SET4H2

Coordination and Support Action SET4H2

Analysis report on hydrogen in the IPs of other IWGs

D3.2

WP3 / T3.1

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List of abbreviations and acronyms

List of abbreviations

Abbreviation	Long form
CCS	Carbon Capture and Storage
cH2	Clean hydrogen
CSA	Coordination and Support Action
CST	Concentrated Solar Thermal Technologies
D	Deliverable
DG RTD	Directorate-General for Research and Innovation
EC	European Commission
ERA	European Research Area
ETIP	European Technology & Innovation Platform
EU	European Union
H2	Hydrogen
HEU	Horizon Europe
HVDC	High Voltage Direct Current ()
IWG	Implementation Working Group
low-C hydrogen	Low-carbon hydrogen
LVDC	Low Voltage Direct Current
MVDC	Medium Voltage Direct Current
MS	Member State
NECP	National energy and climate plans
OPEX	Operational expenditures

PED	Positive Energy Districts
PtX	Power-to-X
PV	Photovoltaic
RES	Renewable Energy Sources
rH2	Renewable hydrogen
R&I	Research and Innovation
SET Plan	Strategic Energy Technology Plan
SRIA(s)	Strategic Research and Innovation Agenda(s)

List of acronyms

Acronyms of CSA SET4H2 consortium partners

AEA: Österreichische Energieagentur - Austrian Energy Agency

BGH2A: Balgarska Asotsiatsia za Vodorod, Gorivni Kletki I Sahranenie na Energia (Bulgarian Hydrogen, Fuel Cell and Energy Storage Association)

EUREC: Association of European Renewable Energy Research Centers

DGEG: Direção-Geral de Energia e Geologia (Directorate General for Energy and Geology)

DLR: Deutsches Zentrum für Luft- und Raumfahrt e.V.

HER: Hydrogen Europe Research

MUR: Ministero dell'Università e della Ricerca

UNIBO: Alma Mater Studiorum – Università di Bologna

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Executive Summary

Hydrogen is emerging as a key enabler in Europe's clean energy transition, with growing relevance across the Strategic Energy Technology (SET) Plan's Implementation Working Groups (IWGs). However, current efforts remain fragmented. To unlock hydrogen's full potential, stronger coordination, regulatory alignment, and targeted investments in infrastructure and innovation are essential. The new IWG on Hydrogen plays a pivotal role in coordinating research and innovation across energy technologies. This report examines how hydrogen is addressed in the IWG's implementation plans, including an analysis of gaps as well as synergies across the IWGs. It highlights the need for stronger collaboration between the Hydrogen IWG and other IWGs to ensure systemic integration and coherence in deploying hydrogen solutions within the European energy transition. The report recommends, in particular, to establish collaboration activities with other IWGs such as Wind and Ocean energy to develop offshore hydrogen production hubs using hybrid renewable systems. Another promising area for collaboration concerns systemic power-to-x projects combining electrolysis and CCU with system integration tailored to Member States' renewable capacity. In order to align hydrogen strategies across IWGs, prioritise case studies, and address integration challenges collaboratively, a temporary, action-oriented cross-IWG task force under the Hydrogen IWG could be established.

1. Objective

The goal of the "Analysis Report on H2 in the IPs of other SET Plan Hydrogen Implementation Working Groups (IWGs)" is to build a comprehensive understanding on how the Hydrogen IWG can effectively coordinate and establish synergies with other SET Plan IWGs. Such coordination aims to enhance the complementarity of actions and promote systemic integration and coherence in the deployment of hydrogen technologies within the broader framework of the European energy transition.

2. Hydrogen as a cross-cutting system facilitator

A significant recognition exists among scientists, industry and policymakers, that renewable hydrogen (rH2) serves as a key precursor of electrofuels, a facilitator to reduce emissions in end-use applications, as well as a candidate for long duration energy storage. However, the fact is that the rH2 market and associated ambitions and expectations have recently entered a phase of consolidation in which high costs, limited demand and lagging implementation of support policies are hampering deployment. Shortfalls in the announced deployment of water electrolysers, are representative of the systemic challenges of scaling up supply, demand and infrastructure at the same time. Even so, in contrast to these recent setbacks contributing to an implementation gap, announced future growth rates of rH2 have increased substantially over the past three years, indicating a backlog of projects as well as further increasing ambition.

This raises questions such as whether in the learning curve the business case at a EU level should focus on rH2 or on clean hydrogen (cH2), whether recent failure rates and the risk of an eminent 'valley of death' can be overcome to meet updated project announcements, whether the expected role of hydrogen in ambitious climate change mitigation scenarios has changed and what plausible implementation pathways exist given currently announced hydrogen support policies.

The Member States (MS) reporting process under the National Energy and Climate Plans (NECPs) shows that – besides the need to meet a strong call for consensus on decarbonisation targets and achievements – the rH2 approach in the case of MS having less access to renewable energy sources requires a careful elaboration and a system integration approach tailored to MS needs. This raises also the question on the fairness and just conditions for an energy transtion in these cases, and derived questions e.g. on what is needed to adjust such an imbalance and how may the SET Plan IWGs contribute introducing adequate answers at that level.

Within the SET Plan, different IWGs currently address renewable and/or low-carbon hydrogen.

Following the identification of different competitive factors that influence the feasibility of clean hydrogen in the energy system, the alignment of the current IWGs portfolio of the SET Plan with the EU H2 Strategy framework is reviewed, and the synergies and consistency of the H2-related activities carried out in the different IWGs are analysed, to conclude about what is missing: a IWG on Clean Hydrogen.

2.1 Competitive factors influencing hydrogen feasibility

Different critical factors influence collectively the competitiveness and feasibility of clean hydrogen in the energy system. One of them - the R&I provided by the SET Plan - is a key competitive factor in the performance and adoption of a hydrogen-based products. In brief, these competitive factors are identified in the following section.

Cost Reduction

- Production costs: Lowering the cost of producing clean hydrogen, particularly through advancements in electrolysis and other renewable-based methods.
- Infrastructure costs: Reducing the costs associated with building and maintaining hydrogen infrastructure, including storage and distribution networks.

Policy and Regulation

- Incentives: Government policies that provide financial incentives, subsidies, and tax breaks for clean hydrogen production and use.
- Standards and Certification: Establishing clear and harmonized standards and certification processes to ensure the traceability, quality and sustainability of clean hydrogen.

R&I and Technological Advancements

- Incremental innovation: Leads to efficiency improvements, enhancing the efficiency of hydrogen production technologies, such as electrolysers, to make them more cost-effective.
- Disruptive innovation: Leads to higher competitive advantages by discovering novel technological approaches and by combining existing technologies with new system components along the hydrogen value chain.

Market Creation

- Demand stimulation: Creating local and global markets for hydrogen by promoting its use in various sectors, including transportation, industry, and energy storage.
- Export corridors and EU Hydrogen Backbone: Developing dedicated hydrogen export corridors, including cross-border infrastructures and hydrogen backbone pipelines, to facilitate international trade of clean hydrogen.

Collaboration

- Value chain integration: Facilitating cooperation across the hydrogen value chain, including producers, consumers, and technology providers.
- International cooperation: Engaging in international partnerships to share knowledge, technology, and best practices.

Environmental Impact

- Sustainability: Ensuring that hydrogen production methods are environmentally sustainable and contribute to reducing greenhouse gas emissions.

- Resource utilization: Efficiently using resources such as water and renewable energy sources for hydrogen production.

Infrastructure Development

- Grids and networks: Balancing supply and demand, they support the scale-up of the hydrogen value chain, and facilitate the integration of variable renewable energy sources into the power grid, and the cross-sector integration.
- Refuelling Stations: Expanding the network of hydrogen refuelling stations to support the adoption of hydrogen-powered vehicles.
- Storage Solutions: Developing advanced and flexible storage solutions to safely and efficiently store hydrogen.

Public Awareness and Acceptance

- Education: Raising public awareness through targeted education initiatives about the benefits of clean hydrogen and its role in the energy transition.
- Acceptance: Building public and industry acceptance through demonstration projects and successful case studies.

2.2 The policy landscape – a very brief overview

The SET Plan is considered a key initiative to drive the development and deployment of low-carbon technologies in the EU. The policy landscape supporting the SET Plan includes several key policy elements, aiming at the advancement of clean energy technologies and Europe’s climate goals:

- **The European Green Deal**: This overarching policy aims to make Europe the first climate-neutral continent by 2050. It provides a comprehensive framework for the SET Plan, emphasizing the need for clean energy innovations.
- **The Net-Zero Industry Act**: This recent legislation reinforces the SET Plan's role by increasing cooperation between policymakers, industry, academia, and investors. It aims to strengthen Europe's industrial leadership in low-carbon technologies.
- **The National Energy and Climate Plans (NECPs):** Each EU member state has developed NECPs to outline its strategies for achieving the EU's energy and climate targets. These plans align with the SET Plan's objectives and ensure coordinated efforts across the EU.
- **Horizon Europe**: This is the EU's research and innovation program, which funds projects that support the SET Plan's goals. It focuses on areas such as renewable energy, energy efficiency, and smart grids.

Adding to that, a set of strategy papers touch (in)directly on the energy system integration approach, namely:

- The **EU Strategy for Energy System Integration** (July 2020), which aims to create a more efficient, resilient, and climate-neutral energy system.
- The **EU Strategy for Hydrogen** (July 2020), which aims to establish hydrogen as a key component in achieving a climate-neutral Europe.

- The **EU Strategy for Offshore Renewable Energy** (Nov 2020), which aims to harness the potential of offshore renewable energy to achieve a climate-neutral Europe.

3. Addressing H2 in the SET Plan IWGs

3.1 How should this initiative align with the EU Hydrogen Strategy?

Goals and Objectives

Decarbonization: The majority of SET Plan IWGs in line with the EU Hydrogen Strategy aim to decarbonize key economic sectors by promoting the production and use of renewable and low-carbon hydrogen.

Innovative technology: They focus on both developing and deploying innovative (hydrogen) technologies, such as the water electrolysis supplied by renewable power to produce renewable hydrogen, or low-C hydrogen from other clean hydrogen production technologies (e.g. SMR + CCS; electrolysis powered by low-carbon (non-renewable) electricity sources).

Market creation: They work towards creating a robust market for hydrogen, ensuring its integration into various sectors like industry, transport, and energy systems.

Key Actions and Developments

Research and Development: The IWGs support R&D projects to improve the efficiency and reduce the costs of production technologies for clean energies and energy vectors such as hydrogen.

Infrastructure Development: They contribute to building the necessary infrastructure for production, storage, and distribution of clean energy, incl. hydrogen.

Policy and Regulation: The IWGs help shape policies and regulations that facilitate the adoption of hydrogen technologies and ensure compliance with EU standards.

Monitoring and Targets

Performance Metrics: Both the IWGs and the EU Hydrogen Strategy set specific targets for energy production capacity and usage, and they monitor progress towards these goals.

Environmental Impact: They assess the environmental benefits of projects, focusing on reducing greenhouse gas emissions and promoting sustainability.

Challenges

Cost Competitiveness: One of the main challenges is making renewable hydrogen cost-competitive with fossil-based hydrogen.

Regulatory Harmonisation: There is a need for harmonised regulations across EU member states to facilitate the cross-border trade and use of hydrogen.

Infrastructure: Developing a comprehensive hydrogen infrastructure remains a significant challenge, requiring substantial investment and coordination.

Timeline and Deliverables

Short-term (2020–2024): Initial focus on decarbonising existing hydrogen uses and increasing production capacity.

Medium-term (2025–2030): Expansion of hydrogen infrastructure and integration into various sectors.

Long-term (2030+): Achieving widespread adoption of renewable and clean hydrogen and significant GHG emission reductions.

To conclude, by promoting co-work at a C&T level, it is acknowledged that the SET Plan IWGs in the frame of the EU Hydrogen Strategy aim to contribute to a sustainable and competitive hydrogen economy in Europe. However, there is the question on how to ensure coordination, synergies and consistency between the hydrogen-related activities carried out by the different IWGs?

3.2 When & how is hydrogen being addressed in each IWG

In the frame of the IWG SET Plan portfolio, to answer the question "when and how is hydrogen being addressed in each IWG", fourteen IWGs have been addressed. Main findings identified on a IWG basis are summarised in this section. For an overview of the full set of citations, please refer to the Annex.

IWG 1 - Solar photovoltaics

IP publication date: July 2023

Website: https://setis.ec.europa.eu/working-groups/photovoltaics_en

The 2023 IWG Photovoltaics Implementation Plan under the SET Plan integrates hydrogen strategies indirectly through a strong emphasis on PV-powered electrolysis, particularly in hybrid energy systems and sector-coupled applications. Therefore, hydrogen strategies are part of a broader energy system integration goal, especially through hybridisation and green hydrogen production via solar-powered electrolysis. While not a standalone objective, hydrogen features prominently in the transition to a flexible, sector-integrated, renewable energy future driven by photovoltaic technologies.

How hydrogen Is addressed

1. **Renewable Hydrogen Production from PV:**

The Plan acknowledges PV's role in enabling the production of green hydrogen through:
a) Electrolysis powered by solar PV
b) Sector coupling of PV with Power-to-X (PtX) technologies. This is framed under the broader narrative that renewable electricity, particularly PV, will become a "primary fuel" of the future, enabling the generation of renewable fuels like hydrogen and synthetic hydrocarbons.

2. **Hybrid Energy Systems (PV + Hydrogen + Storage):**

R&I Roadmap 3 of Challenge 2.4.4 focuses on hybrid systems including:
a) PV combined with green hydrogen, fuel cells, gas turbines, wind, hydro, and storage to deliver grid flexibility, stability, and seasonal balancing;

b) Hydrogen is treated as part of integrated, flexible demand-response architectures, with PV as a principal input.

3. DC Network Integration and Sector Coupling:

PV is also being integrated into DC networks and multi-vector smart grids, which can directly power electrolysers more efficiently, minimising conversion losses.

4. Enabling Technologies:

Activities include digitalisation, advanced system design, and interoperability, which are crucial for aligning PV generation with electrolyser operation profiles, especially under variable renewable conditions.

When hydrogen strategies are enabled (time frame vs implementation focus):

2023–2025: Research and demonstration of hybrid PV systems with embedded hydrogen production components.
2026–2030: Deployment of PV-electrolyser systems in energy hubs and sector-coupled smart grids.

Post-2030: Widespread use of PV for powering large-scale hydrogen production plants and PtX applications.

IWG 2 – Concentrated solar thermal technologies

IP publication date: February 2023

Website: https://setis.ec.europa.eu/working-groups/concentrated-solar-thermal-technologies_en

Concentrated Solar Thermal Technologies (CST) are integral to decarbonising sectors like electricity, heat, and transport. Hydrogen, particularly green hydrogen and its derivatives, is recognised as a strategic vector within the CST roadmap to support deep decarbonisation, sector coupling, and energy autonomy. CST's unique ability to deliver integrated high-temperature heat and electricity makes it a cornerstone for future green hydrogen ecosystems, particularly in southern Europe with high solar irradiation, supporting both industrial transformation and grid stability.

How hydrogen is addressed

- Heat and Power Supply for Hydrogen Production: CST plants can generate high-temperature heat (200 °C − 800 °C) and renewable electricity to power hybrid electrolysis systems. CST can efficiently run alkaline electrolysis (AEL) under constant load and can further reduce hydrogen costs through high-temperature electrolysis (HTEL).
- Thermochemical Pathways: CST is key to developing solar thermochemical processes for water and CO_2 splitting.These processes can yield syngas and synthetic fuels via well-established reactions (e.g., Fischer-Tropsch, water-gas shift), supporting a transition toward sustainable hydrocarbon fuels.
- Continuous 24/7 Hydrogen and Synfuel Production: CST hybrid plants (e.g. combined with PV and/or backup systems) provide baseload energy around the clock, improving electrolyser efficiency and plant utilisation.
- Demonstration of 24/7 baseload production of green hydrogen is targeted by 2030, forming a major strategic pillar of the CST roadmap.

When hydrogen is addressed (time frame versus implementation focus):

Short-Term (2023–2025): CST hybrid pilot projects (e.g., Hydrosol-Plant, Sun-To-Liquid) demonstrate technical feasibility. There is a strategic R&I focus on component reliability, system integration, and cost reduction for hydrogen production begins.

Mid-Term (2026−2030): First-of-a-kind (FOAK) CST-hydrogen systems are deployed commercially. Hydrogen becomes a key application in industrial heat, synthetic fuel production, and dispatchable energy supply.

Long-Term (Post-2030): CST-integrated hydrogen production becomes part of the EU's renewable fuel infrastructure, with scalable and exportable systems contributing to global leadership.

- **Research, Innovation & Demonstration Activity**

Area 6: Thermochemical Production of Solar Fuels and Hydrogen: Includes R&I on hybrid CST systems for green fuel production, focusing on reactor scaling, process intensification, and solar-to-fuel efficiency. Deliverables include analysis of hydrogen formation/degradation products and system design for reliable operation.

Hybrid Systems and Integration: Studies highlight CST + PV + backup energy systems to deliver reliable, low-cost energy for hydrogen production. These systems can serve large industrial plants, combining steam, electricity, and solar heat.

- Strategic Targets (from 2025 Plan)

Target #5: Demonstrate 24/7 economically viable CST-based green hydrogen and solar fuels production by 2030.

System Integration: Design tailored to Member State (MS) needs, incorporating solar fuels, industrial heat, and dispatchable electricity.

IWG 3 - Wind energy

IP publication date: March 2022

Website: https://setis.ec.europa.eu/working-groups/wind-energy_en

Green hydrogen is recognised as a critical enabler for large-scale renewable integration, system flexibility, and deep sector decarbonisation. Hydrogen production from wind power − especially offshore − is a cornerstone of the Wind IWG's implementation plan, offering a pathway for deep integration of renewables, unlocking new markets, and enhancing energy security.

With the rapid expansion of offshore wind capacity, hydrogen will emerge as a key vector to absorb surplus renewable electricity, support energy system integration, and facilitate long-term storage and off-grid utilisation. The convergence of wind technology, hydrogen systems, and infrastructure innovation will define Europe's ability to lead in clean energy by 2030 and beyond.

How hydrogen is addressed

- Energy System Integration: Hydrogen enables sector coupling, transforming wind-generated electricity into a storable and transportable energy carrier through Power-to-X (P2X) pathways. It supports balancing of variable wind supply and enhances the value of wind in the energy market.
- Offshore Wind Synergies: Offshore wind farms can integrate hydrogen production directly through off-grid electrolysis systems. This allows for remote hydrogen generation, reducing dependence on large-scale undersea transmission infrastructure and increasing flexibility in deployment.
- Infrastructure and Conversion: Research is focused on offshore conversion, storage, and transport technologies for hydrogen, alongside HVDC transmission for electricity. Development of energy islands and hydrogen hubs forms part of the longer-term system design.
- Disruptive Innovations: Wind R&D supports novel turbine concepts (e.g., hydrogen-integrated turbines, high-altitude wind systems) for distributed hydrogen production. These innovations aim at cost reductions and unlocking new deployment geographies.

When hydrogen is addressed (time frame vs implementation focus):

Short-Term (2022–2025): Demonstration of off-grid hydrogen-producing turbines, especially in synergy with energy island projects. R&I on energy system models incorporating electricity and hydrogen pathways.

Medium-Term (2026–2030): Scaling up of offshore hydrogen infrastructure. Pilot deployment of hybrid wind-hydrogen systems, with validated energy and economic performance.

Long-Term (Post-2030): Full integration of wind-to-hydrogen supply chains in the offshore and coastal economy. Wind energy becomes a primary feedstock for EU's domestic green hydrogen economy, contributing to decarbonisation targets and energy independence.

- **Research and Innovation Priorities**

Hydrogen Conversion Integration: Integrated electrolysers within wind turbines. Electrolyser operation under variable load from offshore wind.

System Design and Validation: Modelling offshore systems combining wind power and hydrogen production. Designing energy islands with dedicated hydrogen infrastructure.

Storage and Transport: Offshore hydrogen compression, storage, and pipeline transport. Options for onshore reconversion or use in industrial and transport sectors.

IWG 4 - Geothermal energy

IP publication date: December 2023

Website: https://setis.ec.europa.eu/working-groups/geothermal_en

Hydrogen has no direct focus as a strategic vector or energy carrier in this specific IWG Implementation Plan (IP). However, indirect contributions of geothermal energy do intersect hydrogen strategies. They are possible through hybrid systems, system integration and sector coupling. It is the case, being its resource available, when in synergy with other renewable technologies, due to its baseload renewable profile, thermal storage capabilities, integration potential, and very low OPEX. In cases where resilience is fairly scored, geothermal energy is well aligned with long-term hydrogen strategies, making geothermal a strategic enabler within a broader clean energy ecosystem. The IWG IP outlines a comprehensive vision for geothermal energy deployment by 2050, emphasising renewable heating and cooling, dispatchable electricity, underground thermal energy storage, and co-production of critical raw materials. While hydrogen is not an explicit focus, several aspects of the IWG plan are likely to contribute indirectly to the hydrogen economy.

How hydrogen is addressed:

- Baseload Renewable Electricity for Electrolysis: Geothermal power, with capacity factors over 75%, can supply stable, low-carbon electricity to power hydrogen electrolysers more efficiently than intermittent sources like wind or solar. This improves electrolyser utilisation rates, a key economic driver for green hydrogen production.
- Underground Thermal Energy Storage (UTES) for Sector Coupling: UTES systems can help manage seasonal energy demand and supply, enabling better integration of intermittent renewables used for hydrogen production. Thermal energy could be stored and repurposed for Power-to-Heat-to-Hydrogen systems or to stabilise hybrid renewable-hydrogen infrastructure.
- Hybrid Renewable Energy Systems: The IWG promotes hybrid geothermal systems, potentially coupled with solar or wind. Such configurations could support combined electricity and hydrogen production, especially in multi-resource regions.

- Co-location with Industrial Users: Geothermal resources may be co-located with industrial users of hydrogen, allowing for integrated systems where geothermal supplies heat and/or electricity, while hydrogen serves as a feedstock or fuel.
- Flexibility and Grid Services: Geothermal systems can provide flexible output to stabilise grids with large hydrogen electrolysis loads, especially when paired with smart energy systems.

When geothermal might be addressed (time frame versus implementation focus):

2023–2025 (Short Term): Focus remains on enhancing geothermal heating, electricity production, and co-production with raw materials. No direct mention of hydrogen, but system integration and hybrid models begin to emerge.

2026–2030 (Mid Term): With growth in geothermal electricity and heat capacity, contributions to green hydrogen projects through power supply become viable. UTES systems help stabilise supply for coupled renewable-hydrogen systems. If hydrogen becomes a focus of cross-sectoral integration (e.g., through ETIP synergies), geothermal might serve as a supporting renewable baseload.

Post-2030 (Long Term): Geothermal may play a key supporting role in integrated energy systems that include large-scale hydrogen production, especially as energy hubs evolve (e.g., in volcanic areas or hybrid renewable zones), indirectly contributing via grid stability, storage solutions, or clean energy inputs, pending strategic alignment. Potential synergies with critical raw material co-production (e.g., lithium) may feed into hydrogen-related value chains (e.g., batteries, fuel cells).

IWG 5 - Ocean energy (OES)

IP publication date: October 2021

Website: https://setis.ec.europa.eu/working-groups/ocean-energy_en

Hydrogen is not a core pillar of the Ocean Energy Implementation Plan, but it is emerging as a promising strategic vector for hybrid energy systems. Both the 2021 Implementation Plan and the 2024 annual report highlight growing synergies between ocean energy and hydrogen in decentralised production, hybrid systems, and energy storage aligning well with ocean energy's niche in remote, island contexts, and other maritime applications. Though within the IWG itself there is no room therein for a formal hydrogen roadmap, the developments that are emerging through demonstration projects and cross-sector collaboration are paving the way for greater integration by 2030, and positioning ocean energy as a clean power source for hydrogen generation in targeted contexts:

How hydrogen is addressed:

- Green Hydrogen Production in Remote Areas: Wave and tidal power can supply renewable electricity for electrolysis in off-grid or island locations. Korea's KRISO project is a leading example: it uses wave energy to produce hydrogen at the Yongsoo Oscillating Water Column (OWC) site near Jeju Island.
- Desalination and Hydrogen Integration: Ocean energy is being explored for coupled systems, including desalination and hydrogen production, offering a clean, localised solution for water and energy scarcity.
- Hybrid Systems and Off-grid Solutions: Ocean energy combined with offshore renewables, storage, and hydrogen could support self-sufficient coastal and island infrastructures (e.g., REIDS-TMEC in Singapore). These systems reduce the need for costly grid infrastructure while increasing energy resilience.

When hydrogen is addressed (time frame versus implementation focus):

2021–2023: Hydrogen is not explicitly mentioned in the 2021 Ocean Energy Implementation Plan. Focus was on wave and tidal cost reduction and deployment metrics.

2024−2025: Demonstration of hydrogen production from ocean energy begins, notably in South Korea. Studies identify hydrogen integration as part of broader “alternative markets” for ocean energy (e.g., water production, aquaculture, microgrids).

Post-2025 Outlook: Hydrogen expected to play a larger role in hybrid ocean energy systems, particularly in off-grid, island, and export-oriented hydrogen projects. Integration with other clean energy missions suggests further uptake in policy and funding frameworks.

IWG 6 - Direct current technologies

IP publication date: September 2024

Website: https://setis.ec.europa.eu/working-groups/direct-current-technologies_en

Being not a primary focus of the IWG DC technologies implementation plans under the SET Plan, which consists of the High Voltage Direct Current (HVDC), Medium Voltage DC (MVDC), and Low Voltage DC (LVDC), hydrogen is recognised indirectly as a critical downstream application of DC power systems. Through efficient transmission of renewable electricity, by providing stable DC power to electrolysers - especially from offshore wind and solar sources - and through the development of DC microgrids and energy hubs, these DC technological infrastructures are critical enablers for the development of hydrogen economy.

How Hydrogen is addressed:

- Powering Electrolysers for Green Hydrogen: Electrolysers require DC electricity. Both HVDC and LVDC systems are ideally suited to directly power electrolysers without intermediate conversion from AC, reducing energy losses and system complexity. LVDC plans explicitly identify electrolysis for hydrogen as one of the core applications of DC power, alongside electric vehicles, batteries, and heat pumps.
- System Integration and Sector Coupling: HVDC/MVDC networks, especially in offshore and remote renewables, are seen as the backbone for integrating RES like wind and solar, which can feed into hydrogen production plants. These grids provide reliable and controllable power transmission, enabling green hydrogen production far from consumption centres.
- Microgrids and Local Hydrogen Generation: LVDC microgrids, especially in industrial and off-grid settings, are being piloted for self-sufficient energy systems, which can include on-site hydrogen production via electrolysis.
- R&I Enablers: While not targeted directly at hydrogen, the HVDC Implementation Plan supports (a) the development of multi-terminal HVDC systems for offshore renewables, which are potential feeders for hydrogen hubs, and (b) the research into DC-DC converters, DC fault protection, and grid-forming converters, all of which are necessary to manage DC-powered electrolysers and integrate them into future energy systems.

When hydrogen strategies are (indirectly) enabled:

2021–2025: Hydrogen is mentioned indirectly in the LVDC plan as a downstream application for DC-powered systems (e.g., electrolysis). HVDC and MVDC plans prioritise grid development, offshore integration, and system control capabilities necessary to support large-scale RES, which are precursors to clean hydrogen production.

2026−2035: HVDC/MVDC grids enable cost-effective transport of RES electricity to hydrogen plants. LVDC microgrids and industrial systems potentially integrate with local hydrogen production and storage.

Post-2035: Hydrogen production and distribution may be fully integrated into AC/DC hybrid grids, particularly in energy islands, industrial hubs, or deep-sea RES projects.

IWG 7 - Positive energy districts

IP publication date: June 2018 updated in 2021

Website: https://setis.ec.europa.eu/working-groups/positive-energy-districts_en

Hydrogen is not directly addressed or planned for in the Implementation Plan for Positive Energy Districts (PEDs) under the SET Plan Action 3.2 (Smart Cities and Communities). Though it does not explicitly prioritise hydrogen in its strategic framework, when efficiently applied, hydrogen is a potential enabler of future energy system flexibility within PEDs, having an indirect supportive role in the long-term vision of PEDs through energy system integration and sector coupling. The plan focuses primarily on decarbonised, self-sufficient urban districts powered by renewable energy and equipped with smart energy management, storage, and mobility solutions, but lays the structural and innovation groundwork (e.g., PED Labs, integrated energy systems, open innovation models) in urban areas, which could in the future incorporate hydrogen technologies.

How hydrogen is addressed:

- Sector Coupling and Flexibility Services: The PEDs concept includes energy flexibility, storage, and load balancing, where hydrogen could serve as a vector for excess renewable energy storage or fuel for clean mobility. Hydrogen could be part of district-level energy storage systems, converting surplus renewable electricity to hydrogen via electrolysis.
- Integration with Local Renewable Energy: While not specified, PEDs' reliance on local renewable energy (e.g., solar, geothermal, waste heat) and low-carbon systems could allow integration with local green hydrogen production units.
- Future Mobility Solutions: PEDs are envisioned to enable electric vehicle charging and low-emission mobility. Hydrogen could potentially serve fuel cell vehicles or hydrogen public transport within or near PEDs.
- Innovation Zones and Pilot Labs: The plan proposes PED Labs to test new technologies and business models. These innovation playgrounds could include hydrogen-related demonstrations in conjunction with power-to-gas or hybrid storage technologies—though none are detailed as of this edition.

When hydrogen may be addressed (time frame versus implementation focus):

Short-Term (2021−2025): No direct action on hydrogen in the current PED Implementation Plan. Focus remains on establishing 100 PEDs with net-zero energy import and CO_2 emissions, using known technologies like solar PV, heat pumps, storage, and digital management systems.

Medium-Term (Post-2025): As PED Labs evolve and cities experiment with advanced energy systems, hydrogen may be incorporated as part of sector integration strategies, particularly in areas with strong renewable generation potential.

Long-Term: With progress in green hydrogen production and fuel cell deployment, hydrogen could become part of mainstream PED technologies, especially for flexible district energy systems, seasonal storage, and integrated mobility solutions.

IWG 8 – Energy systems

IP publication date: October 2021

Website: https://setis.ec.europa.eu/working-groups/energy-systems_en

The IWG 8-Implementation Plan (2021) for Energy Systems Resilience and Security under the SET Plan does not explicitly mention hydrogen technologies. However, its key enabling technologies − like power-to-gas (PtG) pathways, sector integration, and flexible energy networks − are actively supported. These systemic capabilities are critical implicit enablers for green hydrogen production and its integration into future energy systems. The IWG4-IP lays the infrastructure and regulatory groundwork for hydrogen's scalable integration by 2030 and beyond, aligning well with broader SET Plan and Mission Innovation objectives.

How hydrogen is addressed:

- Power-to-Gas as a Flexibility Tool: The Plan acknowledges Power-to-Gas and Power-to-Liquid as key flexibility mechanisms that allow conversion of surplus renewable electricity into gaseous or liquid fuels − a reference to hydrogen, synthetic methane, and related carriers. This is primarily discussed under flexible generation and storage as part of sector coupling strategies.
- Sector Coupling for Energy Vector Integration: The Implemenation Plan strongly promotes the integration of electricity, gas, heat, and transport sectors, providing the infrastructure and digital backbone necessary for coupling electrolysers and hydrogen storage systems with renewable power grids.
- Storage and Conversion: Under flexibility and economic efficiency, the Plan calls for RD&I to reduce the cost of energy storage technologies, including PtG systems. This suggests support for hydrogen as a long-duration, cross-sector storage medium.
- Support for Flexible Thermal Generation: Innovation targets include retrofits of thermal power plants to operate flexibly and on a wider variety of fuels, such as hydrogen, ammonia, and synthetic methane. This opens the door for integrating hydrogen into existing infrastructure.
- Enabling Infrastructure for Hydrogen: Investments in digitalisation, grid observability, and smart control systems help stabilise variable renewable energy (vRES) and ensure compatibility with intermittent electrolysis operations, key to economic hydrogen production.

When hydrogen strategies are implicitly enabled (time frame versus implementation focus):

2021−2025: Foundation Phase: Development of integrated planning tools, energy vector coupling strategies, and flexible generation. Early support for PtG concepts without named hydrogen projects.

2026−2030: Scale-Up Phase: Expected rise in integration of electrolysers into smart grid systems as part of sector coupling. Increased deployment of hybrid RES-PtG systems for local and regional energy security.

Post-2030: System Integration: Full-scale hydrogen infrastructure and market integration via flexible, resilient, and digitally managed power systems. Hydrogen acts as both a storage medium and fuel within distributed and centralised systems.

IWG 9 – Energy efficiency in buildings

IP publication date: September 2024

Website: https://setis.ec.europa.eu/working-groups/energy-efficiency-buildings_en

The 2024−2025 Implementation Plan of IWG5 (Energy Efficiency in Buildings) under the SET Plan includes explicitly dedicated R&I on hydrogen as:

a) A renewable fuel for microgeneration CCHP - micro combined cooling, heat and power - systems that support low-emission, efficient, resilient, and decentralised/ autonomous energy supply in buildings where applicable.
b) Part of its innovation strategy, particularly in the domain of cross-cutting heating and cooling technologies.

How hydrogen is addressed

- **Micro CCHP Systems Powered by Hydrogen**: One of the key innovation targets (5.2-T3) promotes the development and integration of highly flexible micro-CCHP systems that can run on renewable gases, including green hydrogen, ammonia, methanol, and synthetic methane. Hydrogen is identified as a core fuel to replace natural gas while achieving comparable performance in decentralised energy generation for buildings.

- **Dual-Fuel and Flexible Combustion Technologies**: The plan supports the development of dual-fuel microturbines capable of operating on any mix of hydrogen and natural gas (0%−100%). R&I activities between 2025 and 2028 aim to raise technology readiness levels from TRL6 to TRL7, focusing on combustor design, transient operation, part-load performance, emissions, and reliability testing.
- **Pilot Projects and Demonstrators**: A flagship project involves a demonstration of a hydrogen-powered microgasturbine CCHP system in a temperature-controlled fruit logistics application, starting at TRL8 and aiming to reach TRL9. The system will provide simultaneous heat and cooling (105−165 kW), without adding demand to the local electricity grid − showcasing energy autonomy, emissions reduction, and system resilience.
- **Integration with Smart Grids**: Long-term, these hydrogen-fueled microgeneration systems are expected to integrate with smart building energy systems, improving grid stability, load flexibility, and resilience in areas with constrained electricity infrastructure.

When Hydrogen strategies are implemented (time frame versus implementation focus):

2025−2028 (Short Term): R&D and prototype development for hydrogen-capable micro-CCHP systems. Dual-fuel (hydrogen/natural gas) combustion systems brought to demonstration scale (TRL7–8).

2028−2030 (Medium Term): Completion of demonstration projects, with validated techno-economic and environmental KPIs. Market readiness of CCHP systems for deployment in commercial or residential buildings.

Post-2030 (Long Term): Widespread implementation of hydrogen-fueled CCHP systems across EU buildings. Full integration with smart grids and district energy systems, contributing to the net-zero emissions target for buildings by 2050.

IWG 10 - Sustainable and efficient energy use in industry

IP publication date: 21 December 2021

Website: https://setis.ec.europa.eu/working-groups/sustainable-and-efficient-energy-use-industry_en

The IWG 10 plan embeds hydrogen as a transformative vector for achieving a climate-neutral, resource-efficient, and globally competitive industrial sector. In doing so, it fully integrates hydrogen as a central pillar of industrial decarbonisation and a long-term pillar of EU industrial transformation. Hydrogen is addressed both as a fuel substitute and a chemical feedstock, with a strong focus on the chemicals and iron & steel sectors. Hydrogen is also embedded in cross-sector strategies, particularly in enabling technologies, electrification, and circular economy models.

How hydrogen is being addressed:

1. Chemical Industry (Activity 4.2): Hydrogen is essential to chemical processes (e.g., ammonia, methanol, plastics). The plan targets a shift from fossil-derived hydrogen (Steam Methane Reforming) to low-carbon and green hydrogen via:

- Water electrolysis using renewable electricity
- Methane pyrolysis (producing solid carbon)
- Photo-electrocatalysis (PEC) – enabling hydrogen production using sunlight without external power

TRL Target: Advance from TRL 2−5 to TRL 8−9 by 2035

2. Iron & Steel Industry (Activity 5.1): Promotes direct reduction of iron ore using hydrogen instead of coke or coal. Projects like HYBRIT, H2Future, and GrInHy are piloting large-scale hydrogen-based steelmaking.

TRL Target: TRL 7−9 by 2030, with demo plant investment up to € 1−2 billion per site.

3. CO_2 Utilisation (Activity 4.4 & 5.5): Hydrogen is used to convert CO_2 into fuels and chemicals via Power-to-X (e.g., methanol, syngas). In the steel sector, hydrogen reacts with CO_2-rich mill gases in projects like Carbon2Chem and STEELANOL.

4. Enabling System Integration (Activity 2.2): Encourages non-conventional energy sources, including the use of hydrogen and renewable electricity in industrial processes. Focuses on flexible system design to accommodate variable renewables powering electrolysers.

5. Fuel Flexibility in CHP and Hybrid Plants (Activity 1.4): Development of hybrid polygeneration plants (heat, cold, electricity) includes compatibility with low-calorific gases, such as green hydrogen or biogas.

When Hydrogen strategies are implemented (time frame vs implementation focus):

2021−2025: Research, small-scale pilots, and cross-sector coordination; TRL 4−6 for key systems.

2026−2030: Large demonstration plants in iron & steel and chemicals; TRL 7−8+; funding mobilisation.

2031−2050: Full deployment of green hydrogen in industrial clusters; integration with CCUS and circular economy.

IWG 11 – Batteries

IP publication date: 2021

Website: https://setis.ec.europa.eu/working-groups/batteries_en

The IWG 11 Batteries Implementation Plan (2021) under the SET Plan does not directly prioritise hydrogen technologies, but it explicitly supports hydrogen integration in hybrid energy systems. Hydrogen is recognised in the context of battery hybridisation for stationary energy storage systems (ESS), particularly through battolyser concepts − integrated systems that combine batteries and electrolysers, by bridging short- and long-term energy needs. Though the battoliser concept is not offering a standalone functionality, the hydrogen integration reflects the IWG7 vision of flexible, sector-coupled energy systems, offering a pathway to scale green hydrogen using surplus renewable energy stored in batteries. This positions hydrogen as a complementary storage vector for long-duration and sector-coupled applications.

How hydrogen is addressed:

1. Hybrid Battery-Hydrogen Energy Systems:

R&I Activity 3.1 focuses on hybridisation of battery systems for ESS, addressing use cases where no single storage solution suffices. Hydrogen is included for:
a) Seasonal storage;
b) Power-to-gas applications;
c) Sector coupling (e.g., to mobility, chemical industry).
The integration of a battery with an electrolyser (e.g., 'battolyser') provides a hybrid double-use system. It improves battery performance for short-term storage and, when full, produces hydrogen as a storable fuel or feedstock.

2. Enabling Technologies for Hydrogen Integration:

The battolyser is presented as an innovative dual-purpose device: acting as a battery and switching to electrolysis mode once storage is full. These systems benefit from:
a) Shared electrochemical platforms;
b) Modular DC operation;
c) Renewable grid integration.
Applications include industry, mobility, and decentralised renewable microgrids.

3. Strategic Coordination with other IWGs:

Hydrogen-related hybrid systems are to be developed in coordination with IWG 4 (Energy Systems) and IWG 6 (Industry) to align with hydrogen fuel infrastructure and industrial feedstock strategies.

When Hydrogen strategies are implemented (time frame versus implementation focus):

2021−2025: Concept development and R&I on battolysers and hybrid ESS systems. Emphasis on TRL 4–6 for pilot integration.

2026−2030: Demonstration of full-scale battery-electrolyser hybrid systems. Integration into smart grids and industrial energy hubs.

Post-2030: Deployment of large-scale hybrid battery-hydrogen infrastructures in energy-intensive and seasonal applications.

IWG 12 – Renewable fuels and bioenergy

IP publication date: 5 June 2018, with update in 2021

Website: https://setis.ec.europa.eu/working-groups/renewable-fuels-and-bioenergy_en

Hydrogen has a core strategic focus in the IWG 8 Implementation Plan, integrated across renewable fuels, bioenergy, and energy system sectors, aiming at decarbonising transport, industry, and energy systems. It includes both dedicated actions on renewable hydrogen production and cross-cutting integration of hydrogen in bioenergy and synthetic fuels pathways. Hydrogen is recognised as a key enabler of sector coupling and deep decarbonisation, especially through Power-to-Gas/Liquid technologies and biomass-hydrogen hybrid systems. With dedicated funding, technology-specific targets, and integration into Power-to-X and biomass conversion pathways, IWG 8 strongly supports renewable hydrogen as a vector for EU energy transition, climate targets, and transport decarbonisation.

How hydrogen is addressed

1. Dedicated R&I Activity: Renewable Hydrogen Production: Activity #7 focuses on developing and demonstrating hydrogen production from water electrolysis using renewable electricity. Specific targets:
a) Cost reduction to € 4/kg by 2030;
b) Efficiency improvements (targeting ≤48 kWh/kg H_2);
c) CAPEX reduction for alkaline and PEM electrolysers;
d) TLR: Covers TRL 2 to 9, from early R&D to scale-up.

2. Hydrogen for Transport Decarbonisation: Hydrogen is part of Renewable Fuels for Sustainable Transport, alongside biofuels. Applications include:

a) Fuel cell vehicles (FCEVs);
b) Synthetic methane and methanol derived from hydrogen and CO_2;
c) Substitution of fossil H_2 in refineries (short term) and transport fuels (medium to long term).

3. Sector Coupling and Energy System Integration: Hydrogen is seen as a flexibility vector enabling

a) Storage of excess renewable electricity;
b) Cross-sector energy integration (electricity, heating, transport, and industry);
c) Inter-seasonal and large-scale energy storage solutions.

4. Synergies with Biomass and CO_2 Utilisation:

a) Hydrogen enhances biomass gasification output, enabling more efficient production of advanced biofuels;

b) Power-to-X concepts using hydrogen and CO_2 are supported for producing synthetic renewable fuels, including methanol, DME, and aviation fuels.

When hydrogen strategies are implemented (time frame versus implementation focus):

2021−2025: R&D into electrolyser efficiency and hybrid biomass-hydrogen systems. Early demos.

2026−2030: Demonstration and scale-up of hydrogen-powered renewable fuel chains (TRL 7–9).

Post-2030: Full system integration of renewable hydrogen into transport, power, and industrial sectors.

IWG 13 – CCUS

IP publication date: 2021 updated in 2024

Website: https://setis.ec.europa.eu/working-groups/ccs-ccu_en

The IWG 13 CCUS Implementation Plan firmly embeds hydrogen strategies in both supply (low-carbon H_2 from SMR + CCS) and demand (use in Power-to-X and CCU fuels). Hydrogen is addressed primarily in the context of low-carbon hydrogen production from natural gas with CCS and CO_2 utilisation (CCU) for synthetic fuels. The CCUS strategy supports both blue hydrogen (from fossil fuels with CO_2 capture) and green hydrogen indirectly (via Power-to-X pathways). With defined technical pilots, policy alignment, and industrial symbiosis projects, hydrogen is a key decarbonisation tool within the CCUS roadmap, complementing renewable energy pathways and supporting Europe's 2050 climate neutrality goals.

How Hydrogen is addressed:

1. Hydrogen production via natural gas + CCS (Blue Hydrogen): Hydrogen is explicitly named as one of the key applications of CCS technologies. Low-carbon hydrogen production from steam methane reforming (SMR) with CCS is positioned as a commercially available pathway for industrial decarbonisation. By 2030, the plan anticipates a significant portion of captured CO_2 will be sourced from hydrogen production plants

2. Hydrogen in CCU and Synthetic Fuels (Power-to-X): Hydrogen is used in combination with captured CO_2 to produce e-fuels, such as:

a) Green methanol;
b) Synthetic methane;
c) Hydrocarbons for aviation and shipping fuels. Projects like North-C-Methanol (in the North-CCU-Hub) synthesise methanol from local CO_2 and green hydrogen, powered by renewable electricity and a 65 MW electrolyser.

3. Enabling Policies and Infrastructure - Hydrogen is integrated in the broader EU industrial decarbonisation strategy through:

a) Inclusion in the EU Hydrogen Strategy;

b) Complementarity with the Gas Market Decarbonisation Package;
c) Strategic alignment with IPCEIs (Important Projects of Common European Interest) on hydrogen and low-carbon industries.

4. Technical R&I Support:

a) The updated 2024 targets include at least one pilot project (TRL 7–8) by 2030 focused on CO_2 capture technologies enabling low-emission hydrogen production;
b) Projects exploring synergies between CCS and hydrogen, including: Value chain analyses (e.g., H_2 and ammonia), and hydrogen as a carrier in CCU products.

When Hydrogen strategies are implemented (time frame vs implementation focus):

2021−2025: Early pilots of CCS for hydrogen production; planning of hydrogen-inclusive CCU clusters

2026−2030: Delivery of TRL 7–8 pilots for low-emission hydrogen; rollout of CCU-based fuel projects

Post-2030: Commercial-scale hydrogen production and use in CCU products; strategic infrastructure build-out.

IWG 14 – Nuclear safety

IP publication date: April 2021

Website: https://setis.ec.europa.eu/working-groups/nuclear-safety_en

The IWG 10 Nuclear Safety Implementation Plan addresses hydrogen solely as a safety hazard, particularly in the event of severe nuclear accidents. It includes no strategic or technological role for hydrogen in energy production, decarbonisation, or Power-to-X pathways. However, in the context of safety concerns related to hydrogen explosions in nuclear power plants during severe accidents, hydrogen is mentioned explicitly. Therefore, the role of hydrogen is limited to safety risk mitigation, not as a fuel or decarbonisation strategy. This stands in contrast to other SET Plan IWGs where hydrogen is a key decarbonisation pillar.

How hydrogen is addressed:

1. Hydrogen Explosion Risk in Severe Accidents: In R&I Activity 1 ("Plant safety, risk assessment and severe accidents"), hydrogen is listed among the key safety hazards associated with:

a) In-vessel and ex-vessel corium interactions;
b) Containment behaviour during severe accidents.

The implementation plan includes R&D for:

a) Hydrogen explosion modelling;
b) Hydrogen mitigation systems inside reactor containment;
c) Updated Severe Accident Management Guidelines (SAMGs) considering hydrogen risks.

2. No Role for Hydrogen as an Energy Carrier: Unlike other IWGs (e.g., IWG 6, IWG 8), IWG 10 does not include hydrogen as a clean fuel, nor does it discuss hydrogen production (green, blue, or nuclear-assisted), hydrogen use in cogeneration or electrolysis, or hydrogen in Power-to-X systems.

3. Related Research Infrastructure and Guidelines: Tools like IVMR, FASTNET, and NURESIM are cited for severe accident modelling, including hydrogen explosion scenarios. These contribute to:

a) Emergency preparedness;
b) Post-Fukushima safety measures;
c) Containment design improvements.

When Hydrogen Safety is addressed (time frame versus implementation focus):

2021−2025: Modelling hydrogen explosion risks; designing mitigation systems; SAMG updates

2025−Post-2030: Integration of safety improvements in Gen III/IV reactor designs; continued validation of models

3.3 Analysing the consistency, synergies and gaps of the hydrogen-related activities addressed within the IWGs universe

3.3.1 Consistency

The SET Plan IWGs reflect an overall alignment in recognising the strategic value of hydrogen across supply, demand, and system integration dimensions. IWGs such as CST, Energy Systems, Industry, and Bioenergy demonstrate structured approaches incorporating hydrogen within their research and innovation agendas. However, some IWGs lack explicit hydrogen strategies or adopt narrow perspectives. A more consistent and structured alignment could be achieved by promoting best practices in integration—such as dedicated targets and activities − and fostering coordination between them.

Common elements include shared emphasis on renewable and low-carbon hydrogen, electrolysis development, sector integration (e.g., industry, transport), and leveraging EU policy support mechanisms.

Based on this overview, some commonnalities are identified:

- A clear technology focus in line with the SET Plan mission, and references to hydrogen both from the supply and end-use sides, there is an emphasis on the development and deployment of key technologies like electrolysis, which uses renewable electricity to produce hydrogen.
- Sector integration as a policy target is recognised in several IWG-IPs namely on integrating hydrogen into various sectors, including industry, transport, and energy systems, to optimise resources use and reduce emissions.
- A policy support being acknowledged by several IWGs, as they are already benefitting from EU policies and funding programs designed to accelerate the adoption of clean energy technologies.

3.3.2 Potential synergies

Overall, along the different IWG frameworks and related value chains, there are clear evidences that hydrogen technologies offer an opportunity pathway, at different dimensions, to add value to the Implementation Working Groups (IWGs). Hydrogen presents multiple synergies across the SET Plan IWGs, which include:

- Driving cross-sector innovation and market diffusion of renewable technologies;
- Acting as a system integrator and storage vector supporting energy mix diversification and CO_2 utilisation;
- Facilitating cross-border collaboration for infrastructure and supply security;
- Creating shared frameworks for regulation, safety, and certification;
- Supporting education and reskilling aligned with emerging hydrogen markets;

- Enabling sustainability goals through bio-based and renewable hydrogen hybrid value chains.

These synergies underscore the potential for coordinated action across IWGs and reinforce the case for systemic planning.

A synergy analysis on the role of Hydrogen in the framework of selected IWGs is provided on Table 1.

Table 1: Synergy analysis on the role of Hydrogen in the framwork of selected IWGs.

IWG	Topic	Synergy point
PV	Complementary Roles in Decarbonisation	Hydrogen acts as a flexible load and storage medium for PV, helping stabilise variable generation and decouple production from immediate demand.
	Integration in Hybrid Energy Systems	Hydrogen enables sector coupling, particularly where electrification is less feasible (e.g., high-temperature industry, heavy transport), allowing PV energy to reach new sectors.
	Advancing Power-to-X (P2X) and System Flexibility	Hydrogen broadens the value chain and potential uses of PV, driving investment and demand for both technologies simultaneously.
	Shared R&I and Digitalisation Priorities	Joint R&D (e.g., digitally-optimised PV-electrolyser systems) enhances both cost efficiency and deployment speed.
	European Strategic Autonomy and Industrial Policy	Co-deployment of PV and hydrogen supports European industrial leadership and job creation across integrated value chains.
Wind	Offshore Wind + Hydrogen: Systemic Integration	Hydrogen enhances offshore wind value by providing energy storage, transport flexibility, and sector coupling, especially for hard-to-electrify sectors.
	Power-to-X (P2X) and Green Hydrogen Pathways	P2X integration enables wind energy to extend its decarbonisation reach beyond electricity, into transport, chemicals, and heating.
	Shared Infrastructure and Market Synergies	Combined planning of wind and hydrogen infrastructure reduces costs, accelerates deployment, and minimises spatial conflicts.
	Innovation and Digitalisation	Shared innovation priorities facilitate multi-vector system design, enhancing resilience and optimisation.
	EU Strategic Objectives and Energy Sovereignty	Joint hydrogen-wind strategies reinforce the EU's strategic autonomy and supply chain leadership.
OES	Hybrid Offshore Energy Systems	Offshore-produced hydrogen allows wave and tidal energy to be captured and stored when direct transmission is not feasible, enabling flexible energy dispatch and sector coupling (e.g., fuels, chemicals, industry).
	Power-to-X and Energy Storage	Ocean energy can become a reliable feedstock source for green hydrogen, enhancing the viability of Power-to-X strategies aligned with the EU Green Deal.
	Infrastructure Co-Use	Shared platforms for hydrogen electrolysis and ocean energy converters can reduce capital and operational costs while accelerating deployment timelines.
	R&I Collaboration	Collaborative R&D between ocean energy and hydrogen technologies (e.g., offshore electrolysis, novel moorings, shared PTO systems) can de-risk investment and attract cross-sector funding.
	Strategic Fit with EU Policy	Joint planning for hydrogen and ocean energy enhances European technological leadership and supports industrial ecosystems in coastal regions.

Table 1 - (cont).

IWG	Topic	Synergy point
Energy Systems	Hydrogen as a Flexibility Vector in Integrated Energy Systems	Hydrogen extends system flexibility beyond batteries and demand response, particularly via Power-to-Gas (PtG) and Power-to-Liquid (PtL) technologies, helping balance generation and demand across time scales.
	Sector Coupling and Cross-Vector Integration	Hydrogen enhances the energy system's capability to coordinate multiple vectors, aligning with IWG4's goal of an optimised, interconnected energy network.
	Role in Smart Grids and Digital Platforms	Hydrogen adds a dynamic controllable resource to smart energy systems, especially in hybrid AC/DC grid environments and multi-vector platforms.
	Power-to-X and Resilience	Hydrogen-based Power-to-X solutions align with IWG4's targets of decentralised resilience and backup for local energy networks.
	Innovation, Market Design, and Regulation	Joint innovation in regulatory sandboxes and interoperability standards between IWG4 and hydrogen IWG could accelerate hydrogen's role in integrated energy markets.
EE-Industry	Hydrogen as an Enabling Decarbonisation Technology	Hydrogen is central to industrial energy efficiency where electrification is unfeasible, supporting deep emissions cuts and aligning with the EU Green Deal targets.
	Sector-Specific Hydrogen Applications	These targeted R&I activities integrate hydrogen deeply into industrial transformation pathways, with TRL growth and demonstration targets outlined.
	System Integration and Industrial Symbiosis	Hydrogen contributes to cross-sector system integration and enhances industrial resilience through distributed energy vectors.
	Circular Economy and Resource Efficiency	Hydrogen integrates into circular value chains, enabling co-processing and valorisation of waste carbon and energy.
	Cross-Cutting R&I and Market Uptake Synergies	Hydrogen innovation benefits from shared technology platforms, simulation tools, and policy alignment across industrial sectors.
Bioenergy and Renewable Fuels	Hydrogen as a Bridge Between Bioenergy and Renewable Electricity	Hydrogen serves as a cross-cutting integrator between electricity, bioenergy, and fuels, helping to maximise resource utilisation and sector coupling.
	Power-to-X Synergies: Power-to-Gas and Power-to-Liquid	Hydrogen expands the portfolio of sustainable fuels and reinforces the circular economy by enhancing CO_2 reuse and energy storage capacity.
	Decarbonising Transport Through Renewable Hydrogen	Hydrogen accelerates the shift from fossil to renewable fuels in heavy-duty transport, supporting EU climate targets for 2030 and beyond.
	Cost and Efficiency Targets Aligned with Biofuels	Hydrogen and biofuels share common R&I drivers, enabling collaboration in areas such as catalyst development, hybrid systems, and process integration.
	Shared Infrastructure and Deployment Barriers	A coordinated policy framework can address overlapping infrastructure and investment needs, particularly for distribution and end-use integration.
CCUS	Enabling Low-Carbon Hydrogen via CCUS	CCUS enables scalable, low-carbon hydrogen as a transitional solution, complementing green hydrogen and providing a reliable route for hard-to-abate industrial sectors.
	Shared Infrastructure for Industrial Decarbonisation	Co-locating hydrogen and CCUS infrastructure reduces cost, enhances efficiency, and supports the creation of industrial carbon hubs.
	CCU Synergies: Hydrogen + Captured CO_2 → Synthetic Fuels & Chemicals	Hydrogen + CCU pathways unlock circular carbon economies, enabling de-fossilisation of sectors that depend on carbon-based feedstocks.
	Enabling Negative Emissions with Bio-CCS + Hydrogen	Synergising hydrogen with negative emission technologies accelerates achievement of net-zero targets and supports climate resilience.
	Strategic Alignment with Hydrogen and Industrial IWGs	Hydrogen is a natural convergence point between the CCUS, Energy Systems, Industry, and Bioenergy IWGs, warranting cross-IWG coordination.

3.3.3 Gaps

Several strategic gaps persist:

- Infrastructure: Limited availability of hydrogen pipelines, refuelling stations, and storage impedes scale-up.
- Cost Competitiveness: High production costs for green hydrogen require further technological R&D and scaling.
- Regulatory Fragmentation: Lack of harmonised frameworks hinders integration across Member States.
- Technology Integration: Need for optimised hybrid systems combining hydrogen with RES and storage.
- R&I Continuity: Sustained investment in efficiency, cost reduction, and demonstration projects is essential.
- Market Demand & Awareness: Broader awareness, professional training, and incentives for uptake are lacking.
- Cross-Sector Collaboration: Weak integration across industrial, transport, and energy sectors limits system-level benefits.

A Task Force within the hydrogen IWG could help address these gaps with a structured and integrated approach to targets and activities, tailored to national contexts.

A gap analysis on the role of Hydrogen in the framework of selected IWGs is provided on Table 2.

Table 2 - Gap analysis on the role of Hydrogen in the framework of selected IWGs.

IWG	Topic	Gap
PV	Integration Potential Recognised but Underdeveloped	The IP lacks structured, standalone activities or KPIs focused on the role of PV in renewable hydrogen production or Power-to-X pathways.
	Missing Focus on Direct PV-to-Hydrogen Applications	Absence of focus on electrolyser coupling, system design, cost modelling, and interoperability for PV-based hydrogen generation.
	Insufficient Link to Other SET Plan IWGs	Lack of cross-IWG collaboration mechanisms or joint R&I priorities related to hydrogen undermines systemic energy integration.
	Technology, Policy, and Market Aspects of Hydrogen Overlooked	Hydrogen's role is treated as an indirect add-on, not as a core innovation stream in PV's contribution to decarbonisation.
	Missed Opportunity in Industrial and Transport Decarbonisation	No strategic vision for PV-enabled hydrogen in hard-to-abate sectors like heavy-duty transport or ammonia/steel production.
Wind	Role Recognised but Not Operationalised	Hydrogen is treated as a peripheral element rather than a core, integrated component of wind energy system design and deployment.
	No Dedicated Hydrogen-Wind System Innovation Actions	Absence of dedicated innovation tracks for integrating hydrogen production with wind (especially offshore) limits coordinated development and demonstration.
	Infrastructure and Value Chain Planning Missing	Lack of infrastructure foresight and value chain mapping weakens hydrogen's practical scalability alongside wind power.
	Missed Cross-IWG Coordination Opportunities	Lack of cross-IWG governance or integration mechanisms limits the systemic co-benefits of wind-hydrogen integration.
	Market, Regulatory, and Societal Considerations Underdeveloped	Missing market design, policy, and social readiness dimensions restrict the commercialisation potential of wind-based hydrogen solutions.
OES	Recognition of Hybrid Potential but Lacks Concrete Hydrogen Integration	The plan lacks a dedicated framework or roadmap for using ocean energy (especially wave/tidal) for green hydrogen production.
	No R&I or Demonstration Actions for Ocean-to-Hydrogen Systems	Absence of R&I activities focused on ocean-powered electrolysis, integration with marine infrastructure, or hybrid fuel production.
	Missed Opportunity in Decentralised and Island Energy Systems	Lacks strategic alignment with hydrogen's value for energy autonomy in off-grid island or remote communities powered by ocean energy.
	No Connection to EU Hydrogen Strategies or SET Plan Hydrogen IWG	There is no linkage to broader EU hydrogen initiatives, missing cross-sector coordination and funding opportunities.
	Overlooked Infrastructure and Techno-Economic Planning	No planning for hydrogen-related infrastructure or value chains within ocean energy deployments.

Table 2 - (cont).

IWG	Topic	Gap
Energy Systems	Hydrogen Implicitly Acknowledged but Not Centralised	Hydrogen is not explicitly recognised as a strategic pillar in achieving system flexibility and resilience − despite its growing importance in sector coupling.
	No Dedicated R&I Actions or Innovation Fiches on Hydrogen	Absence of hydrogen-focused innovation activities or KPIs prevents targeted R&D and undermines opportunities for scaling hydrogen within smart energy systems.
	Limited Cross-IWG Coordination	Cross-sector and cross-IWG collaboration is missing, limiting the system-level optimisation hydrogen could enable.
	Infrastructure, Market Design, and Digital Integration Gaps	Hydrogen is excluded from digital, infrastructural, and market innovation frameworks, restricting its integration into future-proof, smart energy systems.
	Missed Role in Local and Regional Energy Systems	Missed opportunity to use hydrogen in decentralised contexts (e.g., regional PtG hubs, island energy autonomy, seasonal storage).
EE-Industry	Hydrogen is Recognised but Narrowly Focused	There is no system-wide hydrogen strategy connecting production, storage, infrastructure, and multi-sectoral uses in energy-intensive industries.
	Absence of Hydrogen Integration in Cross-Sector Activities	Missed opportunity to include hydrogen in energy integration, thermal loops, and smart energy management systems across sectors.
	Lack of Strategic Linkages to SET Plan Hydrogen IWG and Other IPs	Hydrogen activities are sector-isolated and do not benefit from coordinated R&I, shared funding schemes, or joint infrastructure planning.
	No Hydrogen Infrastructure and Value Chain Development	No foresight or planning for hydrogen supply chains, infrastructure, or circular economy integration (e.g., reusing CO_2 with H_2 for e-fuels).
	Policy, Certification, and Market Aspects Underdeveloped	Absence of regulatory and market mechanisms hinder large-scale adoption of hydrogen in industrial decarbonisation.
Bioenergy and Renewable Fuels	Hydrogen is Included, But Not Fully Developed	The IP lacks a comprehensive strategy for hydrogen across the entire value chain, including infrastructure, end-use sectors, and integration with other renewable fuels and energy systems.
	Hydrogen Use Cases in Transport Are Not Fully Explored	There is no clear deployment roadmap or prioritisation of hydrogen applications across transport sectors, limiting its translation into real-world impacts.
	Lack of Cross-Sectoral System Integration	The plan misses opportunities to showcase hydrogen's role in sector coupling and grid flexibility, especially when paired with variable renewables.
	Weak Coordination with Other IWGs and EU Strategies	Hydrogen's inclusion in the plan is siloed, lacking alignment with broader EU initiatives and inter-IWG R&I coordination.
	Infrastructure and Market Aspects Are Underdeveloped	The absence of planning for hydrogen infrastructure and market design creates bottlenecks for scaling production and deployment.
CCUS	Recognition of Hydrogen–CCUS Synergy	Hydrogen is mentioned only as a sub-component of capture technology testing, without a dedicated strategic focus or expanded pathway for integration across sectors.
	No Comprehensive Hydrogen-CCUS Roadmap	Absence of a joint development strategy connecting hydrogen demand with CCUS infrastructure and industrial cluster deployment.
	No Explicit Role for Blue Hydrogen in Industrial Transformation	Missed opportunity to embed blue hydrogen pathways within the IP's broader industrial and cluster-based decarbonisation strategy.
	No Cost Benchmarks or Deployment Targets for Hydrogen	Lack of quantitative planning and techno-economic analysis on hydrogen output, storage, or distribution from CCUS-enabled sources.
	No Cross-IWG or EU Strategy Alignment on Hydrogen	Hydrogen and CCUS efforts are insufficiently linked across IWGs, hindering systemic planning and investment coordination.

4. Conclusion and recommended steps

Hydrogen is a critical cross-cutting enabler in Europe's clean energy transition. Its integration across SET Plan IWGs is growing but remains fragmented. Strengthening coordination, improving regulatory coherence, and investing in infrastructure and innovation are key priorities.

The SET Plan hydrogen IWG will have a critical role on that coordination of R&I efforts, within the hydrogen-related IWG cooperation, where different energy technology paths must play a key role in the frame of energy supply-demand equation, from discrete applications to integrated and sustainable combined solutions, including hybrid technologies and systems, storage at different levels, and the transformative strategies 'power to X'.

Within the IWGs universe represented by supply and demand sides, and following to having addressed consistency, potential synergies and existing gaps regarding hydrogen-related activities therein, it could be asked what steps should be given next to define new activities to reinforce the desired cooperation in the SET Plan ecosystem. Three new activities are proposed to be included in the hydrogen IWG:

- Hybrid Offshore Deployment: Collaborate with Wind and Ocean IWGs to develop offshore hydrogen production hubs using hybrid renewable systems.
- Systemic Power-to-X Projects: Launch projects combining electrolysis and CCU with system integration tailored to Member States' renewable capacity.
- Cross-IWG Task Force: Establish a temporary, action-oriented working group under the hydrogen IWG to align hydrogen strategies across IWGs, prioritize case studies, and address integration challenges collaboratively.

These steps aim to foster a coherent, systemic, and forward-looking hydrogen strategy aligned with the EU's climate goals and the SET Plan's mission.

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Annex

Examples of citations in each IWG-IP, with a focus on Hydrogen

In the frame of the IWG-SET Plan portfolio, to answer the question “when and how is hydrogen being addressed in each IWG”, fourteen IWGs have been addressed.

IWG 1 - Solar photovoltaics

IP publication date: July 2023

"Electricity produced from renewable energy sources... enables production of renewable fuels and feedstocks (such as hydrogen or hydrocarbons, when combined with carbon from sustainable sources)."
— p.4: Highlights the role of PV in powering hydrogen production.

"A range of new PV system types ... include floating systems ... advanced power management, battery storage and hydrogen production."
— p.5: Shows integration of hydrogen production in new PV applications.

"Hybrid systems including demand flexibility (PV + Wind + Hydro with embedded storage + batteries + green hydrogen/fuel cells or gas turbines, etc.)."
— p.14: Presents hydrogen as a key element in hybrid energy systems.

"The objective of this roadmap is to develop systems ... where PV, as an integral contributor, can offer hybrid solutions ... including green hydrogen."
— p.14: Emphasizes green hydrogen’s value in grid-integrated PV systems.

"PV should be looked at as active contributor ... utilizing dependable forecasting tools ... for systems including green hydrogen and fuel cells."
— p.14: Suggests PV-hydrogen synergy for reliable grid integration.

“R&I Activity N.4 – Smart Energy System Integration of Photovoltaics ... Objectives c) Hybrid systems including demand flexibility (PV+Wind+ Hydro with embedded storage + batteries + green hydrogen/ fuel cells or gas turbines, etc)”.

— p.28: Identifies green hydrogen in the IP as a strategic energy vector in the EU integrated energy transition.

IWG 2 - Concentrated solar thermal technologies

IP publication date: February 2023

Pg 4: “CST has also great potential in harder-to-decarbonise areas, in the mid/long term, by developing new “green” fuels (“Green” hydrogen derivatives), allowing an efficient carbon-free operation at constant load and at high capacity factor.”

Pg 8: “Hydrogen and SynFuel production by means of CST-Hybrid plants, as considered e.g., in the EU funded projects HYDROSOL-PLANT10 and SUN-TO-LIQUID11, can provide cost-effectively the energy for hydrogen production around the clock. Higher conversion efficiency levels are achievable, as the electrolysis system can run under constant load. It can thus be coupled to the (today) cheaper alkaline electrolysis technique (AEL) without any disadvantages. The high utilisation not only allows significantly smaller electrolysers to be used, but also makes much more efficient use of the necessary pipeline capacities. Initial estimates show that H2 generation costs can be significantly reduced compared to wind or PV-powered PEM systems. Hydrogen production costs can be further reduced if high-temperature electrolysis (HTEL) is coupled with these systems. In addition to electricity, up to 20% of the energy can be supplied by high-temperature heat (200 °C to 800°C), which can be produced by concentrated solar thermal plants at a low cost. In this way, more hydrogen can be produced per year by the same power plant, while reducing the operating costs. "

Pg 13: "Proposed new strategic targets: #5: Demonstration of 24/7 economically viable solar thermal baseload production of green hydrogen and other solar fuels by 2030."

Pg 14: "Achievement of Strategic Targets...System integration tailored to MS needs (incl. solar fuels: e.g., hydrogen; ind. process heat; dispatchable clean electricity – long term storage)"

Pg 26: Annex I – R&I Activities: #6 "Thermochemical production of solar fuels and hydrogen"

Pg 28-29: Expected deliverables: ... "Analysis of the hydrogen formation and degradation products"

Pg 43: "AREA OF ACTIVITY nº 6: THERMOCHEMICAL PRODUCTION OF SOLAR FUELS AND HYDROGEN"

Pg 44: R&I Activity 6.2: Solar fuels from carbon neutral feedstocks - "Description: "Renewable energy sources (RES) can reduce the dependency on fossil fuels that cause pollutant gas emission and climate change. However, along the way towards a completely "green" future energy system, "hybrid" transitional technologies are needed, involving the coupling of the innovative principles and characteristics of RES with the high-power density, ease of transportation/storage and long-term development that have established liquid hydrocarbon fuels (like e.g., gasoline, diesel, kerosene, or methanol) at a privileged position in our current energy mix. Solar thermochemical processes make use of concentrated solar radiation as the energy source of process heat to drive endothermic reactions. The current state-of-the-art shows that studies of biomass used as feedstock for syngas/hydrogen production have been developed in the past, based on well-known chemical reactions such as the "water gas shift" reaction and the Fischer-Tropsch process ..."

Pg 49: "The combination of a CSP and PV plant is beneficial when reliable power production at low cost is required. Many studies and first plants follow this concept. The concept has limitations when it comes to periods of several days with low sunshine or strong seasonal variation in solar resource. In order to reach fully reliable electricity production at the grid connection point CSP-PV units will be accomplished by backup energy sources. Such a full hybrid can deliver electricity 24/7 around the year. Renewable energy resources are the preferred backup option, although efficient utilization of fossil fuels might be suitable as a mid-term solution. Adding this third element to the hybrid plant, the optimization gets more complex since local availability of backup energy resources enters the field. Produced electricity can either be used in the grid or in large industrial plants with significant electricity and/or heat demand. The production of renewable hydrogen could be one of these customers (e.g., energy for electrolysers that required steam and electricity). The activity heads for the general investigation of the reliable hybrid system in general, providing tools and input data for analysis."

IWG 3 - Wind energy

IP publication date: March 2022

Pg.13: "Energy demand management and Energy System Integration (hydrogen, power to gas).

(…)

Infrastructure and grid development, including research into HVDC technologies, and offshore conversion, storage and transport of other energy carriers (e.g., hydrogen) will be key to the successful integration of offshore wind."

Pg. 14:"2. Value of wind - Cost reductions in wind power must go hand-in-hand with a focus on increasing the value of wind. Energy system integration and sector coupling is key to this, as it enables greater scale and flexibility in the market for green electricity. Power-to-X, including the potential for off-grid production of hydrogen and the recent ambitions for energy islands (e.g., hub and spoke), should be mentioned here. In the offshore environment, synergies with the reorienting oil and gas sector, other offshore renewables and cooperation with blue economy sectors have to be found to utilise both infrastructure and knowhow."

Pg. 19:"Another specific focus is the development of off-grid hydrogen-producing turbines, which it is estimated will have a strong potential for cost savings when used in connection with the planned energy islands."

Pg. 24:Research and develop offshore conversion, storage and transport capabilities for other energy carriers such as hydrogen.

Pg. 32:"3. Develop disruptive technologies

Investigating game changers and new technology solutions in rotor, drive train, support structures and electrical system, including technology developments in other disciplines and completely different concepts like large low induction rotors and high altitude wind power or integrated Hydrogen conversion."

Pg. 34:"3. Sustainable hybrid solutions, storage, and power to X

Combining offshore wind with other renewables, using complementary generation patterns, contributes to improving the security of supply and lowering grid integration costs. Onshore and offshore power-to-X (e.g., to hydrogen), storage and transport are essential to realise the required generation flexibility and security of supply, both in the short term as well as seasonally. Furthermore, integration of these solutions into offshore wind farms is required to facilitate their large-scale and economic integration, including off-grid approaches, i.e., using gas or other alternative energy carriers.

(...) Validate integration of these solutions in offshore wind farms, including off-grid approaches, e.g., isolated offshore wind farms producing hydrogen.

(...) Validated energy system models for assessing alternative developments of offshore energy transmission systems, including electricity and hydrogen."

IWG 4 - Geothermal energy

IP publication date: December 2023

No direct references to hydrogen on this IP.

Pg. 6: "Many sustainable heat supply systems are characterised by high CAPEX and low OPEX. Therefore, an installed capacity tailored to peak demand is not cost effective, while extending the annual operation period is advantageous for meeting energy needs and decarbonisation goals, while reducing levelized cost of energy (LCOE). Optimal utilisation of sustainable heat requires storing large amounts of heat to account for seasonal supply and demand fluctuations."

Pg 10: Enhancement of the performance of power plants through the optimization of the processes and application of innovative environmentally friendly solutions and materials which will increase reliability, availability, and grid-balancing flexibility of the geothermal power systems.

IWG 5 - Ocean energy

IP publication date: October 2021

Pg. 23: InnovFin-EDP12 (Energy Demo Projects) enables the EIB to finance innovative first-of-a-kind-demonstration projects in the fields of renewable energy, sustainable hydrogen and fuel cells. In projects focusing on hydrogen production/distribution, the hydrogen should come primarily from renewable sources. The projects may include first-of-a-kind power, heat and/or fuel production plants and first-of-a-kind manufacturing plants.

Pg. 29: Action 1.2 Demonstration of ocean energy pilot farms …

Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively

Key actions include: …" Integration of storage technologies or combination with other uses such as hydrogen production, desalination or other offshore renewable sources. "

IWG 6 - Direct current technologies (*): LVDC Subgroup – low voltage direct current systems

IP publication date: September 2024

Pg.3: Executive Summary

1.1. Why is low-voltage direct-current (LVDC) important now? Many low/medium-voltage applications already use DC internally:

- Photovoltaics produce DC directly.
- Wind turbines have a DC circuit internally that converts the rotation of the blades to the fixed Alternating Current (AC) grid frequency.
- Battery storage systems are DC, as are electric cars.
- Electrolysis needs DC, e.g., to produce "green hydrogen".
- Many loads are DC or use DC internally: − LED lighting is directly DC-powered. − IT equipment runs on DC. − Motors, in industry or in residential appliances, are controlled by variable speed drives, with frequency converters that have an internal DC link. − Heating and cooling systems, like heat pumps, use DC or are ready for DC supply.

(*) Obs. The Implementation Plan for the HVDC subgroup, published in 2021, was confirmed not to provide any hydrogen references.

IWG 7 - Positive energy districts

IP publication date: June 2018 updated in 2021

Pg. 2: Executive Summary: No references to hydrogen, nor to other specific energy technologies as apparently the main intention is to avoid PEDs being too prescriptive.

"…developed an integrative approach to Positive Energy Districts (PED) including technological, spatial, regulatory, financial, legal, environmental, social and economic perspectives. PEDs will be developed in an open innovation framework, driven by cities in cooperation with industry and investors, research and citizen organisations. In this context, a PED is seen as a district with annual net zero energy import and net zero CO2 emissions, working towards an annual local surplus production of renewable energy."

IWG 8 - Energy systems

IP publication date: October 2021

Pg16: Smart energy system integration. From a technical perspective, new solutions must optimise the integration of renewable energy, provide infrastructure that can host a large number of distributed generation units, increase flexibility by efficiently integrating different energy carriers as well as utilising (local) storage, supply side coordination and demand side response.

Pg 21: This also includes fuel flexibility (capacity to switch between renewable-based fuel as well as conventional, including different rates of mixtures, reacting to availabilities of carbon-neutral synthetic fuels like synthetic methanol or methane, hydrogen, ammonia, biomass derived from waste, etc.).

Pg45: Challenge: To enable the integration of renewable energy sources at the penetration rate considered in the fully decarbonised scenarios and to satisfy the energy demand with renewable sources also during winter the electricity system cannot evolve in isolation. Integrated Energy Systems overcoming the silos among energy vectors need to be developed. New architectures encompassing the entire energy system will be needed addressing and optimising the synergies among all energy vectors (i.e., electricity, gas, heating/cooling, mobility, hydrogen, etc.).

Pg.46: Citizen energy communities, with energy management systems for local multi-energy streams operation, including electrical-storage, P2x generation and storage, and x2P (including CHP based on hydrogen and fuel-cells).

Pg 48: LONG-TERM planning towards a decarbonised integrated energy system requires the upgrading and smartening of planning procedures to include flexible systems coupling of electricity with other energy vectors such as gas (synergies of gas network operation in support to electricity flexibility, cost reduction of Power-to-Gas), heating and cooling (in the presence of district heating networks), liquids, including transformation processes PtX, XtP.

Pg. 56: PtX solutions enabling DER entities – connected to distribution grids – to become more and more active, allowing new service portfolio for the whole energy system beyond electricity.

Pg.57: Improved combustion systems for CO2-neutral fuels (including renewable “green” hydrogen/ natural gas mixtures) will be demonstrated, with particular attention to efficiency and reliability, as well as faster thermal generation ramping down and up and start-up/shut down.

Pg. 58: Development of highly efficient, integrated cogeneration units of varying size with decoupled use of heat & power, powered by hydrogen, biomass and biofuels.

Pg. 59: The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. Storage such as batteries appear as the more accessible technological option to guarantee to RES generation the needed flexibility; on the other side, PtX technologies are emerging as a promising option, allowing as well the desired integration with other “energy-related” networks, i.e., the gas and the heating/cooling ones.

Storage systems and Energy conversion technologies are key factors in ensuring a high degree of flexibility to the energy system as a whole, as well as guaranteeing the deep de-carbonization requested. Storage still lacks a proper valorisation in many scenarios and context, thus limiting the unlocking of its full potential.

PtX technologies need extensive R&I activities, followed by the suitable demonstration at different scales.

Storage systems including batteries will be developed to ensure flexibility and balancing services at all the network levels, at the same time contributing both to the optimal operation of power generation (conventional, fed by CO2-neutral fuels, and Renewable) and to the DSM (Demand Side Management) at the level of final customers. PtX technologies (the most promising appears to be the Power-to-gas one) will increase their role and penetration into the energy system. Potential and limits of these technologies need to be carefully assessed, via simulation and demonstration activities; regulatory issues must also be investigated. There is a strong need to assess the costs/ benefits ratio of PtX technologies and to understand their effective integration in real scenarios, taking into account realistic synergies with gas, heating/cooling and water networks.

Pg. 60: “... and models, to determine optimal size, location and utilisation of storage and PtX technologies and plants, is a pre-condition to ensure their effective deployment.”

Demonstration activities will be undertaken on LONG-TERM energy storage systems (from advanced pumping hydro to other alternative solutions as PtX), solutions for district heating and cooling as sector integration for flexible operation at different energy levels and carriers, solutions for industry and industrial clusters for integrated flexible generation, consumption and storage.

Pg 81: “6.6 Integrated industrial energy systems. Challenge − in order to establish carbon-neutrality in industrial (energy) systems, renewable-based electrification of industrial processes is an important innovation challenge. All forms of renewable power production, e.g., on- and offshore wind, ocean energy, hydropower and solar power, require research and development activities to improve their technological performance, to tackle different aspects of system integration and to lower the costs.

Another important task is to introduce, develop and deploy advanced renewable heating and cooling solutions in the industries. The full utilization of their potential calls for essential developments in system integration and sector coupling concepts as well as new innovative combined solutions and use of digital energy management systems.

Description of RD&I or Programming Activities: 6. Develop and demonstrate system integration and sector coupling concepts for local symbioses of industrial and municipal energy”

IWG 9 - Energy efficiency in buildings

IP publication date: September 2024

Pg. 17: Innovation targets

Target 5.2-T3 Micro CHP/CCHP

- Integration of highly flexible CCHP systems with heat storage, heat pumps and renewable heat sources with the aim of reducing annual fuel consumption
- Development of CCHP technologies running on renewable gases (hydrogen, ammonia, methanol, synthetic gas, etc.) with comparable performances as running on natural gas
- Development of CCHP solutions with post combustion treatments to reduce emissions by >50% and keeping operational flexibility

Pg. 51: Activity fiche No. 6

Ref. Target 5.2-T3 Micro: CHP/CCHP

- Integration of highly flexible CCHP systems with heat storage, heat pumps and renewable heat sources with the aim of reducing annual fuel consumption
- Development of CCHP technologies running on renewable gases (hydrogen, ammonia, methanol, synthetic gas, etc.) with comparable performances as running on natural gas

R&I Activities:

a) **Broad spectrum development and experimentation for hydrogen combustion system** (from TRL6 to TRL7, time frame 2025 - 2028). Develop high flexible dual fuel (hydrogen/natural gas) combustion systems for microturbines to burn any concentration of mixtures of hydrogen in natural gas from 0% hydrogen (100% natural gas) to 100% hydrogen. Review state of the art, simulation and modelling, hydrogen / natural gas combustion chamber and fuel system design, combustion system prototype detailed design and procurement, combustion system prototype testing, data processing and emissions evaluation, enhanced design.
b) **High flexibility development and experimentation for methanol and hydrogen combustion systems** (from TRL6 to TRL7, time frame 2025 - 2028). From combustion systems state of the art define flexible operating concepts (for different use context) able to cope with high variability of trigeneration demand, minimizing emissions. Testing transient operations, minimum load and part loads, assess capabilities and emissions in a wide spectrum of cases.
c) **Short term impact** (by 2030):
By completion of several demonstration projects, reach a proven technological and economic viability for the application of Micro CCHP to buildings based on renewable fuels in distributed energy applications.
The deployment of microgeneration systems powered by green hydrogen or other green fuels will contribute to significant reductions in greenhouse gas emissions from the building sector, meeting the EU's target of reducing emissions by at least 55% by 2030 compared to 1990 levels.
In regions facing electrical grid congestion, microgeneration systems offer a reliable alternative to traditional heating and cooling solutions. By generating energy on-site, these systems can alleviate stress on the grid, enhancing overall grid stability and resilience, which is crucial for accommodating the increasing share of renewable energy sources.

The increased efficiency and reduced energy costs associated with microgeneration systems can drive economic benefits for building owners and occupants. This supports the SET PLAN's objective of fostering a competitive European energy market that delivers affordable energy to consumers.

d) Long term (by 2050):

By 2050, the widespread implementation of microgeneration systems can support the complete decarbonization of the building sector. Utilizing hydrogen and other green fuels aligns with the EU's vision of achieving net-zero greenhouse gas emissions by 2050. These systems will reduce reliance on fossil fuels and significantly cut emissions from heating and cooling. The widespread implementation will also support the exploitation of economies of scale and reach cost reduction objectives for equipment and installation, and support achieving the carbon-neutrality targets for buildings.

Microgeneration systems can be seamlessly integrated into smart grids and advanced energy management systems, enhancing the overall efficiency and flexibility of energy networks. This integration will support the SET PLAN's goal of creating a smart, efficient, and sustainable energy system across Europe.

Pg. 53:

Expected Deliverables:

Demonstration of ultra-low emission combustor design for hydrogen and methanol and its endurance behaviour

Definition of techno-economic and environmental key performance indicators (KPIs) for characterising and comparing CHP-CCHP systems with traditional energy production systems (e.g., boilers, heat pumps, etc. associated with electricity from the grid)

Pg. 53-54: Planned project 1: Demonstration of installation with Combined Heat and Cooling with microgasturbine fed with green hydrogen (potentially selecting a location nearby an available green hydrogen infrastructure) in the temperature-controlled fruit stevedoring application.

This particular application will use both heat and cooling loads at the same time without a determined seasonality. The aim is to reduce the carbon footprint of the logistics of the fruit distribution chain, with no additional demand on local electrical distribution grid. Object of the demonstration is to ascertain the endurance reliability of the microgasturbine system while working with hydrogen fuel. Other objectives will include assessment on carbon savings, overall efficiency, running costs, need of optimisation/addition of heat/cool storage. Sizing of the potential application, electrical power 100 kW, cooling power 105 kW, heat power 165 kW. Start: TRL8, end of project: TRL9.

Pg. 71: Activity Fiche No. 9

Target 5.2-T3 Micro CHP/CCHP:

Integration of highly flexible CCHP systems with heat storage, heat pumps and renewable heat sources with the aim of reducing annual fuel consumption.

Development of CCHP technologies running on renewable gases (hydrogen, ammonia, methanol, synthetic gas, etc.) with comparable performances as running on natural gas.

Development of CCHP solutions with post combustion treatments to reduce emissions by >50% and keeping operational flexibility.

IWG 10 - Sustainable and efficient energy use in industry

IP publication date: 21 December 2021

Rationale for the selection of industrial sectors: Potential to contribute to a wider energy efficiency and decarbonisation scope □ 6 Thematic Groups (2 cross cutting) □ priority R&I activities
TGs: H&C, Systems, Cement, Chemicals, Iron & Steel, Pulp & Paper.

System integration activity fiches (pg 48): Thematic area providing enabling technology(ies) seen as essential to support sector and technology progress towards an IP Action aims (e.g., the use of low-C hydrogen to decarbonise certain industrial processes).
Pg 12-13: CO2 emission reduction from energy use, and particularly in process emissions, carbon capture and use (where 'use' = mineralization, conversion into fuels, chemicals, polymers, materials).
Pg 25: Table with TG targets on activity by 2025, 2030 and 2050.
Pg 33: Energy emissions and process emissions can be transformed into chemicals/fuels/ minerals to reduce some inevitable CO2 emissions and by making use of excess renewable energy streams.
Pg51: Activity 2.2- Nonconventional energy sources in process industry including carbon capture and use

Cements: Manufacturing process □ The rotary kiln □ Raw materials are heated up and decarbonization of the limestone takes place □ Chemical reaction: Calcination (Obs: Causes 60−65% of cement manufacturing emissions)
Pg 27: Table with TG targets on activity by 2025, 2030 and 2050

Chemicals activity fiches (pg 65): …
Activity 4.2 – Integrated production of hydrogen with low CO2 emissions (pg. 17; pg 67)
Hydrogen production with low environmental footprint at competitive cost: In addition to water electrolysis, other technologies are under development for a cost competitive production of hydrogen: methane pyrolysis (from TRL 4-5 to 9 by 2035) or photo-electrocatalysis (from TRL 2-4 to 8-9 by 2035).
R&I (pg67): Technical priorities include optimisation of: reactor design; photocatalyst and photoelectrodes for PEC; and efficient heating concepts for methane pyrolysis.
Activity 4.4 – Utilization of CO2/CO as alternative feedstock in the chemical industry (pg18): PtX (syngas, methanol), direct electrocatalysis (C1 & C1+n molecules), biotechnology routes (C1 & C1+n molecules), direct utilization of CO2 …
Pg 28: Table with TG targets on activity by 2025, 2030 and 2050
Pg 70: Depending on the technology and target molecule, technology TRL varies from 2 to 8. A few technologies are at TRL8 (e.g., methanol, polyol). Many technologies are currently at TRL 4-7 and have potential to reach TRL 8-9 by 2030.

Iron & Steel (pg19)
Pg. 76: Activity 5.1 CO2 emission avoidance through direct reduction of iron ore using hydrogen, instead of NG in the feed of the direct reduction plant
Pg82: 5.4 Process integration: Top gas recycling – Blast furnace using plasma torch
Pg84: Activity 5.5 Carbon Capture Usage and Storage – Reuse of carbon of steelmaking by usage of the steel mill gases as syngas for fuels or chemical products; The usage of CO or CO2 (without or in combination with hydrogen as a resource allows us to reduce the total carbon footprint)
Pg 29: Table withTG targets on activity by 2025, 2030 and 2050.

IWG 11 - Batteries

IP publication date: 2021

Pg 9: With increasing penetration of variable renewable electricity there is a need for highly efficient short term storage, where batteries will be of main importance, and long term (weeks-seasonal) storage where fuel and heat storage are required; storage technologies in the stationary-applications sector will be required to perform multiple or bundled functions, such as a combination of load levelling, frequency regulation, provision of backup power and providing hydrogen as fuel and as feedstock for chemical industries.

Its improved battery performance provides short term hour/day/night storage and, when the battery capacity is full, produce hydrogen as storable fuel or feedstock for the chemical industry.

Pg. 9: This Implementation Plan also covers hybridisation of battery systems ... storage technologies in the stationary-applications sector will be required to perform multiple or bundled functions, such as a combination of load levelling, frequency regulation, provision of backup power and providing hydrogen as fuel and as feedstock for chemical industries. ... Its improved battery performance provides short term hour/day/night storage and, when the battery capacity is full, produce hydrogen as storable fuel or feedstock for the chemical industry.

Pg.12: Professional online courses. Increasing renewable energy generation, growing electricity trade and raising demands for stable energy supply from transmission and distribution networks require flexible solutions and battery storage can provide this flexibility.

Pg 22: (…) with focus on battery- and hydrogen technology for transport applications (IFE, Norway, FME).

Pg.30: BALANCE (Increasing penetration of renewable power, alternative fuels and grid flexibility by cross-vector electrochemical processes), Grant 731224, ongoing ECRIA project 1/12/2016-30/11/2019, 2.86M€ project with 2.5M€ EC funding.

Pg. 40: By contrast, this fiche focusses on developing new equipment for present and future cell chemistries. Its main objective is to enable differentiation by addressing specific market trends: flexibility by equipment modularity, higher environmental standards, and cost reduction through better production efficiency.

Pg. 49: (...) a Ni-Fe battery with an alkaline electrolyser ('battolyser') can provide a hybrid double use system with improved battery performance and, when the battery capacity is full, with competitive and switchable electrolyser to produce hydrogen as storable fuel or feedstock for chemical industry.

Pg. 51: Parties that will implement Battolyser: i) Utilities and renewable power providers requiring short term (seconds-hours) stationary storage as well as seasonal storage in hydrogen fuel; providing better grid stability, the reduction of curtailment (loss of 1GEu last year in Germany, source: EWEA), and the ability to guarantee security of renewable power supply. ii) Automotive sector requires stationary batteries next to EV fast charge stations as well as hydrogen electrolysers for (hybrid) hydrogen transport. iii) Chemical industries that need CO2 emission reduction via electrification and clean hydrogen as feedstock, or for chemical processes.

Pg.62: Furthermore, interoperability, system integration at pack level, standardization, regulations, workforce and education are important.

IWG 12 - Renewable fuels and bioenergy

IP publication date: 5 June 2018, with update in 2021

Pg.3: IP describes targeted implementation approaches for Renewable Fuels for Sustainable Transport (automotive and aviation fuels, as well as hydrogen produced from renewable sources)

Pg4: Strategic fields of implementation & Activities with estimated investments foreseen to be implemented:
a) Renewable Fuels for Sustainable Transport: One [#7] on production of renewable hydrogen from water electrolysis and renewable electricity (needed investment € 0,4 Billion).
b) Successful outcomes depend on enablers and barriers: b.1) Bioenergy enablers being: "Increased integration of renewable fuels/bioenergy in different energy systems, exemplified by power to gas and power to liquid pathways, the use of biomass based energy generation and renewable Hydrogen in heating, cooling and electricity networks."; b.2) Bioenergy specific barriers being: "Restrictions in current policy framework that introduce or maintain unnecessary obstacles to the development of biofuels/bioenergy/renewable hydrogen such as tailpipe emission or grid fees for power-to-fuel applications."

Pg. 6:
a) "Renewable electro-fuels (such as renewable hydrogen, methane, methanol, etc.) are increasingly seen as suitable storage media for excess electricity generated by wind and solar power, facilitating the renewable uptake and integration of the power, transport, industry and heating sectors.";
b) "The use of renewable hydrogen and other renewable liquid and gaseous fuels (Biomass-to-liquid, renewable Power-to-Gas including hydrogen and renewable Power-to-Liquid) could play an important role not only in decarbonizing transport, but also in enabling the cross-sectorial integration of surplus renewable electricity and realizing a fully renewable energy supply linking the electricity, heating, transport and industrial sectors."
c) These technologies could prove indispensable in the scenario where low-carbon renewable electricity needs to be stored either in large quantities or over very long-time (inter-seasonal storage). In addition, renewable hydrogen can also be used for increase the output of biomass, allowing for additional synergies."
Pg. 7: "However, the deployment of some alternative fuels is hampered mainly by high prices of vehicles and lack of recharging /refuelling infrastructure.(ref.4) The Alternative Fuels Infrastructure Directive(ref.5) aims at facilitating the installation of infrastructure to support the deployment of alternative fuels. While the definition of alternative fuels goes beyond renewable fuels, in this context renewable alternatives to petrol and diesel (like renewable electricity, renewable gas and renewable hydrogen) are supported in their deployment."

Pg.8: "The scope of this IP is on bioenergy and renewable fuel solutions for sustainable transport and biomass CHP, mainly large scale. The following targeted technologies are addressed: renewable fuels for transport, other renewable fuels of non-biological origin, bioenergy intermediate carriers, renewable hydrogen and large-scale biomass CHP."

Pg.9: a) "Other RFNBO - There are other promising technologies under development to produce both liquid and gaseous renewable fuels. Renewable electricity can be used to produce renewable hydrogen (H2) which can be used both for transport and non-transport purposes."
b) "Several pathways to use renewable hydrogen as a fuel in transport are also feasible, for example via the use of pure hydrogen in zero emissions fuel cell electric vehicles (FCEVs). It could be converted to synthetic methane or methanol for use in compressed natural gas (CNG) vehicles or as a blending component. Renewable and cost-efficient hydrogen could also be used as substitute of fossil hydrogen used in refineries in the production process of diesel and gasoline, hence reducing the GHG emissions of the transport sector in the short term. Furthermore renewable hydrogen can

be used to substantially increase carbon utilisation in biomass gasification, with high energy efficiency."

Pg. 12: Strategic targets
a) Improved production performance:
"1.2. Other renewable liquid and gaseous fuels: By 2030, improve net process efficiency of various production pathways of advanced renewable liquid and gaseous fuels(ref.11) of at least 30% compared to present levels.
By 2030, for renewable hydrogen production by electrolysis improve net process efficiency to reach 70%. (ref.12)"
b) Improve GHG savings
c) Reduce Costs (excluding taxes and feedstock cost)

Pg.13) "Reduce cost for renewable liquid and gaseous fuels
a) Other renewable liquid and gaseous fuels excluding renewable hydrogen: at least by 50% from 2020 levels (<50 €/MWh)
b) Renewable hydrogen: <7 €/kg by 2020 <4 €/ kg by 2030 (electrolysis, reforming, ...)"

Pg. 15**:** Identified enablers/barriers
a) Identified Enablers:" Support increased integration of renewable fuels/bioenergy in different energy systems, exemplified by power-to-gas and power-to-liquid pathways or use of intermediate bioenergy carriers or renewable hydrogen in existing infrastructure."
b) Identified Barriers: Restrictions in current policy framework that introduce or maintain unnecessary obstacles to the development of biofuels/bioenergy/renewable hydrogen such as tailpipe emission or grid fees for power-to-fuel applications.

Pg. 17: R&I Priorities
a) Criteria for Priorities
The R&I activities should assist achieving the targets for renewable fuels, bioenergy and intermediate bioenergy carriers as set out in the DoI. Criteria for their selection include:
1. Should support the development, demonstration and scale-up encompassing the entire TRL range
2. Should support efficiencies improvements and cost reductions versus the DoI. targets
3. Should boost installing commercial capacity of renewable fuels for transport
4. Should comply with the timeline from now towards 2020 and 2030
b) Other renewable liquid and gaseous fuels – " The case of Hydrogen: #7 Develop and Demonstrate the production of renewable hydrogen from water electrolysis and renewable electricity"

Pg 19: Total Investment for R&I activities (Table 1):

Table 1: Total investment for R&I activities

	Billions €	Industry		MS Funding		EU	
Total Bioenergy and Renewable Fuels for Sustainable Transport	106,61	77,74	73%	22,23	21%	6,64	6%
Renewable Fuels for Sustainable Transport	84,81	62,34	74%	17,48	21%	4,99	6%

FIGURE 1:?

#7 Renewable Hydrogen	0,41	0,24	59%	0,12	28%	0,05	13%
TRL 2-6 (Development)	0,10	0,03	25%	0,05	50%	0,03	25%
TRL 7-8 (Demonstration)	0,06	0,03	50%	0,02	25%	0,02	25%
TRL 9 (Scale-Up)	0,25	0,19	75%	0,05	20%	0,01	5%

FIGURE 2?

Pg. 20: "…from the 7th Framework Programme …"

a) "Five demonstration projects on hydrogen for fuel cell buses are funded under the Fuel Cell Hydrogen Joint Undertaken with € 72 million EU contribution".

Pg. 26: ANNEX I R&I Priorities – R&I Activity #4
- Title: "Develop other renewable liquid and gaseous fuels (excluding hydrogen) through thermochemical/chemical/biochemical/electrochemical transformation of energy neutral carriers with renewable energy"
- Description/ 3rd bullet: "Develop synergies to renewable hydrogen and CO2 streams" (TRL: Advanced research TRL2-3 to TRL5)

Pg. 29-30 R&I Activity #7
Title: Production of renewable hydrogen from water electrolysis and renewable electricity

Targets:
- "By 2020, reduce capex of alkaline electrolysers from 1,600 to 1,250 Euro/(kg/d), reduce renewable electricity consumption from 57 to 50 kWh/kg and improve dynamic performance for better integration with renewables. Respective figures for PEM electrolysers are 2,000 Euro/(kg/d), 55kWh/kg. The aim is for 7 Euro/kg cost of renewable hydrogen (excluding taxes and including feedstock cost; electricity costs is estimated being 60% of the cost) "
- "By 2030, reduce capex of alkaline electrolysers to 800 Euro/(kg/d), reduce renewable electricity consumption to 48 kWh/kg and reduce O&M costs to 16 Euro/(kg/d)/yr for renewable hydrogen production. Respective figures for PEM electrolysers are 1,000 Euro/(kg/d), 50 kWh/kg and 21 Euro/(kg/d)/yr. The aim is for 4 Euro/kg cost of renewable hydrogen (excluding taxes and including feedstock cost; electricity costs are estimated being 60% of the cost)".

Monitoring mechanism: "Competent authority for tracking generation and cancelling of Guarantees of Origin for renewable hydrogen; Annual reporting of industry to monitoring authority.

Description:
- "Development of high pressure electrolysis with renewable hydrogen output pressure of at least 100 bar; rapid response of below 1 second for a hot start and below 10 seconds for a cold start; increased base load current density to at least 4 A/cm2 for PEM or 1 A/cm2 for Alkaline; increased peak-load current density for short periods of up to 1 hour to above 6 A/cm2 for PEM or above 1.5 A/cm2 for alkaline; electrolysis at water temperature of above 80°C."
- "Demonstrate Megawatt-scale electrolysers of minimal footprint installation and operation in renewable hydrogen refuelling stations producing at least 50 tons of H2 per annum using renewable electricity, increasing penetration of renewables with variable production and capturing at the same time revenues for the provision of grid services.
- "Demonstrate business cases for the on-site renewable hydrogen production for refuelling fuel cell vehicles."
- "Develop, establish and operate, a mechanism to guarantee the origin of renewable hydrogen."
- "By 2020 showcase with projects the ability of renewable hydrogen to interact with the grid to further enable RES penetration"

- TRL: Advanced research/Industrial research & demonstration/Innovation & market uptake. Also mention TRL at start and envisaged at the end; Research & Innovation TRL2 to TRL9
- Total budget required: 102 M (TRL 2-6), 60 M (TRL7-8), 250 M (TRL 9) – Amounts correspond to renewable hydrogen production and for electrolysers to the cost of the renewable part in the electricity mix only
- Deliverables (2020−30): Electrolysers of Improved efficiency, dynamic performance and reduced cost; Electrolysers installed in renewable hydrogen refuelling stations; Megawatt-scale electrolysers for the on-site production of renewable hydrogen for fuel cell vehicles; 1 GW of electrolysers installed in 1,000 renewable hydrogen refuelling stations.

- Interested parties: Consortia in RIA/IA projects, local authorities / DG RTD, DG ENER, DG MOVE;
- Implementation instruments: FP RIA, IA, MS programs, European Partnership Initiatives, CEF Transport, CEF Energy
- Indicative financing contribution: MS + EU: 78,8 M(TRL 2−6); MS + EU: 30 M (TRL 7−8); MS + EU: 61,5 M (TRL 9).

IWG 13 - CCUS

IP publication date: 2021, updated in 2024

Pg. 5: (Roadmap): "To conclude, CCS and CCU can support the EU's decarbonisation pathway, delivering climate change mitigation and circularity, CDRs and early, large-scale volumes of clean hydrogen for industry and homes. CCS and CCU can deliver clean economic growth, safeguarding industrial manufacturing and preserving existing jobs, while creating new ones."

Pg 8: "Research & Innovation Activities (…) R&I Activity 2: Delivery of regional CCS and CCU clusters, including feasibility for a European hydrogen infrastructure (targets 2 & 3 and 10)"

Pg. 10: In July 2017 Statoil announced that they are one of three partners (alongside Vattenfall and Gasunie) evaluating options to convert part of the Magnum gas plant in the north of the Netherlands into a hydrogen-powered plant.

Pg. 12: See 'Financing of planned activities to 2020' table under R&I Activity 2: Delivery of regional CCS and CCU clusters, including feasibility for a European hydrogen infrastructure

Pg. 14:"R&I Activity 2: Delivery of regional CCS and CCU clusters, including feasibility for a European hydrogen infrastructure (…) Since then several projects on CO2 capture and hydrogen have been deployed in the territory."

Pg.15: "Feasibility for a European hydrogen infrastructure. "; A European hydrogen infrastructure, combining CCS and hydrogen produced either through the pre-combustion processing of hydrocarbons through Steam Methane Reforming (SMR) or electrolysis using renewable energy, could create options to replace the use of fossil fuels for transport, industry, heating, and cooking applications. This production would take place in large-scale plants and be distributed through existing infrastructure serving natural gas applications. There is also the option to use hydrogen generated from electrolysis, along with captured CO_2 to produce fuels and chemicals, such as methanol, linking to actions identified under R&I Activity 7 (CCU Action).

The CO_2 emissions generated from the hydrogen production process via the SMR route can be captured (by pre-combustion capture technologies) and stored. This also provides opportunities to limit emissions from many small emission sources where CO_2 capture is impractical. There are no technical barriers to large-scale hydrogen production; however, further assessment is needed to improve the understanding of the possibilities and limitations (including potential safety aspects) of using existing infrastructure for the transport and use of hydrogen-enriched natural gas. Also important will be understanding the possible environmental and climate related benefits and trade-offs where hydrogen replaces fossil fuels, including an assessment of the sustainability and CO_2 abatement potential for the various hydrogen production options and uses. In addition, process intensification, process integration and emerging new capture technologies should be investigated to obtain more efficient and economic solutions for hydrogen production."

Pg. 16:"Feasibility for a European hydrogen infrastructure

- Study undertaken into the feasibility of a European hydrogen infrastructure
- Inclusion of feasibility for a hydrogen infrastructure topic in the Horizon 2020 2018/19 Energy Work Programme

(...)

Feasibility for a European hydrogen infrastructure"

Pg.16 (Roadmap): "CCUS SET-Plan targets for 2030 ..." #6: At least three pilots of capture technologies at TRL 7−8 in different industrial applications, including one enabling low-emission hydrogen production. At least six pilots of capture technologies at TRL 5−6, of which at least two pilots to test climate positive solutions such as Bio-CCS and direct air capture (DAC)."

Pg.17:

- "Assessment of the sustainability and CO_2 abatement potential for the various hydrogen production options and uses (…) Feasibility for a European hydrogen infrastructure
- One or more early hydrogen infrastructure projects being developed (…) Feasibility for a European hydrogen infrastructure:"

Pg. 18:"The sustainability and CO_2 abatement potential offered by the replacement of fossil-based hydrogen production options should be included within European and national energy and climate plans (see R&I Activity 8), towards achieving Target 10.

- Study undertaken into the feasibility of a European hydrogen infrastructure by 2020 [proposed].
- Assessment of the sustainability and CO_2 abatement potential for the various hydrogen production options and uses by 2020 [proposed].
- Evaluation of potential for hydrogen to reduce CO_2 emissions in the transport, heating, industrial and power sectors as part of national and international energy and climate plans by 2020 [proposed]."

Pg 18 (Roadmap): To summarise, CCS and CCU can support the EU's decarbonisation pathway, delivering climate change mitigation and circularity, CDRs, and early, large-scale volumes of clean hydrogen for industry and homes. Testing and deploying these technologies at scale during the 2020s will be crucial to Europe's success in achieving net zero by 2050.

Pg. 19 "Feasibility for European hydrogen infrastructure; Providing options for CCS and CCU clusters to develop hydrogen infrastructure will require support from the European Commission and a dedicated topic under the Horizon 2020 Energy Work Programme for 2018/19.

Costs to be determined for R&D and pre-feasibility studies for future hydrogen infrastructure."

Pg. 21:This will act as a seed for a cluster of capture, transport and storage infrastructure which will contribute significantly to the commercial decarbonisation of the region. Infrastructure can be further developed by adding additional CO_2 capture points, such as from hydrogen manufacture for transport and heat, future CO_2 shipping through Peterhead Port to and from Europe, and connection to UK national onshore transport infrastructure such as the FEEDER 10 pipeline which can bring additional CO_2 from emissions sites in the industrial central belt of Scotland including the proposed Caledonia Clean Energy Project.

Pg 22 (Roadmap): "When stimulating CCU innovations, there must be a perspective that the costs for these processes can be significantly reduced in the long term, so that these solutions can compete with other production routes. Access to affordable and abundant renewable energy will be crucial for large scale deployment of some CCU pathways (e.g., fuels and chemicals). Development of renewable hydrogen will have to match and synchronise with CCU requirements, since many CCU pathways are reliant on renewable hydrogen."

Pg. 38 Gaseous emissions containing CO2 (and optionally also CO) from various industrial sectors can be converted to methanol through reduction with hydrogen, and used as a chemical building block or as a fuel. Pilot projects are needed to demonstrate that industrial gaseous flows can be integrated to produce methanol in a cost and energy-efficient manner.

Pg.44: Furthermore, the comprehensive integration of hydrogen as a low carbon energy vector and its production alongside CCS and CCU has been implemented in the JRC-EU-TIMES model.

IWG 14 – Nuclear safety

IP publication date: April 2021

Two references to hydrogen provided.

Pg 6: R&I Activity 1: Plant safety, risk assessment and severe accidents, integrity assessment of systems, structures and components Scope: This includes the development of models and codes for probabilistic safety assessments (PSA) and deterministic assessments of plant transients, use of advanced safety methodologies (including better simulation methods and consideration of ageing effects), assessment of operational margins and new reactor safety systems (increased diversification, robustness and use of passive systems for safety functions) as well as seismic and fire propagation modelling. The highest priority safety research challenges for preventing severe accidents are related to in-vessel and ex-vessel corium/debris coolability and interactions, containment behaviour including hydrogen explosion risks, evaluation of the source term for any potential radioactive releases, potential impact on the environment and evaluation of scenarios should a severe accident occur, emergency preparedness and response.

Pg 16: R&I Activity 9: Cogeneration of heat and electricity Scope: Cogeneration technologies could extend the low-carbon contribution from nuclear fission to the whole energy system by directly providing heat for different applications such as process-heat, district heating, seawater desalination, or contribution to transportation by providing synthetic fuels or hydrogen. High Temperature Gas-cooled Reactor (HTGR) designs able to deliver today process steam close to 600 °C deserve special attention for cogeneration applications. Other types of reactor such as LWRs, and FRs might be deployed for electricity generation, cogeneration or other applications including Small and Modular Reactors (SMR).

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