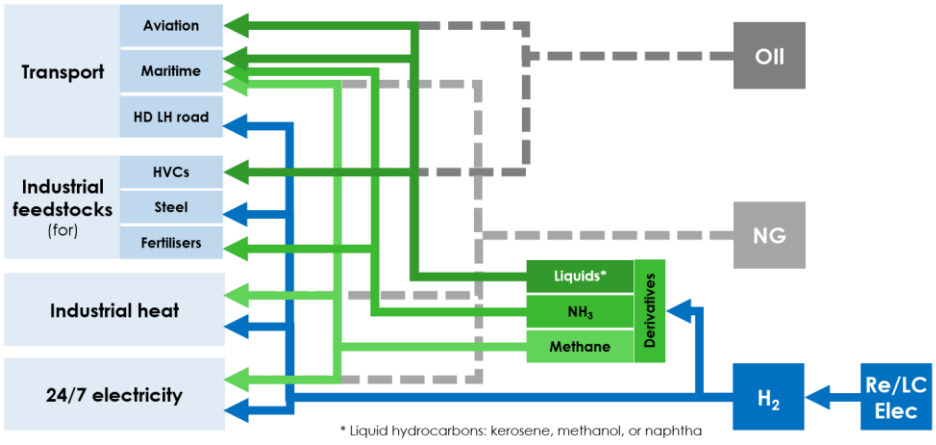
The role of R&I and Deployment in the European Hydrogen Strategy

A renewed, fit-for-purpose strategic R&I & deployment framework for Europe

1. UNLOCKING HYDROGEN'S POTENTIAL THROUGH COMPLETE VALUE CHAINS

Despite significant progress in R&I over recent decades, further advances are needed to improve the competitiveness of hydrogen technologies and enable their widespread deployment. Further advances are needed in performance, cost competitiveness, durability, efficiency, sustainability, material availability, recyclability and manufacturability, alongside continued scale-up towards GW-scale deployment. Addressing these challenges requires a renewed and **coherent R&I approach that combines near-term deployment of mature solutions with the development of next-generation technologies and progressively deeper integration across energy and industrial systems**. This is essential to preserve Europe's global technological leadership and translate it into sustained industrial competitiveness, avoiding a repetition of the photovoltaic sector's experience, where early European strengths did not translate into sustained manufacturing leadership.

Hydrogen R&I must also encompass derivatives such as synthetic fuels (e.g. e-methanol or sustainable aviation fuels) and chemical feedstocks such as ammonia to replace fossil-based products in applications that cannot be fully electrified. Leveraging hydrogen's full potential requires **moving beyond individual technology development to establishing complete clean-molecule value chains linking renewable and low-carbon energy, hydrogen production, derivative synthesis, transport, storage, distribution and end use**.



Simplified depiction of the new clean molecule value chains that need to be deployed for decarbonisation of the identified end-uses. The dotted lines represent existing transport infrastructure used for supply of the clean molecules (HVCs designates feedstock used for production of High Value Chemicals; HD LH road: long-haul heavy-duty road transport, NG: natural gas, Re/LC Elec: Renewable or Low carbon electricity).

Source: Draft report on "Strategic Research and Innovation Priorities for Competitive Hydrogen and its Derivatives" – to be published soon. Report prepared for the Clean Hydrogen Partnership by HINICIO and Technopolis France.

Priority value-chain configurations include **applications where clean molecules can substitute fossil fuels and feedstocks** while retaining much of the existing end-use equipment and infrastructure, as well as

those where direct hydrogen use, new derivatives or fundamentally different production routes require new technologies and delivery systems. These include value chains such as:

- clean hydrogen supply for industrial decarbonisation, including hydrogen-based steel production connected to pipelines and geological storage;
- clean fuel production and bunkering corridors for maritime transport;
- clean fuel supply chains for aviation;
- hydrogen supply, high-capacity refuelling infrastructure and vehicle fleets along major freight corridors;
- integrated supply of clean hydrogen and derivatives to industrial clusters; and
- long-duration molecular storage and conversion for dispatchable electricity.

Building on sustained support for hydrogen R&I over the past decades**,** Europe has significant strengths in research and innovation, engineering, safety, standards, industrial processes and midstream infrastructure. However, **these strengths have not yet translated consistently into deployment at scale**. Europe faces structural disadvantages in energy and engineering costs, manufacturing scale, deployment speed and supply-chain consolidation. A gap remains between successful R&I and demonstration and the delivery of manufacturable products, bankable projects, final investment decisions and repeatable commercial deployment. **An extended R&I agenda is crucial for supporting the full journey from research to industrial investment and deployment.**

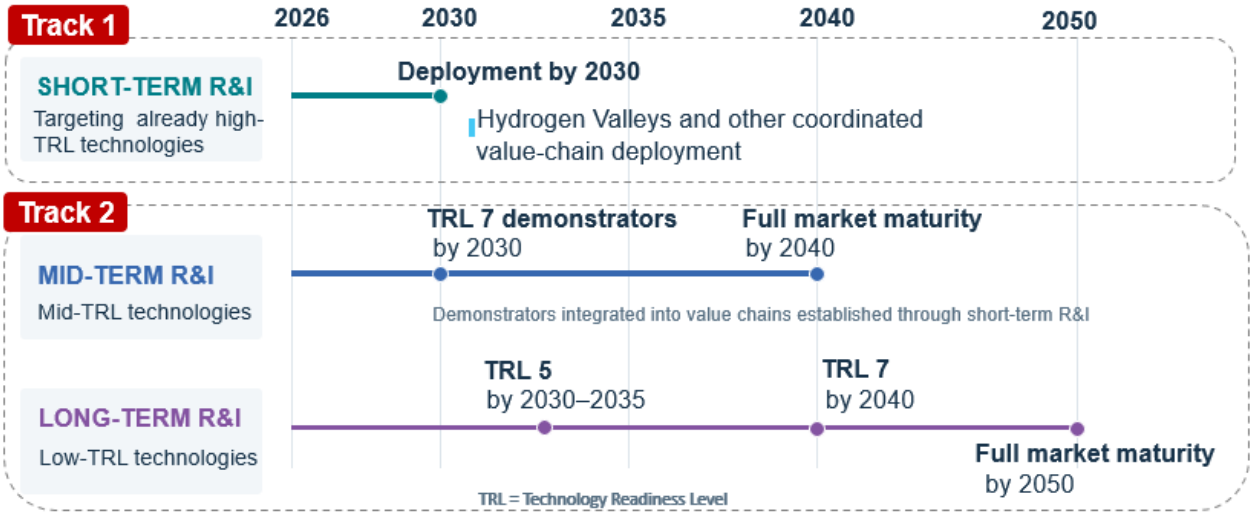
Since 2008, the **Clean Hydrogen Joint Undertaking** and its predecessors have helped advance hydrogen technologies from research and early prototypes to large-scale demonstration and initial commercial deployment across the whole value chain. This includes scaling up electrolyser capacity **from** tens **of kilowatts to hundreds of megawatts,** as well as establishing **the Hydrogen Valleys concept**, encompassing production, storage, distribution, and end-use applications at regional or transnational levels.

2. SUSTAINING EUROPE'S COMPETITIVENESS THROUGH A TWO-TRACK R&I APPROACH TO NEAR-TERM DEPLOYMENT AND LONGER-TERM INNOVATION

Deploying the necessary value chains requires R&I in different areas, including technology and products**,** system design and integration**,** implementation frameworks (such as safety standards and skills)**,** and value-chain deployment**.** This approach should combine R&I actions supporting the deployment of mature solutions (Track 1) with actions supporting the development of next-generation technologies (Track 2):

- **Track 1 accelerates the deployment of complete clean-molecule value chains using high-TRL technologies.** It supports deployment by 2030 through Hydrogen Valleys and other coordinated value-chain projects, with the objective of achieving measurable decarbonisation and industrial impact at scale by 2035. R&I should address the remaining barriers to commercial deployment: durability, reliability, qualification, manufacturability, technical bankability, interoperability, safety, maintainability and standardisation. It should also support the coordinated deployment of production, infrastructure and end-use investments, establishing the industrial base and operating systems into which next-generation technologies can progressively be integrated.
- **Track 2 develops the next generation of technologies and integrated systems.** It focuses primarily on mid- and low-TRL solutions that overcome the intrinsic limitations of incumbent technologies or enable

deeper integration across energy and industrial systems. Mid-TRL solutions target TRL 7 demonstration by 2030 and full market maturity by 2040. Low-TRL solutions follow a longer pathway, targeting TRL 5 by 2030–2035, TRL 7 by 2040 and full market maturity by 2050.



R&I Pathways to full market maturity

The two tracks are mutually reinforcing. Value chains established through **Track 1** provide the **industry base, infrastructure and market foundations** into which **Track 2 technologies can be progressively introduced**. As these technologies mature, they can replace or reconfigure individual system elements and enable deeper integration without requiring entirely new value chains to be built around them.

Deploying these value chains requires stable enabling conditions and sustained coordination among technology suppliers, infrastructure operators, end users, investors, public authorities and research organisations.

An institutionalised public–private partnership, implemented through a Joint Undertaking, provides shared public – private governance, long-term continuity and the dedicated mandated resources needed to coordinate these interdependent actors and investments. By aligning R&I priorities with industrial needs and EU policy objectives, and connecting European, national and regional support, it can avoid the otherwise unavoidable fragmentation and sustain the journey from technology development to coordinated value-chain deployment.

3. FROM R&I TO DEPLOYMENT AT SCALE:

3.1 MANUFACTURING AT THE CORE OF R&I: ENABLING INDUSTRIAL SCALE-UP AND DEPLOYMENT

R&I must develop hydrogen technologies together with the industrial capabilities needed to manufacture and deploy them at competitive cost. This requires **design for manufacturing**, integrating manufacturing requirements into product design from the outset, alongside the development of production equipment, processes, assembly methods and qualification capabilities. It must support both **scale-up**, increasing the capacity of individual systems and components, and **scale-out**, replicating proven units or modules, while preserving performance, quality and reliability.

Manufacturing-oriented R&I should develop the **equipment, tooling, production processes and assembly capabilities needed to manufacture and qualify larger-capacity components, stacks, modules and complete systems efficiently and reliably**. Alongside this scale-up effort, it should increase manufacturing output through greater automation, improved production yield and material efficiency, with **quality assurance** embedded throughout fabrication and assembly. In-line monitoring, factory testing and digital traceability should establish how manufacturing conditions affect operational performance and lifetime. Modular architectures, standardised interfaces and qualified alternative components should support scale-out through repeatable production and strengthen supply-chain resilience, while retaining the configurability needed for different applications.

R&I must also develop deployment and servicing methods alongside products and manufacturing processes. Where technically and economically appropriate, factory-integrated, tested and pre-commissioned modules should reduce onsite work and simplify installation and commissioning. Designs should accommodate maintenance, component replacement, repair, refurbishment, and recycling. Continuous feedback from production, deployment and operation should improve successive systems, helping European technologies progress from project-specific solutions to reliable industrial deployment.

Building on the hydrogen ecosystem that the Clean Hydrogen JU and its predecessors have developed since 2008, **an enlarged Partnership is uniquely positioned to prioritise and align R&I efforts with industry needs,** thereby enabling the scale-up **of manufacturing capacity and the deployment of technologies for hydrogen and its derivatives**.

3.2 ENABLING INVESTMENT-READY AND COMMERCIALLY VIABLE END-TO-END VALUE-CHAINS INCLUDING HYDROGEN VALLEYS

In addition to the above R&I framework, it is necessary to maintain **and reinforce strategic positioning of Hydrogen Valleys**, as they provide a framework for developing and deploying such value chains as integrated systems, bringing together hydrogen and derivative production, infrastructure and multiple end users around anchor demand. In doing so, they provide a practical context for coordinating the interdependent investments and activities required to establish complete value chains.

Their deployment faces two interconnected challenges: a **business-case gap**, where hydrogen production and delivery costs exceed offtakers' willingness to pay, and a **project-readiness gap**, where technical preparation, permitting, commercial agreements or financing arrangements are insufficiently advanced for final

investment decisions (FIDs). Projects are often brought forward for CAPEX/OPEX support before they are investment-ready, contributing to withdrawals and terminations even when funding is available. Assessing maturity, commercial viability and implementation risks is therefore essential.

Targeted support for development expenditure (DEVEX) is needed throughout the pre-FID phase, when expenditure is relatively limited compared with construction, but uncertainty and development risks remain high. Current support, including the valuable Project Development Assistance provided through the Hydrogen Valleys Facility, remains insufficient for demanding late-stage activities such as front-end engineering design (FEED), permitting, offtake negotiations and financial structuring. These require substantially greater technical and financial detail than early feasibility work and are particularly complex for interdependent Hydrogen Valley projects.

Closing this development funding gap—the "valley of death"—would strengthen the investment-ready project pipeline, while allowing weaknesses to be identified and projects revised or discontinued before substantial capital is committed. Combined with CAPEX and OPEX support addressing the commercial viability gap, **DEVEX support would provide continuity across the project lifecycle and accelerate deployment.**

The **Clean Hydrogen Joint Undertaking is uniquely positioned to link R&I funding under the post-2027 Framework Programme with project-development and deployment support, including DEVEX, under the envisaged European Competitiveness Fund**.

Furthermore, the JU could play a role in completing the investment journey by coordinating access to complementary EU, national and regional instruments for larger CAPEX and OPEX support.

This document is informed by the draft report "Strategic Research and Innovation Priorities for Competitive Hydrogen and its Derivatives", which will be published soon. This report is being prepared for the Clean Hydrogen Partnership by HINICIO and Technopolis France with the support of Independent External Experts.