ANNEX to GB decision no CleanHydrogen-GB-2022-13

Clean Hydrogen JOINT UNDERTAKING (Clean Hydrogen JU)

WORK PROGRAMME 2023

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

A/cm^2	Ampere per square centimeter
AE	Alkaline
AEL	Alkaline Electrolysis
AEMEL	Anion Exchange Membrane Electrolysis
AWP	Annual Work Programme
BoL	Beginning of Life
BoP	Balance of Plant
CAEP	Committee on aviation environmental protection
CAPEX	Capital Up-front Expenditure (Investment)
CEF	Connecting Europe Facility
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CHP	Combined Heat and Power
CH_4	Methane
CINEA	European Climate Infrastructure and Environment Executive Agency
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_x	Carbon Oxides
COD	Chemical Oxygen Demand
CRM	Critical Raw Materials
CSA	Coordination and Support Actions
D&E	Dissemination and Exploitation
DLE	Dry Low Emission
EC	European Commission, sometimes also shortened to just Commission
EECS	European Energy Certificate System
EGR	Exhaust Gas Recirculation
EHO	European Hydrogen Observatory
EHS&CP	European Hydrogen Sustainability and Circularity Panel
EHSP	European Hydrogen Safety Panel
EIB	European Investment Bank
EIC	European Innovation Council
EISMEA	European Innovation Council and SMEs Executive Agency
EPC	Engineering, Procurement, and Construction
ERA	European Research Area

ETS	Emission trading system (also seen as EU ETS)
EU	European Union
EU ETS	EU Emission Trading System
EUR	Euro currency (€)
EURAMET	European Association of National Metrology Institutes
F2P	Feedback to Policy
FAQ	Frequently Asked Questions
FAR	Fuel to Air ratio
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
FCG	Fatigue Crack Growth
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/
Fe	Iron
FWC	Framework Contract
GB	Governing Board
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
H2V	Hydrogen Valley Platform
HAZ	Heat Affected Zones
HDV	Heavy-Duty Vehicles
HELLEN	Hydrogen Events and Lesson LEarNed
HHV	Higher Heating Value
HIAD	Hydrogen Safety Reference Database

[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.

hr	hour
HREE	Heavy rare earth materials
HRS	Hydrogen Refuelling Station
HTCP	Hydrogen Technology Collaboration Programme
IA	Innovation Actions
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
IEA	International Energy Agency
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.
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
LBO	Lean blow out
LCA	Life-Cycle Assessment
LCDN	Life-Cycle Data Network
LCI	Life Cycle Inventory
LCOH	Levelised Cost of Hydrogen
LDV	Light Duty Vehicles
LEL	Lower Explosive Limit
LH_2	Liquid Hydrogen
LHV	Lower Heating Value
LNG	Liquefied Natural Gas
LOHC	Liquid Organic Hydrogen Carrier
LOI	Letters of Intent

LREE	Light rare earth materials
LT	Low Temperature
m^2, m^3	Square Meters, Cubic Meters
MEA	Membrane Electrode Assembly
MGA	Model Grant Agreement
MPL	Micro Porous Layer
Mt	Million Tonnes
MW	Megawatt. MW_e refers to MW electric.
N_2	Nitrogen
N_2O	Nitrous Oxide
NH_3	Ammonia
Ni	Nikel
NO_x	Nitrogen Oxides
NG	Natural Gas
NGO	Non-Governmental Organisations
NRMM	Non-Road Mobile Machinery
O_2	Oxygen
O&M	Operation and Maintenance
OPEX	Operational Expenditure
P4P	Processes 4 Planet Partnership
PC	Photocatalytic
PCC	Proton Ceramic Cells
PCCEL	Proton Conducting Ceramic Electrolysis
PDA	Project Development Assistance
PEC	Photoelectrochemical
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
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	Clean Hydrogen JU Programme Office
ppmv	Parts per million volume

Pt	Platinum
PTE	Porous Transport Electrode
PV	Photovoltaic
PV+EC	Photovoltaic + electrolysis
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
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
SLA	Service Level Agreement
SME	Small and Medium-sized Enterprise
SoA	State-of-the-Art
SOC	Solid Oxide Cells
SOEL	Solid Oxide Electrolysis (Cells)
SOFC	Solid Oxide Fuel Cell
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
STH	Solar-to-hydrogen
t	Tonne
TCO	Total Cost of Ownership
TEN	Trans-European Network. TEN-E refers to Electricity, while TEN-T to Transport.
TF	Task Force
TIM	Tools for Innovation Monitoring

tpd	Tonnes per Day
TRL	Technology Readiness Level
TSO	Transmission System Operator
US, USA	United States of America
V	Volt
WP	Work Programme
ZEWT	Zero Emission Waterborne Transport Partnership

1 INTRODUCTION

1.1 Mission statement of Clean Hydrogen JU

Clean Hydrogen JU Vision

Support a sustainable hydrogen economy, contributing to EU's climate goals

Clean Hydrogen JU Mission

Facilitate the transition to a greener EU society through the development of hydrogen technologies.

This document represents the **Annual Work Programme for 2023 of the Clean Hydrogen Joint Undertaking** (hereafter also Clean Hydrogen JU[2], or simply as "the JU"), outlining the scope and details of its activities for the year 2023 including its related budget.

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 funding programme for research and innovation, Horizon Europe[3], 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 production, storage, distribution and end use 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 clean hydrogen in hard to abate sectors. They will be guided to a large extent by EU's Hydrogen Strategy[4] and the policy developments in this context such as the European Green Deal[5] and REPowerEU, 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

[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.
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301
[5] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

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 embedded continuously 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 while 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 second Annual Work Programme (AWP) of the Clean Hydrogen Joint Undertaking (Clean Hydrogen JU), outlining the scope and details of its activities for the year 2023. 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 Europe[6] (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.

Hydrogen can play a critical role for storing the big quantities of renewable energy needed for the clean energy transition and can fill the gap between electrification and the hard-to-abate sectors in industry and 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 CO_2. 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 Integration[7] and Hydrogen Strategies[8]. 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 clean hydrogen supply and demand for a climate-neutral economy. According to the Hydrogen Strategy, "Hydrogen has a strong potential to bridge some of this gap, as a vector for renewable energy storage, alongside batteries, and transport, ensuring back up for seasonal variations and connecting production locations to more distant demand centres." It also tries to address the

[6] 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
[7] Strategy for Energy System Integration. COM(2020) 299 final.
[8] A Hydrogen Strategy for a climate neutral Europe. COM(2020) 301 final.

issue that most of the hydrogen production is today fossil-based, as low-carbon hydrogen is not yet cost-competitive. To achieve this, the strategy outlines several 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 electrolysers in the EU by 2024 and 40 GW of renewable hydrogen electrolysers 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. It especially invited the Commission to outline a pathway towards the roadmap's objectives of installing at least 6 GW of renewable hydrogen electrolysers in the EU by 2024 and 40 GW by 2030. This pathway 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, that makes use of flexible policies.

On 19 May 2021, the European Parliament also adopted a resolution[10] on the European Strategy for Hydrogen. The Parliament stressed the need to maintain and further develop EU technological leadership in clean hydrogen, emphasised the necessity of an EU hydrogen strategy that covers the whole hydrogen value chain, including the demand and supply sectors, highlighted the added value of the development and marketing of innovative electrolysis technologies, and emphasised that the hydrogen economy needs to be compatible with the Paris Agreement, the EU's climate and energy targets for 2030 and 2050, the circular economy, the action plan for critical raw materials and the UN Sustainable Development Goals. It also urged the Commission and the Member States to incentivise the value chain and market uptake of renewable hydrogen, urged also the Commission to build on the Hydrogen Valleys initiative, underlining their important role in initiating the production and application of renewable hydrogen across EU. The EP resolution focused on ramping up the production, developing infrastructures for hydrogen production, storage and distribution, agreed to focus demand side on industry and transport and encourages synergies with deployment funds.

On 28 June 2021 the first ever Climate Law for Europe[11] 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' package[12] 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

[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.

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 CO_2 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 were complemented in Q4 2021 with the Hydrogen and Gas markets Decarbonisation Package[13] and in Q4 2022 with the CO_2 Standards on Heavy-Duty Vehicles[14].

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 Energy Directive[15] proposes the extension of the EU-wide certification system for renewable fuels to include renewable hydrogen[16], as well as targets for transport[17] and industry[18] 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 CO_2 standards for Cars and Vans[21]; the revision of the Alternative Fuel Infrastructure Regulation[22], 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 proposal[23] 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 package[24], 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 regulation[25] and directive[26]

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[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.
[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 CO_2 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).

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 ambitions.

On 18 May 2022 the European Commission presented the REPowerEU Plan[27] to respond to the unprecedented global energy market disruption caused by Russia's invasion in Ukraine. The urgency to transform Europe's energy system by ending the EU's dependence on Russian fossil fuels comes on top of the need to tackle the climate crisis.

One of the main goals of the Plan is the diversification of energy supply and offering support to our international partners. The newly created EU Energy Platform[28], supported by regional task forces, will enable voluntary common purchases of gas, liquified natural gas (LNG) and hydrogen by pooling demand, optimising infrastructure use and coordinating outreach to suppliers. The Platform will also enable joint purchasing of renewable hydrogen. Also, the EU External Energy Strategy[29] will facilitate energy diversification and build long-term partnerships with suppliers, including cooperation on clean hydrogen or other green technologies. The strategy boosts the development of renewables and hydrogen, steps up energy diplomacy and aims to develop major hydrogen corridors in the Mediterranean and North Sea.

Hydrogen will be an integral part of REPowerEU Plan: a target of 10 million tonnes of domestic renewable hydrogen production and 10 million tonnes of imports by 2030 has been set, to replace natural gas, coal and oil in hard-to-decarbonise industries and transport sectors. In addition to this, to accelerate hydrogen projects, the Commission will top-up an additional funding of EUR 200 million to the overall budget of the Clean Hydrogen JU, to be matched by the same amount by the private members, so as to double the number of Hydrogen Valleys in the EU by 2025.

In line with all the policy developments described above, it is crucial that the Clean Hydrogen JU continues to support its new and on-going 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, 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;

[27] SWD(2022) 230 final.

[28] EU Platform established by the EC with the Member States for the common purchase of gas, LNG and hydrogen.

[29] EU external energy engagement in a changing world, SWD(2022) 152 final.

- Facilitating the market uptake of hydrogen via a number of Task Forces and Panels[30];
- 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 2023 of the Clean Hydrogen Joint Undertaking consists of the next 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 195 million. Additional EUR 60 million will be used to support different activities (including topping-up of related call topics) for increasing the number of Hydrogen Valleys across Europe. Specific support actions are also foreseen in the context of the parallel activities described in the SRIA.

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[31] 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 Map[32] to map this large number of (often high-level) objectives to more 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

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

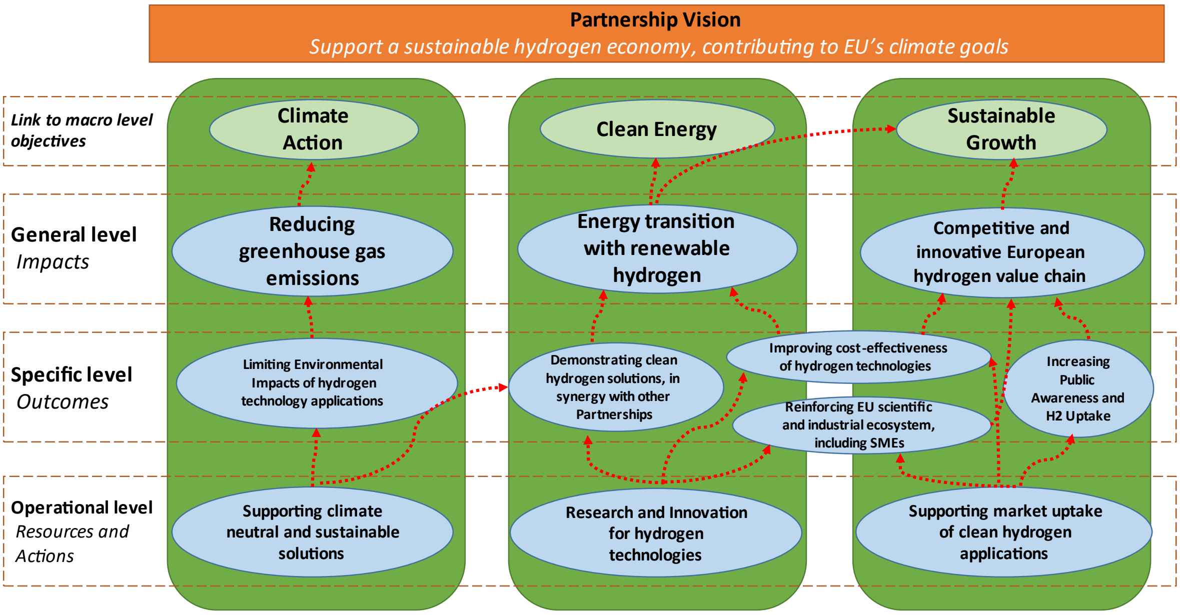
[31] "clean" meaning "renewable" in agreement with the definition of the Hydrogen Strategy, the only definition available at the time of adopting the SBA

[32] See Section 7 of the Clean Hydrogen JU SRIA.

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 Proposals[33], 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 JU[34] 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 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,

[33] In 2023, 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.
[34] The three members of the JU are the European Commission, Hydrogen Europe and Hydrogen Europe Research.

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 are 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 actions[35] 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 in the SRIA:

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 require a cost around 5 €/kg at the pump to achieve cost parity with diesel fuel[36]. For Industry, renewable hydrogen costs must reach levels between 2-3 €/kg as a feedstock[37], in order to achieve parity with fossil-based inputs, once the cost of carbon is included in the feedstock cost.

[35] The actions proposed for all the pillars are based on the final draft of the Strategic Research and Innovation Agenda, final draft October 2020, Hydrogen Europe and Hydrogen Europe Research (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.
[36] See Figure 15 in SRIA-HE/HER
[37] Green Hydrogen Cost Reduction: Scaling up electrolysers to meet the 1.5°C climate Goal, IRENA 2020

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 technology readiness level (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 CO_2 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 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 phase[38].

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.

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.

[38] 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.

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, the FCH JU has pursued the concept of hydrogen territories, which have evolved into the most recent concept of Hydrogen Valleys with the new Clean Hydrogen JU. A Hydrogen Valley is '*a defined geographical area, where the whole hydrogen value chain is implemented, from hydrogen production, storage and distribution, to its end use in various sectors (industry, mobility, housing, agriculture…)'.*

The idea is to demonstrate how all the different parts of the hydrogen value chain fit together in an integrated system approach. This concept has gained momentum and is now one of the main priorities of the 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 offer a competitive solution and work complementary with (or reuse of) other elements: renewable production, gas infrastructure, electricity grid, batteries, etc.

The REPowerEU Plan concurs with the need to develop Hydrogen Valleys based local renewables, demonstrating ecosystems that contribute to a faster sustainable energy transition via renewable hydrogen across the EU. The EC is therefore allocating an additional EUR 200 million for doubling the number of Hydrogen Valleys in the EU, while contributing to the wider goal of consuming 10 million tonnes of domestic renewable hydrogen by 2030. A key objective will be to progressively set up hydrogen local ecosystems which will accelerate the development of a EU hydrogen economy, interconnecting them step by step, and building on local renewable energy resources including mixing them to produce renewable hydrogen. Hydrogen Valleys could have various dimensions and various sets of end use applications.

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.[39] 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 competitiveness and innovation of industries, support the decarbonisation of the economy and reduce dependence on fossil

[39] Strengthening Strategic Value Chains for a future-ready EU Industry, EC, 2019.

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 (RTOs).

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 electrolysers 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, H_2 carriers);
- Advanced understanding of the performance / durability mechanisms of electrolysers 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 support 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 SBA[40] includes a number of tasks that the JU, its Governing Board and its Executive Director (supported by the Programme Office) 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 or complementary calls.

Moreover, it will seek and maximise synergies with and, where appropriate, possibilities for

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

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 preparing for support from deployment funds like the Innovation Fund, 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. According to the SBA, the JU should also support the Commission in its work in the CEM[41] and IPHE[42], both entities working on standardisation.

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 is twofold:

- To 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 a high-level hydrogen safety knowledge and culture within and beyond 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. It is expected that this Panel will start working in 2023.

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

[41] Clean Energy Ministerial
[42] International Partnership on hydrogen and fuel cells in the economy

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 Programme Office will continue to support the JRC and DG R&I by contributing to the Commission activities for the International Energy Agency (IEA) Hydrogen Technology Collaboration Programme (HTCP) where the Clean Hydrogen JU is participating in Task 41 on Analysis and Modelling of Hydrogen Technologies and Task 42 on Underground Hydrogen Storage.

Activities related to Communication

The JU will continue to 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 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 2023

2.1 Executive summary 2023 and message from the Executive Director

2.1.1 Message from the Executive Director

Dear Readers,

Tackling the climate crisis goes hand in hand with the need to transform Europe's energy system and end the EU's dependence on Russian fossil fuels. Clean hydrogen will play a key role in accelerating the green and just transition to the economy of the future. The European Commission RePower EU Plan calls for a consumption of 10 million tonnes of domestic renewable hydrogen in the EU by 2030. Following decades of research and innovation activities, our partnership has paved the way to starting the large-scale deployment of clean hydrogen technologies and transition to a hydrogen economy enabling innovation, growth, jobs and new skills development.

Within the current context there is an ever-stronger urgency to ensure EU R&I programmes deliver impactful results and we want to show exactly how we continue to contribute to this. The 2023 Work Programme of the Clean Hydrogen JU – its second - has an overall budget of EUR 200 million, with its biggest part allocated to the Call for Proposals.

In addition, the EC has allocated EUR 200 million until 2025, for doubling the Hydrogen Valleys across the EU. I am pleased to announce that this budget will be managed by the Clean Hydrogen JU to fund and encourage the development of more Hydrogen Valleys across Europe. In 2023, first commitment of EUR 60 million will be allocated in this respect to Hydrogen Valleys related activities.

Finally, I am pleased to inform you that the Clean Hydrogen JU is planning, in 2023, to develop a unique digital platform - the Clean Hydrogen Knowledge Hub, that will bring together and further develop the existing tools/platforms maintained by the JU, facilitating the access to a variety of data to its members and the wider public.

We are looking forward to seeing the new projects under the Call 2022 kickstart their operation and we look forward to receiving more proposals under the call 2023. Our success depends on the collaboration between the industrial, research and public sectors. We encourage you to keep up the excellent collaboration throughout the coming months – and years.

Enjoy the read!

Bart BIEBUYCK

Executive Director

Clean Hydrogen JU

2.1.2 Executive Summary

The second Annual Work Programme for the Clean Hydrogen JU will build on the Annual Work Programme 2022 and the SRIA, in alignment with the strategy for the implementation of the Programme, as described in Section 1.3.1.

In 2023, one Call for Proposals for an indicative total budget of EUR 195 million is foreseen, plus EUR 60 million from Horizon Europe, to be directed towards Hydrogen Valleys topics according to the REPowerEU Plan. 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 26 topics will be part of the call for proposals, including 7 for Renewable Hydrogen Production, 5 for Hydrogen Storage and distribution, 3 for transport and 4 for heat and power. In addition, 3 projects will support Cross-cutting issues. This call also includes 2 Hydrogen Valleys and 2 Strategic Research Challenge topics. They will be grouped into 11 Innovation Actions (IA), 13 Research and Innovation Actions (RIA) and 2 Coordination and Support Action (CSA). Five 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.

In the same year, the Clean Hydrogen JU intends to also publish three Calls for Tenders, covering subjects of strategic nature for the JU, for an indicative amount of EUR 3.7 million. These concern the development of the European Clean Hydrogen Knowledge Hub, the establishment of a service framework contract for the provision of support for the EHSP and a call for tenders for the setting up of the EHS&CP.

The Clean Hydrogen JU will continue to contribute towards the implementation of EU Policies through different means. The CertifHy3 project aims at facilitating the creation of an EU-wide system of guarantees of origin for hydrogen, with one of its main objectives being the to support the design of a RED II compliant Voluntary Scheme, with the aim to get it recognised by the EC. The JU will continue following and supporting EU energy, climate and transport decarbonisation objectives and policies, both via the selection of topics of scientific research and through studies. Finally, it remains ready to support the European Commission by cooperating with the European Clean Hydrogen Alliance, linking research partnerships with the industrial strategy[43].

A new Framework Agreement between Clean Hydrogen JU and the JRC was signed in the spirit of the previous Framework Contract. The annual Rolling Plan 2023 was agreed in 2022 and will be implemented in 2023. 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, as well as the JRC contribution to the assessment of sustainability of hydrogen and fuel cells.

In terms of knowledge management, the JU 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

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

or regional funds, as it is already the case for projects under cluster 5 of Horizon Europe. The JU intends to have the first brick of the European Hydrogen Observatory fully functional in the first half of 2023, i.e. a continuation of the Fuel Cell and Hydrogen Observatory platform. It will also publish a Call for Tenders for the development of the European Clean Hydrogen Knowledge Hub, a new platform, combining all platforms supported currently by the JU but with additional capabilities. 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) of the JU's predecessors, synergies have become a central piece of the 2021-2027 multi-annual financial framework. In 2023 the JU will further develop its 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 had synergies in their scope and cooperation with other funding sources will be sought specially for the flagship topics.

In 2023 the Clean Hydrogen JU will set up a Regulations, Codes and Standards Strategy Coordination Task Force for the definition, coordination and monitoring of the strategy related to regulations, codes and standards. The Task Force will follow up RCS development and assess further RCS needs of strategic importance to the EU, support the dissemination of results and support the Commission and the Member States in their related activities.

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.

The Clean Hydrogen JU will set up a European Hydrogen Sustainability and Circularity Panel at the Programme level тo support the Clean Hydrogen JU Programme implementation and the transition of the overall European hydrogen sector towards a sustainable and circular hydrogen economy, 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 some working groups of the IEA Hydrogen Technology Collaboration Program. Finally, it will continue supporting the Hydrogen Valleys platform, while contributing also towards the other activities of Clean Hydrogen Mission under MI2.0.

Communication and outreach activities in 2023 will have three main objectives. Firstly, to increase awareness, acceptance, and uptake of clean hydrogen solutions through integrated campaigns. Secondly to highlight the importance of the Clean Hydrogen JU as part of EU R&I on hydrogen and thirdly to enforce Clean Hydrogen's Joint Undertaking role on knowledge on hydrogen technologies at EU level.

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 also promoting other tools supporting further exploitation and dissemination.

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 JU[44]. In continuation of the work undertaken in previous years, corporate processes and procedures will continue to be simplified and improved. The JU will join further EU inter-institutional procurement procedures. Back-office arrangements will be implemented based on the agreed description of the target organisation model by the Executive Directors of the different Joint Undertakings. The Clean Hydrogen JU will take the lead for the organisation of ICT shared services. 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.

[44] 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 2023

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.[45]

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,[46] 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 framework[47] 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 JU[48] 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 JU[49] 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.

[45] Articles 5.2(h), 17.2(a), 19.4(f)/(g)/(o), 36, 74(a) and 171 of the SBA.
[46] HE Regulation Art 50(1) & SBA Art 171(2)(a-c-d-e)
[47] A robust and harmonised framework for reporting and monitoring European Partnerships in Horizon Europe, 2021, RTD, https://europa.eu/!b3TBfW.
[48] Annex I of the SRIA
[49] 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	*Qualitative indicator*	N/A	N/A	N/A	N/A	
	6. Supporting EC in H_2 market uptake	*Qualitative indicator*	N/A	N/A	N/A	N/A	
Outcomes							
Limiting environmental impacts	7. Environmental impact and sustainability	*TBD*[46]	*TBD*[50]	*TBD*[46]	*TBD*[46]	*TBD*[46]	
Improving cost-effectiveness	8. Capital cost of hydrogen applications	€/kW	*TBD*[46]	*TBD*[46]	*TBD*[46]	*TBD*[46]	
Synergies with other partnerships	9. Research and Innovation Synergies	# of projects	5	5	10	20	
Increasing Public Awareness	10. Public perception of hydrogen	*Qualitative indicator*	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	*TBD*[46]	N/A	N/A	N/A	TBD[46] (2030/ 2050)
Energy transition with renewable hydrogen	15. Deployment of electrolysers	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	*Qualitative indicator*	N/A	N/A	N/A	N/A	

[50] 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 JU.

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 in October 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	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 and additional budget from the REPowerEU (approx. one half to be committed in the first two years), with only two additional FTEs[51] for 2022 - 2027. While back-office arrangements are helping to harmonize the working processes between JUs, they have revealed that do not represent a solution for the issue above.	Use of service contracts for support activities in the Operations, while increased coordination will be explored through synergies with other joint undertakings on administrative activities. JU will continue to discuss with the Governing Board (GB) on the adequacy of the current staff establishment plan supported with a real workload analysis for the entire organization. JU will continue to investigate further simplification opportunities, among them such as use of the lump sums as a cost model in new calls/grants implementation.
MEDIUM	Supporting market uptake of clean hydrogen applications	Indicator 5 (Table 1)	Risk that the Clean Hydrogen JU is unable to manage and to report timely on EU hydrogen research and on the Horizon Europe KPIs and indicators, including the Key Impact Pathways, in accordance with its mandate. Relevant KPIs and Key Impact Pathways may not be all fully defined by the deadline for reporting them, while also reporting tools (i.e. CORDA, Horizon Dashboard) may not be ready to automatically report them.	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. The contracts for the Fuel Cell and Hydrogen Observatory (FCHO) and Hydrogen Valleys platform (H2V) will be expanded, with more data being collected. 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.

[51] 'full-time equivalent' positions

Risk Level	Objective	Indicators	Risk Identified	Action Plan
MEDIUM	Financial reporting objectives	Representative error rate	Due to inherent limitation stemming from a definition of H2020 ex-ante controls (trust-based approach) and due to fact that Clean Hydrogen JU encourages participations from newcomers and SMEs in the programme, representative error rate for Clean Hydrogen JU may increase. 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%. Since the ex-post audit strategy for the Horizon Europe has not been defined yet and could potentially result in additional risks for the JU.	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. Application of the feedback from ex-post audits and lessons learnt on ex-ante controls. Continuation of the financial webinars for beneficiaries with higher inherent and control risks. Follow up action after the webinars on reinforced monitoring. JU will assess the possibility of adding lump sum payments in the future calls.
MEDIUM	Synergies with other partnerships and programmes	Indicator 9 (Table 1)	Risk of missing opportunities for synergies with other partnerships and other EC programmes or MS/regional funds for hydrogen technologies due to lack of strategic guidance and consequently JU proper involvement in programming activities.	The programme office continues currently to act on ad-hoc basis on the synergy efforts required by the SBA, building on the extensive experience in implementing such synergies in the predecessor FCH JU (see chapter 2.2.6). Working with the newly established Stakeholder group should be also better explored, to propose and follow-up on synergies with the Programme Office in an effective manner. JU will continue to report to the Governing Board and will continue to seek strategical guidance.

Risk Level	Objective	Indicators	Risk Identified	Action Plan
MEDIUM	Reporting financial objectives / Operational objectives	Indicators 1-5,9,12,13 (Table 1)	Risk that in-kind contribution balances are significantly misstated and some JUs projects failing on eligibility criteria due to lack of clear identification and timely update of private members membership (of Hydrogen Europe and Hydrogen Europe Research) status within JU projects.	A process to ensure eligibility criteria and their continuous monitoring throughout lifetime of the projects should be put in place. JU will continue an active dialogue with the private members and with the Commission central services to further develop the information technology (IT) tools for sufficient data accuracy

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 that are needed to reach the SRIA objectives.

In line with the structure of the SRIA, topics in the Call for Proposals 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 approach 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 KPIs[52] that each of the topics (and successful proposals) should reach.

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

In 2023 the Call for proposals will contribute to the objectives of the Clean Hydrogen JU 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

Hydrogen will be an integral part of REPowerEU Plan. A target of 10 million tonnes of domestic renewable hydrogen production has been set, to replace natural gas, coal and oil in hard-to-decarbonise industries and transport sectors. To seize this opportunity and keep European electrolyser industry at the forefront and to support the achievement of the EU performance and cost targets it is necessary to translate our scientific excellence into technological industrial leadership. To this end, in 2023 the Clean Hydrogen JU will support low TRL research activities aiming at developing new and disruptive cell concepts for improving efficiency, lifetime, and hydrogen production processes in the field of low temperature electrolysis. Similarly in the field of high temperature electrolysis (Solid Oxide and Proton Conducting Ceramic) support will target the development of new and more robust cell and stack designs whilst replacing costly ceramic-based components and reducing critical raw materials. Support to alkaline electrolysis is foreseen aiming at achieving incremental improvements in performances and costs.

Beyond electrolysers, support will also be provided to further validate alternative routes for hydrogen production covering Photoelectrochemical (PEC) and Photocatalytic (PC)

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

production of hydrogen.

Ultimately, there will be support also to three Innovation Action which are considered as flagships, due to their strategic importance in field-demonstration of current developed technologies. The first one concerns the demonstration of a waste to hydrogen plant of at least 3 MW. In the field of electrolysis, support is foreseen for the demonstration of concepts that enable the further valorisation of the by-product O_2 and/or heat from electrolysis (in addition to the obvious hydrogen use). This action seeks to showcase optimum integration of electrolyser technology (>15 MW) into industrial processes and to improve the economics and the total cost of ownership of electrolysers in such applications. Finally, support will be provided to a flagship project looking at the installation and operation of a hydrogen pipeline network in a local area as a solution to interconnect the electrolyser (>10 MW) with a several number of industrial end users.

Scientific priority - Hydrogen Storage and distribution

According to the same REPowerEU ambitions published in May 2022, about 10 million tonnes of renewable hydrogen should also already be distributed throughout Europe in 2030. It is therefore 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. Therefore, in 2023 Clean Hydrogen JU will support a flagship project looking at the large-scale demonstration of underground hydrogen storage.

In addition, an EU-wide logistical infrastructure is still to be developed (to transport hydrogen from areas with large renewable potential to demand points across Europe). Significant work is therefore still needed to have a complete set of technologies that can serve as building blocks for such EU-wide logistical infrastructure. In that respect, in 2023 Clean Hydrogen JU will support a number of actions on this area.

Looking at gaseous hydrogen, in 2023 Clean Hydrogen JU will support Pre-Normative Research addressing the compatibility of Transmission gas grid steels with hydrogen.

In addition, having in mind the expected large-scale deployment of heavy-duty vehicles and the increased use of industrial gaseous hydrogen mainly for trucks and trains, it remains essential to decrease the cost of transportation of such gaseous hydrogen. For this it is necessary to enable transportation of hydrogen at larger pressure than is currently the case and to develop hydrogen refuelling stations (HRS) able to deliver high quantities of gaseous hydrogen. In 2023 Clean Hydrogen JU will therefore support the demonstration of a whole logistic chain from the filling centre (used to load the trailers at high pressure >500 bar), through the trailers on the road up to the hydrogen refuelling station. Projects supported will completement actions supported already in the AWP 2022 and looking at the development of compressed gas tube trailers with increased capacity and new/optimised refuelling protocols and components for high flow HRS.

Finally, in the near-term, liquid hydrogen is expected to become also an essential hydrogen carrier and fuel. In 2023 Clean Hydrogen JU will support research on novel insulation concepts for liquid hydrogen tanks. In addition, an Innovation Action will support the demonstration of liquid hydrogen (LH_2) refuelling stations (delivery flowrate > 5 tonnes LH_2 per hour) for heavy duty applications (in synergy with this, refuelling for aviation environments will be supported in Cluster 5 of the Commission Horizon Europe WP23-24).

Scientific priority - Hydrogen end uses - transport

It is widely agreed that hydrogen will be an essential element (either as a fuel or as part of other fuels like ammonia, acting as hydrogen carriers) to decarbonise the maritime sector. However larger applications require large amounts of power and long lifetimes. In 2023, Clean Hydrogen JU will therefore support research targeting at the validation of high power and long-lasting stacks for multi-MW fuel cells for maritime applications.

On the aviation sector, and in synergies with the Clean Aviation JU, in 2023 Clean Hydrogen JU will support the laboratory validation of Ultra-low NO_x combustion systems for aviation (results to be taken-up by Clean Aviation JU for demonstrations at a later stage).

Finally, to mitigate the climate impact of combustion engines in Non-Road Mobile Machinery (NRMM) (e.g. diesel or gasoline fuelled) an Innovation Action will support the demonstration of hydrogen fuel cell based systems for such applications (mainly in the construction and agricultural sectors).

Scientific priority - Hydrogen end uses - clean heat and power

Hydrogen offers a unique chance also to decarbonise the power generation and heating sectors. In 2023 Clean Hydrogen JU will support all applications included in the SRIA (fuel cells, turbines and burners/furnaces).

On fuel cells the aim will be to develop large power fuel cells for applications where hydrogen impurities can be expected (like equipment for cold ironing in ports).

On gas turbines the Clean Hydrogen JU will continue supporting the necessary research aiming at developing the next generation of gas turbines able to run on hydrogen and variable blends of hydrogen (whilst keeping low emissions and high performances). In addition, an Innovation Action will look at the retrofitting of existing turbomachinery cogeneration systems of at least 10 MW for industrial applications to be able to operate on pure hydrogen.

Finally, support will be provided to the demonstration of retrofitting solutions (e.g. burners, furnaces) using hydrogen for heat production for hard-to-abate industries.

Scientific priority - Cross-Cutting activities

As markets for hydrogen and fuel cell technologies develop and these technologies become more widely adopted, it becomes crucial to prepare the necessary workforce. In 2023, complementing the ongoing project GreenSkills4H2[53] the Clean Hydrogen JU will provide support for the development of an extensive repository of training and education courses which will be used to train and certify a network of trainers (targeting vocational and higher education).

In addition, support will be provided for the development of Product Environmental Footprint Pilots for several FCH Product Categories (from Hydrogen Production to Hydrogen Use),

Finally support will be provided to Pre-Normative Research concerning the determination of hydrogen releases from the hydrogen value chain. Support in this area complements (in synergy) the one included in Cluster 5 of the Commission Horizon Europe WP2023-2024 looking at the Climate impacts of a hydrogen economy.

Scientific priority - Hydrogen Valleys

The European Commission REPowerEU Plan strives to have Hydrogen Valleys established

[53] supported by ERASMUS programme

in all Member States and to double the number of Hydrogen Valleys across Europe by 2025. To support this ambition, in 2023 the Clean Hydrogen JU will continue supporting several flagship[54] Hydrogen Valleys of different scales.

Moreover, as part of the REPowerEU Plan the Commission will provide to the JU an additional budget of EUR 200 million, to accelerate further the deployment of Hydrogen Valleys in Europe, out of which EUR 60 million will be already allocated to such activities in the AWP 2023.

Scientific priority - Hydrogen Supply Chains

In 2023 a tender[55] will continue to be conducted on sustainable supply chain and industrialisation of hydrogen technologies to identify the EU entities for each step of the supply chain, analyse the European manufacturing capacity and find potential gaps in the domestic supply alongside evaluating the competitiveness, circularity and socio-economic aspects.

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. An important objective of all strategic research challenges is to provide input for the development of next generation of technologies (or products) and to identify priorities for future programming.

In 2023 the Clean Hydrogen JU will support two actions. The first one targets the development of advanced materials to reduce costs and produce lighter hydrogen storage solutions (with a focus on gas, liquid or cryo-compressed states supporting high-pressure tanks even up to 1,000 bars). In addition, the EU security of materials supply/independency should be investigated and addressed. All materials used should comply with the actions laid out in the REPowerEU Plan and other EU initiatives relevant to this topic.

The second action aims to generate in-depth understanding of mechanisms underpinning the degradation of fuel cell and electrolyser stacks over long term operation (with the objective of Increasing the lifetime of fuel cell and electrolyser stacks and systems),

[54] For definition of flagship see section 5.3 of SRIA
[55] Call for Tender launched in 2022 (as part of the AWP 2022)

Table 2 Correspondence of topics into the different scientific priorities

	Topic identifier	Topic Title	Type
Renewable Hydrogen	HORIZON-JTI-CLEANH2-2023-01-01	Innovative electrolysis cells for low temperature hydrogen production	RIA
	HORIZON-JTI-CLEANH2-2023-01-02	Innovative Solid Oxide electrolysis cells for intermediate temperature hydrogen production	RIA
	HORIZON-JTI-CLEANH2-2023 01-03	Advances in alkaline electrolysis technology	RIA
	HORIZON-JTI-CLEANH2-2023-01-04	Photo(electro)chemical (PEC) and/or Photocatalytic (PC) production of hydrogen	RIA
	HORIZON-JTI-CLEANH2-2023-01-05	Waste to Hydrogen demonstration plant	IA (flagship)
	HORIZON-JTI-CLEANH2-2023-01-06	Valorisation of by-product O2 and/or heat from electrolysis	IA (flagship)
	HORIZON-JTI-CLEANH2-2023-01-07	Hydrogen use by an industrial cluster via a local pipeline network	IA (flagship)
Hydrogen storage and distribution	HORIZON-JTI-CLEANH2-2023-02-01	Large-scale demonstration of underground storage	IA (flagship)
	HORIZON-JTI-CLEANH2-2023-02-02	Pre-Normative Research about the compatibility of transmission gas grid steels with hydrogen and development of mitigation techniques	RIA
	HORIZON-JTI-CLEANH2-2023-02-03	Novel insulation concepts for LH_2 storage tanks	RIA
	HORIZON-JTI-CLEANH2-2023-02-04	Demonstration of high pressure (500-700 bar) supply chain	IA
	HORIZON-JTI-CLEANH2-2023-02-05	Demonstration of LH2 HRS for Heavy Duty applications	IA
Hydrogen end uses: transport applications	HORIZON-JTI-CLEANH2-2023-03-01	Real environment demonstration of Non-Road Mobile Machinery (NRMM)	IA
	HORIZON-JTI-CLEANH2-2023-03-02	Development of a large fuel cell stack for maritime applications	RIA
	HORIZON-JTI-CLEANH2-2023-03-03	Ultra-low NO_x combustion system for aviation	RIA
Hydrogen end uses: clean heat and power	HORIZON-JTI-CLEANH2-2023-04-01	Development and validation of high power and impurity tolerant fuel cell systems ready to run on industrial quality dry hydrogen	RIA
	HORIZON-JTI-CLEANH2-2023-04-02	Research on fundamental combustion physics, flame velocity and structure, pathways of emissions formation for hydrogen and variable blends of hydrogen, including ammonia	RIA
	HORIZON-JTI-CLEANH2-2023-04-03	Retrofitting of existing industrial sector natural gas turbomachinery cogeneration systems for hydrogen combustion	IA
	HORIZON-JTI-CLEANH2-2023-04-04	Hydrogen for heat production for hard-to-abate industries (e.g. retrofitted burners, furnaces)	IA

	Topic identifier	Topic Title	Type
Cross-cutting Issues	HORIZON-JTI-CLEANH2-2023-05-01	Product environmental footprint pilot for a set of FCH product categories	CSA
	HORIZON-JTI-CLEANH2-2023 -05-02	European hydrogen academy	CSA
	HORIZON-JTI-CLEANH2-2023 -05-03	Pre-Normative Research on the determination of hydrogen releases from the hydrogen value chain	RIA
Hydrogen Valleys	HORIZON-JTI-CLEANH2-2023 -06-01	Large-scale Hydrogen Valley	IA (flagship)
	HORIZON-JTI-CLEANH2-2023 -06-02	Small-scale Hydrogen Valley	IA (flagship)
Strategic Research Challenges	HORIZON-JTI-CLEANH2-2023-07-01	Advanced materials for hydrogen storage tanks	RIA
	HORIZON-JTI-CLEANH2-2023 -07-02	Increasing the lifetime of electrolyser stacks	RIA

2.2.3 Call for Proposals

2.2.3.1 Overview of the Call

The AWP 2023 includes one Call for Proposals as follows:

Call Identifier	Budget (EUR mill)	Publication[56]	Deadline
HORIZON-JTI-CLEANH2-2023-1	195.00	17 January 2023	18 April 2023

The European Commission in its communication "REPowerEU Plan[57]" announced an additional investment of EUR 200 million available for the Clean Hydrogen JU for doubling the Hydrogen Valleys in the EU by 2025.

It is expected EUR 60 million from this budget to be included in the AWP2023 budget either in Hydrogen Valleys topics reserve lists from Call 2022-2 or Call 2023, or other activities to support Hydrogen Valleys – such as project development or technical assistance.

Topic descriptions are detailed starting from the next page.

[56] The Executive Director may decide to open the call up to one month prior to or after the envisaged date of publication.
[57] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483

RENEWABLE HYDROGEN PRODUCTION

HORIZON-JTI-CLEANH2-2023-01-01: Innovative electrolysis cells for hydrogen production

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 3.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 6.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project - see General Annex B.
Procedure	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

Water electrolysis for hydrogen production is a mature and well-established technology with major industrial deployments since the beginning of last century. Nevertheless, it still needs significant improvements. Despite the incremental type of research, a seek for breakthrough solutions should be incorporated into the research performed to transform the technology. These can include novel designs of the cells, as well as application of the disruptive components and introduction of innovative ideas synergistically resulting in systems able, through the continuity of the further research, to fulfil the needs of the gigawatt sized storage of renewable energy.

However, potential availability of systems of such magnitude is quickly transforming electrolytic hydrogen into an industrial commodity and significant barriers with regards to the use of electrolyser devices at such scale remain. Green hydrogen is on average still more expensive than hydrogen produced from reformatted natural gas. Henceforth, innovative actions will be required to: i) remarkably improve the voltage efficiency of water electrolysers ii) dramatically reduce the cost of these devices with the largest share for capital cost still occurring at the stack level, iii) reach durability and robustness levels that are compatible with today's stationary energy systems and iv) address breakthrough solutions for innovative processes such as direct electrolysis of sea water and wastewater.

Hence, the development of disruptive components and cell concepts leading to a dramatical change in efficiency, lifetime, and reducing the total cost of ownership of hydrogen in electrolysis is the goal, transforming these electrolysers into devices of next generation. To the most part, classic alkaline (AEL) and polymer electrolyte membrane (PEM) electrolysis have stacks with materials and components that were developed in the last century. Thick inorganic diaphragms, rudimentary designs for electrodes and porous transport layers, PGM based catalysts and protective layers, and membranes that still fail to avoid gas-crossover at high differential pressure, can be significantly improved for next generation water electrolysers.

Innovative electrolysis cells can be only achieved by a multidisciplinary approach combining outstanding advances such as but not limited to materials science, nano-engineering, bio-hybrids catalysts (such as natural or engineered enzymes, peptides and protein based-maquettes or whole cells interfaced with electroactive materials and/or polymers or combined with organometallics clusters from separate synthesis), and innovative manufacturing approaches. It is expected creation of materials, components, and innovative cell designs that can completely change the paradigm of hydrogen production using devices with improved levels of efficiency, cost, and durability.

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

- Transform electrolysers into next generation devices with a higher level of competitiveness *in comparison to* classic AEL and PEM electrolysers.
- Develop materials that can be used in and/or adapted to water electrolysers. These materials should be fabricated into components with high efficiency, stability, recyclability, no CRMs, the ability to mass-production and a circular-economy character.
- Open new ways for disruptive concepts towards performance levels close to the theoretical Higher Heating Value (HHV) of these electrolysers, i.e., higher to what is typically observed in cells and stacks for conventional AELs and PEMELs.

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

- Strongly reduce the overall use of critical raw materials in the fabrication of cell/stack components to < 1.25 mg/W per cell for PEM electrolysers, and to < 0.3 mg/W for alkaline cells.
- Decrease the electricity consumption at nominal capacity aiming at values below 48 kWh/kg of hydrogen.
- Eliminate or dramatically reduce interface resistance values across cell components.
- Develop diaphragms, membranes, or membrane-less electrolysers that can operate at minimum 5% of partial load operation (nominal load 2 A/cm^2 for PEM and 0.5 A/cm^2 for alkaline cells) without exceeding 0.4 % of H_2 concentration in O_2.
- Long-term stable and efficient materials for high-current density operation, i.e., 1.0 A/cm^2 for AEL and 3.0 A/cm^2 for PEM.

Scope

This topic aims at the development of new and disruptive cell concepts for improving efficiency, lifetime, and hydrogen production processes in the field of water electrolysis, while replacing costly materials on components of the cell and stack. The topic seeks the integration of recent advances in materials science and modern characterisation/fabrication tools, merged into innovative lab scale developments of components of electrolysis cells. The target is to realise at least single cells of TRL 4 and validate all innovative approaches using single cells and short stacks with min. 5 cells.

Proposals should explore more than one of the following innovations:

- Alternative pathways to the oxygen evolution reaction by new anode approaches which allow to reduce the anode potential in acidic media;
- Inclusion of redox mediators to separate anode and cathode reactions;
- Use of nano-engineering, bio-hybrid electrocatalyst materials or integrated multi-functional components as innovative strategies to improve cell performances;
- Application/development of catalysts with low overpotential and combined to low-cost elements (e.g., Fe, Ni, steel), bridging a gap to have stable and low-cost production;
- Novel concepts of triple-phase boundary electrodes (catalyst-support-ionomer) with catalyst utilisation close to 100% and improved thermo-mechanical stability;
- Create novel concepts of membrane electrode assemblies (MEAs) with integrated components (Porous Transport Electrodes (PTEs)), simplified and environmentally friendly manufacturing methods;
- Novel cell design to enhance overall cell efficiency by integrating disruptive concepts (e.g., flow fields using new fluid dynamic effects, novel concepts of micro-fluidic and capillary-fed electrolysers, optimised interfaces between cell materials, or innovative stack components designs);
- Optimised thermal management, e.g., avoiding hot spots in the cells as major cause for catalyst and separator degradation;
- Consortia are expected to build on the expertise coming from both research and industrial community to ensure broad impact by addressing several of the aforementioned items.

Development of Solid-oxide or Proton Conductive materials and cells are excluded from the scope of this specific topic.

It is expected to have access to application based as well as manufacturability requirements (through direct participation of a manufacturing company and/or through an advisory board), to foresee a scaling up of the validated solution.

Proposals are expected to collaborate and explore synergies with the projects supported under topics HORIZON-JTI-CLEANH2-2023 -07-02: 'Increasing the lifetime of electrolyser stacks' and HORIZON-JTI-CLEANH2-2022-07-01: 'Addressing the sustainability and criticality of electrolyser and fuel cell materials'.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

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 protocols[58] to benchmark performance and quantify progress at programme level.

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

HORIZON-JTI-CLEANH2-2023-01-02: Innovative Solid Oxide electrolysis cells for intermediate temperature hydrogen production

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 3.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 3.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project - see General Annex B.

Expected Outcome

Large scale sustainable hydrogen production is necessary to implement hydrogen as an energy vector in a future decarbonised economy. High temperature electrolysers based on solid oxide cells, so-called SOEL, offer the highest electrical efficiency among competing electrolyser technologies, but their capital expenditure (CAPEX) and degradation rates remain higher than AEL and PEMEL. In addition, their capability to operate under dynamic conditions of variable load and rapid start up, as required for direct coupling with renewable and intermittent energy sources, is more limited due to the brittleness and thermal inertia of ceramic components.

The outcome of this topic will be an innovative low-cost and compact cell and stack concept that can be operated at intermediate temperatures (up to<700°C), enabling dynamic operations (i.e. variable load and rapid start and stop) and longer lifetime for energy efficient hydrogen production, therefore contributing to the overall objectives of the Clean Hydrogen JU SRIA to reduce hydrogen production cost to 3 €/kg by 2030.

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

- Cells and stacks produced by scalable manufacturing techniques with potential for later integration and automation into a pilot line;
- Cells and stacks designed for flexible operation at intermediate temperatures (550-700°C) and variable load and rapid start and stop (for coupling with renewable energy sources);
- Renewable hydrogen production with direct coupling of renewable energy sources potentially benefiting from thermal integration and reducing CO_2 footprint;
- European leadership for renewable hydrogen production based on SOEL electrolysers;
- Strengthened European value chain on electrolyser components with decreased reliability of critical raw materials from international imports;

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

- Demonstrate successful start-up of the stack with a hot idle ramp time of 240 second and cold start ramp time of 6 hours;

- Increase current density of cells to 1.2 A/cm^2 for SOEL;
- Demonstrate a degradation rate of 0.75%/1000hr at current density of 1.2A//cm^2;
- Establish a roadmap for defining technological pathways enabling to reach: CAPEX ~ 520 €/(kg/d) and operational expenditure (OPEX) of 45 €/(kg/d)/y, values given in SRIA for 2030;

Scope

The topic focuses on the development of new cell and stack designs, aiming at the replacement of costly ceramic-based components and reduction of critical raw materials (e.g. light and heavy rare earth materials, LREE and HREE)[59], and use of lower cost steels. Improved thermal and load cycling capabilities (faster and higher number of thermal cycles) should be ensured by designing new cells and/or stacks based on e.g. metal supported cells/stacks, cells with integrated interconnect/current collector/electrode and/or metal-based monolith cells/stacks and/or intrinsically more robust cell/stack design/assembly. The stack volume should be reduced compared to state-of-the-art stacks, by 15%. This can be sought by nano-engineering and/or self-assembly of interfaces, integrating several functionalities in single components and/or by developing thinner layers that can also contribute to reduce ohmic losses.

The new sustainable-by-design electrolysers will operate at temperature below 700°C to minimise thermally induced degradation and facilitate direct coupling with renewable sources (heat and steam) from e.g., geothermal plants or solar power plants, with efficient thermal management.

Proposals should address the following:

- Design of new cells and/or stacks based on e.g. metal supported cells/stacks, cells with integrated interconnect/current collector/electrode and/or metal-based monolith cells/stacks and/or intrinsically more robust cell/stack design/assembly, and validation in short stack; any results coming out from the SRC projects (e.g. HORIZON-JTI-CLEANH2-2022-07-01: 'Addressing the sustainability and criticality of electrolyser and fuel cell materials') which could be relevant for this topic should be considered;
- The short stack based on 5 cells with an active area of minimum 25 cm^2 per cell should be operated under representative conditions of the targeted application(s) to evaluate its performance and durability over minimum 1000 hours of continuous testing and 2000 hours of accumulated testing;
- Effect of rapid thermal cycling and load cycling on voltage degradation should be investigated. The testing should be in line with protocols set-up by the JRC;
- Fluid dynamics and multi-physics modelling should be used to determine the optimal cell and stack architectures considering thermal management within the stack and optimising its compactness;
- Increased current density of the cells should be obtained by e.g., designing thinner electrolytes and/or new electrodes with improved materials/architectures;
- Corrosion stability of the metal-based components should be validated in relevant

[59] https://www.crmalliance.eu/hrees

operating conditions, in particular for the steam side of the electrolyser, and if needed, improved by development of protective coatings;

- Degradation mechanisms of the cell/stack components should be identified with respect to temperature and load including in dynamic conditions, ripples and transients;
- The cell and stack manufacturing methods should be based on processes that have the potential to be scaled-up, automatised and mass-manufactured at a later stage;
- Techno-economic evaluation of the steam electrolyser integrated in given application(s) and considering economy of scale will provide the Levelised Cost of Hydrogen (LCOH) and will be used to provide insights into relevant business models. The CAPEX of the novel stack concept should be compared to state-of-the-art SOEL stacks as well as other electrolyser technologies such as PEM and alkaline.

Proposals are expected to address sustainability aspects by reducing the use of critical raw materials compared to state-of-art cells and/or stacks and/or their recycling.

Consortia are expected to build on the expertise from the EU 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 previous EU supported projects such as METSAPP[60], METSOFC[61], RAMSES[62] and NEWSOC[63] and be complementary to them.

Proposals are expected to collaborate and explore synergies with the projects supported under topics HORIZON-JTI-CLEANH2-2023 -07-02: 'Increasing the lifetime of electrolyser stacks' and HORIZON-JTI-CLEANH2-2022-07-01: 'Addressing the sustainability and criticality of electrolyser and fuel cell materials'.

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 protocols[64] to benchmark performance and quantify progress at programme level.

[60] https://cordis.europa.eu/project/id/278257
[61] https://cordis.europa.eu/project/id/211940
[62] https://cordis.europa.eu/project/id/256768
[63] https://cordis.europa.eu/project/id/874577
[64] https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2023-01-03: Advances in alkaline electrolysis technology

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 2.50 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 2.50 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project -see General Annex B.

Expected Outcome

At present, Europe has an industrial leadership on electrolyser technologies with about two thirds of main players globally. The industrial competitiveness and the quality of the technologies together with the background competences should be supported by a continuous development process looking to both incremental improvements and breakthrough innovations, trying to keep competitiveness in both available solutions in the market and next generation technologies. Alkaline electrolysers are, in this respect, a mature and consolidated technology, available in the market at large scale, looking to play the challenge of lighthouse project initiatives at the scale of hundreds of megawatts (MW) or even gigawatts (GW) of power capacity.

However, the AEL technology requires additional improvements in terms of performance and cost reduction from materials to improved balance-of-plants components, control strategies and systems. Research and innovation implementing novel solutions is therefore needed.

These will serve as an outcome to sustain the improvement of the cells and stacks, of the manufacturing processes, of the supply chain support, and will provide an impact on both technology CAPEX and OPEX, as well as the TCO. The R&I activities will consist of a direct support to meet the targets of the SRIA in terms of technology performances, including reaching the targets indicated by the European Hydrogen Strategy, and in order that the technology provides better business cases and integrate better into the specific use cases.

Although AEL is an industrially well-established technology, it presents still some weaknesses when compared to PEM technology. The maximum current density of AEL stacks is generally lower, resulting in bulkier stacks and systems, the dynamic response of AEL is slower, and the minimum current density is limited by safety issues related to gas crossover. However, one of its strengths is the possibility of avoiding the use of expensive and scarce PGM, although many of the large AEL installations that enter service before 2025 are going to rely on AEL technology that includes significant amounts of PGM.

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

- Improve the competitiveness of the expected solutions versus the state of the art today in the market;
- Keep the EU specific sector of AEL in the forefront of international competition;
- Improve the electrolyser's performances (e.g., in terms of current density, dynamic

behaviour) and contribute to the achievement of the SRIA KPIs at the level of system and stack (as per Annex 2 Table 2 State-of-the-art and future targets for hydrogen production from renewable electricity for energy storage and grid balancing using alkaline electrolysers);

- Reduce CAPEX and OPEX of the stack by introducing better performances and improved novel components of the cell and related parts.

Project results are expected to contribute to the following objectives and KPIs of the Clean Hydrogen JU SRIA. At least one of the following KPIs should be improved while maintaining the others at the present state of the art (SoA):

- With the aim to reduce the CAPEX, increase the cell current density (minimum 1.2 A/cm2 @ < 2V). Alternatively, as a means to reduce the OPEX, improve the conversion efficiency (nominal electric consumption <48 kWh/kg @ <2V per cell). The different specific conditions should be demonstrated, and the nominal operating point of the stack being optimised considering overall performance, stack lifetime and the TCO, among others;

- Achieve a degradation rate <0.1%/1000h, measured as % efficiency at lower heating value (LHV) and technology reliability;

- Reduce CAPEX of the stack down to 150 €/kW and OPEX to 35 €/(kg/d)/y;

- Avoid the use of PGM and other CRM to ensure the scalability of the technology.

Additional objectives maybe also targeted such as:

- Improve the dynamic behaviour in cold ramp up and partial load, with higher flexible operation in line with the SRIA KPIs for 'Flexible electrolyser operation';

- Improve operation range, especially at low power (crossover, safety, etc.) at the same performances of the best-in-class technology (e.g. 10-100% PEMEL);

- Decrease the hydrogen and oxygen cross flow phenomena between the anode and cathode side, at a safety standard 50% lower explosive limit (LEL).

Scope

This topic aims at advancing AEL technology by improving performances and reducing costs. AEL technology, despite the high maturity of the proposed market solutions, can be improved in order to keep the EU electrolyser industry at the forefront and to support the achievement of the EU performance and cost targets, widening the range of applications where renewable hydrogen produced by AEL could be deployed to support decarbonisation efforts. Anyway, improved performances and solutions will add margins to this target and a better satisfaction of the specific challenge.

The topic aims to facilitate the integration of innovative lab scale developments in the alkaline electrolysis technologies landscape into pilot industrial scale systems for their validation and further escalation into industrial MW scale systems.

The successful proposal should be able to test and validate in a lab and in a relevant environment the targeted innovative parts or components.

The project should explore some of the following innovations:

- New electrocatalysts and electrode materials for alkaline water electrolysis operating at high current density and high energy efficiency based on non-platinum group metals, and preferably on non-critical materials;
- Novel concepts of porous transport electrodes free of precious metal coatings with integrated micro-porous-layer and electrocatalysts;
- Explore new electrode production technologies for more efficient mass production (e.g., advanced electroplating, plasma spraying, physical vapor deposition), combined with development of electrocatalysts for alkaline water electrolysis;
- Improve the separators and/or (microporous) membranes, reaching higher ionic conductivities (enabling higher current densities), improved mechanical properties (enabling thinner membranes), lower gas cross-over (enabling operation at lower load points without safety issues);
- Realise the novel proposed AEL short stack at the scale of at least 10 kW, with a minimum cell area of 100 cm^2 and at least 10 cells for the stack, validating in a laboratory environment the specific performance targets;
- Investigate the potential to increase the temperature to a higher operating window. Develop new alkaline electrolysis systems operating at high temperature, validated at small scales, to improve the operational temperature and energy efficiency (e.g., over 95°C and below 48 kWh/kg);
- Advanced thermal management to shorten start-up time from warm stand-by, (e.g., by intelligent heat storage or insulation schemes);
- Reduce the use of noble metals and critical raw materials, improving the life cycle assessment aspects;
- Moving a step forward with respect to testing procedures and standardised qualifying tests (e.g., considering results from Qualygrids project as well as referring to JRC standardised protocols).

Taking advantage of JRC EU harmonised protocols[65] for testing of low temperature water electrolysis, it will help updating the standardised testing protocols representative of validating the expected outcomes. This would involve laboratory-based testing of the different integrated improvements into cells and stacks.

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

It is expected to have at least one alkaline electrolyser' manufacturer as a member of the consortium, to exploit the results and foresee a scaling up of the validated solution.

Proposals are expected to collaborate and explore synergies with the projects supported under topics HORIZON-JTI-CLEANH2-2023 -07-02: 'Increasing the lifetime of electrolyser stacks' and HORIZON-JTI-CLEANH2-2022-07-01: 'Addressing the sustainability and criticality of electrolyser and fuel cell materials'.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

[65] https://op.europa.eu/en/publication-detail/-/publication/bbbeba00-ee82-11eb-a71c-01aa75ed71a1/language-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 protocols[66] to benchmark performance and quantify progress at programme level.

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

HORIZON-JTI-CLEANH2-2023-01-04: Photoelectrochemical (PEC) and/or Photocatalytic (PC) production of hydrogen

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 2.50 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 2.50 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	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

Photo(electro)chemical systems have been identified as one of the promising technologies to meet long-term hydrogen-production goals as they integrate the photovoltaic and electrolysis function in a single energy conversion step. Remarkably, the direct use of sunlight to bias the chemical reaction also decouples the hydrogen-production process from power price fluctuations. Together, these provide advantageous prospects for the reduction of both CAPEX and OPEX, especially in geographies with large renewable potential.

From a technological point of view, commercial photo(electro) chemical systems are expected to benefit from simplified Balance-of-Plant (BoP) architectures, enabling a market penetration at both centralised and decentralised level. Additionally, R&D in materials science should aim to discover novel abundant and cost-effective photo(electro) catalyst as well as more integrated process design promises in the photovoltaic, electrolysis and bio-chemical fields.

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

- Development of breakthrough technologies able to harvest the renewable energy source potential in the EU regions and neighbourhoods;
- Strengthening the solar-energy conversion technologies EU value-chain, in terms of both innovation and manufacturing capability;
- Contribute to the demonstration of the first scalable photo(electro)chemical system by 2028;
- Execution of techno-economic analyses and/or technology-transfer scenarios for the simultaneous production of renewable hydrogen and value-added chemicals or biomass/waste reformate obtained from sunlight-driven process.

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

- Reducing CAPEX and OPEX, improving the efficiency of processes and scaling up
- For PEC systems, a solar-to-hydrogen conversion efficiency higher than 15% as well as the build-up of a demonstration PEC cell with an active area of at least 500 cm^2. Additionally, the Faraday efficiency should exceed 90 % and the cumulated operation time under natural sunlight should be higher than 500 hours;
- For PC systems, a solar-to-hydrogen conversion efficiency higher than 5% as well as

the build-up of a demonstration PC reactor with an active area of at least 500 cm^2. Additionally, the cumulated operation time under natural sunlight should be higher than 500 hours.

Scope

Photo(electro)chemical systems are expected to play a major role in renewable hydrogen production, aiming to compete on a medium- to long-term basis with commercial systems comprising separated photovoltaic and electrolysis modules. These systems, despite the continuous improvements being achieved at the stack cost, still suffer from expensive BoP units – especially the electrical components – that typically amount to half the system cost. In addition to that, the LCOH is largely determined by price of electricity needed for the electrolysis process. Innovative technologies, complementing the CAPEX and OPEX optimisation efforts infused to electrolysers R&D, are highly sought to accelerate the market competitiveness of renewable hydrogen.

Notably, solar-to-hydrogen (STH) conversion systems such as photovoltaic + electrolysis (PV+EC) have been widely investigated to tackle the aforementioned issues. Similarly, in the PECDEMO[67] project lab-scale hybrid PEC-PV specimens have reached STH efficiencies above 15% (also under concentrated irradiation), active areas greater than 50 cm^2 and stability of 1000 hours, but not in one device. Improvements to such figures-of-merit have been later demonstrated in the PECSYS[68] project, where STH efficiencies soared higher that 20% on small active areas, while few m^2 devices operating with natural sunlight reported efficiencies of 10%. The rich academic literature witnessed up to 30% STH efficiencies for integrated PV+EC devices under concentrated irradiation, yet industrially relevant demonstration of pure PEC or PC is lagging behind with respect to PV+EC devices. The Innovation Fund supported SUN2HY[69] project which aims to demonstrate a pre-commercial plant having STH efficiency >13% at a scale above $1m^2$ module with a 70,000-80,000 hours stability. To this extent, strategies to get closer or beyond the Shockley-Queisser limit, especially system design featuring solar concentration, should be pursued for PEC and PC. As a result, specific R&I areas are needed to be tackled to further progress PEC and PC before demonstration in an industrially relevant environment as follows:

- Demonstration of a commercially viable PEC or PC devices, i.e. comprising a single component that integrates both the solar harvesting and catalytic function. Therefore, proposals on PV biased electrolysis or PV biased PEC devices are not in the scope of this topic;
- Novel photo-chemical reactor design, based on flow conditions rather than batch or semi-batch prototypes;
- Integration of solar concentration architectures, featuring photon management concepts through suitable optics and heat removal and usage concepts, or via disruptive nanomaterials design that promote local concentration of the incoming radiation;
- Expansion of the arsenal of materials for efficient solar energy conversion, including semiconductor oxides, selenides, nitrides, halide perovskites, polymers and the

[67] https://cordis.europa.eu/project/id/621252
[68] https://cordis.europa.eu/project/id/735218
[69] https://climate.ec.europa.eu/system/files/2022-07/if_pf_2021_sun2hy_en.pdf

respective hybrids, as well as bio-hybrids enzyme-semiconductors, also leveraging on Z-schemes or multi-junction semiconductor systems. Approaches promoting the use of abundant or easily recoverable materials is encouraged;

- Development of effective passivation strategies to mitigate chemical/electrochemical corrosion of semiconductor photoelectrodes and photocatalysts and thereby improve their operational lifetime;
- Development of cost-effective, scalable processing methods enabling the coupling of efficient hydrogen evolution, oxygen evolution or electro-oxidation (co)catalysts to semiconductor photoelectrodes and photocatalysts;
- Alternative photo-chemical reactions beyond conventional water splitting, de-coupling hydrogen and oxygen production in favour of more economically attractive and/or less energy-demanding oxidative reactions, such as biomass/waste photo-reforming or direct saltwater photo(electro)catalysis

The scope of this topic should therefore address the lack of industrially relevant photo-chemical reactor, offering advantages in terms of land-use, simplified system layouts and lower cost. The use of flow conditions is particularly relevant for PC systems, that are often tested in custom batch-type lab reactors without internationally acknowledged measurements protocol and standards. Consequently, projects are expected to validate novel STH conversion reactors in relevant environments. To this extent, monolithic or highly integrated photochemical devices should be developed, while simple electrical connection between photovoltaic cells and electrolysers or PV biased PEC configurations are not in the scope of this topic.

Furthermore, the scope of this action is to validate novel photo-active materials of at least 5% - for PC – and above 15% - for PEC – STH efficiencies. To achieve such goal, proposals are expected to pursue strategies that aim to improve both light harvesting and catalytic properties, namely core/shell or hybrid nanomaterial synthesis, materials showing plasmonic effects or selective photo(electro)catalyst for alternative oxidative reactions beyond water oxidation.

Overall, proposals should address the following targets at the system level:

- A photo(electro)chemical system with a minimum cumulated hydrogen production of 75 kWh/m^2 for PEC or 25 kWh/m^2 for PC systems, respectively, for the 500 hours of pilot demonstration;
- The concepts used in developing the novel reactor should allow scalability to higher throughput not only by numbering up reactors but also by increasing the single reactor throughput;
- Photo(electro)chemical reactions beyond conventional water splitting may be also demonstrated, in particular hydrogen-producing de-coupled reactions improving state-of-the art demonstration of solar-to-chemical energy conversion;
- A functioning prototype of the system should be validated in a relevant environment, in particular by using natural sunlight. Stable STH efficiencies should be demonstrated for a cumulated period of over 500 hours.

Proposals are encouraged to explore synergies with the existing or upcoming projects of the

European Innovation Council (EIC) Pathfinder Challenge 2021[70] on novel routes to green hydrogen production, e.g. OHPERA[71] and GH2[72] projects. In particular, applicants should consider building on the breakthrough solutions and advance semiconducting photocatalysts developed in these projects.

Proposals are expected to include work on addressing sustainability and circularity aspects of proposed technologies including minimisation and/or avoidance of CRM.

[70] EIC Pathfinder Challenges 2021 (HORIZON-EIC-2021-PATHFINDERCHALLENGES-01), https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-eic-2021-pathfinderchallenges-01-04

[71] https://cordis.europa.eu/project/id/101071010

[72] https://cordis.europa.eu/project/id/101070721

HORIZON-JTI-CLEANH2-2023-01-05: Waste to Hydrogen demonstration plant

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 10.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 10.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 5 and achieve TRL 7 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 10.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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): reactor and all units and subunits to allow a proper and independent functioning of the waste to hydrogen plant (e.g. gas upgrading, separation, purification, compression, etc.), costs may exceptionally be declared as full capitalised costs.

Expected Outcome

The sustainable wastes management in Europe is an emerging issue of the circular economy due to the restrictions given by EU Directive (waste streams as defined in the respective regulations including Renewable Energy Directive (2018/2001 EU) and Waste Directive (2008/98/EC), that is encouraging operators and territories (mostly cities, large urban areas and Regions) to enter into a circularity approach, avoiding landfill disposal, and limiting the milage of exports to other plants out of the specific Region/territory. Therefore, the work proposed should be performed in conformity with these and other relevant EU policies and regulation on utilisation of waste.

Wastes cannot be reintroduced into recycling and a second life: they are instead forced to the end of life, within a linear approach. It is therefore of high interest to find alternative ways than the ones described above and drive the territories to find effective and efficient solutions for the wastes' conversion within a more circular approach.

The potential of the sector is huge, considering in Europe there are about 300 million tonnes of wastes, with the hydrogen production capacity of about 30 million tonnes, equal to about 50% of the calorific value of the original waste. This could be an enormous contribution at a net negative carbon emission and with a potential for a LCOH below 3 €/kg and approaching 1.5 €/kg in best plant options. It has an important potential for sustainable economic growth and is a vector of jobs creation.

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

- Development of the technological process optimised for the conversion of the waste to renewable hydrogen, with a >50% conversion efficiency based on energy content of the final product (hydrogen) vs. energy content of the input streams (electric input and wastes);
- Development of the digital twin and the controls of the demo plant;
- System prototype demonstration in operational environment (TRL 7) at relevant industrial scale with above 3 MW scale reactor for at least 4,000 hours;
- Develop new sustainability-oriented business models for treatment plants in optimised territorial management of waste flows, demonstrating the LCOH at a target production cost of <3 €/kg;
- Feasibility study for the upscaling of the technology at the relevant industrial scale, to convert wastes on a regional dimension (in the range of 10,000 tonnes/year of recycled waste or above), including the analysis of technical, economic, social barriers and/or drivers;
- A new and/or improved process addressing both the hydrogen and circular economy in areas with high potential of wastes, including design of the specific territorial services;

Project results are expected to contribute (according to the solution addressed in the project) to the following objectives and KPIs of the Clean Hydrogen JU SRIA:

- In case of hydrogen production via waste/biomass gasification:
  - System carbon yield $H_2/C > 0.27$
  - System capital cost €/(kg/d) < 1.45
  - System operational cost €/kg < 0.0105
- In case of the biological production:
  - System carbon yield $H_2/COD > 0.015$
  - Reactor production rate kg $H_2/m^3/d > 15$
  - System capital cost €/(kg/d) < 400
  - System operational cost €/kg < 3
- Additional target values are listed below:

- Reactor conversion rate kg input material (waste) /h > 1000
- Reactor scale MW > 3
- Operational time h > 4,000 h
- Yearly hydrogen production kg ~180,000

Scope

The scope of this flagship topic is to develop and demonstrate a pilot plant processing wastes and converting them into hydrogen. Different conversion processes maybe be considered, involving for example, but not limited to, gasification, pyrolysis, plasma supported, electrochemical processes, steam gasification, including multistage processes and related reactors.

Projects should bring one of the available conversion technologies to a higher maturity by testing and validating a demonstrator plant with a reactor size of at least 3 MW working in an operational environment for at least 4,000 hours with an equivalent yearly hydrogen production of 180 tonnes H2. Proposals should demonstrate the potential for upscaling and market deployment in the near term. All innovative conversion technologies approaching the expected scale of operation can be considered.

The system developed should include the following options:

- A multi-stage waste to hydrogen technology, at a relevant industrial scale, including all the units and subunits to allow a proper and independent functioning of the plant;
- Eventual gas upgrading, separation, purification and compression stages delivering hydrogen at a minimum purity level of 99.9%, or following the end user requirements, and at a target pressure of 30 bars, integrated and adapted to the specific technology and conversion process;
- A built-in design of the demo technology to optimise the overall conversion efficiency, including options such as solar thermal and/or PV, waste heat and waste gas management with exclusion for downstream energy (co)generation solutions.

Waste in this topic is understood as mainly organic waste (for example but not limited to agricultural residues, sewage, urban waste, etc.) Proposals should focus on wastes without any direct recycling potential and on the production of sustainable, renewable hydrogen (in line with the requirements of the EC proposal for the revision of RED II[73])

Proposals should address the following:

- Improve the operational parameters of the reactor processing wastes beyond the current state of the art;
- Optimisation of the processing of wastes to maximise the process parameters and the hydrogen yield;
- Adapt and validate the technology for a wide acceptance range of wastes, including at high moisture content (up to 50%) and calorific values (from 2 to 5 kWh/kg of waste);
- Increase of the overall efficiency of the processing reactors and units, maintaining use

[73] https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

of waste heat and gas streams as well as integrating other renewable resources e.g., of solar energy for the wastes drying or reactor preheating;

- Increase the overall plant efficiency beyond the present state-of–the-art, as indicated in the previous section;
- Optimise the mass and energy balance of the process including all the products streams (e.g., hydrogen, other coproducts and the internal thermal and electric energy consumption;
- Perform plant multi objective optimisation, dynamic modelling to reach a final optimised design and to identify the process parameters for the demo control and safety strategies;
- Development gas separation and purification units delivering the hydrogen at a minimum purity level of 99.9%, in any case adapted at the end-use application proposed;
- Locate the demo plant in a region with a hydrogen end use identified at least at the scale of the prototype plant;
- Perform a techno-economic analysis with the target of LCOH < 3 €/kgH_2 for the scaled up plant;
- Perform an LCA and LCC analysis comparing the specific technology with other hydrogen production solutions, including electrolysis and conversion of the raw biogas, as well as other waste to energy/renewable fuel (e.g. biowaste) pathways including approaches such as direct incineration, biomethane production through anaerobic digestion, bio-fermentation or classical and plasma arc gasification, pyrolysis.

Proposals are expected to address sustainability and circularity aspects of proposed technologies.

Proposals are encouraged to explore synergies with the existing or upcoming related projects funded by the Innovation Fund [74].

Proposals are also encouraged to explore synergies with projects running under the EURAMET research programmes EMPIR[75] and the European Partnership on Metrology (e.g Met4H2[76]) concerning quality assurance measurements which aim at ensuring that the purity of hydrogen produced is at the expected grade.

Applicants should provide a funding plan to ensure implementation of the project in synergies with other sources of funding. If no other sources of funding will be required, this should be stated clearly in the proposal, with a commitment from the partners to provide own funding. If additional sources of funding will be required, proposals should present a clear plan on which funding programmes at either EU (e.g. Structural Funds, Just Transition Fund, Innovation Fund, Connecting Europe Facility,…) or national levels will be targeted[77]. In these cases, applicants should present a credible planning that includes forecasted funding programmes and their expected time of commitment.

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[74] For example HyValue (https://www.hyvalue.com/innovation-fund/) and FUREC (https://climate.ec.europa.eu/system/files/2022-07/LSC2_List_of_pre-selected_projects_6.pdf)
[75] https://www.euramet.org/research-innovation/research-empir
[76] https://www.euramet.org/index.php?id=1913
[77] Including awarded, secured or planned 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.

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 CertifHy[78]).

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

[78] https://www.certifhy.eu

HORIZON-JTI-CLEANH2-2023-01-06: Valorisation of by-product O2 and/or heat from electrolysis

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 10.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 10.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected achieve TRL 7-8 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 10.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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.

<u>*Expected Outcome*</u>

Large scale economically viable hydrogen production is necessary to implement the ambition of the “Hydrogen Strategy for a climate-neutral Europe”. Improved integration of the electrolyser into industrial process or, more in general, into the energy system is still an open challenge. To achieve this goal, valorisation of by-products is of high importance to improve the business case of green H_2 production. Improved technological solutions will be developed during the project both in terms of integrated hardware as well as control strategies.

Conventionally, an electrolyser vents by-product oxygen into the atmosphere and rejects ~30% of its electricity input as waste heat. The chemical and process industry sector is currently demonstrating that there is value in utilising also the oxygen and recovering the waste heat, but there is now a need to apply this approach to other industries such as, but not limited to non-energy-intensive industries (eg. wastewater treatment, fish farming, healthcare, etc.) and to assess the potential for establishing hydrogen hubs.

The project will be expected to pave the way for further large-scale integration of electrolyser systems into either industrial applications, where the use oxygen and heat integration can improve efficiency and economics of green hydrogen use in industrial processes or into a coupled energy system where excess electricity can be converted into H_2 while waste-heat could be used, for example, to feed a district heating network. The project is expected to demonstrate in an operational environment an improved electrolysis technology at a scale of at least 15 MW.

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

- Innovation of the electrolyser technology and the balance-of-plant integration directly into the industrial process or energy system ensuring a wide commercial impact in at least one application sector;
- Development of techno-economic analysis of the performance of these systems showcasing the business case of the proposed solution at scale;
- Replicability of the solution for at least two different use cases;
- Establishment of optimal strategies to balance supply of O_2 or heat and H_2 with the specific application demand;
- Improving dynamic operation strategies and efficiency, with high durability and availability on-line reliability following the need of the industrial process;
- Footprint (area) reduction through direct integration with industrial process.

The project should show no increased CAPEX and OPEX of the electrolyser system, independently on the chosen technology, increase operational reliability, improved integration within the industrial process, whilst improving the overall economics. SRIA KPIs for 2024 for the relevant technology used should be met.

Scope

Utilisation of the by-product oxygen as well as simplification of the balance-of-plant through integration into the downstream process can improve the economics and the total cost of ownership of the electrolyser.

This flagship topic should focus on improving efficiency of the electrolyser system as well reducing the footprint by optimising the electrolyser system-downstream process integration. Furthermore, the project should give insight into the effect of this integration on electrolyser degradation phenomena compared to a standard electrolysis system, if applicable.

Proposals should address the following:

- Demonstrate an improved electrolyser (>15MW) with innovative balance-of-plant able to deliver hydrogen and oxygen and/or an optimised heat integration with the downstream process. The demonstration should operate for a minimum of 1 year (4,000 cumulated hours at nominal load);
- Demonstrate the scalability to multi-MW of the solution, including optimised control

strategies and the economic benefit at scale including the impact on the final cost of the product;

- Include a plan for use of the installation after the project;
- Quantify the impact of the system operating strategy on the durability of the electrolyser;
- Effect of use of by-product O_2 into the downstream process and/or product properties;
- Assessment of the different industrial activities, utilities or services that could be benefited from heat integration and oxygen production, including their requirements, i.e. purity, profile etc;
- Show complementarity with other EU funded projects such as HORIZON-JTI-CLEANH2-2022-01-08 "Integration of multi-MW electrolysers in industrial applications" and HORIZON-CL4-2022-TWIN-TRANSITION-01-17 "Integration of hydrogen for replacing fossil fuels in industrial applications" or any other relevant EU funding programs.

Consortia are expected to include off-takers for the hydrogen, oxygen and/or heat and an engineering, procurement and construction (EPC) partner for appropriately integrating these electrolyser outputs at the site. Following the commissioning phase, electricity costs are not eligible for funding.

The project should include a clear go/no-go decision point (milestone) ahead of entering the deployment phase. Before this go/no go decision point, the project is expected to 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 therefore expected to clearly demonstrate a proposed pathway to obtaining necessary permits for the demonstration actions and allow for appropriate timelines to achieve these.

Applicants are encouraged to seek synergies with existing projects of the Horizon Europe Process4Planet and Clean Steel partnerships or future topics[79] concerning innovative industrial processes, that could make use of the hydrogen and oxygen and other by-products produced by the electrolyser.

Proposals are also encouraged to explore synergies with projects running under the EURAMET research programmes EMPIR[80] and the European Partnership on Metrology (e.g Met4H2[81]) concerning quality assurance measurements which aim at ensuring that the purity of hydrogen produced is at the expected grade.

Proposals are expected to address sustainability and circularity aspects.

Applicants should provide a funding plan to ensure implementation of the project in synergies with other sources of funding. If no other sources of funding will be required, this should be stated clearly in the proposal, with a commitment from the partners to provide own funding. If additional sources of funding will be required, proposals should present a clear plan on which funding programmes at either EU (e.g. Structural Funds, Just Transition Fund, Innovation

[79] In particular proposals are expected to explore synergies with topic HORIZON-CL4-2024-TWIN-TRANSITION-01-34: Renewable hydrogen used as feedstock in innovative production routes.
[80] https://www.euramet.org/research-innovation/research-empir
[81] https://www.euramet.org/index.php?id=1913

Fund, Connecting Europe Facility,…) or national levels will be targeted[82]. In these cases, applicants should present a credible planning that includes forecasted funding programmes and their expected time of commitment.

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. 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 CertifHy[83]).

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 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 protocols[84] to benchmark performance and quantify progress at programme level.

[82] Including applications for funding planned, applications for funding submitted and funding awarded
[83] https://www.certifhy.eu
[84] https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HORIZON-JTI-CLEANH2-2023-01-07: Hydrogen use by an industrial cluster via a local pipeline network

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 15.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 15.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected achieve TRL 8 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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.
Legal and financial set-up of the Grant Agreements	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, hydrogen pipeline network, 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

Renewable hydrogen offers industry the means to decarbonise thermal and chemical processes that currently rely on fossil fuels or ‘grey’ hydrogen. In an industrial zone the opportunities to switch these processes to renewable hydrogen are improved if off-takers can access it via a local pipeline network (rather than by each having to install a separate electrolyser). Hydrogen can then be produced more cost effectively via a relatively large electrolyser.

This approach is an important next step for decarbonising an industrial area, as opposed to decarbonising an individual process. It is an important steppingstone for enabling the deployment of larger electrolysers and local 100% hydrogen pipelines in a manner that can be reproduced across the industrial zones and ports of Europe. It will thereby help establish an early market for renewable hydrogen prior to the existence of an extensive hydrogen grid, which is a longer-term proposition. The project should be designed for wider replication, or as the first stage of a hydrogen valley, and it may form a component of a larger project such as a hydrogen Important Project of Common European Interest (IPCEI)[85].

This flagship topic involves installing a large electrolyser and a new or repurposed 100% hydrogen pipeline network of sufficient transport capacity to fully or partially decarbonise at least two industrial processes that are located within a single industrial zone, either inland or in coastal areas. The action is open to any type of hydrogen end use and any combination of off-takers in the local area (including chemical processes, co-generation systems, hydrogen gas turbines and any technology that combusts hydrogen or hydrogen/natural gas blends). Where appropriate as a secondary application, it may also provide hydrogen for vehicle

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

- Increasing the scale of deployment;
- Increasing the pressure and capacity for new builds of 100% hydrogen pipelines while reducing their cost;
- System integration & efficiency;
- Improving security and resilience of the energy system, e.g., via hydrogen production using locally available renewable energy sources;
- Assessment of the availability and affordability of clean (pollution free) energy provision for industry, whilst also considering environmental impacts;
- Mutualisation of production or distribution and storage, assuming decentralisation as key parameter;

The following KPIs are targeted:

- The project should show no increased CAPEX and OPEX of the electrolyser system, independently on the chosen technology, increase operational reliability, improved integration within the industrial process, whilst improving the overall economics. SRIA KPIs for 2024 for the relevant electrolyser technology used should be met.
- Hydrogen Pipelines: total capital investment (M€ /km): 1, transmission pressure (bar): 100, H2 leakage (%): 0
- Hydrogen compression: Technical lifetime (years) 14, energy consumption pipeline from 30 to 200 bar (kWh/kg): 2.5, OPEX pipeline (€/kg): 0.03, CAPEX for the compressor pipeline (€/kW): 1,000

Scope

This flagship project requires installing and operating a simple and short hydrogen pipeline network in one local area for interconnecting an electrolyser with a small number of industrial

[85] Two waves of IPCEIs related with clean hydrogen have been approved by the EC: IPCEI Hy2Tech on 15/07/2022 - https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_22_4549; and IPCEI Hy2Use on 21/09/2022 - https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676

end users, with the option to serve other final applications (e.g. mobility) as well. The electrolyser and pipeline system should be developed for integration into the industrial zone and, if needed, associated buffer storage should be foreseen to ensure hydrogen supply dynamics always meet customers´ requirements.

The electrolyser should be viewed as the initial step towards subsequently achieving a much greater rate of hydrogen production and use at scale for the industrial zone. The electrolyser should have a minimum capacity of 10 MW. The pipeline transport capacity should be sufficient to meet the estimated future peak demand for hydrogen by the off-takers, which is expected to be far in excess of the electrolyser capacity.

The electrolyser should be positioned optimally with respect to the electricity grid and any nearby renewable power sources, and it is expected that this will influence the layout and length of the pipeline network. It is envisaged that a hydrogen pipeline within an industrial district could facilitate the proposed approach by serving two or more industrial processes to create an industrial hydrogen cluster.

The co-location of an electrolyser with an industrial process has been demonstrated previously (e.g., for methanol production and oil refining). However, the operation of a number of processes from a small hydrogen pipeline network fed by a central electrolyser has not been yet demonstrated. This requires laying new pipelines or repurposing existing pipelines in order to connect the end users to the electrolyser and incorporating buffer storage as appropriate in order to manage supply/demand mismatches. The hydrogen should be used to fully or partially displace the consumption of a fossil fuel or ‘grey’ hydrogen.

The project is intended to be a first step towards achieving more substantial rates of hydrogen production in the future for off-takers in the chosen industrial zone. It may be an integral part of a much larger scale and longer-term project for the industrial cluster. The proposal should outline the business model upon which the equipment will be operated for the long term (e.g. 10-20 years) and full details of the business model should be finalised during the early stages of the project. The project should conform with the permitting requirements and hydrogen policies of the EU Member State at the location. The demonstration should operate for a minimum of 1 year (4,000 cumulated hours at nominal load).

It is expected that the consortium will include an appropriate range of expertise for integrating the proposed system into the cluster, such as a gas engineering company, a gas or energy distribution or transmission operator and a minimum of two off-takers located within one industrial area.

Following the commissioning phase, electricity costs are not eligible for funding.

Applicants are encouraged to seek synergies with existing projects of the Horizon Europe Process4Planet and Clean Steel partnerships or future topics[86] concerning innovative industrial processes, that could make use of the hydrogen and oxygen and other by-products produced by the electrolyser.

Proposals are also encouraged to explore synergies with projects running under the EURAMET research programmes EMPIR[87] and the European Partnership on Metrology (e.g

[86] In particular proposals are expected to explore synergies with topic HORIZON-CL4-2024-TWIN-TRANSITION-01-34: Renewable hydrogen used as feedstock in innovative production routes.
[87] https://www.euramet.org/research-innovation/research-empir

Met4H2[88]) concerning quality assurance measurements which aim at ensuring that the purity of hydrogen produced is at the expected grade.

Applicants should provide a funding plan to ensure implementation of the project in synergies with other sources of funding. If no other sources of funding will be required, this should be stated clearly in the proposal, with a commitment from the partners to provide own funding. If additional sources of funding will be required, proposals should present a clear plan on which funding programmes at either EU (e.g. Structural Funds, Just Transition Fund, Innovation Fund, Connecting Europe Facility…) or national levels will be targeted[89]. In these cases, applicants should present a credible planning that includes forecasted funding programmes and their expected time of commitment.

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. 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 CertifHy[90]).

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 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 protocols[91] to benchmark performance and quantify progress at programme level.

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[88] https://www.euramet.org/index.php?id=1913
[89] Including applications for funding planned, applications for funding submitted and funding awarded
[90] https://www.certifhy.eu
[91] https://www.clean-hydrogen.europa.eu/knowledge-management/collaboration-jrc-0_en

HYDROGEN STORAGE AND DISTRIBUTION

HORIZON-JTI-CLEANH2-2023-02-01: Large-scale demonstration of underground hydrogen storage

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 20.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 20.00 million
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected achieve TRL 8 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 20.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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): underground hydrogen storage and interfaces of the underground storage with other elements like hydrogen producers, hydrogen consumers and hydrogen dedicated distribution & transmission network, costs may exceptionally be declared as full capitalised costs.

Expected Outcome

Large-scale hydrogen storage has the potential to enable the integration of intermittent renewable energy sources in the gas grid and to support the industrial, mobility and other end-uses of green hydrogen. The aim of this flagship topic is to demonstrate the technical and economic feasibility of large-scale underground hydrogen storage to provide the flexibility to manage the imbalance between intermittent supply from renewables and variability in demand in an integrated electricity-hydrogen energy system, and to qualify all technologies and their components in an integrated storage system (TRL 8) by demonstrating large-scale hydrogen (energy) storage in underground salt caverns and/or gas fields and/or other geological structures, which are located in many places across EU.

As reflected in the EU's Hydrogen Strategy and, more recently, in its REPowerEU Plan, hydrogen will play a key role as a decarbonised energy vector in future EU energy systems. As such, both supply (hydrogen production & hydrogen imports) and demand (hydrogen end-uses) will increase significantly in the coming decades. To balance the growing variations in supply and demand over time periods of days to seasons, hydrogen should efficiently be stored at large scale before it is transported and distributed from production/import locations to industrial, mobility and other end-uses. Large-scale hydrogen storage also has the potential to store energy when renewable electricity production is higher than the demand/capacity of the grid.

This flagship topic aims to demonstrate the economic and technical feasibility and qualify a complete storage system through testing of a large-scale underground hydrogen storage, its contribution to intermittent electricity management, security of supply, interface with hydrogen end-users as well as the economies of scale that can be realised in addition of the first steps accomplished with pilot EU funded projects (e.g Hypster[92], Hystock[93], HYSTORIES[94], HYUSPRE[95]. Project results are expected to contribute to all of the following expected outcomes:

- The achievement of the targets set out in the REPowerEU Plan and EU Hydrogen Strategy;
- Enabling higher integration of renewables within the overall energy system, in particular during an imbalance settlement of the electricity grid, through interfaces between underground hydrogen storage, electrolysers, the electric transmission grid, the hydrogen transmission infrastructures and direct feed end-users;

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

- For Salt Cavern:
  - CAPEX < 30 €/kgH_2 stored and salt cavern storage capacity above 3,000 tonnes H_2 (100%) - (based on the working mass of hydrogen stored, pure hydrogen considered);
  - CAPEX < 32 €/kgH_2 stored and salt cavern storage capacity between 1000 and 3,000 tonnes H_2 (100%) - (based on the working mass of hydrogen stored, pure hydrogen considered);
- For Depleted gas field:
  - CAPEX < 5 €/kgH_2 stored (capital costs include all necessary components to operate the storage system, including compression (to 120 bar max) and purification. The costs refer to the mass of hydrogen recovered from the storage).

92 https://cordis.europa.eu/project/id/101006751
93 https://www.hystock.nl/en/
94 https://cordis.europa.eu/project/id/101007176
95 https://cordis.europa.eu/project/id/101006632

Scope

Considering the source of electricity to be installed (wind and solar capacities), intermittency management of this electricity supply can limit the development of hydrogen production capacities. Based on prior supported projects which already demonstrate pure hydrogen underground storage, this flagship topic aims at integrating the innovation brought by large-scale underground storage to the whole value chain, to better understand how renewable hydrogen can be supplied continuously to industrial, mobility and other end-uses, while allowing production to be intermittent (daily or seasonally) due to renewable electricity supply. To this effect, large-scale underground storage will contribute to limiting the curtailment of renewable electricity and optimise the whole value chain to make energy more sustainable, more secure and more affordable for hydrogen consumers.

Proposals should address the following:

- Demonstrate how a smart large-scale underground hydrogen storage, with a potential storage capacity of at least 1,000 tonnes H_2 (for salt cavern: working mass of hydrogen stored, pure hydrogen considered/for depleted gas field or aquifers: mass of hydrogen recovered from the storage) integrated with renewable hydrogen source can contribute to higher integration of renewable electricity for hydrogen production (directly connected to power generation from renewable energy sources (RES);
- Demonstrate the transformation/conversion process of already existing underground storage from natural gas to hydrogen storage or the use of other geological structures for hydrogen storage;
- Define and analyse the interfaces of large-scale hydrogen underground storage with other elements like hydrogen producers, hydrogen consumers and/or a hydrogen dedicated distribution & transmission network;
- Analyse the sector coupling plus interaction of hydrogen underground storage in the future H2 network and overall future energy system network (including future energy scenarios) in terms of efficiency and possible technical operation modes of the hydrogen storage;
- Make recommendations about the technical and economic reproducibility of the process to other sites in EU;
- Improve overall energy and economic efficiency of the integrated system.

By the end of the project, the results should achieve a system complete and qualified (TRL 8). The proposed cyclic test program should include:

- End-to-end testing to qualify the performance, the integrity, the environmental impact and the safety of the underground storage, and the associated aboveground infrastructure;
- End-to-end testing to qualify the purity of the hydrogen recovered from the underground storage and the efficiency of the purification facilities (fluids & treatment process) required to deliver the hydrogen to the downstream parts of the value chain.
- For caverns:
    - At least a total number of 100 injection & withdrawal cycles of different pressure & volume variation. This cycling program should be representative of future

operating conditions of an underground hydrogen storage in an assumed highly flexible hydrogen market. To that end, the cycling program should demonstrate the ability of underground storage to meet hourly temporal correlation;

    - Short and long-duration storage cycles (including superimposed cycles) with different net ramping rates, amplitudes, periodicities, and stand-by periods. (It is not expected to fill the cavern to 100% then empty it entirely for all 100 cycles).

- For depleted gas fields:
    - At least a complete storage cycle (injection phase followed by the withdrawal phase) that are representatives of the operating conditions of a future underground hydrogen storage in a depleted gas field in compliance with future EU regulation on hydrogen market[96].

Proposals should also:

- Address health, safety and environmental considerations, and proof compliance to international standards (e.g. quality);
- Include plans for transport & distribution of hydrogen from / to storage site;
- Address sustainability and circularity aspects.

Applicants should provide a funding plan to ensure implementation of the project in synergies with other sources of funding. If no other sources of funding will be required, this should be stated clearly in the proposal, with a commitment from the partners to provide own funding. If additional sources of funding will be required, proposals should present a clear plan on which funding programmes at either EU (e.g. Structural Funds, Just Transition Fund, Innovation Fund, Connecting Europe Facility,…) or national levels will be targeted[97]. In these cases, applicants should present a credible planning that includes forecasted funding programmes and their expected time of commitment.

Proposals are also encouraged to explore synergies with projects running under the EURAMET research programmes EMPIR[98] and the European Partnership on Metrology (e.g Met4H2[99]) concerning quality assurance measurements which aim at ensuring that the purity of hydrogen stored is at the expected grade.

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. 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 CertifHy[100]).

[96] On 15/12/2021 under the Fit-for-55 package, the Commission proposed the Gas Decarbonisation Package – a new EU framework to decarbonise gas markets, promote hydrogen and reduce methane emissions; https://ec.europa.eu/commission/presscorner/detail/en/ip_21_6682
[97] Including applications for funding planned, applications for funding submitted and funding awarded
[98] https://www.euramet.org/research-innovation/research-empir
[99] https://www.euramet.org/index.php?id=1913
[100] https://www.certifhy.eu

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-CLEANH2-2023-02-02: Pre-Normative Research about the compatibility of transmission gas grid steels with hydrogen and development of mitigation techniques

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 4.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 4.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project - see General Annex B.
Legal and financial set-up of the Grant Agreements	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.

<u>*Expected Outcome*</u>

This topic is aimed at accelerating the deployment of a safe, flexible, and efficient hydrogen grid by repurposing part of the gas networks, as this solution is expected to be particularly cost-effective compared to the development of new pipes. However, steel embrittlement by hydrogen may limit this possibility. To assess precisely which pipes might be repurposed on a shared basis between EU Member States' authorities and gas transmission operators, Pre-Normative Research on pipe integrity is required to develop a European standard, as current US codes are not adapted to the projected use-cases in EU.

In its strategic vision for a climate-neutral EU in 2050, the European Commission forecasts the share of hydrogen in Europe's energy mix to grow from the current less than 2% to 13-14% by 2050. According to the REPowerEU ambitions published in May 2022, about 20 million tonnes of renewable hydrogen should already be distributed throughout Europe in 2030. For hydrogen to claim such position in the energy mix and as explicitly mentioned in the EU Hydrogen Strategy, it is essential that it becomes an intrinsic part of an integrated energy system, being used for daily or seasonal storage providing buffering functions thereby enhancing security of supply in the medium term. The REPowerEU strategy also calls for an acceleration of the deployment of an EU-wide pipeline infrastructure to transport hydrogen from areas with large renewable potential to demand centres across EU. 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. Total investment needs for key hydrogen infrastructure categories are estimated by the European Commission to be in the range of EUR 28 – 38 billion for EU-internal pipelines by 2030. In light of the EC's REPowerEU proposal and in response to accelerated hydrogen market developments, members of the European Hydrogen Backbone Initiative[101] (gathering 31 European energy

[101] https://www.ehb.eu/

infrastructure operators from 28 countries) have shared an updated vision of the hydrogen grid, with a total length of 53,000 km in 2040 consisting of approximately 60% repurposed existing gas pipelines.

In a nearer term, to distribute hydrogen, EU gas grid operators are investigating the possibility to increase the content of hydrogen blends into natural gas from 2% in volume to 20% in existing Transmission gas grids. In its "Hydrogen and decarbonised Gas Package" revision proposal released in December 2021, the European Commission emphasises the need for a harmonised EU approach for cross-border interconnection points while leaving flexibility to the Member States, with a floor rate for hydrogen blends that could be set at 5% for all cross-border points as of October 2025.

However, first public bibliographic results of R&D supported projects (e.g.: NaturalHY[102], HYready[103], MultiHy[104] or HIGGS[105]) have identified a potential embrittlement effect on some steels used for pipes or network equipment. EU gas Transmission System Operators (TSOs) are currently compelled to refer to US standards (mainly ASME B31.12) that seem to be strongly over-conservative for EU hydrogen transmission use-cases, leading to ineffective investments and slowing down the administrative authorisation processes.

As stated by the European Committee for Standardisation CEN [CEN/TR 17797, March 2022], the State of the Art on gas grid steel integrity show limited available knowledge and a need for additional Pre-Normative Research. Also, there is a strong need to investigate further on specific and critical topics that are insufficiently covered by existing programs, like weld embrittlement or fatigue crack growth (FCG) mechanisms due to atomic hydrogen ingress into the steel. Even if some private or public projects are currently ongoing in some Member States, very limited shared results don't allow other gas TSOs to benefit from such results. Moreover, since their testing protocols and environment are not yet aligned, it would prove anyway very difficult to compare projects' results, with a risk for national TSOs and Authorities to draw misaligned conclusions on each side of the same interconnection. Therefore, it is critical to launch a comprehensive and overarching project at EU level to overcome these hurdles.

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

- De-risking of business cases for an accelerated H2-readiness assessment of existing EU Transmission gas grids for hydrogen and enabling expansion of new dedicated infrastructures.
- Increasing operator, regulator, authorities, and end user confidence in safety of repurposed gas grids by consolidated and exhaustive scientific data.
- Delivering harmonised matrix to assess the hydrogen effect on steels present in the gas grids to get a comprehensive view of the networks' degree of compatibility across EU and reduce the current over-conservative and inefficient approach. These guidelines are aimed at providing impactful Pre-Normative Research key inputs to contribute to the development of Regulation, Codes and Standards and thus enabling a seamless interconnection between hydrogen gas grids.

[102] https://www.gerg.eu/projects/hydrogen/naturalhy
[103] https://www.dnv.com/article/hyready-219355
[104] https://cordis.europa.eu/project/id/263335
[105] https://higgsproject.eu/

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

- Development of technologies and materials to facilitate the transportation of H_2 via the natural gas Transmission grid.
- Enable through research and demonstration activities the safe and affordable transportation of hydrogen through the repurposed natural gas grid.

The following KPIs should be therefore achieved by the end of the project:

- Gas TSOs from the EU reviewed: 70% of EU Member States should be covered;
- Representative EU steels assessed by testing vs operational parameters (steel grade, pressure of H_2, pressure cycling, etc.): 8 to 10 steel grades assessed;
- Design codes & standards optimisation with reduced conservatism vs ASME B31.12: 60% constraint reduction (in terms of Capacity and/or manageable linepack);
- PNR reports delivered to relevant standardisation bodies: Inputs on matrix H_2-readiness assessment with proposed optimised mastercurves (toughness reduction and Fatigue Crack Growth;
- Guidelines for mitigation techniques:
    - Operational parameters guidelines (pressure, cycling…);.
    - Preliminary reports on Innovative technology

Scope

Embrittlement effect on metallic grid materials used for pipes or network equipment is directly linked to the pressure of hydrogen. The project should focus on specific critical issues that are insufficiently covered by existing publicly available knowledge, like hydrogen embrittlement in pipe and girth welds and heat affected zones (HAZ), Fatigue Crack Growth mechanisms and update of criteria for assessment of flaws. To date, no exhaustive characterisation of these effects on transmission grids is available, due to costly and time-consuming test methods and to the diversity of existing networks across the EU, in terms of material grades used, building protocols (e.g. welds) or day-to-day current and future operational parameters (e.g. pressure level and cycling). A particular effort is expected on quantifying these effects versus the main parameters (H_2 pressure, mechanical loading, steel microstructures…).

Modern new steel grades likely to meet the deployment needs of H2 networks should also be investigated (allowing connections of hydrogen producers and consumers to repurposed grids). It is expected that these results will have a strong impact on the development of competitive products by EU pipe manufacturers.

Currently different US standards are used for the design of steel components (e.g. 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 EU gas networks. Moreover, due to the lack of data, these standards propose very conservative design. A preliminary ASME B31.12 sensitivity analysis about the ascending influence of different parameters on the lifetime prediction of pipelines revealed for instance that the conservatism in ASME B31.12 could be potentially optimised in the range between a factor of 2-4. A pronounced optimisation potential is expected by a more precise knowledge of the fatigue crack growth behaviour and well-founded initial defect sizes determined by optimised non-destructive testing methods.

Finally, the gas industry has identified that solutions to mitigate the impact of hydrogen could enable a higher conversion rate for natural gas pipelines to hydrogen operation. Early-stage developments of internal coatings, inhibitors, and preparation of guidelines to adapt network operating conditions are ongoing and need to be accelerated.

This project should cover steel grades constitutive of the gas Transmission networks, that are particularly sensitive to hydrogen embrittlement due to some high strength grades, high service pressure and potentially impacting pressure cycling.

Proposals should:

- First conduct a preliminary bibliographic review to identify the gap analysis, taking into account existing results from former and ongoing projects (e.g. NaturalHY[106], HYready[107], HIGGS[108], project supported under the topic HORIZON-JTI-CLEANH2-2022-05-03 'Safe hydrogen injection management at network-wide level: towards European gas sector transition' and the German TransHyDE[109] flagship project).
- Propose a testing approach covering the most relevant steel grades constitutive of EU transmission gas grids (with a particular attention to ensuring a good geographical coverage) and their different (current and envisioned future) operating conditions (maximum pressure, pressure cycling, etc.) for a 100% hydrogen service (natural gas/hydrogen mixtures are not in the scope of this topic; however, due to the partial pressure of hydrogen being the driving parameter, it is expected that studying various pressure conditions will contribute indirectly to qualifying grid for mixtures as well). This approach should combine mechanical tests and innovative modelling approaches.
- Deliver harmonised protocols and run material tests to measure the mechanical properties affected by the presence of hydrogen which are critical for its integration into networks, based upon the gap analysis performed, and focusing on critical effects (should include fatigue crack growth rate, fracture toughness, and impacts on welds and HAZ) and impact of chemical composition for grid components and future pipes. The shared protocols should ensure all results will be comparable between the different testing laboratories involved and should serve as a standardised reference guideline for future investigations.
- After the testing work-packages, deliver to relevant standardisation bodies a matrix of gas grid steel grades' behaviour in the presence of hydrogen as a function of network operating conditions, assessing the compatibility of vintage and new components. Projects should also define design criteria including the allowed size of defects, depending on the hydrogen gas pressure. It is expected that the projects should propose new Pre-Normative assessment master-curves to reduce current over-conservatism of existing norms that is ineffectively slowing down H_2-readiness assessments. It is also expected that these Pre-Normative results will strongly limit the current redundancy of costly R&D actions conducted in the different EU Member

106 https://www.gerg.eu/projects/hydrogen/naturalhy
107 https://www.dnv.com/article/hyready-219355
108 https://higgsproject.eu/
109 https://www.wasserstoff-leitprojekte.de/leitprojekte/transhyde

States, and deliver common approval guidelines to national authorities. Therefore, it is expected that all the data and results from the projects will be made entirely public.

- Investigate and propose initial guidelines for mitigation techniques limiting hydrogen uptake and thus embrittlement (such as adapted network operating conditions, inhibitors, or coating) for repurposed or new hydrogen grids and document their impact.

In order to ensure an exhaustive geographical coverage, the consortium should include a large panel of TSOs from different EU Member States, whose operated networks represent the variety of EU gas transmission infrastructure. The knowledge and differences in the national networks can be very significant, therefore the EU wide coverage should guarantee full usability of results for EU companies.

Proposals are expected to collaborate and explore synergies with the activities of ENTSOG [110] and those of the European Metrology Programme for Innovation (EMPIR1[61]) and European Partnership on Metrology of EURAME (e.g Decarb[111], MefhySto[112] and Met4H2[113] projects).

Given the scope of this topic), the involvement of formal standardisation bodies as part of the consortia is encouraged, with the aim of facilitating the uptake of the project results.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

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 2.2.6.7 International Cooperation).

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[110] https://entsog.eu/
[111] https://www.euramet.org/european-metrology-networks/energy-gases/activities-impact/projects/project-details/project/metrology-for-decarbonising-the-gas-grid
[112] https://mefhysto.eu/
[113] https://www.euramet.org/index.php?id=1913

HORIZON-JTI-CLEANH2-2023-02-03: Novel insulation concepts for LH2 storage tanks

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 2.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 2.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 2 and achieve TRL 3 by the end of the project - see General Annex B.

Expected Outcome

An important element of the European Hydrogen Strategy is to support the deployment of LH_2 for heavy duty applications and to allow energy transportation over longer distances. A further important element of the strategy is to decrease the cost of hydrogen by development of an international hydrogen trade, which will allow the import into the EU of renewable hydrogen from regions with low-cost renewable power. Ultimately this will benefit the EU's competitiveness, manufacturing capabilities and secure renewable energy supply.

Shipping of LH_2 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. The associated LH_2 import terminals will make LH_2 readily available as a green fuel for shipping, heavy duty mobility and aviation, which is essential for the decarbonisation of these hard to abate sectors. The storage of LH_2 in the import terminal has also the potential to serve as a buffer (back-up) in the overall H_2 and power supply system.

Cryogenic liquefied gases such as LNG or LH_2 differ from each other in some aspects, which is also reflected in the technologies required for their storage. For LNG, which has been in use for decades, capacities of 100,000 to 150,000 m^3 are easy to hold today. In comparison, the largest LH_2 tank constructed today is about 5,000 m^3. LH_2 storage presents several new challenges that greatly impact scalability. EU suppliers of cryogenic storage systems are well positioned to close the gap. KHI[114] has announced a design of 11,000 m^3 and CB&I[115] has announced a design up to 40,000 m^3.

The insulation concepts developed so far are rather complex and costly. At present, nearly one year is spent on site erection for a 150 tonnes LH_2 storage, exposing the project to unpredictable weather and manpower fluctuations. Furthermore, the existing technology is proposed only by non-EU suppliers (namely USA and Japan), while EU is yet to develop an independent innovative solution to preserve its competitive position.

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

- Contribute to the development of safe, cost- and energy efficient storage of large quantities of LH_2. For the import of LH_2 at energy system scale, in the order of GW hydrogen energy flux, large scale LH_2 storage tank concepts need to be developed.

[114] Kawasaki Heavy Industries
[115] Chicago Bridge & Iron Company

An important aspect is to utilise the techno-economic advantage of scale. Targeted dimensions will be in the range of those implemented for LNG import today, e.g., 150,000 m³ per tank, corresponding to 10,000 tonnes of hydrogen.

- Development of novel concepts enabling reduced costs, while maintaining low boil-off rates is therefore expected.
- Foster the basis for large scale trade of LH_2 by 2030 being a supplement and an alternative to the current world-wide LNG trade.

Project results are expected to contribute to the following objectives and KPIs of the Clean Hydrogen JU SRIA for large-scale shipping of bulk liquid hydrogen and should be considered as a reference to meet the desired performance requirements for the new insulation concepts.

- Onshore LH_2 containment tank capex (70 €/kg in 2024, < 20 €/kg in 2030)
- LH_2 boil-off (0.1 %/day in 2024, < 0.1 %/day in 2030)

Scope

The scope of this topic is to develop and validate novel insulation concepts for storage of liquid hydrogen. The concepts developed should be suitable for a later scale-up to dimension similar to LNG storage tanks for shipping and or onshore storage.

The scope for the proposed project should include:

- Definition of insulation concept suitable for LH_2 storage, including novel support structures and/or architecture;
- Material selection and integrity evaluation for LH_2 exposure, e.g., strength, ductility, toughness, thermal expansion and compatibility;
- Thermomechanical evaluation of the insulation concept;
- Evaluation of consequences of fires;
- Insulation application evaluation for large scale tanks and support structure (including the construction methodologies for pre-fabrication, concrete base limitation, innovative supports, reduced schedule for construction/erection…);
- Risk analysis for safe operation (evaluation of hazardous scenarios);
- Concept design and cost estimation for large scale LH_2 tanks;
- Tests at laboratory scale, at least, should be performed to support the viability of the concept at relevant conditions, e.g., with respect to temperature and stress conditions;
- The circularity/sustainability of the solution (material and operation) should be demonstrated.

HORIZON-JTI-CLEANH2-2023-02-04: Demonstration of high pressure (500-700 bar) supply chain

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 5.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 5.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 6 and achieve TRL 8 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 5.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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): necessary equipment and components to demonstrate the supply chain (e.g. filling centre, trailer/s and HRS), costs may exceptionally be declared as full capitalised costs.

Expected Outcome

In order to contribute to the 2030 Climate plan and Green Deal, it is of the utmost importance to improve the Gaseous Hydrogen (GH_2) logistic. From a current 200 bar transportation pressure, the industry needs to move to higher pressure to increase the payload and decrease significantly the cost of transportation. It means to demonstrate the full logistic chain from the filling centre phase (to load the trailers at high pressure), through the trailers rolling on the road to the HRS able to feed the final vehicle.

This higher pressure GH_2 logistic is timely needed to prepare for the deployment of heavy-duty vehicles (as trucks or trains) and corresponding infrastructure (HRS with high quantities of GH_2 delivered), the increase of industrial needs of GH_2 and ultimately to reduce the TCO of an extensive HRS network in Europe.

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

- Make recommendations for future regulation framework covering the implementation of high-pressure trailers at HRS and promoting interoperability;
- Demonstrate trailer operation including the safety and operating modes;
- Demonstrate the operability of the new equipment for tube trailers & infrastructure ensuring the safety of loading/unloading, operation and transportation (including compression, cylinders, valves, safety valves, connection kit…);
- Demonstrate the feasibility of the full chain of loading (compression, cooling when necessary, filling protocol, filling time) and the unloading (feeding HRS);
- Demonstrate the scale economy impacting the TCO.

Project results are expected to contribute to the following objectives and KPIs of the Clean Hydrogen JU SRIA as well as to the following additional KPIs:

- Tube trailer payload: 1,000kg in 2024, 1,500 kg in 2030
- Tube trailer CAPEX: 450 €/kg in 2024, 350 €/kg in 2030
- Operating pressure: 500 bar in 204, 700 bar in 2030
- HRS quantities delivered: 2000 kg/d / 1 HRS in 2024, 4000 kg/d / > 2 HRS in 2030
- Filling Centres @ hp pressure (500-700b): 2 tonnes per day (tpd) filled in trailers in 2024, 15 tpd filled in trailers in 2030)
- # trailers filled @ high pressure (500-700b): 2 #/day in 2024, 10 #/day in 2030

Scope

Proposals submitted in this topic should demonstrate the entire concept of filling centre, trailer fleet and HRS, in complementarity/synergy with the previous two topics supported already in AWP2022 (see below).

Proposals should address the following:

- Design and operate an innovative compression system to fill trailers for a daily capacity in the range of several tons/day in a certain geography;
- Deploy safety concepts to operate safely the filling centres, on road transportation and the HRS at high pressure inlet;
- Demonstrate the economy of scale due to the high pressure at the filling centre (increase of trailer payload) and at the HRS (reduced compression need), and reduced tube trailers rotations logistic pressure by increasing the trailer payload and improving the HRS capacity due to the high-pressure inlet. The project should include a techno-economic assessment of the concept of the filling centre (lessons learned, costs that can be optimised, impact on the final price at the nozzle, different possible configurations. modularity etc.);
- Demonstrate a complete logistic scheme with a distribution radius at relevant scale (minimum several tens of km)

- The demonstration of the filling centres and HRS interoperability (among the commercial actors aiming to participate).

In addition:

- Due the high-pressure operation a special attention should be paid to the safety measures around filling, connecting and driving phase;
- The management of the gas purity in accordance with latest ISO specifications should be demonstrated in order to secure the right operation of hydrogen vehicles;
- As this demonstration is combining 3 different items (filling centres / high pressure trailers / HRS) the mechanical and digital interfaces should be demonstrated properly and fully mastered through an overall quality system;
- In order to improve the GH_2 logistic costs, the project should use the latest available technologies available on the market or under development. In particular, it should include innovative components and subsystems developed in the frame of previous EU funded projects for both infrastructure (innovative compression solutions, filling protocols) and trailers;
- The filling centre should demonstrate the distribution capability to two HRSs minimum;
- The filling centre should fill trailers at high pressure (to be defined in the range of 500 to 700 bar) with a hydrogen payload in the range of 1,000 to 1,500 kilograms.

Applicants are encouraged to consider demonstration systems able to fill and deliver quantities above 2 tonnes/day and the scalability from a technology and economic point of view.

Proposals should collaborate and explore synergies with projects already supported in AWP2022 by the Clean Hydrogen JU as follows:

- While the demonstration of a high-pressure trailer (design and qualification) is already supported by the topic HORIZON-JTI-CLEANH2-2022-02-07: 'Increased hydrogen capacity of GH_2 road trailers', proposals are expected to include the trailer as a qualified transportation tool.
- While the design and the qualification of the HRS is already supported by the topic HORIZON-JTI-CLEANH2-2022-02-10: 'Implementing new/optimised refuelling protocols and components for high flow HRS', proposals are expected to include HRS demonstration as a part of the overall supply chain addressed in the project.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

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.

HORIZON-JTI-CLEANH2-2023-02-05: Demonstration of LH2 HRS for Heavy Duty applications

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 5.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 5.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 4 and achieve TRL 6-7 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 5.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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): HRS and related components, costs may exceptionally be declared as full capitalised costs.

<u>*Expected Outcome*</u>

The topic aims to develop and demonstrate the technological foundations of large LH_2 refuelling stations for the heavy-duty transport sectors such as aviation, maritime and railroad sectors, and thereby address and overcome the challenges that are remaining in their development. The main challenges are the development and demonstration of key equipment at the required scales such as high flowrate liquid hydrogen pumps, the management of higher volume boil-off gas, the lack of safety protocols and overall station integration. Ultimately, this topic aims to facilitate widespread LH_2 delivery across each of the identified transportation sectors.

Hydrogen is liquefied by reducing its temperature to -253°C, increasing its volumetric energy density. This enables hydrogen storage in large quantities and its transportation by road or ship from centralised or decentralised production unit to customers, as well as the LH_2 on-board storage for direct use in heavy-duty vehicles such as trucks, ships, trains or aircraft.

The HRS is a key stage in the hydrogen value chain as it performs the final delivery of hydrogen in gaseous or liquid form to the vehicle tank. Current projects are already developing hydrogen refuelling stations to store and distribute liquid hydrogen to heavy-duty trucks. However, the challenges of larger LH_2 HRS for ships, trains, and aircraft, in terms of flowrate capacities, performance, protocols and working environments (harbour, airport, train depots) are still to be addressed. As maritime, aviation and railroad sectors share similar technological concepts and equipment, this topic aims to demonstrate first their feasibility.

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

- Accelerating the implementation of liquid hydrogen for heavy-duty mobility, especially ships, trains and airplanes;
- Development of common technical concepts and equipment for large refuelling stations, preparing their dissemination to EU rail, maritime and aviation sectors;
- Evaluation and demonstration of operational, inspection and maintenance requirements of large-scale refuelling station;
- Achievement of a cost reduction, energy efficient and low emitting hydrogen value chain.
- Development of guidelines for harmonised interfaces systems and standardisation protocols between refuelling station and tank vessel inside EU to be provided for pre-normative actions and further world-wide adoption.

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

- Station delivery flowrate of liquid hydrogen dispensed corresponding to nominal flowrate of pumping and dispensing system (in tonnes per hour - TPH): > 5;
- Station energy consumption per kg of hydrogen dispensed when the station is loaded at 80% of its daily capacity (in kWh/kg): < 0.3;
- Liquid hydrogen refuelling station contribution in hydrogen price (in €/kg): 2;

Scope

The configuration of a hydrogen refuelling station is primarily defined by the state of hydrogen supplied to the station, either gaseous or liquid, and as supplied to the receiving tank, also gaseous or liquid. Liquid hydrogen refuelling stations are to be understood as refuelling stations storing LH_2 while primarily delivering LH_2, for instance to increase HRS efficiency. Liquid hydrogen refuelling stations are essentially composed of the following sub-systems:

- liquid hydrogen fixed or mobile storage;
- liquid hydrogen pump at low pressure (< 30 bar);
- liquid hydrogen dispenser to vessel / vehicle receptacle (break away, nozzle, flexible, flow meter, coupling);
- boil-off gas management system.

There are currently a number of challenges associated with the scale-up of large liquid hydrogen refuelling stations for the delivery of low-cost liquid hydrogen:

- Current liquid hydrogen low pressure pumping systems have not been demonstrated to reach high delivery flowrates (>5 TPH) at a high TRL (currently at TRL 3) while various challenges are yet to be overcome, including mechanical construction to minimise thermal losses, the filtration and purging processes to deal with condensed particles, and high rotation speeds over extended periods;
- In a liquid hydrogen station, boil-off gas on is mainly expected to be generated during liquid hydrogen loading. This requires the management of significant quantities of low pressure, cold but valuable gaseous hydrogen. Given the very high refuelling flow rates, active recondensation systems are not currently considered feasible due to the high-power requirement, so alternative solutions will have to be developed;
- The integration and assembly of large-scale liquid hydrogen refuelling stations has not previously been demonstrated, given that liquid hydrogen handling difficulty increases with higher flowrates;
- There are no uniform standards and safety regulations for liquid hydrogen refuelling stations while communication and emergency mitigation protocols are still to be developed.

The scope of this topic is to develop, build and operate a liquid hydrogen refuelling station that should demonstrate a delivery flowrate of at least 5 tonnes per hour. The LH_2 HRS should demonstrate a potential for scaling-up with technical and economic improvements. The LH_2 HRS should be capable of reducing the energy consumption and specific cost of hydrogen to prepare for the wide scale deployment of hydrogen for the benefit of heavy-duty transport and its ecosystem with zero emissions. The demonstration of a high-performance large hydrogen refuelling station would impact other SRIA roadmaps related to liquid hydrogen (transportation, storage, end-usage as aviation, etc).

The following activities should be within the scope of this topic:

- Development of a demonstrator with proven scalability in railroad, aircraft or maritime applications;
- Provision of a techno-economic analysis of the performance of these systems including energy consumption (in kWh/kgH_2), CAPEX, OPEX;
- Development of a model to forecast boil-off gas generation during operations;
- Development of a metrology system or methodology for measuring or evaluating the quality and quantity of delivered hydrogen (ortho-para content, temperature, pressure). Proposals are expected to collaborate and explore synergies with the activities of EURAMET's European Metrology Networks[116] (e.g MetHyInfra[117] project).
- Development of a methodology to evaluate hydrogen emissions (including leakage);
- Development of operations protocols, including for fuelling, venting or flaring, stand-by and emergency;

[116] https://www.euramet.org/european-metrology-networks
[117] https://www.euramet.org/european-metrology-networks/energy-gases/activities-impact/projects/project-details/project/metrology-infrastructure-for-high-pressure-gas-and-liquified-hydrogen-flows

- Evaluate the life cycle environmental performance of the system.

Optionally, the demonstration may include the dual usage or the repurposing of LNG import terminals.

Proposals are expected to explore synergies with the topic included in Horizon Europe Work Programme 2023-2024 HORIZON-CL5-2023-D5-01-07: 'Hydrogen-powered aviation' and with the activities of ZEWT partnership.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

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.

HYDROGEN END USES: TRANSPORT APPLICATIONS

HORIZON-JTI-CLEANH2-2023-03-01: Real environment demonstration of Non-Road Mobile Machinery (NRMM)

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 5.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 10.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 4-5 and achieve TRL 7 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 5.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Procedure	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.
Legal and financial set-up of the Grant Agreements	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): fuel cell system, onboard hydrogen storage and other components needed in a hydrogen powered non-road mobile machinery, costs may exceptionally be declared as full capitalised costs.

Expected Outcome

Internal combustion engines (ICEs) in Non-Road Mobile Machinery[118] (NRMM) (e.g. diesel or gasoline fuelled) significantly contribute to global GHG emissions, as well as local air pollution, by emitting carbon oxides (CO_x), hydrocarbons, nitrogen oxides (NO_x), and particulate matter. Moreover, combustion engines cause significant noise and odour disturbances for the driver, the workers and the surrounding environment.

Hydrogen fuel cells appear to be a suitable solution for such types of vehicles compared to batteries. However, the reliability and performance stability of a complete fuel cell system on NRMM in harsh environments, and/or where access to electricity is limited, as it has not been yet demonstrated.

Proposals are expected to contribute to increase the necessary knowledge of hydrogen FC technology and demonstrate systems in specific non-road applications. As such, it will set a robust basis for the future development, from production lines to commercial products, of NRMM vehicles, as well as providing insights with respect to requirements for refuelling stations.

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

- Demonstration of hydrogen FC NRMMs performance and reliability in real environments by 2027;
- Validation of safe hydrogen FC solutions and systems in demanding off-road applications;
- Acquiring data for the calculation of total cost of ownership and comparison with other existing and future technologies;
- Building confidence in hydrogen fuel cell technology and supply chain for all of the off-road industry sectors and thus accelerating their uptake;
- Identification of suitable solutions to any legal or standards requirement likely to prevent the successful introduction of hydrogen FC technology in the various NRMM fields of application;
- Increased energy efficiency of NRMM resulting in energy savings in line with REPowerEU priorities.

Project results are expected to contribute to the following objectives and KPIs:

- Single machine level impact, targeted figures by 2030:
    - Avoided emissions, respectively for 50 /100 / 150 / 250 / 400 kW NRMM: 11,3 / 22,5 / 41,4 / 149,2 / 271,9 tonnes of CO_2-eq / year
    - Hydrogen consumption, respectively for 50 /100 / 150 / 250 / 400 kW NRMM : 1,0 / 1,9 / 3,5 / 12,7 / 23,1 tonnes of H_2 / year
    - External sound power level reduction, respectively for 50 /100 / 150 / 250 / 400

[118] Definition of NRMM as per EU regulation 2016/1628: 'non-road mobile machinery' means any mobile machine, transportable equipment or vehicle with or without bodywork or wheels, not intended for the transport of passengers or goods on roads, and includes machinery installed on the chassis of vehicles intended for the transport of passengers or goods on roads.

kW NRMM :-9 / -10 / -11 / -12 / -13 dB(A)

- Fuel Cell power system on NRMM :
  - Fuel Cell power system lifetime: 80% of conventional power sources by project end, same or better than conventional power source by 2030.
  - Fuel Cell module CAPEX: < 800 €/kW by proejct end, < 500 €/kW in 2030
  - Fuel Cell module availability: 80% of NRMM availability by project end, same or better than NRMM by 2030

Scope

This topic is addressing types of NRMM currently running with an ICE utilising conventional fuels in the construction & mining (excavators, loaders, haulers, bulldozers, etc.) and agricultural & farming (harvesters, cultivators, etc.) sectors.

The scope is to develop and demonstrate mature prototypes of hydrogen FC propelled machinery, operating in a defined end-user ecosystem. Hydrogen should be available on / very close to the work site, for refuelling purposes.

The technology gaps to be addressed are the following:

- NRMM performance should be at the same level as current diesel engine NRMM, through the optimisation of the complete NRMM power supply system: transient mode, high torque availability at low rpm are examples of specific demanding working conditions to be fulfilled to guarantee NRMM performance and efficiency.
- Components and system reliability under the specific working conditions of the various NRMMs :
  - Vibrations and shocks occurring during regular NRMM operation.
  - Filtering system efficiency against dust or any other external pollutant in order to guarantee the fuel cell stack lifetime and avoid early wear and malfunctioning.
- Management of water deposits for stationary type NRMMs.

Proposals should:

- Develop at least two different types of NRMMs relevant for a certain end-user ecosystem, and representative of as many applications as possible in terms of machine power and duty cycles. Applications / work sites considered should belong to the Construction & Mining and/or Agricultural & Farming sectors.
- Develop newly designed vehicles in order to provide an optimal integration of the complete FC system in the NRMM architecture (as such, retrofitting existing ICE vehicles is not in the scope of the topic);
- Run the NRMMs simultaneously at a real operations site, and operate each of them for at least 1,000 NRMM working hours;
- Bring suitable technical solutions and verify the effectiveness and safety of the complete system developed for the specific working conditions and applications of the various types of NRMMs;

- Demonstrate:
    - The performance and reliability of the complete fuel cell system on the different NRMMs;
    - The up-time of machinery and thus work sites with a rapid, secured and safe refuelling process on site based on existing standard protocols, whenever available;
    - As a global outcome, the viability and relevancy of future commercial vehicles;
- Identify suitable solutions to meet relevant legal or standards requirement likely to prevent the successful introduction of hydrogen FC technology in the various NRMM's fields of application. As an example: ATEX classification compliance for mining environment.
- Assess the TCO of the solution developed, both at prototype development stage (small number of vehicles) and projected in 2030 with different market uptake and technologies maturity development.

Proposed projects should prove the scalability and/or the modularity of the solutions demonstrated to either bigger or smaller models of a given type of NRMM.

Internal combustion engines with hydrogen injection are not in scope of this topic

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

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.

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 protocols[119] to benchmark performance and quantify progress at programme level.

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

HORIZON-JTI-CLEANH2-2023-03-02: Development of a large fuel cell stack for maritime applications

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 7.50 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 7.50 million
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 4 and achieve TRL 6 by the end of the project - see General Annex B.

Expected Outcome

Hydrogen as fuel for the maritime sector could be pivotal to foster global maritime decarbonisation as it has significant advantages compared to pure battery electric propulsion. However, such maritime applications require higher power and much longer lifetimes than those developed and achieved so far by state-of-the-art FC stack/systems. In this sense, projects should still validate in relevant environment and according to real end-users needs and load profiles, high power and long-lasting FC stacks to be in the future building blocks of >10 MW FC systems for maritime applications.

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

- Improvements in design, diagnostics and monitoring procedures of FC stacks (also looking at innovative measuring / sensor devices at this purpose);
- Improvements of testing protocols for the quantification of FC stacks performance and lifetime in maritime environments, including accelerated stress tests;
- Contribute to paving the way towards increased competitiveness of EU FC manufacturing companies in the emerging global market for FC technologies in the maritime sector;
- Improvement of overall system performance of FC stacks in order to improve the availability and durability and meet the needs of naval and maritime end users.

Project results are expected to contribute to the following objectives and KPIs of the Clean Hydrogen JU SRIA for fuel cell technology for maritime sector:

- FC power rating: 3MW for 2024, 10 MW for 2030
- Maritime FCS lifetime: 40.000 h for 2024, 80.000 h for 2030
- PEMFC system CAPEX: <1,500 EUR/kW for 2024, 1,000 EUR/kW for 2030;

Following the validation of “marine ready” and reliable FC stacks (able to operate in multi-modal-modular systems) the proposed project should lay the foundations for future developments of fuel cell system for maritime applications.

Scope

Proposals should cover the development of a high-power stack for maritime applications and should address in particular either PEM or Solid Oxide technologies, which are considered the most promising technologies for maritime sector as already proven by the already funded projects MARANDA[120], HyShip[121], FLAGSHIPS[122], and ShipFC.

A large FC stack for maritime applications should be developed by the end of the project according to either one of the following minimum requirements:

- A PEM stack with nominal power in the range of 250-500 kW at beginning of life and with scalability at system level to several tens of MW;

  or

- A Solid Oxide (SO) stack with nominal power in the range of 100-250 kW at beginning of life and with scalability at system level to tens of MW.

Above mentioned power capacity levels should be targeted at single stack level (not at subsystem level, overcoming stacks currently validated in the projects HyShip, FLAGSHIPS, MARANDA and ShipFC) with a robust testing campaign to prove stack reliability.

Research should be undertaken based on the newly developed stacks in view of outlining a pathway for a fuel cell system of high power (multi-MW range) that can be adapted to maritime applications (building on the project outcomes and integrating stacks developed in this project), with spill overs towards stationary applications.

Each project should develop one stack technology (PEM or SO) and therefore, at least one FC stack manufacturer should be part of the consortium.

For this purpose, the stack should be developed and validated in relevant environment (at the end of the project, each stack should reach at minimum TRL 6 considering:

- The optimised design of a large active area stack design (PEMFC stack in the range 250-500kW; SOFC stack in the range 100-250 kW) able to operate in multi-modal modular stack systems towards 10 MW scale (also based on the StaSHH project guidelines[123] defining an open standard for heavy-duty fuel-cell modules);
- At least 2,000 hours of testing of the stack, to be fully characterised in relevant environment, enabling to test modules in moisty and salty conditions and considering different air inlet temperature (to simulate different installation areas on board of vessels);
- The FC stack should be validated to provide power according to sailing profile/load request of a real vessel in a simulation approach;
- High reliability and robustness of FC cell components with high lifetime requirements (> 40,000 hours in maritime application, to be guaranteed via ex-situ and in-situ qualification of components;
- The stack should incorporate features allowing for an on-line diagnostic and prognostics with the goal of reaching a target stack life of 40,000 hours (lifetime of FC stack);
- Demonstration of 40,000 hours stack life should be performed by means of accelerated

[120] https://cordis.europa.eu/project/id/735717/es
[121] https://cordis.europa.eu/project/id/101007205
[122] https://cordis.europa.eu/project/id/826215
[123] https://www.stashh.eu/.

test procedure, which should also be developed as part of the project;

- The definition of manufacturing and production processes and tolerances for the upscale of the components of the large fuel cell stack;
- Multi-modular connected stack should be able to operate when subject to vibrations and to temporary (for limited duration) tilting of +/- 22.5° in all directions;
- Identification of appropriate air filter specific for marine application should be also part of the project;
- Diagnostic and prognostics of the FC Stack should be developed also targeting features that could advice in advance the best timing for air filter replacement;
- Development of innovative measuring / sensor architecture and devices for proposed diagnostics approaches and testing purposes.

Development of a full FC system is not expected at this stage, the focus should be at stack level where versatility (in terms of responsiveness to load demand of different on-board services and type of vessels) is key. Nevertheless, the proposed solutions should be conceived as multi-modular connected stacks. Development of a proper power electronics/conversion architecture to be developed hand-in-hand with proposed stack and development of single stack to be used into the connected stack system below should be integral part of the project. Therefore, the following specifications should be considered:

- Development should include a multi-modular connection for single stacks into one connected stack system with power from 1 to 5 MW;
- The multi-modular connected stack boundary should be designed in a way that the system integrator uses it as a single fuel cell stack;
- Multi-modular connected stack VI curve and more in general electrical characteristics should be compatible with the commonly used power electronic in the marine application for the 1 to 5 MW range;
- Clear plan for further progress of the technologies towards systems integrated in their powertrain applications should be outlined;
- Clear plan for future capability of the proposed SOFC Stack to operate with fuels different than pure hydrogen should be developed (e.g. ammonia, methanol, natural gas (NG), liquid organic hydrogen carriers (LOHC)… - which could serve as transition fuels for the sector in the near future) should be developed.

Looking at future development and on-board integration, the following activities should be envisaged:

- Scale up activities (targeting specific multi-stack FC systems sizes and cost functions), the setup of a roadmap to TRL9 and the development of potential studies for MW-scale integration on board (and FC stack/system design) are also required. At least one use case , supported by an industrial ship-owner/manager (expected to be part of the consortium or of the Advisory Board), should be developed during the project;
- Engagement of end-users is crucial to collect their feedback about the proposed FC technology, also at regulatory and non-technical level. In this sense, support from ZEWT partnership is of particular importance;

- The possibility to study the applicability of proposed FC stack with batteries and in hybrid systems with traditional on-board propulsion system ,e.g . SOFC gas turbine (GT) system (cycle integrating SOFC and GT) and ICE should be explored at simulation or at experimental level.

Cooperation with FC application in other maritime or similar projects is expected (such as StaSHH, HyShip, FLAGSHIPS, MARANDA, ShipFC, etc.) in order to start from their results on stack design. Proposals are expected to explore synergies with the activities of ZEWT partnership.

While designing the FC stack, applicants should apply a ‘circularity by design’ approach and assess the sustainability of the proposed solutions from a life cycle perspective (also benchmarking it with batteries and other FCs not investigated in design/demonstration). e.g. should estimate the carbon footprint expressed in gr CO2-eq/kWh_{el}.

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 protocols[124] to benchmark performance and quantify progress at programme level.

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

HORIZON-JTI-CLEANH2-2023-03-03: Ultra-low NO_x combustion system for aviation

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 8.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 8.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected achieve TRL 4 by the end of the project - see General Annex B.

Expected Outcome

The use of hydrogen as an aviation fuel allows to eliminate the direct CO_2 emissions from aircraft engines completely and thus offers the potential to contribute substantially to the ambition of a net-zero carbon emission aviation as defined in Waypoint 2050[125], and to the European goal to "go climate neutral" by 2050 as described in the European Green Deal. Of the available technologies and the targeted market ranges, a direct burn hydrogen combustion system for the short- and medium-range market will be the preferred configuration because currently 67 % of the global CO_2 emissions from aviation are being emitted by 70 % of the global fleet in this segment while only 30 % of the global CO_2 emissions are being emitted by long-range wide-body turbofan engines and only 3 % of the global CO_2 emissions are being emitted by regional jets (Hydrogen-powered aviation study, p. 16)[126] to which hydrogen fuel cells are currently limited because of their relatively low energy density. Therefore, direct burn hydrogen combustion systems applied to the short- and medium-range market will play the dominant role in decarbonising aviation by using hydrogen as a fuel.

Moreover, in addition to the decarbonisation initiatives, increased focus has recently been put on non-CO_2 emissions, especially NO_x, in order to drive for climate neutrality. Therefore, without the development of specialised ultra-low NO_x combustion technologies, direct burn hydrogen combustion systems are prone to experience higher NO_x emissions than current, state-of-the-art combustion systems operated with Jet-A1 because of higher flame temperatures and the high reactivity of hydrogen when burnt in air. Increased NO_x emissions would have a global warming effect from non-CO_2 emissions and would impact the local air quality around airports which would endanger the acceptance of direct burn hydrogen combustion systems and thus would limit its ability to utilise the available decarbonisation potential. The development of ultra-low NO_x combustion technologies is then an essential requirement for direct burn hydrogen combustion systems.

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

- deliver technologies for Airbus' ZEROe game-changing concepts for future commercial passenger aircraft using hydrogen as the primary energy supply (Airbus ZEROe, 2022[127])

[125] https://aviationbenefits.org/media/167187/w2050_full.pdf

[126] https://www.clean-hydrogen.europa.eu/media/publications/hydrogen-powered-aviation_en

[127] https://www.airbus.com/en/innovation/zero-emission/hydrogen/zeroe

Project results are expected to contribute to the following objectives and KPIs of the Clean Hydrogen JU SRIA as well as to the following additional KPIs:

- Low NOx emitting hydrogen turbines
- Dry low NOx emissions across all engine operating conditions at least as low as current state-of-the-art which is around 50% below regulation in force (CAEP/8).
- Dry low NOx technology with potential to reduce NOx emissions further by no less than 30% compared to state-of-the-art.

Scope

The scope of the topic is to develop a direct burn hydrogen combustion system with low NO_x emissions compatible with aero engine specifications and progress it up to TRL 4. Because of the specific thermo-physical characteristics of hydrogen (very high flame speed, high diffusivity, high reactivity, high flame temperatures, etc.) there are many technological hurdles to overcome in order to realise a reliable and successful low NO_x combustion system. The most difficult and important ones are:

- Effective temperature control in the primary zone to avoid excessive thermal NO_x production
- Reliable and safe ignition and flame stabilisation without autoignition and flash-back
- Wide stability limits necessary to cover typical engine operating ranges
- No overheating of flame holding and combustor structures (dome & liners)
- Control of thermoacoustic instabilities

Therefore, the scope for the development of the low NO_x combustion technology should include the following steps:

- Development of a new innovative fuel injection system capable of creating a homogeneous fuel/air distribution, reliable and safe ignition, and flame stabilisation without autoignition and flash-back, no overheating of flame holding and combustor structures, and effective control of the NO_x production across typical aero engine operating ranges;
- Demonstration of the low NO_x technology in single cup tests with optical access and thermoacoustic measurement capabilities up to relevant operating pressures and temperatures (T_3 = 950 Kelvin, P_3 = 20 bar);
- Demonstration of the low NO_x technology in multi-cup sector combustor tests with different thermoacoustic boundary conditions (open exit and exit restriction), and thermoacoustic as well as emission measurement capabilities up to relevant operating pressures and temperatures (T_3 = 950 Kelvin, P_3 = 40 bar);
- Demonstration of reliable and safe operation across relevant operating range (T_3, P_3, FAR: 950 Kelvin, 40 bar, at least 0.004 - 0.04) without flash-back, auto-ignition, blow-out, and over-heating of combustor hardware;
- Proof of thermoacoustic stability without excessive pressure amplitudes across relevant operating range;
- Contribution to development of EU competitiveness for low NO_x hydrogen direct burn

combustion technologies.

The project should address the following requirements and specifications:

- Reliable and safe combustor ignition at ground start conditions with 100% hydrogen;
- Lean blow-out within limits necessary for typical aero engine operation ($FAR_{LBO} \leq 0.004$);
- Dry low NO_x emissions across all engine operating conditions at least as low as current state-of-the-art which is around 50% below regulation in force (CAEP/8).
- Dry low NOx technology with potential to reduce NO_x emissions further by no less than 30% compared to state-of-the-art.
- Operability and emission performance fulfilled for hydrogen temperatures in the range of 200 – 420 Kelvin;
- Efficient fuel/air mixing without flashback and autoignition across typical aero engine operating range;
- Temperatures of fuel injectors, dome, and combustor liners within limits for targeted engine life;
- Dynamic combustion pressures (P_4) within limits for targeted engine life;
- Combustor length no longer than current state-of-the-art aero engine combustors.

Proposals are expected to co-operate and seek synergies with the projects and activities of the Clean Aviation JU. In particular:

- In Clean Aviation JU Phase 1, an existing turbofan engine will be adapted for the operation with 100% hydrogen and will be demonstrated in a ground test demonstrator in order to prove full system feasibility, starting from the liquid hydrogen tank, through the hydrogen fuel and control system including vaporiser/conditioner, up to the adapted combustor. The successful 100% hydrogen turbofan engine ground test demonstrator is a prerequisite for the planned flight test demonstrator, including contrails measurements by a chasing airplane, at the beginning of Clean Aviation JU Phase 2. Because of the very tight schedule and the challenging tasks in Clean Aviation Phase 1, only limited effort can be put on the development of a low NO_x combustion technology (limited to residence time, mixing and dilution). On the other hand, the time in Clean Aviation JU Phase 2 will be too short to develop the low NO_x combustion technology on time up to the TRL level necessary for the launch of a product development after Clean Aviation JU if no pre-development work has been performed in parallel to Clean Aviation JU Phase 1;
- Therefore, the development of the low NO_x combustion technology is proposed to be performed in this topic up to TRL4 in order to be able to further mature the technology in Clean Aviation JU Phase 2 up to TRL 6. The low NO_x combustion technology developed in the current project will be complementing the “conventional” hydrogen combustion technology developed for the early ground test demonstrator in Phase 1 of Clean Aviation JU. In order to exploit synergies between the two Work Programs, applicants are expected to exchange information with projects selected from the Clean

Aviation JU call topic HORIZON-JU-CLEAN-AVIATION-2022-01-HPA-01[128]: 'Direct Combustion of Hydrogen in Aero-engines', including (but not limited to) engine and/or combustion chamber geometries and specifications, and forecast emissions profiles;

- The development activities in this topic should be closely aligned with the projection of a hydrogen direct burn innovation as defined in Clean Aviation JU in order to develop a targeted low NO_x combustion technology for this application.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

[128] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-ju-clean-aviation-2022-01-hpa-01;

HYDROGEN END USES: CLEAN HEAT AND POWER

HORIZON-JTI-CLEANH2-2023-04-01: Development and validation of high power and impurity tolerant fuel cell systems ready to run on industrial quality dry hydrogen

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 4.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 4.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 3 and achieve TRL 5 by the end of the project - see General Annex B.

<u>*Expected Outcome*</u>

Hydrogen offers a unique chance to decarbonise the power generation and heating sectors reliably and independently from weather or seasonal conditions. Fuel cells are known as the most efficient energy conversion devices, outperforming the conventional power sources. Hydrogen and natural gas-powered fuel cell systems have reached high-level TRL and demonstrated reliable durability in operation. If hydrogen is generated from renewable energy sources, then the fuel cells proposition is unique, as they are the most efficient technology able to produce clean energy with zero emissions. Going up to the MW scale, fuel cells generate power with the highest efficiencies offering a clean and near-silent alternative to conventional solutions such as combustion engines.

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

- Support industrial heavy-duty applications that have considerable potential for CO_2 emission reduction by utilisation of green hydrogen. Specifically, cold ironing (idling) of ships and ground power supply in ports are potential use cases in line with the proposed activity.
- Support the EU industry to establish first value chains for hydrogen use in stationary, port and aviation infrastructure (including maritime and heat re-use for other applications) providing a nucleus for expansion to other areas.
- Prepare the ground for development of commercial / industrial scale combined heat and power (CHP) unit(s) and/or prime power unit(s) from EU suppliers (100 kWe – 1 MWe);
- Support the demonstration of the deployment of the next generation of commercial/industrial scale fuel cell CHP and/or prime power units from EU suppliers.

The project results are expected to contribute to the following objectives and KPIs of the Clean Hydrogen JU SRIA:

- Reduction of CAPEX and TCO of stationary fuel cells of all sizes and end use applications for cold ironing and ground power supply addressed by the current Call;
- Preparation and demonstration of the next generation of fuel cells for stationary

applications able to run under 100% H_2 and other H_2-rich fuels whilst retaining high performance.

- Specifically, the following KPIs are expected to be reached:
  - Electrical efficiency of the system 52% (LHV) at nominal power at Beginning of Life (BoL);
  - Total system power degradation of 0.4% at rated power measured over at least 1,000 hours of continuous operation at nominal operating conditions;
  - 98% availability of the system during whole testing period cumulating ≥ 5,000 operating hours;
  - Warm start time and switching between full and part load operation in 10 minutes;
  - Targeted capital production system costs based on 100 MWe/annum production volume of 2,000 €/kWe;
- Non-recoverable platinum group metals (especially in electrodes) < 0.07 gr/kWe, if platinum group metals are present;
- Improvement of flexibility of systems in operation in particular with reversible fuel cells and integration with thermal storage.

Scope

EU is a world leader in fuel cell technology. Fuel cells "made in Europe" have undergone a successful development and the different types of FC driven devices, mainly in the power range up to 20 kWe, are on the way to deployment in multiple stationary power markets. The EU automotive industry is on the cutting edge of development of hydrogen fuelled heavy duty vehicles, which however are operated with high purity hydrogen and have thus less requirements on longevity.

Development of high power range fuel cell systems projects CISTEM[129], DEMOSOFC[130], ComSos[131], GRASSHOPPER[132]) as well as fuel flexibility towards the blends with hydrogen (project SO-FREE[133]) have been already addressed by previous EU funded projects paving the way for this actual next step : efficient and reliable high power output systems operating on industrial quality hydrogen. The coming "green" hydrogen economy however, requires highly efficient and flexible power generators in the power range 100 kW to 1 MW and that are able to operate with industrial quality dry hydrogen (95% pure). The generators in this power range are required for decarbonisation of maritime, aviation and other sectors, including the energy supply for critical infrastructure (prime power), charging stations for local electrical vehicle fleets, and idling, cold ironing, and ground operation.

This topic aims to bridge the power gap between small stationary and MW installations, by developing and validating a building block in the shape of a renewable hydrogen fuelled fuel cell system (of at least 100 kW), which can be customised for various applications, have a modular design and be impurity tolerant. The duration of the validation should be at least 5,000

129 https://cordis.europa.eu/project/id/325262
130 https://cordis.europa.eu/project/id/671470
131 https://cordis.europa.eu/project/id/779481
132 https://cordis.europa.eu/project/id/779430
133 https://cordis.europa.eu/project/id/101006667

hours. This building block should be able to operate at any location having access to any renewable hydrogen supply sources underground storage facilities initially used for natural gas storage, natural gas grid enabled to transport hydrogen as well as dedicated hydrogen grid. Moreover, the durable and flexible (full and partial load) operations of a ≥ 100 kW fuel cell system with industrial quality dry hydrogen (95% pure) should be also explored. Ability of operation on a second type of fuel or hydrogen blends may be included too. The validation should be performed for use case cold ironing or ground power supply at the site, where industrial quality dry hydrogen fuel without blending is available.

The following activities should be within the scope of this topic:

- Hydrogen fuelled system design and development utilising existing fuel cell stack manufacturing technologies;
- Analysis of impurities in hydrogen coming from renewable hydrogen generators, storage and other sources (expected impurities to be considered are CO, odorants, CH_4, N_2, CO_2, ethane and propane with total content up to 5%) and development of impurity-tolerant system;
- Quantification of degradation in fuel cells and BoP components, and the effect of operation parameters on degradation at different impurity level and operational cycles;
- Risk assessment of safety aspects in relation to the future certification of the system and techno-economical assessment for a selected application;
- System operation with commercially available and affordable hydrogen with major impurities/contaminants including state of health monitoring;
- Dynamic modelling of system performance on hydrogen and hydrogen blends (if reasonable for the application selected) and system dynamic load and transient behaviour operation according to the end-user load profile(s) for selected application(s).

Efficient heat extraction and re-use may be addressed to increase total system efficiency. The utilisation of existing but not commercially available single stack with considerably increased power output, robustness etc. in comparison to the state-of-the-art technology (e.g. 20 kW_e for SOFC, 120 kW_e for PEMFC) may be considered as a cost-effective path to higher power output units in parallel to utilisation of commercially available stacks.

Extraction of hydrogen from different hydrogen carriers is not in the scope of this topic. Consortia are expected to gather comprehensive expertise from the EU research and industrial community to ensure broad impact by addressing the abovementioned items. A participation of end user(s) for the selected system application is expected.

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 protocols[134] to benchmark performance and quantify progress at programme level.

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

HORIZON-JTI-CLEANH2-2023-04-02: Research on fundamental combustion physics, flame velocity and structure, pathways of emissions formation for hydrogen and variable blends of hydrogen, including ammonia

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 3.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 3.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	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 a potential enabler of a low-carbon economy and can be a key instrument for the European Green Deal and the recent REPowerEU Plan objectives. However, hydrogen storage and distribution issues represent a challenge for its implementation: for example, ammonia (NH_3) is currently considered a promising solution as hydrogen carrier to overcome such barriers, but other unconventional hydrogen blends can be identified (including $NH_3/H_2/N_2$ blends obtained through partial decomposition of NH_3) whose reactive features should be well established before their exploitation in combustion applications.

While knowledge on hydrogen enriched natural gas combustion is well established, new blends (like $NH_3/H_2/N_2$ blends) were not investigated enough and require some fundamental research, also exploring conditions due to specific approaches that can be adopted to reduce NO_x emissions like Exhaust Gas Recirculation (EGR). Gaining insights in these unconventional hydrogen blends combustion will contribute to enhance gas turbine fuel-flexibility and to strengthen the backbone of the future hydrogen infrastructure, finally supporting EU's energy system decarbonisation pathway and effectively ensuring the grid stability and security of supply, thus promoting the sustainability of an increasing share of variable renewable energy sources. Besides, progressing technology using hydrogen and its blends as fuel will promote the commercial viability of hydrogen generation, an important step for the realisation of a circular economy system and sustainable development. Finally, the topic fundamental low TRL activities on gas turbines would be beneficial for all combustion applications, including industrial boilers and burners, and marine and aerospace transportation.

Project results are expected to provide fundamental knowledge about several aspects related to the utilisation of hydrogen blends with ammonia or other not well-known hydrogen blends with methane (natural gas) in Dry Low Emission (DLE) gas turbines (which use premixed lean-combustion principles to achieve a reduction in NO_x emissions).

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

- Identify accurate chemical kinetics mechanisms of oxidation and pollutants formation;
- Enhance knowledge in combustion dynamics and define reliable and suitable indexes for the real-time identification of instability precursors;

- Identify fuel-flexible low-NOx combustion technologies, upon exploration of currently promising sequential combustion, EGR and micro-mixing approaches, and evaluate their technological feasibility for applications in distributed systems all the way to large scale power generation plants;
- Overcome the remaining barriers to the performance of combustion units using such blends;
- Ensure a cost effective and safe utilisation of unconventional hydrogen blends, including hydrogen mixtures with ammonia, as gas turbine fuel.

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

- Preparing gas turbines to run on 100% hydrogen, while ensuring the required fuel-flexibility in the energy transition and keeping conversion efficiencies and NO_x emission to acceptable levels.
- Increase hydrogen percentage in the fuel (at least 70% by volume in 2024);
- Maintain low NO_x emissions (<25 ppmv @ 15%O_2/dry @ 70% and 100% vol H_2, or more specifically, 29 NO_x mg/MJ fuel @ 70% vol H_2 in 2024 and 24 NO_x mg/MJ fuel @ 100% vol H_2 in 2030);
- Enhance gas turbine ability to handle hydrogen content fluctuations (at least ±15% points H_2 volume / minute in 2024, with a view to reach ±30% points in 2030).

Scope

Use of natural gas mixtures with high hydrogen content still exhibits high NO_x pollutant emissions, thus requiring the implementation of appropriate combustion technologies in new or existing gas turbines, such as DLE, sequential combustion, EGR and micro-mixing approaches. Besides, although recent research has shown that partial decomposition of ammonia (after transportation) to a blend of ammonia/hydrogen/nitrogen can be an interesting solution, many fundamental aspects of ammonia/hydrogen flames are not yet known, and NO_x emissions are a concern too. Other potential not well-known hydrogen blends could show similar issues.

Proposals should address the following areas of R&I:

- Development/validation of chemical kinetics mechanisms for combustion of unconventional hydrogen blends also in different technological contexts, e.g. with and without exhaust gas recirculation, from atmospheric to industrially relevant pressures, giving special emphasis on NO_x and N_2O formation pathways especially for ammonia/hydrogen blends. Achieving an optimal balance between accuracy and complexity (i.e. computational cost in its use) should be considered as an important achievement;
- Numerical modelling and laboratory-scale experimental investigation of the conditions that ensure static (flashback and blow-out control) and dynamic (control of thermo-acoustic instabilities) stabilisation of premixed and non-premixed flames of unconventional, not well-known hydrogen blends while conserving low-emission performance, from atmospheric to industrially relevant pressures. The specific strategy that will be adopted to pursue the main goal should be clearly described in the proposal

(e.g. fuel/air staging, fuel injection, blending etc.);

- Identification of real-time monitoring strategies of combustion, that can be reasonably implemented in gas turbines. The selected strategy should also come up with the definition of reliable and suitable indexes for the real-time identification of instability precursors.

In developing its concept, proposals are expected to address the following related aspects:

- To lower the environmental impact of the proposed solution (in particular, the level of pollution it will create and in general, the overall contribution to harden the climate emergency);
- To lower the barriers to the deployment of such technologies, including issues related to social acceptance and safety.

Proposals should address the validation of unconventional, not well-known hydrogen blends (like $NH_3/H_2/N_2$ blends) combustion to TRL 4, presenting a robust research methodology and activities, establishing its technological feasibility. The methodology should include proper assessment of the technological feasibility, safety, and risk of using new blends in DLE gas turbines for power generation and transport applications, including environmental, social, and economic risk/benefit balance (e.g. evaluation of cost reduction and efficiency improvements vs consequences in case of accident). These aspects may provide ideas, experiences, technology contributions, knowledge, new approaches and skills.

Successful projects should provide supporting data, guidelines, and design tools for equipment manufacturers in combustion applications (mainly gas turbine).

Consortia are expected to include research and academic centres as well as gas turbine manufactures that can provide guidance and suggestions on the combustion technologies.

Proposals are expected to collaborate and explore synergies with projects supported under the topic “HORIZON-JTI-CLEANH2-2022-04-04: Dry Low NOx combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications”.

HORIZON-JTI-CLEANH2-2023-04-03: Retrofitting of existing industrial sector natural gas turbomachinery cogeneration systems for hydrogen combustion

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 6.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 6.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 5 and achieve TRL 7 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 6.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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 for the action (or developed as part of the action tasks): combustion system of the gas turbine and related components needed to retrofit the gas turbine including hydrogen storage and feed, costs may exceptionally be declared as full capitalised costs.

Expected Outcome

In the gas transmission systems, gas turbines in simple and combined cycles, can achieve a significant reduction of atmospheric pollution and greenhouse gases emissions only by transitioning to carbon-free fuels and by increasing the share of 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 are considered to be the most robust, mature and cost-effective technology, and are bound to reinforce their role as guarantors of grid stability and reliability. To fulfil this role in line with the Paris Agreement's goals[135], power generation from gas turbines needs to be decarbonised.

[135] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Increase of thermal and mechanical efficiency by adopting cogeneration systems can contribute to reduce the carbon footprint of the industrial sector, even if a substantial decarbonisation can be achieved only by blending increasingly higher fractions of hydrogen into natural gas (the gas turbines conventional fuel). The capability for gas turbines to operate on hydrogen-based fuels is a key future requirement to fulfil the target of CO_2-carbon free power generation. Those play a strategic role in achieving the EU energetic independency from sources external to the community (REPowerEU).

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. Therefore, a significant advancement both in gas turbines combustion systems technology (TRL range up to 6) and in gas turbine product industrialisation (TRL range 6-8) is still necessary.

Project results are expected to contribute to the following outcomes:

- Accelerate the achievement of industrial sector decarbonisation via the retrofitting of existing heat and power generation systems with gas turbines able to burn up to 100% hydrogen, while still guaranteeing low NO_x emissions, high efficiencies and operational flexibility to typical values obtained in natural gas combustion conditions.

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

- Demonstrate enhancement of gas turbine flexibility with respect to the state of the art;
- Increase the maximum hydrogen fuel content during the start-up phase;
- Ability to handle increasing hydrogen content fluctuations;
- Increase the minimum ramp rate;
- Increase the level of safety of hydrogen technologies and applications;
- Specifically, the following KPIs are expected to be reached:
    - H_2 content in gas turbine fuel in the range 0 – 100 %vol;
    - NO_x emissions < 25 ppmv @ 15%O_2 (30-100% vol H_2) and < 15 ppmv @ 15%O_2 (0-30% vol H_2);
    - Max H_2 fuel content during start-up up to 100 %vol;
    - Max admitted efficiency reduction in H_2 operation in the range 0.5 – 2 % points;
    - Minimum ramp rate 10 % load / min;
    - Ability to handle H_2 content fluctuations ±30 % vol. / min;
- Maximum admitted power reduction in H_2 operation 0.5 – 2 %points.

Scope

Technological development of gas turbines combustion systems is aimed to handle incremental percentage of hydrogen blended in the natural gas as fuel. A further step, in accelerating the energy sector decarbonisation, is to provide gas turbine solutions able to be used with their own flexibility in handling fast load changes over the wider range of natural gas / hydrogen blends up to the full hydrogen composition.

In parallel with the incremental hydrogen availability offer expected for the next years, the required final TRL 7 is pushing gas turbine technology and products development to the commercialisation phase and the fleet replacement and/or enhancement by the end users by new engine solutions able to provide with hydrogen/natural gas blends, similar performances of the current natural gas ones.

Considering the purpose of retrofitting the combustion system in existing gas turbines fleets for the hydrogen combustion, the targeted gas turbine size for cogeneration applications is at least 10 MWe.

A minimum number of 60 (not continuous) fired hours should be achieved, to properly cover the system behaviour characterisation, including typical transient conditions of gas turbine system operations.

A starting TRL 5 is required, which means that the larger part of the technology effort to develop a retrofittable combustion system able to meet the ambitious targets described by the KPI has been already performed at laboratory scale (e.g. for annular combustion system architecture, a full annular rig full pressure and temperature test successfully performed; for can combustion systems, a single can full pressure and temperature test successfully performed).

In order to reach TRL 7 at the end of the project, proposals should therefore include:

- Detailed simulations aimed to define the cogeneration system expected performances and the gas turbine durability (mean time between maintenance in terms of start-stop cycles number and fired hours);
- Development of dedicated safety and plant integration concepts to enable operation of the retrofit GT unit with up to 100% H_2;
- Execution of a field test with a gas turbine equipped with DLE H_2 system:
    - Availability of a gas turbine engine equipped with DLE H_2 system;
    - Availability of required hydrogen amounts to conduit an engine test campaign with respective feed lines, storage system typically required;
    - System behaviour characterisation, including typical transient conditions of the gas turbine system operation (start-up ramp to full load, loads rejections, turndown limits);
    - Transient conditions characterisation, related to fuel composition variation;
    - Real system environment setup of acoustic damping systems;
    - Availability of a demo plant with a cogeneration system and possibility to perform multiple start-stop cycles;
- Evaluation of the legislative barriers, if any, of using co-generation systems including a gas turbine retrofitted with combustion systems able to operate with fuel compositions up to 100% hydrogen.

Applicants should ensure and provide evidence of the availability of hydrogen, as function of the gas turbine size, both in terms of required quantity fulfilment and its storage and feed.

Proposals are expected to collaborate and explore synergies with projects supported under the topic “HORIZON-JTI-CLEANH2-2022-04-04: Dry Low NOx combustion of hydrogen-enriched fuels at high-pressure conditions for gas turbine applications". In addition, applicants are encouraged to seek synergies with existing projects of the Horizon Europe Process4Planet and Clean Steel partnerships or future topics. In particular with the view of integrating the developed solution(s) into larger scale, real-life applications. Synergies with hydrogen production topics supported by the JU in the current call (such as HORIZON-JTI-CLEANH2-2023-01-07: 'Hydrogen use by an industrial cluster via a local pipeline network') maybe considered for the hydrogen supply during demonstrator tests.

Proposals are expected to address sustainability and circularity aspects.

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.

HORIZON-JTI-CLEANH2-2023-04-04: Hydrogen for heat production for hard-to-abate industries (e.g. retrofitted burners, furnaces)

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 6.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 6.00 million.
Type of Action	Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 5 and achieve TRL 7 by the end of the project - see General Annex B.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 6.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Legal and financial set-up of the Grant Agreements	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 burner and related components needed to integrate it in existing burners/furnaces including hydrogen storage and feed, costs may exceptionally be declared as full capitalised costs.

<u>*Expected Outcome*</u>

When produced with renewable or low-carbon energy sources, hydrogen represents a unique opportunity for the decarbonisation of energy-intensive and hard-to-abate industrial sectors where thermal heat is required. This is notably the case for the steel, glass and ceramics sectors. The overall goal of clean heat and power pillar of the Clean Hydrogen JU SRIA is to support EU 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, including industrial applications.

Over the past years, some progress has been made in the use of hydrogen in burners and furnaces for heat production, notably for blends of hydrogen and natural gas. Moreover, given the current situation of energy dependence in Europe and geopolitical conflicts, interest in the search for alternatives to fossil fuels has grown enormously, mainly among large energy consumers and energy-intensive industries, including the steel, glass and ceramics sectors.

As the share of hydrogen in the gas grid increases and conversion programmes for 100% hydrogen appear, there will be a need for hydrogen-fired industrial burners and furnaces to provide high temperature heat. Gas burners and furnaces units should be 100% hydrogen ready and fulfil the same NO_x emissions standards as gas burners by 2030.

In general, burner technologies provide a unique opportunity to reutilise existing infrastructure, reducing investment costs in new infrastructure and ensuring a cost-competitive transition to renewable gases and zero-carbon power generation. They do not pose strict requirements to fuel gas purity and are able to tolerate traces of other species, enabling therefore the adoption of cost- and energy-effective production and offering hydrogen conversion technologies at large scale.

The vision for 2030 is to have 100% hydrogen ready EU combustion systems fulfilling emission standards, for cleaner and sustainable dispatchable power and high temperature heat. Progressing technology using hydrogen as fuel in intensive industries will promote the commercial viability of hydrogen generation, an important step for the realisation of a circular economy system and sustainable development.

A great challenge in using hydrogen as an energy source is the adaptation of existing industrial plants to this new fuel. Among the technical challenges that hydrogen combustion presents there are its higher flow rate and flame temperature, as well as higher NO_x emissions with respect to natural gas, for example, as well as flame invisibility and greater possibility of leakage than for other fuels.

In addition, for the design of the combustion equipment using hydrogen it is important to take into account its low density, so it is important for the design of the burners to control the speed of gas at the injection points and the possible speed of return of the flame. It is also necessary to study the adaptation of the flames in the different hearths of the furnaces to observe the consequences of a flame temperature higher than other gases and the impact in the quality of the products obtained.

This topic aims to contribute to the demonstration and promotion of the use of H2 for thermal use in industries that are hard to abate. Project results are expected to contribute to all of the following expected outcomes:

- Open a new path for large scale demonstration of H_2 technologies in burners and furnaces, allowing their inclusion in wider viable business models, such as hydrogen valleys. This will allow the assurance of H_2 supply to the demonstrators and a better integration between H_2 production and demand;
- Contributions with a full-scale demonstrator to one of the different energy intensive industrial sectors by 2027;
- New business models for hydrogen-based heat production in energy intensive industries;
- Contributing to EU leadership for next generation hydrogen burners/furnaces solutions based on different technologies that will be applicable for hard to abate and energy

intensive industries.

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

- Understanding the hydrogen combustion mechanism and developing or retrofitting furnaces with combustors and burners respectively able to run on 100% hydrogen whilst respecting the NO_x emissions standards;
- Development of specific actions supporting the direct use/storage of hydrogen and, where applicable, oxygen from electrolysis at low pressure for combustion and include also the flexibility of burners towards various fuels (hydrogen, natural gas, ammonia – normally dedicated but not limited to ambient pressure);
- Development of processes and procedures that could develop to industry standards on safety and plant integration and demonstrate the retrofitting of burners so that they are able to run up to 100% H_2;
- Development of plant integration processes and procedures that could further develop to industry standards, business models and value chains, incl. retrofitting.

The following KPIs should be therefore addressed:

- 100% fossil fuel substitution;
- NO_x emissions equal or below applicable legislation (i.e., for specific region and industry);
- Maintain the quality of the final products (depending on the industrial sector and its standards).

<u>Scope</u>

The scope of this topic is to develop and validate an integrated hydrogen burner system within heating furnaces in energy intensive industrial applications by retrofitting existing furnaces so that they are able to run on up to 100% hydrogen;

Proposals should address the following:

- Development of pure hydrogen and hydrogen/standard fuel mixtures burner to be integrated in existing furnaces compliant NO_x emission standards (industrial scales). Research areas should focus on flame monitoring, optimal mixture formation and impact of buoyancy effects, flame stability & flashback and reduction of emissions. The implementation of the development should be executed on a demonstrator in an operational environment ensuring a TRL 7 at project end. The demonstrator should run for a period of at least 6 months, operating for at least 100h at 100% hydrogen. The furnace thermal output should be of at least 1 MW_{th}.
- Assessment of the impact of the use of hydrogen in its different percentages of substitution for fossil fuels in furnaces and products within different hard to abate application sectors.
- Investigation of the influence of hydrogen and higher gas supply pressures on component tightness.
- Development of concepts for the safe integration of hydrogen in industrial plants in the

sectors of application and demonstration of the retrofitting of burners so that they can be operated safely with up to 100% H_2 including odorants, colorants and others as applicable.

- The hydrogen-based burner should demonstrate the potential to achieve an equal or improved heating performance (in terms of energy used to heat certain mass/volume).
- Investigations of potential impacts on process performance, equipment operation and maintenance under the presence of hydrogen combustion products (heat exchangers, flame detection, heat recovery technologies, burner nozzles, etc.).
- Integration of hydrogen production units in industrial environments with high temperature processes (waste gases enthalpy content, requirements in terms of hydrogen supply pressure and purity, etc.).
- Techno-economic analysis to replicate the solution to other industrial sites. Study the impact of the H_2 cost to the final costs of the final product and impact of CO_2 emissions reduction in the final cost of the product (under ETS program).

Applicants should ensure and provide evidence of the availability of hydrogen, as function of the thermal output of the furnace demonstrated.

Proposals are expected to build on previous projects supported by the Clean Hydrogen JUJU. In addition, applicants are encouraged to seek synergies with existing projects of the Horizon Europe Process4Planet and Clean Steel partnerships or future topics. In particular with the view of integrating the developed solution(s) into larger scale, real-life applications. In addition, synergies with hydrogen production topics supported by the JU in the current call (such as HORIZON-JTI-CLEANH2-2023-01-07: 'Hydrogen use by an industrial cluster via a local pipeline network') maybe considered for the hydrogen supply during demonstrator tests.

Applicants are encouraged to address sustainability and circularity aspects in the activities proposed.

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.

CROSS-CUTTING

HORIZON-JTI-CLEANH2-2023-05-01: Product environmental footprint pilot for a set of FCH product categories

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 1.50 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 1.50 million.
Type of Action	Coordination and Support Action

<u>*Expected Outcome*</u>

Environmental sustainability of FCH systems is a key requirement in the path towards a hydrogen economy, with important effects on sectors such as renewable power generation, residential & industrial energy supply, and passenger & freight transport. In this regard, measuring the environmental sustainability of FCH systems from a life-cycle perspective has become a crucial need. To that end, guidelines for the environmental Life Cycle Assessment (LCA) of FCH systems have already been developed within the scope of JU-funded projects (e.g. FC-HyGuide[136] and SH2E[137]). As a natural step forward, state-of-the-art FCH-specific LCA guidelines should be used in combination with FCH product categorisation to develop related Product Environmental Footprint Category Rules (PEFCRs) for subsequent Product Environmental Footprint (PEF) studies. According to the European Commission (C/2021/9332),[138] PEFCRs are "product category specific, life cycle-based rules that complement general methodological guidance for PEF studies by providing further specification at the level of a specific product category. If a PEFCR exists, this should be used for calculating the environmental footprint of a product belonging to that product category". Hence, PEFCRs aim to provide specific guidance for calculating products' life-cycle environmental impacts with increased reproducibility, relevance, and consistency. Ultimately, the potential of this topic refers to an increased market penetration of FCH products thanks to their robust qualification as an environmentally sustainable investment according to the EU taxonomy.

Within this context, this topic addresses the development and application of a set of thorough PEFCRs in the specific field of FCH products according to the latest version of the European Commission's guidance document for the development of PEFCRs[139], thereby considering the latest recommendations as regards the PEF method[140]. Accordingly, the main project outcome of the topic will consist of PEFCRs developed for, and applied to, FCH product categories (cf. Section "Scope" for further details).

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

- Product categorisation of FCH products, thus facilitating the subsequent development

[136] https://cordis.europa.eu/project/id/256328
[137] https://cordis.europa.eu/project/id/101007163
[138] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM%3AC%282021%299332
[139] Product Environmental Footprint Category Rules Guidance, European Commission, May 2018
[140] C/2021/9332 Annex 1, European Commission, 2021

of future PEF initiatives for other FCH product categories after this topic;

- Enhanced reporting of the life-cycle environmental profile of FCH products thanks to increased reproducibility, relevance, and consistency, by setting clear and robust criteria on transparency, system scope definition, and assessment method;
- Supporting efforts towards methodological consistency and data availability in the field of FCH systems analysis;
- Strengthening the EU value chain on FCH products by effectively implementing a strategy that facilitates the application of life cycle thinking in the FCH sector;
- Enhanced market penetration of environmentally sustainable FCH products;
- Timely positioning of FCH products regarding continuous efforts towards European policy development and updates on key topics such as climate change, renewable energy sources, critical raw materials, circularity, and taxonomy on sustainable finance.

While specifically addressing the environmental dimension of sustainability, project results are expected to contribute to the following objective of the Clean Hydrogen JU SRIA:

- Development of life cycle thinking tools. In this regard, this topic should specifically contribute to the effective establishment of PEFCRs, and therefore environmental LCA, in the FCH sector.

In addition to the objective above, project results are expected to contribute to the following objectives:

- Strengthening the focus on environmental aspects in the framework of the transition to a circular economy; supplying the necessary assessment tools for decision making. In this regard, the results from this topic should facilitate decision-making processes effectively oriented toward environmental aspects in the FCH sector;
- Reinforcing EU's leadership position and accelerating mass-market adoption of sustainable FCH products; enhancing the sustainability and circularity of FCH technologies to support the 'EU Strategy on energy system integration'[141] and contribute to the achievement of the Sustainable Development Goals[142] and the objectives of the Paris Agreement. In this sense, this topic should provide a sound basis for the potential identification and subsequent promotion of environmentally sustainable FCH products.

Moreover, at the programme level, the project is expected to contribute to the objective of "limiting the environmental impact of hydrogen technology applications" by facilitating a sound measure of key performance indicators (KPIs) in terms of environmental impacts (including, among others, greenhouse gas emissions).

Scope

While PEFCRs have already been developed for several product categories (e.g., rechargeable batteries, photovoltaic modules, thermal insulation products in buildings, etc.), no PEFCRs are available for FCH product categories. In this context, and given the

[141] https://energy.ec.europa.eu/topics/energy-systems-integration/eu-strategy-energy-system-integration_en
[142] https://sdgs.un.org/goals

momentum of FCH systems, the prompt development and application of the first PEFCRs specific to FCH product categories should be conducted.

As regards scope, the proposals should develop PEFCRs for at least 3 FCH product categories and apply them to at least 3 case studies within each product category (i.e., at least three sets of PEFCRs in total and at least nine case studies in total). The hydrogen chain coverage attained by the set of FCH product categories should be as comprehensive as possible, including at least one product category relevant to hydrogen production, one relevant to hydrogen final use, and one relevant to another step (e.g., distribution or storage). The robust measurement and reporting of the environmental performance of FCH products should ultimately contribute to enhanced market penetration of FCH solutions.

Considering the general procedure for the development of PEFCRs, the project should involve:

- Lessons learned from work already conducted on product category rules and sectoral guidance in other fields, to provide grounds for FCH-related PEFCRs;
- Stakeholder consultation, the definition of representative products, and screening (simplified environmental footprint for the representative products);
- Iterative PEFCRs drafting and application to at least three products within each product category. This should additionally involve the provision of the datasets (life cycle inventories) used in the case studies into the hydrogen node of the Life-Cycle Data Network (LCDN) managed by the JRC.

According to the goal and scope of the topic, the expected consortium should involve experts in the field of LCA and PEF, while a significant engagement of industrial stakeholders relevant to the concerned FCH product categories is needed too.

HORIZON-JTI-CLEANH2-2023-05-02: European Hydrogen Academy

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 3.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 3.00 million.
Type of Action	Coordination and Support Action

Expected Outcome

The European Commission is placing skills at the heart of the policy agenda, steering investment in people and education and training for a sustainable recovery from the coronavirus pandemic. The European Skills Agenda for sustainable competitiveness, social fairness, and resilience[143] was presented on 1st July 2020, acknowledging education and training as essential elements in the development of the European clean energy transition towards the objectives of the Green Deal.

Hydrogen and fuel cell technologies are expected to play an essential role in the future global energy system. The SET-Plan Education[144] estimated that the increasing activity of the European FCH industry will require a work force of 180,000 trained workers, technicians and engineers by the year 2030. Vocational, college and university educational institutions working separately with no coordination will not be capable of shaping this body of expertise in the time remaining.

A number of EU projects have already developed material, processes and concepts for formal education in schools and universities, also covering some areas of professional development, in the shape of an FCH MSc programme (TeacHy[145]), level 6 technician training (KnowHy[146]), the JESS summer school (TrainHy[147]), first responder training (HyResponse[148]/HyResponder[149]), short courses (HyProfessionals[150]), information for stakeholders (HyFacts[151]), e-learning tools (NET-Tools[152]), and school level teaching material (FCHGo[153]).

However, these activities have remained largely fragmented and often were not continued beyond the end of the project, nor has the developed material been widely publicly available. The COVID-19 period has shown the importance of online teaching and learning and the value that blended learning can bring to educational training. Currently, the ERASMUS+

[143] https://ec.europa.eu/migrant-integration/library-document/european-skills-agenda-sustainable-competitiveness-social-fairness-and-resilience_en
[144] Assessment Report SET-Plan on Education and Training - Working Group: Fuel Cells and Hydrogen. Brussels, 14. Nov. 2012.
[145] https://cordis.europa.eu/project/id/779730
[146] https://cordis.europa.eu/project/id/621222
[147] https://cordis.europa.eu/project/id/256703
[148] https://cordis.europa.eu/project/id/325348
[149] https://cordis.europa.eu/project/id/875089
[150] https://cordis.europa.eu/project/id/256758
[151] https://cordis.europa.eu/project/id/256823
[152] https://cordis.europa.eu/project/id/736648
[153] https://cordis.europa.eu/project/id/826246

GreenSkills4H2 project[154] is developing publicly accessible vocational educational training (VET) materials and train-the-trainers material.

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

- Providing continued (digital) access to high-quality educational material, educational and training programmes, and high-level skills forming in the area of FCH technologies;
- Supporting the build of an adequate and capable highly skilled workforce as a key element of a competitive clean hydrogen value chain and scaling up the emerging European FCH industry;
- Creating more and better jobs, strengthening the FCH industry, research and innovation across all fields of FCH technologies, different energy carriers, and whole system integration;
- Increasing general acceptance of hydrogen technologies as this comes together with the diffusion of general knowledge and with the extensive qualification of hydrogen experts.

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

- Development of educational and training material and build training programmes for professionals and students on hydrogen and fuel cells;
- Raise public awareness and trust towards hydrogen technologies and their system benefits;
- Contribute to the SRIA target by training pupils in primary and secondary education. Project results are expected to contribute with up to 5.000 pupils from primary and secondary education at mid-term;
- Contribute to the SRIA target by training professionals. Project results are expected to contribute with up to 5000 qualified engineers at mid-term;
- Contribute to the SRIA target, universities/ educative centres offering courses on hydrogen. Project results are expected to contribute with up to 105 universities and/or educative centres at mid-term.

In addition to the targets above, in order to meaningfully contribute to the above SRIA targets, the project should fulfil the following targets by mid-term:

- A network of a minimum of 500 schools regularly offering hydrogen-related education;
- Minimum of 5000 engineers, scientists, teachers and academic staff registered as users of the project website (to be measured as ‘experts with the corresponding qualification’;
- A network of a minimum of 100 universities and educational institutions offering hydrogen-related courses (university alliance on hydrogen education);
- A minimum of 100.000 accesses to documents in a multi-lingual library with reference educational material and textbooks specialised in hydrogen topics;

[154] https://hydrogeneuroperesearch.eu/greenskills4h2-kick-off-meeting-6-7-july

- A network of a minimum of 5 jointly used training laboratories to be accessed by teachers, pupils, academic staff, and students for educational purposes.

Scope

The content of material produced by past projects requires major updates to fulfil today's expectations to teaching and learning (e.g., digital access, advanced e-learning formats) as well as translation into different languages to reach a wider audience and form the necessary technical vocabulary. To improve this situation, the education focus needs to shift to establishing a large alliance of universities and institutions that can provide certified educational training and continuously update the teaching materials, thus reflecting the rapidly developing area of FCH technologies and actively supplying the education and training necessary. Hydrogen education at schools should be targeted in order to provide FCH technology basics and foster societal awareness and acceptance.

Future work should then concentrate on further developing, translating, and organising the supply and (digital) access to content and training activities at universities, educational institutions and schools and addressing the issue of a joint qualification framework across the EU university ecosystem. For this purpose, solving the issue of portability of e-learning content and its copyright and supporting ease of implementation on any institutional learning management systems is essential. Proposals should show concrete contributions to the Digital Education Action Plan[155], specially to "*Priority 1: Making better use of digital technology for teaching and learning*" with the aim of greater cooperation at the EU level on digital education and to address the challenges and opportunities of the COVID-19 pandemic.

To this end, proposals should specifically develop at least the following elements:

- Monitoring, analysis, and adaptation to future expert profile requirements in the qualification of engineers and scientists;
- Monitoring and giving access through an online portal to educational material (school and university level) that was already developed with EU public funding support;
- Gathering and revising training materials provided by closed or ongoing EU-supported projects (see above) and understanding, in liaison with industry, the education and training needs of the teachers, students, and pupil audience;
- Establishment of a network of universities and training institutions across the EU that will share into offering FCH technology education and training;
- Establishment of a network of schools across EU that will share the offers of FCH technology education at all teaching levels;
- Coordination (including at MS level) of quality assurance across FCH education and training offerings including assessment of the coverage in hydrogen education/ training in the EU and MS, the building bricks of education/training which are missing, coordination of contents development, development of standards, peer review of teaching materials, delivery formats, etc. Applicants are encouraged to identify the obstacles or barriers at the EU level and those which might need cooperation or

[155] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0022&from=EN

actions at national level for a wider adoption/ endorsement of FCH education and training at the EU and the MS level;

- Creation of a minimum of ten free access high-quality textbooks (150 to 250 pages each) for supplying fundamental knowledge and industry-relevant practical skills in FCH technologies for use by teachers and lecturers in preparing classes, and by students, in a variety of EU languages; this will serve as an extensive reference library, but mainly support educators and trainers in developing their teaching;
- Establishment of a freely accessible online reference library of open-access documents useful for teaching and learning both at universities and schools;
- Provision of a set of free access school-level workbooks in a variety of EU languages, considering different educational levels and school systems, as a reference library for teachers across the EU;
- Development of novel approaches to creating learning materials and online activities based on innovative learning strategies, e.g., from storytelling formats to detailed tutorials on real cases involving industrial contributors, and including new formats such as interviews, collaborative learning activities stimulating student creativity, serious games, contests, etc. depending on the respective level of qualification, and supplying this knowledge in train-the-trainer courses for educators;
- Creation of a network of training laboratories (online and physical) to turn gained knowledge into practical experience; this will serve as a joint resource of teaching labs for the project network of institutions; this activity should also include the development of online digital tools for preparing for practical training sessions, such as serious games and simulations;
- Supply of a range of business, managerial and soft skills development materials with a focus on FCH technologies to nurture the creation of the future leadership for the hydrogen transition, supporting the creation of start-ups and spin outs;
- Creation of a business model and organisational structure that ensures the network and its tools, collected and developed content remain in operation and continue to grow after the project terminates;
- Demonstrate synergies with the ongoing ERASMUS+ project GreenSkills4H2- particularly in the context of the future European Hydrogen Skills Alliance. Synergies are envisioned on key deliverables (H_2 skills needs and training mapping, H_2 skills strategy), governance, dissemination, and communications.

Proposals may also include the following:

- ‘Learning through action’ models of training to prepare and test participants of courses in real-life challenges within the industrial sectors, with industrial partners to the platform offering placements within their company on specific projects;
- Engage with teachers and lecturers to provide support in developing their FCH teaching skills and methodologies, e.g., through online webinars and tutorials;
- Synergies with other existing platforms and/or projects on education and training on hydrogen and hydrogen-related technologies as well as means of collaboration with similar activities ongoing internationally.

Proposals should show links to and synergies with existing platforms and/or projects on education and training on hydrogen and hydrogen-related technologies as well as means of collaboration with similar activities ongoing internationally.

Proposals should show that the consortium is able to interact both with the network of educational and training institutions across all relevant levels of qualification, and on the other hand with national and EU educational institutions and stakeholders, with the goal of establishing the above programme as a sustainable, long-term activity.

A go/no go milestone should be implemented at the mid-term of project operation to allow a review of achievements and a termination of further investments if the goals are not sufficiently met.

HORIZON-JTI-CLEANH2-2023-05-03: Pre-Normative Research on the determination of hydrogen releases from the hydrogen value chain

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 3.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 3.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	n/a
Legal and financial set-up of the Grant Agreements	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.

<u>*Expected Outcome*</u>

The EU's Hydrogen Strategy[156], REPowerEU[157] and other relevant European initiatives, clearly recognise clean hydrogen and its applications as a fundamental pillar of the future European energy system, supporting the energy, industrial and mobility sectors in reaching the EU's ambitious decarbonisation targets. Hydrogen can strongly contribute to the reduction of carbon emissions as it can be produced from renewable energy sources and, when it is consumed, does not emit CO_2. As such, a hydrogen molecule present in the atmosphere does not act as a direct greenhouse gas as it does not have a dipole moment. However, hydrogen can react with other molecules present in the atmosphere (mainly hydroxyl radicals) and increase the lifetime of methane, increase the production rate of ozone and water vapour, thus acting as an indirect greenhouse gas. As it has been widely discussed during the Clean Hydrogen JU Expert Workshop on the Environmental impacts of Hydrogen and reported in the workshop summary report[158], it is therefore crucial to assess that potential hydrogen releases along the entire hydrogen value chain do not have an overall material negative impact on the environment and consequences on the climate.

To date, there is still uncertainty considering the amount of the hydrogen releases expected along the future hydrogen value chains.

The results of the project should allow the scientific and industrial community to understand the practical releases rates (which include all types of anthropogenic emissions – fugitive emissions, technical vents, depressurisation, etc.) across the hydrogen value chain, in order to further assess the potential effects of a hydrogen economy on the climate.

[156] A Hydrogen Strategy for a climate neutral Europe. COM(2020) 301 final
[157] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483
[158] JRC Report: Hydrogen emissions from a hydrogen economy and their potential global warming impact. Link: https://publications.jrc.ec.europa.eu/repository/handle/JRC130362

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

- Identification, quantification, and preparation of an inventory of the types of anthropogenic hydrogen releases expected throughout the hydrogen value chains, including production, handling (e.g., compression, liquefaction, packing into hydrogen carriers, purification), transport and distribution, storage and final uses, in the short (2030) and long term (2050);
- Identification and ranking of the main elements of the hydrogen value chain in terms of the estimated hydrogen release and definition of potential mitigation strategies;
- Simulation and forecasting models of hydrogen releases along the hydrogen value chains for the quantification of the hydrogen releases;
- Identification and investigation of potential measuring technologies to detect and quantify hydrogen releases.

Project results (such as guidelines, methodologies, databases, modelling tools and/or spreadsheets for hydrogen release estimation, experimental results, etc.) are expected to contribute to all of the following objectives and targets of the Clean Hydrogen JU SRIA:

- Develop eco-design guidelines and eco-efficient processes that limit hydrogen releases;
- 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, for assessing the hydrogen releases of the growing H_2 value chain;
- Contribute to the SRIA target by organising safety, PNR/ RCS workshops.
- Contribute to the SRIA target by providing inputs for developing Standards, Technical Specifications, or Technical Reports.

Scope

The natural gas industry has for decades been strongly committed to identifying, quantifying, and mitigating gas releases along the entire value chain, from production (extraction) to final uses. In addition, the effects of releases of gases in the environment have been widely studied and assessed, with the aim of limiting the climate-change effects as much as possible.

While methane emissions is a well-known topic, with emission quantification methods/technologies and mitigation strategies defined, the case of hydrogen is different, as there are no indications/guidelines that exhaustively cover all the different elements of the hydrogen value chain. This case requires in-depth analysis, supported by experimental campaigns, in order to understand the potential leakage rates of hydrogen across its value chain and assess the overall hydrogen releases of a large adoption of this energy vector. The Clean Hydrogen JU Expert Workshop on Environmental Impacts of Hydrogen and the workshop summary report represent a valuable analysis and should be used as reference[159].

Building also on the experience gained in the natural gas sector and on the characterisation of methane emissions, the proposals should therefore assess the potential hydrogen releases

[159] JRC Report: Hydrogen emissions from a hydrogen economy and their potential global warming impact. Link: https://publications.jrc.ec.europa.eu/repository/handle/JRC130362

of the future hydrogen value chains.

In order to assess the potential hydrogen release, the proposals should:

- Identify, classify, quantify and prepare an inventory of the types of anthropogenic hydrogen releases expected throughout the hydrogen chain, including production, handling (e.g., compression, liquefaction, packing into hydrogen carriers, purification), transport and distribution, storage, and final uses;
- Identify the most critical elements of the hydrogen chain with regard to potential hydrogen releases considering the different building blocks (e.g., production, handling, etc.);
- Develop and validate appropriate methodologies and test methods and protocols to provide the required data on releases of hydrogen from the most critical elements of the hydrogen value chain. Methods are needed which fulfil similar roles as in the existing natural gas supply chain. These may include methods to enable the identification of sources of hydrogen releases (for example as in leak detection, maintenance and repair programmes), to quantify the mass emission rates of releases into the atmosphere, and to provide test methods to characterise the performance of equipment for hydrogen use. The methods and protocols should be developed considering the potential for future standardisation;
- Identify the total potential hydrogen releases along the whole hydrogen value chain, considering the different building blocks (e.g., production, handling, end-uses, etc.). The proposals should develop simulation tools able to characterise the total potential hydrogen releases considering the different hydrogen scenarios;
- Identify mitigation measures, engineering solutions, technologies, research and development actions to minimise the release of hydrogen.

Building on the results of the previous activities, the proposals should provide recommendations and dissemination for updating and/or development of new standards at the EU and International levels.

Research and experimental activities, including the industry contributions, should support the scientific community in the assessment of the quantification of the potential impact of the hydrogen release from the hydrogen value chain on the climate, providing data and tools for the quantification of the total hydrogen released. It is strongly recommended that the proposals complement (and include a reference on the synergy approach) the topic published in the Horizon Europe Work Programme 2023-2024 Cluster 5, HORIZON-CL5-2023-D1-01-03: Climate impacts of a hydrogen economy[160] and that its results should be used to assess the potential environmental impact of a hydrogen economy.

Cooperation with EU and International entities and institutions on climate, atmospheric and meteorological expertise, as well as normative and standardisation entities, is strongly encouraged. In particular, proposals are expected to collaborate and explore synergies with the activities of EURAMET's European Metrology Networks[161] (e.g Decarb project[162]).

[160] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/programmes/horizon
[161] https://www.euramet.org/european-metrology-networks
[162] https://www.euramet.org/european-metrology-networks/energy-gases/activities-impact/projects/project-details/project/metrology-for-decarbonising-the-gas-grid

Given the scope of this topic, the involvement of formal standardisation bodies as part of the consortia is encouraged, with the aim of facilitating the uptake of the project 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 2.2.6.7 International Cooperation).

HYDROGEN VALLEYS

HORIZON-JTI-CLEANH2-2023-06-01: Large-scale Hydrogen Valley

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 20.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 20.00 million.
Type of Action	Innovation Action
Technology Readiness Level	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.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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 20.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.
Procedure	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.
Legal and financial set-up of the Grant Agreements	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

A Hydrogen Valley typically require a multi-million EUR 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 end-uses. It serves more than one end sector or application in transport, industry and energy. Whilst most of the projects are located in EU, over the past years, Hydrogen Valleys have gone global, with new projects emerging worldwide. Mission Innovation has set a target of deploying 100 Hydrogen Valleys worldwide by 2030[163].

Hydrogen Valleys are starting to form first regional "hydrogen economies". Already under the previous programme, the JU provided support to a number of Hydrogen Valleys across different locations in EU and of different sizes. It is however necessary to accelerate the deployment of additional Hydrogen Valleys as required by REPowerEU (e.g. to double the number of hydrogen valleys by 2025) and in order to reach the objectives of the European Hydrogen Strategy, and finally overcome common challenges linked to storage and distribution that may be territory specific. 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.

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 which goes beyond the boundaries of the Hydrogen Valley(s) developed as a result of the project;
- Additional large scale Hydrogen Valleys are initiated as a replication in other locations in Europe;
- Improved public perception of hydrogen ecosystems;
- Contribution towards the objectives of the EUGreen Deal, Fit for 55, REpowerEU plan and the EU Hydrogen strategy.

Project results are expected to contribute to the objectives and KPIs of the Clean Hydrogen JU SRIA for Hydrogen Valleys.

Scope

The scope of this flagship topic is to develop and demonstrate a large-scale Hydrogen Valley. It could demonstrate a combination of technologies either in existing and/or new markets for clean hydrogen, especially when applications are used in symbiose with each other.

This topic should demonstrate innovative approaches at system level: global and synergetic integration of hydrogen production, distribution and end-uses technologies. It should also seek integration within a broader energy system, considering elements such as renewable energy production, gas and electricity grid, digitalisation, etc. Technologies demonstrated should be state of the art following technology development previously funded by (but not limited to) the JU.

Proposals should respond to the following technical requirements:

- Showcase the ability of hydrogen and its associated technologies to decarbonise different sectors in EU;
- Demonstrate how hydrogen enables sector coupling and allows large integration of

[163] https://ec.europa.eu/info/news/mission-innovation-launches-new-global-coalition-support-clean-hydrogen-economy-2021-jun-02_en

renewable energy[164];

- Cover the complete value chain of hydrogen from production to distribution, storage and end-use in order to decarbonise regions by harnessing renewables and/or low-carbon energy sources. The proposed solution should provide energy flexibility and improve the regions' system resilience through the use of renewable hydrogen[165];
- Demonstrate a clear pathway for massive GHG reduction, in view for the valley to be further scaled up using (but not limited to) further funding tools dedicated to deployment.
- Produce at least 4,000 tonnes of renewable hydrogen[166] 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 hydrogen applications from at least two different sectors should be part of the project, with a clear focus on energy, industry and transport sectors.

Moreover, it is encouraged to develop proposals in the following areas (but not limited to):

- Multi-modal transport platforms, port and airport eco-systems incl. import/ interconnection (and cooperate with global and EU ports coalition);
- Major urban areas with large fleets of public vehicles (e.g. buses, refuse collection trucks, vans, passenger cars and other LDVs, etc.) with associated multi-modal refuelling stations (i.e. 350 & 700 bar, liquid, etc.);
- Integration of renewables into hard to abate industrial sector via coupling of electrolysis and responsive bulk hydrogen storage;
- Pipeline-based, multi-user hydrogen system;
- Hydrogen from intermittent and inflexible electricity sources;
- Integration of a multi-MW second generation electrolysis in the chemical industry for chemical or thermal processes;
- Offshore hydrogen production.

Volumes of hydrogen produced and distributed for the different end uses should be consistent with the amount of investment considered.

It is expected that the proposals will demonstrate as follows the impact and replicability:

- Clearly and coherently present the Hydrogen Valley beyond the investments/actions to be supported directly by this topic;
- Demonstrate how all actors, public and private, at EU, national and regional level will work together, across the entire value chain, to build a dynamic hydrogen ecosystem in the Member States (or Associated Countries)/Regions involved. In particular, proposals should demonstrate how the Hydrogen Valley development will be accompanied by economic growth, skills development and job creation;

[164] In line with the definitions provided in the Renewable Energy Directive 2018/2001/EU
[165] Please refer to the paragraph Rationale for support of the section 3.7 of the SRIA of the Clean Hydrogen JU
[166] As defined in the SRIA of the Clean Hydrogen JU

- Develop a long-term vision on how the Hydrogen Valley developed is expected to grow also in view of its potential role in an existing or future IPCEI[167];
- Demonstrate the replicability and scalability of the concept with the aim of facilitating further deployments of Hydrogen Valleys in other locations/clusters/hubs in Europe (in line with the additional valleys to be initiated as a result of the project activities – see above). 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 of the ecosystem concept and to engage with other regions in Europe, e.g. peer-to-peer exchange activities, to foster replication already during the duration of the project, with special attention placed on projects including EU regions where Hydrogen Valleys concepts may be less developed at present. In doing this, proposals should address technical and economic feasibility and also aspects related to RCS. Learnings from previous supported projects (e.g. projects BIG-HIT[168], HEAVENN[169] and GreenHysland[170]) should be used in view of standardising impact and replicability aspects. The availability of modelling tools and the different scenarios developed in the previous supported projects should ease the replicability assessment. Proposals should demonstrate how they intend to create links with other Hydrogen Valleys initiatives in Europe (e.g. S3 Hydrogen Valleys Platform[171], HyLand Regions in Germany), but also internationally (e.g. Mission Innovation 2.0 - Clean Hydrogen Mission[172]);
- Demonstrate how collaboration and synergies with other Hydrogen Valleys supported by the Clean Hydrogen JU will be implemented;
- Include significant communication activities and dissemination campaigns with the aim to reach to local citizens and increase public engagement 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, including clear, measurable and ambitious KPIs.

Proposals should:

- Contain a clear calendar defining the key phases of the implementation of the action (i.e. preparation of the specifications of equipment, manufacturing, permitting, deployment and operation) and their duration;
- Foresee enough time for monitoring and assessment including at least 2 years of operations. The monitoring strategy should as a minimum allow to assess compliance

[167] Two waves of IPCEIs related with clean hydrogen have been approved by the EC: IPCEI Hy2Tech on 15/07/2022 - https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_22_4549 ; and IPCEI Hy2Use on 21/09/2022 - https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676
[168] https://cordis.europa.eu/project/id/700092
[169] https://cordis.europa.eu/project/id/875090
[170] https://cordis.europa.eu/project/id/101007201
[171] https://s3platform.jrc.ec.europa.eu/hydrogen-valleys
[172] http://mission-innovation.net/missions/hydrogen/

with the KPIs of the Clean Hydrogen JU SRIA [173] for each of the technologies covered.

Applicants should provide a funding plan to ensure implementation of the project in synergies with other sources of funding. If no other sources of funding will be required, this should be stated clearly in the proposal, with a commitment from the partners to provide own funding. If additional sources of funding will be required, proposals should present a clear plan on which funding programmes at either EU (e.g. Structural Funds, Just Transition Fund, Innovation Fund, Connecting Europe Facility, etc.) or national levels will be targeted[174]. In these cases, applicants should present a credible planning that includes forecasted funding programmes and their expected time of commitment.

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 these LOI will be followed during the Grant Agreement implementation.

Costs of renewable energy plants (e.g. PV or wind plant) or related costs for operation of the Hydrogen Valley (e.g. electricity for electrolyser) are not eligible for 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.

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 CertifHy[175]).

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 the EU Mission on Climate-Neutral and Smart Cities, Mission Innovation 2.0 - Clean Hydrogen Mission and the H2V platform. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.7 International Cooperation).

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[173] https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en

[174] Including applications for funding planned, applications for funding submitted and funding awarded

[175] https://www.certifhy.eu

HORIZON-JTI-CLEANH2-2023-06-02: Small-scale Hydrogen Valley

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 9.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 18.00 million.
Type of Action	Innovation Action
Technology Readiness Level	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.
Admissibility conditions	The conditions are described in General Annex A. The following exceptions apply: The page limit of the application is 70 pages.
Eligibility	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.
Procedure	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.
Legal and financial set-up of the Grant Agreements	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

A Hydrogen Valley typically require 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 end-uses. It serves more than one end sector or application in transport, industry and energy. Whilst most of the projects are located in EU, over the past years, Hydrogen Valleys have gone global, with new projects emerging worldwide. Mission Innovation has set a target of deploying 100 Hydrogen Valleys worldwide by 2030[176].

Hydrogen Valleys are starting to form first regional "hydrogen economies". Already under the previous programme, the JU provided support to a number of Hydrogen Valleys across different locations in EU and of different sizes. It is however necessary to accelerate the deployment of additional Hydrogen Valleys as required by REPowerEU (e.g. to double the number of hydrogen valleys by 2025) and in order to reach the objectives of the European Hydrogen Strategy, and finally overcome common challenges linked to storage and distribution that may be territory specific. 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.

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 which goes beyond the boundaries of the Hydrogen Valley(s) developed as a result of the project;
- Additional large scale Hydrogen Valleys are initiated as a replication in other locations in Europe;
- Improved public perception of hydrogen ecosystems;
- Contribution toward objectives of the EUGreen Deal, Fit for 55, REpowerEU plan and the EU Hydrogen strategy.

Project results are expected to contribute to the objectives and KPIs of the Clean Hydrogen JU SRIA for Hydrogen Valleys.

Scope

The scope of this flagship topic is to develop and demonstrate a small-scale Hydrogen Valley. It could demonstrate a combination of technologies either in existing and/or new markets for clean hydrogen, especially when applications are used in symbiose with each other.

This topic should demonstrate innovative approaches at system level: global and synergetic integration of hydrogen production, distribution and end-usestechnologies. It should also seek integration within a broader energy system, considering elements such as renewable energy production, gas and electricity grid, digitalisation, etc. Technologies demonstrated should be state of the art following technology development previously funded by (but not limited to) the JU.

Proposals should:

- Showcase the ability of hydrogen and its associated technologies to decarbonise different sectors in EU;
- Demonstrate how hydrogen enables sector coupling and allows large integration of renewable energy[177];
- Cover the complete value chain of hydrogen from production to distribution, storage and end-use in order to decarbonise regions by harnessing renewables and/or low-

[176] https://ec.europa.eu/info/news/mission-innovation-launches-new-global-coalition-support-clean-hydrogen-economy-2021-jun-02_en

[177] In line with the definitions provided in the Renewable Energy Directive 2018/2001/EU

carbon energy sources. The proposed solution should provide energy flexibility and improve the Regions' system resilience through the use of renewable hydrogen[178];

- 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[179] for each of the technologies covered;
- Demonstrate a clear pathway for massive GHG reduction, in view for the valley to be further scaled up using but not limited to funding tools dedicated to deployment.
- Produce at least 500 tonnes of clean hydrogen[180] per year using new hydrogen production capacity. Due to the large volumes of hydrogen involved, production plants may be distributed across the territories involved;
- Use the hydrogen produced to supply more than one end sector or application in the energy, industry and transport sectors.

It is encouraged to develop proposal in the following areas (but not limited to):

- Multi-modal platforms, port and airport eco-systems incl. import / interconnection (cooperate with global & European ports coalition);
- Major urban areas with large fleets of public vehicles (e.g. buses, refuse collection trucks, vans, passenger cars & other LDVs, etc.) with associated multi-modal refuelling stations (i.e 350 & 700 bar, liquid, etc.);
- Integration of renewables into hard to abate industrial sector via coupling of electrolysis and responsive bulk hydrogen storage;
- Pipeline-based, multi-user, hydrogen system;
- Hydrogen from intermittent and inflexible electricity sources;
- Integration of a multi-MW second generation electrolysis in the chemical industry for chemical or thermal processes;
- Offshore hydrogen production.
- Volumes of hydrogen produced and distributed for the different end uses should be consistent with the amount of investment considered.

It is expected that the proposals will demonstrate as follows the impact and replicability:

- Clearly and coherently present the Hydrogen Valley beyond the investments/actions to be supported directly by this topic;
- Demonstrate how all actors, public and private, at EU, national and regional level will work together, across the entire value chain, to build a dynamic hydrogen ecosystem in the Member States (or Associated Countries)/Regions involved. In particular, proposals should demonstrate how the Hydrogen Valley development will be

[178] Please refer to the paragraph Rationale for support of the section 3.7 of the SRIA of the Clean Hydrogen JU
[179] https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en

[180] As defined in the SRIA of the Clean Hydrogen JU

accompanied by economic growth, skills development and job creation;

- Develop a long-term vision on how the Hydrogen Valley developed is expected to grow also in view of its potential role in an existing or future IPCEI[181];
- Demonstrate the replicability and scalability of the concept with the aim of facilitating further deployments of Hydrogen Valleys in other locations/clusters/hubs in Europe (in line with the additional valleys to be initiated as a result of the project activities – see above). 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 of the ecosystem concept and to engage with other regions in Europe, e.g. peer-to-peer exchange activities, to foster replication already during the duration of the project, with special attention placed on projects including EU regions where Hydrogen Valleys concepts may be less developed at present. In doing this, proposals should address technical and economic feasibility and also aspects related to RCS. Learnings from previous supported projects (e.g. projects BIG-HIT[182], HEAVENN[183] and GreenHysland[184]) should be used in view of standardising impact and replicability aspects. The availability of modelling tools and the different scenarios developed in the previous supported projects should ease the replicability assessment. Proposals should demonstrate how they intend to create links with other Hydrogen Valleys initiatives in Europe (e.g. S3 Hydrogen Valleys Platform[185], HyLand Regions in Germany), but also internationally (e.g. Mission Innovation 2.0 - Clean Hydrogen Mission[186]);
- Demonstrate how collaboration and synergies with other Hydrogen Valleys supported by the Clean Hydrogen JU will be implemented;
- Include significant communication activities and dissemination campaigns with the aim to reach to local citizens and 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, including clear, measurable and ambitious KPIs.

Proposals should:

- Contain a clear calendar defining the key phases of the implementation of the action (i.e. preparation of the specifications of equipment, manufacturing, permitting, deployment and operation) and their duration;
- Foresee enough time for monitoring and assessment including at least 2 years of operations. The monitoring strategy should as a minimum allow to assess compliance

[181] Two waves of IPCEIs related with clean hydrogen have been approved by the EC: IPCEI Hy2Tech on 15/07/2022 - https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_22_4549 ; and IPCEI Hy2Use on 21/09/2022 - https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676
[182] https://cordis.europa.eu/project/id/700092
[183] https://cordis.europa.eu/project/id/875090
[184] https://cordis.europa.eu/project/id/101007201
[185] https://s3platform.jrc.ec.europa.eu/hydrogen-valleys
[186] http://mission-innovation.net/missions/hydrogen/

with the KPIs of the Clean Hydrogen JU SRIA [187] for each of the technologies covered.

Applicants should provide a funding plan to ensure implementation of the project in synergies with other sources of funding. If no other sources of funding will be required, this should be stated clearly in the proposal, with a commitment from the partners to provide own funding. If additional sources of funding will be required, proposals should present a clear plan on which funding programmes at either EU (e.g. Structural Funds, Just Transition Fund, Innovation Fund, Connecting Europe Facility, etc.) or national levels will be targeted[188]. In these cases, applicants should present a credible planning that includes forecasted funding programmes and their expected time of commitment.

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 these LOI will be followed during the Grant Agreement implementation.

Costs of renewable energy plants (e.g. PV or wind plant) or related costs for operation of the Hydrogen Valley (e.g. electricity for electrolyser) are not eligible for 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.

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 CertifHy[189]).

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 the EU Mission on Climate-Neutral and Smart Cities, Mission Innovation 2.0 - Clean Hydrogen Mission and the H2V platform. Cooperation with entities from Clean Hydrogen Mission member countries, which are neither EU Member States nor Horizon Europe Associated countries, is encouraged (see section 2.2.6.7 International Cooperation).

[187] https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en

[188] Including applications for funding planned, applications for funding submitted and funding awarded

[189] https://www.certifhy.eu

STRATEGIC RESEARCH CHALLENGES

HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 10.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 10.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 2 and achieve TRL 4 by the end of the project - see General Annex B.
Eligibility	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 10.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.

Expected Outcome

For hydrogen, as well as its derivatives, to be a truly sustainable energy vector and part of a future sustainable energy system, their storage technologies need to be further developed. This topic aims to develop a step change, supporting key elements of the long-term needs of hydrogen storage, notably:

- Reduction of whole lifetime costs of hydrogen storage technologies;
- Development of environmentally sustainable and circular storage systems;
- Ensuring the safety of innovative hydrogen storage technologies.

Some projections expect that hydrogen will account for 24% of Europe's energy needs by 2050[190]. This requires storage at multiple stages and transportation between the production and end-use phases, thus there is going to be a need for a significant storage solutions. For example, considering mobility needs, there will be required many storage tanks by 2050[191] with a lifetime from 3 years to 15 years depending on the application. Additionally, there will be a significant number of storage tanks to support the mobility aspect, i.e. in refuelling stations. The outcomes of this topic will consider the new generation of materials required for the storage of all forms of hydrogen and how they can be used in a circular economy business approach.

[190] Hydrogen Roadmap Europe – A sustainable pathway for the European energy transition, Ful Cells and Hydrogen Joint Undertaking, 2019

[191] Assuming a large uptake of hydrogen in road (LDV, HDV), aviation, waterborne and maritime transport applications, replacing the existing European fleet of thermal vehicles in Europe.

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

- Development of multifunctional materials, focusing on reducing the whole life cost of hydrogen storage solutions by 50%. Materials as hydrogen carriers are not in scope of this topic;
- Identification and development of sustainable materials enabling a circular design as per the Circular Economy System Diagram[192];
- Development of standardised inspection and repair methods that can be used to increase the lifetime of hydrogen storage solutions;
- Development of smart solutions that allow for cross-application uses of hydrogen storage, specifically for end of first life scenarios, thus reducing the total number of storage tanks produced;
- Strengthening the EU value chain without an effect on the sustainability aspects of the storage solution, in line with the objectives of the RePower EU action plan[193];
- Improvement of safety aspects relative to hydrogen storage in tanks, considering industrial needs, and thus contributing to improving public acceptance of hydrogen technologies;
- Increase in knowledge of the wider research community, industry and support to the adoption of hydrogen by the wider society;
- This SRC should also provide solutions for technologies for other partnerships within Horizon Europe, including, but not limited to, Clean Aviation, Circular Bio-based Europe, EU Rail and Key Digital Technologies, as well as Clean Hydrogen JU itself.

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

- For aboveground storage of hydrogen there should be an increase in storage size and reduction in capital cost according to the following KPI's:
    - Storage size: 20 tonnes in 2030;
    - Cost reduced: 600 €/kg in 2030.
- For road transport of hydrogen there should be an increase in tube trailer payload, reduction in capital cost and increase in operating pressure according to the following KPI's:
    - For compressed hydrogen, trailer payload: 1,500 kg in 2030;
    - For compressed hydrogen, trailer capital cost: 350 €/kg in 2030;
    - For compressed hydrogen, operating pressure: 700 bar in 2030;
    - For LH_2 trailer payload, trailer payload: 4,000 kg in 2030;
    - For LH_2 trailer payload, trailer capital cost: 100 €/kg in 2030.
- For onboard storage of hydrogen in heavy-duty truck applications there should be a

[192] Ellen MacArthur Foundation - Circular economy systems diagram 2019
[193] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

reduction in capital cost, an increase of gravimetric capacity and increase of conformability according to the following KPI's:

  - For compressed hydrogen, storage tank capital cost: 300 €/kg H_2 in 2030;
  - For liquid hydrogen, storage tank capital cost: 245 €/kg H_2 in 2030 ;
  - For compressed hydrogen, increase in gravimetric capacity: 7% in 2030;
  - For liquid hydrogen, increase in gravimetric capacity: 12% in 2030;
  - For liquid hydrogen, increase in conformability: 55% in 2030.

- For onboard storage of hydrogen for aviation applications there should be an increase in tank gravimetric efficiency, where the gravimetric efficiency of a storage tank is the mass of stored hydrogen divided by the mass of the system (included mass of hydrogen), according to the following KPI:
  - Tank gravimetric efficiency: 35% in 2030.

Scope

Storage of hydrogen is specifically challenging, depending on its physical state; in gas form hydrogen is difficult to contain, whilst in liquid form it requires extremely low temperatures. The current hydrogen storage solutions utilise a number of high-performance materials, such as high-performance steels, aluminium or composites (carbon fibres specifically), which have been developed over many years with projects such as CHATT[194] and more recent THOR[195], which considers both the performance and the recyclability. As these materials substantially affect the cost and mass at system level, it is critical that lower cost and lighter storage solutions are developed for hydrogen technologies to be adopted widely[196]. Ongoing EU funded project SH2APED[197]focuses on cost reduction and safety. However, as materials used in the hydrogen storage solution can be a leading cause behind the environmental impacts,[198] sustainable and circular material solutions are critical for the storage tank materials. There are currently very few materials for storage of hydrogen that could be considered as a sustainable material or developed within the circular economy model.

This topic focuses on developing advanced materials to reduce whole life costs and produce lighter solutions for hydrogen storage, whilst developing sustainable circular economy-based components and considering the environmental and social impacts. The hydrogen storage emphasised under this topic covers the form of gas, liquid or cryo-compressed states supporting high-pressure tanks even up to 1,000 bar.

In addition, the EU security of materials supply/independency should be investigated and addressed. All materials used should comply with the actions laid out in the REPowerEU Plan[199] and other EU initiatives relevant to this topic.

Of particular interest are advanced and next-generation materials with multi-functionality

[194] https://cordis.europa.eu/project/id/285117
[195] https://cordis.europa.eu/project/id/826262
[196] Hydrogen Roadmap Europe – A sustainable pathway for the European energy transition, Ful Cells and Hydrogen Joint Undertaking, 2019
[197] https://cordis.europa.eu/project/id/101007182
[198] ELSA WEISZFLOG & MANAN ABBAS 'Life cycle assessment of hydrogen storage systems for trucks - An assessment of environmental impacts and recycling flows of carbon fibers' 2022
[199] REPowerEU Plan 2022

enabling better integration of the storage into the system or having a notable effect on the total system operation (for example, materials which selfheal, thus reducing maintenance requirements). Moreover, materials which allow for storage solutions that occupy more of the useable space are within the scope of this topic. In order to use the benefits of these materials, in their manufacturing, joining often represents a mandatory task to use the benefits of the developed materials. Such joining processes should not compromise the initial material properties or functions. Development of the joining process should consider how this could enable improvement in environmental sustainability and a reduction in whole life costs.

In addition to materials development, the scope includes the development of methods for the inspection and repair of hydrogen storage systems, starting from initial manufacturing to end of life with a specific concern for where access can be challenging. This should enable and support end of life scenarios and life extension of the hydrogen storage solutions.

Proposals should include the materials development for tank hull (e.g. the bottom portion of the tank) focusing on storage solutions for the following uses:

- Fixed / static storage
- Mobility applications:
    - Road transportation
    - Marine transportation
    - Aerospace transportation
    - Rail transportation

Hydrogen storage solutions for space applications and large underground storage as well as development of hydrogen carrier materials / solid state storage are out of the scope of this topic.

Building across the applications listed, digitalisation of circular economy (open access) system / platforms should be considered as well as contributions to new standards and regulations within scope of this topic.

In order to validate the project, one for each type of the following demonstrators tested in lab environment (TRL 4) with the associated full-sized documentation should be included (the testing conditions should be in line with the objectives and KPIs of the Clean Hydrogen JU SRIA stated above):

- Above ground storage demonstrator:
    - Operating pressure test;
    - Ambient temperatures;
    - Hydrogen gas form;
    - 1 tank containing more than 300 kg of hydrogen.
- Transport of hydrogen demonstrator:
    - Operating pressure test;
    - Ambient temperatures;
    - Liquid hydrogen or gas form;

    - 1 tank containing more than 150 kg of hydrogen.
- Heavy-duty road transport demonstrator:
    - Operating pressure test;
    - Ambient temperatures;
    - Liquid hydrogen or gas form;
    - 1 tank containing more than 40 kg of hydrogen.
- Aviation demonstrator:
    - Operating pressure test;
    - Ambient temperatures;
    - Liquid hydrogen;
    - One tank containing more than 100 kg of hydrogen (Boil-off < 2% in 24 hours).

All objectives mentioned above should be complemented, but not limited to the following additional activities:

- Whole life cost model;
- Environmental sustainability / circular economy review;
- TRL assessment and development plan for increasing from TRL 4 to 8;
- Relevant material testing data to prove demonstrators have the potential to meet full application specification. The following should be considered where relevant:
    - Mechanical;
    - Permeability;
    - Climate appropriate for application e.g. hot and cold testing;
    - Corrosion resistance;
    - Resistance to fire;
- Supply chain plan, linked to the REPowerEU action plan[200], detailing the potential of a sustainable / circular supply chain.

Proposals are expected to explore synergies with the projects supported under HORIZON-CL4-2021-RESILIENCE-01-17 Advanced materials for hydrogen storage'[201] as well as with other relevant projects supported by the Clean Hydrogen JU on hydrogen storage.

Consortia should gather comprehensive expertise and experience from the EU research community to ensure broad impact by addressing the items above. Partners should have proven expertise and the required means of 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

[200] REPowerEU Plan 2022
[201] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl4-2021-resilience-01-17

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. A public annual progress report should include, as necessary, recommendations for future activities and possible organisation of workshops.

An extended similar annual report with detailed technical progress results should be provided internally to the JU for fast tracking activities and further programming. The report should include key innovations against TRL, risks, opportunities, challenges and proposed next steps for the development of next generation of technologies and products.

HORIZON-JTI-CLEANH2-2023-07-02: Increasing the lifetime of electrolyser stacks

Specific conditions	
Expected EU contribution per project	The JU estimates that an EU contribution of maximum EUR 10.00 million would allow these outcomes to be addressed appropriately.
Indicative budget	The total indicative budget for the topic is EUR 10.00 million.
Type of Action	Research and Innovation Action
Technology Readiness Level	Activities are expected to start at TRL 2 and achieve TRL 4-5 by the end of the project - see General Annex B.
Eligibility	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 10.00 million – proposals requesting Clean Hydrogen JU contributions above this amount will not be evaluated.

Expected Outcome

Hydrogen can be used as a feedstock, a fuel, an energy carrier in electrolyser technologies, and thus has many possible applications across industry, transport, power and buildings sectors. Electrolyser technologies have reached a high level of maturity, resulting in both pre-commercial and commercial stack and system solutions available for both low and high temperature technologies. Nevertheless, the durability of current electrolyser stacks requires further improvement to reduce total cost of ownership (both CAPEX and OPEX) and subsequently LCOH. Ongoing efforts are addressing degradation studies with focus on singular mechanisms within constrained implementation and user cases. This has resulted in fragmented research outcomes with lack of common definitions on degradation rate for given operational modes and broad varieties of testing approaches. Furthermore, the superimposition effects of multiple mechanisms are presently unresolved, and there is a lack of knowledge on these effects over long time of operation which is crucial to validate predictive modelling behavior. Enhancement of durability is a Strategic Research Challenge expected to contribute to achieving the SRIA targets by generating advanced understanding of the degradation mechanisms of electrolyser technologies at stack level, inclusive of used stacks.

The project is expected to contribute to the following expected outcomes across technologies, applications and industries:

- Deep understanding of degradation effects at stack level for new and/or used stacks upon operation in real conditions, including RES operation;
- Significant improvements of durability and performance of electrolyser technologies meeting the SRIA targets for 2030;
- Increased flexibility of operation of electrolyser technologies, in particular when

coupled to RES;

- Development of accelerated stress test procedures from the insight into degradation effects;
- Strengthening the EU value chain addressing the sustainability aspects of increasing the life duration, in line with the objectives of the RePower EU action plan.

Project results are expected to contribute to the following (2030) objectives and KPIs of the Clean Hydrogen JU SRIA:

- Pave the way to a reduction of stack performance degradation in line with key performance indicators reported in the SRIA (see below);
- Reduce CAPEX and OPEX of electrolyser technologies (see below);
- Alkaline electrolysis:
  - Degradation: 0.1%/1000h;
  - Current density: 1 A/cm^2;
  - OPEX: 35 €/(kg/d)/y ;
  - CAPEX: 400 €/kW.
- Proton Exchange Membrane Electrolysis:
  - Degradation: 0.12%/1000h;
  - Current density: 3 A/cm^2;
  - OPEX: 21 €/(kg/d)/y;
  - CAPEX: 500 €/kW.
- Solid Oxide Electrolysis (SOEL):
  - Degradation at thermoneutral voltage: 0.5%/1000h;
  - Current density: 1.5A/cm^2;
  - OPEX: 45 €/(kg/d)/y;
  - CAPEX: 520 €/kW.
- Anion Exchange Membrane Electrolysis
  - Degradation: 0.5%/1000h;
  - Current density: 1.5A/cm^2;
  - OPEX: 21 €/(kg/d)/y;
  - CAPEX: 300 €/kW.
- Proton conducting ceramic electrolysis[202]
  - Degradation: 0.5%/1000h;
  - Current density: 0.75A/cm^2;

[202] Not defined in the SRIA

- OPEX: 45 €/(kg/d)/y;
- CAPEX: 520 €/kW.

Scope

Electrolysers are complex systems in which kinetics, electrochemistry and thermophysics drive performance degradation phenomena. Durability of electrolyser stacks is affected by various degradation mechanisms occurring at material, interface, cell and stack levels: for instance, high temperature solid oxide cells (SOCs) and proton ceramic cells (PCCs) are susceptible to impurity poisoning, Ni migration and loss of percolation, oxide scale growth on interconnect, mechanical fracture of seals, delamination of electrodes, thermal runaway etc. Low temperature electrolysers, such as PEMEL and AEL are facing ionomer degradation, passivation of porous transport layers, catalyst dissolution and Ostwald ripening, corrosion of carbon support, bipolar plates, degradation of sealing materials, etc. The coupling of these multi-physics fields, occurring simultaneously at various length scales (atomic, nano, micro, macro), makes it challenging to parameterise individual degradation mechanism, and even more challenging, the effects of their combined occurrence. This is even more complicated when flexible operation is required (in part due to the lack of established testing protocols). Extensive knowledge on durability has been generated by previous EU supported projects[203] on fuel cell, e.g. SOFC-LIFE, STAYERS, DEMMEA, CAMELOT, FURTHER-FC, DOLPHIN, ID-FAST, ROBANODE, HEALTH-CODE, ADASTRA, SOCTESQA, which should be used by the project to further generate in-depth understanding of superimposed mechanisms underpinning the degradation of electrolyser stacks over long term operation. The project will also build on the results from on-going and newly supported fuel cell and electrolyser projects, as well as projects addressing sustainability. Long term degradation studies (at least 10,000 hours) should be firstly carried out on stacks (new or used) representative of commercial or pre-commercial technologies for PEMEL/SOEL/AEL stacks and in the second stage, also include stack concepts developed jointly between academic and industrial partners for AEMEL/ PCCEL technologies. Study of ageing mechanisms should address degradation due to evolution of materials, interfaces and microstructures when the cells/stacks are operated under real conditions (e.g. as a function of temperature, load, pressure, overvoltage, etc.), as well as degradation mechanisms associated with exposure to impurities e.g. from airborne contaminants and transient operation and upon dynamic operations (e.g. coupling with RES). The work should provide guidelines for defining new solutions at the cell and/or stack level to increase lifetime, as well as optimal operations of the cells/stacks. The new solutions should be demonstrated at short stack level. Furthermore, the emphasis should be given on defining predictive modelling of state-of-health / state-of-life for given operation, and on establishing operation solutions diminishing degradation.

The following activities are within the scope of this topic:

- Gather data and a return on experiment available from previous or ongoing projects and/or data available at electrolysis manufacturers having already installed/operated electrolysers, including with RES sources at various scales;
- Identification of lifetime restricting degradation mechanisms and effects of their superposition by modelling and simulation activities validated by relevant experimental

[203] https://cordis.europa.eu/

methods;

- Evaluate the impact of RES electrical profile on electrolysers durability in terms of the dynamic operating conditions;
- Modelling of degradation rates resulting from different degradation phenomena and operating conditions; models should be able to aggregate a variety of degradation mechanisms occurring at various scales and should be validated by experimental data;
- With the support of dynamic modelling, simulation of the transient electrical and thermal behaviour in view of the impacts on degradation effects;
- Development of lifetime prediction models based on the degradation modelling; proposals may include verification testing for such models for selected technologies;
- Development of operation solutions diminishing the degradation in stationary or transient operations (e.g. novel operating and control strategies, diagnostics etc.);
- When relevant, adaptation or improvement of advanced characterisation methods for deeper understanding by in-situ, ex-situ or in-operando analyses will be considered within scope;
- Validation of novel solutions in short stack level (minimum 5 repeating units) for at least 10,000 hours by meeting degradation rate while keeping similar level of performance (current density, hydrogen production rate) or in accelerated stress tests allowing extrapolation to minimum 40,000 hours. New and/or adapted stress tests protocols for unravelling superimposed effects are also within the scope;
- Development of uniform data reporting formats that can potentially be used for machine learning and big data processing to identify and correlate cause and effect of degradation phenomena;
- Assessment of the improved durability on the lifecycle impact of the selected technologies.

Consortia should gather comprehensive expertise and experience from the EU research community to ensure broad impact by addressing the items above. Partners should have proven expertise and the required means of materials degradation, modelling, 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. A public annual progress report should include, as necessary, recommendations for future activities and possible organisation of workshops.

An extended similar annual report with detailed technical progress results should be provided internally to the JU for fast tracking activities and further programming. The report should include key innovations against TRL, risks, opportunities, challenges and proposed next steps for the development of next generation of technologies and products.

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 protocols[204] to benchmark performance and quantify progress at programme level.

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

2.2.3.2 *Conditions of the call and call management rules*

Call identifier: **HORIZON-JTI-CLEANH2-2023-1**

Total budget: **EUR 195 mill**

Indicative budget(s)[205]

Topic	Type of Action	Budgets (EUR million)	Expected EU contribution per project (EUR million)	Number of projects expected to be funded
Publication[206]: 17 January 2023 Deadline[207]: 18 April 2023				
HORIZON-JTI-CLEANH2-2023-01-01	RIA	6	3	2
HORIZON-JTI-CLEANH2-2023-01-02	RIA	3	3	1
HORIZON-JTI-CLEANH2-2023-01-03	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2023-01-04	RIA	2.5	2.5	1
HORIZON-JTI-CLEANH2-2023-01-05	IA	10	10	1
HORIZON-JTI-CLEANH2-2023-01-06	IA	10	10	1
HORIZON-JTI-CLEANH2-2023-01-07	IA	15	15	1
HORIZON-JTI-CLEANH2-2023-02-01	IA	20	20	1
HORIZON-JTI-CLEANH2-2023-02-02	RIA	4	4	1
HORIZON-JTI-CLEANH2-2023-02-03	RIA	2	2	1
HORIZON-JTI-CLEANH2-2023-02-04	IA	5	5	1
HORIZON-JTI-CLEANH2-2023-02-05	IA	5	5	1
HORIZON-JTI-CLEANH2-2023-03-01	IA	10	5	2
HORIZON-JTI-CLEANH2-2023-03-02	RIA	7.5	7.5	1
HORIZON-JTI-CLEANH2-2023-03-03	RIA	8	8	1
HORIZON-JTI-CLEANH2-2023-04-01	RIA	4	4	1
HORIZON-JTI-CLEANH2-2023-04-02	RIA	3	3	1
HORIZON-JTI-CLEANH2-2023-04-03	IA	6	6	1
HORIZON-JTI-CLEANH2-2023-04-04	IA	6	6	1
HORIZON-JTI-CLEANH2-2023-05-01	CSA	1.5	1.5	1
HORIZON-JTI-CLEANH2-2023-05-02	CSA	3	3	1
HORIZON-JTI-CLEANH2-2023-05-03	RIA	3	3	1
HORIZON-JTI-CLEANH2-2023-06-01	IA	20	20	1
HORIZON-JTI-CLEANH2-2023-06-02	IA	18	9	2
HORIZON-JTI-CLEANH2-2023-07-01	RIA	10	10	1
HORIZON-JTI-CLEANH2-2023-07-02	RIA	10	10	1

[205] 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.
[206] The Executive Director may decide to open the call up to one month prior to or after the envisaged date of publication.
[207] The Executive Director may delay the deadline by up to two months. The deadline is at 17.00.00 Brussels local time.

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 and with the General Annexes to the Horizon Europe Work Programme 2023-2024[208] 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.

Admissibility conditions	The conditions are described in General Annex A.
Eligibility conditions	The conditions are described in General Annex B.
Financial and operational capacity and exclusion	The criteria are described in General Annex C.
Award criteria	The criteria are described in General Annex D.
Documents	The documents are described in General Annex E.
Evaluation Procedure	The procedure is described in General Annex F.
Legal and financial set-up of the Grant Agreements	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 2023-2024 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Additional admissibility 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 2023-2024 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Additional eligibility conditions

- For some topics, in line with the Clean Hydrogen JU SRIA, 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 operational 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

[208] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2023-2024/wp-13-general-annexes_horizon-2023-2024_en.pdf

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 JU contribution per topic
HORIZON-JTI-CLEANH2-2023 -01-05
HORIZON-JTI-CLEANH2-2023 -01-06
HORIZON-JTI-CLEANH2-2023 -01-07
HORIZON-JTI-CLEANH2-2023 -02-01
HORIZON-JTI-CLEANH2-2023 -02-04
HORIZON-JTI-CLEANH2-2023 -02-05
HORIZON-JTI-CLEANH2-2023-03-01
HORIZON-JTI-CLEANH2-2023-04-03
HORIZON-JTI-CLEANH2-2023-04-04
HORIZON-JTI-CLEANH2-2023-06-01
HORIZON-JTI-CLEANH2-2023-06-02
HORIZON-JTI-CLEANH2-2023-07-01
HORIZON-JTI-CLEANH2-2023-07-02

- For some topics, in line with the Clean Hydrogen JU SRIA, 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 SRIA 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-CLEANH2-2023 -01-05
HORIZON-JTI-CLEANH2-2023 -01-06
HORIZON-JTI-CLEANH2-2023 -01-07
HORIZON-JTI-CLEANH2-2023 -02-01
HORIZON-JTI-CLEANH2-2023 -02-04
HORIZON-JTI-CLEANH2-2023 -02-05
HORIZON-JTI-CLEANH2-2023-03-01
HORIZON-JTI-CLEANH2-2023-04-03
HORIZON-JTI-CLEANH2-2023-04-04

Additional eligibility condition: Membership to Hydrogen Europe/Hydrogen Europe Research
HORIZON-JTI-CLEANH2-2023-06-01
HORIZON-JTI-CLEANH2-2023-06-02
HORIZON-JTI-CLEANH2-2023-07-01
HORIZON-JTI-CLEANH2-2023-07-02

Financial and operational capacity and exclusion criteria: The criteria is described in Annex C of the General Annexes to the Horizon Europe Work Programme 2023-204 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 2023-2024 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 2023–2024 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Evaluation procedure and ranking: The entire evaluation procedure[5] and ranking are described in Annex F of the General Annexes to the Horizon Europe Work Programme 2023–2024 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-CLEANH2-2023-01-01
HORIZON-JTI-CLEANH2-2023-03-01

Seal of Excellence:

- For the two topics in the Call addressing Hydrogen Valleys, 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 applicants, the Clean Hydrogen JU may share information concerning the proposal and the evaluation with interested financing authorities. In this Annual Work Programme 'Seal of Excellence' will be awarded for the following topic(s):

Seals of Excellence is applicable to the following topics
HORIZON-JTI-CLEANH2-2023-06-01
HORIZON-JTI-CLEANH2-2023-06-02

<u>Legal and financial set-up of the grant agreements:</u> The Legal and financial set-up of the grant agreements including funding rates are described in Annex G of the General Annexes to the Horizon Europe Work Programme 2023–2024 which shall apply mutatis mutandis to the actions covered in this Work Programme.

Specific provisions

In addition to the standard provisions, the following specific provisions in the model grant agreement will apply:

1. *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-CLEANH2-2023-02-02
HORIZON-JTI-CLEANH2-2023-05-03

2. *Ownership of results*

   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.

3. *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 SRIA, 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:

Exceptional declaration of full capitalised costs
HORIZON-JTI-CLEANH2-2023-01-05
HORIZON-JTI-CLEANH2-2023-01-06

Exceptional declaration of full capitalised costs
HORIZON-JTI-CLEANH2-2023-01-07
HORIZON-JTI-CLEANH2-2023-02-01
HORIZON-JTI-CLEANH2-2023-02-04
HORIZON-JTI-CLEANH2-2023-02-05
HORIZON-JTI-CLEANH2-2023-03-01
HORIZON-JTI-CLEANH2-2023-04-03
HORIZON-JTI-CLEANH2-2023-04-04
HORIZON-JTI-CLEANH2-2023-06-01
HORIZON-JTI-CLEANH2-2023-06-02

4. *Subcontracting:*

   For all topics: an **additional obligation regarding subcontracting** has been introduced, namely that subcontracted work may only be performed in target countries set out in the call conditions.

   The beneficiaries must ensure that the subcontracted work is performed in the countries set out in the call conditions.

   The target countries are all Member States of the European Union and all Associated Countries.

<u>Indicative timetable for evaluation and for signature of the grant agreement:</u>

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 EU supply chain of critical key components by e.g. a higher range of common/standardised parts to be produced in EU and Horizon Europe 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 EU 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 R&I Framework Programme.

Specific opportunities for synergies with other partnerships and programmes have been already included in 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 (such as TRUST or its future) 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 in the questionnaire(s), unless they 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"[209] 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 online[210].

Guarantees of origin of hydrogen

For some of the Innovation Actions it is expected that GOs will be used to prove the renewable character of the hydrogen that is produced/used. In this respect consortium may seek 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 CertifHy[211]).

Safety

For all topics a 'safety by design' approach should be considered. In particular, in Innovation Actions proposals should provide a preliminary draft of '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 webpage[212]. In particular: (i) Safety Planning and management in EU hydrogen and fuel cells projects – guidance document and (ii) simple template for a safety plan

[209] 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).

[210] https://www.clean-hydrogen.europa.eu/knowledge-management/technology-monitoring-trust_en

[211] https://www.certifhy.eu/

[212] https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0/reference-documents-ehsp_en

For all topics, 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 events[213]: near misses, incidents, accidents, or the absence of events.

Contribution to Regulation, Codes and Standards

For Innovation Actions, 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 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.

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 protocols[214] to benchmark performance and quantify progress at programme level.

Exploitation of project results

Beneficiaries are invited to put their results on the Horizon Results Platform, while exploring the use of relevant support services offered by the Commission, such as the Horizon Results Booster. These services can prove useful in bringing results generated from research closer to the market

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, determination of hydrogen releases from the H2 value chain and Hydrogen Valleys, consortia are encouraged to include legal entities established in the countries members/participant[215] 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 2023-2024 General Annexes:

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[213] Definitions of near-miss, incident, and accident according to EIGA document INCIDENT/ACCIDENT INVESTIGATION AND ANALYSIS SAC Doc 90/13/E

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

[215] 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
HORIZON-JTI-CLEANH2-2023-02-02
HORIZON-JTI-CLEANH2-2023-05-03
HORIZON-JTI-CLEANH2-2023-06-01
HORIZON-JTI-CLEANH2-2023-06-02

2.2.3.3 List of countries entrusting the JU with national funds for the call 2023

Not applicable

2.2.3.4 Country specific eligibility rules

Given the illegal invasion of Ukraine by Russia and the involvement of Belarus, there is currently no appropriate context allowing the implementation of the actions foreseen in this programme with legal entities established in Russia, Belarus, or in non-government controlled territories of Ukraine. Therefore, even where such entities are not subject to EU restrictive measures, such legal entities are not eligible to participate in any capacity. This includes participation as beneficiaries, affiliated entities, associated partners, third parties giving in-kind contributions, subcontractors or recipients of financial support to third parties (if any). Exceptions may be granted on a case-by-case basis for justified reasons.

2.2.4 Calls for tenders and other actions

2.2.4.1 Calls For Tenders

In 2023, 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 3.7 million**. These activities will be financed with Horizon Europe funds. 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.

The following indicative list of procurements is currently foreseen:

Subject (Indicative title)	Indicative budget (EUR)	Expected type of procedure	Schedule Indicative
European Clean Hydrogen Knowledge Hub *The Clean Hydrogen JU is planning to develop a single platform, the European Clean Hydrogen Knowledge Hub, that will encompass and enrich the available tools/platforms maintained by the JU, facilitating the access to the non-confidential information to its members and the wider public. For further information please see Section 2.2.5.1.* *An on-going feasibility study on the possible architectures for the Knowledge Hub estimates its cost between EUR 1.3 – 3.5 million with an associated effort of 2.640 – 7.320 person days.*	2,500,000	Open procedure	Q2-Q3
European Hydrogen Safety Panel (EHSP) *The Clean Hydrogen JU will conclude a tender to conclude a service framework contract for the provision of support for coordinating and managing the EHSP. For further information please see Section 2.2.6.5.* *The framework contract will be concluded for a maximum duration of 48 months and will have a maximum ceiling of EUR 2 million. The framework contract will be implemented through specific contracts, with a first specific contract to be concluded in 2023 with the indicative budget of 500.000 EUR.*	500,000	Open procedure	Q1-Q2
European Hydrogen Sustainability and Circularity Panel (EHS&CP) *The Clean Hydrogen JU will launch a tender to set up the scope of the EHS&CP based on input of a multidisciplinary pool of experts to support addressing and integration of sustainability and circularity aspects. For further information please see Section 2.2.6.6.*	700,000	Open procedure	Q1-Q2

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 renewable and low-carbon hydrogen under the CertifHy project[216], which has now been taken over by 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 sharing the lessons learned from the CertifHy GO pilot scheme operation while ensuring compliance to article 19 of the RED II[217].

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 2023 (having EC already represented in the steering group of CertifHy3). Based on the preliminary expertise built by CertfiHy, the Association of Issuing Bodies has adopted a new version of the EECS rules which now accommodate Hydrogen GOs in an effort to harmonise GO schemes across Europe. Support has been provided to the issuing bodies of Switzerland and the Netherlands helping them to implement their H2 Go scheme. Within this third phase of CertifHy the consortium has also been actively contributing to the European Commission's Union Database Focus group run by DG ENER.

SET Plan and ERA-net

The Clean Hydrogen JU will continue following and contributing as necessary to the SET-Plan[218] activities, in particular Action 6 "Energy Efficiency for Industry" and Action 8 on "Renewable Fuels and Bioenergy" where the Clean Hydrogen JU is participating in the Core Group. 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[219]/Member States, the JU will examine ways to collaborate 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 programmes, 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 2023 topics are facilitating the progress towards the EU transport decarbonisation objectives by investigating technology building blocks in transport segments

[216] https://www.certifhy.eu/
[217] Renewable Energy Directive II (REDII), OJ L 328, 21.12.2018, p. 82–209
[218] https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan
[219] https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/en/green-hydrogen-for-a-sustainable-future.html

beyond road, such as aviation, maritime and NRMM. Topics are focusing on the development of turnkey-solutions comprising vehicles and mobile HRS in the NRMM segment, while for maritime and aviation the focus is still on the development and integration of components at a rather low TRL.

On the maritime sector the collaboration with European Commission services on regulatory aspects (safety, standardisation, regulation) related to hydrogen as a maritime fuel will continue. Particularly in 2023, this will be underpinned with the work planned under the Clean Hydrogen JU study “Hydrogen in Ports and Industrial Coastal Areas”.

Support to Climate Policy

A number of the topics in the Call 2023 are supporting Climate related policies across the European Commission. In particular there is one cross-cutting topic looking at hydrogen releases from the hydrogen value chain which is relevant to the activities of DG CLIMA. In addition, the transport topic looking at pre-normative research on determination of hydrogen releases from the hydrogen value chain is relevant to DG Environment.

Support to Industrial Policy

The Clean Hydrogen JU remains ready to support DG GROW and cooperate with the European Clean Hydrogen Alliance[220] activities, to ensure synergies as foreseen in Art. 78 (2) of the SBA. The aim is to have a more integrated approach linking research partnerships with the industrial strategy, bringing closer together the hydrogen research and industry communities, as well as sharing more widely the results of research.

In this direction, the Clean Hydrogen JU may be invited to present winning and demonstration ready technologies for further deployment to the Round Tables under the European Clean Hydrogen Alliance. It may also share and discus the state of play of research and development with members of the European Clean Hydrogen Alliance.

Finally, the knowledge platforms supported by the Clean Hydrogen JU, currently the European Hydrogen Observatory and the Hydrogen Valleys platforms and in the future – when implemented – the European Knowledge Hydrogen Hub, will allow the capture, use and sharing of know-how, information and experience from the research and innovation funded activities, with the ultimate goal to become a sustainable tool serving research and industrial communities as well as general public. This will include lessons learnt in particular regarding innovation actions and large flagship initiatives. Alliance members will be invited to cooperate with this Knowledge Hub to help identifying hydrogen solutions at high Market Readiness Levels, solutions mature enough for market deployment.

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

2.2.4.3 *Collaboration with JRC – Rolling Plan 2023*

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 Horizon 2020 period, a Framework Contract between the FCH 2 JU and JRC was approved by the Governing Board on 23/12/2015 and signed by both parties on 18/02/2016. Under Horizon Europe, a new Framework Agreement between Clean Hydrogen JU was signed in the spirit and as continuous of the previous Framework Contract on 29/11/2022.

The scope of the new Framework Agreement covers the activities that JRC provides to the Clean Hydrogen JU, against payment from the Clean Hydrogen JU operational budget. In line with the JRC mission, these support activities will primarily support the formulation and implementation of the Clean Hydrogen JU strategy and activities in the areas of standardisation, technology monitoring and assessment and sustainability. In addition, Clean Hydrogen JU may call upon JRC to perform specific actions for individual projects, by which the JRC provides added value to programme objectives.

The JRC support activities to the Clean Hydrogen JU programme covered by the Framework Agreement are discussed and agreed on an annual basis between the JRC and the Programme Office of the Clean Hydrogen JU, with involvement of representatives of Hydrogen Europe and Hydrogen Europe Research. For the year 2023, a maximum budget of EUR 1 million euro from the Clean Hydrogen JU operational budget is foreseen.

The annual Rolling Plan 2023 describes the annual activities and their related deliverables provided by JRC to Clean Hydrogen JU (Article 2 in the Framework Agreement) against payment. Modifications of the annual Rolling Plan are possible, upon request of all the parties involved, and agreed according to the same procedure. These modifications must however remain below the maximum budget agreed beforehand.

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 support the RCS priorities identified. Specific to PNR activities, it is critical to ensure that their results are developed for and used for RCS development. 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 PNR activities.

Under Horizon Europe, the approach to RCS strategy is being revised, and a new RCS SC Task Force has been set up to better coordinate these activities. JRC will contribute to the high-level activities of this new group, contributing to the activities of the RCS SC Task Force, jointly by all stakeholders. This new approach to the RCS strategy is not yet completely defined and implemented. Therefore, the proposed deliverables may be modified according to the priority set by the RCS SC Task Force activities.

A.1 Contribution to the required preparatory work related to the design and formation of the RCS Strategy group (March 2023).

A.2 Report on the international progress in the area of RCS by international bodies (UN-ECE, ISO/TC 197, IEC/TC105, IMO, IPHE) (December 2023).

B. JRC direct contribution to implementing RCS strategy

The Clean Hydrogen JU supports working groups led by JRC, aiming at a European harmonisation of the existing testing protocols and procedures. The harmonised tests facilitate the assessment of technology progress: they offer a tool to measure in a coherent and consistent way the performance of hydrogen systems and to compare project results without compromising on IPR issues. Their use is voluntary, nevertheless there is evidence that research and industry players make regular use of those already available.

In 2023 the JRC electrolysis testing harmonisation work will continue to complete the task on standardisation of testing of high temperature electrolysis and further pursuing activities, together with the dedicated working groups, tackling the important but not yet completely mature topic of assessing lifetime degradation of electrolysers. It is proposed to organize jointly with the relevant projects in an international context a workshop on electrolyser degradation phenomena and test methodology. The objective is to gather the current SoA on accelerated lifetime degradation and testing protocols. Realistic and accurate accelerated degradation tests will reduce duration and costs of testing. Harmonised, jointly agreed tests will allow for a system-independent performance comparison. This is however a multi-annual effort, requiring also pre-normative research of individual projects

JRC will also continue participation in the activities of ISO/TC 197 Hydrogen technologies and IEC/TC 105 Fuel Cell Technologies dedicated to electrolysers/reversible fuel cells testing standardisation. This work, performed by means of JRC own resources, allows to disseminate in a global context the achievements of European tests harmonisation efforts and to support European interests. In particular, the JRC will take stock of the outcome of a technical report to be issued under the auspices of IEC TC 105 AHG-11 – Accelerated Stress Testing (to be published in 2023). Moreover, JRC follows similar ongoing efforts in the US and searches for possible normative collaboration.

Finally, JRC will continue providing technical support and assistance to individual users on request in regards to the ZERO∇CELL, a single cell test hardware developed by JRC in 2017-2018. The design documentation is available on-line and assistance is granted if requested. The assistance will include advice and technical assistance during manufacturing phase as well as performing verification testing of the produced hardware when requested by users.

B.1 Report summarising the workshop findings on electrolyser lifetime degradation phenomena SoA and a preliminary proposal for setting up harmonised protocols for accelerated stress testing of low temperature electrolysers (December 2023).

B.2 Short summary in form of JRC technical report on the support provided to different stakeholders in relation to JRC ZERO∇CELL, only if required.

C. JRC contribution to programme monitoring and assessment

Programme Monitoring and Technology benchmarking. The JRC will continue supporting the Clean Hydrogen JU on its task under Article 74 of the SBA to “assess and monitor technological progress and technological, economic and societal barriers to market entry, including in emerging hydrogen markets”.

The Clean Hydrogen JU is requested to monitor a number of Key Performance Indicators as described in Section 7 of its SRIA. These indicators concern the Horizon Europe KPIs, the Partnership KPIs, the Clean Hydrogen JU KPIs and its technology KPIs. The JRC may support – as required – in collaboration with the Clean Hydrogen JU in setting up the methodology for defining and monitoring of these KPIs.

To allow for an assessment of European achievement against the international state-of-the-art, so-called 'reference data' also need to be collected. In the past few years, JRC has delivered the reference data related to some priority technologies. In 2023, JRC will support the update of information on the international state-of-the-art for selected technologies, as well as gather information on other hydrogen technologies if requested. This information will be used as an input to all the foreseen actions under technology benchmarking, but also to the Annual Programme Technical Assessment.

The SRIA contains SoA values for 2020 and targets for 2024 and 2030. During the 2022 Annual Programme Technical Assessment JRC identified some inconsistencies and difficulties in the reporting of certain SRIA KPIs. In 2023, JRC plans to check if reporting by projects in TRUST is consistent with KPIs of the SRIA. The current SRIA should be screened as soon as possible to check if there are 2024 targets that need to be revised, or if there are missing targets. The outcome of this exercise is a report with recommendations to the Clean Hydrogen JU in preparation to upcoming evaluation of the JU and the possible need of revision of its SRIA.

The JRC will continue performing historical analyses on the performance of selected Clean Hydrogen 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 can be continued in 2023 for other technologies, including updates of already delivered reports. When the selected technologies concern a limited number of projects, but nevertheless the topic is of interest to the JU, such analysis can be included as part of the Annual Programme Technical Assessment.

C.1 Report on TRUST/ SRIA KPI screening. Inception report (July 2023). Final report (December 2023).

C.2 Update of historical analysis report on project portfolio of Clean Hydrogen JU on the state of the art of electrolysers (October 2023).

C.3 JRC will support the Clean Hydrogen JU in its monitoring and reporting obligations, depending on received requests, by proposing an approach to the monitoring of KPIs. JRC will support the development of guidelines for assessing the social life cycle impact of hydrogen technologies (support to SH2E project, as part of the activities under D.1) and will investigate whether these can be used for the monitoring of the social objectives as defined in the Horizon Europe Regulation and in the SRIA, taking into account available JRC expertise for examining societal impacts. Report on possible approaches to identify indicators of social performance for FCH technologies, also building on the findings of the social LCA study performed in 2022 by JRC (December 2023).

Support to Programme Monitoring and Assessment by means of JRC's TIM analytics. Unit JRC.T.5 will continue to adapt the Clean Hydrogen instance of TIM Analytics to the JU[221]. The

[221] TIM is a data analytics tool gathering scientific literature, patent data, news articles and data from R&D projects funded by the EU, aiming at analysing thematic or technological areas and detecting/monitoring emerging or established technologies. The JRC has developed a specific version of its TIM tool to provide a system customised with features related specifically to Clean Hydrogen's programme, such as tagging functions for FCH beneficiaries.

mapping of technology fields (e.g.: alkaline electrolysers/FC, H2 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 maximize 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. Furthermore, an attempt at retrieving patents for some of the clean hydrogen datasets will be made through patent searches using cooperative patent classification codes, in view to optimising patent recall. These will have to be further discussed with, approved and tested by Clean Hydrogen JU. An effort will be made to provide the JU direct access to the TIM platform as internal users, with access to the Scopus data on scientific literature, with the goal to perform keyword searches. Content delivery will proceed based on requests from Clean Hydrogen JU.

C.4 Maintenance, operation and extension of FCH Technology Innovation Monitoring System Clean Hydrogen TIM (January to December 2023).

Annual Programme Technical Assessment. As in previous years, JRC will perform a full Programme review cycle for the year 2022, with its conclusions delivered in the form of a report.

C.5 Draft report. If required, including an update of methodology for the Annual Programme Technical Assessment considering the lessons learnt from the previous Programme Review (1st draft June 2023, 2nd draft August 2023, additional drafts if necessary).

C.6 Final JRC report (December 2023).

D. JRC contribution to assessment of sustainability of hydrogen and fuel cells

According to the Clean Hydrogen JU SRIA, sustainability is one of the three focus areas of the Horizontal Activity 1: Cross-cutting Issues. To improve sustainability and circularity, the JU key focus areas for development and support are complete and integrated life cycle thinking tools, enhanced recovery of PGMs/CRMs including per- and polyfluoroalkyl substances (PFAS), development of recycling integrated processes, and development of eco-design guidelines and eco-efficient processes.

In 2022, the JRC continued assessing the life cycle based deliverables of all ongoing projects and actively supported the projects resulted from the call 2020 (SH2E, Best4Hy, and eGHOST projects). Besides, JRC worked in developing a strategy for the creation and the maintenance of a dedicated life-cycle inventory (LCI) database with FCH technology LCI data using the LCDN infrastructure and worked in a guidance document for the integration of LCI datasets (from projects) in a “Hydrogen node” of the LCDN. Furthermore, JRC continued performing the life cycle assessment of various modes of hydrogen delivery.

Building on the outcomes of the activities initiated or carried out last year, in 2023, JRC will continue assessing the life cycle based deliverables of all ongoing projects and will continue supporting the projects resulted from the call 2020 (SH2E, Best4Hy, and eGHOST projects), supporting the development of harmonised guidelines for assessing the environmental life cycle impact of hydrogen technologies (with the focus on efficient use of critical raw materials used in the FCH technologies value chains), and supporting the identification of KPIs for social aspects of FCH technologies. Besides, JRC will continue supporting the Clean Hydrogen JU in developing a LCI data collection process to collect datasets from projects, and for using the LCDN infrastructure to host these datasets in a “Hydrogen node”, addressing in particular data quality requirement (e.g., International Reference Life Cycle Data System / Environmental Footprint compliance) and other methodological aspects (e.g. End of Life modelling and Circular Footprint Formula). Furthermore, in view of the launch of the European Hydrogen Sustainability and Circularity Panel (EHS&CP), expected in 2023, the JRC will provide support to the Panel on certain aspects, decided in coordination with the Clean Hydrogen JU, if requested.

In 2022, JRC provided a deliverable where different pathways for H2 delivery are compared in terms of environmental impacts. The analysis covered the 16 environmental impact categories recommended by the Environmental Footprint method (e.g., climate change, acidification, eutrophication). Results highlighted the need to delve deeper in the investigation of two environmental categories considered (i.e., water use, abiotic resource depletion) to uncover potential showstoppers for different options of hydrogen delivery due to the unavailability suitable water supply or critical raw materials.

D.1 JRC will produce a report on its supporting activities provided to projects. The report will include the outcomes of the regular review and assessment 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), and the summary of the activities performed for supporting the projects resulted from the call 2020: SH2E, Best4Hy, and eGHOST projects. (June and December 2023 for the interim and final report respectively).

D.2 JRC will report on the activities performed with regards to the LCI data collection process and on the development and use of a “Hydrogen node” in the LCDN infrastructure. (December 2023)

D.3 JRC will report on the support (if requested) provided to the EHS&CP.

D.4 JRC will continue the investigation initiated with the 2022 JRC assessment on the environmental impact of delivering hydrogen, focusing on the impact of water use and critical resources. The goal for this deliverable is to uncover potential showstoppers for different options of hydrogen delivery due to the unavailability suitable water supply or critical raw materials. (December 2023)

E. 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 title	Effort [PM]
A	Support to formulation and implementation of RCS strategy (RCS SC group)	1
B	Direct contribution to implementing RCS strategy (Harmonisation)	4
C	Contribution to programme monitoring and assessment	28
D	Assessment of sustainability	9
	Manpower Totals [PM]	**42**
		Overview indicative costs (with overhead) [k€]
	Manpower	*550*
	Missions	*22*
	Consumables (for B.2)	*10*
	Workshop costs (for B.2)	*25*
	Hardware (TIM, C.4)	*10*
	Subcontract[222] (for Scientific & Technical services, D)	*18*
	Specific costs[223] (for IT Scientific / Information System, D)	*70*
	Specific costs[224] (for TIM, C.4)	*100*
	Scopus license (for TIM, C.4)	*10*
	Total indicative cost for 2023	**815**

Costs includes overhead costs = 25%
JRC will report on a regular basis (every month) on deliverables progress.

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

[222] Expert contract as a follow-up of social LCA analysis and datasets external review.
[223] IT intramuros consultants to work on LC inventories.
[224] These costs include the work of IT consultants, other TIM staff and of the TIM Team leader, as well as queries design, visualisations customization, cleaning of results and other activities identified in the rolling plan. Costs also cover hosting Clean Hydrogen systems, software upgrades, security fixes and maintenance.

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 KPIs;
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. Programme Review 2023

Technology and programme monitoring will continue through the annual Programme Review performed by the JU, which can be separated into four main activities: (a) The annual data collection exercise, (b) the JRC Annual Programme Technical Assessment Report, (c) the Programme Review Report and (d) the Programme Review Days.

The annual data collection exercise from projects is mainly performed via the internally developed data collection platform TRUST (Technology Reporting Using Structured Templates)[225] and complemented via a survey to collect additional qualitative information. Projects will be invited to provide their data in 2023 concerning results generated in 2022.

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 of their origin.

In the Programme Review Report 2020-21, JRC identified certain issues related to the data collection exercise. The evaluation of the filled-out EU-Survey self-assessments and data provided in TRUST revealed considerable variation in the completeness and quality of the information provided. For this reason, one of the aims in 2023 is to further restructure and simplify data collection, improving delivery and reliability of data. In parallel, but on the longer term, the tools used for the data collection should be improved, having in mind the gradual transition to the Hydrogen Knowledge Hub (see 2.2.5.1 (D) below). A data collection workshop with the data providers shall be organised in the second half of January, to provide clarifications on the process and the templates that the projects need to fill in. Finally, the data collection will be brought forward one month, from March to February, thus providing a period of two months for the projects to submit their data, instead of one as up until 2022.

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

Following the conclusion of the annual data collection exercise, JRC will perform a detailed assessment and will produce a report, the Annual Programme Technical Assessment, with observations on the major accomplishments of the projects, difficulties encountered and evaluating the performance of the Programme against the KPIs.

Progress and findings of the Programme Review will be presented in the annual Programme Review Report, planned to be published end of 2023. Following the changes in the 2023 structure of the report, adapted to the new objectives and research priorities of the Clean Hydrogen JU, the Report will again include a more complete overview of the Programme, its budget and its evolution, it's progress towards its strategic objectives and recommendations on possible new topics for research.

Continuing the good experience and practice, the 13th annual Programme Review Days will be organised in autumn 2023. Initiated in 2011 (as an answer to the JU mid-term evaluation recommendations), 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 have been lately introduced to highlight and celebrate annually 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 continue examining ways[226] to monitor technology progress and deployment also for these projects, integrating this information in a single 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 EU funded projects.

B. European Hydrogen Observatory (EHO)

Up to 2022, the Clean Hydrogen JU and its predecessor FCH JU, contributed 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)[227]. 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.

In the end of 2022, a new contract was signed for the Observatory, following a public procurement procedure[228] with the goal of the smooth replacement of the FCHO by the European Hydrogen Observatory (EHO) and its further enhancement, in line with the objectives and activities of the Clean Hydrogen JU.

For 2023 the main challenge for the EHO is to have it fully functional in the first half of 2023,

[226] Initial contacts have taken place with most relevant partnerships and EU Programmes. Nevertheless, expanding the scope of the technology monitoring is dependent on how the other partnerships and EU Programmes will assure that their projects contribute as requested to the annual data collection exercise of the JU.
[227] https://www.fchobservatory.eu/
[228] https://etendering.ted.europa.eu/cft/cft-display.html?cftId=11107

with new activity and no obvious disruptions. Apart from resolving certain issues that were observed during the operation of FCHO, a number of new functionalities are foreseen, including a new restricted information portal, the possibility for third parties to voluntarily provide their own data, a collaboration space for the JU, the administrator and the data providers, etc.

Considering the importance of acquiring high quality validated data for EHO, while recognising the key position of private members Hydrogen Europe and Hydrogen Europe Research in the collection of such data for their own uses, a separate contract was signed with these two parties. The main objective of the contract is the acquisition of services that will ensure the periodic delivery of predefined, up-to-date and validated datasets to the JU, to support (and complement) the regular update of EHO.

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. 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), pilot on Green Hydrogen[229].

Moreover, the Hydrogen Valley platform (H2V),[230] co-funded by the JU in support to the European Union in its co-lead role under the Mission Innovation, will continue to be developed to foster exchange of know-how and best practices at the EU and international level. This includes the expansion of the Platform to support the overall goal of reaching 100 Hydrogen Valleys by 2030, and at least three by each member of the Mission Innovation Clean Hydrogen Mission. Within its 'toolbox' section, the Platform will enhance its role in providing useful information about other hydrogen websites and platforms, features the most recent and important studies from key players and organizations in the hydrogen world, and presents insights about the Hydrogen Valley platform stakeholders.

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 platform TRUST, the EU Survey questionnaire used for the annual data collection activity and the TIM tool maintained by JRC. These will be complemented by the tools provided by DG RTD for monitoring R&I projects (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 continue to be enriched with more information concerning the Clean Hydrogen JU's projects, technology developments, etc. Combined with EHO, the two websites shall remain a central source of information related to clean hydrogen in Europe.

In the longer-term though the platforms and tools maintained by the Clean Hydrogen JU needs to be further upgraded and integrated in a new structure, in order to keep up with the

[229] https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/en/green-hydrogen-for-a-sustainable-future.html
[230] https://www.h2v.eu/hydrogen-valleys

developments and expectations of the sector, who have been increasingly looking towards a single platform to contain most relevant information. The Clean Hydrogen JU is planning to address the issues mentioned above, by developing a single platform, the Clean Hydrogen Knowledge Hub, that will encompass and enrich the available tools/platforms.

A study[231] was performed in 2022 to assist the Clean Hydrogen JU in identifying the best architecture(s) for the Clean Hydrogen Knowledge Hub and how it can be developed from the current state. Based on the results of the study and the identified preferred architecture, the Clean Hydrogen JU will proceed in 2023 in procuring services for the development of the Clean Hydrogen Knowledge Hub.

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 Group[232]) 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 2023, 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 (F2P) 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 (e.g. the F2P plans and the F2P Knowledge Repository) to support implementation is set. Considering the dense climate and energy policy framework at EU level (further reinforced by the Fit-for-55 combined with the Gas and Hydrogen Market packages adopted in 2021, and recently the REPowerEU Plan) 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 CERTIFHY3). In addition, the outcomes of the study (to be delivered throughout 2023) on sustainable supply chain and industrialisation of hydrogen technologies is expected to be of relevance to policy makers at DG GROW and Clean Hydrogen Alliance, for instance for monitoring the progress on the competitiveness of clean energy technologies.

The European Hydrogen Observatory maintained by the Clean Hydrogen JU will also be an

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[231] On-going study procured under the BEACON FWC of DIGIT under the title "*Supporting the Clean Hydrogen JU to setup up a Hydrogen Knowledge Hub*". When concluded, the final report and all its findings will become available on the website of the Clean Hydrogen JU.

[232] 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.

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 implemented via the Call for Proposals

Synergies with other European Partnerships and programmes at programming/planning level

The Clean Hydrogen JU will remain proactive in taking up opportunities for collaboration with other EU Programmes, European partnerships, EU agencies, initiatives and actions with the potential for synergy with its research and innovation agenda.

Regular exchanges with the relevant European partnerships is foreseen either through the Stakeholders Group or bilaterally on an ad-hoc basis, in view of aligning priorities of JU roadmaps with the different Work Programmes timeframes (see section above). The aim is to coordinate annual topics to ensure strong complementarity and synergies.

Since the early stages of preparation of the topics included in the Call for Proposals the Clean Hydrogen JU has interacted with the members of its Stakeholder Group as well as with a number of European partnerships, responsible for different EU programmes[233]. Given that only a limited number of European partnerships are represented under the Stakeholders Group – an advisory body to the Governing Board of the JU – this cooperation faced different formats but managed to take their views into account, to the extent possible, in the design of this Call for Proposals. In addition, to the extent possible, the Clean Hydrogen JU has attempted to take into account information received internally during preparation of Horizon Europe Work Programme 2023-24. All this has allowed to identify synergies on an ad-hoc basis and avoid potential overlaps during the drafting process.

Synergies with the activities of members of the Stakeholder Group of the Clean Hydrogen JU have been identified as follows: with ENTSO-G concerning topic HORIZON-JTI-CLEANH2-2023-02-02: 'Pre-Normative Research about the compatibility of Transmission gas grid steels with hydrogen and development of mitigation techniques' while with EURAMET concerning topics HORIZON-JTI-CLEANH2-2023-02-02: 'Pre-Normative Research about the compatibility of Transmission gas grid steels with hydrogen and development of mitigation techniques', HORIZON-JTI-CLEANH2-2023-02-05: 'Demonstration of LH2 HRS for Heavy Duty applications' and HORIZON-JTI-CLEANH2-2023-05-03: PNR on the determination of hydrogen releases from the hydrogen value chain. In addition, synergies with EURAMET are foreseen concerning quality assurance measurements for the purity of hydrogen produced and/or stored in topics HORIZON-JTI-CLEANH2-2023-01-05: 'Waste to Hydrogen demonstration plant', HORIZON-JTI-CLEANH2-2023-01-06: 'Valorisation of by-product O2 and/or heat from electrolysis', HORIZON-JTI-CLEANH2-2023-01-07: 'Hydrogen use by an industrial cluster via a local pipeline network' and HORIZON-JTI-CLEANH2-2023-02-01: 'Large-scale demonstration of underground hydrogen storage'.

The aviation topics in the Call 2023 are a result of a collaboration between Clean Hydrogen JU and Clean Aviation JU. In 2023 the Clean Hydrogen JU proposes to support topic HORIZON-JTI-CLEANH2-2023-03-03: 'Ultra-low NOx combustion system for aviation' (ready

[233] Annex 7 of the Clean Hydrogen JU SRIA provides more information on Common R&I Roadmap between the Clean Hydrogen JU and other partnerships

to be taken-up by Clean Aviation JU demonstrations at a later stage).

Additional synergies have been identified between the topic HORIZON-JTI-CLEANH2-2023-02-05: 'Demonstration of LH2 HRS for Heavy Duty applications' and with the topic included in Horizon Europe Work Programme 2023-2024 HORIZON-CL5-2023-D5-01-07: 'Hydrogen-powered aviation'.

Synergies between the Clean Hydrogen JU and the Zero Emission Waterborne Transport partnership have been identified for topic HORIZON-JTI-CLEANH2-2023-03-02: 'Development of a large fuel cell stack for maritime applications'.

Synergies between the Clean Hydrogen JU and the Processes4Planet and Clean Steel partnerships have been identified for the topics HORIZON-JTI-CLEANH2-2023-01-06: 'Valorisation of by-product O2 and/or heat from electrolysis', HORIZON-JTI-CLEANH2-2023-01-07: 'Hydrogen use by an industrial cluster via a local pipeline network', HORIZON-JTI-CLEANH2-2023-04-03: 'Retrofitting of existing industrial sector natural gas turbomachinery cogeneration systems for hydrogen combustion' and HORIZON-JTI-CLEANH2-2023-04-04: 'Hydrogen for heat production for hard-to-abate industries (e.g. retrofitted burners, furnaces)'.

Synergies with the European Innovation Council have been identified for the topic HORIZON-JTI-CLEANH2-2023-01-04: 'Photoelectrochemical (PEC) and/or Photocatalytic (PC) production of hydrogen'.

Finally synergies between the topic HORIZON-JTI-CLEANH2-2023-01-05: 'Waste to Hydrogen demonstration plant' and projects supported by the Innovation Fund have been identified.

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. This is expected for all flagship projects.

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 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.

2.2.6.2 Collaborations with other programmes, agencies and partnerships to deliver synergies (at implementation level)

The effective operational cooperation in 2022 between the Clean Hydrogen JU and the European Innovation Council and SMEs Executive Agency (EISMEA), and namely its flagship innovation programme to identify, develop and scale up deep-tech breakthrough technologies and game changing innovations - European Innovation Council (EIC) - is now reaching a higher degree of commitment, formalised by the signature of a Letter of Intent[234] in November 2022. Its objectives are to (1) Exchange content based information on selected and funded grants and beneficiaries (ongoing and ended grants/projects) as well as non-selected grants and applicants in the field of innovative hydrogen based technologies; (2) enabling effective sharing of information and reporting of EIC hydrogen related grants/projects in the Clean Hydrogen JU database (e.g. TRUST), and vice versa; (3) Aligning funding opportunities regarding hydrogen based technologies within the European institutions; and (4) Enabling pipeline synergies by considering successive funding opportunities for further uptake of results stemming from the EIC topics via the Clean Hydrogen JU annual calls – and vice versa. Collaboration with EISMEA will continue similarly in 2023.

As in the past, exchanges of the Clean Hydrogen JU in 2023 will also extend to the Executive Agencies in charge of managing other parts of Horizon Europe (and related partnerships topics) and other Programmes in areas relevant to hydrogen technologies.

In particular, the Clean Hydrogen JU and the European Climate Infrastructure and Environment Executive Agency (CINEA) will continue to explore potential synergies and areas of collaboration for the energy and transport sectors under both Horizon Europe and CEF Transport[235] programmes.

As needed, the Clean Hydrogen JU will also continue to collaborate with other European bodies and agencies (under the coordination of the policy Directorates-General 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.

For instance, cooperation with the Innovation Fund is also envisaged, having in mind the quickest path towards exploitation of results and ramp-up of industrial capacity following successful higher TRL projects implemented under the Clean Hydrogen JU. This will materialise in joint workshops[236] and round tables where project beneficiaries of JU funding can share their learnings and expectations, thus creating a sustainable pipeline of projects to the Innovation Fund.

At national level the Clean Hydrogen JU will work to identify opportunities for collaboration (co-funding but also at programming level) with national programmes, mainly via the States Representative group - an advisory body to the Governing Board of the JU. Ad-hoc exchanges with responsible of national programmes (e.g. German NOW) will continue in 2023 (building on the good practices of former years).

2.2.6.3 Supporting regions and Member States through technical assistance

In view of setting up a structured cooperation mechanism between the JU and Managing Authorities of Member States and Regions, a Technical Assistance tender will run throughout 2023. The objectives of this procurement are (1) to analyse the state of play of hydrogen development in Member States/ Regions by inventorying national initiatives/ strategies/ roadmaps but also its Research & Innovation programmes envisioning funding and financing

[234] https://www.clean-hydrogen.europa.eu/media/news/clean-hydrogen-joint-undertaking-and-european-innovation-council-and-smes-executive-agency-start-2022-11-25_en
[235] 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.
[236] First workshop scheduled for February 2023.

for hydrogen topics; (2) create a cooperation mechanism (e.g. a template of a Memorandum of Understanding) to ensure effective funding and financing strategies for R&I and exploitation of results to meet such potential, namely by generating synergies for sound exploitation of results from JU projects and development of industrial capacities supporting the deployment of FCH technologies around Europe; and (3) to propose and develop a two-way collaboration on knowledge transfer between Member States/ Regions' Managing Authorities and the JU, supporting among others the role of the JU as a knowledge hub for hydrogen and an enhancer of synergies between different EU, national and regional funds regarding clean hydrogen research and innovation leading to value chains creation and deployment in Europe. The procurement will test this approach with at least 10 managing authorities and will foresee its replication to any other willing to engage in such cooperation with the JU.

In 2023 the Clean Hydrogen JU will also continue providing Project Development Assistance (PDA) for Regions with a focus on Cohesion Countries, Outermost Regions and Islands. In addition, in collaboration with Mission Innovation 2.0, the Clean Hydrogen JU will continue with the activities of the Hydrogen Valley platform[237] . The platform will see new Hydrogen Valleys added allowing the most advanced Hydrogen Valleys around the globe to provide insights into their project development. It will also allow interested actors to get in touch with Hydrogen Valley developers directly through a dedicated matchmaking section.

2.2.6.4 Regulations, Codes and Standards Strategy Coordination

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 PNR 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 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 JU members such as European Commission, Hydrogen Europe and Hydrogen Europe Research, and with the support from the 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 EU and beyond, with the focus but not limited to Standards.

In 2023, the RCS SC Task Force 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 focus but not limited to standards.

[237] https://h2v.eu/

2. Assessment of RCS development needs of strategic importance in EU. 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 EU industry and research organisations.
3. Identification and prioritisation of the needs for research and innovation, and coordination actions to support the RCS development identified as strategic for EU and that standardisation and regulatory aspects are appropriately addressed in the Programme.
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.
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.
6. Furthermore, the RCS SC Task Force will also support the Commission and the Member State organisations in its activities on international regulatory cooperation when required and will support the synergies related to RCS with other partnerships.

2.2.6.5 European Hydrogen Safety Panel

The European Hydrogen Safety Panel initiative[238] was launched 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”.

The mission of the EHSP in the Programme is 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 a high-level hydrogen safety knowledge and culture within and beyond the Programme.

The EHSP is 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 have the necessary scientific competencies and expertise covering the technical domain needed to make science-based recommendations to the Clean Hydrogen JU.

In 2023, the EHSP will continue and concentrate the effort on several activities within each task force (TF), as detailed in the next sub-sections. Nevertheless, in view of the increased support expected from the EHSP in the Clean Hydrogen JU Programme in 2023 and onwards, the Clean Hydrogen JU will conclude in 2023 a service framework contract for the provision of support for coordinating and managing the EHSP, strengthening its coordination, activities, and impact. For further information please see Section 2.2.4.1.

[238] https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0_en

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 the JU-funded projects by ensuring that all projects address and incorporate state-of-the-art in hydrogen safety appropriately. In 2023, the guidance document "Safety Planning and Management in EU Hydrogen and Fuel Cells Projects"[239] will be further developed. 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 when needed.

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. Activities within this task force in 2023 will be to provide guidance in research needs on safety along the hydrogen chain, with special attention in developing areas such as, but not limited to, heavy-duty vehicles, aviation, rail, and waterborne applications. In addition, international links with the US Hydrogen Safety Panel[240], the International Association HySafe[241] (and related international activities like the International Conference on Hydrogen Safety - ICHS 2023), the IPHE[242], and the Hydrogen Council[243] will be further strengthened. Last, the revision of the internal emergency crisis management procedure (and links with '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 learnt and provide further general recommendations to all stakeholders.

EHSP activities in 2023 will continue with the addition of new events in HIAD 2.0, e.g., with the incidents registered in the Hydrogen Tools Portal (H2Tools)[244] and/or those in the public domain. The EHSP will also review and assess these events and the lessons learnt and statistics obtained from this information will be summarised in a new release of the document "Statistics, lessons learnt and recommendations from the analysis of the Hydrogen Incidents and Accidents Database (HIAD 2.0)"[245]. Furthermore, the EHSP will continue updating the lists of the engineering models, CFD models/tools, and risk models/tools, and will release a guidance document on "Hydrogen Safety Engineering".

TF.4 Public outreach

This task force focuses on the broad exchange of information with relevant stakeholders,

[239] https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0/reference-documents_en
[240] https://h2tools.org/hsp
[241] https://hysafe.info/
[242] https://www.iphe.net/
[243] https://hydrogencouncil.com/en/
[244] https://h2tools.org/
[245] https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0/reference-documents_en

including the public. The activities in 2023 will focus on updating and expanding the content on the EHSP web page, including a set of Frequently Asked Questions (FAQs) 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 the EU, while contributing to promoting a high-level hydrogen safety culture and a safe hydrogen market in the EU and beyond, if possible.

2.2.6.6 European Hydrogen Sustainability and Circularity Panel

Sustainable development is at the heart of the European Green Deal[246], which along with other policies[247] 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.

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, and
- To promote and disseminate knowledge and a more sustainable and circular culture within and beyond the Programme.

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

[246] COM(2019) 640 final.
[247] https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-holistic-approach-sustainable-development_en

focal point or “advisor” to the Programme in these matters in an independent, coordinated, and consolidated way.

In 2023, he the Clean Hydrogen JU will launch a tender to set up the scope of the EHS&CP based in the input of a multidisciplinary team of experts. This tender will also have to prioritise the activities around three main areas, as detailed below, and support the Clean Hydrogen JU in defining the future panel activities and its working plan. For further information please see Section 2.2.4.1.

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 considered 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.

2.2.6.7 International Cooperation

The recent Communication of the European Commission on the global approach to research and innovation[248] 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

[248] Europe's strategy for international cooperation in a changing world, COM(2021) 252 final.

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 2023 in areas of cross cutting nature, such as regulatory frameworks (in particular for topics HORIZON-JTI-CLEANH2-2023-02-02: Pre-Normative Research about the compatibility of Transmission gas grid steels with hydrogen and development of mitigation techniques and HORIZON-JTI-CLEANH2-2023-05-03: Pre-Normative Research on the determination of hydrogen releases from the hydrogen value chain). These areas play a very important role in early market activation and where intellectual property rights are less of an issue. International cooperation is also foreseen for the two topics dealing with Hydrogen Valleys (HORIZON-JTI-CLEANH2-2023-06-01: Large-scale Hydrogen Valley and HORIZON-JTI-CLEANH2-2023-06-02: Small-scale Hydrogen Valley).

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)[249] and the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)[250]. The Clean Hydrogen JU will hence continue in 2023 to collaborate closely with the EC representatives in the steering committees of these international agreements/associations, in particular within the working-groups on Task 42 ‘Hydrogen Underground Storage’, ‘on Task 41 ‘Analysis and Modelling of Hydrogen Technologies’ and in the definition of Tasks on ‘Renewable Hydrogen’ and ‘Hydrogen Export value chains’.

Following the successful and close collaboration of the FCH 2 JU with EC representatives on the Mission Innovation 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 contract that will last until mid-2024, 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 Commission in its co-lead activities (see also section 2.2.5.1.C, regarding collaboration in terms of knowledge management). While the revamped Platform under the new contract will be made public in Q1-2023, reflecting also a survey for new Hydrogen Valleys that will expand significantly the database worldwide and is expected to contribute effectively and ahead of time the targets set forward by the Clean Hydrogen Mission members, the Platform shall also become more dynamic, with automatic and regular updates expected in view of capturing how each Hydrogen Valley and, in a wider perspective the wider Hydrogen sector, is evolving in terms of actual deployment.

For concrete references to international collaboration in the Call for Proposals see section 2.2.3.2 of this document.

[249] http://ieahydrogen.org/
[250] http://www.iphe.net/

2.3 Support to Operations of Clean Hydrogen JU for 2023

2.3.1 Communication, dissemination and exploitation

2.3.1.1 Communication

A. Communication objectives

The communication plan in 2023 will support the priorities identified in the current work-programme. Moreover, it will ensure that Clean Hydrogen JU's communication objectives are adapted to respond to the changes driven by the legal obligations, a new organisational strategy and social, technological and policy developments. By delivering targeted communication activities will also ensure that all stakeholders will continue to be duly informed about the activities of the Clean Hydrogen JU and consequently, of the technologies progress.

The following main objectives will lead the communication activities in 2023:

1. Increase awareness, acceptance, and uptake of clean hydrogen solutions through integrated campaigns. Based on the results of the Public Opinion Survey on the level of awareness and acceptance of hydrogen technologies across EU, it will aim to create and adapt a positive narrative around hydrogen, as an important part of the solution to the current energy challenges.

2. Position the Clean Hydrogen JU as the main EU tool for the funding of hydrogen research and technology demonstration in Europe and an important contributor to the development of the hydrogen technologies sector. Communicate about the funding opportunities offered by the Partnership and attract valuable applications.

3. Establish Clean Hydrogen's reputation as a centre of knowledge on hydrogen technologies at EU level.

<u>N.B. Public Opinion survey analysis</u>

An important element for determining some of the objectives and their implementation will be the insights into the results of the on-going public opinion survey on the topic of awareness and acceptance of hydrogen technologies (that started in 2022 and whose results will be delivered in 2023); based on its findings, additional activities and objectives could be foreseen, and some of the activities could be revised at mid-term. They will also be complemented by the activities of the related project funded under the call 2022 (topic HORIZON-JTI-CLEANH2-2022-05-01: Public understanding of hydrogen and fuel cell technologies).

Milestone/Activity/Topic	When	Channels / tools
Results of the 2022 Call	January – February 2023	Website, social media, newsletter
Launch of 2023 Call	January – February 2023	The launch of 2023 Call will be shared via a press release in all EU MS. Additionally packs including timings for 2023, call to action, national data and factsheets.
Public opinion survey report (TBC)	February 2023	Website, social media, newsletter
Media campaign	March – December 2023	Articles in traditional media, social media

B. Target audiences

- Policymakers and authorities (EU, National, regional, local & International)
- Clean Hydrogen JU Advisory bodies
- Other EU partnerships
- Opinion formers (media, experts, NGOs, etc.)
- European hydrogen community: JU beneficiaries, researchers, industry representatives
- SMEs (potential beneficiaries)
- Consumers/ citizens

C. Main messages and 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 (January 2023)
- Hydrogen valleys – e.g. concrete benefits of the hydrogen economy for the EU citizens, socio-economic benefits, benefits for and involvement of SMEs; participation in the H2V platform and related label/certificate.
- Green recovery: continued investment in research, innovation and deployment of clean hydrogen technologies as the cornerstone of EU's economic recovery and in response to the energy crisis;
- Renewable hydrogen production milestones: Towards 6 GW of renewable hydrogen electrolysers in the EU by 2024 and 40 GW of renewable hydrogen electrolysers 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 EU.

Topics	Angles
Clean Hydrogen technology	**Benefits and performance** of the clean hydrogen technology for the decarbonisation of the EU's economy: no greenhouse gas emissions, almost no air pollution. It can be an alternative (and eventually replacement) to fossil fuels in heavy industries and other parts of the economy. **Uses of clean hydrogen**: clean hydrogen can be used as a feedstock, a fuel, energy carrier and energy storage. **Applications of clean hydrogen**: industry, transport (land, water and air transport), power and buildings sectors. **EU Hydrogen Strategy**: clean hydrogen as a key technology to meet the 2050 climate and energy targets of the EU in the context of the European Green Deal and REPowerEU. **European clean hydrogen economy:** To achieve the ambitions laid out in the European Green Deal and the REPowerEU Plan, the clean hydrogen technologies in the EU are entering a new stage of development towards large-scale deployment and transitioning to a European clean hydrogen economy. It is not merely the transition to a fuel replacement but a shift to a new system with political, technical, environmental, and economic disruptions and opportunities. The new clean hydrogen economy will stimulate innovation and growth, create jobs and enable skills development. Hydrogen valleys are a particular way of developing the new clean hydrogen economy. They are hubs that cover the entire hydrogen value chain in a specific city or region and aim to scale up hydrogen deployment, while also creating interconnected hydrogen ecosystems across Europe.
Clean Hydrogen Joint Undertaking (Clean Hydrogen Partnership)	**The Clean Hydrogen Joint Undertaking is a unique public private partnership** supporting research and innovation activities in hydrogen technologies in Europe. It is composed of three members - the European Commission, fuel cell and hydrogen industries in Europe - represented by Hydrogen Europe - and the research community represented by Hydrogen Europe Research.

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 the JU will 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

Online communication will remain the preferred channel for all audiences in 2023. The website, together with the social media channels, are the main gateway to the organisation. The website will evolve with the JU and it will progressively add new content and elements throughout 2023, 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 predecessors: H2V, FCHO, EHSP e-HRS availability and the website dedicated to the Hydrogen Week (which may be further integrated in the future Knowledge Hub –see above related section).

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. The JU will promote content via the following channels throughout the year, by means of both paid and organic campaigns.

Channel	Audience	Content	Objective
Twitter	Journalists and Media Stakeholders	Pictures; Short videos; Links to external content (including news); Polls; Live transmission of events	Build reputation and leadership, focusing on what's new: promote news, partnerships, projects and initiatives events and activities
LinkedIn	Professionals Experts	Pictures; Short videos; links to extended content, news; articles;	Cultivate the relationships with networks of experts, get in touch with industry/business stakeholders
YouTube	Non specialist audiences	Videos; Live streaming	Build visibility and reputation with a broader public; You tube has the second-largest search engine after Google Search and its content has a long life
Instagram	Non specialist audiences	Photos, videos	New account to build visibility and reputation with a broader, younger public

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 JU 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.

In this context, the JU is looking at integrating social media advertising in its campaigns, so that it earns more followers and reach out to a more general audience. Through social media advertising, it 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 JU Newsletter will be sent out to the subscribers' database, in the 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. The focus will be always 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 EU countries. Further communication towards audiences in the Central and East-European countries should be continued and enhanced. A dedicated media plan will be developed for this purpose, and will be implemented through a campaign continuing the efforts started in 2022.

The Clean Hydrogen Joint Undertaking's media efforts will revolve around three general topics such as, Clean Hydrogen technology, Clean Hydrogen Joint Undertaking and Clean Hydrogen JU funding opportunities (calls for proposals and expression of interest for various topics). These three topics are strongly interconnected and will be used as a basis for content development tailored to the different target audiences, focus countries, tools and channels.

Events

The JU will organise a mix of events with both online and physical presence (always in line with the latest Covid-sanitary recommendations).

In particular and in line with the SBA, the JU will convene 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 (most probably throughout the Programme Review days, following on the example in 2022).

The European Clean Hydrogen JU Forum and the Programme Review Days are the two major annual events for the JU; they come together in what has already been established as the "European Hydrogen Week" as of 2020.

The Hydrogen Week represents already a brand in itself, which the JU wants to consolidate further, promote, and use it to differentiate the EU annual events(s) from the numerous events on hydrogen taking place in Europe, Brussels and beyond. The JU will also use the occasion to showcase the synergies between and with the various Commission services/programmes, industry and research partners and reflect on the entire hydrogen value chain from production, storage, to transport, distribution and utilisation.

In addition, the JU aims to work with the EU presidencies in 2023 to organise joint event(s) every 6 months (and if possible, on the agendas of the respective presidencies), contribute to SET-PLAN and R&I days, European Sustainable Energy Week, EU Regions week, contribute to the European Hydrogen Forum of the Clean Hydrogen Alliance, and participate in other events that EC / partnerships are organising.

Finally, other JU own events may also include:

- Call 2023 Info Day;
- Own webinar series – following up on experience last years, the JU may continue its successful online events to allow for discussion around its new priorities and projects (and their achievements or final reports);
- Projects events – such as demonstrations, projects visits, etc;
    - Participation in major EU/international exhibitions (HyVolution, Hannover Messe, World Hydrogen Summit 2023 in Rotterdam, BusWorld etc) and conferences (International Safety Conference, Conference of the Parties (COP));
- Workshops with EU and international counterparts .

Monitoring and measuring impact of communication activities

The impact of the online communication efforts will be measured using the Europa Analytics reports for website and newsletter 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 strategy for dissemination and exploitation of the projects results in Horizon Europe[251]. The governance of the D&E Strategy for Horizon Europe mandates that the Horizon Dissemination & Exploitation Group will be one of the pillars (together with the Horizon Feedback to Policy Group) to coordinate implementation. Clean Hydrogen JU is planning to continue participating and contributing through 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[252]:

- Horizon Results Platform[253]: 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 Radar[254]: A European Commission initiative to identify high potential

[251] Dissemination & Exploitation Strategy for Horizon Europe - Towards an Integrated Dissemination & Exploitation Ecosystem, European Commission, DG-RTD, CIC, 2020

[252] IP Booster, a specialised professional Intellectual Property service for public research organisations to help them develop their intellectual property strategy, was completed in December 2021

[253] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform

[254] https://ec.europa.eu/digital-single-market/en/innovation-radar

innovations and innovators in EU-funded research and innovation projects, based on a data driven method;

- Open Research Europe[255]: The new EC scientific publishing service for fast publication and open peer review for research scientific articles stemming from H2020 and Horizon Europe projects across all subject areas. The platform makes it easy for project beneficiaries to comply with the open access terms of their funding and offers researchers a publishing venue to share their results and insights rapidly and facilitate open, constructive research discussion.
- Horizon Results Booster[256]: 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;
- Standardisation Booster[257]: A 24-month European Commission initiative started in 2022, aiming to provide consultancy services to guide and support beneficiaries and consortia of R&I projects to make sure they take the right strategic approach and contribute efficiently to the Standardisation process and increase and valorise their results by contributing to the creation or revision of standards. It responds to the main priorities (so-called urgencies) outlined in the European Strategy on Standardisation[258].

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 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 (for the ongoing H2020 and the new Horizon Europe projects), as foreseen in the MGA. Especially after the funding period, 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.

Clean Hydrogen JU and its predecessor, Fuel Cells and Hydrogen 2 JU, support the Innovation Radar initiative since its pilot in 2018. This exercise has so far been conducted during the project mid-term reviews, where possible innovative activities are analysed by a dedicated expert. He/she has to fill out one questionnaire per possible innovation flagged by the PO, with the aim to provide information in a structured and quantified way and allow introduction into the list of the innovations of IR. The Innovation Radar exercise has been incorporated lately in the PMON workflow in Sygma/Compass, which gives the flexibility to the project officers to update existing or submit questionnaires for new innovations that happen

[255] https://open-research-europe.ec.europa.eu/

[256] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/d-e-booster

[257] Horizon Europe Standardisation Booster (https://hsbooster.eu/)

[258] European Strategy on Standardisation aims to speed up the pace of innovation through the development of efficient Standards that might be capable to accelerate the transition towards a more resilient, green and digital economy and to protect democratic values in technology applications - https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13099-Standardisation-strategy_en

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 by connecting them with possible investors and corporates (fundraising, venture building and networking). One concrete example of this is Dealflow.eu[259], a matchmaking platform supported by the European Commission to help projects commercialize their innovations, 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. Finally, during the Innovation Awards organized each year during the Hydrogen Week, 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 funds to procure the necessary services and supplies so that it reaches its objectives and adequately supports its operations and infrastructures. To make tender and contract management as effective and efficient as possible, Clean Hydrogen JU resorts extensively to EU inter-institutional tenders and multi-annual framework contracts. Most essential framework contracts are or will be in place at the end of 2022. Clean Hydrogen JU has also concluded several Service Level Agreements (SLAs) with other Directorate-Generals and Departments of the European Commission for support to various administrative activities.

Clean Hydrogen JU expects also to join the following EU inter-institutional procurement procedures in 2023 (since the current framework contracts end in 2023):

- Travel agency services
- Software for innovation, diversity, and solution services to purchase software-as-a-service products and licences.
- Consulting services
- Audits and controls
- Learning and development
- Event management

In addition, it will launch a new procedure on consent management tool.

Clean Hydrogen JU will work on further simplifying the management of procurement activities by using automated procedures. It is expected that in 2023 the JU will use all the functionalities of Public Procurement Management Tool (PPMT). Together with the use of the eSubmission tool (publication of open and negotiated calls for tender, provision of Q&A platform in compliance with the Financial Regulation, possibility of electronic submission only, as well as e-request and e-invoicing), eTendering (for preparing and managing call for tenders) and eNotices (for publication of contract notices to the Official Journal), it will achieve the objective

[259] https://dealflow.eu/

of a more efficient execution of procurement procedures, ensuring a wider access through digitalization.

2.3.3 Other support operations

2.3.3.1 ICT management

ICT provides the ICT infrastructure, tools and services to enable the staff members to work and the teams to collaborate.

The Joint Undertaking JU strategic objective in the field of IT 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 stakeholders.

and will be supported in 2023 by specific objectives in the following five areas: ICT governance, Information and document management, and digital transformation.

ICT 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. We will also continue to join any added-value interinstitutional framework contracts or inter-agency joint procurement (see also above in section 2.3.2 "Procurement and contracts".

Back-office arrangements will be gradually implemented based on the agreed description of the target organisation model by the Executive Directors. The Clean Hydrogen JU will take the lead for the organisation of ICT shared services.

The digital infrastructure, we will continue to rely on the secure pan-European networks for the Commission, executive agencies and other European institutions. The common conference center of the White Atrium building will be upscaled with the necessary audio-visual functions to held hybrid meetings.

The year 2023 also has the challenge of a possible change in the ICT service provider for infrastructure, network and user support; should the ICT service provider selected in the end of 2022 be different from the current one, the transition to the next ICT service provider for all Joint Undertakings needs to be secured. The hand-over will be documented, understandable, unambiguous, applicable and relevant to each person.

The main objective of **Information and document management** is to use a portfolio of secure, state-of-the-art corporate digital solutions. The Clean Hydrogen JU will continue to use or adopt flagship digital solutions developed by DIGIT, such as for example: SysPer, ARES, eProcurement, eGrants, Next-EUROPA. In 2023, we foresee the implementation of AresBridge to complement the IT tool Hermes-ARES-NomCom already adopted as document management system. AresBridge will be integrated in our recent Microsoft 365 SaaS to facilitate the registration and filing of documents. The Clean Hydrogen JU will exploit the potential of data, information, knowledge and content management for running the program, communication to citizens and stakeholders and best staff engagement. In 2023, we will further develop the digital solutions already available to the Joint Undertaking facilitate the interaction with internal actors. To that effect, we will build dedicated collaboration platform using SharePoint and develop the new intranet.

Other projects related to the extended use of EC tools will be carried out, such as the deployment of new modules in SysPer (MiPS for mission management, Job descriptions, NDP for numérisation des dossiers personnels – see below paragraph 2.3.4 related to the HR management), and the introduction of PPMT in the area of procurement (see above paragraph 2.3.2).

In the area of **Digital transformation**, the main objective is to build a performing digital infrastructure and a fit-for-purpose Digital Workplace, that will be modernised by equipping each staff member with 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.

Regarding the objective to reinforce the JU's resilience to ever evolving digital security threats, the Cybersecurity will be reinforced by the implementation of the new Infosec regulation and the dedicated role of Cyber Security Officer.

2.3.3.2 Logistics and facility management

Logistics and facility management will be adapted to the new ways of working, in line with the Commission decision on new ways of working and hybrid working.

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 2023, special focus will be put on the following:

- Preparation and update of the job descriptions in a new JIS module in SysPer as a top priority; anticipating to complete this by mid-2023 (see also above in paragraph 2.3.3.1);
- Completion of the personnel files using ‘Numérisation Dossiers Personnels’ (NDP) of all (past and current) staff members in SysPer, to be completed by the end of February (see also above in paragraph 2.3.3.1);
- Ensuring that all new staff will follow a mandatory training on ‘Ethics and Integrity’;
- Implementation of the EC tool MiPS for missions (see also above in paragraph 2.3.3.1);
- Implementation of the Probationary period module to be used in SysPer;
- Recruitment of a temporary agent (AD position) for budget management, a contract agent and an additional Seconded National Expert (see below the Staff Establishment Plan in paragraph 2.3.4.3). This will be done using the new platform for recruitment, SYSTAL.

In line with the EC priorities for 2019 - 2024, the Clean Hydrogen JU will continue to promote:

- 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;
- Hybrid working to maintain a good work-life balance in accordance with the Commission decision on new ways of working and hybrid working adopted in April 2022;
- Encourage and create synergies between JUs, in accordance with the requirements of article 13 of the SBA and following the back-office arrangement study and preparatory actions carried out in 2022: in the field of HR management, eight JUs are working closely together and will reinforce their cooperation in the areas of recruitment, confidential counsellors (in continuation of the current practice where the JUs have set up a common Network of Confidential Counsellors since 2019) and HR digitalisation.

2.3.4.3 Staff Establishment Plan

The JU team consists of 29 positions (27 TAs and 2 CAs). In addition, staff resources include 2 Seconded National Experts (SNE). The 2023 Staff Establishment Plan is shown below:

Function group and grade	***2022***				***2023***	
	Authorised budget		***Actually filled as of 31/12***		***Authorised budget***	
	Permanent posts	***Temporary posts***	***Permanent posts***	***Temporary posts***	***Permanent posts***	***Temporary posts***
AD 16						
AD 15						

Function group and grade	2022				2023	
	Authorised budget		Actually filled as of 31/12		Authorised budget	
	Permanent posts	Temporary posts	Permanent posts	Temporary posts	Permanent posts	Temporary posts
AD 14		1		1		1
AD 13						
AD 12		2		2		2
AD 11						
AD 10						2
AD 9		5		5		3
AD 8		4		4		2
AD 7		2		2		5
AD 6		3		3		2
AD 5						
TOTAL AD		17		17		17
AST 11						
AST10						
AST 9		1		1		2
AST 8		1		1		1
AST 7		1		1		1
AST 6		1		1		
AST 5		2		2		5
AST 4		3		3		
AST 3		1		1		1
AST 2						
AST 1						
TOTAL AST		10		10		10
AST/SC 6						
AST/SC 5						
AST/SC 4						
AST/SC 3						
AST/SC 2						
AST/SC 1						
TOTAL AST/SC		10		10		10
TOTAL AD+AST+ AST/SC		27		27		27
GRAND TOTAL	27				27	

Contract Agents	*FTE corresponding to the authorised budget 2022*	*Executed FTE as of 31/12/2022*	*Headcount as of 31/12/2022*	*FTE corresponding to the authorised budget 2023*
Function Group I-IV	*2*	*1*	*1*	*2*
TOTAL	*2*	*1*	*1*	*2*

Seconded National Experts	*FTE corresponding to the authorised budget 2022*	*Executed FTE as of 31/12/2022*	*Headcount as of 31/12/2022*	*FTE corresponding to the authorised budget 2023*
	2	*1*	*1*	*2*
TOTAL	*2*	*1*	*1*	*2*

Recruitment forecasts 2023 following retirement/mobility or new requested posts					
Job title in the JU	***Type of contract (Official, CA, TA)***		***TA/Official***		***CA***
			Function group/grade of recruitment internal (Brackets) and external (single grade) foreseen for publication		***Recruitment Function Group (I, II, III and IV)***
	Due to foreseen retirement/ mobility	***New post requested due to additional tasks***	***Internal (brackets)***	***External (brackets)***	
Budget Officer	*1*			*AD5*	
Contract Agent FGIV	*1*				*FGIV*
SNE					

2.4 Governance activities

2.4.1 Governing Board

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 Articles 15 and 80 of the Single Basic Act. The GB is composed of three representatives of the European Commission on behalf of the EU, six representatives of the Industry Grouping (Hydrogen Europe) and one representative of the Research Grouping (Hydrogen Europe Research).

The GB is planning to hold three meetings in 2023. The indicative key decisions of the GB in 2023, either in meetings or through written procedures in accordance with the Rules of procedure adopted in 2022, are listed below:

Key decisions in 2023 – timetable	Quarter (Q1, Q2, Q3, Q4)
Assessment of the Annual Activity Report for 2022	Q2
Selection of the Executive Director of the Clean Hydrogen JU	Q2
Adoption of the AWP for 2024	Q4

In addition, depending on the timing of EC decisions, implementing rules on staff regulations may be submitted to the GB for adoption.

2.4.2 States Representatives Group

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 the SRG without undue delay of the follow-up it has given to recommendations or proposals provided by the SRG, including the reasoning if they are not followed up.

The Chairperson and Vice-chairpersons of the SRG shall have the right to attend the meetings of the GB and take part to its deliberations without voting rights.

The SRG will hold at least two meetings in 2023. Issues to be covered include:

- opinion on the Annual Activity Report for 2022,
- opinion on the 2024 AWP of the Clean Hydrogen JU,
- Submission of the SRG's 2022 annual report on national and regional policies on Hydrogen.

2.4.3 Stakeholders Group

The Stakeholders Group is the other 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".

The Chairperson of the SG shall have the right to attend the meetings of the GB and take part to its deliberations without voting rights.

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 2022, the following actions were identified for 2023:

- Regarding the component Control Environment, a revision of the job description will take place in 2023 and the Business Continuity Plan (BCP) will be revisited in 2023 in view of hybrid mode of working;
- Regarding the component of the Risk Assessment, an internal risk assessment guidance will be implemented early in 2023;
- Regarding the component Information and Communication, an adoption of the updated Communication Strategy is envisaged for 2023.

2.5.1 Financial procedures

The financial procedures guide Clean Hydrogen JU operations and lay out how the JU uses and manages its funds and resources. The workflows in place follow the financial rules, as adopted via the GB Omnibus decision of 17 December 2021 and the general framework applicable in the Commission.

As stakeholder in the Horizon Europe programme, the JU will apply a system of internal control in its grant management, which is aligned with the control framework developed by the Commission for the implementation of the programme.

In grant management, reporting and validation of costs for H2020 and Horizon Europe grants will be done via the EC IT tools (SyGMa and COMPASS). Experts reports and validation of costs are supported by EMI and COMPASS. All payments will be executed via the ABAC IT tool (EC accounting system). ABAC LCK is used for contract management and reporting purposes.

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 2018/1046 [1], "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 2023, 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 newcomers and 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 (observing COVID 19 constraints, if any);
- 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;
- Implementing 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 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 2023, focus will be put on the following:

- In cooperation with CAS, launching of new H2020 audits in two rounds: early in 2023 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;
- Building on the knowledge gained in H2020, to participate in establishing the Horizon Europe ex-post audit strategy (in cooperation with CAS).

[1] OJ L193, 30.7.2018 p.66

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 2023, 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;
- participate to FAIR meetings organised by DG R&I and common trainings organised for the JUs (in cooperation with CAS).

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 2023, 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 2023 the Clean Hydrogen JU will:

- Liaise with the independent auditor (contracted in 2022 based on the results of the reopening of competition under EC (DG BUDG) FWC) to audit Clean Hydrogen JU accounts for 2022 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 Clean Hydrogen JU annual accounts;
- Provide the necessary information and support for ECA audit on 2022 and 2023 accounts;
- Assist and support ECA in their new horizontal audit for the JUs for 2023 (topic is still

to be announced);

- 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 2023

The 2023 budget covers all administrative and operational needs for the year.

It is noted that the budget of the JU shall be adapted to consider the amount of the Union contribution as laid down in the budget of the Union.

The following tables present revenues and expenditure in 2023 and a comparison with 2022 budget (as after 2nd amendment).

Revenues
2023 administrative budget will be financed by frontloaded commitment from EC (under H2020) and private members contributions. 2023 operational budget will be financed by:
Union existing commitments for completion lines (FP7 and H2020). Horizon Europe operational appropriations will be financed by fresh appropriations of the Union and Union commitments entered in previous years. In addition, an amount of 60,000,000 in terms of commitments and 36,000,000 in terms of payments will be funded through third countries contribution and will finance additional hydrogen valleys.
These appropriations are complemented by reactivations of appropriations that became available in previous years and are introduced in the initial budget.

The table below provides an overview of the statement of revenues for 2023.

STATEMENT OF REVENUE										
		Financial year 2023				**Financial year 2022**				**Remarks**
Heading	*Title Chapter Article Item*	Commitment Appropriations	In %	Payment Appropriations	In %	Commitment Appropriations	In %	Payment Appropriations	In %	
EU contribution (excluding EFTA and third countries contribution)		198,709,380	74%	279,666,110	86%	153,368,916	49%	105,027,075	89%	
of which (fresh C1) Administrative (Title 1&2)			0%		0%		0%		0%	
of which frontloaded commitments (Title 1 and Title 2)	2002	3,530,303	1%	3,266,235	1%	3,368,916	1%	3,368,916	3%	
of which FP7 Operational (Title 3)	2001		0%	2,952,898	1%		0%		0%	
of which H2020 Operational (Title 3)	2005		0%	56,743,130	17%		0%	23,586,529	0%	
of which Horizon Europe Operational (Title 3)	2006	195,179,077	73%	216,703,846	66%	150,000,000	48%	78,071,631	0%	*In 2022 PA refer to 2021 EC commitment In 2023* PA: 117,107,446.1 from 2023 EC commitment, 90,000,000 from 2022 EC commitment and 9,596,399.92 from 2021 EC commitment
EFTA and third countries contribution		64,820,923	24%	42,681,089	13%	3,776,084	1%	2,497,129	2%	*Clean Hydrogen JU does not manage EFTA and third countries contribution directly. Therefore EFTA lines will be added to the EU contribution as above*
of which Administrative EFTA (Title 1&2)	2002		0%	68,918	0%	71,084	0%	71,084	0%	EFTA for H2020 calculated at 2.11%
of which Operational EFTA in FP7 (Title 3)	2001	-	0%	62,306	0%	-	0%	-	0%	EFTA for FP7 calculated at 2.11%

STATEMENT OF REVENUE										
		Financial year 2023				**Financial year 2022**				**Remarks**
Heading	*Title Chapter Article Item*	Commitment Appropriations	In %	Payment Appropriations	In %	Commitment Appropriations	In %	Payment Appropriations	In %	
of which Operational EFTA in H2020 (Title 3)	2005	-	0%	1,197,280	0%	-	0%	497,676	0%	EFTA for H2020 calculated at 2.11%
of which Operational EFTA in Horizon Europe (Title 3)	2006	4,820,923	2%	5,352,585	2%	3,705,000	1%	1,928,369	2%	EFTA for Horizon Europe calculated at 2.47%
Of which operational third countries excluding EFTA (Title 3)	2006	60,000,000	22%	36,000,000	11%		0%		0%	60,000,000 in CA and 36,000,000 in PA in Horizon Europe line in 2023
Financial Members other than the Union contribution		3,530,303	1%	3,335,153	1%	3,440,000	1%	3,440,000	3%	
Hydrogen Europe contribution to administrative costs	2003	3,036,060	1%	2,868,232	1%	2,958,400	1%	2,958,400	3%	
Hydrogen Europe Research contribution to administrative costs	2004	494,242	0%	466,921	0%	481,600	0%	481,600	0%	
Unused appropriations from previous years		127,395	0%	834,022	0%	153,255,956	49%	6,856,049	6%	
Of which administrative 2020	3018		0%		0%	876,566	0%	876,566	1%	
Of which administrative 2021	3021	127,395	0%	517,694	0%	332,434	0%	332,434	0%	
Of which administrative 2022	3022		0%		0%		0%		0%	
Of which operational 2020	3019		0%		0%		0%		0%	
Of which operational 2021	3020		0%	316,328	0%	151,492,043	48%	5,647,049	5%	*In 2022:* An amount of 150,000,000 was committed by EC in 2021 but inscribed in 2022 budget of the JU. It is presented here

STATEMENT OF REVENUE										
		Financial year 2023				**Financial year 2022**				**Remarks**
Heading	*Title Chapter Article Item*	Commitment Appropriations	In %	Payment Appropriations	In %	Commitment Appropriations	In %	Payment Appropriations	In %	
										In 2023: FP7 PA: 24,123.25 H2020 PA: 292,204.34
Of which operational 2022	3023		0%		0%	554,913	0%		0%	
TOTAL ESTIMATE REVENUE		**267,188,000**		**326,516,374**		**313,840,956**		**117,820,254**		

Expenditure

Overall the administrative budget (Titles 1 and 2) will show a decrease by 10 % compared to 2022. In more details:

Title 1 - Staff

Title 1 (staff costs) represents 59% of the administrative budget for 2023 and will increase by 7% compared to 2022. It covers salaries and allowances for staff and external personnel as presented in the establishment plan under section 2.3.4.3. Title 1 also includes mission expenses, training and socio-medical costs, expenditure related to recruitment, reception, events and representational costs. External services costs include trainees, installation allowance, daily subsistence and the costs of PMO services.

Salaries and allowances for staff in the establishment plan (temporary agents) will show an increase by 9% compared to 2022. Salaries and allowances costs in the beginning of 2023 are expected to be nearly 7% higher than in beginning of 2022. The evolvement of purchasing power in 2022 will lead to an adjustment of salaries and allowances in 2 phases in 2022. In addition, a 3% increase to 2023 costs is assumed to take place in December 2023 with a retroactive effect as of July 2023, giving a net impact of 1.5% to salaries' increase. An additional 0.5% is the effect of step advancement and reclassifications as in the staff establishment plan.

Salaries and allowances for external personnel (contract agents and seconded national experts) will show an increase by 8% compared to 2022 provisions, as a consequence of salaries adjustments as explained above.

Expenditure related to recruitment, mission expenses, socio-medial infrastructure, training and representational costs will remain at 2022 levels, as no additional needs are identified.

External services will show a decrease by 25% compared to 2022 provision due to the estimation for less interim needs.

Title 2 - Infrastructure and operating costs

Title 2 (infrastructure and operating costs) represents 41% of the administrative budget for 2023 and will decrease by 28% compared to 2022.

It covers rentals and building costs that are expected to decrease by 49% as in 2022 there was a one-time provision for refurbishment costs. It is noted that rental provision is increased by 6% (anticipated inflation rate in Belgium in 2022) and building charges are increased by 30% due to the upsurge in energy prices.

IT costs will decrease by 14% as certain one-time provisions were included in 2022, notably the development of a dedicated website for Hydrogen week and a specific contract for mapping of existing and prospective knowledge management tools. The same applies for the decrease in information and communication costs by 17% since 2022 included a provision for the construction of a modular booth.

Under other infrastructure and operating expenditure, until 2022 the cost for experts and evaluators were included. As of 2023, these services will be covered by Title 3 budget (operational costs).

On the other side, there will be a 10% increase to telecommunication and postage costs due to expected adjustments in telephony contracts due to inflation and since this budget line is usually consumed.

Running costs in connection with operating activities include specific contracts under the framework contract for the e-HRS availability (estimated at EUR 120,000) and the needs for project technical assistants (estimated at EUR 1,050,000). The latter will show an increase compared to the provision in 2022 as technical assistance will be needed in support of the Horizon Europe grant agreement preparations, hence the 27% increase in this budget line.

Other budget lines will remain at 2022 levels (movable property, current administrative expenditure and meeting expenses) since no additional needs are expected.

Title 3 - Operational costs

2023 budget includes:

FP7: payment appropriations for the last FP7 payment of the only outstanding grant agreement.

H2020: payment appropriations for 53 payments (32 final and 21 interim) as well as procurement activities financed by this budget.

Horizon Europe: commitment appropriations will cover for the call of 2023, JRC collaboration as announced in section 2.2.5.3, procurement activities as described in section 2.2.5.1 (for the creation of 2 panels for sustainability and circularity as well as safety, and the European Hydrogen Knowledge hub), and experts (evaluators and reviewers), the latter estimated for an amount of EUR 700,000. Appropriations also include a EUR 60,000,000 provision on funding additional valleys. Payment appropriations will cover for the remaining pre-financing to grants expected to be signed in the beginning of 2023 (relating to the 1st deadline of call 2022), as well as the entire pre-financings to the grants from the 2nd deadline of the call 2022 and call 2023. In addition, there is a provision for pre-financing to grants expected to be signed under hydrogen valleys.

STATEMENT OF EXPENDITURE								
		Financial year 2023				**Financial year 2022**		**Remarks**
Heading	*Title Chapter Article Item*	Commitment Appropriations	% ratio 2023/2022	Payment Appropriations	% ratio 2023/2022	Commitment Appropriations	Payment Appropriations	
1 - Staff costs		*4,221,000*	*107%*	*4,221,000*	*107%*	*3,958,000*	*3,958,000*	
Salaries and allowances	11	3,941,000	*109%*	3,941,000	*109%*	3,625,000	3,625,000	
- Of which establishment plan posts	1101	3,675,000	*109%*	3,675,000	*109%*	3,378,950	3,378,950	Includes basic 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
- Of which external personnel	1102	266,000	*108%*	266,000	*108%*	246,050	246,050	Includes salaries, entitlements and allowances for Contract Agents and Seconded National Experts
Expenditure relating to Staff recruitment	1200	5,000	*100%*	5,000	*100%*	5,000	5,000	Miscellaneous expenditure on staff recruitment (travel expenses for interviews)
Mission expenses	1300	60,000	*100%*	60,000	*100%*	60,000	60,000	Mission claims and travel agency tickets
Socio-medical infrastructure	1401	15,000	*107%*	15,000	*107%*	14,000	14,000	Medical service and mobility costs
Training	1402	30,000	*100%*	30,000	*100%*	30,000	30,000	Training costs
External services	1500	166,000	*75%*	166,000	*75%*	220,000	220,000	Includes: Interim staff and trainees Installation allowance, daily subsistence, resettlement allowance and removal costs for staff arriving/departing Cost of PMO provisions
Receptions, events and representation	1600	4,000	*100%*	4,000	*100%*	4,000	4,000	Representation and receptions
2 - Infrastructure and operating costs		*2,967,000*	*72%*	*2,967,000*	*72%*	*4,131,000*	*4,131,000*	

STATEMENT OF EXPENDITURE								
		Financial year 2023				**Financial year 2022**		**Remarks**
Heading	*Title Chapter Article Item*	Commitment Appropriations	% ratio 2023/2022	Payment Appropriations	% ratio 2023/2022	Commitment Appropriations	Payment Appropriations	
Rental of building and associated costs	2000	436,000	*51%*	436,000	*51%*	855,000	855,000	Rent, works, insurance, common charges (water/gas/electricity), maintenance, security and surveillance
Information, communication technology and data processing	2100	445,000	86%	445,000	86%	520,000	520,000	IT purchases, hardware and software, licences, software development
Movable property and associated costs	2200	20,000	100%	20,000	100%	20,000	20,000	Purchases and rental of office equipment, maintenance and repair
Current administrative expenditure	2300	9,000	100%	9,000	100%	9,000	9,000	Office supplies, library, translation service, bank charges and miscellaneous office expenditure
Postage/ Telecommunications	2400	11,000	110%	11,000	110%	10,000	10,000	Telephones, video conferences and postal services
Meeting expenses	2500	50,000	100%	50,000	100%	50,000	50,000	Official meetings such as SRG, Scientific Committee, Governing Board and caterings
Information and communication	2600	755,000	83%	755,000	83%	910,000	910,000	External communication and events
Running costs in connection with operational activities	2700	1,241,000	127%	1,241,000	127%	977,000	977,000	Project technical assistance, audits, consulting activities and accounting services with DG BUDG (until 2022)
Studies	2800							
Other infrastructure and operating expenditure	2900		0%		0%	780,000	780,000	Costs for experts: monitors and evaluators
TOTAL ADMINISTRATIVE COSTS (1+2)		*7,188,000*	*89%*	*7,188,000*	*89%*	*8,089,000*	*8,089,000*	
3 - Operational costs		*260,000,000*	*85%*	*319,328,374*	*291%*	*305,751,956*	*109,731,254*	

STATEMENT OF EXPENDITURE								
		Financial year 2023				Financial year 2022		Remarks
Heading	*Title Chapter Article Item*	Commitment Appropriations	% ratio 2023/2022	Payment Appropriations	% ratio 2023/2022	Commitment Appropriations	Payment Appropriations	
FP7	3001			3,039,328		-	-	This appropriation shall cover the operational costs of the JU regarding FP7 grants (pre-financings, interim and final payments) and studies.
H2020	3002		*0%*	58,232,615	*196%*	2,046,956	29,731,254	This appropriation shall cover the operational costs of the JU regarding H2020 grants (pre-financings, interim and final payments), studies and JRC contribution.
Horizon Europe	3003	260,000,000	*86%*	258,056,431	*323%*	303,705,000	80,000,000	This appropriation shall cover the operational costs of the JU regarding Horizon Europe grants (pre-financings), studies and JRC contribution.
TOTAL EXPENDITURE		**267,188,000**	**85%**	**326,516,374**	**277%**	**313,840,956**	**117,820,254**	

4 ANNEXES

4.1 IKAA 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 2023 – 31 December 2023. The Plan includes Additional Activities for a total amount of **EUR 904.78 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 confidentiality purposes, only aggregated values of the additional activities are presented in the table below.

DETAILED ESTIMATED IKAA FOR 2023		
Detailed description of the AA	**Type of contributor**	**Estimated value AA for 2023 (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	13.68
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	8.25
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	0.23
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	5.03
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	27.72

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	0.59
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	5.28
SUB TOTAL (A)		**60.78**

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	18.83
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	7.37
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	12.45
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	1.70
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	34.15
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	0.16
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	8.66
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	0.15
SUB TOTAL (B)		**83.47**

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	28.80
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	4.49
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	74.68
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	1.05
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	14.69
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	2.23
SUB TOTAL (C)		**125.94**

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	77.73
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	94.48
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	4.07
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	28.29
E Improve, through research and innovation, including activities related to lower TRLs, the cost-effectiveness, efficiency, reliability, quantity and	Private members	4.89

quality of clean hydrogen solutions, including production, distribution, storage and end uses developed in the Union		
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	0.17
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	9.99
SUB TOTAL (D)		**219.62**

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	0.03
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	0.83
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	1.64
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	2.65
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	0.06
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	0.44
SUB TOTAL (E)		**5.65**

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		
A To contribute to the objectives set out in the communication from the Commission of 17 September 2020 on Stepping up Europe's 2030	Private members	12.18

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		
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	3.10
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	38.67
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	0.28
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	4.24
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	0.87
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	2.03
SUB TOTAL (F)		**61.37**

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	10.64
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	32.02
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	20.73

D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	3.09
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	59.62
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	3.49
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	5.54
SUB TOTAL (G)		**135.13**

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	114.27
B To contribute to the implementation of the 2020 European Commission's Hydrogen Strategy for a climate neutral Europe	Private members	26.95
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	9.36
D To stimulate research and innovation on clean hydrogen production, distribution, storage and end use applications	Private members	1.76
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	11.95
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	0.59
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	Private members	47.81

production, distribution, storage and use for transport and energy-intensive industries as well as other applications		
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	0.13
SUB TOTAL (H)		**212.82**
TOTAL ESTIMATED IKAA		**904.78**

4.2 Link of Clean Hydrogen JU operational activities with its Strategy Map

Table 3. Clean Hydrogen JU Strategy Map: Actions, Outcomes and Impacts

Operational level resources and actions (Linked to the JU's objectives and additional tasks in the SBA and the strategy map)	**Action-1** Supporting climate neutral and sustainable solutions
	Action-2 Research and Innovation for hydrogen technologies
	Action-3 Supporting market uptake of clean hydrogen applications
Specific level outcomes (Linked to the JU's specific objectives in the SBA and the strategy map)	**Outcome-1** Limiting the environmental impact of hydrogen technology applications
	Outcome-2 Improving the cost-effectiveness of clean hydrogen solutions
	Outcome-3 Demonstrating clean hydrogen solutions, in synergy with other partnerships
	Outcome-4 Increasing public awareness and uptake of hydrogen technologies
	Outcome-5 Reinforcing EU scientific and industrial ecosystem, including SMEs
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)	**Impact-1** Action against climate change by drastically reducing greenhouse gas emissions
	Impact-2 Transition to a clean energy system with renewable hydrogen as one of its main pillars
	Impact-3 Emergence of a competitive and innovative European hydrogen value chain

Table 4. Criteria for linking Clean Hydrogen JU activities with Strategic Objectives

Strategy Map Objective	KPI Name	Unit of measurement	Criteria for linking Activities with Objectives
Resources (input), processes and activities			
1. Supporting sustainable solutions	*1a. Hydrogen end-use solutions in hard to abate sectors*	*% of budget*	The activity should target either the hard to abate sectors (industry, heavy-duty transport) or have as an objective or KPI linked to sustainability
	1b. Circular and sustainable solutions	*% of budget*	
2. R&I for hydrogen technologies	2. Early research projects	% of budget	The activity should either start with TRL up to 3 or end with TRL of at least 7.
	3. Demonstration projects	# of projects	
3. Supporting market uptake of clean hydrogen applications	4. Education and training	# of projects	Either activities addressing education and training, or activities related to the monitoring of technology progress, RCS or international initiatives.
	5. Monitoring technology progress	*Qualitative indicator*	
	6. Supporting EC in H2 market uptake	*Qualitative indicator*	
Outcomes			
4. Limiting environmental impacts	7. Environmental impact and sustainability	*TBD*	The activity should have as an objective or KPI linked to sustainability
5. Improving cost-effectiveness	*8.a Capital cost of electrolysers*	€/kW	The activity should have as an objective or KPI linked to the reduction of CAPEX or increase of efficiency
	8.b Capital cost of heavy-duty transport applications	€/kW	
6. Synergies with other partnerships	9. Research and Innovation Synergies	# of projects	The activity should demonstrate synergies with other partnerships or Programmes
7. Increasing Public Awareness	10. Public perception of hydrogen	*Qualitative indicator*	The activity should have as an objective to measure or affect the awareness in relation to hydrogen technologies.
8. Reinforcing EU scientific and industrial ecosystem, including SMEs	11. Total persons trained	# of persons	Either activities promoting research, education and training or ones strengthening the links between various parts of hydrogen value chain and SMEs
	12. Patents and publications	#of patents / publications	
	13. Promoting cross-sectoral solutions	# of projects	
Impacts			
9. Reducing GHG emissions	14. Expected avoided emissions	Mt of CO2-eq	The activity should have a direct or indirect impact on the reduction of GHG emissions, e.g. through clean hydrogen production or consumption
10. Energy transition with renewable hydrogen	15. Deployment of electrolysers	Gigawatt	The activity should have a direct or indirect impact on the production or use of renewable hydrogen
	16. Market uptake of clean hydrogen	Mt of clean hydrogen consumed	
11. Competitive and innovative European hydrogen value chain	17. Total cost of hydrogen at end-use	€/kg	The activity should have a direct or indirect impact on the reduction of cost of hydrogen (to make it more competitive), the innovation aspects of hydrogen or the strengthening of the value chain.
	18. Size of private hydrogen sector	*Qualitative indicator*	

Table 5. Expected contribution of operational actions to Strategy Map elements[260]

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-CLEANH2-2023-01-01	✓	✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-01-02	✓	✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-01-03	✓	✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-01-04		✓		✓	✓			✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-01-05	✓	✓		✓	✓				✓	✓	✓
HORIZON-JTI-CLEANH2-2023-01-06	✓	✓		✓	✓	✓		✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-01-07	✓	✓		✓	✓	✓		✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-02-01		✓			✓	✓		✓		✓	✓
HORIZON-JTI-CLEANH2-2023-02-02		✓	✓					✓			✓
HORIZON-JTI-CLEANH2-2023-02-03	✓	✓			✓			✓			✓

[260] 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-CLEANH2-2023-02-04		✓			✓			✓			✓
HORIZON-JTI-CLEANH2-2023-02-05		✓			✓	✓		✓			✓
HORIZON-JTI-CLEANH2-2023-03-01	✓	✓		✓	✓				✓		✓
HORIZON-JTI-CLEANH2-2023-03-02	✓				✓	✓			✓		✓
HORIZON-JTI-CLEANH2-2023-03-03	✓	✓		✓		✓			✓		✓
HORIZON-JTI-CLEANH2-2023-04-01	✓	✓		✓	✓			✓	✓		✓
HORIZON-JTI-CLEANH2-2023-04-02	✓	✓		✓	✓			✓	✓		✓
HORIZON-JTI-CLEANH2-2023-04-03	✓	✓		✓		✓		✓	✓		✓
HORIZON-JTI-CLEANH2-2023-04-04	✓	✓		✓		✓		✓	✓		✓
HORIZON-JTI-CLEANH2-2023-05-01	✓		✓	✓				✓			✓
HORIZON-JTI-CLEANH2-2023-05-02			✓					✓			✓
HORIZON-JTI-CLEANH2-2023-05-03	✓		✓	✓		✓		✓			✓

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-CLEANH2-2023-06-01	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-06-02	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HORIZON-JTI-CLEANH2-2023-07-01		✓			✓			✓			✓
HORIZON-JTI-CLEANH2-2023-07-02		✓			✓			✓	✓	✓	✓
Other Activities											
Support to EU Policies			✓				✓	✓			✓
Knowledge Management			✓				✓	✓			✓
Collaboration with other entities			✓			✓	✓	✓			✓
RCS SC			✓				✓	✓			✓
EHSP			✓				✓	✓			✓
EHS & CP	✓		✓	✓			✓	✓			✓
International Cooperation			✓				✓	✓			✓
Communication			✓				✓	✓			✓
Dissemination & Exploitation			✓				✓	✓			✓
Study-01 – European Hydrogen Knowledge Hub			✓				✓	✓			✓

4.3 Renewable Hydrogen Production. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2023

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 show as a “O”.

Renewable Hydrogen Electrolysis	*Type of Action*	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-CLEANH2-2023-01-01: Innovative electrolysis cells for low temperature hydrogen production	RIA	O	X	X		O		
HORIZON-JTI-CLEANH2-2023-01-02: Innovative Solid Oxide electrolysis cells for intermediate temperature hydrogen production	RIA	O	X	X		O		
HORIZON-JTI-CLEANH2-2023-01-03: Advances in alkaline electrolysis technology	RIA	X	X	X		O		
HORIZON-JTI-CLEANH2-2023-01-06: Valorisation of by-product O2 and/or heat from electrolysis	IA	X	X	X	O	O	X	
HORIZON-JTI-CLEANH2-2023-01-07: Hydrogen use by an industrial cluster via a local pipeline network	IA	X	X	X	O	O	X	

Renewable Hydrogen **Other routes of renewable hydrogen production**	*Type of Action*	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-CLEANH2-2023-01-04: Photoelectrochemical (PEC) and/or Photocatalytic (PC) production of hydrogen	RIA	O	X		X
HORIZON-JTI-CLEANH2-2023-01-05: Waste to Hydrogen demonstration plant	IA	O	X	X	X

4.4 Hydrogen Storage and Distribution. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2023

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 show as a “O”.

Hydrogen storage and distribution Hydrogen Storage	*Type of action*	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
HORIZON-JTI-CLEANH2-2023-02-01: Large-scale demonstration of underground hydrogen storage	IA	X		O	X
HORIZON-JTI-CLEANH2-2023-02-03: Novel insulation concepts for LH2 storage tanks	RIA	X			
HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks	RIA	X			

Hydrogen storage and distribution Hydrogen in the Natural Gas Grid	*Type of Action*	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-CLEANH2-2023-01-07: Hydrogen use by an industrial cluster via a local pipeline network	IA		O
HORIZON-JTI-CLEANH2-2023-02-02: Pre-Normative Research about the compatibility of transmission gas grid steels with hydrogen and development of mitigation techniques	RIA	X	X

Hydrogen storage and distribution Liquid Hydrogen Carriers	*Type of action*	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.
n/a					

Hydrogen storage and distribution Improving Existing Hydrogen Transport means	*Type of Action*	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-CLEANH2-2023 -02-04 Demonstration of high pressure (500-700 bar) supply chain	IA		X		
HORIZON-JTI-CLEANH2-2023-01-07: Hydrogen use by an industrial cluster via a local pipeline network	IA	O			
HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks	RIA		X	X	

Hydrogen storage and distribution **Compression, Purification and Metering Solutions**	*Type of Action*	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-CLEANH2-2023-01-07: Hydrogen use by an industrial cluster via a local pipeline network	IA	O				
HORIZON-JTI-CLEANH2-2023-02-04: Demonstration of high pressure (500-700 bar) supply chain	IA	O				
HORIZON-JTI-CLEANH2-2023-05-03: Pre-Normative Research on the determination of hydrogen releases from the hydrogen value chain	RIA					O

Hydrogen storage and distribution **Hydrogen Refuelling Stations (HRS)**	*Type of Action*	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-CLEANH2-2023-02-04: Demonstration of high pressure (500-700 bar) supply chain	IA	O			X
HORIZON-JTI-CLEANH2-2023-02-05: Demonstration of LH2 HRS for Heavy Duty applications	IA	X	O		X

4.5 Hydrogen end uses: Transport. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2023

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 show as a "O".

Hydrogen end uses: Transport applications **Building Blocks**	*Type of Action*	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-CLEANH2-2023-03-01: Real environment demonstration of Non-Road Mobile Machinery (NRMM)	IA	X			O
HORIZON-JTI-CLEANH2-2023-03-02: Development of a large fuel cell stack for maritime applications	RIA	X		O	O
HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks	RIA		X	O	O

Hydrogen end uses: Transport applications **Heavy-Duty Vehicles**	*Type of Action*	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-CLEANH2-2023-03-01: Real environment demonstration of Non-Road Mobile Machinery (NRMM)	IA	X	X	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-CLEANH2-2023-03-02: Development of a large fuel cell stack for maritime applications	RIA	O	X	X	
HORIZON-JTI-CLEANH2-2023-02-05: Demonstration of LH2 HRS for Heavy Duty applications	IA				O
HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks	RIA				O

Hydrogen end uses: Transport applications **Rail Applications**	*Type of Action*	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**	*Type of Action*	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-CLEANH2-2023-03-03: Ultra-low NOx combustion system for aviation	RIA		X			
HORIZON-JTI-CLEANH2-2023-02-05: Demonstration of LH2 HRS for Heavy Duty applications	IA			O		
HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks	RIA				O	

4.6 Hydrogen end uses: Clean Heat and Power. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2023

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 show as a “O”.

Hydrogen end uses: Clean Heat and Power **Fuel Cells**	*Type of Action*	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-CLEANH2-2023-04-01: Development and validation of high power and impurity tolerant fuel cell systems ready to run on industrial quality dry hydrogen		X	X		O	

Hydrogen end uses: Clean Heat and Power **Turbines, boilers and burners**	*Type of Action*	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-CLEANH2-2023-04-02: Research on fundamental combustion physics, flame velocity and structure, pathways of emissions formation for hydrogen and variable blends of hydrogen, including ammonia	RIA	X	O
HORIZON-JTI-CLEANH2-2023-04-03: Retrofitting of existing industrial sector natural gas turbomachinery cogeneration systems for hydrogen combustion	IA	X	X
HORIZON-JTI-CLEANH2-2023-04-04: Hydrogen for heat production for hard-to-abate industries (e.g. retrofitted burners, furnaces)	IA		X

4.7 Cross-cutting issues. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2023

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 show as a “O”.

Cross-cutting issues **Sustainability, LCSA, recycling and eco-design**	*Type of Action*	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.
HORIZON-JTI-CLEANH2-2023-05-01: Product environmental footprint pilot for a set of FCH product categories	CSA	X	O	
HORIZON-JTI-CLEANH2-2023-05-03: Pre-Normative Research on the determination of hydrogen releases from the hydrogen value chain	RIA		O	

Cross-cutting issues **Education and public Awareness**	*Type of Action*	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-CLEANH2-2023-05-02: European hydrogen academy	CSA	X	O

Cross-cutting issues **Safety, Pre-Normative Research and RCS**	*Type of Action*	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-CLEANH2-2023-02-02: Pre-Normative Research about the compatibility of transmission gas grid steels with hydrogen and development of mitigation techniques	RIA		X
HORIZON-JTI-CLEANH2-2023-02-05: Demonstration of LH2 HRS for Heavy Duty applications	IA		O
HORIZON-JTI-CLEANH2-2023-05-03: Pre-Normative Research on the determination of hydrogen releases from the hydrogen value chain	RIA	O	X

4.8 Hydrogen Valleys, Supply Chain and Strategic Research Challenge. Objectives of the Clean Hydrogen JU addressed in the Call for Proposals 2023

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 show as a “O”.

Hydrogen Valleys	*Type of Action*	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 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 optimization 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
HORIZON-JTI-CLEANH2-2023-06-01: Large-scale Hydrogen Valley	IA		X	
HORIZON-JTI-CLEANH2-2023-06-02: Small-scale Hydrogen Valley	IA		X	

Supply Chain	*Type of Action*	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-CLEANH2-2023-01-01: Innovative electrolysis cells for low temperature hydrogen production	RIA	`		X
HORIZON-JTI-CLEANH2-2023-01-03: Advances in alkaline electrolysis technology	RIA			X

Strategic Research Challenges	*Type of Action*	Low or free PGM catalysts (including bioinspired catalysts), reducing critical (raw) materials use in electrolysers 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 electrolysers and fuel cells.
HORIZON-JTI-CLEANH2-2023-07-01: Advanced materials for hydrogen storage tanks	RIA		X	
HORIZON-JTI-CLEANH2-2023-07-02: Increasing the lifetime of electrolyser stacks	RIA			X