and cost reduction to lower the overall hydrogen liquefaction cost and activate the LH₂ market at a competitive price in the near future.

Project results are expected to contribute to all of the following expected outcomes:

- Development an innovative hydrogen liquefaction sub-system (sub-modules, cycle or even equipment) that should:
 - Demonstrate technical and economic improvements with a potential for scaling-up
 - Be capable of reducing the energy consumption and specific cost of hydrogen liquefaction
- Prepare/initiate the massive deployment of liquid hydrogen for the benefit of heavy-duty transport with zero emission.
- Impact on a positive manner other hydrogen Europe Roadmaps related to liquid hydrogen (transportations, usages as aviation, HRS)

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- To increase the efficiency and reduce the costs of hydrogen liquefaction technologies.
- To contribute to the roll-out of next generation liquefaction technology to new bulk hydrogen production plants.

In terms of technical KPIs the project should aim at achieving the following:

- Reducing the H2 liquefaction energy intensity to 8-10kWh/kg H2
- Reducing H2 liquefaction cost to <1.5€/kg

Scope

A hydrogen liquefaction process is composed of the following main technological sub-systems: Pre-cooling, Cooling, Coldbox (Heat exchangers, ortho-para conversion), turbines and finally boil-off gas management.

There are currently various challenges associated to the production of low-cost liquid hydrogen:

- Only few developments working on optimising hydrogen cycles at a high TRL have been proposed;
- Current hydrogen energy consumption for liquefaction is around 10 to 12 kWh/kg equivalent to 35% of the hydrogen energy content on LHV vs power basis;
- Market development and cost strategies need to be developed for viable business models to promote LH2 product as an effective way of transporting hydrogen or eventually as a fuel;
- There are no uniform standards and safety regulations for liquid hydrogen.

To overcome the technological barriers of hydrogen liquefaction and to prepare a future massive industrial deployment at a high TRL, the high-performance hydrogen sub-system to be developed in proposals should address the following technical issues:

- An innovative concept different from what is used today. This can be focused at the system level or on one of the sub-system of a liquefaction unit;
- Construction of an industrial prototype at limited scale;
- Evaluate the performance, durability and efficiency of the prototype;
- Demonstrate the capability of the concept to be operated at lower load (in the range 50-100% of the nominal capacity) to be in line with future of renewable/low-carbon hydrogen production -e.g. by water electrolysis coupled with renewable electricity);
- Demonstrate according to the industrial prototype operation the H2 liquefaction energy intensity target between 8 - 10 kWh/kg considering feed hydrogen at 20 bar and 15 °C;
- The validated industrial prototype should prove and support the scalability of the innovative concept to suit flowrates above 100 TPD.
- TRL start of the project: 3 and TRL at the end of the project: 5

The proposed technology to be developed should be benchmarked against the technologies commercially available today based on the Helium Brayton Cycle and the Claude Cycle, both with externally supplied liquid inert nitrogen (LIN) for precooling on a small scale and should demonstrate a lower energy consumption.

Proposals should also address the following economic and regulatory issues:

- The innovative concept should demonstrate a specific liquefaction cost at around 1 to 2 €/kg for a small scale unit;
- The project should define a suitable roadmap to prepare the deployment of low carbon liquid hydrogen solutions;

- The project should address safety aspects of supplies of liquid hydrogen (infrastructure aspects);
- Propose accurate business models for the scale-up of the industrial phase for commercialisation purposes;
- Assess the various advantages of using renewable liquid hydrogen in heavy-duty mobility in terms of emission reduction compared to tradition fuels including the boil-off management for the overall supply chain;
- Asses the various advantages of using renewable liquid hydrogen to valorise renewable energy used for the production of renewable hydrogen in an off-grid configuration;
- Contribute to the development of regulations, codes and standards needed for the LH2 safety issues;
- Define training requirements for operators in regards to LH2 safety operations.

Proposals are expected to address sustainability and circularity aspects.

HORIZON-JTI-CLEANH2-2022-02-04: Ammonia to Renewable Hydrogen: efficient system for ammonia cracking

Specific conditions		
<i>Expected contribution per project</i>	<i>EU</i>	The JU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>		The total indicative budget for the topic is EUR 3.00 million.
<i>Type of Action</i>		Research and Innovation Action
<i>Technology Readiness Level</i>		Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project See General Annex B.

Expected Outcome

Liquid hydrogen carriers will play a significant role in diversifying Europe’s energy supply corridor, transporting hydrogen at scale (>1,000 tonnes of hydrogen transported per day), especially across larger distances. Low carbon footprint, high energy density and easy storage and transportation are important key factors for their application. Amongst all liquid hydrogen carriers, ammonia has proven itself as a carbon free and sustainable candidate and, very importantly, it presents advantages of a one-way transport, in fact, ammonia does not need to be directly recovered and recycled after the dehydrogenation step (to release hydrogen). Moreover, even if safety and toxicity concerns have been raised, ammonia has been produced industrially for over 75 years, with a large existing infrastructure and offtake. However, further studies to assess the large-scale potential of ammonia as a hydrogen carrier are needed and energy efficiency and environmental impacts have to be carefully addressed.

Ammonia synthesis can be performed close to centralised hydrogen production sites, but their dehydrogenation needs to be easily obtained locally for different applications after transportation. Many technical and economic challenges related to dehydrogenation step and sustainability need to be overcome.

In order to bring ammonia cracking to the next stage of maturity project results are expected to contribute to all of the following outcomes:

- Contribute to Europe technology leadership developing innovative reactors and catalysts for the dehydrogenation of ammonia as well as new integrated solution for heat management and hydrogen separation and purification;
- Reducing the use of critical raw materials in ammonia dehydrogenation reaction;
- Improving the economics of the ammonia dehydrogenation process;
- Develop new business models related to the use of hydrogen from ammonia for various applications, such as centralised and distributed power generation, shipping, heavy mobility, etc;
- Contributing to the understanding of Europe need in terms of infrastructure and regulation for the management of liquid hydrogen carriers;

- Foster the demonstration of the solutions developed in the project throughout Europe.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA: (especially for Pillar 2: Hydrogen storage and distribution – Sub Pillar: liquid H₂ carriers):

- Develop a range of hydrogen carriers that will be used commercially to transport and store hydrogen while improving their roundtrip efficiency and lowering their cost;
- Contribute to the SRIA KPIs on hydrogen carrier delivery cost, for 3000km ship transfer (Targets: 2024 = 2.5 €/kg, 2030 = <2€/kg);
- Contribute to the SRIA KPIs on hydrogen carrier specific energy consumption (Targets: 2024 = 17kWh input/kgH₂ recovered, 2030 = 12 kWh input/kgH₂ recovered). This figure encompasses the energy consumption for the production of ammonia from hydrogen, for which the project shall retrieve the value from the state of the art.

Scope

State of the art systems for H₂ recovery from ammonia require reaction units and catalysts operating at high temperatures (550-800°C) for complete ammonia conversion and are principally based on fired and heat transfer limited cracker design. The application of heat sources to deliver the required thermal energy is a restricting challenge for ammonia as a reliable Hydrogen carrier. Moreover, components thermal losses, power consumed by pumps, and loss of hydrogen due to imperfect recovery in conventional separation and purification section represent other important issues to address for the next generation ammonia dehydrogenation plants. In this regard, proposals should contain a set of principles applied in catalyst and reactor design, which can bring significant benefits in terms of process intensification and chain efficiency, lower capital and operating expenses, higher quality of products, less waste and improved process safety. Therefore, it is of interest to develop and demonstrate, at prototype scale, low-cost catalysts and integrated reactors that can deliver hydrogen at a high rate per volume from ammonia dehydrogenation at relatively low temperatures and high conversion so that zero-carbon pure hydrogen can be transported at long distances.

More in detail proposals should include:

- Development of catalyst (CRMs free catalysts or reduction of CRMs use should be considered) and reactor for the ammonia dehydrogenation at lower temperature compared to state of the art, capable to:
 - ensuring the highest possible ammonia conversion (>98%) reducing the downstream cleaning/recycling steps;
 - improving the overall thermal efficiency of the ammonia dehydrogenation step;
 - providing high reliability, ease of operation, and cost-effectiveness to hydrogen production.
- A demonstration system, running for at least 500 hours and producing at least 10 kg H₂/day at atmospheric pressure;
- Demonstration of hydrogen fuel quality (according to ISO 14687:2019) from dehydrogenation of the liquid hydrogen carrier in relevant conditions;

- Demonstration of Scalability of the developed system to large-scale production (equivalent to the 100 tH₂/day) for long distance transportation;
- A Life Cycle Assessment of the developed system in the frame of the whole supply chain: ammonia inventory and make-up, (de)hydrogenation steps, temporary storage, shipping, CRM net consumption, etc;
- Techno-economic analysis for the scalability of the developed system to large-scale production for long distance transportation, i.e. 1000 t H₂/day, including centralised hydrogenation plant, storage, shipping and distributed dehydrogenation plants.

In order for the proposal to reach the expected outcome, the deliverables should be disseminated at the end of the proposal to the hydrogen mobility and hydrogen refuelling infrastructure sectors and relevant working groups of the standardisation technical committee's such as ISO TC 197, CEN TC 268, including the hydrogen purity standard ISO14687 and EN17124, related to hydrogen fuel sampling.

Proposals are expected to address sustainability and circularity aspects.

HORIZON-JTI-CLEANH2-2022-02-05: Efficient system for dehydrogenation of liquid organic hydrogen carriers

Specific conditions		
<i>Expected contribution per project</i>	<i>EU</i>	The JU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>		The total indicative budget for the topic is EUR 3.00 million
<i>Type of Action</i>		Research and Innovation Action
<i>Technology Readiness Level</i>		Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project See General Annex B.

Expected Outcomes

Liquid hydrogen carriers will play a significant role in diversifying Europe's energy supply corridor, transporting hydrogen at large scale (>1,000 t H₂/day) especially across longer distances. In this frame, liquid organic hydrogen carriers (LOHC) have attracted attention of Europe's research and industry community. LOHC provide the possibility of transporting significant amount of hydrogen during hydrogenation/dehydrogenation cycles. Availability and degradation issues should be further studied to assess the large-scale potential of these liquid carriers. In addition, energy efficiency and environmental impacts have to be carefully addressed.

The hydrogenation of LOHCs can be performed close to centralised hydrogen production sites, but their dehydrogenation needs to be easily obtained locally for different applications. Many technical, environmental and economic challenges related to dehydrogenation step need to be overcome.

Project results are expected to contribute to all of the following expected outcomes:

- Contribute to Europe technology leadership, developing innovative reactors and catalyst for the dehydrogenation of LOHC, including integrated solutions for heat management and hydrogen purification;
- Reducing the use of critical raw materials in LOHC dehydrogenation reaction;
- Develop affordable business models related to the use of hydrogen carried on by LOHC for various applications, such as centralised and distributed power generation, shipping, heavy mobility, etc;
- Contributing to the understanding of Europe need in terms of infrastructure and regulation for the management of liquid hydrogen carriers;
- Foster the demonstration of the solutions developed in the project throughout Europe;
- Contribute to the social acceptance of hydrogen technologies, demonstrating safe solutions for hydrogen transportation by LOHC.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA: (especially for Pillar 2: Hydrogen storage and distribution – Sub Pillar: liquid H₂ carriers):

- To continue the research on carrier cycling performance, chemistries, catalysis and reactors which show potential for improved roundtrip efficiency and life cycle assessment.
- Develop a range of hydrogen carriers that will be used commercially to transport and store hydrogen while improving their roundtrip efficiency and lowering their cost.
- Contribute to the SRIA KPIs on hydrogen carrier delivery cost, for 3000km ship transfer (Targets: 2024 = 2.5 €/kg, 2030 = <2€/kg);
- Contribute to the SRIA KPIs on hydrogen carrier specific energy consumption (Targets: 2024 = 17 kWh input/kgH₂ recovered, 2030 = 12 kWh input/kgH₂ recovered).

Scope

State of the art systems for H₂ recovery from LOHC require reaction units and catalysts operating at temperatures between 200 and 400 °C depending on the type of molecule. The application of heat sources to deliver the required thermal energy is a restricting challenge for selected organic liquids as a reliable hydrogen carrier. Moreover, components thermal losses, power consumed by pumps, and loss of hydrogen due to imperfect recovery in conventional separation and purification section represent other important issues to address for the next generation LOHC dehydrogenation plants.

The project should develop and demonstrate reactors and catalyst dedicated to the dehydrogenation of LOHC. In particular, the project should contain a set of principles applied in catalyst and reactor design, which can bring significant benefits in terms of process intensification and chain efficiency, lower capital and operating expenses, higher quality of products, less wastes and improved process safety. Therefore, it is of interest to develop and demonstrate, at prototype scale, low-cost catalysts and integrated reactors that can deliver hydrogen at a high rate per volume from LOHC dehydrogenation at relatively low temperatures and high conversion, so that zero-carbon pure hydrogen can be transported at long distances.

The proposal should contain:

- Development of catalyst (CRMs free catalyst or reducing of CRM use should be considered) for the LOHC dehydrogenation at lower temperature compared to the state of the art:
 - ensuring the highest possible dehydrogenation reaction conversion (>95%);
 - improving the overall thermal efficiency of the LOHC dehydrogenation step;
 - providing high reliability, ease of operation, and cost-effectiveness to hydrogen production;
 - an integrated system with high reliability, ease of operation, low materials degradation and cost-effectiveness to hydrogen production from LOHC.
- A fully CO₂-free dehydrogenation process;
- A demonstration system, running for at least 500 hours and producing at least 10 kg

H₂/day at atmospheric pressure;

- Demonstration of the absence of contaminants, by-products and degradation products from the dehydrogenation of LOHC in real conditions (hydrogen quality according to ISO 14687:2019);
- Demonstration of scalability of the developed system to large-scale production (equivalent to the 100 t H₂/day) for long distance transportation;
- A Life Cycle Assessment of the developed system in the frame of the whole supply chain: LOHC inventory and make-up, (de)hydrogenation steps, temporary storage, shipping, CRM net consumption, etc;
- Techno-economic analysis for the scalability of the developed system to large-scale production for long distance transportation, i.e. 1000 t H₂/day, including centralised hydrogenation plant, storage, shipping and distributed dehydrogenation plants.

In order for the proposal to reach the expected outcome, the deliverables are expected to be disseminated at the end of the action to the hydrogen mobility and hydrogen refuelling infrastructure sectors and relevant working groups of the standardisation technical committee's such as ISO TC 197, CEN TC 268, including the hydrogen purity standard ISO14687 and EN17124, related to hydrogen fuel sampling.

Proposals are expected to address sustainability and circularity aspects.

HORIZON-JTI-CLEANH2-2022-02-06: Development of large scale LH2 containment for shipping

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 6.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 6.5 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 2-3 and achieve TRL 5 by the end of the project See General Annex B.

Expected Outcome

An important element of the European Hydrogen strategy is to support liquid hydrogen(LH2) deployment for various usages and to allow the energy transportation over longer distances. A further important element of the Hydrogen strategy is to contribute to the cost decrease by importing energy from low-cost zones by development of an international hydrogen trade, and thereby also enabling import of hydrogen to the European Union. In the end this will lead to increase the EU's competitiveness, manufacturing capabilities and secure the energy supply.

Shipping of LH₂ will represent a flexible means for transport of larger quantities of hydrogen over longer distances, as well as for regional distribution without a gas-grid. LH₂ also represent a dense form suitable for fuel storage for energy demanding applications.

Project results are expected to contribute to all of the following expected outcomes:

- Enable safe, cost- and energy efficient transport of bulk LH₂. Large scale LH₂ ship storage concepts need to be developed for shipping of LH₂ at energy system scale, in the order of GW hydrogen energy flux. An important aspect is to utilise the techno-economic advantage of scale;
- Allow for the development of LH₂ containment for shipping exceeding the currently demonstrated size of about 1,250 m³, corresponding to 90 tonnes of hydrogen. At present, large-scale solutions for the storage and bulk transportation of liquid hydrogen are in their infancy. It is expected that the development will foster the basis for large scale trade of LH₂ by 2030 being a supplement and later an alternative to the current world-wide LNG trade;
- Design a scalable liquid hydrogen storage to large dimensions, in the range of those implemented for LNG shipping today, e.g. 200,000 m³ per ship, distributed between a relevant numbers of storage tanks. Such a capacity will correspond to 14,000 tonnes of hydrogen transported per ship;
- Demonstration and first application of the developed liquid hydrogen storage technology may be at reduced scale

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- LH₂ containment tank capacity [tonnes]: 350 in 2024 and 2.800 in 2030
- Capex of installed LH₂ containment tank [€/kg]: 50 in 2024 and <10 in 2030
- LH₂ boil-off [%/day]: 0.5 in 2024 and <0.3 in 2030

Scope

The scope of this topic is to develop and validate containment concepts intended for the bulk shipping of liquid hydrogen. The concepts developed should also be suitable for a later scale-up.

Multiple European technology providers have started to design and develop LH₂ containment solutions, e.g. based on the IMO Type B, Type C and membrane tank designs currently available for LNG shipping, as well as for other novel concepts. Due to the considerably lower temperature of LH₂ than LNG, as well as the lower heat of vaporisation and different material compatibility characteristics, totally novel insulation concepts need to be developed if LH₂ should be contained with equally or lower boil-off rate as current LNG concepts.

The scope for the proposed project should include:

- Concept selection for large scale LH₂ containment to be used in shipping;
- Approval in Principle (AIP) for the LH₂ containment concept by one of the major IACS classification societies;
- Materials and component selection and integrity testing for LH₂ exposure, e.g. strength, ductility, toughness, thermal expansion, sloshing and compatibility;
- Sub-system testing for thermo-mechanical validation;
- Detailed design, construction, and testing of a scaled-down prototype of at least 10 t LH₂ capacity;
- General Approval for the LH₂ containment system by one of the major IACS classification societies;
- Development of a preliminary integrated ship design with a corresponding cost estimation;

The topic could have potential synergies with the topic from ZEWT: HORIZON-CL5-2021-D5-01-07 “Enabling the safe and efficient on-board storage and integration within ships of large quantities of ammonia and hydrogen fuels”, but the targeted tank size in the present topic will most likely require a different conceptual approach.

Proposals are expected to address sustainability and circularity aspects.

HORIZON-JTI-CLEANH2-2022-02-07: Increased hydrogen capacity of GH 2 road trailers

Specific conditions	
<i>Expected contribution per project</i>	<i>EU per</i> The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.5 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project See General Annex B.

Expected Outcome

Due to its low volumetric density, hydrogen presents major challenges for transportation and distribution. Currently, compressed hydrogen transport faces limitations (mainly the delivery of small quantities of compressed hydrogen at low pressure) which inhibits its potential to become a widespread energy carrier. Moreover, the improvement and scale-up of transport and distribution technologies are needed for hydrogen to be transported efficiently, in high volumes, across large geographical areas. This topic aims to improve the efficiency of compressed hydrogen transport in order to achieve the optimum efficiency, taking into account the physical limitations.

The existing solutions operating at 500 bar have not yet reached the physical optimal efficiency and the optimum cost. Research and innovation should address this problem of increasing the mass of hydrogen transported during a transport. This objective can be reached by a significant increase in the operating pressure of the tubes employed in the transport while ensuring the safety of people and goods.

The amount of hydrogen transported with each trip defines the efficiency of compressed hydrogen transport. Increasing the amount transported by increasing volumetric capacity and/or pressure, therefore, has an impact on several parts of the logistic chain. Project results are expected to contribute to all of the following expected outcomes:

- Reduce the cost and the environmental footprint of transporting compressed hydrogen;
- Decreases the number of transport rotations between the site of production and the delivery site;
- Decreases the compressor size at the hydrogen refuelling station (HRS).

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- For the GH2 logistic: improve the cost and quantities transported;
- For the HRS capability: improve the delivered capacities and reduce the cost of the molecule at the nozzle by increasing the quantities available.

The efficiency of the solutions proposed should be evaluated with respect to the KPIs indicated below and taking into account the proposed short-term (2024) and long-term (2030) objectives proposed in the SRIA of the Clean Hydrogen JU.

- From a 350kg SoA @ 200 bar to some cases 850kg H₂ @ 300b to 1300kg @ high Pressure in 2030;
- CAPEX/kg H₂ payload should evolve from 600-650 in 2021 to 450 €/kg H₂ in 2024 and ultimately to >350 in 2030 with the high pressure;
- The goal by the end of the project would be to show a tube trailer with a payload of payload of 1.2 tonne and a capex of 400 €/kg H₂.

Other KPIs to be reached by the end of the project are:

- Operating pressure: above 500 bar;
- Tubes gravimetric capacity 5-5.3%;
- Minimum cylinder/tube retest period 5 year.

Scope

As mentioned above, the improvement of compressed hydrogen transport requires a technical improvement that also takes into account financial, regulatory and normative aspects. Commercial solution starts to exist on the market in particular for pressure at 500 bar. The challenge is to go to higher pressure at a very significant lower cost.

The scope of this topic is to develop and validate a solution with a minimum payload of 1.2 tonne of compressed hydrogen above 500 bar by end of the project. The solution should be cost competitive compared to existing solutions reaching at least a cost of 600-650 €/kg of hydrogen.

Proposals should investigate the following aspects:

Technical aspects

There are several parameters to take into account. The increase in the transport efficiency is directly linked to the increase in the operating pressure and the decrease of the tube weight, which will allow a significant improvement in the mass per unit of compressed hydrogen transported. Existing transport solutions use an operating pressure (service pressure) of 200 bar. Solutions with higher pressure start to be available. The final objective is to reach an operating pressure of 700 bar by 2030.

At constant volume, the increase in operating pressure increases the mass of hydrogen contained in each gas tube. But, with no improvements in the tubes design and materials efficiency, increasing the pressure will significantly increase the weight of the tubes containing hydrogen. This will increase the lorry fuel consumption and the transport cost and environmental footprint. In addition, in compliance with EU regulation, the authorised transport weight in a trailer is limited. Therefore, new solutions, based on new competitive materials or concepts, are needed to achieve the target of 1,500 kg H₂ tube trailer payload at operating pressure 700 bar by 2030, such as but not limited to:

- New lighter tubes manufactured with/without liners of improved performance

materials (high strength alloyed steel, stainless steel or polymeric material) in combination with improved reinforcement (composite), in order to increase the pressure conditions, reducing the weight of the tube and assuring the requested safety levels and durability, with affordable manufacturing costs. Considerations for resistance to corrosion to be considered as necessary;

- The deployment of a new design of high-pressure cylinder based on regulatory / normative documents (as per example EN 17339 that allows composite tubes with reduced safety factor);
- Large diameter composite tubes;
- More efficient filament winding and components such as valves, etc.

Applicants should propose new solutions to decrease the specific weight (e.g. per unit of hydrogen transported) of the package.

All proposed solutions should take into account the safety of the peoples and goods. The proposal should describe the method that the applicant will apply to take into account the safety aspects for the transportation system (trailer, container, bundle), tube, frames, pressure relief system (e.g. risk assessment), etc.

Financial aspect

The proposed solutions should be innovative in terms of capital expenditure. That aspect may be addressed by using, innovative design, cost-effective materials, competitive manufacturing techniques, innovative organisation, etc.

The proposals may should also address the Total Cost of Ownership (TCO).

Regulatory and normative aspect

In order to protect the people and goods, the design, manufacturing and use of compressed gas solutions are heavily regulated by international (e.g. RID/ADR), EU (e.g. TPED) regulations and ISO (International Standard Organisation) and CEN (European Committee for standardisation) standards. Technical innovative solutions may not be covered by existing standards and regulations.

The applicant should identify if the proposed solutions are covered by existing standards and/or regulations. A maximal hazard potential and its likelihood should be taken into account. If gaps are identified, the proposal should list these gaps and indicate the relevant activities that should be performed to fill these gaps.

The applicant should include actions to monitor regulatory developments and as necessary and relevant, participate in working groups working on this topic.

HORIZON-JTI-CLEANH2-2022-02-08: Development of novel or hybrid concepts for reliable, high capacity and energy-efficient H2 compression systems at real-world scale

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 5.00 million
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to achieve TRL 7 by the end of the project See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): compression prototype/s and related components, costs may exceptionally be declared as full capitalised costs.

Expected Outcome

Interest for hydrogen as an energy carrier is growing and receiving support in different sectors at an unprecedented rate. Many use-cases for low carbon hydrogen solutions are currently being investigated and include mobility, industrial processes & back-up power. Power-to-gas plants and hydrogen injection into new or pre-existing gas pipeline networks are some of the production and distribution options being developed.

Today, sustainable hydrogen production technologies (e.g. electrolyzers, biomass pyrolysis, etc) can only achieve low outlet pressures of 30 bar or less. As a result, a compression step is necessary before gaseous hydrogen can be stored and distributed, as trailer, requiring specific refilling centre.

Hydrogen compression is one of the obstacles to achieving an economical and energy-efficient hydrogen infrastructure. Several mechanical compressor technologies exist but their performances (in terms of CAPEX, OPEX, maintenance, electricity consumption and

noise) are insufficient. Innovative, non-mechanical compression technologies have been developed in previous FCH JU projects⁹³ (PHAEDRUS, Don Quichote, H2Ref, COSMHYC, COSMHYC XL, COSMHYC DEMO) over the past few years and have increased in TRL. However, in order to satisfy the ever increasing and evolving demand for hydrogen as a decarbonisation strategy, the different compression concepts need to be further developed and their ability to meet a wider range of use cases needs to be demonstrated under real operating conditions. In particular, these technologies should demonstrate an improved efficiency compared to mechanical compressors, a higher reliability resulting in lower maintenance costs, a strong flexibility to compress hydrogen from different sources with different profiles (purity, flow rates, pressure levels), and be appropriate to be installed in noise-sensitive environments.

Project results are expected to contribute to all of the following expected outcomes:

- Contributions to at least 1 full scale demonstrator for hydrogen mobility or industrial use of hydrogen by 2025;
- Contributing to keep European leadership in the hydrogen infrastructure solutions, based on compression technologies that will be applicable for hydrogen mobility, power-to-gas and industrial use of hydrogen (as refilling centre);
- Breakthrough and game changing technologies for hydrogen compression will be fully demonstrated by 2026;
- Foster the replication of the solutions demonstrated in the project in at least 5 additional locations by 2028;
- Strengthening the European value chain on hydrogen infrastructure by supporting the development of new EU industrial companies (incl. SMEs) active in innovative compression technologies;
- Lowering the costs of production of renewable hydrogen, thus accelerating the expansion of a hydrogen-based infrastructure (for which hydrogen compression is a key element).

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- To develop more efficient compressor technologies;
- To reduce the total cost of ownership of compression and purification technologies;
- To increase the reliability and lifetime of compression and purification technologies.

H2 compression optimisation as a result of the project will contribute to strengthening the business model for renewable hydrogen production from sustainable technologies (such as water electrolysis via renewable energies), thus further supporting the decarbonisation of the energy sector. Hydrogen distribution methods, such as road transport and hydrogen injection into the gas grid will also greatly benefit from the project, supporting the expansion of the hydrogen refuelling station network in Europe in all sectors of hydrogen mobility (light duty, heavy-duty, trains, ships, etc), thanks to increased reliability and cost-efficiency of the compression bottleneck.

The following KPI's should be reached at the end of the project:

- Technical lifetime: Feasibility of achieving 20 years lifetime for the compression

⁹³ https://www.clean-hydrogen.europa.eu/projects-repository_en

solution in the mid-term;

- MTBF: 10,000 hours in the short term, with a perspective for 25,000 hours in the long-term (for example by extrapolation and using accelerated tests in the demonstration phase, inherent reliability of chosen components, etc);
- Final pressure target depending by application:
 - Filling Centres: range (300-700) bar
 - HRS: 350-700 bar
 - Pipeline for pure GH₂ or blended gas: above 90bar
- Electricity consumption lower than 4 kWh/kg immediately and lower than 3.2 kWh/kg in the mid-term, starting by a hydrogen source at 10 bar, or demonstrating it;
- Maintenance costs of 0.1 €/kg immediately, with perspective to achieve 0.03 €/kg in the long term;
- CAPEX of 1,200 €/(kg H₂/day) for demonstration system and prove cost reduction up to 600 €/(kg H₂/day) when produced in large series.

Scope

Experience and lessons learnt from hydrogen demonstration projects over the past years clearly point to hydrogen compressors as one of the most critical components in terms of costs, performance and reliability. As one of the core components of most hydrogen installations, improving the state of the art of compressors is of high importance for the future success of hydrogen landscapes.

Several projects⁹⁴ have successfully shown the potential of different novel compression technologies and first prototypes have been commissioned and operated at limited scale (4 kg/h in COSMHYC, 8 kg/h in COSMHYC DEMO). There is now a need to scale-up the technologies to >1 t/day to meet the requirements of emerging use cases, incl. gas grid injection, HRS for heavy mobility and distribution supply chain (refilling centre). In addition, while previous projects focused on use cases with limited constraints on the hydrogen source (very high purity, stable supply pressure and flow rate), there is a need to increase the robustness and flexibility of new compression technologies to adapt to a broader range of hydrogen sources with varying gas quality to decrease costs and improve reliability in an industrial context

This topic aims to further develop innovative compression concepts, helping them reach the necessary maturity for large scale deployment. It involves developing, scaling-up, building, installing and testing a compression prototype at a client site with real-life applications (e.g. a hydrogen refuelling station, hydrogen production from renewable energies coupled with a filling centre, gas grid injection) and at a representative scale:

- Filling Centres: 4-20 tonnes/day;
- HRS: 0.5-4 tonnes/day;
- Pipeline for pure GH₂ or blended gas: 1-10 tonnes/hr.

⁹⁴ https://www.clean-hydrogen.europa.eu/projects-repository_en

It should consist of either an innovative compression solution, or a combination of different solutions including at least one innovative technology. The solution should demonstrate high levels of availability and efficiency, with low costs, low maintenance requirements, and high operational safety.

The demonstration duration should be at least one year of one compression solution at representative scale in a real commercial use case (gas grid injection, mobility, filling centre or a combination of uses) with an availability of at least 95%. In addition, the compression concept's potential regarding scalability, industrialisation and commercialisation at mass production scale should be proven.

The technology should demonstrate to be well-adapted to a wide range of hydrogen-based applications in all parts of the value chain. In addition, the concept should show its ability to be directly connected to a renewable hydrogen source without the need for further compression steps, and to scale-up above capacity in the mid-term, above reported.

The scope of the project should include the development, manufacturing, installation, and operation of the innovative hydrogen compressor, as well as the necessary resources for measuring, monitoring, treating and interpreting data for a techno-economic analysis throughout the project. The durability of the solution should be shown using specific accelerated stress tests, highlighting a low degradation rate and high reliability.

Proposals should identify a demonstration site and end-users where the compression technology will be applied. A limited share of the funding may be allocated to the costs induced by the surrounding infrastructure to which the compression solution will belong and contribute, including studies, civil engineering, and other equipment (such as HRS, filling centre or gas grid injection facility).

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is used. In this respect consortium may seek out the purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the purchase and cancellation of non-governmental certificates (e.g CertifHy⁹⁵).

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

⁹⁵ <https://www.certifhy.eu/>

HORIZON-JTI-CLEANH2-2022-02-09: Sampling methodology and quality assessment of HRS

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 4 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 4 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project See General Annex B.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Beneficiaries must, up to 4 years after the end of the action, inform the granting authority if the results could reasonably be expected to contribute to European or international standards.

Expected Outcome

In order to contribute to the 2030 Climate plan, the 'Fit for 55' climate action plan and Green Deal, it is of the utmost importance that the quality of hydrogen fuel dispensed at the Hydrogen Refuelling Station (HRS) is meeting the applicable requirements (Directive on Alternative Fuels Infrastructure, Directive 2014/94/EU⁹⁶ and proposal for a regulation on the deployment of alternative fuels infrastructure 2021/0223(COD)⁹⁷ and standards EN17124:2018 & ISO14687:2019. The presence of impurities will cause Fuel Cell (FC) degradation and will dramatically impact the FC durability of the zero emission Fuel Cell Electrical Vehicles (FCEV's). This will have detrimental effects on customer satisfaction and competitiveness of the FC technology, jeopardising the establishment of the hydrogen society.

To secure the dispensing of H2 up to quality standard, significant measures from production up to HRS nozzle should be taken. In addition, a hydrogen quality assurance plan guaranteeing the quality at the nozzle should be in place. These requirements are directly affecting the hydrogen price. EN17124:2018 is describing two possible hydrogen quality assurance methodologies: a prescriptive approach and a Risk Assessment (RA) based approach. It is the current industry consensus that the RA approach is the most cost effective one, but it cannot be applied as the required Occurrence Class for each impurity is not clarified in the EU market (as described in ISO19880-8:2019 & EN17124:2018). In addition, the existing EU hydrogen quality laboratories still need to be fully validated according to ISO21087:2019 for real market application. Furthermore, in case an HRS is

⁹⁶ <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094>

⁹⁷ https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf

dispensing impure hydrogen, the station should be closed for maintenance until the problem is solved; a procedure that has long been established in detail for conventional fuels. In conclusion, the hydrogen quality management directly impacts the hydrogen price as well as the availability of the refuelling stations and consequently are affecting the Clean Hydrogen for Europe JU objectives.

Project results are expected to contribute to all of the following expected outcomes:

- Widespread utilisation of the cost effective hydrogen quality assurance system by HRS operators based on RA as described in ISO19880-8:2019 & EN17124:2018 enabled by the developed Occurrence Class statistically representing the EU market (by 300 samples during the project);
- EU based hydrogen quality assurance infrastructure, including an operational network of at least 5 laboratories with market-proven capability confirmed through regular proficiency testing to the required standards;
- Alignment and standardisation of the hydrogen quality sampling and analysis at the nozzle of EU HRS, including an interoperable methodology and approach for 350 & 700 bar sampling;
- Guided future research efforts in the field of hydrogen quality (e.g. online analysers, sensors) based on the established open source database of hydrogen impurity occurrence representative to the EU market.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA: (Pillar 2: Hydrogen storage and distribution - Hydrogen refuelling stations):

- To support the availability of heavy-duty Hydrogen Refuelling Stations:
 - 98% of HRS availability for 350 & 700 bar stations;
 - Mean time between failures of 144 and 72 days for 350 & 700 bar stations respectively.
- To support the creation of a network of Heavy-duty Hydrogen Refuelling Stations across Europe while contributing to the decrease of the total cost of ownership of Hydrogen Refuelling stations by more than 50%:
 - decrease of HRS contribution in the hydrogen price to €2 and €3 per kg for 350 & 700 bar stations respectively;
 - achievement of total cost of ownership (TCO) of €10 and €6 per kg for Light Duty and Heavy-Duty FCEV respectively.

Scope

The HyCoRa and HYDRAITE FCH JU funded projects⁹⁸ focussed on the impact of hydrogen impurities on the FC (in particular to assess the severity level) and conducted a limited sampling effort, resulting in about 48 samples taken and analysed from the market over a period of about 6 years. The outcome was that not all HRS are conform to the existing quality standards; in addition, this amount of publicly accessible data is too limited to be representative to the occurrence of impurities in the EU market. Such information is required in order to enable the cost-efficient RA quality assurance approach (requiring the Occurrence Class next to Severity Level as described in EN17124:2018). The EURAMET

⁹⁸ https://www.clean-hydrogen.europa.eu/projects-repository_en

MetroHyVe⁹⁹ project developed sampling and hydrogen quality analysis methodologies on laboratory scale that need still to be validated for real market application. In addition, an initial effort in hydrogen purity laboratory proficiency testing was conducted; 4 impurities (H₂S, CO, N₂ & H₂O) were evaluated by 13 global laboratories, showing significant differences between laboratory results. Thereof, a regular continuation of the inter-laboratory comparison for the entire list of contaminants stipulated by the technical standards is required.

Following actions need to be tackled in order to address the expected outcomes successfully:

- Clarification of the Occurrence Class of the impurities in the EU market (as stipulated in ISO19880-8:2019 & EN17124:2018 (Table 2 – Occurrence Classes for each impurity)), to enable the RA approach for hydrogen quality assurance. The number of samples acting as a base to define the Occurrence Class is described in action number 3, stated below. Next to the hydrogen quality samples, all required HRS specifics to allow the utilisation of this information as an input for the Occurrence Class of the HRS quality RA should be collected. These will be defined based on input obtained from at least 5 relevant stakeholders such as gas & technology suppliers and HRS operators;
- Validate the capability of at least 5 EU based hydrogen purity laboratories, for both sampling as well as analysing hydrogen according to the applicable standards ISO19880-1:2020, ISO19880-8:2019, EN17124:2018 and ISO21087:2019, or their respective revisions. Validity of the utilised techniques should be evidenced by mass market investigation of the EU hydrogen quality as stipulated in action number 3, stated below. Next, proficiency testing up to standard level should be regularly conducted and has to be an integral part of the activity. The proficiency results should be made publicly available in an anonymised way. Root cause analysis should be conducted in case of diverging test results and countermeasures should be developed. Utilisation of technologies and methodologies researched in past funded projects (see above) is expected and support from the EU metrological network is recommended;
- As a prerequisite to support activity 1 & 2, and to make the information available for future learnings, a publicly accessible hydrogen quality database representing the hydrogen quality supplied in the EU should be established. In order to get a representative and statistical overview of the hydrogen quality dispensed at 350 & 700 bar stations in the EU market, at least 100 samples from the HRSs should be collected and analysed per year, of which maximum 25% of the samples are obtained from the same HRS. The utilised methodologies' interoperability should be maximised to be applicable on different pressures (350 & 700 bar). The location of samples taken will be in proportion to the geographically spread of HRSs across the EU. In addition, the occurrence of at least 4 impurities beyond EN17124:2018 and ISO21087:2019: i.e. new non-standardised impurities or not well-defined impurities such as 'total' sulphur or halogenated compounds of a selected number of samples should be investigated by utilisation of wide scope analytical techniques.

⁹⁹ https://www.euramet.org/research-innovation/search-research-projects/details/project/metrology-for-hydrogen-vehicles/?tx_euramettcp_project%5Baction%5D=show&tx_euramettcp_project%5Bcontroller%5D=Project&Hash=306d1f42e20989c0b2658abf0f76c8ca

- Based on the output of objectives 1, 2 and 3, a working group should clarify the development need or improvement opportunities in the field of hydrogen quality assurance. In addition, recommendations to support the development of the future HRS sampling standard (ISO19880-9, TC197) should be made.

As the scope of the topic contains significant portions of measurement and analysis, cooperation with the European metrology community, such as the European Metrology Network for Energy Gases¹⁰⁰ of EURAMAT, should be pursued. Within this context proposals should explain how they would complement and avoid overlaps with the ongoing activities of EURAMET, e.g. project MetroHyVe2¹⁰¹.

In order for the proposal to reach the expected outcome, the deliverables should be disseminated at the end of the proposal to the hydrogen mobility and hydrogen refuelling infrastructure communities and relevant working groups of the standardisation technical committee's such as ISO TC 197, ISO TC 158 & CEN TC 268, including the new standard under development ISO19880-9 (TC 197), related to HRS sampling. Proposals are encouraged to include a formal standardisation body within the consortium.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

¹⁰⁰ <https://www.euramet.org/european-metrology-networks/energy-gases/what-we-do/>

¹⁰¹ https://www.euramet.org/research-innovation/search-research-projects/details/project/metrology-for-hydrogen-vehicles-2/?L=0&tx_euramettcp_project%5Baction%5D=show&tx_euramettcp_project%5Bcontroller%5D=Project&hash=9875d9a3fb9cfbdf8e44d44e12ac5eea

HORIZON-JTI-CLEANH2-2022-02-10: Implementing new/optimised refuelling protocols and components for high flow HRS

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 4.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 8.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 6 by the end of the project. See General Annex B.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches , grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds.

Expected Outcome

The development of hydrogen powered heavy-duty vehicles (HDV) is key to be able to decarbonise transport of passengers and goods. To achieve this effectively, hydrogen refuelling station (HRS) technologies need to be upgraded to address the refuelling needs of heavy-duty vehicles. The actions described herein will contribute to bring appropriate HDV HRS and HDV HRS components on the market.

Project results are expected to contribute to all of the following expected outcomes:

- Fully developed and ready to commercialise HRS components (nozzle, hose, cooling unit, safety critical devices, pressure regulator or flow control valve, filters, advanced safety-related communication interface, flow meter etc) meeting the refuelling needs of HDV;
- Certification of the above-mentioned components according to relevant ISO, OIML or CEN standards. If related standard is still under development, contribution to standard writing in order to ensure components compatibility with future and enable certification in the short term;
- Demonstration of the fully integrated chain of specific HDV HRS components on at least 2 different HDV HRS for a total of 300 refuelling events each;
- Full demonstration of new standardised refuelling protocols for heavy-duty vehicle developed in ISO TC 197 WG24 or other standardisation body, as well as approval concept for the conformity of the station to the protocol.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA (Pillar 2: Hydrogen storage and distribution – Sub-pillar Hydrogen Refuelling Stations:

- To tackle the technical challenges associated with heavy-duty hydrogen refuelling stations in order to develop a commercial solution that conforms to the heavy-duty requirements;
- To increase the reliability and availability of Hydrogen Refuelling Stations;
- To support the creation of a network of Heavy-duty HRS across Europe.

In particular projects results are expected to contribute to the attainment by 2024 of the relevant KPIs identified in the SRIA of the Clean Hydrogen JU including:

- HRS mean time between failures: 72 hours (700 bar) and 144 hours (350 bar);
- Annual maintenance cost: 0.5 €/kg (700 bar) and 0.35 €/kg (350 bar);
- HRS CAPEX(200 – 1000 kg/d): 1,5- 4 k€ / (kg/Day) @ 700 bar and 0.65-2.5 0.35 k€ / (kg/Day) @ 350 bar;

In order to contribute to these KPI, the following additional KPI should be targeted:

- The target price for the complete refuelling line downstream compressor and storage should be 300 k€ with following components target price for 50-100 unit/year: Nozzle 6 k€; Hose 2 k€; Advanced bidirectional communication interface: 2k€; Break away: 2.5 k€; Flow measuring device: 25 k€; Cooling system: 200 k€; Pressure regulator or flow control valve: 6 k€.

Scope

To fulfil future HDV refuelling needs such as fuelling a 100 kg HD truck storage system in 10 minutes, an HDV refuelling point should reach a mean fuelling rate of approximately 170 g/s with a peak fuelling rate up to 300 g/s. To guarantee optimal refuelling performances, reliabilities and costs for a wide range of possible HDV storage capacities and configurations, new fuelling protocols based on advanced and safe communication between vehicle and station (e.g. the one developed in ISO TC 197 WG24 based notably on feedback from PRHYDE project¹⁰²) should be implemented. To meet these requirements, proposals should develop, test and certify appropriate components to bring them to commercialisation.

Proposals should address:

- Qualification of the components:
 - Identify the gaps in terms of standards, market availability and testing;
 - Perform a qualification roadmap individual for each component, with specific targets;
 - At the end of the project, identify potential missing gaps, components, experience to be continued before full market implementation.
- Qualification of the protocol:
 - Implement the components developed in the qualification program or potential alternatives
 - Define a refueling protocol validation roadmap, accounting for available standards

¹⁰² https://www.clean-hydrogen.europa.eu/projects-repository_en

- Check that each component performs as expected in a full assembly
- Validate the protocol on various testing
- Dissemination of the outcomes;

During the project, those of the following components that are not available on the market should be developed, tested, certified and brought to commercialisation:

- Nozzle, break away and hose: H70 and H35 very high flow nozzle, break away and hose should be designed for 300 g/s peak flow. A particular attention should be paid to limit pressure drop and heat transfer from the surrounding atmosphere. The project should contribute from the beginning of the project to ISO TC 197/WG5 and WG22 currently working on a new version of ISO 17268 and ISO 19880-5. The components developed should be certified according to previously mentioned standard if published before the end of the project. The feedback on current components drawbacks (size, weight and manoeuvrability, freezing preventing disconnection of nozzle at the end of the refuelling, fragility when dropped, life duration) should be considered.
- Advanced bidirectional communication interface (HRS and vehicle side): Optimised refuelling protocol able to address a wide range of on-board storage systems and configurations will need an advanced communication interface between vehicles and stations, sufficiently reliable to allow communicated data to be used for safety critical decision in the refuelling protocol. The interface should be developed in collaboration with major European HDV manufacturers. The project should contribute as soon as possible to ISO TC 197 WG24 Task force 2 working on ISO 19885-2 standard on the definition of communications between the vehicle and dispenser control systems.
- Flow measuring device: The project should develop a flow meter compatible with high flow rate (170 g/s mean flow rate, 300 g/s peak flow, targeting >100kg total mass per refuelling) for H35 and H70. An entire measuring device (including flow meter, calculator etc) ready to be implemented on a dispenser should be developed and certified according to OIML R139.
- Cooling system: The cooling system should be able to cool hydrogen to obtain a hydrogen temperature at the dispenser of -20°C or below, for a mean fuelling rate of 170 g/s with peak flow of 300 g/s. During design phase the balance between refuelling performance versus the cost (CAPEX and OPEX) of the cooling system should be studied. Particular attention should be paid to reducing the footprint
- Pressure Regulator or Flow Control Valve: The component should be able to control the pressure ramp rate or the flow appropriately to follow new refuelling protocols and manage corresponding range of flow/pressure variations. A focus should be paid to reaching the needed reliability of valves.
- Safety critical devices, valve, filter and other components: The project may develop any specific components of the refuelling line downstream compressor and storage that is not available on the market with characteristic suitable for HDV refuelling. Particular attention should be paid to reach sufficient flow coefficient to limit pressure drop throughout the whole system. Special focus should be paid to reach high reliability throughout the fuelling system. Development of efficient and long-life filters to keep contamination and wear to a

minimum will be necessary and investigated as during the project.

- Dispenser: Most of the above-mentioned component should be integrated in a dispenser that should follow ISO 19880-2. The project should also pay attention to propose standardised integration and sizes of the dispenser in a logic of one fit all.

The targeted rated pressure of the developed components should be at least 138% of the nominal working pressure following the recommendation of chapter 8 of ISO 19880-1. The component shall be developed within the first 2.5 years of the project to allow 1.5 years for integration and testing in a full refuelling line assembly.

During the project, a fully integrated component chain from pressure regulator to nozzle and associated control command should be designed and built and should be integrated on at least two HRS having storage and/or compression capability allowing several 100 kg HDV onboard storage per day. A testing phase of at least 6 months under relevant operating conditions should take place during the project. Full experimental set up details and experimental data of the tests should be made publicly accessible at the end of the project.

HRS architecture may be based on direct compression or transfer from high-pressure cascade storage, but these components (compressor and storage) are not the focus of the scope of this action and only a minor share of project funding should be related to storage, compressor and further station adaptations. The control command of these HRS should integrate new HDV refuelling protocols currently under development in ISO TC 197 WG24 or other standardisation bodies. The project should take part as soon as possible to ISO TC 197 WG24 task force 3 working on ISO 19885-3 technical document on new high flow refuelling protocols to better understand these protocols and contribute with feedback on implementation challenges. This project should benefit from the work previously carried out by the PRHYDE¹⁰³ project on HDV refuelling protocols.

The project should assess hazard and associated risk of refuelling with the developed fuelling line and should benefit from, but also provide added value compared to the work previously carried out by the MultHyFuel¹⁰⁴ project on the safety considerations for the HRS design.

Applicants are encouraged to involve component manufacturers, HRS manufacturers, HRS operators and heavy-duty vehicle manufacturers.

¹⁰³ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹⁰⁴ https://www.clean-hydrogen.europa.eu/projects-repository_en

HORIZON-JTI-CLEANH2-2022-02-11: Development and demonstration of mobile and stationary compressed hydrogen refuelling solutions for application in inland shipping and short-distance maritime operations

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 7.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 7.00 million.
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 6 by the end of the project. See General Annex B.
<i>Eligibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The page limit of the application is 70 pages.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): bunkering prototype/s and related components, costs may exceptionally be declared as full capitalised costs.

Expected Outcome

Hydrogen and hydrogen derivative fuels are expected to play a vital role in enabling the decarbonisation of shipping and maritime activities. Many projects are underway seeking to develop hydrogen fuel cell systems to provide both auxiliary and propulsive power for vessels at a range of scales, with strong engagement from ship designers, ship builders, owners and operators, as well as fuel cell developers. However, these organisations may not be well placed to develop the understanding of technical and societal parts of bunkering infrastructure deployment required to facilitate market uptake of hydrogen-fuelled solutions. This action will address that gap.

This topic aims to contribute to setting standards for future inherently safer hydrogen bunkering for inland shipping, and for short-distance sea-going maritime applications, including in island contexts. Developing these solutions is of vital importance to facilitating further innovation activity in deploying hydrogen solutions in shipping, as well as in de-risking future investments.

Project results are expected to contribute to, but not limited to, the following expected outcomes:

- Improved understanding of the health and safety requirements for hydrogen bunkering in a range of operational shipping contexts, which will make bunkering more efficient and inherently safer to reduce hazards and consequences of potential incidents, and thus de-risk future developments;
- Closed knowledge gaps on characteristic hazards and associated risks;
- Lessons learned which can inform heavy-duty refuelling development for other sectors, to facilitate further deployment of hydrogen in a wide range of transport and freight sectors;
- Identification of regulatory challenges and barriers, and areas of focus for pre-normative research and regulatory reform, in order to unlock future fuelling of heavy-duty applications;
- Guidelines and/or draft standards for hydrogen bunkering components and systems to increase the coherence of innovation activities and improve uptake throughout Europe and beyond;
- Leveraging the opportunities associated with shipping as an off-take sector in the development of business cases for hydrogen storage and distribution networks.
- Improved understanding of requirements for type approval for both ship-to-shore and ship-to-ship interfaces and control systems to facilitate widespread commercialisation of the solutions;
- Deployment of hydrogen bunkering infrastructure of at least 800 kg H₂/day capacity in project locations;
- A boost in the uptake of hydrogen-fuelled vessels, and associated commercialisation benefits for the broader hydrogen economy;
- Training for vessel crew and bunker terminal personnel, which can be replicated.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA, (especially for Pillar 2, Hydrogen Storage and Distribution –Sub Pillar: HRS):

- Availability [%]: >97% in 2024 and 99% in 2030
- Mean time between failure [d];
 - For 700 bar: 72 in 2024 and 168 in 2030
 - For 350 bar: 144 in 2024 and 336 in 2030
 - For liquid hydrogen: 216 in 2024 and 504 in 2030
- HRS contribution in hydrogen price [€/kg]:
 - For 700 bar: 3 in 2024 and 2 in 2030
 - For 350 bar: 2 in 2024 and 1.25 in 2030
 - For liquid hydrogen: 3 in 2024 and 2 in 2030

Scope

It is expected that scalable bunkering solutions will best be developed through the demonstration of innovative systems which can deliver hydrogen to vessels safely, quickly and at low cost. The technical development for these solutions should be accompanied by

work to understand the underlying physical phenomena, develop health and safety practices, satisfy existing and suggest new regulatory requirements as needed, deliver appropriate classification of the solutions developed, and facilitate wide roll out of the solution. Previous desk-based studies have proposed the development of a corridor of hydrogen bunkering hubs at key connecting ports across Europe, and it is expected that this initiative will be tied to a location with developed offtake for compressed hydrogen gas. To realise these ambitions, standardisation of the developed engineering solutions, including components such as refueller, connections, nozzles, as well as of fuelling protocols, is also a key priority.

There are a number of different approaches to developing appropriate bunkering solutions, which will be more or less relevant according to local requirements. Maximum impact for the action will be secured by tying the solution developed to a local need, to enhance the commercial case for the adoption of the solutions developed. To ensure that the solutions developed address the full range of challenges foreseen, the action should focus on one of two distinct focus areas:

- A pipe-to-ship stationary refuelling solution which is multi-modal, in that it can address refuelling requirements for a range of vehicles including trains and trucks, as well as account for refuelling for shore-to-ship power. The infrastructure and fuelling protocols should be designed for simultaneous bunkering operations and should be able to scale in future;
- A floating ship-to-ship or platform-to-ship bunkering system and protocol, to facilitate efficient hydrogen delivery without the need for vessels to visit a port or stationary refuelling station, as well as to provide resilience and redundancy. If this focus area is selected, then the successful project should cooperate with the successful project of HORIZON-JTI-CLEANH2-2022-03-05, working on the barge-to-barge bunkering.

Proposals should also:

- Demonstrate a smart and safe logistics solutions and develop a market standard to support front-running shipping projects;
- Evaluate the proposed solutions from technical and economic points of view, including robustly considering business models and the cost of hydrogen delivered;
- Address health, safety and environmental considerations, and should take account of standards in development internationally;
- Specifically, build upon existing blueprints deriving from liquified natural gas protocols and international standards developed for those. To this end project consortia should seek to involve key sector stakeholders, such as port authorities, classification societies, ship designers, ship owners and specifically international organisation such as the Society of International Gas Tanker and Terminal Operators (SIGTTO), the International Association of Ports and Harbours (IAPH) and the Society for Gas as a Marine Fuel (SGMF);

Ensure to build upon best practice developed in current and near-term pilot projects wherever possible.

The HORIZON-JTI-CLEANH2-2022-02-11 and HORIZON-JTI-CLEANH2-2022-03-05 topics are highly complementary and synergies between the two should be sought by applicants. As the scope of the project is embedded within the activities of other

partnerships, namely the Zero Emission Waterborne Transport (ZEWT) co-programmed partnership, cooperation with them should also be pursued.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is used. In this respect consortium may seek out the purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the purchase and cancellation of non-governmental certificates (e.g CertifHy¹⁰⁵).

¹⁰⁵ <https://www.certify.eu/>

HYDROGEN END USES: TRANSPORT APPLICATIONS

HORIZON-JTI-CLEANH2-2022-03-01: Development and optimisation of reliable and versatile PEMFC stacks for high power range applications

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 3.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 7.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project See General Annex B.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches , grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds.

Expected outcome

Developing and deploying cost-competitive and mature Hydrogen Fuel Cell technology by 2030 is crucial for reaching EU's aim of reducing greenhouse gas emissions while maintaining economic growth. Innovative solutions addressed by the proposals submitted for this topic will contribute to the clean and sustainable transition of the transport sector towards climate neutrality, targeting here its exploitation primarily for road transport, while considering possible spill over benefits for maritime, rail and aviation. The major expected long-term impact is an actual support to cost-competitive deployment of reliable Fuel Cell based heavy-duty land transport, thanks to advances in the PEMFC stack which is the core and one of the main technology building blocks for fuel cell-based propulsion systems.

Cost, power density, efficiency and durability are the key parameters for successful fuel cell stack implementation in heavy-duty transport applications. The final outcomes will be enhanced performance and durability assessed at stack level, through optimised and sustained operation validated at high efficiency under high load. These results will also facilitate integration and the adaptation of the innovative solutions to various user profiles and applications, taking into account hybridisation and fair compromise between stack and system performance.

Project results are expected to contribute to all of the following outcomes:

- Deployment of the developed solutions by PEMFC stack manufacturers (2027);
- Uptake of the developed solutions by Fuel Cell system developers for their further implementation in trucks, ships, aircrafts or trains (2030);

- Contribution to Clean Hydrogen JU SRIA KPIs (2024 and 2030) on PEMFC stacks and systems for road transport applications;
- Identification of new possible routes or breakthrough for PEMFC based on new knowledge (>2030);
- Proposal of technical ideas adaptable for developments of FC systems for ships, trains or aircrafts (>2030);
- Contribution to Regulation Codes and Standards in the fields of PEMFC or hydrogen for transport (continuously).

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Ready-for-integration solutions for high efficiency PEMFC stacks, demonstrating required cost, durability and performance;
- Innovations and advances to mitigate issues for both high power and high efficiency usage: on comprehensive operating strategy of the PEMFC; on design of the cell unit; or on design of the overall stack;
- Improved knowledge on performance limitations and degradation issues for these high power PEMFC.

Quantified indicators, included in the Clean Hydrogen JU SRIA KPIs (for 2024) for assessment of these objectives are:

- An increase in efficiency versus the stated starting point. Proposals should hence specify the starting point for the technology and system considered.” A FC stack durability of 20,000 hours with beginning of life power density of 1.0 W/cm² at 0.675V. Both should be demonstrated following boundary conditions given in the scope;
- A global stack cost lower than 75 €/kW and a PGM loading of 0.35 g/kW. Given that the scope is focused on technical improvements of the stack technology, not including direct cost reduction, nor MEA components development, the purpose will be to assess the indirect impact on cost and on specific PGM-loading [g/kW] of the innovations and developments conducted;
- Agreed validated protocols representative of targeted usage as needed for appropriate assessment of KPIs. Different types of use can be considered including the power demand of balance of plant and auxiliary devices;
- Supplementary outcomes can be promoted such as: new methodologies or tools, new measurement or simulation methods, characterisation or testing protocols, numerical simulation software or services;

Scope

Advances in the PEMFC stacks technology are needed to support deployment of Fuel Cell heavy-duty transports. Cost-competitive and reliable integration require stack solutions particularly tailored for sustained operation at high stack-power. Proposals should focus on applicability of their developments in the field of land transport, primarily road, while considering possible spill over benefits for maritime, rail and aviation

Proposals should address innovative concepts, designs, methods and/or operating-strategies. Related investigations may tackle cell and stack levels, including flow-fields,

bipolar plates or assembling features (e.g. mechanical aspect), as well as the range, the distribution or the management of the operational conditions (e.g. thermal or reactant gases feeding aspects). The overall process should build on comprehension of the currently proven PEMFC technology and further development at stack level targeting optimised operation for high efficiency and extended durability at high stack power density. For the range of power envisioned, increasing efficiency would enhance the overall system with respect to volume savings for fuel storage.

Innovation on MEA is out of scope of this topic. Work should therefore be conducted on validated components, including commercialised or developed in other actions. Availability of baseline features on MEA should be a prerequisite: for commercial or promising R&D products, agreement of companies or developers to provide needed parameters and to allow deep analysis as relevant for reaching expected outcomes is needed. Maximum total loading should be 0.5 mg PGM/cm².

Optimisation should be supported by advanced experimental and simulation tools to analyse the impact of stacks features on their functional properties (e.g., performance level and limitations, voltage losses, electrochemical characteristics) regarding application requirements and system specifications. Local insights, especially meaningful for the large active area considered, should be assessed for different zones, between cells and across interfaces by in- and ex-situ characterisations and by simulations using cell- and stack-design based models. A better specific understanding of global and local mechanisms, occurring in cells and stacks operated at high power and affecting both performance and degradation, should be acquired thanks to spatially distributed analyses. Data will be used to clarify the influence of components, design, assembly or working features (e.g., load profiles, conditions and events). Developed experimental, monitoring or model-based approaches should be exploited to promote expected innovations and advances on comprehensive operating strategy of the PEMFC and on design of the cell unit or of the overall stack.

Compliance with the targeted KPIs, assessment of progress and final validation should be examined at stack scale (minimum 5 kW, or 10-cell-stack and scale-1 cell surface) under relevant conditions representative of actual use, taking into account system requirements for the targeted applications. Validated agreed protocols (including accelerated testing) should be applied to confirm and quantify improvements in areal power density, stack or system efficiency and lifetime. These protocols will be developed within the project if needed or selected in agreement with previous initiatives and in cooperation with relevant applicative roadmaps.

Focusing the development on advanced research work while monitoring progress and validating final optimisation at representative scale under protocols and conditions relevant for system level, is expected to achieve expected outcomes with efficient innovative solutions applicable for short-term integration.

Proposals should, where relevant, build on previous/on-going FHC JU projects¹⁰⁶ addressing transport and similar activities, aligning particularly with: ID-FAST, IMMORTAL or MORELife regarding degradation understanding or ageing protocols; INSPIRE, DOLPHIN for developments on stacks; STaSHH for outcomes related to stack integration.

Proposals should demonstrate how the results would benefit to the whole industry, while protecting intellectual property for the involved partners. With this in mind, proposals should include public deliverables and describe how project data will be made available to the

¹⁰⁶ https://www.clean-hydrogen.europa.eu/projects-repository_en

large public.

Consortia should include at least one partner in the consortium for the exploitation of the project results and willingness to exploit the results should be demonstrated. It is encouraged to include actors from research and industry, the latter being interested in PEMFC stacks or system deployment.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹⁰⁷ to benchmark performance and quantify progress at programme level.

¹⁰⁷ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-03-02: Innovative and optimised MEA components towards next generation of improved PEMFC stacks for heavy-duty vehicles

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 6.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project See General Annex B.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches , grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds.

Expected outcome

Hydrogen as fuel in transportation has significant advantages compared to pure battery electric propulsion, especially for heavy-duty applications. But these applications require higher power and much longer lifetimes than those developed and achieved for SoA passenger cars. Further improvements of SoA components of MEAs represent a major opportunity for both increasing the areal power density and long-term durability of PEMFCs. Innovations should address the core components of MEAs – membrane, catalyst layer, microporous layer and gas diffusion media – and specifically their interactions within an MEA.

Project results are expected to contribute to all of the following expected outcomes:

- Contribute to paving the road for increased competitiveness of and market shares for European fuel cell companies in the emerging global market for PEMFC technologies in transport;
- Improvement of overall system performance of FC systems in order to improve the availability and durability and meet the needs of FCH heavy-duty vehicle (HDV) end-users;
- Improvements in design and monitoring procedures of FC systems;
- Provide MEA components that contribute to the achievement of the SR IA KPIs for HDV;
- Improve the understanding and prediction of MEA performance and lifetime;
- Support the development of specific applications for MEAs (particularly for HDV, but

also transferable to rail, aviation, maritime etc) by means of materials characterisation and parameterisation of material properties;

- Provide models that support European companies developing new MEA and MEA materials and components. Enable these target groups to simulate the influence of MEA material properties on performance and degradation processes. Such physics-based MEA models are expected to become part of their workflow which is necessary to develop competitive application-specific MEAs with high durability;
- Up-take of MEA parameterisation, simulation, and support services by the target groups to strengthen the European value chain on fuel cell stacks;
- Increasing fuel efficiency during the whole FC lifetime and thereby foster the market introduction of HDV;
- Contribute to harmonisation of testing protocols for quantification of MEA performance and lifetime, including accelerated stress tests.

This topic addresses objectives for hydrogen end uses in transport applications, sub-pillars Building Blocks and HDV. In particular, project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Improvement of the overall system performance for fuel cell stack technology in terms of power density, reliability and durability (KPIs for low TRL in 2024: Power density of 1.2 W/cm²@0.65 V, FC stack durability of 20,000 h);
- Reduction of PGM loading (KPI: PGM loading for low TRL < 0.30 g/kW in 2024);
- Contribute to the reduction of the FC stack cost for HDV (KPI: < 75 EUR/kW in 2024) through affordable MEA materials and components and cost of manufacturing;
- Improvements in the design and health monitoring of core components for FC stacks;
- Improvement of overall system performance of FC systems in order to improve the availability and durability and meet the needs of FCH HDV end-users;
- Improvements in design and monitoring procedures of FC systems.

Scope

Despite substantial research work continuously conducted in the field, the knowledge acquired so far shows that SoA components or methods followed for their enhancement do not reach the performance and lifetime targets for heavy-duty transport. This topic is focused on building blocks for HDV with an expectation for synergies, adaptability, and compatibility with other areas such as maritime, aviation, trains etc. Challenges to be addressed by proposals are:

- Durable and active catalysts and advanced supports are required to achieve high ORR activity and to assure long lifetime by mitigation of ECSA loss, and reduction of oxygen transport resistance. The end of life (EoL) performance of MEA in HDV applications needs to be simulated and experimentally assessed.
- The chemical and mechanical stability of the PEM can limit the lifetime in HDV applications especially at increased operating temperatures. Therefore, robust and durable membranes and ionomers are essential.

- Electrode design needs to be improved to meet the HD KPIs involving tailored ionomer loading, Pt particle size distribution and location, as well as improved catalyst ionomer interaction. The challenge is to tailor electrodes for HDV applications, where electrocatalyst-ionomer interactions and integration is improved and PGM loading is reduced.

The approach should be based on an analysis of the limitations of MEA components in terms of particularly lifetime and fuel efficiency and held against the targets for the next generation technology.

A combination of materials characterisation, optimised catalysts – support interaction, MEA fabrication, testing and modelling is considered the key to gain deeper understanding of the limitations involved in previous generation stack components. Quantification of barriers to the fluxes of mass, energy, charge, and momentum at target operating conditions of MEA for HDV is needed to progress on tailored materials and controlled structures.

Innovative materials (catalyst, catalyst support, ionomer, hydrophobic/hydrophilic treatments etc.) and components (membrane, catalyst layer, microporous layer and gas diffusion media) are expected to be fabricated and characterised at lab scale. Possible developments are, for example, membranes that are stable at high temperature (up to 120°C), high activity catalysts that are stable, improvement of the catalyst support to avoid corrosion of carbon at high voltage (start/stop) etc.

The structure of components and interfaces should be improved reflecting operational conditions representative for heavy-duty application. Analysis, optimisation, and lifetime prediction of MEA should be supported by SoA multiscale simulation. MEA models should capture the coupled transport of heat, charge, and mass, and electrochemical reactions in all MEA components and across all interfaces, including two-phase water transport, heat production/cooling. It is important to account for antagonistic transport effects to determine the impact of changes in materials, components, interfaces properties, morphology or dimension on the performance of cells and on degradation processes. Validation strategies should be based on accelerated stress tests representative for heavy-duty applications and component-specific simulation of different degradation processes.

Reproducible MEA structures and properties are prerequisites to assess MEA performance limitations and to identify transport barriers. Existing fabrication processes applied to integrate new materials/components within innovative MEA or specifically developed to realise new materials/components or structures should be demonstrated. Innovation on MEA components is also expected from the design, fabrication and analysis of alternative MEA constructions, including the reduction of PGM content, recovery of waste and recycling of components, thus facilitating the adoption of the circular economy principles. Variation of morphology, hydrophobicity, Pt content, and adaption of MEA structures to the flow-field etc. are possible approaches.

Innovation can be reached by improved model parameterisation from ex-situ characterisation of materials/components/interfaces properties, morphology. For instance, there is a significant uncertainty in the properties of commercially available components, especially of catalyst layers, microporous layers or membranes made of composite materials. The ionomer transport properties, either in the catalyst layer or in the membrane (hydration, electroosmotic drag, water diffusivity, protonic conductivity), need to be better parameterised.

Improving MEA durability in relevant testing environment without sacrificing performance is a key aspect of this topic. Therefore, MEA degradation modelling is expected to address the different sub-components of the MEA (e.g. catalyst, GDL, MPL, catalyst layer, ionomer) and their interactions. MEA simulation may also be used to predict the relation between operating temperature, cell voltage and the durability of electrodes and membranes.

Test hardware capable for reliable model parametrisation should be developed or be available for the implementation and the test of both performance and durability of reference and developed MEA. Project consortia should include the capability to manufacture MEA compatible with high volume manufacturing to ensure future exploitation potential to be reached. Final validation of MEAs should be performed by using single cells and possibly in short stacks in-line with EU standardisation activities. MEA durability assessment should be performed on the cell level for a minimum of 1,000 hours of operation with extrapolation possibly up to 20,000 hours. Access to OEM single cell/stack testing hardware for final validation is requested.

Target groups are companies fabricating MEA components, MEAs, and the scientific community working on new materials and components.

A TRL 4 should be targeted as final TRL considering the current state of the art MEA used in LDV applications and related knowledge and experience from the previous FCH JU projects¹⁰⁸ (e.g. GAIA, Immortal). Development of PGM free catalysts, new fabrication and scale up processes are out of scope. Work will be conducted on SoA fabrication methods of Pt or Pt alloys/C based catalyst layers and should consider the recovery and recycling of by-products and waste. A company being able to manufacture MEAs should be part of the consortium for better exploitation value. Participation of an OEM or a stack manufacturer is encouraged. At least, an OEM should be part of the project's advisory board. Projects should build synergies with current projects¹⁰⁹ on MEA/components development for light-duty applications (e.g. FURTHER-FC, DOLPHIN, GAIA). Agreement of companies to extract material parameterisations by ex-situ characterisation should be sought to gain predictive numerical simulation results.

Proposals are expected to address sustainability and circularity aspects.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹¹⁰ to benchmark performance and quantify progress at programme level.

¹⁰⁸ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹⁰⁹ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹¹⁰ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-03-03: Large scale demonstration of European H2 Heavy-Duty Vehicle along the TEN-T corridors

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of maximum EUR 30.00 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 30.00 million
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 7 and achieve TRL 8 by the end of the project See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The maximum Clean Hydrogen JU contribution that may be requested is EUR 30.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): trucks, fuel cell system, on-board hydrogen storage and other components needed in a hydrogen truck, costs may exceptionally be declared as full capitalised costs.

Expected outcome

Hydrogen has proven to be the alternative to conventional ICE operated on fossil fuels, especially for long range and flexible zero emission (ZE) Heavy-Duty (HD) mobility, where direct electrification with large batteries cannot meet the intensive usage and payload requirements. Large scale fleet deployments and operations are needed. Wheels on the roads, operated by different operators in different EU markets and geography, providing insight on relevant business cases for potential buyers, and then the respective refuelling infrastructure in order to guarantee the long-haul distance are needed.

Hydrogen mobility currently is not always perceived as a viable zero emission alternative against ICE and BEV. Allowing relevant fleet owners and operators to experience first-hand the technology would play an important role in changing this perception of the technology.

Furthermore, their lighthouse function will set an example for many other potential end-users, who can benefit from the experience of the ‘front-runners’. Next to this, the parallel introduction of multiple fleets throughout a variety of operations, in multiple EU Member States, will increase the credibility of hydrogen as a commercial alternative. For this to happen it is necessary to break through the current vicious circle (small quantities because of high prices and high prices because of small quantities).

This flagship¹¹¹ topic aims to address all of the aspects above mentioned via the deployment of a large fleet of fuel cell HDV across several countries and use cases.

Current research shows that boosting economies of scale on the short term, will enable hydrogen to become economically feasible as from 2025. In this sense this project represents a critical step in that direction. It will initiate and substantially accelerate the initial cost reduction of fuel cells trucks by enabling the relevant supply chains to reach critical mass, which in turn will accelerate the attainment of the Total Costs of Ownership (TCO) competitiveness.

As enabler, heavy-duty, long-haul truck has proven to be the ideal market-segment for doing this. It is often forgotten that the market size, combined with the total energy consumption, and a high potential to generate (concentrated) vehicle fleets, provides the ideal situation to function as a flywheel for other markets. Current market research is expecting 100,000 vehicles in 2030 and growing to >100,000 hydrogen trucks per year (representing 25-30% of the yearly truck sales). The end goal is to make hydrogen for Heavy-Duty applications economical viable without funding's in the next 5-10 years.

In earlier programs the feasibility of hydrogen in distribution trucks was demonstrated (H2Share¹¹² 27 tonne and Hydrogen Region 2.0¹¹³ 44 tonne truck). The FCH JU funded H2Haul¹¹⁴ project intends to upscale the tractor truck to long haul operation along defined corridors near the operator.

In total 16 trucks will be deployed in the H2Haul project. As seen in comparable markets, such as public transport, a logical transition step for operators is to start with a demonstrator, then move to a small series and towards a first fleet of 20 to 40 vehicles, before they have fully embraced the technology as a ‘normal’ alternative. These single fleets will drive the OEM and suppliers forward as they need to work in parallel to be able to provide the right product and service proposition. To this end, the FCH JU funded StasHH¹¹⁵ project aims to define a standardised fuel cell module in order to facilitate growth and economy of scale.

Therefore, the next step (before hydrogen trucks can be delivered at large scale in the Important Projects of Common European Interest (IPCEI projects) are the flagships projects: allowing the truck agglomerates (OEM) to have a hydrogen truck ready for sale in limited numbers and to integrate the hydrogen truck as platform in their product line and service organisation. Furthermore, the data collected in such a flagship project is key to allow truck manufacturers and transport companies to strengthen and validate the operational and financial viability of hydrogen trucks for daily operation.

A critical success factor is the network of HRS to ensure the hydrogen refill demand is available on the route showing the hydrogen trucks long haul capabilities along major

¹¹¹ For definition of flagship see section 5.3. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

¹¹² <https://www.nweurope.eu/projects/project-search/h2share-hydrogen-solutions-for-heavy-duty-transport/>

¹¹³ <https://www.waterstofnet.eu/en/hydrogen-region-2-0>

¹¹⁴ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹¹⁵ https://www.clean-hydrogen.europa.eu/projects-repository_en

transport corridors throughout Europe. In addition, a truck refuelling market could enable a faster deployment of HRS and a lower price of hydrogen delivered thanks to higher volume associated than when solely supplying light duty vehicles.

Project results are expected to contribute to all of the following expected outcomes:

- Economy of Scale for all hydrogen components, and as a result demonstrate a significant decrease in TCO per tonne per km by truck OEM, HRS operators and transport companies working together, making heavy-duty hydrogen trucks operationally and financially viable;
- Increase in sales of the total volume of trucks as similar TCO decreases can be expected in other markets and applications (e.g.: refrigerating trucks);
- Contribute to the expansion of the hydrogen truck service network and HRS network through Europe and along the TEN-T core and comprehensive network. This should require OEM agreement to mitigate the risk of creating stranded assets and to concentrate resources;
- The creation of a competitive offering of several models of hydrogen trucks (from different truck OEM) and creating added value for the European Industry;
- Promote hydrogen trucks and refuelling as an operationally and financially viable alternative for BEV trucks and biofuels, contributing to the resolution of a maximum scope of technological (e.g. lifetime and durability, HRS/truck compatibility), operational (e.g. driving range, payload capacity, refuelling time), regulatory (e.g. tax exemptions and incentives), and financial challenges (TCO), making hydrogen trucks operationally and financially viable for transport companies in Europe;
- Comparison of the different zero emission trucks on performance, range, environment, TCO, etc;
- Gathering of relevant technical and financial data in different conditions from truck operation: range, speed-, load profile, refuelling time and the supply of hydrogen: (public) pipeline network, tube trailer (different pressures), local electrolysis etc;
- Providing a growing market that becomes increasingly interesting for competition between hydrogen component suppliers and enabling the transition from job shop and batch manufacturing towards mass production of hydrogen trucks and HRS;
- Demonstrate the implementation/feasibility of harmonised legislation extended to HD trucks (UN R134) by the main truck OEM in Europe;
- Strong dissemination and awareness program, involving a maximum number of transport and logistic companies;
- Fostering innovative truck operator business models lowering the financial, operational and technological risk barrier for transport and logistics companies to adopt hydrogen trucks. Strengthening global competitiveness of European truck OEM in the heavy-duty truck segments;
- As international operation is foreseen, a broad spectrum of use cases is covered (climate, road conditions, daily operations);
- Limit the cost per truck below EUR 450,000. In addition, it is also expected to see the cost of trucks decrease throughout the duration of the action. OEM in the project should monitor and report on the cost evolution.

Hydrogen will be one of the dominant solutions enabling Horizon Europe to contribute to a more liveable and Carbon neutral Europe towards 2050. The 'Hydrogen Economy' (Users and Suppliers) will benefit from the approach of this proposal. This flagship project on hydrogen trucks will contribute to this by the fact that developments will shift from technology into applications (EU wide) and thus will accelerate the use of hydrogen as an alternative fuel. This will result in the critical reduction of costs in order for Hydrogen to settle as an operationally and financially viable alternative to ICE and BEV. The end goal is to make hydrogen for Heavy-Duty applications economical viable without funding's in the next 5-10 years.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Availability of trucks: 90%;
- Average consumption of trucks: proposals should specify their targets, and it is encouraged to go for under 10 kg/100km for the 38-40 tonnes range;
- Kilometres driven during the project:
 - Long haul: 60,000 km/year/truck;
 - Distribution: 40,000 km/year/truck;
- Each truck should be operated for a minimum of 2 years;
- Range for 50% of the trucks > 600km

Hydrogen Refuelling Infrastructure (HRS)

It is expected that the refuelling infrastructure accompanying the fleet of trucks to be deployed in the project should be in line with the guidelines of the proposal for a regulation on the deployment of alternative fuels infrastructure 2021/0223(COD)¹¹⁶, in particular:

- One HRS every 150 km (or every 450 km in case of LH₂) on both core and comprehensive TEN-T network and in each urban node¹¹⁷
- Ability to refuel at 350 & 700 bar, minimum capacity of 2 t/day

In addition:

- HRS availability: 95%;
- Refuelling operation: 6 kg/min @700 bar
- The inclusion of HRS allowing refuelling under 10 minutes for Liquid Hydrogen (LH₂); is encouraged;

Scope

To produce and operate a minimum of at least 150 homologated fuel cells hydrogen trucks, including a service/maintenance/dealer/parts network along defined comprehensive TEN-T¹¹⁸ corridors throughout Europe and to operate them supported by a backbone of HRS for a minimum of 2 years, all of the following actions should be addressed in the proposals:

¹¹⁶

https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf

¹¹⁷ Following AFIR guidance, Article 6. <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0559>

¹¹⁸ https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

- Minimum 150 hydrogen trucks delivered by at least 3 different truck OEM (not part of the same group), with a minimum of 20 trucks per OEM cluster. The cost per truck should remain under EUR 450,000€, unless properly justified and a short term path to achieve the cost goal will be presented;
- Minimum 6 operators from as many different EU countries along the core and comprehensive TEN-T corridor(s). It is suggested to have as many transporters/shippers as possible in order to trigger a significant impact on dissemination activities. Links among a number of the deployment sites are strongly encouraged (i.e. proximity leading to sharing of HRS);
- The trucks can be tractor or rigid based with a minimum tonnage of 19 tonnes for rigid and a minimum tonnage of 37 tonnes for tractors. More than 65% of the trucks should be long haul and > 37 tonnes. Vans are excluded from funding;
- The fuel cell vehicles powered with hydrogen should be capable of long-haul operation and they should be deployed along the core and comprehensive TEN - T corridors;
- The minimum range of 50% of the trucks should be 600 km without refuelling under all driving conditions. The rest of the trucks can target a regional intensive use with, if needed, two (local) refilling's per day and a minimum range of 400 km without refilling;
- The vehicles should operate for a minimum of 40,000 km or 60,000 km (according to the truck type) per year, per truck, per operator for a minimum of 2 years. The operational data of these trucks has to be gathered and processed by an independent organisation. Such organisation could be a partner, but independent from trucks' suppliers;
- Include a data monitoring strategy (with minimum parameters to be monitored) that would allow evaluate the overall financial, environmental and technical performance of each of the truck operation profile / fleet in the project in sufficient detail. In addition, a sufficient subset of the trucks (representative of each OEM fleet and of the use cases) should be placed under a detailed data monitoring to gather relevant information at truck level (speed, load profile, journeys, etc). Costs related to the monitoring equipment are eligible;
- The truck models deployed in the framework of the project should become commercially available in limited numbers after the project in order to increase real-time data gathering and improve the next generation Heavy-Duty hydrogen vehicles;
- In order to stimulate the EU hydrogen and fuel cell market, for each vehicle the share of main hydrogen subsystems –originated from the EU should be reported;
- The truck OEM, HRS operators and transport companies such as transporters and shippers (their adhesion are key to ensure the success of the initiative), should cooperate to contribute to the adoption of regulatory incentives and technical harmonisation of hydrogen trucks and HRS on a European level;
- Innovative business models are encouraged such as turn-key solutions to end-users and/or leasing;
- An overall plan for deployment (with different stages) that goes beyond the timeline of this project should be foreseen. The needs of support for later stages should be

justified in view of closing the funding gap in a dynamic environment where hydrogen trucks become increasingly competitive with incumbent technologies.

Proposals should contain a calendar clearly defining the key phases of the implementation of the action (i.e. preparation of the specifications of trucks and HRS, manufacturing, deployment and operation) and their duration. Proposals should foresee enough time for monitoring and assessment. In that respect proposals are therefore encouraged to put forward ambitious deployment plans including the deployment of a significant percentage of the fleet within the first 2 years of the action, in order to fully unlock the potential of European FCH solutions in the HD segment and contribute to the EU CO₂ emission standards for new heavy-duty vehicles (EU 2019/1242) targets.

The refuelling infrastructure and its associated costs are not in the scope of this topic. Applicants are therefore strongly encouraged to seek support from alternative sources of funding and/or financing and provide such additional plan to minimise the risk of the implementation of vehicles and associated infrastructure and maximise its impact.

Applicants are therefore encouraged to submit complementary proposals to Clean Hydrogen JU (for the deployment of the vehicles) and to CEF Transport (for the deployment of the refuelling infrastructure)¹¹⁹.

Furthermore applicants may consider additional synergies with other Programmes (e.g. European Structural and Investment Funds, Recovery and Resilience Facility, Just Transition Fund, Connecting Europe Facility, Innovation Fund, Modernisation Fund, LIFE, etc) and/or clustering with other projects within Horizon Europe or funded under other EU, national or regional programmes, or having loans through the EIB or other promotional or commercial banks; such synergies should be reflected in a financing structure and strategy describing the business model, including envisaged sources of co-funding/co-financing and in line with state-aid rules.

Additionally synergies with the 2ZERO partnership topic HORIZON-CL5-2022-D5-01-08¹²⁰ should be explored and developed where possible.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is used. In this respect consortium may seek out the purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the purchase and cancellation of non-governmental certificates (e.g CertifHy¹²¹).

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

Activities developing test protocols and procedures for the performance and durability assessment of electrolyzers and fuel cell components proposals should foresee a

¹¹⁹ The Connecting Europe Facility (CEF) for Transport (CEF-T) work programme 2021-2023 has a 3-year rolling call running for the Alternative Fuel Infrastructure Facility, with deadlines every 6 months, [https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport#:~:text=The%20Connecting%20Europe%20Facility%20\(CEF,and%20upgrading%20the%20existing%20one.](https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport#:~:text=The%20Connecting%20Europe%20Facility%20(CEF,and%20upgrading%20the%20existing%20one.)

¹²⁰ <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-2022-d5-01-08>

¹²¹ <https://www.certifyhy.eu/>

collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹²² to benchmark performance and quantify progress at programme level.

¹²² https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-03-04: Liquid hydrogen tanks for heavy-duty vehicles

Specific conditions	
<i>Expected contribution per project</i> EU	The JU estimates that an EU contribution of around EUR 2.5 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 5.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 4 and achieve TRL 6 by the end of the project. See General Annex B.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches , grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Beneficiaries must, up to 4 years after the end of the action, inform the granting authority if the results could reasonably be expected to contribute to European or international standards.

Expected outcome

Commercial trucks are responsible for a quarter of road transport CO₂ emissions. For the decarbonisation of lighter and heavier commercial trucks in local transport batteries and pressure storage technologies for hydrogen are suitable. On the other hand, these energy storage systems are less suitable for heavy and long-distance transport due to their low volumetric energy density and the limited space constraints according to regulations in Europe.

Onboard LH₂ tanks could be an enabler for zero emission mobility in heavy and long-distance road transport. In comparison to the state-of-the-art 350 bar or 700 bar storage, LH₂ can enable much higher volumetric energy system density (up to double as compared to 700 bar) and simpler refuelling station design; advantages that are of utmost importance for the space, mass, time, and fuel cost constraint application. However, the actual performances of onboard LH₂ tanks are not known precisely since not enough prototype development nor testing has been performed. Critical issues such as boil-off sensitivity, achievable capacity (for a given volume) and refuelling interface need to be addressed.

This topic will provide sufficient information on the critical issues related to onboard LH₂ tanks for heavy-duty vehicles road application, so that a well-informed decision can be

made by stakeholders on key technical bottlenecks to be solved or possible showstoppers for the technology.

Project results are expected to contribute to all of the following expected outcomes:

- Onboard truck demonstration of a high-density hydrogen system by 2025;
- Deployment of cost-effective, long range zero emission solutions for trucks by 2030;
- Drastically improved understanding of onboard cryogenic hydrogen storage systems challenges;
- European leadership in onboard cryogenic hydrogen storage.

By reducing the storage cost and enabling long-range truck transportation, this project will greatly contribute to the transport end-uses objectives as detailed in the SRIA of the Clean Hydrogen JU.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Onboard tank
 - Storage tank CAPEX: 320 Euros/kgH₂
 - Gravimetric Capacity: 10 wt%_H₂
 - Volumetric capacity: 40 gH₂/L system
 - Dormancy¹²³: 48 hours
 - Venting rate¹²⁴: <2%/day
- Refuelling solution
 - Filling rate: 8 kg/min
 - Coupling mass: < 3 kg
 - Installation time (before flowing LH₂): 30 s
 - Removal time: 30 s
 - Energy consumption:<0.5 kWh/kgH₂
 - Station boil-off: < 2%/day

Scope

The scope of the topic is the full-scale analysis of existing concepts to store LH₂ to develop and integrate an improved LH₂ vessel in at least 2 road long distance heavy-duty vehicles, with over 800km range without refuelling, to evaluate the feasibility of the technology. Capacities and refuelling speeds should be in the 40-100 kg LH₂ in one or more vehicle storages depending on the vehicle design and 7-10 kg/min range, respectively. Cost estimates for the storage system should be provided.

The analysis shall contain materials (including resistance to corrosion as necessary), piping and instrumentation, controls, safety designs but also refuelling procedures, interfaces, and balances of plant equipment to propose modification or creation of relevant norms. Key parameters for heavy-duty road vehicles shall be the focus of the project, including easy handling and connection at the refuelling without specialised personal, effect of dormancy and boil-off, space limitation, limited volume compared to larger storages, long lasting

¹²³ dormancy/thermal autonomy is defined here as the time the vehicle should be parked without releasing any H₂, irrespective of its tank's capacity or pressure, and demonstrated using real life duty cycle simulations with test bench measured insulation performance

¹²⁴ venting rate is defined as the rate of H₂ that is released when the system is parked at its venting pressure

safety equipment.

The analysis shall be done to provide improvements and optimisation on different aspects, physical parameters of the LH₂ to density, tanks composition and peripherals regarding volumetric efficiency and potential losses of hydrogen in the overall efficiency.

Proposals should focus on defining, building and understanding of a full scale LH₂ tank system for heavy-duty road application and its refuelling, with at least a complete test bench fulfilling the technical readiness level. This can be completed by a refuelling solution with dispenser and/or an onboard vehicle demonstration.

Proposals should include an investigation from the end-user perspective, by simulating real-life utilisation (hydrogen extraction, driving, parking, refuelling) and making sure that the state-of-charge, the actual boil-off, and the refuelling are compatible with the expectations. Pressure in the LH₂ storage tank should be compatible with the pressure at which the fuel cell typically operates, and obviously with the boil-off target. Alternatively, mitigation strategies should be proposed. The mechanical design should be compatible with all requirements typical of the trucking industry in terms of durability, exposure to harsh environments, vibrations, accelerations, safeties, and exceptional loads e.g. fire. The validation of concepts shall occur through an experimental program backed up by simulation activities, that will allow to expand the concept to wider range of constraints.

All the activities and results should consider the current European Commission Implementing Regulation EU 2021/535¹²⁵ (liquid hydrogen storage systems) and other relevant standards. The results of the project should be used to support the development of new or revised legal requirements or standards, especially extending the scope addressed by GTR13 and its type approval part the R134. The consortium should establish links with ongoing projects¹²⁶ dedicated to relevant applications such as H2HAUL and PRHYDE/project funded under Call 2018 “Topic FCH-04-2-2019: Refuelling Protocols for Medium and Heavy-Duty Vehicles”. The consortium should take into account current activities concerning LH₂ storage, such as the subcooled LH₂ fuelling method developed within an open working group at the Clean Energy Partnership¹²⁷.

The following activities are considered to be out of scope for this topic: liquefaction technologies, well-to-wheels costs, liquid hydrogen supply chain.

¹²⁵ https://eur-lex.europa.eu/eli/reg_impl/2021/535/oj

¹²⁶ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹²⁷ <https://cleanenergypartnership.de/en/home-eng/>

HORIZON-JTI-CLEANH2-2022-03-05: Large scale demonstration of hydrogen fuel cell propelled inland waterway vessels

Specific conditions	
<i>Expected EU contribution per project</i>	The JU estimates that an EU contribution of maximum EUR 15.00 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 15.00 million
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 6 and achieve TRL 8 by the end of the project See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The maximum Clean Hydrogen JU contribution that may be requested is EUR 15.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): vessels, fuel cell system, on-board hydrogen storage and other components needed in a hydrogen fuel cell hydrogen vessel, costs may exceptionally be declared as full capitalised costs.

Expected outcome

The total volume of goods transported via inland waterways through the 27 European Union countries was 523 million tonnes in 2019 (source: EUROSTAT); this was transported by about 12,700 cargo vessels and 2,300 tugs and push boats using cost-effective and safe logistics solutions via TEN-T transport corridors. The new targets of the Green Deal and the Fit for 55 package open new perspectives for accelerated development of inland water transportation using renewable hydrogen. Eliminating emissions from these vessels, while creating a strong commercial proposition, will boost the European waterborne transport sector and have a major positive impact on air pollution and GHG emissions. Given that inland vessels last for over 40 years, and the current (low) rate of new building, both new building and retrofitting the existing fleet are key to reaching the emission

reduction targets and establishing a rapid market uptake.

The spectrum of hydrogen alternatives, the boundary conditions for successful integration as well as codes and standards are new and not widely available yet. Obligatory periodic inspection and maintenance, upgrades or retrofits are executed by many European yards. Their main expertise and experience, however, is with traditional fossil fuel and ICE technologies. The same holds for crew, bunkering and refuelling personnel, and ship owners. All should be upskilled to either design, integrate or work with hydrogen systems.

Several projects have demonstrated the feasibility of zero-emissions hydrogen propelled inland shipping. However, large scale uptake asks for a holistic approach covering the whole value chain. This includes the need for investing in public development, standardisation and integration of hydrogen propulsion and bunkering systems, a clear regulatory framework for technical execution, on-board integration, crew and bunkering personnel education and qualification, as well as a robust regulatory framework for the introduction of hydrogen as a fuel in EU waters. This will increase the uptake of hydrogen fuel cell technology and zero emission inland navigation and bring the application within reach of the sector and end-users. Ultimately, the sector should be supplied by a well distributed, resilient and consolidated market on components for retrofitting, new building and spare parts, with a fuel infrastructure that is integrated in the multimodal transport chain, supporting local industries.

This flagship¹²⁸ topic aims to address all of the aspects above mentioned via the deployment of a fleet of inland waterway vessels.

Project results are expected to contribute to all of the following expected outcomes:

- Retrofitting existing diesel propelled vessels with fuel cells and electric propulsion systems will have become the state-of-the-art. The integration of hydrogen fuel cells, hydrogen storage and distribution (infrastructure, bunkering, piping, and on board and onshore) solutions, based on a Europe-wide, harmonised regulatory framework, has become daily business;
- Track record of technical, financial and environmental performance resulting from the deployment and operation of a fleet of inland waterway vessels;
- At least 10% of all vessels in operation (about 1,500) will be hydrogen fuel cell propelled, covering the whole territory of the EU inland waters, creating a market for about 500¹²⁹ tonnes hydrogen per day;
- Hydrogen propelled vessels will be allowed to sail all inland waters in the EU using standardised regulations, without the need for lengthy approval processes;
- The sector uses common systematic design and engineering methods to achieve integrated ship and power train refits and new build solutions, such that further standardisation of the power train components (modules) is accelerated, allowing the rapid deployment of these technologies across the fleet.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Product design reaching type approval [number]: 15 in 2024 and 40 in 2030;

¹²⁸ For definition of flagship see section 5.3. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

¹²⁹ assuming an average consumption of 125 tonnes a year per vessel (reference 110m vessel with 1MW FC).

- PEMFC system CAPEX [€/kW]: 1,500 in 2024 and 1,000 in 2030;
- Maritime FCS lifetime [h]: 40,000 in 2024 and 80,000 in 2030.

Scope

First demonstrators funded by previous FCH-JU projects, as well as other projects in recent years, have primarily focused on the demonstration of technical feasibility of fuel cells on board inland vessels. A large-scale demonstration is now required to further the uptake of fuel cells and hydrogen in this sector. This flagship project should include:

- at least 5 inland vessels (retrofitting and/or new build), with FC power above 500kW and preferably at 1 MW scale;
- at least 2 vessel types;
- 2 vessels should operate for at least 2 years, and the others for at least 1 year;
- vessels that should be able to bunker hydrogen in at least 2 different ports;
- creating a corridor, connecting to hydrogen infrastructure, aligned with the TEN-T¹³⁰ network;
- preferably one vessel is a (self-propelled) hydrogen bunker barge, which can bunker vessels alongside while in transit, at anchorage, or at the pier;
- An overall plan for deployment (with different stages) that goes beyond the timeline of this project should be foreseen. The needs of support for later stages should be justified in view of closing the funding gap in a dynamic environment where hydrogen shipping becomes increasingly competitive with incumbent technologies.
- A detailed data monitoring strategy (with minimum parameters to be monitored) that would allow evaluate the overall financial, environmental and technical performance of each of the vessel to be deployed in the project in sufficient detail. Costs related to the monitoring equipment are eligible.

It is highly recommended that the project collaborates with other projects (e. g. RH2INE¹³¹, GREENPORTS,¹³² MAGPIE¹³³ and PIONEERS¹³⁴) on bunkering and refuelling infrastructure to align interfaces and create a robust hydrogen bunkering infrastructure along the TEN-T.

The proposed hydrogen fuel cell electric powertrain and storage should be a modular and easy-to-scale solution, in order to reduce conversion time as well as design and development cost for future vessels. On the technology side, the project should result in:

- Fuel cell systems, hydrogen storage and hydrogen distribution components meeting the unique requirements of inland waterway navigation, including but not limited to corrosion, performance, lifetime, and safety;
- Fuel cell systems, hydrogen storage and hydrogen distribution components with type approval, to increase market acceptance and ensure safety under all conditions;

¹³⁰ https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

¹³¹ <https://www.rh2ine.eu/>

¹³² <https://greencportsproject.eu/>

¹³³ <https://cordis.europa.eu/project/id/101036594>

¹³⁴ <https://cordis.europa.eu/project/id/101037564>

- The development of resilient value chains in order to provide high quality products and solutions suitable for long-term commercial operations;
- Solutions which preferably build upon the lessons learned in StasHH¹³⁵ and consider circularity by design for equipment and business models;
- Secure approvals/exemptions from regulating bodies resulting in general permission for hydrogen powered inland vessels to navigate European waterways.

The project should focus on converting those ship types that have the highest impact on emissions. Nevertheless, it is expected that the developed solutions are also applicable to other vessel types and should be adaptable to different operations and associated power and energy consumption profiles. System dimensioning and integration should therefore be based on representative measurement data, allowing for optimal operations and efficient fuel consumption. A systematic retrofit design approach should result in general guidelines or advice for retrofitting inland vessels.

In order to successfully integrate modular hydrogen-based solutions on a large scale and embed them in the EU inland navigation industry, the project should at least perform the following dissemination and communication activities:

- During the project, results should be disseminated to the inland navigation sector, including training, integration & operation manuals and procedures, to enable knowledge transfer resulting in capacity building and general acceptance of maritime hydrogen fuel cell technology which would initiate other hydrogen vessel projects;
- Show the impact achieved via a lifecycle assessment (vessel, technology and operation) comparing the conventional (original) and new (retrofitted) situations;
- Include shipowners, shipyards, ship designers, maritime system integrators, ship operators, port authorities and classification authorities and all key staff within these organisations that would be involved in operating these technologies on board and on shore;
- Contribute to setting the standard when it comes to rules and regulations for type-approval and technical documentation;
- Establish a link with Zero Emission Waterborne Transport co-programmed partnership (ZEWTP) to ensure that technical knowledge (best practices) can be exported to the larger and more complex (e.g. sea going) vessels.

The HORIZON-JTI-CLEANH2-2022-02-11 and HORIZON-JTI-CLEANH2-2022-03-05 topics are highly complementary and synergies between the two should be sought by applicants.

The refuelling infrastructure and its associated costs are not in the scope of this topic. Applicants are therefore strongly encouraged to seek support from alternative sources of funding and/or financing and provide such additional plan to minimise the risk of the implementation of vehicles and associated infrastructure and maximise its impact.

Applicants are therefore encouraged to submit complementary proposals to Clean Hydrogen JU (for the deployment of the vessels) and to CEF-T (for the deployment of the

¹³⁵ https://www.clean-hydrogen.europa.eu/projects-repository_en

refuelling infrastructure)¹³⁶.

Furthermore applicants may consider additional synergies with other Programmes (e.g. European Structural and Investment Funds, Recovery and Resilience Facility, Just Transition Fund, Connecting Europe Facility, Innovation Fund, Modernisation Fund, LIFE, etc.) and/or clustering with other projects within Horizon Europe or funded under other EU, national or regional programmes, or having loans through the EIB or other promotional or commercial banks; such synergies should be reflected in a financing structure and strategy describing the business model, including envisaged sources of co-funding/co-financing and in line with state-aid rules.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is used. In this respect consortium may seek out the purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the purchase and cancellation of non-governmental certificates (e.g CertifHy¹³⁷).

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

Activities developing test protocols and procedures for the performance and durability assessment of electrolyzers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹³⁸ to benchmark performance and quantify progress at programme level.

¹³⁶ The Connecting Europe Facility (CEF) for Transport (CEF-T) work programme 2021-2023 has a 3-year rolling call running for the Alternative Fuel Infrastructure Facility, with deadlines every 6 months, [https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport#:~:text=The%20Connecting%20Europe%20Facility%20\(CEF.and%20upgrading%20the%20existing%20one.](https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport#:~:text=The%20Connecting%20Europe%20Facility%20(CEF.and%20upgrading%20the%20existing%20one.)

¹³⁷ <https://www.certify.eu/>

¹³⁸ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-03-06: Development and optimisation of a dedicated Fuel Cells for Aviation: Development of dedicated stack (100s kW) with the objective of MWs full system

Specific conditions	
<i>Expected contribution per project</i>	<i>EU per</i> The JU estimates that an EU contribution of around EUR 20 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 20.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 4 and achieve TRL 5-6 by the end of the project See General Annex B.

Expected outcome

The use of Fuel Cells enables the generation of electricity aboard the aircraft from hydrogen (stored in a dedicated tank) and oxygen (air) without any CO₂, NO_x, particles emission as the only by-products of the reaction are water and heat. Therefore, these technologies have the potential to strongly reduce aviation emissions & pave the way to climate neutrality. Additionally, they can drastically reduce the noise when compared to gas turbines, both when a/c moving (flight/taxi) and on ground/stopped (while operating non propulsive energy systems).

Depending on the power delivered, fuel cells can supply either non-propulsive systems (electrical anti-ice systems, electrical Environmental Control System, Green Taxiing) or propulsive systems (electrical engines and propeller).

Experience shows that aviation constraints (weight, altitude) will require specific technologies in order to meet necessary KPIs.

Project results are expected to contribute to all of the following expected outcomes:

- Preliminary design of fuel cell systems with high efficiency and high gravimetric power density, compatible with aeronautical specifications and constraints and
- The maturation of necessary sub-components for this system (stack, balance of plant components etc) up to TRL5.

At the end of the project, performed lab and ground tests should have proven concept feasibility. The technologies will then be further matured under the support of the Clean Aviation partnership, embedded and integrated in a specified architecture for demonstrations.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- FC module durability [h]: 20,000 in 2024 and 30,000 in 2030;
- FC system efficiency [%]: 45 in 2024 and 50 in 2030;
- FC system availability [%]: 95 in 2024 and 98 in 2030;

- FC system gravimetric index [kW/kg]: 1 in 2024 and 2 in 2030.

In addition to the KPIs above and when considering a system size of 1.5MW the proposal should also contribute to the achievement of the following:

- Power Densities @stack level > 3kW/kg in nominal power (and not peak power);
- Membrane Electrode Assembly > 1.25 W /cm²;
- Understanding of the ageing kinetics (= performances degradation in time) ;
- Environmental conditions: temperature, pressure, vibration and other area of interest (i.e. DO 160) compatible with aircraft environment;
- Demonstration fully answers the qualification needs.

The stack to be developed under this topic should be compatible with the requirements of the Clean Aviation Partnership SRIA in order to be implemented in ground and in-flight demonstrations scheduled within Clean Aviation partnership.

Scope

The technology (Proton Exchange Membrane Fuel Cell) that is emerging from the automotive industry through car manufacturers is of interest for aeronautic industry, but some issues are still to be solved (hydrogen storage and distribution from the tank to the fuel cell system are not considered here)

- The power of the fuel cell systems coming from the automotive industry is usually limited roughly to 100kW. Aviation needs are more in the range of 1 to 5MW depending on the size of the aircraft and/or the systems to supply with power (propulsive or non-propulsive). Development of 250 kW FC stack and scalability of FC system and components for an at least 1.5 MW module seems thus compulsory in order to allow aircraft application. This target is moreover clearly defined in the Clean Aviation SRIA;
- The stacks available today are not adapted to the environment in which they will have to operate: temperature ISA-35, pressure 0,2 bar (45 kft), vibrations, etc;
- The requested power is not achievable with only one stack. The following should be defined:
 - The optimal size of the stack;
 - The architecture of multi-stack systems.
- The cost of the technology needs to be reduced. Sizing a unitary stack of a reasonable amount of power will ease its integration in different size of aircraft and for propulsive and non-propulsive systems. This will increase the numbers and ease cost reduction;
- The lifetime of the fuel cells should be increased;
- Safety issues shall be considered right from the start. The means of compliance in order to answer to qualification/certification needs are not available. The certifications rules should be created/adapted.

Proposals should target a fuel cell system with a power density > 1.5kW/kg at a power level of at least 1 MW. The goal is to bring the technologies and sub systems to TRL5 at the end

of the project, with lab and ground tests in a relevant environment.

This topic is crucial regarding the commercialisation of FC Systems in aviation.

The integration of the full system into the aircraft needs to be considered and anticipated but is not the key focus and will be dealt with in a separated Work Programme. In the frame of Clean Aviation Partnership, an open call is expected to be launched to cover system integration and demonstrations.

Proposals should tackle the following aspects:

Requirements & specification

- Define a system compatible with aircraft (A/C) environment and constraints (safety, durability, availability, temperature, pressure);
- Define architecture to optimise weight and adequation to safety requirements. A system requirement and a high-level architecture optimum should be defined and agreed early in the project;
- Derive necessary technological bricks to be matured up to TRL5.

Fuel cell stack subsystem

- Increase the power density of the stack, by optimising designs through several means, for example but not exhaustive: lightweight metal substrates, high performance Membrane Electrode Assembly (MEA)/flow field combination, optimised stack compression system;
- Define and design stack architectures (i.e.: liquid cooled / 2-phase cooled). Separate paths may be explored;
- Increase the operating temperature of the stack and its capability to support larger inlet/outlet cooling temperature ranges, without compromising its lifetime;
- Analyse the robustness of the fuel cell stack to contaminants or other pollution source of the membrane;
- Reduce pressure losses over the stack, especially on the cathode, to balance stack performance versus system performance.
- The stack to be developed under this topic should be compatible with the requirements of the Clean Aviation Partnership SRIA in order to be implemented in ground and in-flight demonstrations scheduled within Clean Aviation partnership.

Balance of Plant (BoP) subsystem

- Define and resize anode and cathode BoP for stack regulation. BoP architectures may differ depending on stack architecture;
- Define a lightweight and robust stack monitoring system, easy to install and repair.

Besides, great care should be taken to the fuel cell interfaces, which will impact the trade off and overall system benefits:

Thermal management subsystem

- Fuel cell stack thermal management is key and should be analysed.
- Proposals will also have to cope with preliminary design of stack heat management.

The realisation of fuel cell system driven aviation belongs from the maturity and understanding of fuel cell system components and behaviour in aircraft environment. Based on stack developments scheduled in the first phase of the project, a focus on fuel cell system behaviour at continuous (more than 15 minutes) max power operation is strongly encouraged, so that dedicated heat management bricks will have to be developed. The technology drivers, components and behaviours which will be functionally upgraded can be (non exhaustive list): cathode air supply, intercoolers HEX, cathode humidifier, anode recirculation, relative humidity sensors, stack cooling pump, stack cathode and cooling flow pressure drop. Major focus will be (on at least a 300kW electric FC unit) the integration, debug and test of a FC module at max constant cooling temperature under A/C conditions. An additional focus will be the thermal optimisation of the cooling system and controls during major load changes.

Air supply subsystem

- Define the air supply subsystem adapted to high altitude conditions (high compression rate and efficiency) and propose potential technological bricks in order to ensure this function: air inlet, filter, compressor and turbine, intercooler, humidification system, cathode recirculation, water separation, water management, air exhaust, piping and tubing, valves, temperature management, flow measurement and associated control.

Other hydrogen sub systems (storage, distribution) are outside of the scope of this topic. Proposals may include activity for the test bed development for FC testing in simulated A/C applications, and the development of relevant test protocols for performance and lifetime assessment for A/C load and operating environment profiles.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹³⁹ to benchmark performance and quantify progress at programme level.

¹³⁹ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-03-07: Development of specific aviation cryogenic storage system with a gauging, fuel metering, heat management and monitoring system

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 10.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 10.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 1 achieve and TRL 3 by the end of the project (CFRP ¹⁴⁰). Activities are expected to start at TRL 2 achieve TRL 4 by the end of the project (system). See General Annex B.

Expected outcome

To fulfil the ambitions of a commercial zero emission aircraft a liquid hydrogen (LH₂) fuel storage system is needed. In the first phase of Clean Hydrogen (2022-2025) two functional demonstrators shall be built. The demonstrators shall be in the range of 50 kg – 150 kg LH₂ capacity due to technical objectives and the available budget. Objectives of the project are the design and development of a lightweight LH₂ tank (demonstrator 1), and the integration of the storage system for a safe function and operation of a LH₂ tank on board of an aircraft (demonstrator 2). This local operation is not in the scope of this topic.

Demonstrator 1: The LH₂ tank will be used to address the need of a lightweight vessel. So, the demonstrator purpose is everything around the material selection (e.g. fibre reinforced materials) for the tank itself, liner and its insulation and the manufacturing of such a lightweight liquid hydrogen aircraft storage tank.

Demonstrator 2: The LH₂ tank will be used to validate the operation of such a storage including design and integration of components needed for a safe function (filling, structural health monitoring, overpressure, thermal management, boil off, sloshing, vaporising depending on a system safety analysis).

Project results are expected to contribute to all of the following expected outcomes:

- The demonstrators will be used to develop and validate computational models addressing static and dynamic behaviour (sloshing) as well as component sizing capabilities;
- System models of the operational behaviour will be developed and validated on the basis of hydrogen by operating and testing these demonstrators. The system simulation should cover the static and especially the transient cases with the interaction and fluid motion of liquid hydrogen (sloshing) and thermodynamic environment in the tank. In fact, in space applications the pressure drop induced by these types of interactions is well known and accounted for in the cryogenic tank

¹⁴⁰ Carbon Fibre Reinforced Polymer

design. The models will be used for functional analysis with failure hazards assessment, system safety analysis and common mode analysis of the system;

- The storage vessels and associated components should withstand defined normal static and failure fatigue load cases as well as the demanding environmental (including shock & vibration) and reliability requirements associated with commercial aviation (DO160, DO178, DO254). At the same time the hydrogen storage design and its installation should account for thermal deformation as well as pressure and temperature fluctuations during operation and filling at a delta temperature of ~300 K;
- The vessel (demonstrator 1) is required to store hydrogen safely at cryogenic temperatures for extended durations, with low boil-off quantities (see KPI) as well as superior gas barrier properties. This requires insulation technologies that are durable and lightweight, as well as liner and tank wall concepts with low gas permeability;
- Vacuum technologies shall also be studied and matured in order to fulfil the aircraft operation needs;
- Adequate safety precautions have to be implemented, which are covered by a secure design together with measurement and monitoring sensors and detection system;
- Necessary non-destructive testing and other inspection methods are needed and have to be developed and validated, because also the build and acceptance of such a storage has to undergo specially defined qualification tests. Due to budget reasons, this will not be part of this road map.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Tank gravimetric efficiency [%weight]: 16 in 2024 and 35 in 2030
- LH₂ tank capacity [kgLH₂]: 50-150
- Dormancy: >24 hours
- Venting rate: < 2%/day
- Filling rate: 300-500 kg/h (for analysis 5 t/h)
- Boil-off: < 2%/day after dormancy
- Maximum diameter: < 1 m (for analysis <3m)
- Minimum operating pressure: 1 bar (pump fed) – 3 bar (pressure fed)
- Maximum operating pressure: 3 bar (pump fed) – 8 bar (pressure fed)
- Insulation Vacuum: $1 \cdot 10^{-5}$ mbar

Scope

Proposals should focus on the development of an aerospace applicable liquid hydrogen storage system. There are various thermal, mechanical, safety and system integration challenges associated with this. Compared to kerosene in the wing, hydrogen storage leads to additional mass for the aircraft and requires additional space (LH₂ has 4 times the volume compared to kerosene at iso-energy content). Therefore it has a significant impact on the overall energy required for a mission due to both weight and volume with drag

penalty.

Today's hydrogen tanks for storing liquid hydrogen in aerospace are mostly made of metal. For space application this solution is still valid, because of power available, non-reuse and costs. But having in mind commercial aviation, the focus should be on enhancing the reliability of the metal tank and piping performance while designing a LH₂ storage system made of light carbon fibre reinforced materials. Using these components, a significantly improved gravimetric index for the whole storage system can be achieved. The drawback of using these materials is that the laminate quality or laminate architecture are of particular importance for permeability. Different test specimens, different semi-finished products made of glass, carbon, fibres with polymer or metal matrix, different additives, liners and architectures as well as protective coatings have to be considered. In addition, a selection of adhesives has to be made for use in cryogenic environments.

Besides the material selection and definition and control of the manufacturing process other aspects of the function and safe operation of a liquid hydrogen storage should be taken into account. The pressure and temperature of the LH₂ should be monitored to validate feed and fuel gauging functions under flight accelerations. The analysis of dynamic loads as a result of fuel sloshing should be addressed numerically and experimentally, as well as the pressure development in the tank due to the interaction of the sloshing hydrogen and the thermodynamic environment in the tank. The design solution should address the changing pressure by either active or passive means (e.g. active pressurisation control or passive anti-sloshing devices), to ensure safe operation of the engine feed systems.

A hydrogen content control and gauging system is required to provide accurate data on mission fuel throughout the flight, minimising unusable fuel and meeting all applicable airworthiness regulations. The structural integrity of the hydrogen tank has to be monitored by structural health monitoring (SHM), which can detect and locate damage. The system shall manage both normal and failed system states safely. Wireless and low energy systems shall be investigated to maximise safety and maintainability. The tank should have means to safely manage overpressure cases by a venting system to minimise risk of ignition and the impacts of cryogenic temperatures.

For operation the LH₂ evaporation and gas warm-up requires a considerable amount of energy. It has to be investigated how the thermal load will be injected into the storage with a focus on transient behaviour and start-up procedures. The hydrogen fuel tank should be able to facilitate applications of hydrogen burn engines as well as hydrogen fuel cell-based powertrains with minor adaptations only, permitting for either centralised boil off or distributed boil off management.

Considerations to the refuelling interface should be given, but the interface it-self is out of scope of this topic. Boundary conditions for this refuelling consideration include:

- Aircraft refuelling at a rate of approximately 5 tonnes/hour with means to refuel a cold or a warm vessel
- The cryogenic fuel will be distributed from one, or multiple tanks in the aircraft to an end user system.
- A standard coupling as an interface to refill aligned or adapted as well with other mobility sectors that allows a safe, reliable operation by the ground staff.

The gained experiences on the two storage demonstrators will be used in phase 2 (2026-2030) to obtain and define the certification regulation of commercial aviation hydrogen storages. Furthermore, in phase 2 (2026-2030) larger tanks have to be developed to

become flight worthy.

HORIZON-JTI-CLEANH2-2022-03-08: Development and optimisation of a dedicated Fuel Cells for Aviation: disruptive next-gen high temperature Fuel Cells technology for future aviation

Specific conditions		
<i>Expected contribution per project</i>	<i>EU</i>	The JU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>		The total indicative budget for the topic is EUR 5.00 million
<i>Type of Action</i>		Research and Innovation Action
<i>Technology Readiness Level</i>		Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project. See General Annex B.

Expected outcome

The use of Fuel Cells enables the generation of electricity aboard the aircraft from hydrogen (stored in a dedicated tank) and oxygen (air) without any CO₂, NO_x, particles emission as the only by-products of the reaction are water and heat. Therefore, these technologies have the potential to strongly reduce aviation emissions & pave the way to climate neutrality. Additionally, they can drastically reduce the noise when compared to gas turbines, both when aircraft is moving (flight/taxi) and on ground/stopped (while operating non propulsive energy systems).

Depending on the power delivered, fuel cells can supply either non-propulsive systems (e.g electrical anti-ice systems, electrical Environmental Control System, Green Taxiing, etc) or propulsive systems (electrical engines and propeller).

Experience shows that aviation constraints (such as weight, altitude etc) will require specific technologies in order to meet the necessary KPIs.

Project results are expected to contribute to the following expected outcomes:

- The maturation of necessary Low TRL new generation of fuel cell technology, operating higher than 120°C (constant operation) to unlock thermal management issues for high power systems;
- Demonstration of the developed technology in lab test conditions (single cell or short stack).

At the end of the project, performed lab tests will have proven concept feasibility. The technologies will then be further matured in Clean Aviation Programme, embedded and integrated in a specified architecture for demonstrations.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- FC module durability [h]: 20.000 in 2024 and 30.000 in 2030;
- FC system efficiency [%]: 45 in 2024 and 50 in 2030;
- FC system availability [%]: 95 in 2024 and 98 in 2030.

In addition to the KPIs above and when considering a system size of 1.5MW the proposal should also contribute to the achievement of the following:

- Fuel cell Gravimetric index @system level > 1.5 kW/kg nominal power, under nominal aviation environmental conditions. Note: For computation, the following “system” definition is proposed: Fuel Cell stack + Anode & Cathode BoP (incl. by-products management) + Thermal Management BoP (excl. Heat exchanger);
- Fuel cell Gravimetric Index @stack level > 3 kW/kg in nominal power (and not peak power);
- Power density @ Membrane Electrode Assembly > 1.25 W/cm²;
- Ageing kinetics (= performances degradation in time) is understood;
- Environmental conditions: temperature, pressure, vibration and other area of interest (Ie DO 160) compatible with aircraft environment.

Scope

The technology (Proton Exchange Membrane Fuel Cell) that is emerging from the automotive industry through car manufacturers is of interest for aeronautic industry, but some issues are still to be solved (hydrogen storage and distribution from the tank to the fuel cell system are not considered here):

- Aviation needs are in the range of 1 to 5MW depending on the size of the aircraft and/or the systems to supply with power (propulsive or non-propulsive). This target is clearly defined in the Clean Aviation SRIA¹⁴¹. Such power level requires capability to dissipate almost the same power of heat, in a dedicated thermal management system;
- Current fuel cell technologies developed by automotive industry operate lower than 100°C at constant operation, which means that fuel cell thermal management system will have to evacuate a large amount of power with a low-grade heat due to FC low temperature;
- Thermal management and especially heat dissipation using a low-grade heat have a massive impact on aircraft performance: aircraft drag increase implies to boost aircraft propulsive system sizing (leading to manage more heat) and requires more energy for the same mission (leading to take on more fuel, and therefore to boost aircraft propulsive system);
- Fuel cell operating temperature increase (120°C +) would significantly help to reduce thermal management effect on aircraft flight performances, and unlock fuel cells applications for high power generation systems;
- Current developed High Temperature PEM-FC technologies (Phosphoric acid doped PBI-based MEAs for instance) are not at the expected level of performance for aeronautic target.

Proposals should target a disruptive 120°C+ constant operating temperature fuel cell technology with the same performances as current state-of-the-art low Temperature PEM technologies.

The integration of such a new fuel cell technology into an aircraft fuel cell system needs to be considered and anticipated but is not the scope of this topic.

¹⁴¹ https://www.clean-aviation.eu/sites/default/files/2022-01/CAJU-GB-2021-12-16-SRIA_en.pdf

Proposals should address the following aspects:

Requirements & specification

- Early in the project, define a projected fuel cell stack using this disruptive fuel cell technology compatible with aircraft environment and constraints (safety, durability, availability, temperature, pressure);
- Define disruptive MEA of this technology specification. Disruptive MEA requirement and a high-level MEA architecture should be defined and agreed early in the project;
- Derive necessary technological bricks to be matured up to TRL 4.

MEA architecture, global consistency and performance

- Define a global MEA architecture by considering the interactions between all the components, layers and interfaces of a MEA: previous development of a disruptive MEA for automotive applications highlighted the need to take into account the global architecture of this component. High performance materials assembly do not meet the expected characteristics (performance, durability) of each component of a MEA taken individually. The overall architecture definition is the key for the development of an efficient MEA;
- Increase the kinetics of the Oxygen Reduction Reaction (ORR), main limiting reaction for PEM MEA;
- Design and develop an efficient electrolyte-catalyst interface to optimise the electrochemical active area;
- Design and optimise the Gas Diffusion Layer (GDL), Micro Porous Layer (MPL) and electrode interfaces to facilitate reactants and products management and ensure good electrical properties;
- Eco-design of the MEA has to be taken into account.

Proton or anion electrolyte technology

- Design a fuel cell technology working at 120°C+ (constant operation);
- Design an electrolyte technology with high proton or anion conductivity and no electrical conductivity;
- Define an electrolyte technology with low gas permeability;

Electrodes

- Design electrodes working at 120°C+ (constant operation);
- Design and optimise a cathode to improve ORR kinetics;
- Define and optimise the catalyst loading for Hydrogen Oxidation Reaction (HOR);
- Optimise catalysts support to improve electrochemical active area on both electrodes.

Gas diffusion layer

- Design GDL working at 120°C+ (constant operation);
- Design and optimise GDL composition and structure to efficiently transport and evacuate reactants from the bipolar plate channels to the electrodes, especially on

cathode side where the oxygen transport to the catalysts has a major impact on performances at high current densities;

- Optimise electrical conductivity of GDL;
- Design and optimise GDL with an efficient water management at 120°C+.

In addition, great care should be taken to strength, durability of the MEA, and transient start-up / shut down mode. In particular proposals should address the following:

MEA strength

- Design a MEA able to work with different pressures between anode and cathode ;
- Design a MEA with high mechanical resistance.

MEA Durability

- Design a MEA with a durability > 20,000 h.

Start and stop operations

- Design a MEA able to undergo start and stop operations with limited degradation rate;
- Define a MEA able to start at cold temperature.

Proposals may include activity for the test bed development for FC testing, and the development of relevant test protocols for performance, lifetime assessment and operating environment profiles.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹⁴² to benchmark performance and quantify progress at programme level.

¹⁴² https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HYDROGEN END USES: CLEAN HEAT AND POWER

HORIZON-JTI-CLEANH2-2022-04-01: Design and industrial deployment of innovative manufacturing processes for solid oxide fuel cells systems and fuel cell components

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of maximum EUR 7.00 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 7.00 million.
<i>Type of Action</i>	Innovation Action
<i>Manufacturing Readiness Level</i>	Activities are expected to start at MRL 4 and achieve MRL 7 by the end of the project. See Call management and general conditions section.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The maximum Clean Hydrogen JU contribution that may be requested is EUR 7.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): manufacturing equipment and tooling, costs may exceptionally be declared as full capitalised costs.

Expected outcome

Fuel cells offer the highest electrical efficiency for conversion of chemically stored energy. They can significantly contribute to an efficient use of produced hydrogen carriers and to the reduction of overall CO₂ emissions. The Clean Hydrogen Joint undertaking has a set a vision to reach for 2030 accumulated fuel cell installed power of >2.5 GW with total production rates >500 MW/year. Cost reductions have been achieved as part of the FCH 2 JU but additional reductions are needed to increase the market penetration of fuel cell solutions. The stacks are still the main cost driver for the fuel cell system, additional cost reductions can be achieved through high quality level and increased automation of stack manufacturing. One of the objectives of the Clean Hydrogen Partnership is to reach stack manufacturing costs (solid oxide) of ≤800 €/kW at annual production volume of single

manufacturing line of at least 100 MW.

Project results are expected to contribute to the following expected outcome:

- Cost reduction of fuel cell systems by automation of specific and time-consuming manufacturing steps;
- Increased fuel cell systems and component manufacturing capacity of European industry establishment of a European supply chain of specialised solid oxide cells (SOC) manufacturing equipment;
- Improved sustainability of the manufacturing processes and products; significantly reduce or reuse waste and lower the energy and carbon footprint.

In addition, project results are expected to contribute to at least one of the following specific (quantified) outcomes:

- Automation of stack assembling and sealing with yield >90%;
- Automation of cell manufacturing with integrated quality control measured and yield >95%;
- High speed interconnect manufacturing and coating within the specification of stack manufacturer;
- Time-efficient and inexpensive quality control procedures suitable for inline inspection.

Project results are expected to directly contribute to all of the following objectives of the Clean Hydrogen JU SRIA Pillar 3, Hydrogen End Uses: Clean heat and Power:

- reduction of CAPEX of stationary fuel cells of all sizes and end use applications. The target is to reach stack production cost <800 €/kW at production capacity of 100 MW/year;
- support of development of processes suitable for mass manufacturing.

In addition, due to high synergies in manufacturing of SOFC and SOEL stacks this topic will also contribute to the following objectives for pillar 1 Renewable Hydrogen Production

- reduction of electrolyser CAPEX below 520 €/kW;
- increasing scale of deployment and series production for steam electrolysis.

Scope

The manufacturing of solid oxide fuel stacks and stack components according to state-of-the-art is performed by a large amount of human force. The degree of automation for cell and interconnect production reaches 30% and for stack manufacturing stays below 15%, however the target values of 50-65% for 2026 should be reached to enable the envisaged high-volume production. The manufacturing processes reached reasonable yields but often are historically developed and not designed for automation. Re-design of critical steps for mass-production manufacturing, development of automation of human workforce and time-consuming manufacturing processes in stack and/or components manufacturing and quality control are entirely addressed by present call.

Support under the FCH 2 JU managed to create a track record of projects¹⁴³ (HeatStack, SOSLeM, qSOFC) directed towards cost-effective manufacturing of components, stacks

¹⁴³ https://www.clean-hydrogen.europa.eu/projects-repository_en

and systems. The development in the HeatStack project showed the potential to reduce the production cost of the sealing in the SOFC stack by 90%. The glass sealing inside the stack is estimated to be responsible for about 10% of the stack production costs. In addition, the qSOFC project contributed considerably to solid oxide stack development by enhancing manufacturing and quality assurance at key parts of the all-European stack manufacturing value chain. This project concluded that a stack cost level of 1000 €/kW is achievable at production levels of 15 MW/year. The specific improvements include: increase speed of cell production, interconnect manufacturing and stack conditioning processes. Finally, the SOSLeM project helped to create a new stack production plant, making the manufacturing process cheaper, cleaner and smarter by introduction of automated laser welding, simplification of the design for automated component stacking and end-of-line testing.

The scope of this topic is to adapt and develop manufacturing processes on a prototype tool that can then serve several manufacturers. It aims at establishing a European supply chain of specialised SOC manufacturing equipment that can be adapted by several manufacturers, or even exported to overseas markets in scenario where European technology is licensed for local production in overseas territories. The supply of equipment is a market opportunity on its own, though the proximity with the domestic manufacturers supports their ability to stay ahead of competition.

The design for manufacturing and automation should be considered along the whole value chain of stack production. The joint effort on several subjects such as component supply chain, process automation, stack and system manufacturing are needed to address the challenges of cost reduction by automation and upscaling.

Proposals should address the following:

- Proof of concept, design and adaptation of approaches from automation industry, whose implementation for the production of cells, stack components or stacks, could significantly improve production process for selected critical manufacturing processes should be considered;
- The demonstration of two or more automated production steps, initially performed manually with considerable time effort, should be performed. The ones with the greater impact on costs and waste production should be considered preferably;
- Archetype for the mass production of FC, definition of a virtual production process with a high degree of automation (at least 75%) and implementation of mature methodologies known from automation industry for target production volume of at least 100 MW/year (from 20,000 to 100,000 units/year depending on nominal stack power) utilising the developed automated production step should be planned;
- Techno-economic assessment and demonstration of stack output of 100 MW/year (corresponding from 20,000 to 100,000 units/year depending on single stack power) resulting in target manufacturing costs <800 €/kW_e should be provided;
- Digital concept for complete component tracking and continuous validation of virtual twins for component and/or stack manufacturing should be considered;
- Circularity assessment in technology / prototypes development should be provided;
- The IPR on the manufacturing tool and equipment is to be with the automation company, in order to enable other manufacturers to benefit from the experience and to strengthen the overall sectors competitiveness in Europe.

At least one of following manufacturing processes should be addressed:

- Sealing process of high temperature solid oxide cells: design, implementation, test of automated sealing stations for stack manufacturing with easy stack connection-disconnection and integrated cost-effective sealing process control and quality assessment for 20,000 to 100,000 units/year;
- Ceramic cell production for solid oxide cells. Automated ceramic cell production, which cover the areas of raw material quality control, semi-products manufacturing, layer deposition technology, sintering (i.e. tunnel furnace), handling of green and sintered parts and quality monitoring able for a cell production capacity from 1.5 to 4 million units/year;
- High speed bipolar plate production and coating, production related quality monitoring and comprehensive testing methods using artificial intelligence and machine learning algorithms, if required, designed for cell production capacity from 1.5 to 4 million units /year.

By the end of the project the production process utilising automated steps, initially performed by manual working force, should be successfully demonstrated resulting in considerable (>60%) reduction of production time and costs of corresponding manufacturing steps.

Activities are expected to start at MRL 4 and achieve MRL 7 by the end of the project.

The topic is not intended to cover the establishment of pilot or full-scale manufacturing plants, or basic research on new materials, or fundamentally new cell and stack designs. The focus of the project is to demonstrate, in an industrial environment, the possibility of automating the most expensive processes, today performed manually or with technologies not suitable for the achievement of the production objectives described in the topic. The project should close the gaps for design and supply of automated turn-key equipment for production of stacks and/or stack components.

Consortia should include industrial partners responsible for: automation, quality control and stack or stack component manufacturing. A leading role is expected to be taken by the automation/equipment manufacturer/s in the consortium. The industrial partners should be supported by research institutes, which focus on but not limited to: relevant manufacturing technologies, failure analysis in manufactured components, implementation of non-destructive testing (NDT) and novel quality control methods, artificial intelligence and machine learning algorithms for quality management, post-operation analysis of stacks and components.

Consortia are encouraged to explore synergies and cooperation with Made in Europe partnership (Cluster 7) as well as to seek for additional national funding.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

Proposals are expected to address sustainability and circularity aspects. In particular, circularity and sustainability by design concepts should be holistically considered towards the whole technology chain.

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

HORIZON-JTI-CLEANH2-2022-04-02: Ammonia powered fuel cell system focusing on superior efficiency, durable operation and design optimisation

Specific conditions	
<i>Expected contribution per project</i>	<i>EU per</i> The JU estimates that an EU contribution of around EUR 4.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 4.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project. See General Annex B.

Expected outcome

Fuel cells are known as the most efficient energy conversion outperforming conventional power sources. Hydrogen and natural gas-powered fuel cell systems have reached high-level technology readiness levels (TRL) and demonstrated reliable durability in operation. However, today's roadblock preventing fuel cells from winning a greater share of the power market is the lack of availability of affordable, carbon free, and easily transportable fuel. Against this background ammonia shows huge potential as hydrogen carrier. Liquid ammonia - with twice as much hydrogen as liquid hydrogen by volume and carbon-free formulation – unleashes a new dimension in fuel cells applications. Ammonia as a fuel in fuel cells can provide a great impact on de-fossilisation in all power consuming sectors of the global economy. A use of ammonia for industrial business-to-business (B2B) prime power and long-term backup power production provides opportunity for further decrease of carbon dioxide emissions in regions having easy access to this fuel.

Project results are expected to contribute the following expected outcome:

- support European industry across the whole value chain in the development of the next generation power appliances utilising ammonia as a fuel;
- demonstration of high efficiency, fuel cell-based systems operated on ammonia as a means to provide new options for de-fossilisation of different energy sectors and facilitate establishing value chains between fuel cell industry and existing players in industrial markets;
- contribute to the decarbonisation of autonomous power systems operated on a liquid carbon-free fuel e.g. digital data transmission sector, such as telecom (5-15 kWe), communication support for critical infrastructures (up to 5 kWe), energy supply (up to 10 kWe) for early warning systems (i.e. hazardous climate-related event transmitters. These market opportunities represent a suitable stepping stone to deploy fuel cell systems with high efficient energy conversion rate of ammonia fuel to power within a reasonable timeframe;
- Set the basis for the development of large power generators in the 100 kW and MW scale for e.g. harbours where ammonia is available as commodity already today. Green ammonia figures as a candidate to become the future standard fuels in

maritime applications;

- Gain and transfer knowledge and experiences to the maritime providing sector.

Project results are expected to directly contribute to all of the following objectives of the Clean Hydrogen JU SRIA Pillar 3, Hydrogen End Uses: Clean Heat and Power:

- Prepare and demonstrate the next generation of fuel cells for stationary applications able to run under (renewable) hydrogen-rich fuels whilst keeping high performance;
 - Target: Electrical efficiency of the system $\geq 50\%$; total system power degradation $\leq 3\%$ at nominal power measured over at least 1,000 hours of continuous operation; availability of the system $\geq 90\%$ during whole testing period gathering $\geq 3,000$ operating hours; fuel cell system able to operate at partial loads;
- Fuel cells operating on alternative (renewable) fuels; Target: 5-15 kW fuel cell system operating with green ammonia including operation at partial load;
- New technologies and components to reduce costs and improve flexibility in operation. Target: fuel cell system costs $\leq 5,000$ €/kWe for 100 MW annual production.

Scope

The scope of this topic is to design, manufacture and validate in relevant environmental an ammonia fuelled fuel cell system with a total electrical power output of 5-15 kW_{el}. The system should operate for at least 3,000 hours and be also validated for operation at partial loads.

The system requires innovative scientific and engineering solutions. The focus of research may include innovative fuel cell design and should include BoP components and integrated ammonia cracker, safe and durable operation. For system development proposals may use available fuel cell technologies. Fuel cell manufacturers should be part of consortia.

Balance of plant (BoP) components needed for ammonia-driven fuel cells determine overall efficiency and durability of the system and should be designed taking into consideration the following requirements:

- Ammonia cracker integration into the system without external power should allow a fully autonomous operation;
- System design and integration of BoP should enable to maximise heat recovery;
- System should demonstrate dynamic load and relevant operating conditions in respect to the intended application;
- Power consumption for internal needs should be minimised.

Proposals should address the following:

- System design and development utilising existing fuel cell manufacturing technologies;
- Development of ammonia-tolerant BoP components;
- Dynamic modelling of system performance;
- Identification of degradation mechanisms in fuel cells and BoP components (including ammonia purity and degree of ammonia cracking), and effect of operation

parameters;

- Risk assessment of safety aspects in relation to the future certification of the system;
- Techno-economical assessment for a selected application;
- System operation / state of health monitoring;
- System operation with various grades of ammonia, including concentrations of ammonia in the feeding gas and impurities/contaminants;
- System–dynamic load and transient behaviour according to the end-user load profile(s) for selected application(s).

Consortia are expected to gather comprehensive expertise from the European research and industrial community. Participation of end user(s) for the selected system application is also expected.

Activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹⁴⁴ to benchmark performance and quantify progress at programme level.

¹⁴⁴ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-04-03: Reversible SOC system development, operation and energy system (grid) integration

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 5.50 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 5.50 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project. See General Annex B.

Expected outcome

Reversible Solid Oxide systems (rSOC) have a huge scope in the stationary energy sector because both power generation, in Fuel Cell operation (FC mode), and hydrogen production, in Electrolyser operation (EL mode), can take place within the same system. What this means is the CAPEX (Capital Expenditure) costs can greatly be reduced. Another key advantage with the rSOC technology is the possibility for sector coupling. This means rSOC systems coupled to industrial processes can help industries go down the zero emission or carbon neutral path.

Project results are expected to contribute to all of the following expected outcomes:

- Enable Renewable hydrogen production and its injection in the gas or hydrogen grid at a distributed level, offering new business models for hydrogen supply for gas and energy companies;
- Allow the balancing of power grids when excess renewable energy is flowing in, leading to new and attractive practices for electric power companies and new businesses;
- Enable localised storage of hydrogen in a micro-grid scenario. This would help in the development of new concepts for delivery of hydrogen for fuel cell vehicles (also off-road, construction machines etc.), similar to the concept of localised battery charging points;
- Pave the way for large (10 MW onwards in Fuel Cell Mode/30 MW in electrolyser mode) reversible solid oxide systems parks (similar to solar or wind parks). Such large parks will be capable of absorbing excess renewable energy and transforming it to renewable hydrogen and other useful fuels/chemicals in a green way.

Project results are expected to directly contribute to the following objectives of the Clean Hydrogen JU SRIA:

- For Pillar 3, ‘Hydrogen End Uses: Clean heat and Power: Improve flexibility of systems in operation in particular with reversible fuel cells;
- For sub-pillar 1 ‘Electrolysis’: Demonstrate the value of electrolysers for the power system through their ability to provide flexibility and allow higher integration of

renewables’.

In doing this the following KPIs should be addressed:

- Transient operation of the final system:
 - Number of switching cycles between FC & EL Modes – at least two per day;
 - Time for transition (in minutes) from one mode to another in the range of below 30 min.
- System Roundtrip efficiency – at least 38% (with hydrogen) or higher (with natural gas) for 2024. The efficiency should be computed for a configuration where the rSOC is connected to the gas grid which acts as supplier and receiver of the gas needed or produced;
- Degradation rate (quantified with combined FC & EL Modes) below 0.4% per 1,000 hours on stack level after 2024;
- Projected system capital cost below 6,000 EUR/kWe after 2024 and going down to 3,500 EUR/kWe by 2030. This refers to the overall reversible SOC system costs whose reference power is the nominal one in fuel cell mode.

This topic will also contribute to set the basis for solutions aiming at facilitating sector coupling and hence contributing to the objectives of the Hydrogen Valleys pillar.

Scope

Reversible solid oxide systems are expected to play a major role in future seasonal/periodical energy storage methods. Previous FCH JU projects¹⁴⁵ such as BALANCE, SElySOs, ECO and NewSOC have explored some of the most promising proposals with respect to systems, materials and process chains that are suitable when using a reversible solid oxide system. In BALANCE the concept of rSOC was the highlight and activities focussed on rSOC operation and implementation. The projects REFLEX and SWITCH also include rSOC at the core of their systems. In REFLEX, hydrogen is generated locally and re-used by the same system. The system can be operated in island mode or in electricity grid connected, no connection is made to the gas grid. SWITCH focuses on the continuous supply of hydrogen for industrial or mobility use. The rSOC at the heart of the systems provides the arbitrage of using either electricity or methane as source of hydrogen, according to the best available source at any moment. The SWITCH system can operate on methane from the gas grid although reinjecting hydrogen back into the grid is not foreseen at any moment. Moreover, other projects dealing with monitoring, diagnostics and control for SOC have provided a reference framework for the implementation of solutions that are able to guarantee optimal operation and durability of stack and BoP (Balance of Plant).

The current rSOC stacks/systems lack clear performance specifications when used on blends of natural gas and hydrogen. Therefore, still a large gap needs to be filled both at the system and cell/stack level that call for further research. Learnings and findings from the above projects should form the base for the investigations proposed in this topic.

The scope of this topic is to design and develop a reversible solid oxide system of at least 5 kWe in fuel cell mode and capable of absorbing at least 15 kWe in electrolysis mode. The solution developed should be validated in a relevant environment. Continuous operation of at least 3 months should also be demonstrated.

¹⁴⁵ https://www.clean-hydrogen.europa.eu/projects-repository_en

The reversible solid oxide system (rSOC) should be designed and developed to allow for:

- Full compatibility with the existing natural gas grid of today and the hydrogen grid of tomorrow in addition to the electricity grid. This will in turn contribute to achieving the following major objectives i) transition from natural gas to hydrogen as an energy vector ii) decentralised energy production, iii) balancing the high variability of electric energy from renewables and iv) energy security;
- Connection to both the gas grid and the electricity grid. The gas for FC Mode operation will be taken from the gas grid and the hydrogen produced from EL Mode operation (with or without processing) will be fed back to the gas grid;
- Reinjection of gas/hydrogen into the gas grid. In the case of reinjection as hydrogen, local concentration monitoring and mixing with natural gas (diluting it) is of essence. The alternative option of performing co-electrolysis raises the challenge of collecting and storing CO₂ of sufficient purity for co-electrolysis operation. This can potentially be coupled to the storage of oxygen produced in the electrolysis mode. Proposals can adopt any of these approaches;

Addressing the issues above will help promoting a prosumer hydrogen-based stationary sector.

Proposals should address the following at the system level:

- A rSOC system capable of generating at least 5 kW_e in fuel cell mode and capable of absorbing at least 15 kW_e in electrolysis mode needs to be developed, in line with the KPIs mentioned in the expected outcomes;
- The concepts used in developing the system should allow scalability to higher powers not only by adding individual stacks but also by increasing the stack power;
- The system should be able to operate not only with 100% hydrogen as fuel but also with mixtures of hydrogen and natural gas in Fuel Cell mode. In Electrolysis mode the system should be able to operate either in steam electrolysis or co-electrolysis mode, depending on the best possible approach leading to compatibility with the gas grid;
- A functioning prototype of the system should be validated in a relevant environment. A mix of hardware and hardware in the loop components can be chosen, to demonstrate how the system would work when deployed in the real world. A set of suitable algorithms and logics should also be implemented in order to monitor, diagnose and control the system for optimal operation in both modes and during switching. Safe operating strategies and appropriate design maps for system operation should be addressed. Electrical load following in electrolysis mode is quite critical; hence, performance with respect to load following should be quantified in a suitable manner;
- The reversible solid oxide system should have a common set of BoP (Balance of Plant) for both modes of operation. This is to ensure that the CAPEX cost stays low. The downstream gas/chemical processing system is a separate system of its own and is not part of the rSOC system which is to be developed and tested.

Proposals should address the following at cell & stack level:

- On the cell level, either commercially available cells may be used, or electro-catalytic materials can be specifically engineered keeping reversible operation in

mind. The cells should perform up to the current standards or higher and should meet the KPIs given above. The same should be replicated on the short stack and full stack levels. The cell should be able to operate at a current density of at least 1.5 A/cm² or higher in both modes of operation. Transient time during switching between modes should be quantified and kept low for practical operations;

- Appropriate State of health monitoring methods and monitoring tools should be developed and implemented which can predict performance degradation when cell is operated the two modes EL (with steam electrolysis and/or co-electrolysis) and FC (with several combinations of feeding mixtures);

These methods and tools should be translated for use on stack level and implemented on the full system.

Proposals should also demonstrate how the solution developed would allow to create a synergy between the gas transmission system operator and electric transmission system operator. In addition, proposals should develop and propose early business models targeting at energy companies including gas and power utilities.

Activities developing test protocols and procedures for the performance and durability assessment of electrolyzers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols¹⁴⁶ to benchmark performance and quantify progress at programme level.

¹⁴⁶ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2022-04-04: Dry Low NO_x combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 4.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 8.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 4 and achieve TRL 6 by the end of the project. See General Annex B.
<i>Procedure</i>	The procedure is described in General Annex F. The following exceptions apply: To ensure a balanced portfolio covering complementary approaches, grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds.

Expected outcome

A significant reduction of atmospheric pollution and emissions of greenhouse gases from power generation can only be achieved by transitioning away from fossil fuels and by increasing the share of Renewable Energy Sources (RES). However, the volatility in power output introduced by increasingly large shares of RES in the future energy system represents a key challenge. In this context, gas turbines (GTs) are considered to be the most robust, mature and cost-effective technology especially for large-scale power generation and are bound to reinforce their role as guarantors of grid stability and reliability. In order to fulfil this role in line with the Paris Agreement's goals, power generation from gas turbines needs to be decarbonised. A convenient approach to achieve this is by blending increasingly higher fractions of hydrogen into natural gas – the gas turbines' conventional fuel.

Project results are expected to contribute to the following expected outcomes:

- Develop a portfolio of solutions of full-scale gas turbine combustors for decarbonised, dispatchable and flexible heat and power generation across different systems sizes; from distributed systems all the way to large scale power generation plants;
- Ensure a cost-effective and safe utilisation of hydrogen as gas turbine fuel, including issues related to social acceptance of hydrogen-fired power plants by local communities.

Project results are expected to directly contribute to the objectives of the Clean Hydrogen JU SRIA Pillar 3, 'Hydrogen End Uses: Clean heat and Power' on preparing gas turbines to run on 100% hydrogen, whilst keep conversion efficiencies and NO_x emission to acceptable levels. In particular the following objectives and related KPIs as included the Clean

Hydrogen JU SRIA should be addressed:

- Allow substantial increase of hydrogen-firing capabilities of new or existing gas turbine combustion systems to volumetric Hydrogen fractions between 70% and 100%;
- Demonstrate emission-compliant operation, in line with emission limits set by legislation;
 - Target @ 70% vol H₂: <25 NO_x ppmv@15%O₂/dry or 29 NO_x mg/MJ fuel
 - Target @ 100% vol H₂: <25 NO_x ppmv@15%O₂/dry or 24 NO_x mg/MJ fuel
- Demonstrate operational (load) flexibility of gas turbines, within the standard specifications for natural gas operation, at all Hydrogen fractions (0-100%);
 - Target for maximum H₂ content during start-up of 20% volume H₂ in 2024 with a view to reach 100% volume H₂ for 2030;
 - Target for maximum efficiency reduction in H₂ operation of 10% points @70% Volume of H₂ for 2024 with a view to reach 10% points @100% H₂ in 2030;
 - Target for minimum ramp up rate of 10% load / minute @70% volume H₂ in 2024 with a view to reach 10% load / minute @100% H₂.
- Allow for a significant variability of the hydrogen fraction in natural gas, depending on the actual availability of hydrogen, which should be handled seamlessly by the gas turbine combustion system:
 - Target for handling H₂ content fluctuations of ±15% H₂ volume / minute in 2024 with a view to reach ±30% H₂ volume / minute in 2030.

Scope

The capability for gas turbines to operate on hydrogen-based fuels is a key future requirement to fulfil the target of CO₂-free power generation. Currently, the maximum volumetric hydrogen fraction, up to which commercially available gas turbines can be operated with, lies between 30% and 50% depending on the specific gas turbine class and type. Ongoing H2020 projects (HYFLEXPOWER147, FLEXnCONFU148) are focusing on power-to-gas-to-power technologies and partly also address hydrogen combustion in gas turbines. They are focussing on the whole power-to-gas-to-power system and hence either on small GT sizes (12MW in HYFLEXPOWER) or target to demonstrate small hydrogen fractions (FLEXnCONFU). Consequently, significant technological advancements in the gas turbines' combustion systems are required to further reduce and ultimately eliminate natural gas from the fuel blend.

The peculiar thermodynamic and combustion properties of hydrogen (e.g. diffusivity, reactivity, flame speed etc.) pose new challenges towards the achievement of a stable combustion process. These challenges are greatly increased for hydrogen combustion at the high-pressure conditions, which are relevant for gas turbine operation.

The scope of this topic is to design and demonstrate in relevant environment a scaled and full-size combustion system, i.e. same geometry and fire power as finally installed in the gas turbine. It is expected that experimental investigation will be performed up to full-load

¹⁴⁷ <https://cordis.europa.eu/project/id/884229>

¹⁴⁸ <https://cordis.europa.eu/project/id/884157>

condition at least on a single burner of the gas turbine, including the monitoring and control in case of new combustors as well as for retrofits. These combustion systems should be capable of operating at full gas turbine pressure conditions with any concentration of hydrogen admixed with natural gas and focus on volumetric hydrogen contents between 70-100%, i.e. well beyond the capability of state-of-the-art commercial gas turbines.

Activities are expected to start at TRL4 and should foresee the necessary laboratory experiments and numerical modelling leading to the design and validation of a full-size combustion chamber. At the end of the project duration, the proposed and developed solutions should achieve TRL6 and be validated in a relevant environment.

In order to achieve the expected outcomes, the development of the combustion system development should have in mind the following constraints and present solutions to overcome the associated technical hurdles:

- Stable combustion properties of hydrogen-rich flames demonstrated in full-scale combustor hardware at high pressure gas turbine conditions and across the entire GT load. This includes static (no flame flashback) as well as dynamic stability (no thermo-acoustic instabilities)
- Ensure sufficiently high firing temperatures to maintain high cycle efficiency of the respective gas turbine class.
- Ensure ultra-low emissions of air pollutants, in particular those of nitrous oxides (NO_x)
- Development of solutions for a combustion system that is capable to overcome previously mentioned technical challenges without the use of diluents (e.g. nitrogen, steam dilution, etc).

Consortia are expected to include turbine manufacturers. It is also encouraged to seek the involvement of plant operators. In addition, proposals should demonstrate that they will have access to the infrastructure that will be necessary to undertake the full-size testing.

As there may be different means to address the aforementioned technical hurdles, the specific research activities should be clearly detailed in the project proposal. Preferably the topic will support complementary approaches for small to medium power industrial gas turbines (above 12 MW electric) and large heavy-duty gas turbines (above 200 MW electric).

CROSS-CUTTING

HORIZON-JTI-CLEANH2-2022-05-01: Public understanding of hydrogen and fuel cell technologies

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of around EUR 1.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 1.00 million.
<i>Type of Action</i>	Coordination and Support Action
<i>Technology Readiness Level</i>	n/a

Expected outcome

Public and consumer understanding and acceptance will play a critical role in the successful future adoption of hydrogen and fuel cell (FCH) applications, both in the residential and the transport sectors. As markets for FCH technologies develop, citizens may react in different ways to hydrogen policies and infrastructures in their countries, regions and cities, and consumers and end-users will decide whether fuel cell applications fit their circumstances. The transition to hydrogen therefore not only poses technological challenges; it also requires a better understanding and response to cross-cutting issues related to citizen and consumer understanding and acceptance as well as broader environmental, socio-cultural and political issues.

Project results are expected to contribute to some of the following outcomes:

- Understanding public perceptions and reactions to hydrogen and fuel cell technologies;
- Identification of the main individual-level determinants of public understanding and acceptance of FCH technologies;
- Enhancing involvement of citizens in the implementation of solutions contributing to the transition to hydrogen and fuel cells;
- Understanding the pathways to influence public opinion by analysis of the current depiction of FCH technologies in broadcasts, newspapers, and social media, and from this developing a public information strategy;
- Assessment of the specific role of the socio-economic and environmental impacts of FCH technologies in both the public acceptance of FCH technologies and informed decision-making.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRJA: (especially for Cross-cutting issues - Area: Education and Public Awareness):

- to raise public awareness and trust towards hydrogen technologies and their system benefits, through the provision of guidelines/good practices and various engagement activities such as general public conferences and workshops,

brochures, public show rooms, e.g. museum displays; addressing and informing local authorities, certification bodies, first responders, etc.

Scope

The challenge for this topic is to further understand reactions and attitudes towards FCH technologies among citizens, consumers, and stakeholders in Europe for developing a comprehensive set of guidelines/good practices and engagement activities to increase public awareness and trust, supporting the mass uptake of FCH technologies in Europe. The successful proposal should generate empirical evidence regarding public attitudes towards FCH technologies in Europe. This knowledge will inform the future implementation of actions aimed at devising more effective ways of involving citizens and stakeholders in FCH related aspects and projects.

Activities should take into account the outcomes of the public tender launched in 2021 by the FCH 2 JU on the "public opinion survey and measures to be taken to overcome the challenges"¹⁴⁹ as well as previous and ongoing FCH projects and initiatives engaging the public, on previous social research on public attitudes and reactions to hydrogen and fuel cell technologies and specific social research initiatives on FCH technologies and applications such as the activities of the HYACINTH project¹⁵⁰ (FCH 2 JU, 2014-2017), facilitating the learnings from past and on-going experiences and successes for the development of the final guidelines/good practices and engagement activities.

Activities should focus on FCH technologies as a whole and should target the public and specific groups of stakeholders from sectors and territories for which the development and deployment of FCH technologies can play an important role.

Activities should include social research and public engagement activities, implemented in a significant number of Member States or associated countries, covering but not limited to EU-13 countries, such as world cafes, panel debates, focus groups, workshops, demonstrations, 'hands-on' events (e.g.: museum workshops), surveys, exhibitions, social media campaigns, etc. targeted at the public and relevant FCH stakeholders and coming from a collaborative, science-driven framework that involves social/sustainability scientists and FCH experts, scientists experts in popular science, scientific content editors, etc. as needed. Projects should provide a quantitative assessment of the impacts foreseen, providing the metrics and/or indicators to assess the impacts of the engagement activities towards the identified target groups.

The use of bridging tools (for instance, Social Life Cycle Assessment) to facilitate the connection between the technical and social dimensions and enable informed decision-making is encouraged. In this regard, the joint work between social sciences experts and experts in the entire FCH value chain, among others, should result in sound guidelines and materials for future FCH public engagement programmes, projects, and outreach activities.

A balanced overall coverage of EU countries should be sought. All categories of the population, including minorities, youth and the elder generation, as well as urban, peri-urban and rural areas, should be considered.

Activities should envisage links and synergies with existing platforms and/or projects on FCH technologies as well as means of collaboration with similar activities ongoing internationally.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 -

¹⁴⁹ <https://etendering.ted.europa.eu/cft/cft-display.html?cftId=8895>

¹⁵⁰ https://www.clean-hydrogen.europa.eu/projects-repository_en

Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

HORIZON-JTI-CLEANH2-2022-05-02: Safety of cryogenic hydrogen transfer technologies in public areas for mobile applications

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 2.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.00 million.
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	n/a
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Beneficiaries must, up to 4 years after the end of the action, inform the granting authority if the results could reasonably be expected to contribute to European or international standards.

Expected outcome

International regulations addressing CO₂ emissions are forcing all industries to rethink their processes to become more sustainable. When it comes to the heavy-duty transport or shipping industry for instance, the use of liquified hydrogen (also referred to as liquid hydrogen or LH₂) as an energy carrier and/or fuel appears essential in the short- to mid-term to reach the set objectives.

Transfer of LH₂ and its technical handling is relatively well known for industrial gas or space applications. However, experience with LH₂ in public and populated areas in new distribution applications, such as truck refuelling stations or port bunkering stations for example, is limited or non-existent.

Project results are expected to contribute to all the following expected outcomes:

- Detailed risk analysis (hazard identification, frequency and consequence assessment) for LH₂ transferring operations for ships, trucks and stationary tanks fillings;
- Generic hazard (or safety) distances for LH₂ transferring operations in the different applications, also addressing the possible presence of SimOps (Simultaneous Operations), to be implemented in codes and standards and to be suggested as first estimates for permitting;
- Guidelines for design of LH₂ transferring facilities (safety barriers, mitigation devices, layout, fire protection, pad material, venting);
- Consensual loading procedures (hose connection & disconnection, purging, grounding, instrumentation, certification of personnel) for LH₂ transferring operations;
- Disseminate the project outcomes to authorities (giving permits), notified bodies and other industrial actors;

- Provide science-based inputs to appropriate international standardisation activities.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA: (especially for Cross-cutting issues - Area: Safety, Pre-Normative Research and Regulations, Codes and Standards):

- Increase the level of safety of hydrogen technologies and applications;
- Support the development of RCS for hydrogen technologies and applications, with the focus on standards;
- Contribute to the SRIA KPIs for Safety, PNR & RCS, organising safety workshops (Targets: 2024 = 2 workshops/year, 2030 = 4 workshops/year);
- Contribute to the SRIA KPIs for Safety, PNR & RCS, providing inputs for developing Standards, Technical Specifications, or Technical Reports at the international level (Targets: 2024 = 0.9 No/ project, 2030 = 1 No/ project).

Scope

The risk management aspects concerning the transfers of LH₂ are critical and need to be technically addressed to provide a solid basis for future standardisation and safety regulation. The project should provide practical outputs (as safe procedures and installation/implantation rules) based on the current LH₂ hazards knowledge available and/or developed in previous projects, such as the FCH 2 JU PRESLHY and HyResponder projects¹⁵¹ for instance.

Proposals should:

- Define at least, but not limited to, 3 applications related to hydrogen mobility involving LH₂ transfer such as filling a stationary tank, bunkering of ships or refuelling a truck;
- Define the LH₂ transfer devices (hoses, vents) and operational conditions (mass flow rate, temperature, pressure);
- Perform a risk analysis of the operations for each application including the definition of the accidental scenarios, their quantification in frequencies and consequences;
- Propose safety barriers, suitable hazard zoning strategies and separation distances and validate their efficiency;
- Analyse the possible hazards and risks of co-activities and simultaneous operations and determine, if needed, additional validated barriers and separation distances;
- Disseminate risk-based recommendations and guidelines on LH₂ transferring facilities;
- Develop and disseminate consensual loading procedures (hose connection & disconnection, purging, grounding, instrumentation, certification of personnel) for LH₂ transferring operations;
- Provide science-based recommendations, guidelines and procedures to the concerned industry groups and standardisation committees.

Proposals should identify and target the relevant standard(s) at the scope and activities should envisage links and synergies with existing platforms and/or projects on LH₂ as well

¹⁵¹ https://www.clean-hydrogen.europa.eu/projects-repository_en

as means of collaboration with similar activities ongoing internationally. Proposals are encouraged to include a formal standardisation body within the consortium.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

HORIZON-JTI-CLEANH2-2022-05-03: Safe hydrogen injection management at network-wide level: towards European gas sector transition

Specific conditions	
<i>Expected contribution per project</i>	<i>EU per</i> The JU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 3.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 3 and achieve TRL 6 by the end of the project ¹⁵² See General Annex B.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Beneficiaries must, up to 4 years after the end of the action, inform the granting authority if the results could reasonably be expected to contribute to European or international standards.

Expected outcome

To date, the approach taken to inject hydrogen in the gas networks is left to be defined on a local basis in terms of concentration threshold, locations and purity. This fragmentation could cause significant interoperability issues, particularly when the quantities of hydrogen injected into the gas network will be more widespread geographically and probably variable in time. The impact on gas transportation and distribution (T&D) network components (e.g. valves, fittings, reduction stations, etc) and on all end-users connected to the gas infrastructure, with respect to the nominal 100% hydrogen and transients in the blend compositions is not fully understood.

To address these gaps, it is vital to map European gas T&D infrastructure and interact with operators in order to collect information about materials, components, technology and their readiness for hydrogen blending. It is also vital to develop knowledge for localisation of hydrogen injection, managing concentration fluctuations for blends and a detailed understanding of the implications of repurposing pipes for hydrogen duty.

The need for protocols for inspection and monitoring emerges from the development of networks carrying new gases or gases for which they were not originally designed. Preventive measures (inspection) and solutions to mitigate the impact of hydrogen at component level are still at a low level of maturity or not yet fully adapted to the integration of hydrogen into networks.

Project results are expected to contribute to the following expected outcomes:

- Definition of methods, tools and technologies for multi-gas network management

¹⁵² TRLs at the start and at the end of the project are not referred to the specific actions proposed in the scope, but to the whole set of actions proposed, that due to the wide scope and the interaction with the harmonisation and regulatory activities will vary from TRL 3 to TRL 6.

and quality tracking, including simulation, prediction and safe management of transients, in view of widespread hydrogen injection in a context of European -wide interoperability and gas market reform;

- Best practice guidelines for handling the safety of hydrogen in the natural gas infrastructure, managing the risks (with prevention and mitigation protocols) for guaranteeing the safe interoperability of gas transport at European level;
- Mapping and assessing T&D infrastructure components at European level to identify best available technologies, the hydrogen readiness of components, network technologies and monitoring protocols in order to steer stakeholders towards effective regulation and technical standards, network repurposing and modernisation investments.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA (especially for Pillar 2, Hydrogen Storage and Distribution –Sub Pillar: Hydrogen in the Natural Gas Grid, and for Cross-cutting issues - Area: Safety, Pre-Normative Research and Regulations, Codes and Standards):

- Development of technologies and materials to facilitate the transportation of hydrogen via the natural gas grid;
- Enable through research and demonstration activities the transportation of hydrogen through the natural gas grid either by blending or via repurposing to 100% hydrogen;
- Increase the level of safety of hydrogen technologies and applications;
- Support the development of RCS for hydrogen technologies and applications, with the focus on standards;
- Contribute to the SRIA KPIs for Safety, PNR & RCS, organising safety workshops (Targets: 2024 = 2 workshops/year, 2030 = 4 workshops/ year);
- Contribute to the SRIA KPIs for Safety, PNR & RCS, providing inputs for developing Standards, Technical Specifications, or Technical Reports at the international level (Targets: 2024 = 0.9 No/ project, 2030 = 1 No/ project).

Scope

This topic aims to define comprehensive technical information, standard protocols for the managing of a multi-gas network and give scientific-based evidence in order to help stakeholders towards the development of effective regulation and technical standards, network repurposing and modernisation investments.

The GERG CEN H2 PNR project¹⁵³ has helped to define a comprehensive list of impacted standards and a gap analysis for managing these standards through targeted PNR, and the project should aim to interact with these identified priorities at CEN TC level where possible.

Proposals should also support the aims of the Hydrogen and Decarbonised Gas Market Package¹⁵⁴ which provides the regulatory framework within which future gas networks will operate.

¹⁵³ <https://www.gerg.eu/project/hydrogen/>

¹⁵⁴ https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/hydrogen-and-decarbonised-gas-market-package_en

Proposals should address the management and control of transients of composition of natural gas and hydrogen mixtures for safe end use. In particular:

- Injection of hydrogen in existing gas grids can lead to a heterogeneous quality delivered to end-users. Quality variation should be predicted and controlled and injection strategies of hydrogen in the gas grid are needed.

Facing multiple production and injection points, complex grids, time-varying injection volumes and end-user demand volumes, the goal to predict and control gas quality in hydrogen blends could be addressed with a twofold approach. On one hand, by developing open modelling tools for gas network simulation, on the other hand, by identifying key technologies for quality tracking and the mitigation of quality variation in the natural gas network.

Solutions for the coordination of the hydrogen production and blending installations and their operations are required both from technical and regulatory points of view to guarantee quality control and to provide gas operators with the tools to manage a harmonised playing field for investors at EU level. Therefore, modelling should identify strategies for optimal injection points and gas network control, to evaluate pure or blended hydrogen injection strategies and to perform gas quality tracking and control. The project should analyse these issues in view of the intersectoral integration through power-to-hydrogen. Both gas distribution and transmission networks should be considered.

On the other hand, it is necessary to identify key technologies for quality tracking and the ones that are able to subsequently mitigate quality variation in the natural gas network, fully integrated with a dedicated ICT infrastructure for the digitalisation of the sector. Guidelines can also provide input for new technical norms that may spur innovation in selected network technologies for quality tracking and control.

Proposals should provide guidance to assist the injection of hydrogen in the gas infrastructure across Europe, consistently highlighting the new issues, the technical and administrative barriers and gaps by using a clear methodology that will give the basis to the definition of EU technical standards, which should include also the ICT protocols.

In addition, proposals are strongly encouraged to address the following activities:

- Analysis of delivered gas quality impacts on repurposed and new pipelines.

Proposals are expected to build on previous projects investigating the effects of hydrogen quality through repurposed pipelines (such as the Cadent Gas Hydrogen Grid to Vehicle project¹⁵⁵), with a specific focus on the effect of the hydrogen presence (and its variation) on all the items of the networks (e.g. valves, fittings, sealants, reduction stations, etc).

In addition, proposals are encouraged to perform gas quality testing of real samples. The analysis obtained will be undertaken along the delivery chain from the industrially produced hydrogen to storage and transmission and distribution through to final appliances. On the one hand, the work will support European industry to confidently produce, transport and store hydrogen with no impact to the end-user due to gas quality issues. On the other hand, it will help in generating a methodology to set specific hydrogen acceptability and hydrogen variation limits in

¹⁵⁵ https://smarter.energynetworks.org/projects/nia_cad0022

sections of the gas infrastructure, depending on the status of the existing infrastructure and the functional requirement of the connected appliances.

The results will support the further development and revision of a new EN standard for hydrogen quality in gas grids. It will also provide knowledge to develop new guidance on performing risk assessments for hydrogen-natural gas blends quality in gas grids.

- Analysis and inspection of infrastructure component behaviour in the presence of hydrogen.

Proposals are expected to build on the outputs of CEN H2 PNR (GERG) and other projects such as the HIGGS project¹⁵⁶. Additionally, it is expected to cooperate with the project resulting from topic HORIZON-JTI-CLEANH2-2022-02-01 which will be developing parallel testing protocols for metallic materials. A systemic analysis of the existing grid infrastructure is expected, shifting from single material compatibility to the evaluation of the fitness-for-purpose of components of the gas infrastructure.

Proposals are encouraged to develop a database of gas grid components (valves, fittings, gaskets, sealant, metering, odourisation, reduction stations, etc) behaviour in the presence of hydrogen correlated to the operating conditions of the networks and the materials that constitute them, assessing the compatibility of vintage and new gas infrastructures with hydrogen. The expected outcomes are therefore the mapping of components installed in European gas networks and the assessment of the compatibility of each single item. A ready-for-hydrogen ranking of all the existing items on the gas networks, together with the knowledge of the acceptability limits of end-user appliances, may be useful to define the best available network configurations for hydrogen blending management, different blending limits, priorities for modernisation and repurposing of existing assets, different safety requirements and protocols for the inspection (e.g. leak detection) and consequent management of risks. This should also be mapped with the quality and mitigation requirements for existing appliances (e.g. taken from the outcomes of projects such as THyGA¹⁵⁷).

Based on the outcomes of the above activities proposals are expected to develop protocols for inspecting (in-line inspection and non-destructive testing tools) and monitoring the integrity of pipelines and other equipment exposed to hydrogen, for the detection of the leakages and the correlated countermeasures and offer innovative solutions for non-inspectable pipes, both at transmission and distribution level.

Proposals should identify and target the relevant standard(s) at the scope and activities should envisage links and synergies with existing platforms and/or projects as well as means of collaboration with similar activities ongoing internationally. Proposals are encouraged to include a formal standardisation body within the consortium.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

¹⁵⁶ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹⁵⁷ https://www.clean-hydrogen.europa.eu/projects-repository_en

HORIZON-JTI-CLEANH2-2022-05-04: Development of validated test methods and requirements for measuring devices intended for measuring NG/H2 mixtures

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of around EUR 2.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 2.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to achieve TRL 4 by the end of the project. ¹⁵⁸ See General Annex B.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Beneficiaries must, up to 4 years after the end of the action, inform the granting authority if the results could reasonably be expected to contribute to European or international standards.

Expected outcome

No validated test methods for measuring devices used in the distribution and transmission of hydrogen-enriched natural gas currently exist. Therefore, a scientific approach to identify the hydrogen limits in NG mixtures and tolerances for the currently implemented measuring devices in the existing networks such as, for example, but not limited to, gas meters, volume conversion devices, pressure transmitters and transducers, quality analysers, is not possible. To date, type approval for measuring devices is carried out based on dedicated EN standards while the test gases composition is commonly in accordance with EN 437:2018, Test gases - Test pressures - Appliance categories (which limits the percentage of hydrogen in the test gases to 23%) or EN ISO 6145 method for quality analyser. However, there is no confirmation that the requirements and the procedure of the existing standards allow a validated assessment of the performances of measuring devices in the case of different and unsteady hydrogen and NG mixtures (considering hydrogen concentration in the range between 0% to 100% vol.), and especially for pure hydrogen. Since larger quantities of hydrogen are expected to be injected into the European gas networks in the future, the existing situation represents a barrier to the decarbonisation of the existing NG networks.

Results of the work will facilitate the development of revisions and updates of the European standards concerning measuring devices which are installed on the gas transport and distribution infrastructure, subject to the requirements of the MID 2014/32/EU, OIML (OIML R137, OIML R140, etc.) and other relevant metrological rules.

Project results are expected to contribute to all the following expected outcomes:

- Identifying hydrogen content limits for currently installed measuring devices (e.g. gas meters, volume conversion devices, pressure transmitters and transducers,

¹⁵⁸ TRL of 4 is to be meant as readiness level of the test methods and requirements rather than technology.

quality analysers) on the gas networks in terms of technical and metrological performances at different levels of hydrogen rate under dynamic network conditions;

- Supporting the manufacturing industry of gas measuring devices to have a clear vision of the problems connected to the presence of hydrogen blending with natural gas, helping them define their industrial plans concerning, for example, but not limited to, innovations aiming to ensure accurate measurement and billing;
- Supporting the natural gas TSOs (Transmission System Operators) and DSOs (Distribution System Operators) in the identification of the efforts required to convert existing natural gas networks to allow the safe transportation and distribution of different amounts of hydrogen and to ensure the most accurate billing to the final end-users;
- A boost in the entry into the market of hydrogen production technologies, thanks to the identification of potential barriers and technical solutions about the performances of measuring devices in order to accommodate variable volumes of hydrogen in the gas grid.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA (especially for Pillar 2, Hydrogen Storage and Distribution –Sub Pillar: Hydrogen in the Natural Gas Grid, and for Cross-cutting issues - Area: Safety, Pre-Normative Research and Regulations, Codes and Standards):

- Development of technologies and materials to explore and support the transportation of hydrogen via the natural gas grid;
- Enable through research and demonstration activities the transportation of hydrogen through the natural gas grid either by blending or via repurposing to 100% hydrogen;
- Support the development of RCS for hydrogen technologies and applications, with the focus on standards.
- Contribute to the SRIA KPIs for Safety, PNR & RCS, providing inputs for developing Standards, Technical Specifications, or Technical Reports at the international level (Targets: 2024 = 0.9 No/ project, 2030 = 1 No/ project).

Scope

Building on existing results from previous and ongoing projects such as, for example, NewGasMet¹⁵⁹ or Decarb¹⁶⁰, or the technical documents by EURAMET, experimental data from lab tests is necessary to validate technical and metrological requirements for measuring devices.

Proposals should develop validated test methods and requirements on existing measuring devices used in the gas distribution and transmission networks, that will result, among others, in the definition of hydrogen limits and tolerances for currently used measuring devices. The measuring devices to be considered should include, at least, but not limited to gas meters, volume conversion devices, pressure transmitters and transducers, and quality analysers.

¹⁵⁹ <https://newgasmet.eu/>

¹⁶⁰ https://www.euramet.org/research-innovation/search-research-projects/details/project/metrology-for-decarbonising-the-gas-grid/?tx_eurametctcp_project%5Baction%5D=show&tx_eurametctcp_project%5Bcontroller%5D=Project&L=0&Hash=68727f268894f4b2afd6c2cd62e69051

Proposals should:

- Define the test condition range for the measuring devices that will be tested: temperature, pressure, total gas mixture flowrate, etc. based on the expected in-field conditions (transportation and/or distribution networks). Hydrogen percentages should cover the range between 0% to 100% vol;
- Select the characteristics of the tested measuring devices. Particularly, the project should define specific criteria for the selection of:
 - Flow measuring devices that will be tested such as the type of gas meters and related size (maximum flowrate);
 - Quality analysers, including but not limiting to gas chromatographs;
 - Pressure transmitters and transducers;
 - Any other measuring devices included in the project.

The requirements for accuracy and metrological traceability of reference measuring equipment should be identified to test the measuring devices addressed in the project;

- Define a coherent methodology and proper tests programs (i.e. protocols) with the aim of identifying hydrogen limits and tolerances for the measuring devices indicated in the project. Particularly, the tests should consider different hydrogen percentages in the Natural Gas mixture in both stationary (fixed hydrogen concentration) and dynamics (variable in time hydrogen concentration) conditions;
- Perform testing activities based on the protocols designed. Testing of measuring devices should be performed in at least two laboratories and/or test centres to ensure the requirements of the developed procedures;
- Evaluate the impacts on the measuring devices in order to provide indication for further technical requirement, for example, but not limited to, the evaluation of the impact of hydrogen on the current recognised algorithms used for calculation of compressibility factor Z (EN ISO 12213, part 1 to 3) and their suitability for metrological purposes;
- Provide recommendations and dissemination for updating and/or development of new standards at international level. Recommendations should be provided on the following points, at least to European and National gases and metrology associations:
 - Development and validation of technical and metrological requirements:

In consideration of test results from the previous activities, development, validation and conformity assessment of technical and metrological requirements for measuring devices is needed to assure compliance of the currently used systems according to the requirements defined by standards or law for safety and process control in hydrogen technologies (as MID, OIML and other applicable metrological rules).
 - Definition of limits and tolerances for measuring devices:

Experimental definition of hydrogen limits and tolerances for currently

used measuring devices both in terms of components' failure and degradation (i.e. safety) and metrological performances.

The project should identify and target the relevant standard(s) at the scope and activities should envisage links and synergies with current research projects concerning the measure of NG/H₂ mixtures, such as those of the European Metrology Programme for Innovation and Research (EMPIR¹⁶¹) and European Partnership on Metrology of EURAMET. Collaboration with the activities of the Selected Research Topics SRT-v09 "Metrology for the hydrogen supply chain (Met4H2)"¹⁶², which is expected to start in 2022, should also be foreseen. Proposals are encouraged to include a formal standardisation body within the consortium.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

¹⁶¹ <https://www.euramet.org/research-innovation/research-empir/about-empir/>

¹⁶² https://msu.euramet.org/current_calls/greendeal_2021/index.html

HORIZON-JTI-CLEANH2-2022-05-05: Research & Innovation co-operation with Africa on hydrogen

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of EUR 1.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 1.00 million.
<i>Type of Action</i>	Coordination and Support Action
<i>Technology Readiness Level</i>	n/a
<i>Eligibility</i>	<p>The conditions are described in General Annex B.</p> <p>The following additional eligibility criteria apply:</p> <p>At least three partners from three different African countries must be part of the consortium.</p> <p>Due to the scope of this topic, legal entities established in all member states of the African Union are exceptionally eligible for EU funding.</p>

Expected outcome

Project results are expected to contribute to all of the following expected outcomes:

- Reinforce the activities in the long term of the African Union and European Research and Innovation Partnership on Climate Change and Sustainable Energy;
- Provide knowledge and multidisciplinary scientific based evidence of renewable hydrogen including the environmental, social and economic trade-offs;
- Benefit African and European researchers, industry, investors, financial institutions, and decision makers;
- Provide policy recommendations as to how, where and when Renewable Hydrogen deployment in Africa can best contribute to the continent's clean energy transition while fostering sustainable growth and development in line with EU policies, values and interests;
- A sustained network of African experts and expertise in renewable hydrogen and its application;
- Contribute to increasing renewable energy generation in the African energy systems.

Scope

The aim of this research is to gain a better understanding and identify the necessary measures to be taken, to create enabling conditions for the development of renewable hydrogen technology and market that would contribute to the social, economic and environmental transition of the African continent.

The results of this comprehensive and multidisciplinary research would benefit African and European researchers, investors, industry, financial institutions, as well as policy makers.

For the European Union, this research will contribute to shape future cooperation with African partner countries envisaging the development of renewable hydrogen value chains, aligned with international best standards and positioning the European industry as a credible investment partner.

The proposal should not focus on specific renewable hydrogen technology. The proposal should explore potential research, innovation and technological options for production, storage, transportation, distribution and usage of renewable hydrogen and the associated environmental impacts (considering a life cycle perspective); exploring alternative business models, techno-economic aspects, industrial implications and market opportunities; geopolitical consideration vis a vis the development of a global hydrogen market and the socio-economic implications on the African continent; network requirements, etc.

Proposals should identify the potential geographical and thematic areas where EU and African countries could develop mutual understanding and cooperation based on local production of hydrogen based on renewable energy locally available. At least two such areas should be developed in detail to exemplify the benefits and impacts.

One of the main deliverables would be a strategic and comprehensive innovation roadmap (SRI) to technology development and market introduction in the context of African national and continental industrial strategy and energy infrastructures. This SRI needs to highlight the mutual benefits to stakeholders, citizens and policies of both African Union and European Union.

In addition, it should:

- take into consideration the associated social, economic and environmental implications of alternative deployment paths of renewable hydrogen and other power fuels in Africa taking into consideration a life cycle approach and the relevant global value chains;
- identify possible barriers and opportunities to the introduction of renewable hydrogen technologies.

The proposal should also:

- define the life cycle assessment (LCA) methodology to assess the social, economic and environmental impacts of such development
- foresee the inventory of relevant regulations and standards, and absence thereof, as well as policy and other incentives planned or in place to deliver renewable hydrogen projects.
- identify local training needs

The proposal should take into account any relevant past and current studies on renewable hydrogen in Africa. Building on these studies the proposal should use the existing activities to propose the creation of a network of the major African actors in the area of hydrogen produced from renewable energy either directly or indirectly, transport of hydrogen and use of hydrogen. Proposals should ensure that the network created is sustainable and long lasting.

HYDROGEN VALLEYS

HORIZON-JTI-CLEANH2-2022-06-01: Hydrogen Valleys (large-scale)

Specific conditions	
<i>Expected contribution per project</i>	<i>EU</i> The JU estimates that an EU contribution of maximum EUR 25.00 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 25.00 million
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	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. See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The maximum Clean Hydrogen JU contribution that may be requested is EUR 25.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
<i>Procedure</i>	The procedure is described in General Annex F. Seals of Excellence will be awarded to applications exceeding all of the evaluation thresholds set out in this work programme, but cannot be funded due to lack of budget available to the call.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): hydrogen production plant, distribution and storage infrastructure and hydrogen end-uses, costs may exceptionally be declared as full capitalised costs.

Expected outcome

Building on the successful experience of previous years (Hydrogen Valleys in the FCH 2 JU call 2019 and Hydrogen Islands in the FCH 2 JU call 2020), this topics calls for the

deployment of a flagship¹⁶³ Hydrogen Valley with interlinkages to other places of hydrogen production and/or consumptions outside its boundaries. This represents a novelty as the Hydrogen Valleys supported to date are confined to a specific geography.

Proposals under this topic are expected to demonstrate how they contribute to the objectives of the European Hydrogen Strategy and the European Green Deal.

Project results are expected to contribute to all of the following expected outcomes:

- Activate a long-lasting hydrogen economy in the targeted region/s and that goes beyond the boundaries of the Hydrogen Valley/s developed as a result of the proposal;
- Replicable model for mutualisation of hydrogen production or distribution and storage, in view of optimisation of investments as key parameter for financial viability;
- At least 5 additional Hydrogen Valleys of at least a similar size and scope as the one required in this topic are initiated in other locations in Europe;
- Improved public perception of hydrogen ecosystems, contributing towards an EU hydrogen infrastructure backbone in any possible way, e.g. HRS network, hydrogen pipeline, NG pipeline retrofitted to hydrogen, etc.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA for Hydrogen Valleys. In particular:

- System integration: integrating several elements together to improve overall synergies and facilitate sector coupling;
- System efficiency: improvement of overall energy and economic efficiency of the integrated system;
- Improved security and resilience of the energy system, e.g. via hydrogen production using locally available renewable energy sources,
- Market creation: demonstration of new market for hydrogen
- Complementarity of hydrogen with RES, integration with other technologies, existing infrastructure;
- Assessment of the availability and affordability of clean (pollution free) energy provision for industry and cities uses; whilst also considering environmental impacts like water utilisation;
- Mutualisation of production or distribution and storage, assuming decentralisation as key parameter;
- Help set or test regulation requirements at the relevant governance level;
- Increase the knowledge management with assessment of the socio-economic and environmental impacts, including the concept of digital twin assuring an effective monitor and optimisation strategy for the operation and further development of the valley;
- Development of public awareness of hydrogen technologies including

¹⁶³ For definition of flagship see section 5.3. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

contributions from Social Science and Humanities if this was relevant.

- Support development of Hydrogen Valleys in areas of Europe with no or limited presence of Hydrogen Valleys.

In addition, proposals should demonstrate how they intend to reach the KPIs of the Clean Hydrogen JU SRIA 2021-2027 for each of the technologies deployed in the Hydrogen Valley.

Scope

A Hydrogen Valley is a defined geographical area where hydrogen serves more than one end sector or application in mobility, industry and energy. They typically comprise a multi-million euro investment and cover all necessary steps in the hydrogen value chain, from production (and often even dedicated renewable electricity production) to subsequent storage and its transport & distribution to various off-takers. Whilst most of the projects are located in Europe, over the past years, Hydrogen Valleys have gone global, with new projects emerging worldwide.

Hydrogen Valleys are starting to form first regional "hydrogen economies". Already under the FCH JU provided support to a number of Hydrogen Valleys¹⁶⁴ across different locations in Europe and of different sizes. It is however still necessary to accelerate the deployment of additional Hydrogen Valleys already now in view of the objectives of the European hydrogen strategy¹⁶⁵. To do this it is necessary to have testbed projects to act as first real-life cases for piloting global hydrogen markets. These projects need to be expanded in scale to demonstrate the full range of benefits from the use of hydrogen as an energy carrier. This topic addresses this need by calling for a Hydrogen Valley of a large scale with high levels of hydrogen production. It also intends to stimulate the activation of hydrogen markets that go beyond the boundaries the Hydrogen Valley location.

The scope of this topic is to develop, deploy and demonstrate a large-scale hydrogen valley with interlinkages to other places of hydrogen production and/or consumptions outside its boundaries. The size and other characteristics are given further below. To increase the impact, it is encouraged to accommodate these requirements across two separate interconnected valleys located in different intra-EU regions¹⁶⁶ whether within the same Member State/Associated country or not; in such cases, exchange of hydrogen is expected to exceed 20% of the overall annual production in order to have a meaningful impact, and individual regions would not be required to achieve the minimum project size of 5,000 tonnes/yr (outlined below) but would still be required to demonstrate minimum thresholds for percentages dedicated to end uses in various sectors as outlined below.

Technical

Proposals should:

- Showcase the ability of hydrogen and its associated technologies to decarbonise different sectors in EU through this renewable hydrogen flagship project;
- Demonstrate how hydrogen enables sector coupling and allows large integration of renewable energy on the selected territory;
- Include clear plans for transport, storage and distribution of hydrogen;

¹⁶⁴ https://www.clean-hydrogen.europa.eu/projects-repository_en

¹⁶⁵ https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

¹⁶⁶ For definition purposes, regions are those defined as such by the European Commission:

<https://ec.europa.eu/eurostat/web/regions-and-cities/overview>

- Cover the complete value chain of hydrogen from production to distribution, storage and end-use in order to decarbonise regions by harnessing renewables with significant fluctuations in seasonal energy demand, while at the same time allowing matching supply and demand on a daily basis. The proposed solution should thus provide energy flexibility and improve the Regions' system resilience through the use of renewable hydrogen. Applicants are expected to consider the environmental impact, including water utilisation;
- Foresee enough time for monitoring and assessment and at least 2 years of operations. The monitoring strategy should as a minimum allow to assess compliance with the KPIs of the Clean Hydrogen JU SRIA 2021-2027 for each of the technologies covered, as mentioned in the expected outcome section.

Size and characteristics of the Hydrogen Valley

Proposals should demonstrate:

- Production of at least 5,000 tonnes of renewable hydrogen¹⁶⁷ per year using new hydrogen production capacity. Due to the large volumes of hydrogen involved, production plants may be distributed across the territories involved.
- At least two FCH applications from at least two different sectors should be part of the project. The following sectors and applications can be considered for the use of renewable hydrogen, with a clear focus on energy, industry and transport sectors:
 - Industry sector: Industrial application valorising hydrogen such as refineries, steel industry, metallurgy, glass industry, ammonia or methanol production. Other industry applications are not excluded;
 - Energy sector: Possible applications on heat and power for commercial/residential buildings, service sector and industry, hydrogen 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;
 - Transport sector: Buses, cars (private cars and / or captive fleets such as taxis), delivery vans and small trucks, medium and heavy-duty trucks (also for long haul trips), specialty vehicles (garbage trucks and sweepers), trains, waterborne applications (boats/ships and port logistics), airborne applications (small and medium airplanes, drones and UAVs), material handling vehicles. Other transport applications are not excluded.

It is expected that the majority of the produced hydrogen will be dedicated to industrial applications, yet at least 20% of the hydrogen produced should serve other applications. In addition, if applicable as indicated above, cross-regional exchange/distribution of hydrogen is expected to be at least 20% of the hydrogen produced in the project and could be bidirectional depending on the location of storage.

The volumes of hydrogen produced and distributed for the different end uses should be consistent with the amount of investment considered.

¹⁶⁷ As defined in the EU Taxonomy – see: https://eur-lex.europa.eu/resource.html?uri=cellar:d84ec73c-c773-11eb-a925-01aa75ed71a1.0021.02/DOC_2&format=PDF, p.57

Hydrogen Markets

Proposals should:

- Demonstrate existing and new markets for renewable hydrogen, especially when applications are used in synergies;
- If applicable, pilot implementation of a transnational-regional/intra-EU renewable (certified via a relevant scheme) hydrogen market / trading of hydrogen across regions/borders.

Economic growth

Proposals should:

- Demonstrate how all actors, public and private, at European national and regional level will work together, across the entire value chain, to build a dynamic hydrogen ecosystem in the Member States/Regions involved. In particular proposals should demonstrate how the Hydrogen Valley development will be accompanied by economic growth, skills development and job creation;
- Promote and enable a renewable hydrogen ecosystem in the region(s), as a new economic vector and as mechanism of creating value for their population;
- Promote the economic growth and focus shifting of EU regions to new technologies and areas (e.g. reindustrialisation based on hydrogen technologies);
- Demonstrate the expected value added that the development of the Hydrogen Valley will bring to the affected region/s by including the intended approach that would be followed to maximise the value added created.

Impact and replicability

Proposals should:

- Develop a long-term vision on how the Hydrogen Valley developed is expected to grow also in view of its potential role in an Important Project of Common European Interest that may be in the making;
- Demonstrate the replicability and scalability of the project with the aim of facilitating further deployments of Hydrogen Valleys in other locations in Europe. Proposals should therefore address efforts to provide and transfer the learnings on how to best scale-up and transfer the solutions investigated within the selected territory to other interested areas. Proposals are therefore expected to develop a clear replication strategy and to engage with other regions in Europe, e.g. peer-to-peer exchange activities, to foster replication already during the duration of the action, with special attention placed on projects including Central and Eastern European regions where Hydrogen Valleys may be less developed at present. In doing this, proposals should address technical and economic feasibility and also aspects related to Regulation Codes and Standards. In that sense, learnings from previous similar projects (e.g. H2020 projects BIG-HIT¹⁶⁸, HEAVENN¹⁶⁹ and Hysland¹⁷⁰) should be lifted in view of mutualising and standardising impact and replicability aspects. Proposals should demonstrate how they intend to create links with other Hydrogen Valleys initiatives

¹⁶⁸ <https://www.bighit.eu>

¹⁶⁹ <https://heavenn.org>

¹⁷⁰ <https://greenhysland.eu>

in Europe (e.g. S3 Hydrogen Valleys Platform¹⁷¹, HyLand¹⁷² Regions in Germany), but also international (e.g. Mission Innovation 2.0 - Clean Hydrogen Mission¹⁷³);

- Include sufficiently targeted and professional communication activities and campaigns with the aim to increase public acceptance of hydrogen ecosystems. Given the flagship nature of this topic, the proposals are expected to pay attention to this aspect and to demonstrate how this would be professionally addressed.

Commitment of stakeholders and additional sources of financing/funding

Proposals should contain a calendar clearly defining the key phases of the implementation of the action (i.e. preparation of the specifications of equipment, manufacturing, deployment and operation) and their duration. Proposals should foresee enough time for monitoring and assessment.

Applicants may consider additional synergies with other Programmes (e.g. European Structural and Investment Funds, Recovery and Resilience Facility, Just Transition Fund, Connecting Europe Facility, Innovation Fund, Modernisation Fund, LIFE, etc.) and/or clustering with other projects within Horizon Europe or funded under other EU, national or regional programmes, or having loans through the EIB or other promotional or commercial banks; such synergies should be reflected in a financing structure and strategy describing the business model, including envisaged sources of co-funding/co-financing and in line with state-aid rules.

Evidence of the Commitment and role of public authorities (Member States, Regions and Cities) and of any other necessary stakeholders at least in the form of Letters of Intent (LOI) should be provided. The practical implementation of this LOI will be followed during the Grant Agreement implementation.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is produced/used. In this respect consortium may seek out the issuance/purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the issuance/purchase and cancellation of non-governmental certificates (e.g. CertifHy¹⁷⁴).

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

¹⁷¹ <https://s3platform.jrc.ec.europa.eu/hydrogen-valleys>

¹⁷² <https://www.hy.land/>

¹⁷³ <http://mission-innovation.net/missions/hydrogen/>

¹⁷⁴ <https://www.certify.eu/>

HORIZON-JTI-CLEANH2-2022-06-02: Hydrogen Valleys (small-scale)

Specific conditions	
<i>Expected EU contribution per project</i>	The JU estimates that an EU contribution of maximum EUR 8.00 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 8.00 million.
<i>Type of Action</i>	Innovation Action
<i>Technology Readiness Level</i>	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. See General Annex B.
<i>Admissibility conditions</i>	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
<i>Eligibility</i>	The conditions are described in General Annex B. The following additional eligibility criteria apply: At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research. The maximum Clean Hydrogen JU contribution that may be requested is EUR 8.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
<i>Procedure</i>	The procedure is described in General Annex F. Seals of Excellence will be awarded to applications exceeding all of the evaluation thresholds set out in this work programme but cannot be funded due to lack of budget available to the call.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G. The following exceptions apply: Purchases of equipment, infrastructure or other assets used for the action must be declared as depreciation costs. However, for the following equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks): hydrogen production plant, distribution and storage infrastructure and hydrogen end-uses, costs may exceptionally be declared as full capitalised costs.

Expected outcome

Building on the successful experience of previous years (Hydrogen Valleys in the FCH 2 JU call 2019 and Hydrogen Islands in the FCH 2 JU call 2020), this topic calls for the deployment of a flagship¹⁷⁵ Hydrogen Valley in areas of Europe with no or limited presence of Hydrogen Valleys such as, but not necessarily limited to, Central and Eastern European Countries.

Proposals under this topic are expected to demonstrate how they contribute to the objectives of the European Hydrogen Strategy and the European Green Deal.

Project results are expected to contribute to all of the following expected outcomes:

- At least [5] additional H2 Valleys projects are initiated before 2027;
- Replicable model for production or distribution and storage and end-use applications, in view of optimisation of investments as key parameter for financial viability;
- Improved public perception of H2 ecosystems, with the aim to contributing towards an EU hydrogen infrastructure backbone, e.g. HRS network, H2 pipeline, NG pipeline retrofitted to H2, etc.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA for H2 Valleys. In particular:

- System integration: integrating several elements together to improve overall synergies and facilitate sector coupling;
- System efficiency: improvement of overall energy and economic efficiency of the integrated system;
- Improved security and resilience of the energy system, e.g. via hydrogen production using locally available renewable energy sources,
- Market creation: demonstration of new market for hydrogen
- Complementarity of hydrogen with RES, integration with other technologies, existing infrastructure;
- Assessment of the availability and affordability of clean (pollution free) energy provision for industry and cities uses; whilst also considering environmental impacts like water utilisation;
- Mutualisation of production or distribution and storage, assuming decentralisation as key parameter;
- Help set or test regulation requirements at the relevant governance level;
- Increase the knowledge management with assessment of the socio-economic and environmental impacts, including the concept of digital twin assuring an effective monitor and optimisation strategy for the operation and further development of the valley;
- Development of public awareness of hydrogen technologies including contributions from Social Science and Humanities if this was relevant.

¹⁷⁵ For definition of flagship see section 5.3. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

- Support development of Hydrogen Valleys in areas of Europe with no or limited presence of Hydrogen Valleys.

In addition, proposals should demonstrate how they intend to reach the KPIs of the Clean Hydrogen JU SRIA 2021-2027 for each of the technologies deployed in the H2 Valley.

Scope

A Hydrogen Valley is covering a defined geographical area in which hydrogen serves in general more than one end user or application in mobility, industry and energy. They typically comprise a substantial financial investment and cover as much as possible the necessary steps in the hydrogen value chain, from production (and often even dedicated renewable electricity production) to subsequent storage and its transport & distribution to various off-takers. Hydrogen Valleys are starting to form regional "hydrogen economies". Such projects are necessary for piloting global hydrogen markets and should be expanded in number or scale to demonstrate the full range of benefits from the use of hydrogen as an energy carrier

The scope of this topic is to develop, deploy and demonstrate a hydrogen valley having the aim to increase in size and characteristics overtime. Particular attention is given to actions supporting the design and development of a Hydrogen Valley in areas of Europe with no or limited presence of Hydrogen Valleys such as, but not necessarily limited to, Central and Eastern European Countries.

Technical

Proposals should:

- Showcase the ability of hydrogen and its associated technologies to decarbonise one or two sectors in EU through this renewable hydrogen flagship project;
- Demonstrate how hydrogen enables sector coupling and allows integration of renewable energy on the selected territory;
- Include plans for transport, storage and distribution of hydrogen with a growing level of ambition over the years;
- Cover the complete value chain of H2 from production to distribution, storage and end-use in order to decarbonise a geographical area by harnessing renewables with significant fluctuations in seasonal energy demand, while at the same time allowing matching supply and demand on a daily basis. The proposed solution should thus provide energy flexibility and improve the Regions' system resilience through the use of renewable hydrogen. Applicants are expected to consider the environmental impact, including water utilisation;
- Contain a calendar clearly defining the key phases of the implementation of the action (i.e. preparation of the specifications of equipment, manufacturing, deployment and operation) and their duration. Proposals should foresee enough time for monitoring and assessment. The monitoring strategy should as a minimum allow to assess compliance with the KPIs of the Clean Hydrogen JU SRIA 2021-2027 for each of the technologies covered, as mentioned in the expected outcome section.

Size and characteristics of the H2 Valley demonstration

Proposals should:

- Produce at least 500 tons of renewable H₂¹⁷⁶ per year;
- Use the hydrogen produced to supply more than one end sector or application in the mobility, industry, and energy sector. The two main applications should each use at least 20% of the whole hydrogen produced.

The volumes of H₂ produced and distributed for the different end uses should be consistent with the amount of investment considered.

H2 Markets

Proposals should demonstrate existing and new markets for renewable hydrogen, especially when applications are used in synergies.

Economic growth

Proposals should:

- Demonstrate how different actors, public and private, at European national and regional level will work together, across the entire value chain, to build a dynamic hydrogen ecosystem in the geographical area involved. In particular, proposals should demonstrate how the Hydrogen Valley development will be accompanied by economic growth, skills development and job creation;
- Promote and enable a renewable hydrogen ecosystem in the area, as a new economic vector and as mechanism of creating value for their population;
- Promote the economic growth and focus shifting to new technologies (e.g. reindustrialisation based on hydrogen technologies);
- Demonstrate the expected value added that the development of the Hydrogen Valley will bring to the affected region/s by including the intended approach that would be followed to maximise the value added created.

Impact and replicability

Proposals should:

- Develop a medium-to long-term vision on how the Hydrogen Valley developed is expected to grow;
- Demonstrate the replicability and scalability of the project with the aim of facilitating further deployments of Hydrogen Valleys in other locations in Europe;
- Build on the learnings and create links with previous and ongoing similar projects (e.g. H2020 projects BIG-HIT¹⁷⁷, HEAVENN¹⁷⁸ and GreenHysland¹⁷⁹);
- Demonstrate how they intend to create links with other H₂ Valleys initiatives in Europe (e.g. S3 Hydrogen Valleys Platform¹⁸⁰, HyLand¹⁸¹ Regions in Germany) but also international (e.g. Mission Innovation 2.0 - Clean Hydrogen Mission¹⁸²);
- Include sufficiently targeted and professional communication activities and campaigns with the aim to increase public acceptance of H₂ ecosystems.

¹⁷⁶ As defined in the EU Taxonomy – see: https://eur-lex.europa.eu/resource.html?uri=cellar:d84ec73c-c773-11eb-a925-01aa75ed71a1.0021.02/DOC_2&format=PDF, p.57

¹⁷⁷ <https://www.bighit.eu/>

¹⁷⁸ <https://heavenn.org/>

¹⁷⁹ <https://greenhysland.eu/>

¹⁸⁰ <https://s3platform.irc.ec.europa.eu/hydrogen-valleys>

¹⁸¹ <https://www.hy.land/>

¹⁸² <http://mission-innovation.net/missions/hydrogen/>

Commitment of stakeholders and additional financing/funding

Applicants may consider additional synergies with other Programmes (e.g. European Structural and Investment Funds, Recovery and Resilience Facility, Just Transition Fund, Connecting Europe Facility, Innovation Fund, Modernisation Fund, LIFE, etc.) and/or clustering with other projects within Horizon Europe or funded under other EU, national or regional programmes, or having loans through the EIB or other promotional or commercial banks; such synergies should be reflected in a financing structure and strategy describing the business model, including envisaged sources of co-funding/co-financing and in line with state-aid rules.

Evidence of the Commitment and role of public authorities (Member States, Regions and Cities) and of any other necessary stakeholders at least in the form of Letters of Intent (LOIs) should be provided. The practical implementation of this LOIs will be followed during the Grant Agreement implementation.

This topic is expected to contribute to EU competitiveness and industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

It is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is produced/used. In this respect consortium may seek out the issuance/purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the issuance/purchase and cancellation of non-governmental certificates (e.g. CertifHy¹⁸³).

Proposals should provide a preliminary draft on 'hydrogen safety planning and management' at the project level, which will be further updated during project implementation.

Proposals are expected to contribute towards the activities of Mission Innovation 2.0 - Clean Hydrogen Mission. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.8 International Cooperation).

¹⁸³ <https://www.certify.eu/>

STRATEGIC RESEARCH CHALLENGES

HORIZON-JTI-CLEANH2-2022-07-01: Addressing the sustainability and criticality of electrolyser and fuel cell materials

Specific conditions	
<i>Expected contribution per project</i>	The JU estimates that an EU contribution of maximum EUR 10 million would allow these outcomes to be addressed appropriately.
<i>Indicative budget</i>	The total indicative budget for the topic is EUR 10.00 million
<i>Type of Action</i>	Research and Innovation Action
<i>Technology Readiness Level</i>	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project.
<i>Eligibility</i>	<p>The conditions are described in General Annex B.</p> <p>The following additional eligibility criteria apply:</p> <p>At least one partner in the consortium must be a member of either Hydrogen Europe or Hydrogen Europe Research.</p> <p>The maximum Clean Hydrogen JU contribution that may be requested is EUR 10.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.</p>

Expected outcome

Electrolyser and fuel cell technologies have reached a level of maturity but still depend heavily on critical raw materials (CRM) in their key components, including platinum group metals (PGM). The outcome of this topic, based on the excellence and expertise of European research, is expected to support European industry in their future development of next generation electrolysers and fuel cells comprising sustainable and recycled materials components and avoiding use of materials of high level of criticality. This topic is a Strategic and Research Challenge¹⁸⁴ expected to contribute to achieving the SRIA targets for electrolysers and fuel cells with radically different and sustainable materials technologies and is a pioneering venture internationally to achieve the ambitious goals of these technologies for European industry at lower environmental cost. This topic will also contribute to advancing European efforts in the Mission Innovation 2.0 - Clean Hydrogen Mission.

Critical materials considered in the topic include both the critical raw materials as defined by the European Union's most recent assessment of CRM¹⁸⁵ and materials with sustainability or environmental concerns, such as those deriving from poly/perfluoroalkyls. Such critical raw materials are considered 'strategic dependencies' in the area of hydrogen technologies.¹⁸⁶

Project results are expected to contribute to all of the following expected outcomes:

¹⁸⁴ For definition of Strategic Research Challenges see section 3.9. of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

¹⁸⁵ COM(2020) 474 - Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0474>

¹⁸⁶ <https://ec.europa.eu/info/sites/default/files/strategic-dependencies-capacities.pdf>

- Contribute to a sustainable and durable EU component supply chain by reducing the CRM content, notably of rare earth metals, PGMs and cobalt, in electrolyzers and fuel cells, and by developing replacement materials free of CRMs or environmentally unacceptable or non-sustainable components¹⁸⁷;
- Contribute to increasing the yield of ionomer and CRMs recovered from used cells and membrane electrode assemblies and from scraps and wastes by recycling;
- While keeping at least the same performance and durability as SoA in the Clean Hydrogen JU SRIA, contribute to achieving the PGM reduction target levels of the SRIA for AEM, PEM and alkaline electrolyzers and PEMFC for 2024 and beyond, and to reducing the amount of non-recoverable rare earth CRM in catalysts and electrolytes by at least 50% of the current (2021) rare earth CRM content in solid oxide and proton conducting ceramic electrolyzers and fuel cells;
- Develop at least three innovative solutions for each technology (PEM, AEM, AEL, PCC and SOC) for further prioritisation and development in specific dedicated RIAs of the Clean Hydrogen JU.

Project results are expected to contribute to all of the following objectives of the Clean Hydrogen JU SRIA:

- Low or free PGM catalysts and reducing critical raw materials in electrolyzers and fuel cells according to the following KPIs:
 - For PEMEL catalysts: 1.25 mg_{CRM}/W in 2024 and 0.25 mg_{CRM}/W in 2030
 - For AEL catalysts: 0.3 mg_{CRM}/W in 2024 and CRM-free catalysts in 2030
 - For AEMEL catalysts: 0.4 mg_{CRM}/W in 2024 and CRM-free catalysts in 2030
 - For fuel cell catalysts for HDV: < 0.3 g_{PGM}/kW in 2024 and <0.25 g_{PGM}/kW in 2030
- Develop enhanced recovery processes for PGMs/CRMs in hydrogen-based technologies, for instance:
 - 0.07 g/kW_{el} in 2024 and 0.01 g/kW_{el} in 2030 of non-recoverable CRM (i.e. Pt) as catalyst for low-temperature PEMFC in stationary applications
- AEL: reach high current density without noble metals;
- PEMEL: Reduce precious metals content in catalysts and consider recycling, develop PGM-free catalysts, develop new/advanced membranes;
- Research at material level for PEMFC to reduce or replace PGM loading;
- Reducing use of critical raw materials in stationary fuel cells;
- Research to optimise the CRM and ionomer recycling from FC and electrolyzers at end-of-life and processes from scraps and wastes:
 - minimum 30% in 2024 and 50% in 2030 of recycled CRM/PGM (other than Pt) at the system level;

¹⁸⁷ COM(2020) 667 final, EU chemical strategy for sustainability, https://ec.europa.eu/environment/strategy/chemicals-strategy_en

- minimum 95% in 2024 and 99% in 2030 of Pt recycled from FC/electrolysers at end-of-life;
- minimum 70% in 2024 and 80% in 2030 of ionomer recycled from FC/electrolysers at end-of-life.
- Minimisation of environmental impact/aim for circularity (energy, resources/material, recyclability).

Scope

A robust supply chain based on validated sustainable materials and components will ensure that the competitiveness of European electrolyser and fuel cell industry is not compromised by future legislative or supply constraints. Some of the current fuel cell and electrolyser technologies have developed from historically niche applications where reliability and performance were deemed more important than long-term sustainability, use of critical raw materials or even cost. This has led to the use of CRM in catalysts, electrolytes, coatings and bipolar plates at levels that are not sustainable over the long term, in the absence of robust separation and recycling routes. It has also led to ubiquitous recourse to ionomer membranes based on perfluoro sulfonic acid electrolytes, novel recycling and validated re-use routes of which are essential.

These materials are critically important in providing the requested high levels of performance and durability of state-of-the-art fuel cells and electrolysers. Breakthrough research is required to find alternatives in order to guarantee the development of a secure and clean hydrogen economy in Europe. To date, focus on reducing precious metals loading has been on reduction or replacement of platinum in proton exchange membrane fuel cells. However, these are only two aspects of a much broader requirement to address the sustainability of the critical materials used with a view to their replacement, reduction and/or recycle/re-use.

This topic addresses the sustainability of the fuel cell and electrolyser component supply chain by the development of technical advancements in (i) replacement of the critical (raw) materials currently used in fuel cells and electrolysers (ii) reduction in the amount of CRM used (iii) developing recycling approaches for materials critical for fuel cells and electrolysers, including novel means of dissociating and separating components.

The following items are within the scope of this topic, which comprise both low and high temperature electrolyser and fuel cell technologies:

- Development, characterisation and validation of novel materials free of critical raw materials (according to the European Union's 2020 CRM list), non-sustainable or environmentally unacceptable components, or with reduced content of such critical materials or components in fuel cells and electrolysers to levels consistent with the SRIA targets without compromising their performance and durability;
- Development of innovative materials, coatings, processing routes, electrode architectures and cell designs to reduce platinum group metal and other CRMs loading in electrolysers and fuel cells;
- Development of breakthrough high-efficiency solutions for recycling the critical materials and critical components of fuel cells and electrolysers, including associated separation steps, with focus on recycling of perfluoro sulfonic acid ionomers for reuse, and on recycling of iridium. Industrially mature technologies are

already in use for platinum recycling, however, solutions designed to reduce the potential environmental impact of non-Pt components of a Pt alloy (for instance, non-exclusively, Ni and Co) within the recycle stream are within the topic scope;

- Lifecycle analyses of the most prospective new technology/ies to demonstrate the sustainability of the proposed solutions.

The development of characterisation and test methods and protocols for evaluation of new and recycled materials and of complete cells is considered within the scope of the topic, however alignment should be made with those in use to qualify current state-of-the-art materials (i.e. those using critical raw materials, platinum group metals and perfluoro sulfonic acid membranes and ionomers).

The novel materials or materials from an intended recycling loop should be validated for their performance and durability in single cells using, as far as possible, EU harmonised protocols (including, as relevant, tolerance to impurities) with direct comparison with the performance/durability of cells with current, state-of-the-art materials under the same conditions.

Consortia should gather comprehensive expertise and experience from the European research community to ensure broad impact by addressing several of the items above. Partners should have proven expertise and the requisite means of electrolyser and fuel cells materials development, characterisation and testing. Industrial guidance is considered essential, for instance through an industrial advisory board. Proposals should explain how the results will be exploited, and how key advances from the activities will be communicated to the broader community to ensure rapid uptake of developments by end-users. To facilitate this communication, dissemination should have high priority and most deliverables should be public. The public annual progress report should include, as necessary, recommendations for future activities.

2.2.3.2 Conditions of the call and call management rules

Call identifier: **HORIZON-JTI-CLEANH2-2022**

Total budget: **EUR 300.5 mill**

Indicative budget(s)¹⁸⁸

Topic	Type of Action	Budgets (EUR million)	Expected EU contribution per project (EUR million)	Number of projects expected to be funded
Publication ¹⁸⁹ : 01 March 2022				
Deadline ¹⁹⁰ : 31 May 2022				
HORIZON-JTI-CLEANH2-2022 -01-01	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2022 -01-02	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2022 -01-03	RIA	5	2.5	2
HORIZON-JTI-CLEANH2-2022 -01-06	RIA	4	4	1
HORIZON-JTI-CLEANH2-2022 -01-07	IA	9	9	1
HORIZON-JTI-CLEANH2-2022 -01-09	RIA	6	3	2
HORIZON-JTI-CLEANH2-2022 -02-02	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2022 -02-03	RIA	5	5	1
HORIZON-JTI-CLEANH2-2022 -02-07	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2022 -02-08	IA	5	5	1
HORIZON-JTI-CLEANH2-2022 -02-09	RIA	4	4	1
HORIZON-JTI-CLEANH2-2022 -02-10	RIA	8	4	2
HORIZON-JTI-CLEANH2-2022 -03-02	RIA	6	3	2
HORIZON-JTI-CLEANH2-2022 -03-03	IA	30	30	1
HORIZON-JTI-CLEANH2-2022 -03-04	RIA	5	2.5	2
HORIZON-JTI-CLEANH2-2022 -03-05	IA	15	15	1
HORIZON-JTI-CLEANH2-2022 -03-06	RIA	20	20	1
HORIZON-JTI-CLEANH2-2022 -03-07	RIA	10	10	1
HORIZON-JTI-CLEANH2-2022 -03-08	RIA	5	5	1
HORIZON-JTI-CLEANH2-2022 -04-02	RIA	4	4	1
HORIZON-JTI-CLEANH2-2022 -04-03	RIA	5.5	5.5	1
HORIZON-JTI-CLEANH2-2022 -04-04	RIA	8	4	2
HORIZON-JTI-CLEANH2-2022 -05-02	RIA	2	2	1
HORIZON-JTI-CLEANH2-2022 -05-04	RIA	2	2	1
HORIZON-JTI-CLEANH2-2022 -05-05	CSA	1	1	1
HORIZON-JTI-CLEANH2-2022 -07-01	RIA	10	10	1

¹⁸⁸ 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.

¹⁸⁹ The Executive Director may decide to open the call up to one month prior to or after the envisaged date of publication.

¹⁹⁰ The Executive Director may delay the deadline by up to two months. The deadline is at 17.00.00 Brussels local time.

Topic	Type of Action	Budgets (EUR million)	Expected EU contribution per project (EUR million)	Number of projects expected to be funded
Publication ¹⁹¹ : 01 March 2022				
Deadline ¹⁹² : 20 September 2022				
HORIZON-JTI-CLEANH2-2022 -01-04	RIA	4	2	2
HORIZON-JTI-CLEANH2-2022 -01-05	RIA	6	6	1
HORIZON-JTI-CLEANH2-2022 -01-08	IA	18	18	1
HORIZON-JTI-CLEANH2-2022 -01-10	IA	20	20	1
HORIZON-JTI-CLEANH2-2022 -02-01	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2022 -02-04	RIA	3	3	1
HORIZON-JTI-CLEANH2-2022 -02-05	RIA	3	3	1
HORIZON-JTI-CLEANH2-2022 -02-06	RIA	6.5	6.5	1
HORIZON-JTI-CLEANH2-2022 -02-11	IA	7	7	1
HORIZON-JTI-CLEANH2-2022 -03-01	RIA	7	3.5	2
HORIZON-JTI-CLEANH2-2022 -04-01	IA	7	7	1
HORIZON-JTI-CLEANH2-2022 -05-01	CSA	1	1	1
HORIZON-JTI-CLEANH2-2022 -05-03	RIA	3	3	1
HORIZON-JTI-CLEANH2-2022 -06-01	IA	25	25	1
HORIZON-JTI-CLEANH2-2022 -06-02	IA	8	8	1

Through their participation in projects funded under this call and in accordance with point (d) of Article 28(3) of Council Regulation (EU) 2021/2085, Title II, it is estimated that an additional 61 million EUR in-kind contributions will be provided by private members, constituent entities or the affiliated entities of either, participating in the indirect actions published in this call.

In accordance with Articles 11(1), point (b), and 78 (1) of Council Regulation (EU) No 2021/2085 the estimated value of the costs incurred by the private members, constituent entities or the affiliated entities of either, in implementing additional activities (referred to as In-Kind in Additional Activities (IKAA)) is set out in the 2022 Additional Activities Plan, annexed to this document

Call management and general conditions

This section sets the general conditions applicable to calls and topics for grants under this Annual Work Programme. It also describes the evaluation and award procedures and other criteria.

The call included in this Work Programme, including evaluation and award procedures, will be managed according to and the proposals should comply with the Call conditions below

¹⁹¹ The Executive Director may decide to open the call up to one month prior to or after the envisaged date of publication.

¹⁹² The Executive Director may delay the deadline by up to two months. The deadline is at 17.00.00 Brussels local time.

and with the General Annexes to the Horizon Europe Work Programme 2021–2022¹⁹³ that shall apply mutatis mutandis to the call covered in this Annual Work Programme (with the exceptions introduced in the specific topic conditions). There is no derogation from the Horizon Europe Rules for Participation.

<i>Admissibility conditions</i>	The conditions are described in General Annex A.
<i>Eligibility conditions</i>	The conditions are described in General Annex B.
<i>Financial and operational capacity and exclusion</i>	The criteria are described in General Annex C.
<i>Award criteria</i>	The criteria are described in General Annex D.
<i>Documents</i>	The documents are described in General Annex E.
<i>Evaluation Procedure</i>	The procedure is described in General Annex F.
<i>Legal and financial set-up of the Grant Agreements</i>	The rules are described in General Annex G.

If a topic deviates from the general conditions or includes additional conditions, this is explicitly stated under the specific conditions for the topic.

Admissibility conditions: The conditions are described in Annex A of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Additional conditions

- For all Innovation Actions the page limit of the applications are 70 pages.

Eligibility conditions: The conditions, including countries eligible for funding, type of actions and definition of TRL are described in Annex B of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Additional conditions

- For some topics, in line with the Clean Hydrogen JU SRIA¹⁹⁴, an additional eligibility criterion has been introduced to limit the Clean Hydrogen 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:

Additional eligibility condition: Maximum contribution per topic
HORIZON-JTI-CLEANH2-2022 -01-07
HORIZON-JTI-CLEANH2-2022 -03-03
HORIZON-JTI-CLEANH2-2022 -03-05

¹⁹³ https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-13-general-annexes_horizon-2021-2022_en.pdf

¹⁹⁴ See section 5.3. 'Types of action: specific provisions and funding rates' of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

HORIZON-JTI-CLEANH2-2022 -04-01
HORIZON-JTI-CLEANH2-2022 -06-01
HORIZON-JTI-CLEANH2-2022 -06-02

- For some topics, in line with the Clean Hydrogen JU SRIA¹⁹⁵, an additional eligibility criterion has been introduced to ensure that one partner in the consortium is a member of either Hydrogen Europe or Hydrogen Europe Research. This concerns topics targeting actions for large-scale demonstrations, flagship projects and strategic research actions, where the industrial and research partners of the Clean Hydrogen JU are considered to play a key role in accelerating the commercialisation of hydrogen technologies by being closely linked to the Clean Hydrogen JU constituency, which could further ensure full alignment with the Strategic Research and Innovation Agenda of the Industry and the SRIA¹⁹⁶ of the JU. This approach shall also ensure the continuity of the work performed within projects funded through the H2020 and FP7, by building up on their experience and consolidating the EU value-chain. This applies to the following topics:

Additional eligibility condition: Membership to Hydrogen Europe/Hydrogen Europe Research
HORIZON-JTI-CLEANH2-2022 -01-07
HORIZON-JTI-CLEANH2-2022 -01-08
HORIZON-JTI-CLEANH2-2022 -01-10
HORIZON-JTI-CLEANH2-2022 -02-08
HORIZON-JTI-CLEANH2-2022 -03-03
HORIZON-JTI-CLEANH2-2022 -03-05
HORIZON-JTI-CLEANH2-2022 -04-01
HORIZON-JTI-CLEANH2-2022 -06-01
HORIZON-JTI-CLEANH2-2022 -06-02
HORIZON-JTI-CLEANH2-2022 -07-01

- For one topic the following additional eligibility criteria have been introduced to allow African countries to i) participate in proposal, ii) be eligible for funding and iii) ensure a sufficient geographical coverage of the African continent. This concerns the following topic:

Additional eligibility condition: Participation of African countries
HORIZON-JTI-CLEANH2-2022 -05-5

Manufacturing Readiness Assessment

- For some topics a definition of Manufacturing Readiness Level has been introduced in the Annexes of the Annual Work Programme. This is necessary to evaluate the status of the overall manufacturing activities included in the following topics:

¹⁹⁵ see section 5.2. 'Conditions for participation and eligibility for funding' of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

¹⁹⁶ for further details, see section 5.2 of the Clean Hydrogen JU SRIA

Manufacturing Readiness Assessment
HORIZON-JTI-CLEANH2-2022 -01-04
HORIZON-JTI-CLEANH2-2022 -04-01

Financial and operational capacity and exclusion criteria: The criteria is described in Annex C of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Award criteria: The criteria, including threshold(s), scoring and weighting, is described in Annex D of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Documents: The documents including the submission of proposals are described in Annex A of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Evaluation procedure and ranking: The entire evaluation procedure¹⁹⁷ and ranking are described in Annex F of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Exceptions:

- For some topics in order to ensure a balanced portfolio covering complementary approaches, grants will be awarded to applications not only in order of ranking but at least also to one additional project that is / are complementary, provided that the applications attain all thresholds

Exemption to evaluation procedure: complementarity of projects
HORIZON-JTI-CLEANH2-2022 -01-03
HORIZON-JTI-CLEANH2-2022 -01-04
HORIZON-JTI-CLEANH2-2022 -01-09
HORIZON-JTI-CLEANH2-2022 -02-10
HORIZON-JTI-CLEANH2-2022 -03-01
HORIZON-JTI-CLEANH2-2022 -03-02
HORIZON-JTI-CLEANH2-2022 -03-04
HORIZON-JTI-CLEANH2-2022 -04-04

Seal of Excellence

- For two topics in the Call the ‘Seal of Excellence’ will be awarded to applications exceeding all of the evaluation thresholds set out in this Annual Work Programme but cannot be funded due to lack of budget available to the call. This will further improve the chances of good proposals, otherwise not selected, to find alternative funding in other Union programmes, including those managed by national or regional Managing Authorities. With prior authorisation from the applicant, the Clean Hydrogen JU may share information concerning the proposal and the evaluation with interested financing authorities, subject to the conclusion of confidentiality

¹⁹⁷ including indicative timetable for evaluation and for signature of the grant agreement

agreements. In this Annual Work Programme ‘Seal of Excellence’ will be piloted for topic

Seals of Excellence is applicable to the following topics
HORIZON-JTI-CLEANH2-2022 -06-01
HORIZON-JTI-CLEANH2-2022 -06-02

Legal and financial set-up of the grant agreements: The Legal and financial set-up of the grant agreements¹⁹⁸ including funding rates are described in Annex G of the General Annexes to the Horizon Europe Work Programme 2021–2022 which shall apply mutatis mutandis to the actions covered in this Work Programme.

In addition to the standard provisions, the following specific provisions in the model grant agreement will apply:

Intellectual Property Rights (IPR), background and results, access rights and rights of use (article 16 and Annex 5 of the Model Grant Agreement (MGA)).

- An additional information obligation has been introduced for topics including standardisation activities: ‘Beneficiaries must, up to 4 years after the end of the action, inform the granting authority if the results could reasonably be expected to contribute to European or international standards’. These concerns the topics below:

Additional information obligation for topics including standardisation activities
HORIZON-JTI-CLEANH2-2022 -02-09
HORIZON-JTI-CLEANH2-2022 -03-04
HORIZON-JTI-CLEANH2-2022 -05-02
HORIZON-JTI-CLEANH2-2022 -05-03
HORIZON-JTI-CLEANH2-2022 -05-04

- For all topics in this Work Programme Clean Hydrogen JU shall have the right to object to transfers of ownership of results, or to grants of an exclusive licence regarding results, if: (a) the beneficiaries which generated the results have received Union funding; (b) the transfer or licensing is to a legal entity established in a non-associated third country; and (c) the transfer or licensing is not in line with Union interests. The grant agreement shall contain a provision in this respect.

Full capitalised costs for purchases of equipment, infrastructure or other assets purchased specifically for the action

- For some topics, in line with the Clean Hydrogen JU SRIA¹⁹⁹, mostly large-scale demonstrators or flagship projects specific equipment, infrastructure or other assets purchased specifically for the action (or developed as part of the action tasks) can exceptionally be declared as full capitalised costs. This concerns the topics below:

¹⁹⁸ Including Starting date & project duration, Milestones and deliverables, Form of grant, funding rate and maximum grant amount, Budget categories and cost eligibility rules, Reporting & payment arrangements

¹⁹⁹ See section 5.3. ‘Types of action: specific provisions and funding rates’ of the Clean Hydrogen JU Strategic Research and Innovation Agenda 2021 – 2027

Exceptional declaration of full capitalised costs
HORIZON-JTI-CLEANH2-2022 -01-07
HORIZON-JTI-CLEANH2-2022 -01-08
HORIZON-JTI-CLEANH2-2022 -01-10
HORIZON-JTI-CLEANH2-2022 -02-08
HORIZON-JTI-CLEANH2-2022 -03-03
HORIZON-JTI-CLEANH2-2022 -03-05
HORIZON-JTI-CLEANH2-2022 -04-01
HORIZON-JTI-CLEANH2-2022 -06-01
HORIZON-JTI-CLEANH2-2022 -06-02

Indicative timetable for evaluation and for signature of the grant agreement:

Unless otherwise stated in the specific call conditions, the timing for evaluation and grant preparation is as follows:

- information on the outcome of the evaluation: around 5 months from the deadline for submission;
- indicative date for the signing of grant agreements: around 8 months from the deadline for submission.

Common elements applicable to the topics in the Call

EU competitiveness and industrial leadership

In line with the activities started already in the FCH 2 JU, the Clean Hydrogen 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.

All topics included in the Call are expected to contribute to EU competitiveness and EU industrial leadership by supporting a European value chain for hydrogen and fuel cell systems and components.

Opportunities for synergies

The EU's Recovery and Resilience Facility (RRF) aims to mitigate the economic and social impact of the coronavirus pandemic, to address structural challenges in the member states and to make European economies and societies more sustainable, resilient and better prepared for the opportunities of the green and digital transitions. Applicants are encouraged to consult the national recovery and resilience plans in order to identify specific mentions of synergies with Horizon Europe and to detect further opportunities for complementarity between the plans' rich R&I portfolio and the Framework Programme.

Specific opportunities for synergies with other partnerships and programmes have been included the topic description where relevant.

Contribution to the monitoring framework of the Clean Hydrogen JU

For the purpose of monitoring technology progress against state-of-art, but also to identify how each of the projects contributes to the Clean Hydrogen JU targets, objectives and indicators described in the SRIA, supported projects shall report directly or indirectly on an

annual basis in a secure online data collection platform managed by the Clean Hydrogen Joint Undertaking during the course of Horizon Europe. The reporting shall consist of filling in the template questionnaire(s) relevant to the project content (and the technology development and TRL). The projects will need to submit all information included the questionnaire(s), unless they request and receive an exception from the Programme Office. The information is submitted by default as public, but the projects can request for certain fields to be considered as “confidential”²⁰⁰ except for the fields that constitute or directly inform KPIs of the Clean Hydrogen JU. The submission of the questionnaire(s) shall be integrated as a specific annual deliverable in the grant agreement. Indicative template questionnaire(s) can be consulted online²⁰¹.

Guarantees of origin of hydrogen

For some of the topics involving Innovation Actions and related successful actions it is expected that Guarantees of origin (GOs) will be used to prove the renewable character of the hydrogen that is produced/used. In this respect consortium may seek out the issuance/purchase and subsequent cancellation of GOs from the relevant Member State issuing body and if that is not yet available the consortium may proceed with the issuance/purchase and cancellation of non-governmental certificates (e.g CertifHy²⁰²).

Safety

For all topics a ‘safety by design’ approach should be considered. In particular, topics involving Innovation Actions and related successful actions, proposals should provide a preliminary draft on ‘hydrogen safety planning and management’ at the project level, which will be further developed during project implementation (deliverables to be reviewed by the European Hydrogen Safety Panel). Reference documentation and guidance is available on the EHSP webpage²⁰³. In particular: (i) Safety Planning and management in EU hydrogen and fuel cells projects – guidance document and (ii) simple template for a safety plan

For topics involving Research and Innovation Actions or Innovation Actions and related successful projects, projects should report any safety-related event that may occur during the project implementation 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 2.0, and the Hydrogen Event and Lessons LEarned database, HELLEN. Projects reporting on safety should report annually either the safety-related events²⁰⁴: near misses, incidents, accidents, or the absence of events.

Contribution to Regulation, Codes and Standards

For topics involving Innovation Actions and related successful projects, proposals are encouraged to consider a public report with both the Legal and Administrative Processes (LAP) and the Regulations, Codes and Standards relevant to the technologies and/or applications at the project scope, the barriers and/or gaps identified during the project implementation, and any other relevant information in order to share the lessons learned

²⁰⁰ The Clean Hydrogen 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 non-attribution of their source). Progress and findings that can be shown will be made public (normally associated to the Clean Hydrogen JU annual Programme Review exercise).

²⁰¹ https://www.clean-hydrogen.europa.eu/knowledge-management/technology-monitoring-trust_en

²⁰² <https://www.certifhy.eu/>

²⁰³ https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0/reference-documents-ehsp_en

²⁰⁴ Definitions of near-miss, incident, and accident according to EIGA document INCIDENT/ACCIDENT INVESTIGATION AND ANALYSIS SAC Doc 90/13/E

and provide recommendations to support the update and/or development of suitable and enabling legal and regulatory frameworks for hydrogen and fuel cell technologies and applications.

Contribution to sustainability and circularity

For all topics applicants are encouraged to address sustainability and circularity aspects in the activities proposed. For a number of selected topics this has been included explicitly in the scope. These topics are:

<i>Explicit reference to sustainability and circularity aspects</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-01</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-02</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-03</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-04</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-06</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-08</i>
<i>HORIZON-JTI-CLEANH2-2022 -01-09</i>
<i>HORIZON-JTI-CLEANH2-2022 -02-03</i>
<i>HORIZON-JTI-CLEANH2-2022 -02-04</i>
<i>HORIZON-JTI-CLEANH2-2022 -02-05</i>
<i>HORIZON-JTI-CLEANH2-2022 -02-06</i>
<i>HORIZON-JTI-CLEANH2-2022 -03-02</i>
<i>HORIZON-JTI-CLEANH2-2022-04-01</i>
<i>HORIZON-JTI-CLEANH2-2022-07-01</i>

Activities developing test protocols

For all topics, activities developing test protocols and procedures for the performance and durability assessment of electrolysers and fuel cell components proposals should foresee a collaboration mechanism with JRC (see section 2.2.4.3 "Collaboration with JRC"), in order to support EU-wide harmonisation. Test activities should adopt the already published EU harmonised testing protocols²⁰⁵ to benchmark performance and quantify progress at programme level.

International Collaboration

In recognition of the benefits that international collaboration can bring, it will also be promoted via the Calls for Proposals by encouraging international collaboration beyond EU Member States and Horizon Europe Associated Countries.

In particular for topics dealing with hydrogen in the gas grid, public acceptance, safety and Hydrogen Valleys, consortia are encouraged to include legal entities established in the countries members/participant²⁰⁶ in the Clean Hydrogen Mission under MI2.0 under the following topics, without prejudice to the countries eligible for funding set out in Horizon Europe - Work Programme 2021-2022 General Annexes:

²⁰⁵ https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

²⁰⁶ For the list of countries which are members/participant to Hydrogen Innovation Challenge, please see: <http://mission-innovation.net/our-members/>

Explicit encouragement for International Collaboration
<i>HORIZON-JTI-CLEANH2-2022-02-01</i>
<i>HORIZON-JTI-CLEANH2-2022-02-02</i>
<i>HORIZON-JTI-CLEANH2-2022-02-09</i>
<i>HORIZON-JTI-CLEANH2-2022 -05-01</i>
<i>HORIZON-JTI-CLEANH2-2022-05-02</i>
<i>HORIZON-JTI-CLEANH2-2022-05-03</i>
<i>HORIZON-JTI-CLEANH2-2022-05-04</i>
<i>HORIZON-JTI-CLEANH2-2022-06-01</i>
<i>HORIZON-JTI-CLEANH2-2022-06-02</i>

In addition, the Work Programme addresses cooperation with African countries in topic HORIZON-JTI-CLEANH2-2022 -05-05.

Collaboration with developing world countries supported by the Climate Technology Centre & Network (CTCN) under the UN Environment Programme is also encouraged.

For more information on International Collaboration see section 2.2.6.8 of this document.

2.2.3.3 List of countries entrusting the JU with national funds for the call 2022

Not relevant

2.2.3.4 Country specific eligibility rules

Not relevant

2.2.4 Calls for tenders and other actions

2.2.4.1 Calls For Tenders

In 2022, the Clean Hydrogen Joint Undertaking will carry out a number of operational activities via calls for tenders (i.e. public procurement) for an indicative amount of **EUR 2.5 million**. These activities will be financed by Horizon Europe. The procurement activities are covering subjects of a strategic nature for the Clean Hydrogen JU, providing input to R&I priority setting and supporting further financing, deployment and commercialisation of renewable hydrogen and fuel cells projects.

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>European Hydrogen Observatory</i> Public procurements foreseen to ensure the smooth and improved replacement of the current FCHO platform by the European Hydrogen Observatory with a foreseen duration of 4 years; the procurement activities include a call for tender for services and the provision of services by the Members in accordance with article 43.4 of the Financial Rules of the Clean Hydrogen JU. In close collaboration and complementarity to related activities of private members.	2,000,000	Open procedure	Q1
<i>Study on sustainable supply chain and industrialisation of hydrogen technologies</i> Tender study to update the EU manufactures list along the hydrogen value chain technologies, find potential gaps / bottlenecks in the supply and provide mitigation actions. The estimated duration is 18 months.	500,000	Open procedure	Q2-Q3

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

2.2.4.2 Support to EU policies

Hydrogen Guarantees of Origin

Since 2014, the FCH 2 JU has been working on developing a GO Scheme for Green and Low-Carbon Hydrogen under the CertifHy project²⁰⁷, which has now passed to the Clean Hydrogen JU. Since then, the third phase of work (CertifHy3) has started. CertifHy3 intends to accelerate the establishment of harmonised and mutually recognised Guarantees of Origin Schemes for renewable and non-renewable hydrogen across Members States, by

²⁰⁷ <https://www.certifyhy.eu/>

sharing the lessons learned from the CertifHy GO pilot scheme operation while ensuring compliance to article 19 of the RED II²⁰⁸.

An important objective of CertifHy3 is to support the design of a RED II compliant Voluntary Scheme, with the aim to get it recognised 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. Close collaboration between Clean Hydrogen JU and European Commission on this work will continue in 2022 (having EC already represented in the steering group of CertifHy3).

SET Plan and ERA-net

The Clean Hydrogen JU will continue following and contributing as necessary to the SET-Plan²⁰⁹ activities, in particular Action 6 “Energy Efficiency for Industry” and Action 8 on “Renewable Fuels”. The Clean Hydrogen JU is also taking part to the Sustainable Transport Forum Expert Group and its sub-groups, concerning the strategic rollout plan for alternative fuels infrastructure.

Considering the large potential for collaboration of the JU with ERA/Member States, the JU will examine ways to begin collaboration with ERA for regular exchange of information to follow up on the ERA/JU activities in the future, update each other on the topics/results from both programs, and potentially align topics (and complement funding) in future calls for proposals. As a first step, ERA and the JU should identify ways to align their SRIAs and find ways to complement each other, avoiding overlaps.

Support to transport policies

A number of the Call 2022 topics are facilitating the progress towards the objectives of the proposal for a regulation on the deployment of alternative fuels infrastructure 2021/0223(COD)²¹⁰, by investigating technology building blocks on hydrogen infrastructure equipment and processes such as electrolysers, safety and leak detection, transport and storage, novel compression technologies, hydrogen quality and protocols. Moreover, two flagship topics in the Call 2022 propose to support the deployment of hydrogen trucks and inland vessels and, in synergy, the Connection Europe Facility for Transport, would cover the refuelling infrastructure part for the realisation of the alternative fuels targets for hydrogen along the TEN-T networks.

On the maritime sector the collaboration with European Commission services and European Maritime Safety Agency (EMSA)²¹¹ on regulatory aspects (safety, standardisation, regulation) related to hydrogen as a maritime fuel will continue. Particularly in 2022, this will be underpinned with the work planned under the Clean Hydrogen JU study “Hydrogen in Ports and Industrial Coastal Areas”.

During 2022, a study supported by the Clean Hydrogen JU on “Impact of Deployment of Battery Electric Vehicles and Fuel Cells Electric Vehicles Infrastructure” should be finalised. The study aims at defining the optimal blend between electric recharging and hydrogen refuelling infrastructure through a comprehensive analysis. The results should help to determine strategies for the deployment of both electric charging and hydrogen refuelling infrastructure. Representatives of the industry as well as of the European

²⁰⁸ Renewable Energy Directive II (REDII), OJ L 328, 21.12.2018, p. 82–209

²⁰⁹ <https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan>

²¹⁰

https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf

²¹¹ <http://www.emsa.europa.eu/>

Commission are involved in the steering group ensuring that all relevant stakeholders can contribute and that policy recommendations emerging from the study are taken on board by policy makers.

Support to Industrial Policy

The Clean Hydrogen JU remains ready to support DG GROW and cooperate with the European Clean Hydrogen Alliance²¹² activities, to ensure synergies as foreseen in Art. 78 (2) of the SBA. These activities should include the joint and parallel holding of Clean Hydrogen JU partnership forum with the European Hydrogen Forum of the Clean Hydrogen Alliance.²¹³

2.2.4.3 Collaboration with JRC – Rolling Plan 2022

The Commission's Joint Research Centre (JRC) undertakes high quality research in the field of fuel cells and hydrogen that is of considerable relevance to the implementation of the Clean Hydrogen JU activities.

During the FP7 period, cooperation between the JRC and FCH JU was structured under a Framework Agreement that covered support activities which 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 (FWC) between FCH 2 JU and JRC was approved by the Governing Board on 23/12/2015 and was signed by both parties on 18/02/2016. This Framework Contract has been taken over by the Clean Hydrogen JU until its end (December 2022). A new FWC is planned to be signed between JRC and the Clean Hydrogen JU by 2023, in the spirit of the current FWC.

The scope of the current Framework Contract therefore covers the activities that JRC provides to the Clean Hydrogen JU, both free of charge and against payment from the Clean Hydrogen JU operational budget. In line with the JRC mission, these support activities will primarily contribute to formulation and implementation of the Clean Hydrogen JU strategy and activities in the areas of support to standardisation and technology monitoring and assessment. In addition, the Programme Office may call upon JRC to perform testing as a service to Clean Hydrogen JU, providing added value to programme objectives by complementing activities of Clean Hydrogen JU funded projects.

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

The annual Rolling Plan 2022 (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 (heading B of Article 2 in the Framework Contract) against payment. The additional activities which JRC performs without payment (heading A in Article 2) are not part of the annual Rolling Plan. They consist of activities within international collaborations, as well as in support of programme definition and implementation.

A. JRC support to formulation and implementation of RCS strategy

In general, RCS activities at Clean Hydrogen JU consist of identifying and prioritising RCS needs of strategic importance for the EU including the pre-normative activities required to

²¹² https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

²¹³ Art 83 (c) of SBA.

support the RCS priorities identified. Specific on PNR activities, it is critical to ensure that their results are developed for and used for RCS development. To this purpose, a RCS Strategy Coordination group was created, as defined in the Section 4.2 of the MAWP 2014-2023. Throughout H2020, JRC has been part of RCS SC group, providing the state of the art and gaps analysis required for the mentioned RCS and PNR prioritisation. A key result of the efforts during H2020 is the now stronger link between Clean Hydrogen JU PNR projects and the standardisation development occurring outside the frame of the Clean Hydrogen JU.

Under Horizon Europe, the approach to RCS strategy and the RCS group will be revised, and a new RCS Task Force created. JRC will contribute to the high-level activities of this new body, contributing to the annual strategic prioritisation of the PNR/RCS needs, jointly by all stakeholders. Since this new approach to RCS strategy is not yet completely defined, no specific deliverable is set for 2022.

B. JRC direct contribution to implementing RCS strategy

To provide inter-project comparable results and to facilitate assessment of technology progress without compromising on intellectual property rights (IPR) issues, FCH 2 JU formed working groups lead by JRC, aiming at a European harmonisation of the existing testing protocols and procedures. The harmonised tests should be consented to by industry and enable a consistent performance assessment. JRC will also participate to the standardisation activities of IEC TC 105 Fuel Cell Technologies. This work, performed by means of JRC own resources, allows to disseminate in a global context the European tests harmonisation achievements and to support European interests. Moreover, JRC follows similar ongoing efforts in the US, for a possible co-normative collaboration.

In 2021, the FCH 2 JU working group on test harmonisation for high temperature water electrolysis (HTE) applications, coordinated by the JRC, has published the terminology report. Also the multiannual effort on low temperature water electrolysis tests was finalised with a protocols harmonisation report, which integrated also the finding of project QUALYGRIDS.

The JRC electrolysis harmonisation work will continue pursuing harmonisation activities, together with the dedicated working groups, on energy performance of high temperature steam electrolysers. The work commenced in 2021 and the report, being a proposal for development of future protocols will be finalised in collaboration with the dedicated WG in the first half of 2022.

In the period 2017-2018, JRC has designed and manufactured a reference test cell hardware for PEM fuel cells the ZERO ∇ CELL, a single cell test hardware aiming at minimising the effect of the testing device on the overall test results. Since 2019, JRC has extensively tested the hardware, and has made the design of the ZERO ∇ CELL hardware available to relevant European projects and stakeholders. JRC will continue to provide technical support and assistance to individual users on request.

JRC will also support the ongoing Ad ASTRA project by carrying out testing activities in their labs.

- B.1 Support provided to the FCH community for the use of JRC ZERO ∇ CELL single cell test hardware for PEM fuel cells (including feedback from users). Annual activity report (December 2022).
- B.2 Report on EU harmonised testing procedure for determination of water electrolyser energy performance - Energy consumption of electrolyser systems.

B.2.a Draft report for public stakeholder consultation (September 2022).

This implies interactions and agreement with the work group before the date.

B.2.b Final report (December 2022).

- B.3 Report on EU harmonised testing protocols for high temperature electrolysis: performance and durability of stacks and systems. Draft for public stakeholder consultation (December 2022).
- B.4 Summary on experimental activities performed in the frame of the AD ASTRA project (December 2022).

C. JRC contribution to programme monitoring and assessment

Technology benchmarking

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 2022, 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.

In 2019, the JRC has begun a historical analysis of the performance of selected FCH JU projects against the overall Programme Targets, using, wherever possible, quantitative values and KPIs 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 be continued in 2022 for other technologies, following the 2019/2020 reports on electrolysis and stationary fuel cells.

- C.1 Support to knowledge management through technology monitoring and assessment of the Clean Hydrogen JU project portfolio. Historical analysis report on project portfolio of FCH JU and FCH 2 JU on the state of the art of FCEV, hydrogen buses and hydrogen fuelling stations (December 2022).

Support to Programme Monitoring and Assessment by means of JRC tools.

Unit JRC.I.3 will continue to adapt to the needs of the Clean Hydrogen JU the JRC Tools for Innovation Monitoring (TIM). 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 analysing thematic or technological areas, tracking currently used or emerging technologies. The JRC has developed 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 mapping of technology fields (alkaline electrolyzers/FC, hydrogen production methods, polymer electrolyte membrane FC/electrolysers and solid oxide FC/electrolysers, transport applications, hydrogen safety) will be annually broadened, with the additional provision of some data cleaning, in order to maximise accuracy of publishable results. New metrics based on publications and patents, to assist the monitoring and reporting of relevant KPIs will be further discussed and possibly developed in TIM. An effort will be made to provide to Clean Hydrogen JU direct access to the TIM platform (software) as internal users, in order to be able to perform keyword searches. Content delivery will proceed based on requests of the Clean Hydrogen JU.

- C.2 Maintenance, operation and extension of FCH Technology Innovation Monitoring System FCH TIM (December 2022).

Programme Annual Review. As in previous years, JRC will perform a full programme review cycle for the year 2022, in the form of an internal report.

- C.3 Update of methodology for the Programme Review in view of the transition to the Clean Hydrogen Joint Undertaking. This will consider the lessons learnt from the previous Programme Reviews and the needs for a lighter and more effective impact (February 2022).
- C.4 Draft report (1st draft June 2022, 2nd draft August 2022).
- C.5 Final JRC internal report, delivered before the Programme Review Days 2022 (September 2022).

D. JRC contribution to assessment of sustainability of hydrogen and fuel cells

Sustainability Aspects

One of the main strategic objectives of the Clean Hydrogen JU, as laid down in the SRIA, is to boost the share of FCH technologies in a sustainable, low-carbon energy and transport system. Among the specific objectives, the Clean Hydrogen JU aims to better manage the use of EU-defined 'critical raw materials' and to ensure that environmental (and social) impacts along the life cycle are minimised. As a tool to support and monitor progress on the sustainability objectives, the Clean Hydrogen JU has defined a Life Cycle Assessment (LCA) methodology which is to be applied to its projects and products.

LCA was 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 need for a harmonisation effort in the approach to LCA was identified, and a dedicated call topic was included in the AWP 2020. With the funding of three LCA projects (i.e., i.e. SH2E, Best4Hy, and eGHOST), in 2022 JRC will support efforts for this harmonisation. Moreover, JRC plan to contribute to the development of a "criticality indicator" and the guidelines for assessing the social life cycle impact of hydrogen technologies. For this, the Programme Office of the Clean Hydrogen JU will enable JRC involvement within the mentioned projects. In addition, JRC will continue the life cycle assessment of various modes of hydrogen delivery, including the analysis of transport means and conversion of hydrogen to different carriers. The assessment started in 2021 limited to the global warming impact, and it will be completed in 2022 with the investigation of additional environmental categories (e.g., resource use).

In 2022, the JRC will continue to assess the life cycle based deliverables of all ongoing projects and report to the Clean Hydrogen JU. JRC will also support the Clean Hydrogen JU in developing a strategy for life cycle data collection from projects and population of a LCI database with FCH technology data.

- D.1 Report on the JRC supporting activities on life cycle-based aspects of all ongoing projects (December 2022). JRC will support the projects resulted from the call 2020 (i.e. SH2E, Best4Hy, and eGHOST): JRC plans to contribute to the harmonisation effort in the approach to LCA, including related to LCI data. This activity will also cover contributions to the development of a "criticality indicator" and of the

guidelines for assessing the social life cycle impact of hydrogen technologies.

The report will also include the annual review of the life cycle based deliverables of all ongoing JU projects (i.e., spreadsheet with the review of each deliverable, and a summary with the main outcomes of the review).

- D.2 Report on Life cycle environmental performances of hydrogen transport options (June 2022). JRC will continue the life cycle assessment of various modes of hydrogen delivery, including the analysis of transport means and conversion of hydrogen to different carriers. The assessment started in 2021 on global warming impact and will be completed in 2022 with the investigation of additional environmental categories (e.g. resource use).
- D.3 Proposal for a strategy for life cycle data collection from projects and population of a LCI database with FCH technology data (December 2022). JRC will support FCH JU in developing a strategy for LCI data collection from projects, addressing in particular data quality requirement (e.g. ILCD compliance/EF compliance), for the creation and the maintenance of a dedicated LCI database with FCH technology LCI data using the Life Cycle Data Network infrastructure. The JRC will produce a guidance for the integration of LCI datasets in a “Hydrogen node” of the Life Cycle Data Network, covering technical and organisational aspects: the on-going projects will hence be able to submit their LCI datasets to the “hydrogen node”. At least one exemplary dataset will be integrated into the “hydrogen node”.

E. JRC contribution to safety, and safety awareness

Since the launching of the European Hydrogen Safety Panel in 2017 (see the dedicated section in the Addendum to the Multi - Annual Work Plan 2014 - 2020), JRC activities related to hydrogen safety have been progressively integrated in those of ESHP. These activities consisted in first instance in the maintenance and continuous population of the hydrogen accidents database HIAD 2.0. In 2018-2020 the EHSP has collected new events and delivered them to HIAD 2.0, while JRC has performed their validation, by performing quality check, harmonising event descriptions and finally approving (or rejecting) the public sharing of the event. Since 2019, the EHSP has assessed the new data by statistical analyses and extracted lessons learnt. This joint JRC-EHSP work resulted in a comprehensive report in 2021, summarised in a contribution to the International Conference on Hydrogen Safety ICHS2021, which received the best paper award. The JRC has also extracted Report lessons learned from incidents in specific sectors, upon requests of the EHSP or individual external HIAD 2.0 users.

The operation and utilisation of the HIAD 2.0 has naturally identified improvements needs. JRC and the EHSP are collecting all these improvements, to be implemented in a future major upgrade of the database structure.

In addition to HIAD 2.0, JRC manages also the restricted-access database HELLEN (Hydrogen Events and Lesson LEarNed): HELLEN has the same structure as HIAD 2.0, but contains the events (incidents or accidents) occurring during the execution of any Clean Hydrogen JU Project. There is a commitment to provide event description to HELLEN for all the Clean Hydrogen JU projects. Access to HELLEN is limited only to selected staff of the Clean Hydrogen JU and to the JRC-HIAD team.

Since 2020, JRC has reduced its safety-related activities in the field of hydrogen technologies. This is due also to the increased taking-up of activities by the EHSP. In 2021, the JRC databases were taken off-line due to new security requirements. This did not stop

the population and analysis of the data, but requires in 2022 a solution for the re-location of the databases, with possible passage of ownership.

- E.1 HELLEN operation: HELLEN population with the events delivered by projects and annual report (December 2022).
- E.2 Contribution to the EHSP activities, in particular in the field of hydrogen safety, including co-writing of relevant reports (continuous).
- E.3 Report on the return of experience for specific sectors as contribution to the workshops organised by the EHSP (before the dates of the workshops).
- E.4 Proposal for re-location of the two databases onto a new online platform, with possible passage of ownership (December 2022).

F. 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]
B.1	Support to formulation and implementation of RCS strategy (RCSSC group)	0.5
B.2	Direct contribution to implementing RCS strategy (Harmonisation)	7.0
B.3	Contribution to programme monitoring and assessment	20.0
B.4	Assessment of sustainability	10.0
B.5	Support to safety aspects	1.0
	Manpower Totals [PM]	38.5
		Overview indicative costs (with overhead) [k€]
Manpower		450
Missions		10
Consumables (for B.2.4)		10
Hardware (TIM, B.3.2)		10
Service Contract consultants (TIM, B.3.2)		95
Subcontract (for historical analysis)		50
Subcontract (for LCA expertise, B.4)		60
Subcontract (for preparatory work to re-locate databases of B.5)		10

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.

2.2.5 Follow-up activities linked to past calls: monitoring, evaluation and impact assessment

2.2.5.1 Knowledge management.

Knowledge management refers to a range of practices and techniques used by organisations to create, share and exploit knowledge to achieve organisational goals. The primary focus of these activities in the Clean Hydrogen JU is:

- a. Monitor progress towards the achievement of the objectives of the Clean Hydrogen JU objectives and its technology KPI;
- b. Strengthen the knowledge capacity of hydrogen value chain actors through data collection and knowledge collection;
- c. Support evidence-based implementation of Union policies;

The ultimate goal of this approach is to gradually turn the Clean Hydrogen Joint Undertaking into the Knowledge Hub for Hydrogen in Europe, and the Programme Office into a knowledge intensive organisation.

For the coming year, the Knowledge Management Team is planning to work towards these goals through the actions below. JRC will continue being an important partner to the Clean Hydrogen JU, supporting all knowledge activities, as described in Section 2.2.4.3.

A. Annual Data Collection Exercise and Programme Review Report for 2022

Technology and programme monitoring will continue with the annual data collection exercise from projects using the internally developed data collection platform TRUST (Technology Reporting Using Structured Templates)²¹⁴. Following its successful development and use, projects will be invited similarly to provide their data in 2022 concerning results generated in 2021. In 2022 the data collection templates will need to be adapted accordingly to reflect the new objectives and research priorities of the Clean Hydrogen JU. An effort to reduce the administrative burden and facilitate the submission from new projects will be made by significantly reducing the requested information from the projects to what is considered most essential for the Programme and technology monitoring.

Data collected will allow the benchmarking of the technology progress reported by the projects against the SoA and the Clean Hydrogen JU targets, as defined in the SRIA. Moreover, the annual iterations of the data collection exercise provide the necessary input for the development of a database of project results over time. The Clean Hydrogen 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 and in a manner that ensures anonymity

²¹⁴https://www.fch.europa.eu/sites/default/files/documents/TRUST_ExplanationFile_Draft_2019%20%28ID%205709356%29%20%28ID%205833842%29.pdf

of their origin.

Progress and findings of the data collection exercise will be presented in the annual Programme Review Report, planned to be published in autumn 2022. Similar to the data templates, in 2022 the structure of the report will also be adapted to the new objectives and research priorities of the Clean Hydrogen JU. Moreover, the content may be adjusted and become less technical, in an effort to make the report more friendly to the public and policy makers.

Continuing the good experience and practice, the 12th annual Programme Review Days will be organised in autumn 2022. Initiated in 2011, this annual event presents the progress of the portfolio of hydrogen relevant projects funded by the EU research programmes, 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. Furthermore, the Best Success Stories and the Best Innovation Awards are additional activities highlighting the results of collaboration between research, industry and policy makers, and projects achievements.

Finally, considering that in the recent (and most importantly forthcoming) years hydrogen topics are increasingly addressed in various EU programmes and partnerships under Horizon Europe, the Clean Hydrogen JU will examine ways to monitor technology progress and deployment for all these projects, integrating this information in one EU hydrogen database. The ultimate goal would be that all projects relevant to hydrogen participate in the Clean Hydrogen JU's annual data collection exercise, thus providing an up to date and complete database of the output from all European funded projects.

B. Fuel Cell and Hydrogen Observatory (FCHO)

The Clean Hydrogen JU contributes towards the monitoring of the deployment of hydrogen technologies, the adoption of related policies and academic activities and research results through the Fuel Cells & Hydrogen Observatory (FCHO)²¹⁵. FCHO is an open platform providing data and up to date information about the entire hydrogen sector, aiming to address the lack of data publicly available at EU and national level concerning the uptake of fuel cell and hydrogen technologies on the EU market and the absence of a coordinated methodology on how to monitor their market evolution.

FCHO is planned to remain as the main portal for European hydrogen data. In this respect, a new procurement process is foreseen in 2022 in order to ensure that FCHO will be maintained and continuously expanded, in order to fill in current knowledge gaps, improve visualisations and further facilitate the diffusion of knowledge. Data quality controls shall be further enhanced, to ensure FCHO provides a robust set of data. Considering the development of similar observatories and knowledge hubs by other international organisations, way to collaborate with them will be examined.

C. Collaboration in terms of knowledge management with Member States and Hydrogen Valleys

Collaboration with Member States and Hydrogen Valleys will be vital in ensuring the Knowledge Hub goal of the Clean Hydrogen JU. There will be significant mutual benefits by exchanging information on hydrogen activities and technology developments. Moreover, the Clean Hydrogen JU will provide the opportunity to the Member States and Hydrogen Valleys to present more widely their activities, mainly through the State Representative Group (SRG) and the European Research Area (ERA).

²¹⁵ <https://www.fchoobservatory.eu/>

Moreover, the Hydrogen Valley platform (H2V),²¹⁶ co-funded by FCH 2 JU and Mission Innovation, will be further developed to foster exchange of know-how and best practices at the European and international level.

D. Knowledge Management Tools

The Programme Office will continue to use and further develop the tools used in its predecessor FCH 2 JU to collect and monitor information, most notably the data collection platform TRUST and the TIM tool developed by JRC. These will be complemented by the tools provided by DG RTD (CORDA, COMPASS, CORTEX, etc), as well as the databases and tools developed internally to better manage information for supporting the operations of the Programme Office.

The Clean Hydrogen JU website will be enriched with more information concerning the Clean Hydrogen JU's projects, technology developments, etc. Combined with FCHO, the two websites should become a one stop shop for all information related to clean hydrogen in Europe.

As all the above-mentioned tools and platforms are independent and accessed separately, in 2022 the Programme Office will investigate whether a new platform could be introduced, integrating the existing tools and platforms, and further enhancing their capacity. Such a platform would include a data collection tool (TRUST), as well as an extended (project) database fed by many different sources, analysis capabilities and strong reporting and visualisation capabilities. It would also integrate or host the existing platforms supported by Clean Hydrogen JU, such as FCHO, H2V and the HRS availability map.²¹⁷

2.2.5.2 Feedback to policy

The Clean Hydrogen JU is contributing to the activities of several services in the European Commission. Contributions vary in content and format, but the common goal is to provide 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 several technical groups organised by the EC (e.g. the Horizon Feedback to Policy Group²¹⁸) 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 also includes feedback from projects and studies to the EC in contribution to relevant energy, transport and clean air policy files.

In 2022, the Clean Hydrogen JU Programme Office will continue to reinforce the collaboration with policy makers in the European Commission by providing input, under ad-hoc requests or in a more structured manner. The new Framework for Feedback to Policy is the main initiative to support evidence-informed policy design and evaluation. Prepared and piloted by the Common Implementation Centre, the new Framework is expected to support and coordinate the process within the Climate, Energy and Mobility cluster in Pillar II of the Programme, as soon as the new structure with the establishment of the Joint Teams and the new processes and tools to support implementation is set. Considering the dense climate and energy policy framework at EU level, further reinforced by the recent Fit-

²¹⁶ <https://www.h2v.eu/hydrogen-valleys>

²¹⁷ <https://h2-map.eu/>

²¹⁸ The Horizon Feedback to Policy Group will be one of the pillars of the governance structure to coordinate implementation, according to the D&E Strategy for the post-H2020 period and the Horizon Europe.

for-55 and the Gas and Hydrogen Market packages adopted in 2021, the Clean Hydrogen JU expects frequent interactions and a high level of requested contributions in this context (e.g. regarding the certification system for low-carbon gases to be developed to complete the work started in the Renewable Energy Directive with the certification of renewable gases, which overlaps with the relevant initiative of the Clean Hydrogen JU under the project CertifHy).

The Fuel Cells and Hydrogen Observatory (FCHO) maintained by the Clean Hydrogen JU is also an important resource in the context of the feedback to policy, containing useful information on hydrogen technologies, deployment, policies, funding and research - related information (publications, patents and trainings).

2.2.6 Cooperation, synergies and cross-cutting themes and activities

2.2.6.1 Synergies with other Programmes

Horizon Europe is the research and innovation support programme in a system of European and national funding programmes that shares policy objectives. Through the programme, special attention will be given to ensuring cooperation between universities, scientific communities and industry, including small and medium enterprises, and citizens and their representatives, in order to bridge gaps between territories, generations and regional cultures, especially caring for the needs of the young in shaping Europe's future. Applicants should consider and actively seek synergies with, and where appropriate possibilities for further funding from, other R&I-relevant EU, national or regional programmes (such as ERDF²¹⁹, ESF²²⁰, JTF²²¹, EMFF²²², EAFRD²²³ and InvestEU²²⁴), where appropriate, as well as private funds or financial instruments. The ERDF focuses amongst others on the development and strengthening of regional and local research and innovation ecosystems and smart economic transformation, in line with regional/national smart specialisation strategies. It can support building research and innovation capacities and uptake of advanced technologies and roll-out of innovative solutions from the Framework Programmes for research and innovation through the ERDF. The EU's Recovery and Resilience Facility (RRF) aims to mitigate the economic and social impact of the coronavirus pandemic, to address structural challenges in the Member States and to make European economies and societies more sustainable, resilient and better prepared for the opportunities of the green and digital transitions. Applicants are encouraged to consult the national recovery and resilience plans in order to identify specific mentions of synergies with Horizon Europe and to detect further opportunities for complementarity between the plans' rich R&I portfolio and the Framework Programme.

2.2.6.2 Synergies implemented via the Call for Proposals

Synergies with other European Partnerships and programmes

Since the early stages of preparation of the topics included in the Call for Proposals the Clean Hydrogen JU has interacted with a number of European partnerships, responsible for

²¹⁹ European Regional Development Fund; https://ec.europa.eu/regional_policy/en/funding/erdf/

²²⁰ European Social Fund; https://ec.europa.eu/regional_policy/en/funding/social-fund/

²²¹ Just Transition Fund; https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/just-transition-mechanism/just-transition-funding-sources_en

²²² European Maritime and Fisheries Fund; https://ec.europa.eu/fisheries/cfp/emff_en

²²³ European Agricultural Fund for Rural Development; https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/rural-development_en

²²⁴ InvestEU Programme; https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan/whats-next-investeu-programme-2021-2027_en

different EU programmes²²⁵. Their views have been taken into account in the design of this Call for Proposals. This has allowed to identify synergies and avoid overlaps.

For the flagship topics on heavy-duty vehicles and inland waterway vessels synergies with the Connecting Europe Facility are expected for the Hydrogen Refuelling Infrastructure.

The aviation topics in the Call 2022 are a result of a collaboration between Clean Hydrogen JU and Clean Aviation Partnership. In 2022 the Clean Hydrogen JU proposes to support three topics aiming at the development of fuel cells and liquid hydrogen tanks for aviation applications. The integration of these technologies into ground and in flying demonstrators would be in the scope of Clean Aviation partnership at a later stage.

Synergies between the Clean Hydrogen JU and the Zero Emission Waterborne Transport (ZEWT) partnership have been identified for the on-board storage topic and on the wider use of hydrogen rich fuels in ships. In addition, it is expected that the flagship project on inland waterways vessels will seek collaboration with ZEWT. On road transport the Clean Hydrogen JU flagship topic on heavy-duty vehicle may benefit from synergies with the 2Zero partnership topic looking at multi-powertrain zero-emission systems for heavy-duty vehicles.

Similarly, exchanges have taken place with the Processes4Planet (P4P) and Clean Steel partnerships. Potential synergies between the Clean Hydrogen JU topic on Integration of multi-MW electrolysers in industrial applications with existing projects or future topics of this partnership concerning innovative industrial processes have been identified.

For the Clean Hydrogen JU topic on novel routes for green hydrogen production applicants are encouraged to seek collaboration with the European Innovation Council's Pathfinder Challenge.

In addition, synergies with the European Partnership on Metrology have been identified for the Clean Hydrogen JU topics dealing with measuring devices and sampling methodologies.

Finally Clean Hydrogen JU manufacturing topics are expected to create links and seek synergies with the Made in Europe Partnership.

Synergies with Member States and regional programmes

Applicants may consider additional synergies with other Programmes (e.g. European Structural and Investment Funds, Recovery and Resilience Facility, Just Transition Fund, Connecting Europe Facility, Innovation Fund, Modernisation Fund, LIFE, etc.) and/or clustering with other projects within Horizon Europe or funded under other EU, national or regional programmes, or having loans through the EIB or other promotional or commercial banks; such synergies should be reflected in a financing structure and strategy describing the business model, including envisaged sources of co-funding/co-financing and in line with state-aid rules.

For the flagship topics significant additional sources of funding and/or financing are expected. In this respect, synergies with other Programmes and/or clustering with other projects within Horizon Europe or funded under other EU, national or regional programmes, or having loans through the EIB or other promotional or commercial banks are expected.

In addition, for the Hydrogen Valleys topics, Seals of Excellence will be awarded to applications exceeding the evaluation thresholds set out in this work programme but cannot

²²⁵ Annex 7 of the Clean Hydrogen JU SRIA provides more information on Common R&I Roadmap between the Clean Hydrogen JU and other partnerships

be funded due to lack of budget available to the call. The Seal of Excellence will further improve the chances of sound proposals, otherwise not selected, to find alternative funding in other Union programmes, including those managed by national or regional Managing Authorities.

2.2.6.3 Collaborations with other agencies and partnerships to deliver synergies

The Clean Hydrogen JU will remain proactive in taking up opportunities for collaboration with other European partnerships, EU agencies, initiatives and actions with the potential for synergy with its research agenda.

Examples of past collaborations include joint studies with other Joint Undertakings and synergies with other European Union funded programmes including the Transport Challenge of Horizon 2020, the Connecting Europe Facility for Transport (CEF Transport) and Interreg programmes.

Collaboration in 2022 will build on the good cooperation with European partnerships started in 2021. Regular exchanges with the relevant European partnerships is foreseen either through the Stakeholders Group or bilaterally, in view of aligning priorities of our roadmaps with the different Work Programmes timeframes. The aim is to coordinate annual topics to ensure strong complementarity and synergies.

Exchanges of the Clean Hydrogen JU in 2022 will also extend to the Executive Agencies in charge of managing other parts of Horizon Europe in areas relevant to fuel cells and hydrogen technologies. On the energy sector the Clean Hydrogen JU and the European Climate Infrastructure and Environment Executive Agency (CINEA) will continue to explore potential synergies and areas of collaboration, especially on fuel cells for stationary applications and hydrogen production and storage. On the transport sector, the Clean Hydrogen JU continues collaborating with CINEA (under both Horizon Europe and CEF Transport²²⁶ programmes) on activities related to heavy-duty transport applications (e.g. trucks, inland navigation or maritime applications) and related hydrogen refuelling infrastructure.

In addition, the Clean Hydrogen JU will continue collaborating with the European Defence Agency²²⁷ (EDA) with the objective to foster the adoption of hydrogen solutions for dual use technology applications.

As needed, the Clean Hydrogen JU will continue to collaborate with other European bodies and agencies (under the coordination 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 while increasing the impact within areas that are of common interest.

In addition, the Clean Hydrogen JU will continue exploring the awarding of the Seal of Excellence²²⁸ to flagship topics in future AWP.

²²⁶ Connecting Europe Facility (CEF) has a 3-year rolling call running for the Alternative Fuel Infrastructure Facility (with deadlines every 6 months). Complementarity with the JU calls will be sought, in view of increasing the impact of both programmes.

²²⁷ European Defence Agency (<https://www.eda.europa.eu/>)

²²⁸ As per Article 7(#7) – setting the *Principles of the Programme* concerning synergies, Article 15 – *Alternative, combined and cumulative funding and transfers of resources*, and Annex IV – *Synergies with other Union programmes* of the [Regulation \(EU\) 2021/695](#) establishing Horizon Europe.

2.2.6.4 Supporting regions and Member States through technical assistance

Hydrogen Valleys

Over recent years, the Hydrogen Valley concept has emerged as a firmly established term in the European funding and collaboration landscape. Building on the FCH 2 JU Regions and Cities Initiative launched in 2016, a "European Hydrogen Valleys partnership" was created under the "Smart Specialisation for Industrial Modernisation" framework of the European Commission. In parallel, the FCH 2 JU awarded two European regions dedicated funding to pursue their tailor-made Hydrogen Valley concepts (H2Valley and H2Island under the 2019 and 2020 calls respectively), projects that it will continue to support and monitor in 2022. Building on the successful experience of previous years, the Clean Hydrogen JU proposes to support a Hydrogen Valley of a scale significantly larger to what has been supported to date. In this year topic the ambition is to support the deployment of a large-scale hydrogen valley with interlinkages to other places of hydrogen production and/or consumptions outside its boundaries. This represents a novelty as the Hydrogen Valleys supported are confined to a specific geography.

With the goal of raising the concept further at the regional level and bringing more Regions up to speed in developing hydrogen economies at the local level, the FCH 2 JU launched also a pilot Project Development Assistance (PDA) for Regions, which finished in June 2021. The latter assisted 11 regions, of which 5 from Central and Eastern Europe MS, effectively contributing to bring new regions up to speed with the technology maturity of FCH products and generating new H2Valleys across Europe.

Funding/financial engineering activities at the JU are an integrated component of these activities with MS and Regions, enabling the development of large-scale sectoral integrated projects under the Hydrogen Valleys concept.

Technical assistance for Member States and European regions²²⁹

Building on the momentum, in 2022 the Clean Hydrogen JU intends to continue with the activities launched (or to be launched) from AWP2021 of the FCH 2 JU (e.g. '*Technical assistance support to generate synergies with Member States/Regions*', '*Project Development Assistance (PDA) for Regions II - Cohesion Countries, Outermost Regions and Islands*' and '*MI2.0 H2Valley Platform*'). These activities of the JU will be continuing to raise the uptake of projects' results by MS and Regions, ensuring effective cooperation between different stakeholders and pooling of funding and financing resources.

2.2.6.5 Regulations, Codes and Standards Strategy Coordination (RCS SC)

The implementation of suitable and hydrogen-specific regulatory and enabling frameworks is crucial for the EU-wide deployment of hydrogen, fuel cells and hydrogen-based technologies to meet the goals set out in the EU Hydrogen Strategy.

As stated in the Clean Hydrogen JU SRIA (JU SRIA, section 4.3), the JU will contribute to supporting the implementation of hydrogen-specific regulatory and enabling frameworks by a strategic and coordinated approach to RCS issues within the Programme, which will mostly be implemented through Pre-Normative Research activities.

Whilst most of the PNR activities in the JU Programme will be implemented as part of the activities within the Horizontal Activity 1: Cross-cutting Issues (JU SRIA, Section 3.6), a

²²⁹ Additional activities with Member States and Regions, as well as on financial engineering, may emerge once the Council Regulation establishing the Clean Hydrogen Joint Undertaking is adopted later in 2021.

strategic and coordinated approach is needed at the Programme level. To this end, the Clean Hydrogen JU will set up a Regulations, Codes and Standards Strategy Coordination Task Force, composed of the European Commission, Hydrogen Europe and Hydrogen Europe Research, and the Clean Hydrogen JU Programme Office.

The main goal of the RCS SC Task Force is the definition, coordination and monitoring of the strategy related to RCS within the Programme with the ultimate goal of increasing the EU impact in RCS development in Europe and beyond, with the main focus but not limited to Standards.

In 2022, the Clean Hydrogen JU will set up the JU's RCS SC Task Force which will prioritise the coordination of the following activities:

1. Follow up of RCS development related to hydrogen, fuel cells and hydrogen technologies through a continuous global watch function with the main focus but not limited to standards.
2. Assessment of RCS development needs of strategic importance in Europe. Building on the previous activity and in consultation with relevant stakeholders, the RCS SC Task Force will assess what RCS developments could contribute the most to foster a regulatory friction-less EU-wide hydrogen market, while meeting the EU Hydrogen Strategy goals and the interests of the European industry and research organisations. This will facilitate to lay down the RCS strategy in the Programme.
3. Identification and prioritisation of the needs for research and innovation, and coordination actions to support the RCS development identified as strategic for Europe and that standardisation and regulatory aspects are appropriately addressed in the Programme. This will contribute to the development of the JU's Work Programmes and will support the Annual Union Work Programme for European standardisation when necessary.
4. Follow up and support the research and innovation, and coordination actions undertaken in the Programme contributing to ensure to the best possible actual use of PNR results in RCS developments. This support can encompass the establishment of a systematic and structured approach to supporting formal liaison between SDOs and projects, financial support to entities for participation in SDOs, etc.
5. Dissemination of results. This could include the collection and effective transfer of PNR/RCS-relevant results in regulatory and standardisation bodies, targeted communication actions, awareness workshops, etc.

The RCS SC Task Force will support the Commission and the Member State organisations in its activities on international regulatory cooperation when required, will ensure the Clean Hydrogen JU will speak with one single voice and will support the synergies related to RCS with other partnerships.

2.2.6.6 European Hydrogen Safety Panel (EHSP)

The FCH 2 JU launched the European Hydrogen Safety Panel initiative²³⁰ in 2017 to support the development and deployment of inherently safer hydrogen systems and infrastructure, contributing to achieving the following vision: "hydrogen and fuel cell technologies shall be safely developed, safely introduced, and safety used in projects as well as in the wider society". To achieve this vision, the EHSP activities started in the FCH

²³⁰https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0_en

2 JU will continue and will be reinforced in the Clean Hydrogen JU.

- The mission of the EHSP in the Programme will be twofold: To assist the Clean Hydrogen JU at both programme and project levels, in assuring that hydrogen safety is adequately addressed and managed, and
- To promote and disseminate hydrogen safety knowledge and culture within and outside of the Programme.

Like in the FCH 2 JU, the EHSP in the Clean Hydrogen JU is envisaged as a multidisciplinary pool of experts grouped in ad-hoc working groups (task forces) according to the tasks to be performed and to expertise. Collectively, the members of the EHSP will have the necessary scientific competencies and expertise covering the technical domain needed to make science-based recommendations to the Clean Hydrogen JU.

In 2022, the EHSP will concentrate the effort on the following activities, organised by task force (TF).

TF.1 Support at project level

The activities in this task force aim at coordinating a package of measures to avoid any accident by integrating safety learnings, expertise, and planning into FCH 2 JU funded projects by ensuring that all projects address and incorporate the state-of-the-art in hydrogen safety appropriately. In 2022, the FCH 2 JU document “Safety Planning and Management in EU Hydrogen and Fuel Cells Projects – Guidance document”²³¹ published in 2021 will be updated. Furthermore, the EHSP will continue to perform Safety Plans Reviews, i.e. – assessing the Safety Management of ongoing projects, and Safety Specific Sessions will be organised with projects or sets of projects with similar applications coverage.

TF.2 Support at programme level

The EHSP works under this task force are intrinsically linked with the activities of the previous task force but with a broader cross-cutting dimension, focused on the Clean Hydrogen JU Programme, and how safety-related aspects can be enhanced within the overall Programme and activities. The main activity within this task force in 2022 will be to provide further guidance in developing areas including but not limited to heavy-duty vehicles, aviation, rail, and waterborne applications. In addition, the links with the homologue US Hydrogen Safety Panel, the International Association HySafe (and related international activities such as Research Priorities Workshop), the IPHE and the Hydrogen Council will be further strengthened. Last, further development of emergency crisis management document (and links to ‘crisis communication’) will be also performed.

TF.3 Data collection and assessment

Activities in this task force are centred on the collection and analysis of hydrogen safety-related data to derive lessons learned and provide further general recommendations to all stakeholders.

EHSP activities over 2022 will continue on the assessment of safety data end events in HIAD 2.0 with the addition of new events, including events from countries such as Japan and China, as well as from incidents registered in the H2Tool, which are also in the public domain. In close collaboration with the JRC, the EHSP members will complete and update the review and assessment of the events and the lessons learned and statistics obtained

²³¹ www.clean-hydrogen.europa.eu/system/files/2021-09/Safety_Planning_Implementation_and_Reporting_for_EU_Projects-Final.pdf

from this information and will issue a new release of the document “Statistics, lessons learnt and recommendations from the analysis of the Hydrogen Incidents and Accidents Database (HIAD 2.0)”²³², last published in 2021. This new release will also include an in-depth analysis of some specific sectors in line with the EHSP workshops to be organised by task force 1 as well as failing components in all the events.

Last, a set of activities on reviewing the contribution and research progress in the field of hydrogen safety will be performed. This work was initiated in 2021, and the activities in 2022 are envisaged to encompass:

- Enlarge and enrich the list (compiled in 2021) of engineering models and risk assessment approaches with brief comments/recommendations, including clarifying if already available in the e-library.
- Enlarge and enrich the list (compiled in 2021) the list of Computational Fluid Dynamics (CFD) models with brief comments and recommendations.

Based on these works, a guidance document on Hydrogen Safety Analysis will be issued, including references to the engineering, risk and CFD tools above mentioned.

TF.4 Public outreach

This task force focuses on the broad exchange of information with relevant stakeholders, including the public. The activities in 2022 will focus on updating and expanding the content on the EHSP web page, including a set of Frequently Asked Questions on hydrogen safety, updated lists of events and resources, etc. The EHSP will also deliver oral or poster presentations at relevant safety, fuel cell and/or hydrogen technology conferences, organise workshops with relevant stakeholders (either as public outreach from TF4 or targeting specific JU projects in TF1), and work in close cooperation with the Communication Team at Clean Hydrogen JU.

Altogether, the EHSP will contribute to coordinating and establishing approaches to address hydrogen safety-related matters in Europe, while contributing to promoting a hydrogen safety culture and a safe hydrogen market in Europe and beyond if possible. To this end, in view of the reinforced support expected from the EHSP in the Clean Hydrogen JU Programme, different working arrangements will be explored in 2022 to maximise the EHSP contribution to the Programme and in the last instance, its impact. To this end, in 2022 the Clean Hydrogen JU will launch a tender with a view to concluding a service framework contract for the provision of support for coordinating and managing the EHSP as of 2023.

2.2.6.7 European Hydrogen Sustainability and Circularity Panel (EHS&CP)

Sustainable development is at the heart of the European Green Deal²³³, which along with other policies²³⁴ has set the EU on a course to become a sustainable climate-neutral and circular economy by 2050.

Hydrogen and fuel cell technologies will play an essential role in the sustainable transition and future energy system. Nevertheless, the hydrogen technologies and their value chains need further development to become an environmentally sustainable, socially responsible and circular market value proposition.

²³² <https://www.fch.europa.eu/sites/default/files/documents/Lessons%20learnt%20from%20HIAD%202.0-Final.pdf>

²³³ COM(2019) 640 final.

²³⁴ https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-holistic-approach-sustainable-development_en

The Clean Hydrogen JU is committed to contribute to putting the EU hydrogen sector at the forefront of the sustainable and circular transition of hydrogen technologies and their associated value chains. To this end, the research and innovation actions supported within the Horizontal Activity 1: Cross-cutting Issues (JU SRIA, section 3.6), and within the Horizontal Activity 3: Hydrogen Supply Chains (JU SRIA, section 3.8) will play a key role in providing the methodological foundation to strengthen the sustainability and circularity of hydrogen technologies and their industrial value chains in Europe. Nevertheless, the transition towards a fully-fledged sustainable and circular hydrogen economy requires an integrated approach beyond these activities. To this end, the Clean Hydrogen JU will set up a European Hydrogen Sustainability and Circularity Panel at the Programme level.

The EHS&CP will support the Clean Hydrogen JU Programme implementation and the transition of the overall European hydrogen sector towards a sustainable and circular hydrogen economy. The mission of the EHS&CP in the Programme will be two-fold:

- To assist the Clean Hydrogen JU in assuring that sustainability and circularity aspects are adequately addressed and managed at both programme and project levels, encompassing environmental, social and economic aspects as a whole, and
- To promote and disseminate knowledge and a more sustainable and circular culture within and beyond the Programme.

In 2022, the Clean Hydrogen JU will set up the EHS&CP. The EHS&CP is envisaged as a multidisciplinary pool of experts (10-15 experts approx.) with knowledge and experience in the relevant areas, covering the technical domain needed to make science-based recommendations to the Clean Hydrogen JU. The EHS&CP will act as a focal point or “advisor” to the Programme in these matters in an independent, coordinated, and consolidated way.

The EHS&CP will prioritise the activities around three main areas.

1. Support at the Programme and project level. At the Programme level, the EHS&CP will support and coordinate the development of an overarching and comprehensive strategy on sustainability and circularity. At the project level, the EHS&CP will define and coordinate a package of measures to raise the sustainability and circularity of the JU’s funded projects by integrating learnings, expertise and planning.
2. Data collection and assessment. The EHS&CP will support and coordinate the development of a systematic data collection approach to extract valuable information from the JU’s funded projects to provide further guidance to both projects and the Clean Hydrogen JU based on a regular monitoring activity. This could include the development of sustainability and circularity indicators to monitor progress and a better understanding of environmental and social impacts of products and services, identifying “hot spots” within the value chains where interventions have the greatest potential to improve sustainability and circularity while providing data and knowledge to support the JU in making informed decisions, etc.
3. Public outreach. EHS&CP activities in this category may include the development of a regularly updated webpage containing for example lessons learned and links to other important hydrogen-sustainable and circular-related information, the drafting of news items, setting up events, etc.

Altogether, the EHS&CP will provide the Clean Hydrogen JU a unique, practical, and direct support to reach the following objective: ensure that the sustainability and circularity

considerations are taken into account in the development and implementation of research and innovation actions supported in the Programme, and across the Programme, integrating and balancing the three dimensions of sustainable development: the economic, social and environmental.

2.2.6.8 *International Cooperation*

The recent Communication of the European Commission on the global approach to research and innovation²³⁵ presents the EU's new strategy on international cooperation on research and innovation. The EU aims to take a leading role in supporting international research and innovation partnerships and to deliver innovative solutions for making our societies green, digital and healthy.

The strategy builds on two principal objectives: preserving openness in international research and innovation cooperation, while promoting a level playing field and reciprocity underpinned by fundamental values.

In line with these objectives and in order to better support and European Commission to align with, facilitate and accelerate worldwide market introduction of fuel cell and hydrogen technologies, the Clean Hydrogen 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 Clean Hydrogen JU are involved in these developments, establishment of links with other major FCH related programmes globally is deemed important. This is particularly valid during 2022 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 refuelling 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 IEA under the Hydrogen Technology Collaboration Program (IEA Hydrogen)²³⁶, Technology Collaboration Programme on Advanced Fuel Cells (IEA AFC) and International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)²³⁷. The Clean Hydrogen JU will hence continue in 2022 to collaborate closely with the EC representatives in the steering committees of these international agreements/associations, in particular within the working-groups on 'Renewable Hydrogen', 'Hydrogen Underground Storage', 'Hydrogen Export Value Chains' and on 'Data and Modelling'.

Following the successful and close collaboration of the FCH 2 JU with EC representatives on the Mission Innovation – IC8 and the setting up of the Hydrogen Valley Platform, a platform for exchanges between worldwide initiatives on hydrogen valleys, the Clean Hydrogen JU will continue to contribute in this direction. It will maintain and further improve the Hydrogen Valleys platform through a public procurement published on 10/12/2021,²³⁸ while contributing also towards the other activities of Clean Hydrogen Mission under MI2.0, aiming to make clean hydrogen cost competitive to the end user by reducing end-to-end costs by 2030. In this context, the Clean Hydrogen JU will support the European

²³⁵ Europe's strategy for international cooperation in a changing world, COM(2021) 252 final.

²³⁶ <http://ieahydrogen.org/>

²³⁷ <http://www.iphe.net/>

²³⁸ <https://etendering.ted.europa.eu/cft/cft-display.html?cftId=9670>

Commission in its co-lead activities (see also administrative procurements).

For concrete references to international collaboration in the Call for Proposals see section 2.2.3.2 of this document.

2.3 Support to Operations of Clean Hydrogen JU for 2022

2.3.1 Communication, dissemination and exploitation

2.3.1.1 Communication

A. Communication objectives

Communication activities will support the priorities identified in the current AWP and will ensure that all stakeholders will continue to be duly informed about the activities of the Clean Hydrogen JU. Three main elements will form the basis for communication in 2022:

1. Developing the communications policy for the entire duration of the JU;
2. Establishing the brand;
3. Determining the level of awareness and acceptance of hydrogen technologies.

B. Developing the communications framework

Strategic communication to all stakeholders and an increased outreach effort to the public, with the development of a targeted awareness campaign, will be key for a successful communication by the JU in 2022.

A new, multi-annual communications strategy for the 2022-2027 period is being developed, to ensure a solid strategic framework for communications and the coherence and continuity of the activities. This strategy is intended to guide Clean Hydrogen's communications through changes driven by the new legal obligations, a new brand, a new organisational strategy cycle and social, technological and policy developments.

Targeted raising awareness activities are essential for increasing social acceptance and trust in hydrogen-based technologies throughout the European Union, in particular for bridging the potential lack of knowledge or mistrust of key stakeholders directly involved in the first phases of mass deployment in Europe.

Rebranding

To reflect the objectives of the Clean Hydrogen JU, a new, compelling, modern visual identity has been developed and will be promoted throughout 2022. The new visual identity tells a visual 'story' able to encompass Clean Hydrogen JU mission and vision and show the power of partnership by "connecting the dots".

Overall, the communication tone and visuals of the Clean Hydrogen JU align with the European Commission style guidelines and its visual identity. In particular, the new website will be a part of the Europa domain and will integrate the visual elements of the European Institutions. This institutional look is reflecting the new position of hydrogen as one of the key topics for the EU, reinforced by the recent flagship policy initiatives (Hydrogen strategy, Green Deal, Fit for 55, etc.). The message is that hydrogen is at the core of EU policy, and the JU is the instrument which brings together the public and private sectors to work together to implement the policy.

The visual identity also includes brand elements common to all EU partnerships, following European Commission's guidelines.

Promoting the new brand will be key to establishing the JU towards its main stakeholders; this will be done by clearly communicating about the Clean Hydrogen JU as the successor of the FCH JU in all documents and publications and by raising awareness of the new logo

Public opinion analysis

“The partnership will increase public and private awareness, acceptance, and uptake of clean hydrogen solutions, in particular through cooperation with other European partnerships under Horizon Europe”

An important element for determining some of the objectives of the strategy and their implementation will be the insights into the public opinion on the topic of awareness and acceptance of hydrogen technologies. Based on the results of a public opinion survey planned for 2022, additional activities and objectives could be foreseen, and some of the activities could be revised at mid-term. The mid-term review will show the trend/evolution of the public awareness.

In addition to the overall perception of hydrogen as an important energy vector, the survey shall also analyse the public perception on safety and efficiency of this technology, fields of application most suitable for hydrogen as well as the level of perception of hydrogen as a sustainable energy source, necessary for reaching European climate goals.

C. Communication objectives

- Ensure a smooth transition from the FCH 2 JU to the Clean Hydrogen JU, communicating clearly about the new JU.
- Establish and maintain the Clean Hydrogen brand (as a new EU partnership under Horizon Europe) ensuring that all branding elements are in place and are being used; launch and promote the new website
- Establish the communication framework of the new programme (strategy, website, new visual identity)
- Gather insights into the public opinion on the topic of awareness and acceptance of hydrogen technologies; determine/measure the baseline for the public awareness
- Position the JU as an important factor in the development of the hydrogen technologies sector and an important contributor to the EU Green Deal objectives

Timeframe	End 2021 - 2022
Communication state	Launch and establish
Focus	Launch of the new JU Brand awareness Transition FCH – CH Public opinion analysis Audience analysis
Specific Objectives	Establish the Clean Hydrogen brand as an EU partnership under Horizon

	<p>Europe, building on the successful Fuel Cells and Hydrogen Joint Undertaking.</p> <p>Establish and promote the communication framework of the new programme (new website, new visual identity)</p> <p>Gather insights into the public opinion on the topic of awareness and acceptance of hydrogen technologies; determine/measure the baseline for the public awareness</p> <p>Communicate successfully about the first call for proposals of the new JU, generate valuable applications</p> <p>Position the JU as an important factor in the development of the hydrogen technologies sector and an important contributor to the EU Green Deal objectives</p> <p>Continue the promotion of FCH JU projects and initiatives, their results (a separate chapter, included in AWP2022 for FCH JU includes more details about the communication of the FCH JU programme).</p>
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D. Target audiences

- Policymakers and authorities (EU, National, regional, local & International)
- Clean Hydrogen Advisory bodies
- Other EU partnerships
- Opinion formers (media, experts, NGOs etc.)
- European hydrogen community: former FCH JU beneficiaries, researchers, industry representatives
- SMEs (potential beneficiaries)
- Consumers/ citizens

E. Main messages / Communication themes

Clean Hydrogen JU will continue to deliver clear, accurate, up-to-date and consistent messages that resonate with a variety of audiences, from policymakers to researchers and industry. Communication themes will cover:

- Launch and results of the first call for proposals (March and respectively end of 2022)
- Concrete benefits of the hydrogen economy for the European citizens, socio-economic benefits, benefits for and involvement of SMEs;
- Green recovery: continued investment in research, innovation and deployment of clean energy, decarbonisation technologies as the cornerstone of Europe's post COVID-19 economic recovery;
- Towards 6 GW of renewable hydrogen electrolyzers in the EU by 2024 and 40 GW of renewable hydrogen electrolyzers by 2030.
- The stories about the technology, the journey and the successes are a powerful narrative therefore we will continue to build as well on “legacy” aspects – i.e. promotion of ongoing flagship projects in key areas relating to heavy-duty transport, shipping industry, maritime transport, aviation, as a solid foundation for the

development of a hydrogen economy in Europe.

The following initiatives will also be included in the 2022 communications:

- CertifHy study - Public summary for 12 months to be published on the new website (jan/feb)
- FCHO reports and preparation for the next stage of the knowledge hub (April/May)
- 'Study on the impact of deployment BEV and FCEV infrastructures'
- Study on 'H2 in ports' Inception report and network meetings in 2022

F. Main channels and tools

To be able to respond to today's fast communication landscape, the tools and channels employed will be integrated as much as possible, for maximum impact. Moreover, as proposed in the chapter on guiding principles, taking into account the current social context we aim to have a powerful online communications; the preferred approach is to use fewer channels but with tailored content (which means tailored messages, tone of voice, formats and posts frequency).

Website

Due to the current health situation, we estimate that online communication will remain the preferred channel for all audiences in 2022. The website, together with the social media channels, is the main gateway to the organisation. It provides comprehensive, impactful and relevant information that allows audiences to fully explore and understand the role and work of the Clean Hydrogen JU.

The new website – www.clean-hydrogen.europa.eu is built as part of the Europa.eu family, following the EWPP (European Web Publishing Platform) guidelines and templates provided by the European commission's IT directorate (DIGIT). The website will evolve with the JU and we will progressively add new content and elements throughout 2022, developing further its features.

In addition to its main website, Clean Hydrogen will oversee as well a series of associated digital platforms inherited from the FCH JU: H2V, FCHO, EHSP and the website dedicated to the Hydrogen Week.

Social media

A social media plan will complement the general media plan, to allow for a wider distribution of the content and will be built around major events and initiatives.

Through social media, the JU will disseminate a wide variety of digital content quickly, efficiently and extensively. This content includes videos (e.g. interviews with stakeholders, project stories), visuals (e.g. animated GIFs, images), short written posts, and hashtags. The choice of format will depend on the specific platform they are created for (e.g. Twitter, LinkedIn, etc.) and the information needs of the target audience.

Clean Hydrogen will keep in touch with its audiences every day through the social media channels, and engage with them directly, thus creating a strong, transparent and interactive relationship and nurturing the community of subscribers / followers.

We are looking at integrating social media advertising in our campaigns, so that we earn more followers and reach out to a more general audience. Through social media advertising, we will gain visibility and expand the audience as organic posts have more and more difficulty to stand out. Advertising can be used to: promote the new website of the JU,

to announce its main events and calls for proposal and can be focused on specific countries / regions). The JU will look as well to using new(er) channels to increase outreach, such as Instagram.

Newsletter

The Clean Hydrogen Newsletter will be sent out to our subscribers' database, in a new format based on the Newsroom template of the European Commission. It will be adapted to contain both "flash news" whenever there is an important programme update / activity and a monthly edition, which summarises the latest news and includes as well policy elements and relevant news from media and third party sources. However, the focus will be on the programme activity.

Media

Public awareness and acceptance remains a critical issue for the deployment of hydrogen and fuel cells technologies and the media plan will be adapted to include a more diverse range of media in different European countries. Further communication towards audiences in the EU13 countries should be continued and enhanced. A dedicated media plan will be developed for this purpose.

In addition, the successful results of the FCH JU legacy projects will be promoted, through:

- Collaboration with the communication unit of the European Commission's Directorate-General for Research and Innovation, responsible for services such as the Horizon Magazine, Futuris and the webpage for EU research success stories.
- Continued collaboration with H2View 's 'Pillars of Progress' series, whose articles are based on the content of the FCH 2 JU Success Stories.

Events

The JU will organise a mix of events with both online and physical presence (always in line with the latest sanitary recommendations).

In particular, the European Clean Hydrogen JU Forum and the Programme Review Days are the two major events for the JU; following-up from FCH JU they come together in what has already been established as the "European Hydrogen Week".

The hydrogen week represents a brand in itself, which we want to consolidate further, promote, and use it to differentiate our flagship events from the numerous events on hydrogen taking place in Brussels and beyond. We will also use the occasion to showcase the synergies between and with the various Commission services, industry and research partners and reflect on the entire hydrogen value chain from production, storage, to transport, distribution and utilisation.

In addition, we aim to work with the EU presidency (France, Czechia) to organise a joint event every 6 months, contribute to SET-PLAN R&I days, European Sustainable Energy Week, EU Regions week, hydrogen week, contribute to the European Hydrogen Forum of the Clean Hydrogen Alliance, and participate in other events that EC / partnerships are organising (TRA, TEN-T days).

Other events include:

- Call Info Day;
- Own webinar series – following up from the FCH JU Clean hydrogen can continue its successful online events to allow for discussion around its new priorities and projects;

- Projects events – demonstrations projects visits;
- Participation in major international exhibitions (Hannover Messe) and conferences (safety conference, COP27);
- Workshops with European and international counterparts (i.e. 8th International Infrastructure Workshop).

Monitoring and measuring impact of communication activities

The impact of the FCH 2 JU communication efforts will be measured using the Europa Analytics reports for website performance, and default social media analytics available on each of the platforms, namely Twitter, LinkedIn and YouTube.

2.3.1.2 Dissemination and exploitation of projects results

All dissemination and communication (D&E) activities of the Clean Hydrogen JU will be in line with the European Commission's strategies for dissemination and exploitation of the projects results in Horizon Europe²³⁹. According to the D&E Strategy for the post-H2020 period and the Horizon Europe, the Horizon Dissemination & Exploitation Group will be one of the pillars of the governance structure to coordinate implementation. Clean Hydrogen JU is planning to continue participating and contributing to this group.

Furthermore, as also depicted in the D&E Strategy, an ecosystem of services and tools has been established to enhance circulation of knowledge stemming from R&I projects:

- Horizon Results Booster²⁴⁰: A package of tailor-made specialised services to maximise the impact of R&I public investment and further amplify the added value of the Programme, by building the capacity of projects for disseminating research results, increasing their potential for exploitation and improving access to markets;
- IP Booster²⁴¹: Specialised professional Intellectual Property service for public research organisations looking to realise value from their research results;
- Horizon Results Platform²⁴²: A result-oriented platform for project beneficiaries to upload their results, to valorise and promote them to the targeted groups (e.g. business partners, angel investors, venture capitals, policy makers, business development assistance etc);
- Innovation Radar²⁴³: A European Commission initiative to identify high potential innovations and innovators in EU-funded research and innovation projects, based on a data driven method;
- Dealflow.eu²⁴⁴: Mainly addressed to innovations analysed by the Innovation Radar, this package of services aims to support EU-funded start-ups in commercialising their innovations and connect them with investors and corporates (fundraising, venture building and networking).
- Open Research Europe²⁴⁵: The new EC scientific publishing service for fast publication and open peer review for research scientific articles stemming from

²³⁹ Dissemination & Exploitation Strategy for Horizon Europe - Towards an Integrated Dissemination & Exploitation Ecosystem, European Commission, DG-RTD, CIC, 2020

²⁴⁰ <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/d-e-booster>

²⁴¹ <https://ipbooster.meta-group.com/>

²⁴² <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform>

²⁴³ <https://ec.europa.eu/digital-single-market/en/innovation-radar>

²⁴⁴ <https://dealflow.eu/>

²⁴⁵ <https://open-research-europe.ec.europa.eu/>

H2020 projects.

As part of the knowledge management activities but also in the context of the Project Management workflow, the Programme Office will keep on checking compliance with the Horizon Europe and H2020 Model Grant Agreement (MGA) provisions in D&E, encouraging the projects not only to implement their D&E plans, to update and revise them when necessary, but also to try to benefit from the opportunities provided by the D&E ecosystem to facilitate and enhance their D&E activities during and after the end of each project, focusing especially on the exploitation efforts of the key exploitable results. This provision is valid during and after the end of the funding cycle of the projects (in 2022 practically for the ongoing H2020 projects), as foreseen in the MGA. Especially after their lifetime, projects will be contacted to remind the key results owners about their contractual obligations to enable dissemination and exploitation of them and on the available tools provided by the EC to help them accomplish this task.

Having started participating in Innovation Radar since the pilot launched in 2018, the Clean Hydrogen JU will continue to participate in this innovation repository. The Innovation Radar exercise has so far been conducted during the project mid-term reviews where a dedicated expert is mandated to identify potential innovations and is required to fill out a questionnaire with the aim of providing information in a structured and quantified way. The Innovation Radar exercise is currently incorporated in the Project Monitoring Workflow in Sygma/Compass, which gives the flexibility to the project officers to update existing or submit questionnaires for new innovations that happen up to the final reporting even without the use of an expert to contribute in the process; the Programme Office will assess whether this new feature can be applied successfully and effectively to flag innovations of our projects that comes later in the project lifecycle, even if without the use of experts.

Furthermore, the identified innovations/innovators can be supported for further exploitation and dissemination. One concrete example of this is Deaflow.eu, a new action supported by the European Union's Horizon 2020 Research and Innovation Program to help projects commercialise their innovations ("go to Market"), by facilitating access to clients and investors and providing high-end coaching services. The service gives priority to the projects that are already analysed by the Innovation Radar. Also, during the Innovation Awards organised each year during the Programme Review Days, 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.

2.3.2 Procurement and contracts

Clean Hydrogen JU allocates part of the administrative budget to procure the necessary services and supplies needed to support its operations and infrastructures.

As a good practice, the Clean Hydrogen JU will continue seeking to join inter-institutional tenders either launched by the European Commission or in agreement with other Joint Undertakings.

In order to maximise effectiveness and cost-efficiency in procurement, the JU is already using a wide range of eProcurement solutions: eTendering (for preparing and managing a call for tenders), eNotices (for the publication of calls for tenders), eSubmission (for receiving and opening tenders) and eInvoices (for the electronic reception of commercial invoices). The Programme Office will closely monitor any developments in eProcurement with a view to further optimise its business processes.

Moreover, the FCH 2 JU deployed and uses EU Sign, the e-solution providing a qualified

electronic signature, equivalent of blue ink signatures, to align with the Commission's Digital Strategy driven by the 2019-2024 priorities of President von der Leyen, which set out a vision for the European Commission to lead by example in digital transformation. In addition, contract management reporting has become more efficient with the use of ABAC²⁴⁶ LCK.

Clean Hydrogen JU expects to be invited in the following procedures in 2022:

- External services for onsite and offsite development;
- Provision of Audiovisual production services;
- Advice, Benchmarking and Consulting services in information and communication technology;
- Graphic design services;
- Event management and conference assistants;
- Modular exhibition booth.

In addition, Clean Hydrogen JU may launch the following procedures:

Subject	Indicative budget (€)	Expected type of procedure	Indicative launch date
Service Contracts for support activities ²⁴⁷	To be decided following a market research	open	Q1-Q2
Managed IT services	3,000,000 ²⁴⁸	open	Q2
Leasing of an additional hydrogen powered car	50,000	negotiated	Q3
Renewal of UPS maintenance and batteries replacement (for JU server)	20,000	negotiated	Q3

2.3.3 Other support operations

2.3.3.1 IT and logistics

Document Management, digital transformation and information management

The Joint Undertaking overall objective is to lead by example in digital transformation. This transition is clustered on the following pillars:

- paperless, streamlined procedures that use technology to remove mechanical tasks;
- improved access to and use of data to work more efficiently and be more transparent;
- staff collaborating efficiently and easily anytime, anywhere and with all

²⁴⁶ Accrual Based Accounting system provided by the European Commission

²⁴⁷ May be implemented through more than 1 procedures, if needed

²⁴⁸ The indicative budget is the total value of the contract for the six Joint Undertakings located in the White Atrium building, for a duration of four years. The part of the contract for the Clean Hydrogen JU is estimated at 18% of that total value

stakeholders.

In addition, the Joint Undertaking will exploit the potential of data, information, knowledge and content management for running the program, communication to citizens and stakeholders and best staff engagement.

The Joint Undertaking will build a performing digital infrastructure and a fit-for-purpose Digital Workplace and will deliver modern, trustworthy, efficient, and transparent IT Governance.

The Joint Undertaking will strive to improve its environmental impact in all its actions and will actively promote measures to reduce the related day-to-day impact of the administration and its work.

In 2022, these overall objectives will be supported with the following specific actions (per area):

Document Management

- Registration of the documents linked to Grants in the JU filing plan,
- Phasing out of our current archiving system “M-files”,
- Application of the Administrative Retention Policy (ARP) on physical files: elimination, historical archives and digitalisation of those for which the ARP is still running.

Information Management

The Joint Undertaking will continue to use or adopt flagship digital solutions developed by DIGIT, such as for example: SYSPER, ARES, eProcurement, eGrants, Next-EUROPA.

The following implementations to complement the IT tool Hermes-ARES-NomCom already adopted as document management system are foreseen for 2022:

- AresBridge in our recent Microsoft 365 SaaS to facilitate the registration and filing of documents;
- A dedicated FCH digital seal to make the Qualified Electronic Signature process leaner and fully integrated in ARES.

In 2022, the JU will further develop the digital solutions already available to facilitate the interaction with internal actors.

To that effect it is foreseen to develop:

- Dedicated collaboration platform using SharePoint and develop the new intranet;
- Reinforce our web presence with a new website compliant with the Europa Web Publishing Platform (EWPP) hosted under the Next-EUROPE platform.

Digital Transformation Management

The digital workplace for each staff member will be modernised:

- Each staff member will be equipped with new modern IT equipment allowing for more flexibility under the new teleworking working scheme;
- The support services will be oriented to more self-service functionality to fit the remote working capabilities (reset password/account, remote deployment of applications, etc);

- The use of cloud services and storage will be encouraged (Onedrive, remote desktop);
- The meeting rooms and staff computer will be equipped to support the ability to participate in calls, videoconferences, and other collaborative workgroup from anywhere at any time.

Cybersecurity

The cybersecurity will be reinforced by the implementation of the new Infosec regulation and the future dedicated role of Cyber Security Officer.

IT Governance

The IT Governance will be further developed by renewing, extending or creating Service Level Agreements for the common digital infrastructure to improve synergies and efficiencies among the new Joint Undertakings. The IT Officer will therefore contribute to the CBO study on administrative functions incorporating the Clean Hydrogen JU specificities. The IT Officer will also continue to join any added-value interinstitutional framework contracts or inter-agency joint procurement.

The digital infrastructure, will continue to rely on the secure pan-European networks for the Commission, executive agencies and other European institutions. The common conference centre of the White Atrium building will be up-scaled with the necessary audio-visual functions to held hybrid meetings.

Sound environmental management

The Joint Undertaking plan to transform the program office into a safe, modern and welcoming place to work, with good quality, sustainable and green solutions.

Year 2022 will contribute to the delivery and implementation of:

- remote work as integrated way of working;
- more dynamic approaches to the use of office space;
- the use of modern technologies (such as “more wireless, less cables”, Wi-Fi everywhere, connected meeting rooms);
- the use of web/videoconferencing-based meetings as valid sustainable alternative to staff missions and physical meetings, which represents a significant benefit in terms of environmental footprint, efficiency, and work-life balance.

2.3.4 Human Resources

2.3.4.1 HR Management

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.

2.3.4.2 Strategy for achieving efficiency gains and synergies

In 2022, special focus will be put on the following:

- Preparation and start of operation of common back-office arrangements with other

joint undertakings, as set forth in the Article 13 of the SBA;

- Preparation and update of the job descriptions in a new JIS module in SYSPER (available for a use since 19 October 2021) as a top priority;
- Completion of the personnel files using NDP 'Numérisation Dossiers Personnels' of all (past and current) staff members in Sysper;
- Updating the newcomers' pack for permanent staff, for the trainees, interim staff; and establishment of the newcomers' pack for service contract consultants;
- Ensuring that all new staff will follow a mandatory training on 'Ethics and Integrity';
- Implementation of the EC tool MIPS to be used for missions;
- Implementation of evaluation and promotion module to use for future appraisal exercise;
- Preparation of the internal procedure on staff handover process and checklists for staff members leaving the organisation;
- Using the new platform for recruitment, SYSTAL, phasing out of ISA November 2022;
- Preparation of the Code of Conduct for advisory bodies of Clean Hydrogen JU;
- Recruitment of the 2 AD posts and the additional AST post will be completed.

In line with the EC priorities for 2019 -2024, and following the pandemic, Clean Hydrogen JU will continue to promote:

Back-office arrangements

In its Article 13, the Single Basic Act calls 8 Joint Undertakings to operate back-office arrangements by concluding service level agreements. Such arrangements shall include at least the following areas, subject to confirmation of viability and following screening of resources:

- (a) human resource support;
- (b) legal support;
- (c) information and communication technologies;
- (d) accounting (excluding treasury);
- (e) communication;
- (f) logistics, events and meeting room management;
- (g) support for audit and anti-fraud strategy.

As per the SBA, these back-office arrangements shall be provided by one or more selected joint undertakings to all others.

In 2022, the Joint Undertakings will assess the viability of back-office arrangements in common for the functions identified above and, where required, explore alternate possible arrangements. The back-office arrangements for which the viability assessment is positive, will be set up with an objective to be in operation by the end of 2022.

New ways of working and Wellbeing

Home office equipment and work equipment need to be compatible, upgrade for IT office

equipment is foreseen for the near future.

Gender and geographical balance

Diversity aiming at ensuring geographical balance where possible and gender balance will be important considerations in selection procedures, without compromising competency-related criteria.

Development and Talent management

It is important for staff members to be able to follow trainings to improve their work skills but it is as important to work on talent management, meaning that staff members can develop their skills in subjects of interest not necessarily related to the current job.

Encourage and create synergies between JUs

The JUs will create more synergies amongst them, especially in areas as HR. Trainings and workshops in the interest of all staff members can be organised together.

2.3.4.3 Staff Establishment Plan

The JU team of statutory staff consists of 29 positions (27 TA and 2 CA). We have 2 recruitment procedures ongoing (see point 2.3.4.2.)

In addition, staff resources include 2 Seconded National Experts (SNE).

The 2022 Staff Establishment Plan is shown below:

Grade	2020 budget	2020 filled	2021 budget	2022 Budget
AD 14	1	1	1	1
AD 13	-	-	-	
AD 12	-	-	2	2
AD 11	2	2	-	
AD 10	-	-	-	
AD 9	4	4	5	5
AD 8	4	4	3	4
AD 7	1	1	2	2
AD 6	3	3	2	3
AD 5	-	-	-	-
Total AD²⁴⁹	15	15	15	17
AST 9	1	1	1	1
AST 8	1	1	1	1
AST 7	1	1	1	1
AST 6	1	1	1	1
AST 5	1	1	2	2
AST 4	4	4	3	3

²⁴⁹ AD stands for Administrator

Grade	2020 budget	2020 filled	2021 budget	2022 Budget
AST 3				1
Total AST²⁵⁰	9	9	9	10
Function Group IV	1	1	1	1
Function Group III	1	1	1	1
Function Group II	1	1	1	0
Total Contract Agents	3	3	3	2
Total Seconded National Experts	2	2	2	2

2.4 Governance activities

The Governing Board (GB) is the main decision-making body of the Clean Hydrogen JU. It shall have overall responsibility for the strategic orientation and the operations of the Clean Hydrogen JU and shall supervise the implementation of its activities in accordance with Article 15 and Article 80 of the Single Basic Act. 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 in 2022.

The indicative key decisions of the GB in the year 2022 are listed below:

Key decisions in 2021 – timetable	Quarter (Q1, Q2, Q3, Q4)
Appointment of the members of the Stakeholders Group	Q1
Adoption of the SRIA	Q1
Adoption of the amended AWP for 2022	Q1
Assessment of the Annual Activity Report for 2021	Q2
Adoption of the AWP for 2023	Q4

In addition, depending on the timing of EC decisions implementing rules on staff regulations may be submitted to the GB for adoption.

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 Europe Framework Programme. The SRG shall be consulted and, in particular review information and provide opinions on the following matters: (a) programme progress of the Clean Hydrogen JU and achievement of its targets and expected impacts; (b) updates to the SRIA; (c) links to the Horizon Europe and other initiatives related to Hydrogen; (d) draft work programmes; (e) involvement of SMEs; (f) actions taken for dissemination and exploitation of results along the value chain; (g) annual activity report. 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

²⁵⁰ AST stands for Assistant

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 2022. Issues that are likely to be covered include:

- opinion on the 2022 AWP of the Clean Hydrogen JU,
- opinion on the AAR for 2021,
- opinion on the 2023 AWP of the Clean Hydrogen JU.

The Stakeholders Group is the second advisory body to the GB, to be consulted on various horizontal issues or specific questions in areas relevant to the work of the Clean Hydrogen JU.

Based on Recital 34 of the Single Basic Act: it requires that “With a view to ensuring that joint undertakings are aware of the positions and views of stakeholders from the entire value chain in their respective fields, joint undertakings should be able to set up their respective advisory stakeholders’ groups, to be consulted on horizontal issues or specific questions, as per the needs of each joint undertaking”.

In accordance with the general provisions of Article 22(2) of the Single Basic Act “The stakeholders’ group shall be open to all public and private stakeholders, including organised groups, active in the field of the joint undertaking, international interest groups from Member States, associated countries or other countries”

In particular, for the Clean Hydrogen Joint Undertaking, Article 84(1) mentions that “The stakeholders’ group shall consist of representatives of sectors which generate, distribute, store, need or use clean hydrogen across the Union, including the representatives of other relevant European partnerships, as well as representatives of the European Hydrogen Valleys Interregional Partnership and of the scientific community”.

2.5 Strategy and plans for the organisational management and internal control systems

FCH 2 JU revised Internal Control Framework was adopted by the Governing Board in August 2018 and re-adopted by the Omnibus decision for the Clean Hydrogen JU in December 2021.

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.

Following the assessment of the internal control systems carried out in 2021, the following actions were identified for 2022:

- Regarding the component of the risk assessment, an antifraud awareness session will take place in 2022;
- Regarding the component Control Activities, to implement and follow up on implementation of the mitigation measures identified in the Data Protection Impact Assessments (DPIA);

- Regarding the component Information and Communication component, use of Qualified Electronic Signature in Ares to be implemented in 2022.

2.5.1 Financial procedures

The financial procedures established under the FCH 2 JU continue to be applicable for the operations of the Clean Hydrogen JU and lay out how the JU uses and manages its funds and resources. The workflows in place follow the Financial Rules, the general framework applicable in the Commission and the H2020 rules and guidance.

For grant agreements, the reporting and validation of costs is done via the EC IT tools (SyGMA, COMPASS). Payments are executed via the ABAC IT tool (EC accounting system).

2.5.2 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 2018/1046²⁵¹, “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 Clean Hydrogen JU project, finance and legal officers); mid-term reviews carried out by external experts and ad-hoc technical reviews (when deemed necessary).

Clean Hydrogen 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 2022, specific attention will be put to the following elements of ex-ante control:

- 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 Common Audit Service (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;
- Establishing a system to measure the impact of our ex-ante controls;
- Participation in establishing the Horizon Europe ex-ante control strategy including risk fiches related to anti-fraud.

Ex-post controls for H2020 programme are defined as the controls executed to verify financial and operational aspects of finalised budgetary transactions in accordance with Article 19 of 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. Clean Hydrogen JU ex post controls of FCH 2 JU grants include

²⁵¹ OJ L193, 30.7.2018 p.66

financial audits which are monitored by CAS (Unit H2) of the Common Implementation Centre (CIC), in close cooperation with the Clean Hydrogen JU, except for implementation which remains fully with the Clean Hydrogen JU. CAS may also outsource the audit work to external audit firms for the FCH-H2020 grants.

In 2022, focus will be put on the following:

- In cooperation with CAS, launching of new H2020 audits in two rounds: early in 2022 based on analytical risk-profile review of the main beneficiaries and later in 2022 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;
- Building on the knowledge gained in H2020, to participate in establishing the Horizon Europe ex-post audit strategy.

2.5.3 Anti-fraud initiatives

Clean Hydrogen JU implements the common Research Anti-Fraud Strategy. In March 2019, 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 Clean Hydrogen JU takes part. Furthermore, for areas of expenditure other than grants, the Clean Hydrogen 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 leads to the conclusion that the residual risks (after mitigating actions) are low.

In 2022, Clean Hydrogen JU will:

- continue to apply harmonised preventive measures for fraud detection, e.g. via enhanced-monitoring tool available as a new feature in Sygma-Compass workflow;
- implement the anti-plagiarism check of project deliverables;
- participate to FAIR meetings organised by DG R&I;
- arrange an awareness raising session on fraud prevention and detection.

2.5.4 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 2022, focus will be put on providing input and assistance to IAS in conducting their reviews / audits as per the Annual Audit Plan of the IAS for the Clean Hydrogen JU.

As regards European Court of Auditors (ECA) audits, in 2022 the Clean Hydrogen JU will:

- Liaise with the independent auditor (contracted in 2020 based on the results of the reopening of competition under EC (DG BUDG) FWC) to audit Clean Hydrogen JU accounts for 2021 as required by the Financial Rules of the Clean Hydrogen JU);
- Follow up and implement any recommendation made in the previous ECA reports

on the FCH 2 JU annual accounts;

- Provide the necessary information and support for ECA audit on 2021 and 2022 accounts;
- Assist and support ECA in their horizontal audit on HR and staffing of the JUs announced in December 2021;
- Support the ECA team in their field or remote missions for Clean Hydrogen projects selected (on a sample basis) for an ex-post financial review, including follow up with Clean Hydrogen JU beneficiaries and with CAS.

3 BUDGET 2022

2022 budget covers all administrative needs for the year, financed only by H2020 credits, as well as H2020 and Horizon Europe operational activities.

The estimated revenue of the JU for the year 2022 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.

The 1st amendment to 2022 complements the initial budget with the following provisions:

- Horizon Europe operational commitments (EUR 303 705 000) and payments (EUR 80 000 000), both under expense budget line 3003. Operational commitments will cover the launch of the 1st call under Horizon Europe as well as procurement plan as detailed in section 2.2.4, whereas payments will cover mainly the first pre-financing needs. They will be financed by fresh appropriations from the Union under Horizon Europe, as detailed under revenue budget line 2006.
- H2020 commitment appropriations will increase by EUR 238 894.05 (expense budget line 3002) to complement the procurement activities financed under H2020. This additional provision will be financed through reactivations of unused appropriations from previous years, as detailed under revenue budget lines 3022 and 3023.
- Administrative commitment and payment appropriations of EUR 1 209 000 to cover increased needs in communication (+ EUR 210 000 for the construction of a modular booth), in service contracts (+280,000 for service contracts for support activities, implementing the procurement procedure listed under section 2.3.2; in addition, + EUR 50 000 for an assignment on consulting services in the field of human resources) as well as evaluators under expert contracts and meetings (+ EUR 649 000). These additional expenses will be financed entirely by reactivations of unused appropriations from previous years as stated in the revenue table under budget lines 3018 and 3021.

On the other side, H2020 payment appropriations (expense budget line 3002) will decrease by EUR 16 574 050 as an outcome of updated payment needs. This decrease will be applied to the fresh appropriations asked by the Union (revenue budget line 2005).

Table 3.1: Revenues (amount in EUR)

Title Chapter Article Item	Heading	Budget 2020 CA (executed)	Budget 2020 PA (executed)	Budget 2021 CA (executed)	Budget 2021 PA (executed)	Initial budget 2022.0 CA	Initial budget 2022.0 PA	Amendment 2021.1 CA	Amendment 2021.1 PA	Amended budget 2022.1 CA	Amended budget 2022.1 PA	Remarks
20	SUBSIDIES AND REVENUES											
2001	European Commission subsidy for operational expenditure (7th Framework Programme)	0	4,521,322		340,041	0	0			0	0	Council Regulation 2021/2085 of 19 November 2021 on the establishment of the Clean Hydrogen Joint Undertaking
2002	European Commission subsidy for administrative expenditure	2,381,733	2,381,733	2,649,250	2,649,250	3,440,000	3,440,000			3,440,000	3,440,000	Council Regulation 2021/2085 of 19 November 2021 on the establishment of the Clean Hydrogen Joint Undertaking includes EFTA (2.41% in 2020, 2.66% in 2021 and 2.47% in 2022)
2003	Hydrogen Europe contribution for administrative expenditure	2,048,290	2,048,290	2,278,355	2,278,355	2,958,400	2,958,400			2,958,400	2,958,400	Council Regulation 2021/2085 of 19 November 2021 on the establishment of the Clean Hydrogen Joint Undertaking
2004	Hydrogen Europe Research contribution for administrative expenditure	333,443	333,443	370,895	370,895	481,600	481,600			481,600	481,600	Council Regulation 2021/2085 of 19 November 2021 on the establishment of the Clean Hydrogen Joint Undertaking
2005	European Commission subsidy for operational expenditure (Horizon 2020)	81,510,246	76,127,865		44,315,319	0	40,658,254		-16,574,050	0	24,084,204	Council Regulation 2021/2085 of 19 November 2021 on the establishment of the Clean Hydrogen Joint Undertaking includes EFTA (2.41% in 2020, 2.66% in 2021 and 2.47% in 2022)
2006	EC subsidy Horizon Europe							303,705,000	80,000,000	303,705,000	80,000,000	Council Regulation 2021/2085 of 19 November 2021 on the establishment of the Clean Hydrogen Joint Undertaking includes EFTA (2.41% in 2020, 2.66% in 2021 and 2.47% in 2022)
2007	JU revenues	3,863,870	3,863,870	2,015,423	2,015,423							Interest, income from liquidated damages & others
	Total title subsidies and revenues	90,137,582	89,276,523	7,313,923	51,969,283	6,880,000	47,538,254	303,705,000	63,425,950	310,585,000	110,964,204	
30	REACTIVATIONS											
3014	C2 reactivation of appropriations for administrative expenditure (2018)	662,380	662,380							0	0	Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative activities
3015	C2 reactivation of appropriations for operational expenditure (2018)	263,606	12,286,651							0	0	Financial rules article 6 - unused CA for operational costs re-entered to be used for operational activities
3016	C2 reactivation of appropriations for administrative expenditure (2019)	424,410	1,294,096	250,000	250,000					0	0	Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative activities
3017	C2 reactivation of appropriations for operational expenditure (2019)	12,784,309	300,000							0	0	Financial rules article 6 - unused CA for operational costs re-entered to be used for operational activities
3018	C2 reactivation of appropriations for administrative expenditure (2020)			43,500	964,403			876,566	876,566	876,566	876,566	Financial rules article 6 - unused PA for administrative costs re-entered to be used for administrative activities
3019	C2 reactivation of appropriations for operational expenditure (2020)			5,441,287	3,035,085					0	0	Financial rules article 6 - unused CA for operational costs re-entered to be used for operational activities
3020	C8 reactivation of appropriations for operational expenditure (2021)			2,800,000						0	0	Financial rules article 6 - unused CA for operational costs re-entered to be used for operational activities
3021	C2 reactivation of appropriations for administrative							332,434	332,434	332,434	332,434	Financial rules article 6 - de-committed CA for administrative activities re-entered to be used for administrative activities

Title Chapter Article Item	Heading	Budget 2020 CA (executed)	Budget 2020 PA (executed)	Budget 2021 CA (executed)	Budget 2021 PA (executed)	Initial budget 2022.0 CA	Initial budget 2022.0 PA	Amendment 2021.1 CA	Amendment 2021.1 PA	Amended budget 2022.1 CA	Amended budget 2022.1 PA	Remarks
	<i>expenditure (2021)</i>											
3022	<i>C2 reactivation of appropriations for operational expenditure (2021)</i>					1,474,819	5,647,049	17,224		1,492,043	5,647,049	Financial rules article 6 - unused CA for operational costs re-entered to be used for operational activities
3023	<i>C8 reactivation of appropriations for operational expenditure (2022)</i>							221,670		221,670	0	Financial rules article 6 - unused CA for operational costs re-entered to be used for operational activities
	Total title reactivations	14,134,705	14,543,127	8,534,787	4,249,488	1,474,819	5,647,049	1,447,894	1,209,000	2,922,713	6,856,049	
	TOTAL REVENUES	104,272,287	103,819,650	15,848,709	56,218,771	8,354,819	53,185,304	305,152,894	81,392,907	313,507,713	117,820,254	

Table 3.2: Expenditure (amount in EUR)

Title Chapter Article Item	Heading	Executed 2020		Executed 2021		Initial budget 2022.0		Amendment 2021.1	Amendment 2021.1	Amended budget 2022.1		Ratio 2020/2022	Ratio 2020/2022	Comments
		Commitments	Payments	Commitment appropriations (CA)	Payment appropriations (PA)	CA	PA	CA	PA	CA	PA	CA	PA	
1	STAFF EXPENDITURE													
11	STAFF IN ACTIVE EMPLOYMENT	3,281,888	3,256,817	3,515,254	3,429,142	3,825,000	3,825,000	20,000	20,000	3,845,000	3,845,000	85%	85%	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, daily subsistence, resettlement allowance and removal costs for staff arriving/departing Cost of PMO provisions
12	EXPENDITURE RELATED TO RECRUITMENT	576	576	9,451	9,451	5,000	5,000			5,000	5,000	12%	12%	Miscellaneous expenditure on staff recruitment (travel expenses)
13	MISSIONS AND TRAVEL	21,522	31,038	11,000	5,826	60,000	60,000			60,000	60,000	36%	52%	Mission expenses
14	SOCIOMEDICAL INFRASTRUCTURE AND TRAINING	22,710	25,219	33,992	27,750	44,000	44,000			44,000	44,000	52%	57%	Training, medical service and mobility costs
15	ENTERTAINMENT AND REPRESENTATION EXPENSES	4,532	3,481	2,124	3,175	4,000	4,000			4,000	4,000	113%	87%	Representation and receptions
	TOTAL TITLE 1	3,331,228	3,317,130	3,571,822	3,475,344	3,938,000	3,938,000	20,000	20,000	3,958,000	3,958,000	84%	84%	
2	BUILDING, EQUIPMENT AND MISCELLANEOUS EXPENDITURE													
23	CURRENT ADMINISTRATIVE EXPENDITURE	345,462	341,859	353,580	350,651	855,000	855,000			855,000	855,000	40%	40%	Rent, works, insurance, common charges (water/gas/electricity), maintenance, security and surveillance
24	CORRESPONDENCE, POSTAGE AND TELECOMMUNICATIONS	411,491	382,205	458,180	464,887	520,000	520,000			520,000	520,000	79%	74%	IT purchases, software licences, software development
22	MOVABLE PROPERTY AND ASSOCIATED COSTS	0	0	498	0	20,000	20,000			20,000	20,000	0%	0%	Purchases and rental of office equipment, maintenance and repair
23	CURRENT ADMINISTRATIVE EXPENDITURE	7,937	5,622	6,772	5,782	9,000	9,000			9,000	9,000	88%	62%	Office supplies, library, translation service, bank charges and miscellaneous office expenditure
24	CORRESPONDENCE, POSTAGE AND TELECOMMUNICATIONS	22,038	12,082	10,961	10,765	10,000	10,000			10,000	10,000	220%	121%	Telephones, video conferences and postal services
25	EXPENDITURE ON FORMAL AND OTHER MEETINGS	14,962	18,227	0	0	50,000	50,000			50,000	50,000	30%	36%	Official meetings such as SRG, Scientific Committee, Governing Board
26	COMMUNICATION COSTS	524,705	371,568	608,276	537,226	700,000	700,000	210,000	210,000	910,000	910,000	58%	41%	External communication and events
27	SERVICE CONTRACTS	148,087	209,952	156,453	160,626	647,000	647,000	330,000	330,000	977,000	977,000	15%	21%	Studies and audits
28	EXPERT CONTRACTS AND MEETINGS	246,927	252,867	87,750	90,900	131,000	131,000	649,000	649,000	780,000	780,000	32%	32%	Costs related to expert contracts (evaluations, mid-term, ad-hoc and final reviews)
	TOTAL TITLE 2	1,721,608	1,594,383	1,682,471	1,620,836	2,942,000	2,942,000	1,189,000	1,189,000	4,131,000	4,131,000	42%	39%	
	TOTAL TITLE 1+2 (ADMINISTRATIVE EXPENDITURE)	5,052,835	4,911,513	5,254,293	5,096,181	6,880,000	6,880,000	1,209,000	1,209,000	8,089,000	8,089,000	62%	61%	

Title Chapter Article Item	Heading	Executed 2020		Executed 2021		Initial budget 2022.0		Amendment 2021.1	Amendment 2021.1	Amended budget 2022.1		Ratio 2020/2022	Ratio 2020/2022	Comments
		Commitments	Payments	Commitment appropriations (CA)	Payment appropriations (PA)	CA	PA	CA	PA	CA	PA	CA	PA	
3	OPERATIONAL EXPENDITURE													
3 0 0 1	Implementing the research agenda of FCH Joint Undertaking: 7th Framework Programme (FP7)	0	6,101,482	0	1,091,651	-	-			0	0	0%	74%	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	93,347,310	87,889,956	10,057,144	42,621,296	1,474,819	46,305,304	238,894	-16,574,050	1,713,713	29,731,254	0%	296%	This appropriation shall cover the operational costs of the JU regarding H2020 grants (pre-financings, interim and final payments), studies and JRC contribution.
3 0 0 3	Implementing the research agenda of FCH Joint Undertaking: Horizon Europe					0	0	303,705,000	80,000,000	303,705,000	80,000,000	100%	0%	
TOTAL TITLE 3 (OPERATIONAL EXPENDITURE)		93,347,310	93,991,438	10,057,144	43,712,948	1,474,819	46,305,304	303,943,894	63,425,950	305,418,713	109,731,254	31%	86%	
TOTAL EXPENDITURE		98,400,145	98,902,951	15,311,437	48,809,128	8,354,819	53,185,304	305,152,894	64,634,950	313,507,713	117,820,254	31%	84%	

Revenues

As per articles 76, 77 and 81 of the Council Regulation No 2021/2085 of 19/11/2021, the Union shall contribute 50%, the Industry Grouping 43% and the Research Grouping 7% to the administrative budget.

The administrative budget for 2022 will be financed entirely by Members' contributions under H2020.

Operational expenses are covered entirely by the EC subsidy. For the 2022 budget, both H2020 and Horizon Europe appropriations will be used. The commitment appropriations for H2020 come from unused appropriations of previous years that are reactivated in 2022 budget. The commitment and payment appropriations for Horizon Europe refer to fresh appropriations.

Expenditure

Overall, the administrative budget (Titles 1 and 2) will show an increase by 54% (EUR 2 834 707) compared to the executed 2021.

In more details:

Title 1 – Staff

Title 1 (staff costs) will represent 48% of the administrative costs in the 2022 budget. It mainly covers salaries (97% 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 11% (EUR 386 178) compared to 2021 committed amounts. This is due to:

- An increase by 9.4% in budget line for staff in active employment. The budget will be increased since 3 additional staff persons will be recruited in 2022, in line with the Staff Establishment Plan. An indexation of 2% (applicable as of the second half of the year) is included in this provision. On the other side, interim contracts are estimated to be less (5) than in 2021 (9).
- Sociomedical infrastructure and training will increase by 29% (EUR 10 008) due to the increased medical costs estimated (pre-recruitment and annual medical tests) as well as the increased mobility costs.
- Mission expenses will quadruple compared to 2021 execution as more missions are foreseen for 2022 with the ease of travel restrictions. Nevertheless, missions will not reach at the level of pre-covid era.

On the other side, recruitment expenses will be lowered in 2022 but this is only because in 2021 most costs came from the assessment centre for the recruitment of the new Head of Unit. This year's provision will cover for the new recruitments as per the Staff Establishment Plan.

Title 2 – Infrastructure

Title 2 represents 52% of the administrative costs in 2022. Title 2 will more than double compared to 2021. This is mainly due to a significant increase in service contracts as well as rentals and building charges. In more details:

- Service contracts will increase by nearly 6 times (+EUR 820 547 compared to 2021). The main reason for this increase is the provision of intra-muros services in the field of communication, knowledge management and project management with the aim to

provide business continuity. The provision for these services is EUR 705 000. In addition, a provision for audits in annual accounts is included in 2022 (EUR 55 000) compared to 2021. This assignment is contracted on a biannual basis. Adding to these is a provision for an assignment on consulting services in the field of human resources (EUR 50 000).

- Communication costs will increase by 50% (EUR 301 724) on the assumption that European Hydrogen week in 2022 will be carried out with increased physical presence. In addition, the construction of a modular booth is foreseen.
- Rentals and building charges will be more than doubled compared to 2021 (increase by EUR 501 420) due to the office space refurbishment costs.
- IT costs will increase by 14% (EUR 61 820) due to a planned upgrade of audiovisual equipment for the meeting rooms of the 1st floor, costs associated to office space refurbishments and Infosec new regulation costs.
- Expert contracts and meetings will increase by EUR 692 250 as a provision for the evaluators is included. In addition, a marginal increase of mid-term and final reviews is anticipated.
- Movable property will double (an increase of EUR 19 502) because of anticipated office furniture purchases in the context of new office arrangements.

On the other side, telecommunication costs will remain at the level of 2021 execution as the effect of migrating fixed telephony to MS Teams Voice, being free of charge.

Title 3 – Operational

The amended 2022 budget includes both H2020 and Horizon Europe commitment and payment appropriations.

For H2020, commitment appropriations are coming from reactivation of unused appropriations from 2021 and 2022 for an amount of EUR 1 713 713 and will cover amongst else:

- JRC plan for 2022 (committed for EUR 695 000).
- The second specific contract under the framework contract for the Guarantees of Origin (EUR 488 000).
- The work of European Hydrogen Safety Panel 2022 (EUR 211 819).

H2020 payment appropriations will cover for H2020 interim and final payments (currently 62 are estimated, 17 final and 45 interim) as well as procurement activities included in previous AWP, payments for JRC (balance of 2021 plan and pre-financing for 2022) and payments for the expert contracts in European Hydrogen Safety Panel for 2021. Following a large-scale update of 2022 foreseen payments, the actual amount needed will be decreased by EUR 16 574 050 compared to the initial budget.

Horizon Europe commitment appropriations will cover the call that will be published in 2022 and the procurement plan as detailed in section 2.2.4. The payment appropriations will be used for the pre-financing of the 1st part of the call, for which the grants are estimated to be signed by end of 2022.

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 to meet budget commitments made in previous financial years as well as in 2022.

CLEAN HYDROGEN JOINT UNDERTAKING

Budget 2022

SUMMARY SCHEDULE OF PAYMENTS (Operational)

2020 Outturn		2021 Outturn		2022 Budget		Difference (2022/2021)	
Committed	Paid	Committed	Paid	CA	PA	CA	PA
93,347,310	93,991,438	10,057,144	43,712,948	305,418,713	109,731,254	2937%	151%

DETAILS OF PAYMENT SCHEDULE (Operational)

FP7

Commitments		Payments					Outstanding amount	Total
		2022	2023	2024	2025			
Commitments still outstanding (RAL)		3,039,328	0	3,039,328	0	0	0	3,039,328
TOTAL		3,039,328	0	3,039,328	0	0	0	3,039,328

H2020

Commitments		Payments					Outstanding amount	Total
		2022	2023	2024	2025			
Commitments still outstanding (RAL)		118,600,257	29,731,254	58,232,615	13,187,944	4,273,152	13,175,292	118,600,257
TOTAL		118,600,257	29,731,254	58,232,615	13,187,944	4,273,152	13,175,292	118,600,257

Horizon Europe

Commitments		Payments					Outstanding amount	Total
		2022	2023	2024	2025			
2022 commitments		303,705,000	80,000,000	102,056,431	30,189,942	44,133,454	47,325,173	303,705,000
TOTAL		303,705,000	80,000,000	102,056,431	30,189,942	44,133,454	47,325,173	303,705,000

State of play on 17/01/2022: RAL refers to open commitments on 17/01/2022

FP7: RAL refers to FCH open commitments from 1 grant for which the final payment is foreseen for 2023

H2020 pre-2020 RAL refers to 90 grants for which final payment is not yet done (hence not de-committed yet), 4 open commitments from procurement activities and 1 global commitment for the remaining procurement activities of AWP 2021, the open commitment for JRC 2021 and 2022 and the open commitment for EHSP 2021 contracts. In addition, it includes the unused appropriations from previous years that will be reactivated with the 1st amendment of 2022

Horizon Europe: payment appropriations for 2022 assume the pre-financing of half of the amount of the call, the 2nd round of pre-financings for the remaining part of the call is foreseen for 2023. Payment schedule for 2024 and 2025 is estimated based on historical trends

4 ANNEXES

4.1 ICAA Plan

Hydrogen Europe Industry and Hydrogen Europe Research Members of the Clean Hydrogen Joint Undertaking - are hereby jointly submitting their Additional Activities Plan covering the period of 1 January 2022 – 31 December 2022. The Plan includes Additional Activities for a total amount of EUR 520.765 million.

For the reporting of the annual additional activities plan annexed to the main part of the work programme, a scope of the additional activities is presented according to categories in line with the Article 78 of the COUNCIL REGULATION (EU) 2021/2085.

As required by the COUNCIL REGULATION, the additional activities included in the plan should contribute to the objectives the Clean Hydrogen Joint Undertaking. Therefore, each activity included in the annual plan is linked to one of the objectives of the Clean Hydrogen Joint Undertaking, as per Article 73.

For the confidentiality purposes, only aggregated values of the additional activities are presented in the table below.

ADDITIONAL ACTIVITIES PLAN – CLEAN HYDROGEN JOINT UNDERTAKING

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
A Pre-commercial trials and field tests		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe’s 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people, the European Green Deal and the European Climate Law by raising the Union’s ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, and climate neutrality at the latest by 2050	Private members	8.851
B To contribute to the implementation of the 2020 European Commission’s Hydrogen Strategy for a climate neutral Europe	Private members	4.029
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	6.950
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	3.842
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	14.596
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union’s hydrogen value chain while supporting the uptake of industry-related skills	Private members	1.055
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	4.462
SUBTOTAL (A)		43.786

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
B Proof of concept		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people, the European Green Deal and the European Climate Law by raising the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, and climate neutrality at the latest by 2050	Private members	23.315
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	6.398
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	11.815
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	3.018
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	23.471
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	0.529
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	10.124
SUBTOTAL (B)		78.671

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
C Improvement of existing production lines for up-scaling		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people, the European Green Deal and the European Climate Law by raising the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, and climate neutrality at the latest by 2050	Private members	8.100
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	0.427
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	28.517
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	1.256
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	14.215
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	3.010
H Increase public and private awareness, acceptance, and uptake of clean hydrogen solutions, in particular through cooperation with other European partnerships under Horizon Europe	Private members	0.006
SUBTOTAL (C)		55.531

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
D Large scale case studies		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people, the European Green Deal and the European Climate Law by raising the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, and climate neutrality at the latest by 2050	Private members	56.062
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	19.158
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	1.789
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	0.568
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	5.845
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	0.163
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	5.679
H Increase public and private awareness, acceptance, and uptake of clean hydrogen solutions, in particular through cooperation with other European partnerships under Horizon Europe	Private members	0.174
SUBTOTAL (D)		89.437

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
E Awareness-raising activities on hydrogen technologies and safety measures		
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	0.486
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	0.183
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	1.055
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	1.322
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	0.115
H Increase public and private awareness, acceptance, and uptake of clean hydrogen solutions, in particular through cooperation with other European partnerships under Horizon Europe	Private members	0.096
SUBTOTAL (E)		3.257
F Uptake of results from projects into products, further exploitation and activities within the research chain either at higher TRLs or in parallel strands of activity		
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	0.624
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	32.907
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	0.780
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	2.363
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	0.035
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	1.040

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
SUBTOTAL (F)		37.749
G The research and innovation activities or projects with a clear link to the Strategic Research and Innovation Agenda, and co-funded under national or regional programmes within the Union		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people, the European Green Deal and the European Climate Law by raising the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, and climate neutrality at the latest by 2050	Private members	15.402
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	0.529
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	7.215
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	22.445
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	64.091
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	3.495
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	3.034
SUBTOTAL (G)		116.211

DETAILED ESTIMATED IKAA FOR 2022		
Detailed description of the AA	Type of contributor	Estimated value AA for 2022 (in M€)
H Other, contributing to the JU objectives		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people, the European Green Deal and the European Climate Law by raising the Union's ambition on reducing greenhouse gas emissions to at least 55% below 1990 levels by 2030, and climate neutrality at the latest by 2050	Private members	72.645
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	3.609
C To strengthen the competitiveness of the Union clean hydrogen value chain, with a view to supporting, in particular for SMEs, the acceleration of the market entry of innovative competitive clean solution	Private members	13.806
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	4.473
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union	Private members	1.341
F Strengthen the knowledge and capacity of scientific and industrial actors along the Union's hydrogen value chain while supporting the uptake of industry-related skills	Private members	0.124
G Carry out demonstrations of clean hydrogen solutions with a view to local, regional and Union-wide deployment, aiming to involve stakeholders in all Member States and addressing renewable production, distribution, storage and use for transport and energy-intensive industries as well as other applications	Private members	0.115
H Increase public and private awareness, acceptance, and uptake of clean hydrogen solutions, in particular through cooperation with other European partnerships under Horizon Europe	Private members	0.009
SUBTOTAL (H)		96.121
TOTAL ESTIMATED IKAA		520.765

4.2 Link of Clean Hydrogen JU operational activities with its Strategy Map

Table 4 Clean Hydrogen JU Strategy Map: Actions, Outcomes and Impacts

<p>Operational level resources and actions (Linked to the JU’s objectives and additional tasks in the SBA and the strategy map)</p>	<p>Action-1 Supporting climate neutral and sustainable solutions</p>
	<p>Action-2 Research and Innovation for hydrogen technologies</p>
	<p>Action-3 Supporting market uptake of clean hydrogen applications</p>
<p>Specific level outcomes (Linked to the JU’s specific objectives in the SBA and the strategy map)</p>	<p>Outcome-1 Limiting the environmental impact of hydrogen technology applications</p>
	<p>Outcome-2 Improving the cost-effectiveness of clean hydrogen solutions</p>
	<p>Outcome-3 Demonstrating clean hydrogen solutions, in synergy with other partnerships</p>
	<p>Outcome-4 Increasing public awareness and uptake of hydrogen technologies</p>
	<p>Outcome-5 Reinforcing EU scientific and industrial ecosystem, including SMEs</p>
<p>General Level Impacts (Linked to the general objectives in the SBA specific to the JU, the priorities of the Union and the strategy map of the JU)</p>	<p>Impact-1 Action against climate change by drastically reducing greenhouse gas emissions</p>
	<p>Impact-2 Transition to a clean energy system with renewable hydrogen as one of its main pillars</p>
	<p>Impact-3 Emergence of a competitive and innovative European hydrogen value chain</p>

Table 5 Expected contribution of operational actions to Strategy Map elements²⁵²

Operational Activities	Operational level resources and actions			Specific level outcomes					General Level Impacts		
	Action 1	Action 2	Action 3	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Impact 1	Impact 2	Impact 3
Calls for Proposals											
HORIZON-JTI-CLEANH2-2022-01-01	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-01-02	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-01-03	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-01-04	✓	✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2022-01-05		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-01-06	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-01-07		✓			✓		✓	✓		✓	✓
HORIZON-JTI-CLEANH2-2022-01-08	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2022-01-09	✓	✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2022-01-10		✓			✓		✓	✓		✓	✓

²⁵² Based on the description of the relevant topics. Exact correspondence with KPIs to be determined based on the selected proposal for each topic.

Operational Activities	Operational level resources and actions			Specific level outcomes					General Level Impacts		
	Action 1	Action 2	Action 3	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Impact 1	Impact 2	Impact 3
HORIZON-JTI-CLEANH2-2022-02-01		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-02-02		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-02-03	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-02-04		✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-02-05		✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-02-06	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-02-07		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-02-08		✓			✓		✓			✓	✓
HORIZON-JTI-CLEANH2-2022-02-09		✓				✓		✓		✓	✓
HORIZON-JTI-CLEANH2-2022-02-10	✓	✓						✓			✓
HORIZON-JTI-CLEANH2-2022-02-11	✓	✓			✓	✓	✓			✓	✓
HORIZON-JTI-CLEANH2-2022-03-01	✓	✓		✓				✓	✓		✓

Operational Activities	Operational level resources and actions			Specific level outcomes					General Level Impacts		
	Action 1	Action 2	Action 3	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Impact 1	Impact 2	Impact 3
HORIZON-JTI-CLEANH2-2022-03-02	✓	✓		✓				✓	✓		✓
HORIZON-JTI-CLEANH2-2022-03-03	✓	✓			✓	✓	✓	✓		✓	✓
HORIZON-JTI-CLEANH2-2022-03-04	✓	✓						✓			✓
HORIZON-JTI-CLEANH2-2022-03-05	✓	✓			✓	✓	✓	✓		✓	✓
HORIZON-JTI-CLEANH2-2022-03-06	✓	✓				✓		✓		✓	✓
HORIZON-JTI-CLEANH2-2022-03-07	✓	✓				✓		✓		✓	✓
HORIZON-JTI-CLEANH2-2022-03-08	✓	✓				✓		✓		✓	✓
HORIZON-JTI-CLEANH2-2022-04-01	✓	✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2022-04-02		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-04-03		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-04-04	✓	✓						✓			✓
HORIZON-JTI-CLEANH2-2022-05-01			✓				✓				✓

Operational Activities	Operational level resources and actions			Specific level outcomes					General Level Impacts		
	Action 1	Action 2	Action 3	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Impact 1	Impact 2	Impact 3
HORIZON-JTI-CLEANH2-2022-05-02	✓	✓						✓			✓
HORIZON-JTI-CLEANH2-2022-05-03		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-05-04		✓						✓			✓
HORIZON-JTI-CLEANH2-2022-05-05			✓					✓			✓
HORIZON-JTI-CLEANH2-2022-06-01	✓	✓			✓	✓	✓	✓		✓	✓
HORIZON-JTI-CLEANH2-2022-06-02	✓	✓			✓	✓	✓	✓		✓	✓
HORIZON-JTI-CLEANH2-2022-07-01	✓	✓		✓				✓	✓		✓
Other Activities											
Calls for Tenders			✓				✓	✓			✓
Support to EU Policies			✓				✓	✓			✓
Knowledge Management			✓				✓	✓			✓
Collaboration with other entities			✓			✓	✓	✓			✓
RCS			✓				✓	✓			✓
EHSP			✓				✓	✓			✓
International			✓				✓	✓			✓

Operational Activities	Operational level resources and actions			Specific level outcomes					General Level Impacts		
	Action 1	Action 2	Action 3	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Impact 1	Impact 2	Impact 3
Cooperation											
Communication			✓				✓	✓			✓
Dissemination & Exploitation			✓				✓	✓			✓
Study-01 - FCH Observatory II			✓				✓	✓			✓
Study-02 – Hydrogen Supply Chain			✓					✓			✓

4.3 Renewable Hydrogen Production. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2022

The following tables indicate the contribution of each of the topics included in the Call for Proposals to the objectives of the Clean Hydrogen JU SRIA.

Where a topic addresses an objective directly this is shown with an “X”. When an objective is addressed indirectly by a topic this is shown as a “O”.

Renewable Hydrogen Electrolysis	<i>Type of Action</i>	Reducing electrolyser CAPEX and OPEX	Improving dynamic operation and efficiency, with high durability and reliability, especially when operating dynamically	Increasing current density and decreasing footprint	Demonstrate the value of electrolysers for the power system through their ability to provide flexibility and allow higher integration of renewables	Ensure circularity by design for materials and for production processes, minimising the life-cycle environmental footprint of electrolysers	Increasing the scale of deployment	Improved manufacturing for both water and steam electrolysis
HORIZON-JTI-CLEANH2-2022 -01-01: Development and validation of pressurised high temperature steam electrolysis stacks (SOE)	RIA	O	X	X		O		
HORIZON-JTI-CLEANH2-2022 -01-02: Development and validation of pressurised high temperature steam electrolysis stacks (PCCE)	RIA	O	X	X		O		
HORIZON-JTI-CLEANH2-2022 -01-03: Development of low temperature water electrolysers for highly pressurised H2 production	RIA	O	X	O		O		
HORIZON-JTI-CLEANH2-2022 -01-04: Design for advanced and scalable manufacturing of electrolysers	RIA	X	O	O		X	O	X
HORIZON-JTI-CLEANH2-2022 -01-05: Scaling up of cells and stacks for large electrolysers	RIA	X	O	X			X	O
HORIZON-JTI-CLEANH2-2022 -01-07: Bringing green hydrogen MW scale off grid installations closer to technical and financial maturity	IA		X		X		X	
HORIZON-JTI-CLEANH2-2022 -01-08: Integration of multi-MW electrolysers in industrial applications	IA	X	X	X	O	O	X	
HORIZON-JTI-CLEANH2-2022 -01-09: Scaling-up technologies for SOEL	RIA	X		X		O	X	O
HORIZON-JTI-CLEANH2-2022 -01-10: Demonstrating offshore production of green hydrogen	IA	O	X	O	X		X	

Renewable Hydrogen Electrolysis	<i>Type of Action</i>	Reducing electrolyser CAPEX and OPEX	Improving dynamic operation and efficiency, with high durability and reliability, especially when operating dynamically	Increasing current density and decreasing footprint	Demonstrate the value of electrolysers for the power system through their ability to provide flexibility and allow higher integration of renewables	Ensure circularity by design for materials and for production processes, minimising the life-cycle environmental footprint of electrolysers	Increasing the scale of deployment	Improved manufacturing for both water and steam electrolysis
HORIZON-JTI-CLEANH2-2022-04-03: Reversible SOC system development, operation and energy system integration					X			
HORIZON-JTI-CLEANH2-2022-04-01: Design and industrial deployment of innovative manufacturing processes for solid oxide fuel cells systems and components	IA	O						O

Renewable Hydrogen Other routes of renewable hydrogen production	<i>Type of Action</i>	Reducing CAPEX and OPEX	Improving the efficiency of processes	Increasing carbon yield for processes based on biomass/raw biogas (kg hydrogen / kg carbon)	Scaling up
HORIZON-JTI-CLEANH2-2022-01-06: Efficiency boost of solar thermochemical water splitting	RIA	X	X		X

4.4 Hydrogen Storage and Distribution. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2022

The following tables indicate the contribution of each of the topics included in the Call for Proposals to the objectives of the Clean Hydrogen JU SRIA.

Where a topic addresses an objective directly this is shown with an “X”. When an objective is addressed indirectly by a topic this is shown as a “O”.

Hydrogen storage and distribution Hydrogen Storage	<i>Type of action</i>	To undertake research aimed at improving cost and efficiency of aboveground storage solutions.	To demonstrate distributed aboveground storage solutions available at a capital cost lower than 300 €/kg by 2030	To undertake research activities on underground storage to validate the performance in different geologies, to identify better and more cost effective materials and to encourage improved designs.	Demonstrate the large-scale underground storage across various media at a capital cost lower than 30 €/kg by 2030
n/a					

Hydrogen storage and distribution Hydrogen in the Natural Gas Grid	<i>Type of Action</i>	Development of technologies and materials to explore and support the transportation of H2 via the natural gas grid	Enable through research and demonstration activities the transportation of hydrogen through the natural gas grid either by blending or via repurposing to 100% hydrogen
HORIZON-JTI-CLEANH2-2022 -02-01: Compatibility of Distribution non-steel metallic gas grid materials with hydrogen	RIA	X	X
HORIZON-JTI-CLEANH2-2022 -02-02: Hydrogen and H2NG leak detection for continuous monitoring and safe operation of HRS and future hydrogen/H2NG networks	RIA	X	X
HORIZON-JTI-CLEANH2-2022 -05-04 : Development of validated test methods and requirements for measuring devices intended for measuring NG/H2 mixtures	RIA	X	X
HORIZON-JTI-CLEANH2-2022 -05-03: Safe hydrogen injection management at network-wide level: towards European gas sector transition	RIA	X	X

Hydrogen storage and distribution Liquid Hydrogen Carriers	<i>Type of action</i>	To increase the efficiency and reduce the costs of hydrogen liquefaction technologies.	To contribute to the roll-out of next generation liquefaction technology to new bulk hydrogen production plants.	To continue the research on carrier cycling performance, chemistries, catalysis and reactors which show potential for improved roundtrip efficiency and life cycle assessment.	Develop a range of hydrogen carriers that will be used commercially to transport and store hydrogen while improving their roundtrip efficiency and lowering their cost.
HORIZON-JTI-CLEANH2-2022 -02-03: Validation of a high-performance hydrogen liquefier	RIA	X	X		
HORIZON-JTI-CLEANH2-2022 -02-04: Ammonia to Green Hydrogen: efficient system for ammonia cracking for application to long distance transportations	RIA			X	X
HORIZON-JTI-CLEANH2-2022 -02-05: Efficient system for dehydrogenation of liquid organic hydrogen carriers for application to long distance transportations	RIA			X	X

Hydrogen storage and distribution Improving Existing Hydrogen Transport means	<i>Type of Action</i>	To increase the pressure and capacity for new builds of 100% hydrogen pipelines while reducing their cost.	To reduce road transport costs of compressed hydrogen by increasing the capacity of tube trailers.	To improve the efficiency of road transport of liquid hydrogen while reducing costs.	To enable scale-up of solutions for shipping of bulk liquid hydrogen and support its commercialisation.
HORIZON-JTI-CLEANH2-2022 -02-07: Increased hydrogen capacity of GH 2 road trailers	RIA		X		
HORIZON-JTI-CLEANH2-2022 -02-06: Development of large scale LH2 containment for shipping	RIA				X

Hydrogen storage and distribution Compression, Purification and Metering Solutions	<i>Type of Action</i>	To develop more efficient compressor and purification technologies	To reduce the total cost of ownership of compression and purification technologies	To reduce the energy and consumption and increase the recovery factor of purification technologies	To increase the reliability and lifetime of compression and purification technologies	To improve metering technologies and standards, especially in terms of accuracy and protocols.
HORIZON-JTI-CLEANH2-2022 -02-08: Development of novel or hybrid concepts for reliable, high capacity and energy-efficient H2 compression systems at real-world scale	RIA	X	X		X	
HORIZON-JTI-CLEANH2-2022 -02-09: Sampling methodology and quality assessment of HRS	RIA					O

Hydrogen storage and distribution Hydrogen Refuelling Stations (HRS)	<i>Type of Action</i>	To tackle the technical challenges associated with heavy-duty hydrogen refuelling stations in order to develop a commercial solution that conforms to the heavy-duty requirements;	To increase the reliability and availability of Hydrogen Refuelling Stations;	To support the creation of a network of Heavy-duty HRS across Europe;	To decrease the total cost of ownership of Hydrogen Refuelling Stations.
HORIZON-JTI-CLEANH2-2022 -02-10: Implementing new/optimised refuelling protocols and components for high flow HRS	RIA	X	O		O
HORIZON-JTI-CLEANH2-2022 -02-11: Development and demonstration of mobile and stationary compressed hydrogen refuelling solutions for application in inland shipping and short-distance maritime operations	IA	X	O	O	O
HORIZON-JTI-CLEANH2-2022 -03-03: Large scale demonstration of European H2 Heavy-Duty Vehicle along the TEN-T corridors	IA			O	O
HORIZON-JTI-CLEANH2-2022 -03-05: Large scale demonstration of hydrogen fuel cell propelled inland waterway vessels	IA			O	O

Hydrogen storage and distribution Hydrogen Refuelling Stations (HRS)	<i>Type of Action</i>	To tackle the technical challenges associated with heavy-duty hydrogen refuelling stations in order to develop a commercial solution that conforms to the heavy-duty requirements;	To increase the reliability and availability of Hydrogen Refuelling Stations;	To support the creation of a network of Heavy-duty HRS across Europe;	To decrease the total cost of ownership of Hydrogen Refuelling Stations.
HORIZON-JTI-CLEANH2-2022 -02-07: Increased hydrogen capacity of GH 2 road trailers					○
HORIZON-JTI-CLEANH2-2022 -02-09: Sampling methodology and quality assessment of HRS			○		○

4.5 Hydrogen end uses: Transport. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2022

The following tables indicate the contribution of each of the topics included in the Call for Proposals to the objectives of the Clean Hydrogen JU SRIA.

Where a topic addresses an objective directly this is shown with an “X”. When an objective is addressed indirectly by a topic this is shown as a “O”.

Hydrogen end uses: Transport applications Building Blocks	<i>Type of Action</i>	Improving overall system performance for fuel cell stack technology in terms of power density, reliability and durability	Reduction or replacement of PGM loadings and development of new materials advancing the performance of on-board storage technology;	Improvements in design, health monitoring and manufacturability of core components for fuel cell stacks and on-board storage technology;	Extending the EU leadership on FC production from automotive to maritime and aviation, given the high pressure for decarbonisation of these sectors.
HORIZON-JTI-CLEANH2-2022 -03-01: Development and optimisation of reliable and versatile PEMFC stacks for high power range applications	RIA	X		O	O
HORIZON-JTI-CLEANH2-2022 -03-02: Innovative and optimised MEA components towards next generation of improved PEMFC stacks for heavy-duty vehicles	RIA	X	X		O
HORIZON-JTI-CLEANH2-2022 -03-04: LH2 tanks for heavy-duty vehicles	RIA			X	O

Hydrogen end uses: Transport applications Heavy-Duty Vehicles	<i>Type of Action</i>	Reducing the cost of core components such as modules and stacks in order to foster the competitiveness of FC heavy-duty applications;	Improving overall system performance of FC systems in order to improve the availability and durability and meet the needs of FCH HDV end users;	Improvements in design and monitoring procedures of FC systems;	Supporting and accelerating the wide roll out of FC HDV.
HORIZON-JTI-CLEANH2-2022 -03-03: Large scale demonstration of European H2 Heavy-Duty Vehicle along the TEN-T corridors	IA	X	O	O	X

Hydrogen end uses: Transport applications Waterborne applications	Type of Action	Scaling up FC designs towards commercially relevant applications	Reducing the CAPEX of PEMFC or SOFC systems for maritime applications;	Improving overall system performance for FC and stacks, especially in terms of power density, bunkering rate and operational flexibility;	Supporting the wide roll out of FC ships, by providing adequate fuel, storage and bunkering infrastructure and developing new solutions for ships based on hydrogen and its derivative fuels.
HORIZON-JTI-CLEANH2-2022-03-05: Large scale demonstration of hydrogen fuel cell propelled inland waterway vessels	IA	O	X	O	X
HORIZON-JTI-CLEANH2-2022-02-11: Development and demonstration of mobile and stationary compressed HRS for application in inland shipping and short-distance maritime operations	IA				X

Hydrogen end uses: Transport applications Rail Applications	<i>Type of Action</i>	Reducing the cost of stacks;	Improving reliability and durability at stack and FC system;	Improving power output while reducing weight and dimension of the module;	Supporting the roll out of FC trains, by providing the viability of the FCH solution in the train transport segment..
n/a					

Hydrogen end uses: Transport applications Aeronautic applications	<i>Type of Action</i>	Improving overall system and stack performance for scalable FC in terms of power density, durability and availability;	Reducing NO _x emissions of turbines;	Addressing Airport infrastructure (of both liquid and compressed hydrogen) and refuelling tech / procedures;	Developing aviation dedicated technological bricks, focusing in particular on on-board storage and distribution components and system of liquid hydrogen.	Addressing safety and regulation, specific to hydrogen for aviation applications
HORIZON-JTI-CLEANH2-2022 -03-06: Development and optimisation of a dedicated Fuel Cells for Aviation: from dedicated stack (100s kW) up to full system (MWs)	RIA	X				O
HORIZON-JTI-CLEANH2-2022 -03-07: Development of specific aviation cryogenic storage system with a gauging, fuel metering, heat management and monitoring system	RIA			O	X	O
HORIZON-JTI-CLEANH2-2022 -03-08: Development and optimisation of a dedicated FCs for Aviation: disruptive next-gen high temperature FCs technology for future aviation	RIA	X				O

4.6 Hydrogen end uses: Clean Heat and Power. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2022

The following tables indicate the contribution of each of the topics included in the Call for Proposals to the objectives of the Clean Hydrogen JU SRIA.

Where a topic addresses an objective directly this is shown with an “X”. When an objective is addressed indirectly by a topic this is shown as a “O”.

Hydrogen end uses: Clean Heat and Power Fuel Cells	<i>Type of Action</i>	Reducing CAPEX and TCO of stationary fuel cells of all sizes and end use applications	Prepare and demonstrate the next generation of fuel cells for stationary applications able to run under 100% H2 and other H2-rich fuels whilst keeping high performance	Improve flexibility of systems in operation in particular with reversible fuel cells and integration with thermal storage	Reducing use of critical raw materials and recycling them for further usage	Support development of processes suitable for mass manufacturing
HORIZON-JTI-CLEANH2-2022-04-01: Design and industrial deployment of innovative manufacturing processes for solid oxide fuel cells systems and	IA	X			X	X
HORIZON-JTI-CLEANH2-2022-04-02: Ammonia powered fuel cell system focusing on superior efficiency, durable operation and design optimisation	RIA		X			
HORIZON-JTI-CLEANH2-2022-04-03: Reversible SOC system development, operation and energy system (grid) integration	RIA			X		

Hydrogen end uses: Clean Heat and Power Turbines, boilers and burners	<i>Type of Action</i>	Allow turbines to run on higher admixtures of H2, up to 100% whilst keeping low NO _x emissions, high efficiencies and flexible operation;	Develop concepts on safety and plant integration and demonstrate the retrofitting of turbines, boilers and burners so that they are able to run up to 100% H2.
HORIZON-JTI-CLEANH2-2022-04-04: Dry Low NO _x combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications	RIA	X	X

4.7 Cross-cutting issues. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2022

The following tables indicate the contribution of each of the topics included in the Call for Proposals to the objectives of the Clean Hydrogen JU SRIA.

Where a topic addresses an objective directly this is shown with an “X”. When an objective is addressed indirectly by a topic this is shown as a “O”.

Cross-cutting issues Sustainability, LCSA, recycling and eco-design	<i>Type of Action</i>	Develop life cycle thinking tools addressing the three dimensions of sustainable development: economic, social, and environmental.	Develop eco-design guidelines and eco-efficient processes.	Develop enhanced recovery processes in particular for PGMs/CRMs and per- and polyfluoroalkyl substances.
n/a				

Cross-cutting issues Education and public Awareness	<i>Type of Action</i>	Develop educational and training material and building training programs for professionals and students on hydrogen and fuel cells.	Raise public awareness and trust towards hydrogen technologies and their system benefits..
HORIZON-JTI-CLEANH2-2022 -05-01: Public understanding of hydrogen and fuel cell technologies	CSA		X

Cross-cutting issues Safety, Pre-Normative Research and RCS	<i>Type of Action</i>	Increase the level of safety of hydrogen technologies and applications	Support the development of RCS for hydrogen technologies and applications, with the focus on standards
HORIZON-JTI-CLEANH2-2022 -05-02 : Safety of cryogenic hydrogen transfer technologies in public areas for mobile application	RIA	X	X
HORIZON-JTI-CLEANH2-2022 -05-03: Safe hydrogen injection management at network-wide level: towards European gas sector transition	RIA	X	X
HORIZON-JTI-CLEANH2-2022 -05-04 : Development of validated test methods and requirements for measuring devices intended for measuring NG/H2 mixtures	RIA		X
HORIZON-JTI-CLEANH2-2022 -02-02 : H2 and H2NG leak detection for continuous monitoring and safe operation of HRS and future hydrogen/H2NG networks	RIA	X	
HORIZON-JTI-CLEANH2-2022 -02-09: Sampling methodology and quality assessment of HRS	RIA		X

Cross-cutting issues Safety, Pre-Normative Research and RCS	<i>Type of Action</i>	Increase the level of safety of hydrogen technologies and applications	Support the development of RCS for hydrogen technologies and applications, with the focus on standards
HORIZON-JTI-CLEANH2-2022 -02-10: Implementing new/optimised refuelling protocols and components for high flow HRS	RIA		O
HORIZON-JTI-CLEANH2-2022 -03-04: Liquid hydrogen tanks for heavy-duty vehicles	RIA		X

4.8 Hydrogen Valleys, Supply Chain and Strategic Research Challenge. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2022

The following tables indicate the contribution of each of the topics included in the Call for Proposals to the objectives of the Clean Hydrogen JU SRIA.

Where a topic addresses an objective directly this is shown with an “X”. When an objective is addressed indirectly by a topic this is shown as a “O”.

Hydrogen Valleys	<i>Type of Action</i>	<p>System integration: integrating several elements together to improve overall synergies and facilitate sector coupling</p> <p>System efficiency: improvement of overall energy and economic efficiency of the integrated system</p> <p>Improved security and resilience of the energy system, e.g. via hydrogen production using locally available renewable energy sources</p> <p>Market creation: demonstration of new market for hydrogen</p>	<p>Complementarity of hydrogen with RES , integration with other technologies, existing infrastructure</p> <p>Assessment of the availability and affordability of clean (pollution free) energy provision for industry and cities uses</p> <p>Mutualisation of production or distribution and storage, assuming decentralisation as key parameter</p> <p>Help set or test regulation requirements at the relevant governance level</p>	<p>Increase the knowledge management with assessment of the socio-economic and environmental impacts, including the concept of digital twin assuring an effective monitor and optimization strategy for the operation and further development of the valley</p> <p>Development of public awareness of hydrogen technologies including contributions from Social Science and Humanities if this was relevant</p>
HORIZON-JTI-CLEANH2-2022 -06-01: H2 Valley (large-scale)	IA		X	
HORIZON-JTI-CLEANH2-2022 -06-02: H2 Valley (small-scale)	IA		X	

Supply Chain	<i>Type of Action</i>	Identification of potential vulnerabilities in EUs hydrogen supply chain;	Development of new and improved manufacturing technologies and production processes that facilitate the safe and sustainable use of non-critical (raw) materials as well as facilitate the adoption of the circular economy principles;	Reducing the use of critical (raw) materials. with sustainability or environmental concerns, such as for instance those deriving from poly/perfluoroalkyls.
HORIZON-JTI-CLEANH2-2022 -07-01: Addressing the sustainability and criticality of electrolyser and fuel cell materials	RIA		O	X
HORIZON-JTI-CLEANH2-2022 -01-04: Design for advanced and scalable manufacturing of electrolysers	RIA		O	X
HORIZON-JTI-CLEANH2-2022 -02-04: Ammonia to Renewable Hydrogen: efficient system for ammonia cracking	RIA			X

Supply Chain	<i>Type of Action</i>	Identification of potential vulnerabilities in EUs hydrogen supply chain;	Development of new and improved manufacturing technologies and production processes that facilitate the safe and sustainable use of non-critical (raw) materials as well as facilitate the adoption of the circular economy principles;	Reducing the use of critical (raw) materials. with sustainability or environmental concerns, such as for instance those deriving from poly/perfluoroalkyls.
HORIZON-JTI-CLEANH2-2022 -02-05: Efficient system for dehydrogenation of liquid organic hydrogen carriers	RIA			X
HORIZON-JTI-CLEANH2-2022 -04-01: Design and industrial deployment of innovative manufacturing processes for solid oxide fuel cells systems and fuel cell components	IA		O	
Hydrogen Supply Chain Study (planned)	study	X		

Strategic Research Challenges	<i>Type of Action</i>	Low or free PGM catalysts (including bioinspired catalysts), reducing critical (raw) materials use in electrolyzers and fuel cells, and safe and sustainable use of all material, including developing of perfluorosulfonic acid (PFAS)-free ionomers and membranes.	Advanced materials for hydrogen storage (e.g. carbon fibres, H2 carriers...)	Advanced understanding of the performance / durability mechanisms of electrolyzers and fuel cells.
HORIZON-JTI-CLEANH2-2022 -07-01: Addressing the sustainability and criticality of electrolyser and fuel cell materials	RIA	X		

4.9 Manufacturing readiness levels (MRL)

- MRL 1 - Manufacturing Feasibility Assessed
- MRL 2 - Manufacturing Concepts Defined
- MRL 3 - Manufacturing Concepts Developed
- MRL 4 - Laboratory Manufacturing Process Demonstration
- MRL 5 - Manufacturing Process Development
- MRL 6 - Critical Manufacturing Process Prototyped
- MRL 7 - Prototype Manufacturing System
- MRL 8 - Manufacturing Process Maturity Demonstration
- MRL 9 - Manufacturing Processes Proven
- MRL 10 - Full Rate Production demonstrated and lean production practices in place

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