Clean Hydrogen Partnership

European Hydrogen Sustainability and Circularity Panel

The European Hydrogen Sustainability and Circularity Panel

Towards a sustainable and circular hydrogen economy

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Table of Contents

List of Acronyms

Acronyms	Definition
AWP	Annual Work Programme
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CEAP	Circular Economy Action Plan
Clean Hydrogen JU	Clean Hydrogen Joint Undertaking
CO_2	Carbon Dioxide
CRM	Critical Raw Material
CRMA	Critical Raw Materials Act
EHS&CP	European Hydrogen Sustainability & Circularity Panel
EoL	End-of-Life
ERDF	European Regional Development Fund
ESPR	Ecodesign for Sustainable Products Regulation
ETS	Emissions Trading System
EU	European Union
FP7	Seventh Framework Programme
GHG	Greenhouse Gas
GOs	Guarantees of Origin
IA	Innovation Action
JRC	Joint Research Centre
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCOH	Levelized Cost of Hydrogen
LOHC	Liquid Organic Hydrogen Carrier
MW	Megawatt
NIMBY	Not In My Backyard
NZIA	Net-Zero Industry Act

Acronyms	Definition
OPEX	Operational Expenditure
PA	Public Awareness
PEM	Proton Exchange Membrane
PNR	Pre-normative Research
RED II	Renewable Energy Directive II
RED III	Renewable Energy Directive III
RFNBO	Renewable Fuels of Non-Biological Origin
RIA	Research and Innovation Action
S&C	Sustainability and Circularity
S-LCA	Social Life Cycle Assessment
SET	Strategic Energy Technology
SOEL	Solid Oxide Electrolysis Cell
SRIA	Strategic Research and Innovation Agenda
TF	Task Force
TMA	Technology Monitoring and Assessment
TRL	Technology Readiness Level
U.S.	United States

Executive summary

Executive Summary

This report summarises the activities of the European Hydrogen Sustainability & Circularity Panel (EHS&CP) during its first twelve months of operation, from February 2024 to February 2025. It describes the main activities and results obtained by the EHS&CP and shares the panel's recommendations on future activities to help further the integration of sustainability and circularity (S&C) in the work of the Clean Hydrogen Joint Undertaking (JU), its projects, and the wider hydrogen economy.

The EHS&CP was established to enhance the integration of S&C principles in hydrogen technologies and improve the alignment of hydrogen deployment with the EU's climate neutrality and circular economy objectives. Over its first year, the panel has assessed Clean Hydrogen JU-funded projects, developed methodological approaches to evaluate sustainability performance, and formulated strategic recommendations to embed sustainability more effectively in the Clean Hydrogen JU programme.

This work took place amid an evolving regulatory landscape, strengthening sustainability requirements across the hydrogen value chain. The European Green Deal, Fit-for-55 package, and REPowerEU set ambitious decarbonisation targets, while the Renewable Energy Directive III and the Delegated Acts on Renewable Hydrogen establish criteria for additionality, emissions savings, and renewable energy correlation. The Hydrogen and Gas Markets Decarbonisation Package and the Net-Zero Industry Act support hydrogen market integration to secure supply chains and promote circular resource management. Emerging initiatives like the Ecodesign for Sustainable Products Regulation and the Green Claims Directive enhance sustainability governance through stricter requirements on product durability, recyclability, and transparency. These evolving policies shape hydrogen projects' sustainability, reinforcing the role of the EHS&CP in ensuring that projects meet evolving sustainability requirements.

During its first tenure, the EHS&CP reviewed 356 Clean Hydrogen JU-funded projects across hydrogen production, storage and distribution, end-uses, and cross-cutting activities, assessing S&C integration. Findings show economic indicators, particularly CAPEX, OPEX, and Levelized Cost of Hydrogen (LCOH), are most widely applied, while environmental, circularity, and social aspects are inconsistently addressed. Life Cycle Assessments (LCAs) and greenhouse gas (GHG) emissions assessments were more systematically included under the Horizon 2020 Programme, but circularity indicators – such as material criticality, recyclability, and resource efficiency – are most often overlooked. Social dimensions, including social acceptance and labour considerations, are largely absent. The analysis underscores the need for more comprehensive sustainability reporting and a stronger alignment with circular economy principles to ensure that hydrogen development contributes to decarbonisation while minimising resource impacts and maximising societal benefits.

To reinforce S&C in Clean Hydrogen JU-funded initiatives, the EHS&CP has identified key actions at the project, programme, and governance levels. Strengthening data collection and reporting is critical, with structured methodologies, standardised templates, and digital tracking tools improving transparency and comparability. At the project level, capacity-building measures, clearer guidance on sustainability integration, and benchmarking case studies will support best practices in implementation. At the programme level, embedding S&C requirements in funding calls, expanding collaboration with institutions such as the Joint Research Centre (JRC), and enhancing policy coherence across hydrogen initiatives will be essential. Communication and stakeholder engagement should be reinforced through workshops, policy dialogues, and mechanisms to recognise projects demonstrating excellence in S&C integration.

Over the past year, the EHS&CP has provided an evidence-based foundation for embedding S&C principles into the Clean Hydrogen JU and the wider hydrogen economy. Moving forward, ensuring that S&C considerations are systematically integrated across hydrogen-related policies, projects, and funding instruments will be important to positioning hydrogen as a pillar of Europe's green transition.

Activities of the European Hydrogen Sustainability & Circularity Panel

The European Hydrogen Sustainability & Circularity Panel

This report provides a summary of the activities of the European Hydrogen Sustainability & Circularity Panel under its first tenure following its inception in February 2024. It describes the main activities and results obtained by the expert panel and shares the panel's recommendations on future activities to ensure further integration of sustainability and circularity in the work of the Clean Hydrogen JU, its projects and the hydrogen economy.

Introducing the EHS&CP

The European Hydrogen Sustainability & Circularity Panel (EHS&CP)[1] was established by the Clean Hydrogen Joint Undertaking (JU) in February 2024. Its mission is to embed Sustainability and Circularity (S&C) into hydrogen technologies, ensuring the European hydrogen economy aligns with the EU's climate neutrality and sustainability goals. The EHS&CP serves as an advisory body that evaluates existing sustainability practices, identifies gaps, and develops recommendations to strengthen the sustainability and circularity dimensions of Clean Hydrogen JU-funded projects and initiatives.

The establishment of the EHS&CP reflects the EU's commitment to a sustainable and circular hydrogen economy, particularly in light of the European Green Deal and the Circular Economy Action Plan, as well as linked to its relevance for energy independence as raised in the REPowerEU Plan, and the Net-Zero Industry Act. As hydrogen plays a crucial role in decarbonisation, the panel works to help ensure that its deployment is environmentally responsible, economically viable, and socially equitable.

Objectives

The EHS&CP operates with two core objectives:

1. Helping the Clean Hydrogen Partnership to address S&C at both the programme and project levels, encompassing environmental, social and economic aspects
2. Promoting and disseminating knowledge for a more sustainable and circular culture within and beyond the programme.

In its first tenure, the EHS&CP carried out a range of activities to support the integration of S&C principles into the Clean Hydrogen JU programme and projects. Key areas of action carried out by the panel included:

1. Reviewing and screening Clean Hydrogen JU projects to evaluate sustainability integration, assess project methodologies, and identify best practices and gaps for improvement. This also involved exploring guidelines and methodologies to strengthen S&C integration in future projects

[1] For more information, see: https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-sustainability-and-circularity-panel_en

2. Selecting S&C indicators along with their definition of calculation methods, KPIs and monitoring frameworks to track the adoption and impact of S&C aspects.
3. Providing strategic recommendations to support Clean Hydrogen in alignment with key policy initiatives, such as ensuring sustainability requirements are embedded in Clean Hydrogen JU project calls and research strategies.
4. Enhancing data collection and monitoring by proposing data collection approaches to extract S&C information from projects and improve data reporting for better benchmarking and transparent tracking of project impacts.
5. Engaging stakeholders to promote knowledge exchange among researchers, industry, and policymakers, including collaborating with the Joint Research Centre (JRC) to assess and implement sustainability measures in hydrogen-based technologies.

Panel composition

The Panel is composed of 15 experts[2] from diverse fields representing academia and industry from across Europe, representing 10 different nationalities, who were selected based on their expertise in hydrogen production, storage, distribution, and end-use applications (Figure 1). The EHS&CP is organised into four Task Forces (TFs), each focusing on a critical aspect of the hydrogen value chain. Below is the delineation of experts and within their respective TFs.

- TF 1: Hydrogen Production, led by Javier Dufour (Professor at the Rey Juan Carlos University of Madrid, and Head of Systems Analysis Unit at IMDEA Energy) which focused on embedding sustainability into hydrogen production technologies examining aspects such as Life Cycle Assessment (LCA), energy consumption, environmental impact, and resource efficiency to ensure hydrogen production aligns with S&C principles.
- TF 2: Hydrogen Storage & Distribution, under the leadership of Claudio Pistidda (Head of the Department of Materials Design, Helmholtz-Zentrum Hereon GmbH) with a focus on the development of materials and systems for hydrogen storage and compression while minimising the environmental footprint of transport and distribution networks.
- TF 3: Hydrogen End Uses, led by Sotirios Karellas (Professor, National Technical University of Athens) to link hydrogen technologies with industrial users looking into the sustainability of hydrogen applications in sectors such as industry, transport, and power generation.
- TF 4: Cross-Cutting Issues was headed by Alessandro Agostini (Head of the Sustainability of Energy Technologies Unit at ENEA) with the aim of tackling broader sustainability challenges beyond specific hydrogen processes. This includes regulatory frameworks, economic viability, policy alignment, and social and educational aspects.

[2] https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-sustainability-and-circularity-panel/members_en

Figure 1 Task Forces and experts

Overview of the activities of the EHS&CP

In its first twelve months, the EHS&CP implemented a set of activities to advance S&C throughout the Clean Hydrogen JU programme and its projects. Activities included policy assessment, indicator development, project screening, and strategic recommendations aimed at advancing S&C principles so they can become better integrated across the hydrogen value chain.

Key activities implemented

- Activity 1 – Data collection & project screening: Proposed a methodology to extract S&C data from Clean Hydrogen JU-funded projects, enabling a structured evaluation of sustainability performance.
- Activity 2 – Knowledge management & reporting: Provided input to enhance Clean Hydrogen JU's knowledge management activities, improving project data reporting and transparency.
- Activity 3 – Assessment of S&C in Clean Hydrogen JU projects: Conducted an in-depth review of S&C integration levels within Clean Hydrogen JU-funded projects, identifying best practices and areas for improvement.
- Activity 4 – Strategy development for future work programmes: Supported the definition of a comprehensive Clean Hydrogen JU S&C strategy, shaping key actions for upcoming annual work programmes (AWPs).
- Activity 5 – Indicator development & monitoring frameworks: Developed KPIs, sustainability indicators, and tracking methodologies to monitor the adoption and achievements of S&C principles in Clean Hydrogen JU projects.
- Activity 6 – Recommendations for improving the integration of S&C: Identify challenges to integrating S&C into Clean Hydrogen JU projects, outlining key actions and recommendations to be adopted by the Clean Hydrogen JU in future programmes and projects.
- Activity 7 – Guidelines for future projects: Identified methodologies, tools, and best practices to enhance S&C integration in upcoming Clean Hydrogen JU-funded initiatives.
- Activity 8 – Collaboration with the JRC: Partnered with the JRC to assess and implement sustainability frameworks for hydrogen-based technologies, aligning with broader EU research initiatives.

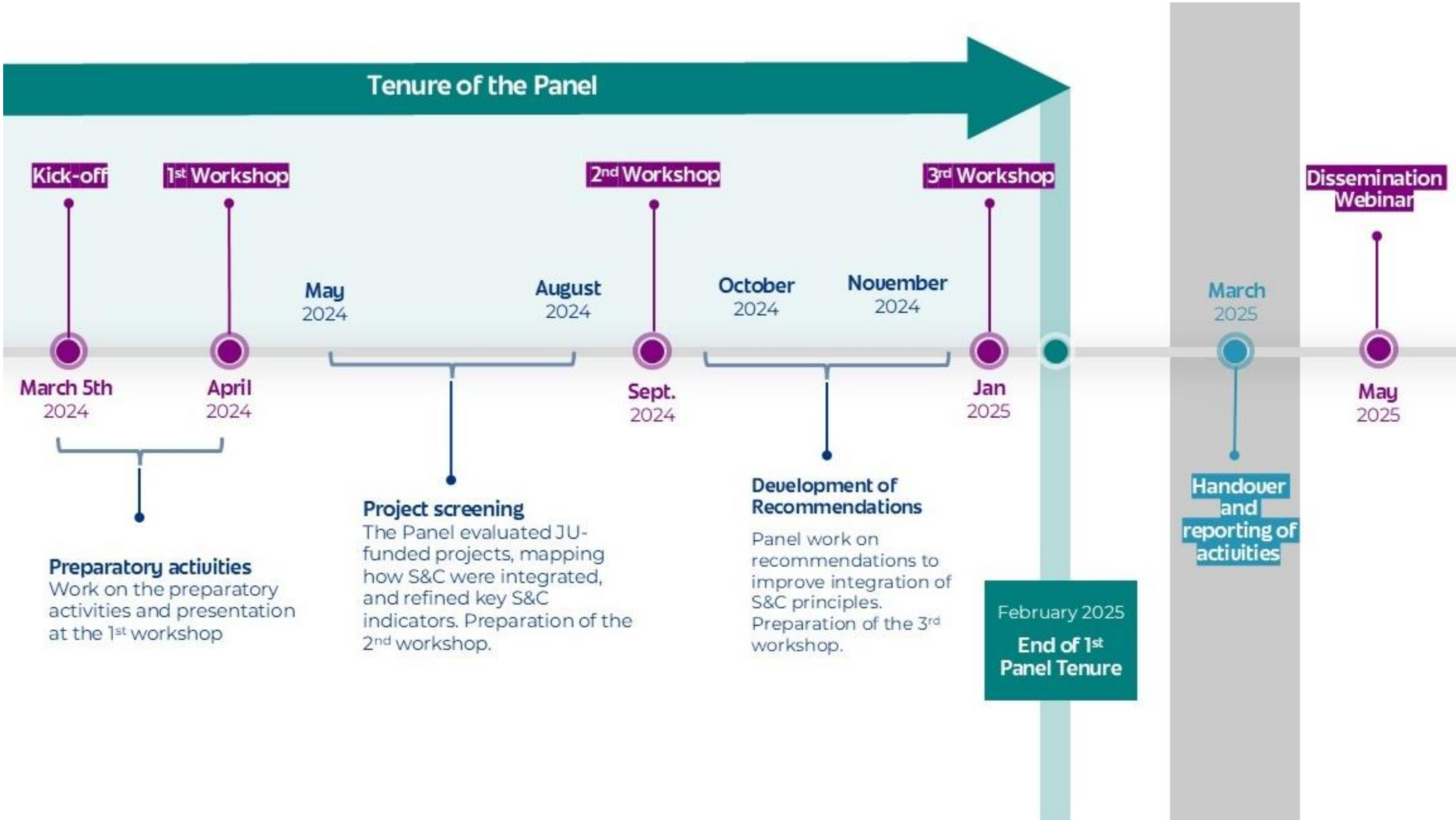
Through these activities, the EHS&CP established a foundation for embedding S&C into Clean Hydrogen JU's projects and programme. This approach ensures that sustainability remains at the core of technology development, project evaluation, and long-term strategic planning within Clean Hydrogen JU. The panel's efforts have reinforced the methodological basis for assessing the incorporation of S&C aspects in hydrogen projects, contributed to the definition and refinement of harmonised indicators, and informed the development of strategic actions within Clean Hydrogen JU's research and funding activities.

These contributions collectively strengthen the panel's role in enhancing the coherence**,** consistency, and long-term applicability of sustainability-driven measures in the European hydrogen economy.

Timeline

The first year of activities began with a kick-off meeting on March 5, 2024, setting the groundwork for the objectives of the EHS&CP. Following this, the panel held three key workshops: the first in April 2024, presenting preparatory activities; the second in September 2024, assessing progress and stakeholder input; and the third in January 2025, consolidating findings and recommendations. In February 2025, the panel finalised its first tenure (Figure 2).

Figure 2 Timeline for the delivery of the EHS&CP's first panel tenure



Results from the EHS&CP

The activities implemented by the EHS&CP resulted in the following three outcomes:

1. A better understanding of sustainability and circularity in the context of the hydrogen economy, focusing on the political context for sustainability and hydrogen, the impacts of scaling up hydrogen, and an understanding of existing indicators for assessing the sustainability and circularity of hydrogen projects.
2. An assessment of past and ongoing Clean Hydrogen JU projects and how they incorporated considerations for sustainability (economic, environmental and social) as well as circularity in their activities.
3. A forward-looking exercise on how sustainability and circularity can be further integrated into the work of the Clean Hydrogen JU, its programme and its projects, thereby having a positive impact on the wider hydrogen economy.

In the following three sections, the specific results of these overarching outcomes are described in more detail.

1. An introduction to hydrogen sustainability and circularity[3]

Hydrogen plays a central role in the EU's strategy to achieve climate neutrality. Several policy efforts are aimed at integrating S&C principles into its legislative and regulatory framework. Through a combination of policy initiatives, funding mechanisms, and strategic actions, the EU seeks to establish a hydrogen economy that is not only technologically advanced but also environmentally responsible, economically viable, and socially inclusive. This section outlines key policy instruments shaping the S&C dimensions of hydrogen, including legislative frameworks, funding mechanisms, and international policy developments influencing the EU's approach.

The policy context

The EU has positioned hydrogen as a cornerstone of its transition to climate neutrality and has taken concrete steps to improve how S&C principles are integrated into its legislative and regulatory frameworks. Through a series of policy initiatives, funding mechanisms, and strategic actions, the EU aims to develop a robust and sustainable hydrogen economy while ensuring environmental, social, and economic viability. This subsection outlines the key policies shaping the sustainability and circularity S&C dimensions of hydrogen and highlights EU legislative frameworks, funding instruments, and international policy considerations.

Current EU legislative and policy frameworks

The European Green Deal provides the overarching framework for Europe's ambition to become climate-neutral by 2050. Under the Green Deal, the Fit-for-55 package sets binding targets for reducing greenhouse gas (GHG) emissions by at least 55% by 2030 and introduces measures that directly impact the hydrogen sector. Measures include stricter carbon pricing mechanisms under the EU Emissions Trading System (ETS), which encourages

[3] A full report was also developed by the Panel and can be accessed on the Clean Hydrogen JU's website: Clean Hydrogen Partnership (2024) European Hydrogen Sustainability and Circularity Panel. Introduction to Hydrogen Sustainability, available here.

investment in renewable hydrogen as a decarbonisation solution, and the Carbon Border Adjustment Mechanism (CBAM), which imposes carbon costs on imported hydrogen, ensuring a level playing field with EU-produced low-carbon hydrogen.

The REPowerEU Plan was introduced as part of the European Union's response to the energy crisis resulting from Russia's invasion of Ukraine. It accelerates hydrogen deployment as a key alternative to fossil fuels by setting ambitious targets, including the production of 10 million tonnes of renewable hydrogen within the EU and the import of an additional 10 million tonnes by 2030, intending to reduce dependence on Russian fossil fuels and enhance Europe's energy security.

The EU Hydrogen Strategy (2020) outlines a phased approach to scaling up hydrogen technologies, prioritising renewable hydrogen produced through electrolysis powered by renewable electricity. The strategy promotes the development of hydrogen infrastructure, sector integration, and certification mechanisms to support the transition towards a sustainable hydrogen economy.

The Renewable Energy Directive (RED II), adopted in 2018, set sustainability criteria for biofuels, biogas, and Renewable Fuels of Non-Biological Origin (RFNBOs), including hydrogen, ensuring alignment with environmental and social principles. It introduced Guarantees of Origin (GOs) to certify renewable hydrogen production. In 2023, RED III strengthened these requirements by raising the binding renewable energy target to 42.5% by 2030, with an ambition to reach 45%, and mandating a minimum of 70% GHG emissions savings for RFNBOs. It also enhanced traceability rules for GOs to prevent double-counting. The Delegated Acts on Renewable Hydrogen (2023) further refined sustainability criteria by introducing the additionality principle, requiring electrolysers to use newly added renewable electricity, and establishing temporal correlation rules ensuring hydrogen production matches renewable electricity generation on a monthly basis, tightening to hourly matching from 2030. The Acts also set geographical correlation requirements, stipulating that hydrogen production must occur within the same or interconnected electricity market as the renewable power source. These measures ensure that hydrogen deployment supports decarbonisation while adhering to circularity principles.

The Hydrogen and Gas Markets Decarbonisation Package was adopted in 2024 and provides a regulatory framework to facilitate the integration of hydrogen into Europe's energy system. It introduces common rules for hydrogen transport, storage, and trade, establishing a legal framework for infrastructure development and market operations. Its key provisions include the creation of a European hydrogen transport network, supported by independent system operators, the implementation of certification schemes for low-carbon hydrogen, defining a GHG emissions threshold of 3.38 kg CO_2/kg H_2, and rules on limiting the blending of hydrogen into natural gas grids to a maximum of 5% by volume at interconnection points.

The Net-Zero Industry Act (NZIA), introduced in 2024, enhances the competitiveness of European clean energy technologies, including electrolysers and fuel cells. It mandates that at least 40% of key net-zero technologies be produced within the EU to strengthen Europe's leadership in clean hydrogen manufacturing and supply chains.

The Critical Raw Materials Act (CRMA) secures access to essential materials required for hydrogen production and storage, such as platinum group metals and rare earth elements. It promotes increased domestic extraction, as well as recycling and circularity strategies to reduce Europe's dependency on imported CRMs.

The evolving policy landscape

The impact of the EU policies on the hydrogen market is not yet evident, but could be unlocked through early Hydrogen Valley markets – regional, integrated ecosystems that bring together all parts of the hydrogen value chain – where startups should play a key role in enhancing competitiveness.

The Carbon Pricing Mechanism, primarily driven by the EU ETS, internalises carbon costs, incentivising investment in low-carbon technologies, including hydrogen. The CBAM extends this principle by imposing carbon costs on products imported to the EU, ensuring competitiveness for EU-produced low-carbon hydrogen while discouraging carbon leakage.

The Ecodesign for Sustainable Products Regulation (ESPR) is set to replace the Ecodesign Directive and expand sustainability criteria beyond energy efficiency to include material durability, reparability, and recyclability. The ESPR is expected to impact hydrogen-related technologies by ensuring they adhere to EU circularity and sustainability objectives.

The Green Claims Directive, proposed in 2023, aims to combat greenwashing by setting strict requirements for environmental claims made by companies, including those in the hydrogen sector. It mandates that sustainability assertions, such as low-carbon or renewable hydrogen labels, be scientifically substantiated, independently verified, and based on LCA to ensure transparency and consumer trust, which can strengthen the credibility of hydrogen-related sustainability claims.

The Circular Economy Action Plan (CEAP) aims to drive resource efficiency, waste reduction, and sustainable product design across industries. Future measures will further strengthen circular business models and integrate sustainability into EU market practices, indirectly shaping the hydrogen sector through material use and recycling standards.

Funding mechanisms supporting sustainable hydrogen

The EU has established multiple funding programmes to accelerate the deployment of sustainable and circular hydrogen technologies, including:

- Horizon Europe, which supports research and innovation in hydrogen production, storage, and applications.
- The Innovation Fund, which finances large-scale decarbonisation projects, including renewable hydrogen and industrial applications.
- The Connecting Europe Facility (CEF), which funds hydrogen infrastructure development, including pipelines and refuelling stations.
- The European Regional Development Fund (ERDF) and the Cohesion Fund, which provide support for regional hydrogen projects and industrial decarbonisation.
- The Hydrogen Bank, launched in 2023, facilitates financial de-risking for renewable hydrogen investments, ensuring cost competitiveness and accelerating market uptake.

Complementing these EU funding programmes are the National Hydrogen Strategies of Member States. As of December 2024, 20 EU Member States have a hydrogen strategy, with two Member States (Romania and

Sweden) having draft strategies[4]. These generally outline targets and priorities for hydrogen deployment, but can also provide additional national funding instruments. Building on these are the Important Projects of Common European Interest (IPCEI), which give Member States the ability to jointly fund projects in advanced technologies. There are currently four IPCEIs on hydrogen: Hy2Tech focusing on the technology value chain; Hy2Use focusing on integrating hydrogen in industrial processes; Hy2Infra focusing on the distribution and storage; and Hy2Move focusing on mobility and transport applications[5].

Finally, beyond these different funding programmes, the Clean Hydrogen JU programme has the goal of accelerating the development and deployment of the European value chain for safe and sustainable clean hydrogen technologies. As such, it supports research and innovation to strengthen the knowledge and capacity of scientific and industrial sectors. This is mainly done through its Strategic Research and Innovation Agenda[6] and the funding is disseminated through calls for proposals.

International perspectives on hydrogen sustainability

As hydrogen emerges as a globally traded energy carrier, different regions are defining sustainability and circularity in different ways, which in turn is shaping investment flows and international supply chains. While the EU prioritises renewable hydrogen from electrolysis powered by renewable electricity, other major economies take broader approaches to hydrogen sustainability.

The United States (U.S.), through its National Clean Hydrogen Strategy (2023), focuses on deploying hydrogen in industry, transport, and power generation, defining clean hydrogen based on carbon intensity rather than production source. The Inflation Reduction Act (2023) incentivises hydrogen production with tax credits up to $3 per kilogram for hydrogen emitting less than 0.45 kg CO_2/kg H_2, and offering lower subsidies for higher-emission hydrogen, but has faced criticism for funding blue hydrogen from fossil gas with carbon capture as part of its $7 billion hydrogen hub program.

Japan has been engaged in hydrogen research since 1973 and formalised its Hydrogen Strategy in 2017. Unlike the EU, Japan follows a technology-neutral approach, supporting blue hydrogen, ammonia-based hydrogen, and renewable hydrogen without specific environmental criteria. The strategy sees hydrogen as a means to enhance energy security and industrial decarbonisation rather than prioritising S&C.

All three economies aim to scale up hydrogen, but their regulatory approaches significantly differ. While the EU enforces sustainability criteria, the U.S. prioritises cost-competitive carbon intensity thresholds, and Japan maintains a diversified technology approach. These differences highlight the challenge of aligning global hydrogen certification schemes and sustainability standards, which will be crucial for establishing a transparent international hydrogen market.

Challenges and future considerations

Significant challenges remain in integrating S&C into a European hydrogen economy. One major issue is the lack of standardised sustainability metrics, as current policies do not provide a harmonised methodology for assessing hydrogen's environmental impact and circular economy performance. This creates inconsistencies in how projects measure and report their sustainability contributions. Additionally, the complexity of certification

[4] European Hydrogen Observatory. Policies and Standards. National Strategies, available here: https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/policies-and-standards/national-strategies.
[5] For more information, see: European Commission, Approved IPCEIs in the Hydrogen value chain, available here: https://competition-policy.ec.europa.eu/state-aid/ipcei/approved-ipceis/hydrogen-value-chain_en.
[6] https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en

schemes presents a barrier, with Hydrogen GOs varying across jurisdictions, leading to discrepancies in market access and sustainability verification. Another challenge is the limited integration of circular economy principles, as many hydrogen projects still lack comprehensive end-of-life strategies for electrolysers and fuel cells, restricting material recovery and recycling efforts.

Addressing these gaps requires a coordinated policy approach. A unified European certification system for sustainable hydrogen could ensure consistency in carbon intensity and circularity tracking across Member States. Furthermore, circular economy principles should be systematically integrated into hydrogen infrastructure planning and funding criteria, emphasising resource efficiency, recyclability, and reuse.

The impacts of scaling up hydrogen

The large-scale deployment of hydrogen technologies presents both opportunities and challenges for the transition to a sustainable and clean energy system. Hydrogen can enhance energy security, integrate renewable energy sources, and contribute to decarbonisation, but its expansion also raises concerns regarding resource use, environmental impacts, and infrastructure needs.

A key challenge in scaling up hydrogen lies in the modelling tools used to assess its deployment. Current techno-economic optimisation models often fail to capture S&C criteria, which limits their ability to fully account for hydrogen's environmental and socio-economic impacts. Current models tend to effectively quantify GHG emissions, but often neglect broader factors such as air pollution, land use, water consumption, and CRMs. Hydrogen's role in integrating non-dispatchable renewables through power-to-gas technologies also remains underrepresented in energy system models.

One of the most debated aspects of hydrogen deployment is water consumption. Electrolysis, the primary method for producing renewable hydrogen, requires 15 to 100 litres of water per kilogram of hydrogen, depending on the technology and cooling systems used. While hydrogen electrolysis is more water-efficient than fossil-based hydrogen production, its expansion in water-scarce regions could exacerbate local resource pressures. In such areas, desalination may provide a viable solution, adding some costs to hydrogen production. On the other hand, integrating hydrogen with renewable energy could offset water use by reducing demand for cooling in fossil-based power plants. Overall, local availability of water resources must be factored into hydrogen deployment strategies.

Another critical consideration is the availability of CRMs such as platinum, iridium, and rare earth elements, which face supply chain vulnerabilities due to geopolitical concentration and extraction & processing challenges. While the overall material demand for hydrogen technologies remains lower than that of other clean energy sectors, projected demand for platinum and iridium could exceed current global production levels by the 2030s and 2040s, respectively. To mitigate these risks, investments in material substitution, recycling, and circular economy approaches are essential. The EU's Critical Raw Materials Act seeks to enhance CRM recovery and reduce dependency on primary extraction, reinforcing sustainability in hydrogen supply chains.

The expansion of renewable hydrogen production and use will also have a significant impact on electricity demand. Electrolysers require substantial renewable energy input, making the availability of low-cost renewable electricity a determining factor for hydrogen's economic viability. Countries with abundant solar and wind resources, land availability, and grid infrastructure are best positioned to become major producers of renewable hydrogen. However, scaling up hydrogen production could compete with direct electrification, particularly in sectors where battery storage may offer a more efficient alternative. Grid expansion and sector coupling strategies, including the use of hydrogen for seasonal energy storage, will be needed to balance supply and demand in a decarbonised energy system.

The land footprint of hydrogen infrastructure must also be considered. Large-scale renewable hydrogen production relies on extensive solar and wind farms, which require substantial land areas. While electrolysis-based hydrogen generally has a lower land impact than biomass-derived hydrogen, land competition with agriculture and conservation areas could pose challenges. Strategic siting of hydrogen facilities, co-locating production with industrial hubs, and integrating hydrogen into existing energy infrastructure can help minimise land use conflicts.

Hydrogen's storage and transport present additional challenges. Unlike conventional fuels, hydrogen has a low volumetric energy density, and thus requires specialised infrastructure such as pipeline networks, high-pressure storage, cryogenic tanks, and chemical carriers (e.g., ammonia, liquid organic hydrogen carriers). Each method comes with its own trade-offs in terms of energy efficiency, cost, and environmental footprint. While repurposing existing natural gas pipelines for hydrogen transport is a potential solution, the risk of hydrogen embrittlement must be carefully managed. Large-scale underground hydrogen storage in salt caverns and depleted gas fields are also being explored, but this requires further research to address microbial activity, leakage risks, and long-term stability and cyclability.

Beyond technical and environmental concerns, public acceptance plays a crucial role in hydrogen deployment. Large-scale hydrogen projects, particularly storage sites, pipelines, and refuelling stations, can face resistance from local communities due to perceived safety risks, land use concerns, and industrial disruption. The phenomenon is often referred to as "Not In My Backyard" (NIMBY) opposition. Transparent public engagement strategies and active community participation in planning processes are key to fostering societal acceptance and avoiding project delays.

Successful hydrogen scaling will require strong cooperation between policymakers, industry, research institutions, and civil society. Given the complexity of still immature hydrogen value chains, it will be key to align regulatory frameworks, certification schemes, and sustainability standards across different jurisdictions to create a transparent and efficient international hydrogen market. Collaboration on research, innovation, and infrastructure development will also be key to overcoming technical and economic barriers.

In brief, hydrogen's large-scale adoption requires careful planning and targeted policy measures to address challenges related to resource use, infrastructure, environmental impacts, and public acceptance.

Sustainability and Circularity indicators for hydrogen

The EHS&CP has developed a framework to assess the environmental, economic, social, and circularity aspects of hydrogen technologies. These indicators are set to improve the alignment of hydrogen with climate goals, circular economy principles, and social responsibility standards.

Sustainability in hydrogen technologies requires a life-cycle approach, assessing impacts from production to end-of-life (EoL). The Environmental Footprint (EF) methodology developed by the European Commission provides a well-established framework for environmental assessments. Similarly, economic feasibility, social responsibility, and circularity indicators must be integrated to provide a full picture of hydrogen's sustainability performance.

The EHS&CP has underlined key dimensions and indicators for hydrogen sustainability:

Environmental indicators

The EF methodology identifies key impact categories to evaluate hydrogen's environmental performance:

- Climate impact measured through global warming potential (kg CO_2 eq.)
- Water use impacts (m^3 world eq. deprived water)
- Air pollution effects on human health and air quality (PM2.5, NOx, SOx, NMVOC)
- Resource use and depletion of critical resources (kg Sb eq., MJ fossil fuel use)
- Acidification and eutrophication impacting soils and water systems (mol H+ eq., kg N eq.).

Material criticality

Hydrogen technologies rely on materials that are economically important but highly vulnerable to supply risks[7]. The following indicators assess material sustainability:

- Content of critical materials, measuring the reliance on CRMs such as iridium, platinum, and rare earth elements (% or g/kg H_2).
- Content of strategic materials, assessing the use of other strategic metals such as nickel, aluminium, titanium or copper used in hydrogen production (% or g/kg H_2).

Economic indicators

Economic viability is crucial for the large-scale adoption of hydrogen technologies. The key economic indicators identified are:

- CAPEX, measuring upfront investment costs (Capital Expenditure, €/kW or €/kg H_2)
- OPEX, accounting for maintenance and operational costs (Operational Expenditure, €/kg H_2/year).
- Levelized cost of hydrogen, estimating hydrogen production cost over the system's lifetime ($LCOH_2$, €/kg H_2).

For fair comparisons, OPEX and $LCOH_2$ calculations must be standardised for consistency across assessments.

Social indicators

Hydrogen's social impact is gaining attention, particularly regarding labour conditions and equity. Social indicators identified include:

- Forced labour in raw material extraction (% of supply chain impact)
- Child labour and unethical labour practices (% of sectoral impact)
- Women in the hydrogen labour force (% of workforce)

[7] World Bank Group (2022) Sufficiency, sustainability, and circularity of critical materials for clean hydrogen. https://documents1.worldbank.org/curated/en/099340012132232793/pdf/P1740030a03d520a60a5570f776c34e1701.pdf.

- Gender wage gap and pay disparities (average earnings differential, %)
- Health expenditure of broader public health impacts of hydrogen projects (% of GDP or per capita impact).

As social impact assessment methodologies mature, data availability and harmonisation will be key challenges to address.

Circularity and end-of-life indicators

The end-of-life phase of hydrogen-related products is still underdeveloped, with limited availability of industrial-scale recycling processes. To strengthen circularity, the following indicators are proposed:

- Recyclable materials content, assessing the share of materials with existing recycling pathways (%).
- Recycled materials content, identifying the proportion of reused materials in new hydrogen technologies (%).
- Renewable materials content, measuring the integration of renewable components (%)
- By-product utilisation, quantifying how much waste from hydrogen production is repurposed or recycled (%).

While the environmental and economic indicators are well-established, social and circularity indicators require further development. The EHS&CP additionally recommends:

- Standardising economic and social impact assessments for consistent data reporting across projects.
- Expanding research into the end-of-life phase of hydrogen products and improving recycling and material recovery.
- Enhancing the traceability of CRMs to ensure compliance with ethical sourcing regulations.

Advancing the monitoring and adoption of these indicators can help hydrogen project developers measure their progress in S&C, and demonstrate their alignment with EU objectives for a clean, just, and circular energy transition.

2. Sustainability and Circularity in the context of the Clean Hydrogen JU

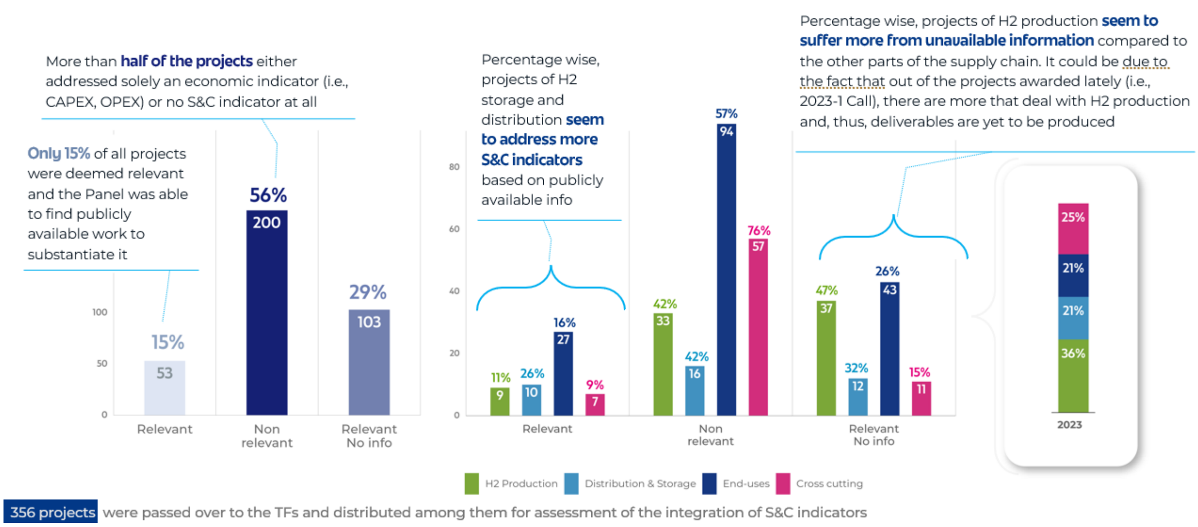
Analysis of the integration of S&C into Clean Hydrogen JU-funded projects

The EHS&CP undertook a comprehensive review of 356 projects funded by the Clean Hydrogen JU to assess the extent to which S&C principles were integrated across the hydrogen value chain. The screening and assessment were carried out for the list of indicators identified above. Each project was evaluated based on publicly available documentation, including project abstracts, deliverables, publications, and funding call requirements. Where accessible data was limited, expert judgement was applied to infer the likely extent of S&C integration.

Over half of the projects (56%) either addressed only economic indicators or failed to include any explicit S&C considerations. Of the total projects assessed, 15% were deemed relevant, meaning they included S&C elements that could be substantiated through publicly available data. Another 29% were considered potentially relevant but lacked accessible information to confirm their alignment with S&C objectives (Figure 3). The findings were that economic indicators – such as CAPEX, OPEX, and Levelized Cost of Hydrogen (LCOH) – are the most frequently considered, while environmental and social dimensions are often secondary or missing entirely

Among the different segments of the hydrogen supply chain, hydrogen distribution and storage projects demonstrated a comparatively stronger emphasis on S&C indicators, based on available reporting. By contrast, hydrogen production projects exhibited the highest degree of information gaps, which may be partially due to most of these being initiated under the 2023 call and having yet to produce publicly available deliverables. This discrepancy underscores the ongoing challenge of ensuring consistent reporting and transparent evaluation of sustainability and circularity performance across all Clean Hydrogen JU-funded initiatives.

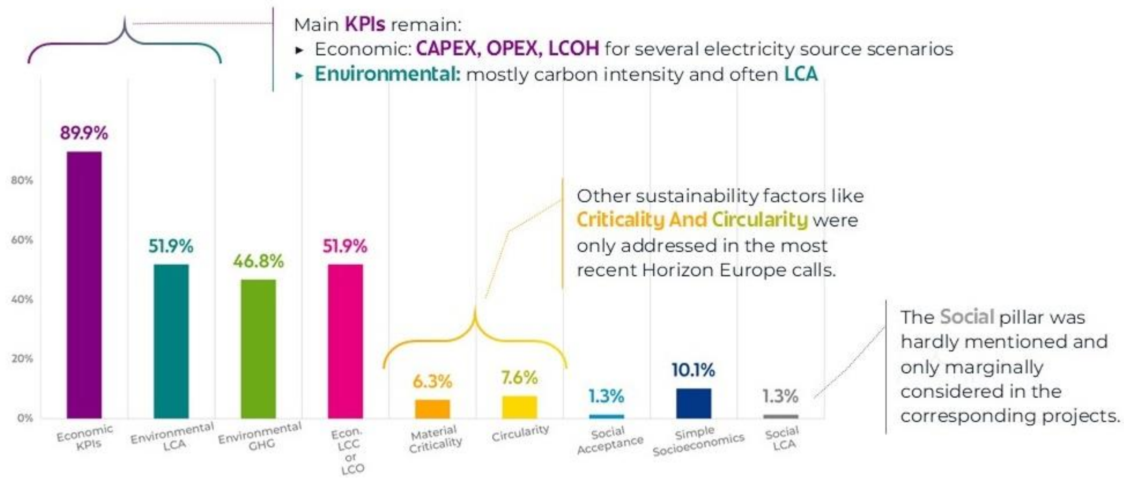
Figure 3 Screening of all FCH JU & Clean Hydrogen JU-funded projects



Hydrogen production projects

Economic KPIs overwhelmingly dominated within the 79 hydrogen production projects assessed, with 89.9% of projects focused on cost metrics. Environmental considerations were present in roughly half of the projects, with 51.9% incorporating LCA and 46.8% addressing GHG emissions. However, other sustainability factors, such as circularity and material criticality, were scarcely addressed, appearing in only 7.6% and 6.3% of projects, respectively. Social indicators were almost absent, with Social Life Cycle Assessment (S-LCA) and social acceptance considerations appearing in just 1.3% of projects. This imbalance indicates that while carbon intensity assessments are relatively common, broader circular economy principles and social sustainability remain largely unaddressed in hydrogen production (Figure 4).

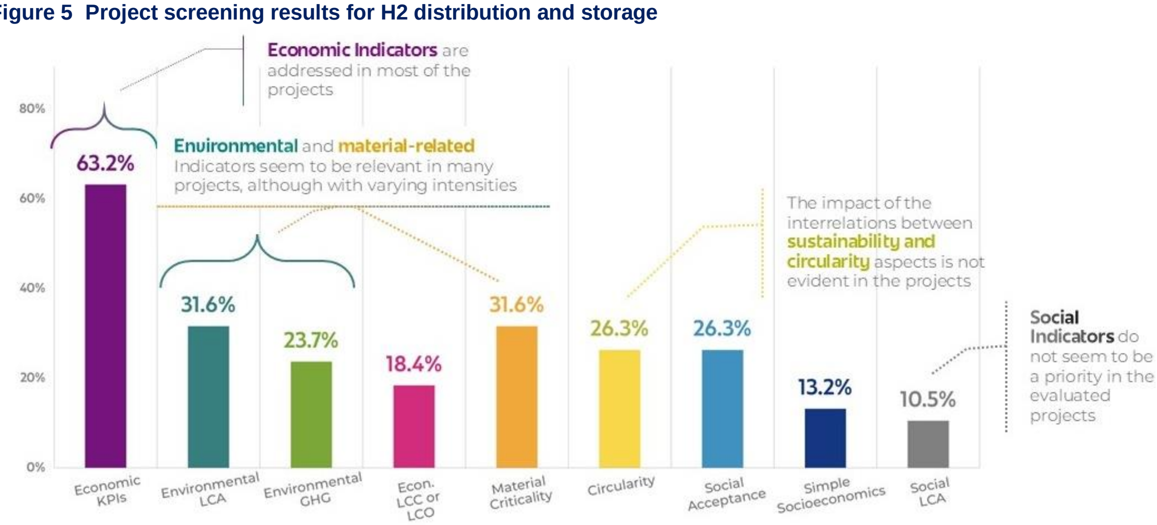
Figure 4 Project screening results for H2 production



Hydrogen distribution and storage projects

The 38 projects assessed in hydrogen distribution and storage displayed a more balanced consideration of sustainability compared to hydrogen production. Economic KPIs were included in 63.2% of projects, while environmental LCAs appeared in 31.6%, and GHG emissions in 23.7%. Material criticality, an increasingly relevant concern in hydrogen infrastructure, was considered in 31.6% of projects, and circularity in 26.3%, reflecting growing awareness of resource efficiency. Social indicators remained underrepresented, but social acceptance was addressed in 26.3% of projects – significantly higher than in production projects (Figure 5). A key issue identified in this category was the lack of interrelations between sustainability and circularity aspects, suggesting that while some indicators were addressed, they were not integrated into a cohesive framework.

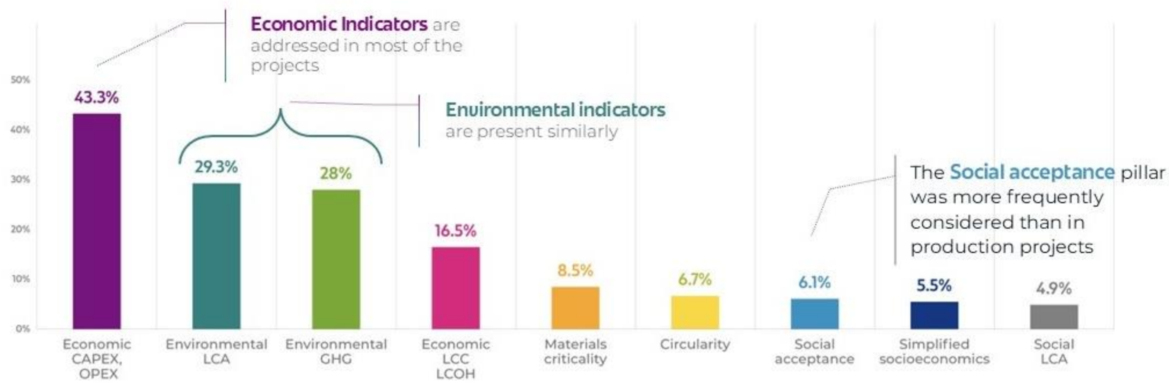
Figure 5 Project screening results for H2 distribution and storage



Hydrogen end-use projects

Of the 164 hydrogen end-use projects reviewed, 57% were considered non-relevant, meaning they either explicitly lacked sustainability elements or focused primarily on economic objectives. Among the relevant projects, economic KPIs were addressed in 43.3% of cases, while environmental LCA (29.3%) and GHG emissions (28%) were present at similar levels. Material criticality and circularity, at 8.5% and 6.7%, respectively, remained underexplored (Figure 6). Social acceptance was more frequently considered than in production projects, appearing in 6.1% of cases. Notably, Innovation Action (IA) projects demonstrated a greater emphasis on sustainability than Research and Innovation Actions (RIA), likely reflecting the increased focus on deployment-stage considerations in later-phase projects.

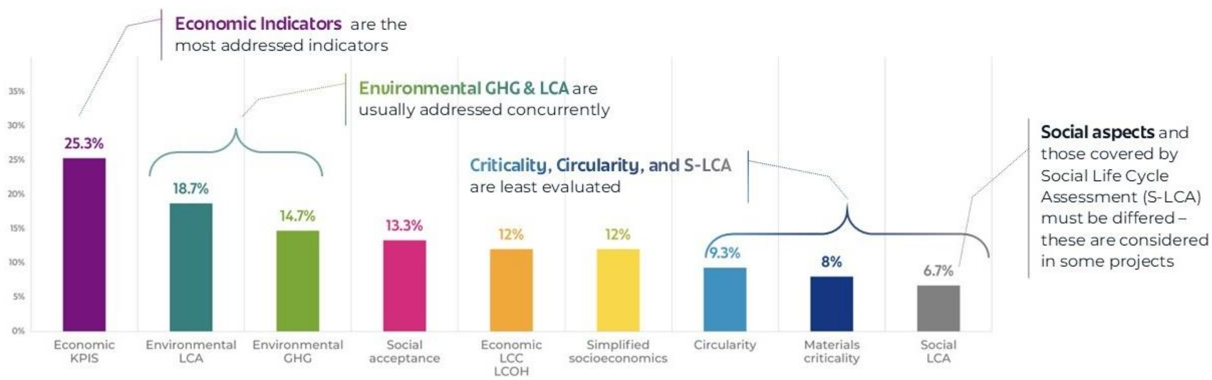
Figure 6 Project screening results for H2 end uses



Cross-cutting activities

Cross-cutting projects, which include regulatory frameworks, pre-normative research, and knowledge dissemination, showed the weakest integration of S&I indicators. Economic KPIs were again the most prevalent (addressed in 25.3% of projects), while environmental LCA (18.7%) and GHG emissions (14.7%) were considered in a limited number of cases (Figure 7). Social acceptance was incorporated into 13.3% of projects, though S-LCA remained largely absent at just 6.7%. Notably, circularity and material criticality (both essential components of sustainable hydrogen systems) were among the least assessed indicators in this category, appearing in just 9.3% and 8.0% of projects, respectively. This finding highlights a critical gap in the broader governance and regulatory ecosystem supporting hydrogen sustainability.

Figure 7 Project screening results for H2 cross-cutting activities



Key takeaways

The project screening showed that economic considerations continue to dominate Clean Hydrogen JU-funded projects, while S&C remain inconsistently addressed. Environmental factors, particularly LCA and GHG emissions, have gained traction in some areas but remain secondary to cost considerations. Circularity and material criticality are underdeveloped, particularly in production and cross-cutting activities, where their integration is minimal. Social sustainability is the most neglected aspect, with social LCA, socio-economics, and public acceptance largely absent from project frameworks. Moving forward, strengthening sustainability reporting requirements, embedding circular economy principles more systematically, and prioritising social impact assessments will be essential to advancing a truly sustainable and circular hydrogen economy.

The evolution of S&C integration into Clean Hydrogen JU funding Programmes

The analysis of the 356 funded projects over the three funding phases – FP7 (2008–2013), Horizon 2020 (2014–2022), and Horizon Europe (2022–2024) – shows that the integration of S&C principles within Clean Hydrogen JU funding programmes has evolved significantly over three major funding phases. Initially, research and innovation efforts focused on advancing hydrogen technologies primarily through efficiency improvements and cost reduction, with limited attention to environmental and resource considerations. As the understanding of hydrogen's role in achieving climate neutrality deepened, so did the requirements for projects to incorporate LCAs, GHG emissions reduction targets, circularity strategies, and social impact evaluations. The latest funding cycle under Horizon Europe has further reinforced these principles, introducing quantified KPIs for CRM reduction, end-of-life strategies, and sustainability-by-design frameworks. Figures 8-11 illustrate this trajectory and highlight the increasing complexity and ambition of sustainability requirements across four key areas: hydrogen production, storage and distribution, end-uses, and cross-cutting areas.

Hydrogen production – a progressive integration of S&C criteria

In the FP7 period (2008–2013), hydrogen production research was largely driven by cost and performance objectives, with sustainability considerations playing a secondary role. Technologies such as alkaline electrolysis (AEL), solid oxide electrolysis cells (SOEL), and biogas reforming were prioritised. It wasn't until

2010 that LCA requirements were introduced, specifically for large-scale AEL projects, following the publication of the HyGuide methodology[8]. By 2012, projects were required to assess catalyst availability and recyclability, marking the first attempt to integrate resource efficiency criteria.

Under Horizon 2020 (2014–2022), sustainability requirements became more structured. In 2014, the first carbon footprint intensity assessments for hydrogen production were introduced. The CertifHy certification[9] scheme, established in 2016, provided a framework for defining renewable hydrogen based on emission reduction criteria, aligning with broader EU climate goals. However, circularity remained underdeveloped, with only a few calls referencing material recovery. By 2019, the reduction of EU-defined CRMs became an explicit target, particularly in electrolysis systems. In 2020, minimum CO_2 reduction targets of 60% per kilogram of hydrogen produced were mandated, reinforcing the shift towards low-carbon emission hydrogen pathways.

With Horizon Europe (2022–2024), sustainability and circularity have become more central to the evaluation criteria. While initial calls in 2022 merely encouraged the inclusion of S&C aspects, 2023 introduced more specific KPIs, such as CRM content limits for electrolysis cells (<1.25 mg/W in PEM electrolysers, <0.3 mg/W in AEL electrolysers). The 2023 call for proposals also saw the launch of a flagship waste-to-hydrogen demonstration, directly embedding circular economy principles into hydrogen production. The most recent 2024 calls have further refined sustainability expectations. They emphasise LCA methodologies, CRM substitution strategies, and recycling efficiency targets and introduce social LCA (S-LCA) for the first time.

Hydrogen storage and distribution – increasing focus on circularity and efficiency

Hydrogen storage and distribution technologies initially focused on technical and economic feasibility, with sustainability playing a minor role. In FP7 (2008–2013), research concentrated on compressed and liquid hydrogen storage, pipeline transport, and hydrogen refuelling stations, with the first sustainability-oriented inclusion emerging in 2010, when an LCA requirement for liquefaction facilities was introduced. Social acceptance was briefly considered in 2011, in projects that assessed public perceptions of high-pressure hydrogen storage.

During Horizon 2020 (2014–2022), sustainability considerations expanded to include techno-economic feasibility assessments and material efficiency measures. In 2016, the first circularity requirements were introduced, mandating the use of non-CRM materials in hydrogen compression and purification technologies. The following years saw growing attention to underground hydrogen storage and liquid organic hydrogen carriers (LOHC), with requirements for waste heat recovery efficiency (>70%) and life cycle GHG assessments emerging in 2017.

Horizon Europe (2022–2024) has set clear sustainability KPIs for storage and distribution. Calls from 2023 introduced CAPEX limits for underground hydrogen storage (<€30/kg H_2 stored in salt caverns, <€5/kg for depleted gas fields) and efficiency targets for liquid hydrogen containment, including boil-off minimisation. Sustainability aspects of compression technologies have also gained traction, with structured requirements for recyclability and CRM substitution. These advances are supporting hydrogen infrastructure development with long-term decarbonisation and circularity objectives.

[8] FC-HyGuide (2011) Guidance Document for performing LCAs on Fuel Cells and H_2 Technologies.
[9] See here: https://www.certifhy.eu/ngc-certification/.

Hydrogen end-uses – expanding beyond efficiency and cost

Hydrogen end-use applications, particularly in mobility, power generation, and industrial processes, have historically been evaluated based on economic feasibility and technical performance. During FP7 (2008–2013), the emphasis was on fuel cells for transport and industrial applications, with sustainability considerations largely absent. Horizon 2020 introduced LCA and CO_2 footprint assessments for hydrogen-powered mobility in 2016, followed by efficiency benchmarks for refuelling stations and industrial hydrogen applications in 2019.

Under Horizon Europe (2022–2024), end-use applications must now incorporate resource efficiency, recyclability, and social impact assessments. Calls from 2022 required hydrogen end-use projects to outline circularity strategies, although the methodologies remained vague. In 2023, KPIs for CRM reduction in fuel cell manufacturing were introduced, alongside new requirements for public perception studies and stakeholder engagement. The 2024 calls expand these expectations, introducing the reduction in the use and increase in recycling of CRMs, and the improvement in the quality of Life Cycle Assessments.

Cross-cutting themes – embedding S&C into hydrogen governance and standards

Beyond technology development, the Clean Hydrogen JU has progressively strengthened S&C across regulation, policy frameworks, and capacity building. FP7 laid the groundwork with the HyGuide methodology (2010), setting initial guidelines for LCA. Horizon 2020 expanded on this with pre-normative research on sustainability methodologies, including circularity assessments and eco-design principles. By 2020, dedicated funding calls focused on standardising sustainability reporting and enhancing transparency in hydrogen project evaluations.

Horizon Europe continues to reinforce these principles, with 2023 and 2024 calls mandating structured sustainability reporting frameworks. The most recent calls emphasise harmonised data transparency, the development of sustainability KPIs across all hydrogen value chains, and open-access repositories for sustainability performance metrics. These measures are meant to help ensure the accountability and comparability of hydrogen projects for a more robust governance structure of Europe's hydrogen economy.

Conclusions on the overall trend

Overall, the findings show that early research prioritised technical and economic feasibility, with later funding cycles progressively integrating S&C principles and culminating in the structured, KPI-driven approach of Horizon Europe. Figures 8-11 below illustrate this evolution and demonstrate the increasing scope and complexity of S&C requirements across the hydrogen value chain. Moving forward, the full integration of S&C criteria will require improvement through clearer enforcement mechanisms, transparent reporting, and harmonised methodologies. These efforts will be key to positioning hydrogen as a truly sustainable pillar of Europe's clean energy future.

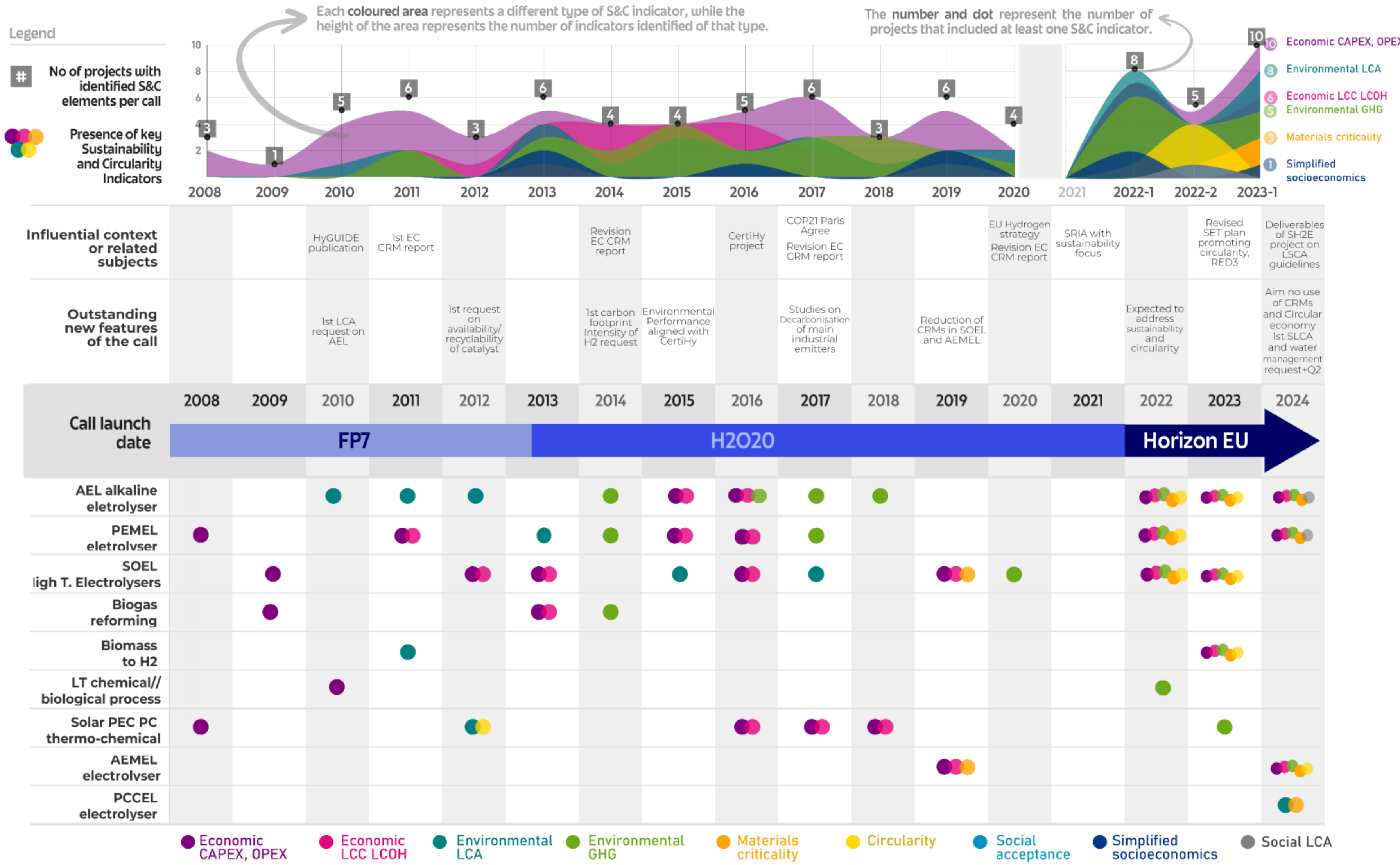


Figure 8 Analysis of the inclusion of S&C in the Clean Hydrogen JU AWPs for H2 production

Figure 9 Analysis of the inclusion of S&C in the Clean Hydrogen JU AWPs for H2 distribution and storage

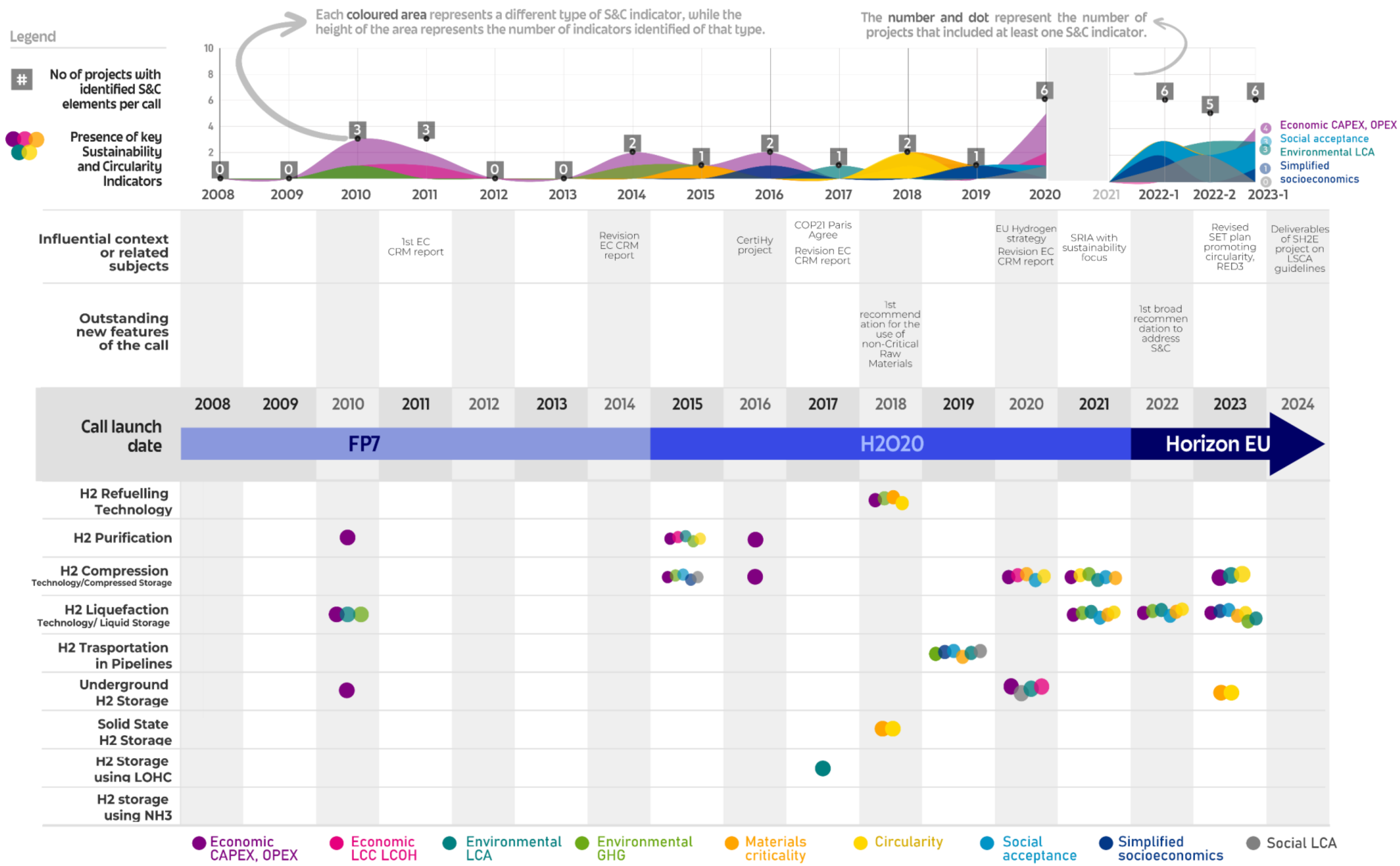


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Figure 10 Analysis of the inclusion of S&C in the Clean Hydrogen JU AWPs for H2 end-uses

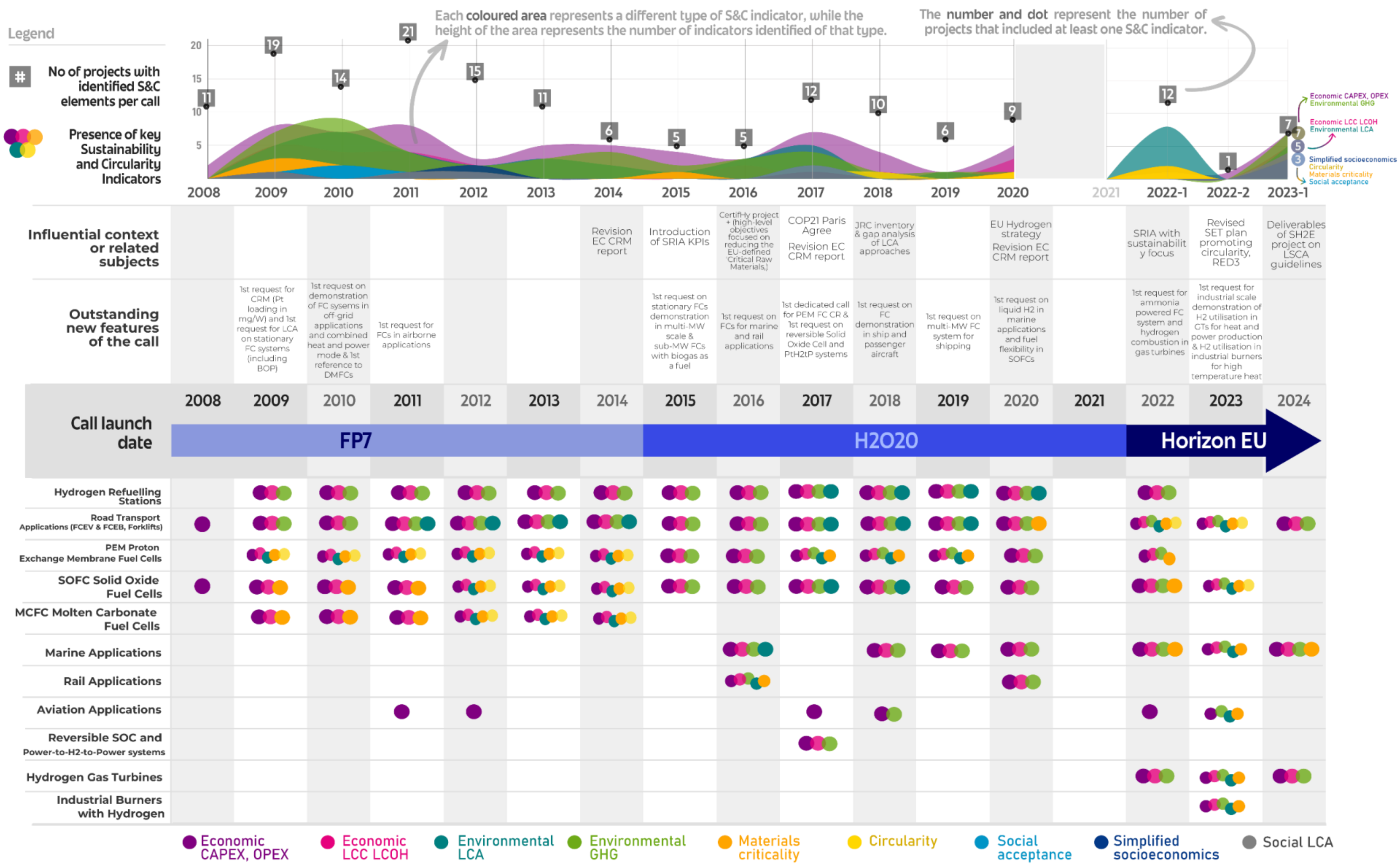
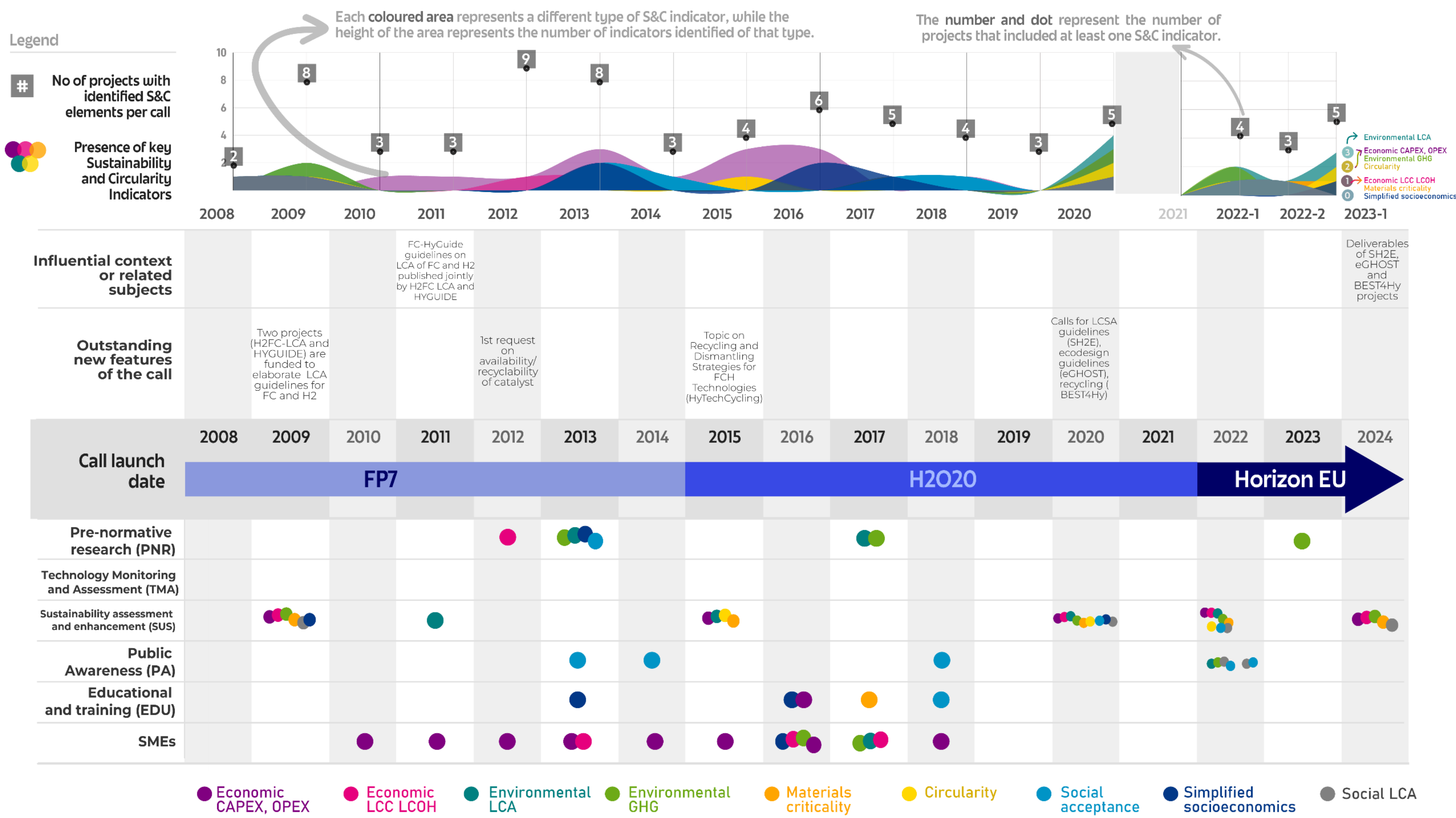


Figure 11 **Analysis of the inclusion of S&C in the Clean Hydrogen JU AWPs for H2 Cross-cutting topics**



3. Looking forward: Recommendations to further integrate sustainability and circularity

To further integrate the S&C into the Clean Hydrogen JU, the EHS&CP has identified four key areas of attention: data collection and assessment, project-level support, programme-level integration, and communication. Strengthening these areas through targeted activities by the panel and the JU will enhance decision-making and project and programme implementation while ensuring that hydrogen technologies deployment aligns with sustainability goals and circular economy principles.

Strengthening data collection and assessment

Access and delivery of good-quality information is the basis to ensure that sustainability is appropriately addressed. Therefore, reliable data collection is key to measuring the integration of S&C into hydrogen projects. In the future, the EHS&CP should further focus on harmonising reporting methods and improving data transparency. Recommendations to achieve this include:

- Ensure the availability of common databases and S&C indicators to facilitate the assessment of S&C for different project types based on their Technology Readiness Levels (TRLs) and hydrogen value chain segment.
- Support the development of common assessment methodologies with predefined contextual parameters and benchmarks, which will allow for harmonised assessments and comparability of results.
- Improving data quality and comparability through knowledge sharing facilitated by templates, guidelines and trainings, thereby enabling projects to integrate better data collection and assessment methodologies.

Supporting S&C at the project level

To maximise the impact of project outcomes concerning sustainability and circularity, it is important to help project owners to integrate S&C into their initiatives. The EHS&CP should focus on capacity building, practical guidance and knowledge sharing, such as:

- Encouraging data availability and public deliverables while balancing confidentiality. Ensuring Clean Hydrogen JU-funded projects prioritise transparency for S&C-related documents to facilitate knowledge-sharing and, where needed, prepare both public and confidential versions of documents.
- Develop benchmarking case studies based on exemplary Clean Hydrogen JU-funded projects, providing benchmarks for the integration of S&C and facilitating life cycle sustainability assessments.
- Review achievements in S&C integration by identifying impactful projects to extract lessons and disseminate best practices among other projects.
- Capacity and capability development through training sessions and workshops offered to project owners to equip them with the necessary skills to consistently apply S&C methodologies.

Embedding S&C at the programme level

At the programme level, the definition of common actions and coordination among the multiple stakeholders would allow the Clean Hydrogen JU to take strategic actions to standardise sustainability measures, optimise funding calls, and strengthen collaboration on S&C. Actions to facilitate this include:

- Enable S&C integration across the programme by supporting the development of a central knowledge repository and the optimisation of call topics to incorporate mandatory S&C deliverables for higher TRL projects, and aligning these with EU policy goals.
- Intensify collaboration with key stakeholders, including the JRC, EU policymakers, and industry leaders, to prevent duplication of efforts in developing sustainability assessment methodologies and support agenda-setting, driving a unified approach to sustainability.
- Capacity building and strategic guidance for Clean Hydrogen JU staff to support them on emerging S&C trends and tools, and optimise funding allocations towards S&C.
- Support long-term programme innovation by reviewing the results of current programmes and exploring new deliverables on sustainability, as well as incentives such as public recognition through awards on sustainability for projects that exceed sustainability benchmarks.

Enhancing Communication and Visibility

For S&C principles to be widely understood and implemented, the EHS&CP suggests prioritising stakeholder engagement and public outreach in particular through:

- Acting as ambassador and enhancing the visibility of S&C principles by, for example, attending high-profile events as the European Hydrogen Week and regularly developing public reports on advancing S&C in hydrogen.
- Regular communication deliverables, including annual reports, white papers, and educational materials, should explicitly highlight progress on S&C initiatives within the Clean Hydrogen JU.
- Contributing to the recognition of progress and achievements through awards for outstanding projects, best practices, and explicitly highlighting progress on S&C.
- Supporting the harmonisation of terminology around hydrogen S&C and mainstreaming it to improve understanding among key actors and highlight the relevance of both sustainability and circularity as an integral part of it.

Implementing these recommendations will help to advance S&C as one of the fundamental pillars of hydrogen deployment within the Clean Hydrogen JU and potentially the EU hydrogen economy. The next iteration of the EHS&CP can significantly contribute to building a truly sustainable hydrogen economy by implementing these recommendations

A message from the EHS&CP

Hydrogen technologies are essential for the European Union (EU) in its pursuit of climate neutrality by 2050, as outlined in the European Green Deal, and in enhancing energy security through the RepowerEU initiative by diversifying energy supply and by maximising the effective utilisation of intermittent regional renewable energy sources.

Renewable low-carbon hydrogen is an important means for decarbonising hard-to-abate industries such as the metallurgical industry, refineries, fertilizers, and transportation. Incorporating hydrogen into a circular economy framework promotes environmental sustainability while fostering economic growth, job creation, and worldwide leadership in clean energy technology. Scaling up clean hydrogen technologies fosters energy systems innovation, infrastructure development, and cross-border collaboration. Sustainability and circularity in hydrogen production and usage ensures that resources are efficiently utilised.

Strengthening the holistic integration of economic, environmental, and social factors in hydrogen sustainability assessment is a demanding yet crucial task that requires consistency in S&C definitions, the adoption of comprehensive and innovative tools, and the advancement of scaling-up methods. A comprehensive, consistent and continuous tracking of Sustainability and Circularity aspects in hydrogen will be crucial to evaluating the effectiveness of framework programs in achieving Europe's sustainability targets and Green Deal commitments. The development of methodologies, indicators, and case studies to assess hydrogen technologies at different maturity levels is crucial for ensuring a thorough assessment.

Investing in training and public awareness is essential to enhance the sustainability and acceptability of hydrogen deployment. Equally important is promoting effective coordination and collaboration among value chain stakeholders, including innovative SMEs, to drive effective and inclusive progress in incorporating sustainability and circularity within the hydrogen sector.

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Photograph taken during the 3rd workshop of the EHS&CP, held in Brussels on January 21st 2025

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