



Unlocking the hydrogen economy — stimulating investment across the hydrogen value chain

Investor perspectives on risks,
challenges and the role of the public sector



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FOREWORD

Given both rapid and increasingly damaging climate change, the race to develop the clean, carbon-neutral energy carrier of the 21st century is on.

Hydrogen is among the technologies with the greatest potential to reduce global carbon emissions, especially in hard-to-abate industrial sectors, and thereby address our damaging impact on the planet's climate and ultimately our living conditions. Today hydrogen is predominantly produced from fossil fuels, yet there is a great opportunity to switch to lower-carbon methods based on "green hydrogen" produced with renewable energy.

The world has woken up to hydrogen's potential to make a substantial impact towards the "net zero" objective. In 2020 the European Union launched its European Hydrogen Strategy and similar plans were announced at national level — outlining ambitious goals to establish the infrastructure necessary for the widespread adoption of hydrogen as a clean energy carrier. Many projects are now in various phases of development across Europe. As the EU climate bank, we applaud these developments and stand ready to act.

However, like many technologies at a similarly early stage of development, deploying low-carbon hydrogen at scale brings significant challenges — economic, industrial and operational. The magnitude of investment that will be required over the coming decades is expected to run into the hundreds of billions of euros — which will require not only public support, but the full force of the financial sector and the relevant ecosystem of industrial players.

I am extremely pleased that the EIB's Advisory Services have actively engaged with key industrial and financial players across Europe to assess their appetite for investing in hydrogen-based technologies and the constraints they face. Armed with this understanding, we hope to identify ways to bring down these barriers and provide solutions.

This report outlines a view of what it will take to rally investors in support of hydrogen-based technologies and their enabling infrastructure. Support schemes such as market-making mechanisms that would provide clarity to both suppliers and users of hydrogen have great potential and I am greatly encouraged by the blueprint for such schemes that have already been launched.

Solutions will also include financial instruments, such as credit enhancement or risk-sharing schemes, to improve access to low-cost financing. In-kind advisory support will also play a key role in preparing large-scale demonstration projects, for example key Important Projects of Common European Interest (IPCEI) or "lighthouse" projects. I am confident that a combination of these measures can meaningfully accelerate the transition to low-carbon hydrogen at scale. It is hard to imagine a successful transition to the impending Industrial Revolution 4.0 without addressing the carbon emissions problem of earlier phases in our economic development.

Lastly, I would like to thank our colleagues at the European Commission for working with us on this initiative and for their sponsorship. We at the EIB stand ready to support hydrogen-based projects with advice and money in pursuit of the objectives of the European Green Deal.

Jean-Christophe Laloux, Director General, Head of Operations, European Investment Bank

EUROPEAN COMMISSION ENDORSEMENT

Hydrogen has the potential to store and distribute renewable energy and decarbonise hard-to-abate sectors in industry and transport. As a result, it is a key element to help achieve the European Green Deal and a clean energy transition in Europe.

The European Union is determined to be a frontrunner in developing a green hydrogen economy, in line with our climate neutrality and zero pollution long-term goals. To that end, we are committed to using the full range of EU funding and regulatory instruments.

Building on the hydrogen and energy system integration strategies launched under the European Green Deal in 2020, along with the creation of the European Clean Hydrogen Alliance and launch of a new Clean Hydrogen Joint Undertaking, the European Union is creating a robust framework aimed at spurring innovation and investments along the whole hydrogen value chain.

Hydrogen is an important component of the European Union's research and innovation agenda, with EU framework programmes having supported research and innovation activities on hydrogen for over a decade, in particular through the Fuel Cells and Hydrogen Joint Undertaking.

To enable the widespread use of clean hydrogen, public funding and private investment in research and innovation need further support to improve and test hydrogen technologies, before they can reach mass production and be successfully integrated into industrial value chains.

A good example is the green hydrogen pilot initiative launched in 2021 under the European Research Area, which aims to develop and implement a strategic research and innovation agenda for green hydrogen between the European Commission and EU Member States.

To galvanise investments in clean hydrogen in Europe, it is vital to map hydrogen's investment landscape in the region and identify regulatory barriers that investors may perceive as constraining their financial decisions.

This is why we have commissioned the study underlying this important report. By consulting key companies and investors operating across the hydrogen value chain (from production and transport to storage and key applications) and asset classes (venture capital, private equity, commercial banks), the report examines the current state of investment activity on hydrogen in the European Union.

Importantly, the report sheds light on risks and challenges perceived by investors, such as uncertainties related to the technical performance of hydrogen-based equipment. It also identifies potential levers that could be activated from a public financing and regulatory standpoint, in particular at EU level, to mitigate such risks and further drive investments in hydrogen.

This report carried out by the European Investment Bank in partnership with the European Commission represents an important step to take forward the European Union's hydrogen agenda. It will better equip policymakers in their efforts to strengthen and expand a sector of such strategic importance for Europe's decarbonisation, technological sovereignty and energy autonomy in the years to come. I would like to thank the Bank for this joint work and look forward to future collaboration opportunities.

**Jean-Eric Paquet, Director-General, European Commission,
Directorate-General for Research and Innovation**

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INTRODUCTION

This report highlights the key takeaways from an investor consultation with 46 market participants conducted by the European Investment Bank’s Advisory Services at the request of the European Commission, under the InnovFin Advisory initiative.

This study is based on a consultation with financial investors, industrial companies and experts active across the hydrogen sector. It aims to provide insight and understanding regarding the key priorities driving the market. The results serve as a basis to support the European Commission’s development of an investment agenda for hydrogen in the context of the European Green Deal and Horizon Europe.

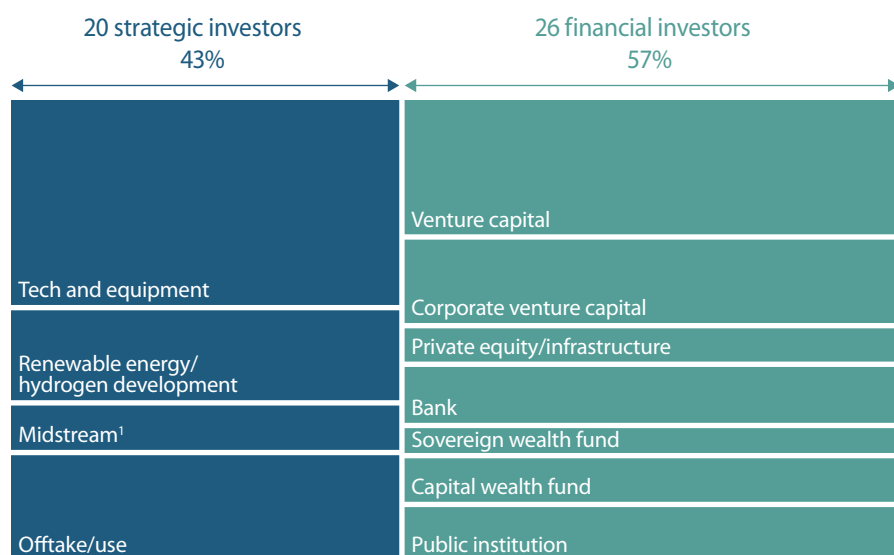
Following a market mapping exercise, a representative sample of 46 players were consulted through semi-structured interviews aimed at understanding their investment strategies for hydrogen, their perceived challenges and constraints, and their views on how to unlock the development of hydrogen as a mass-scale solution to reducing greenhouse gas emissions.

A digital questionnaire was shared with respondents to facilitate the quantitative evaluation of responses. The sample included 20 industrial companies across the hydrogen value chain and 26 financial investors across multiple asset classes spanning early-stage innovation financing and later-stage infrastructure financing. Figure 1 provides an overview of the sample composition.

This report translates the key feedback collected through this process, articulated in key findings and recommendations. Forward-looking views and recommendations expressed by participants are supplemented, where appropriate, with the perspective of the European Investment Bank’s Advisory Services.

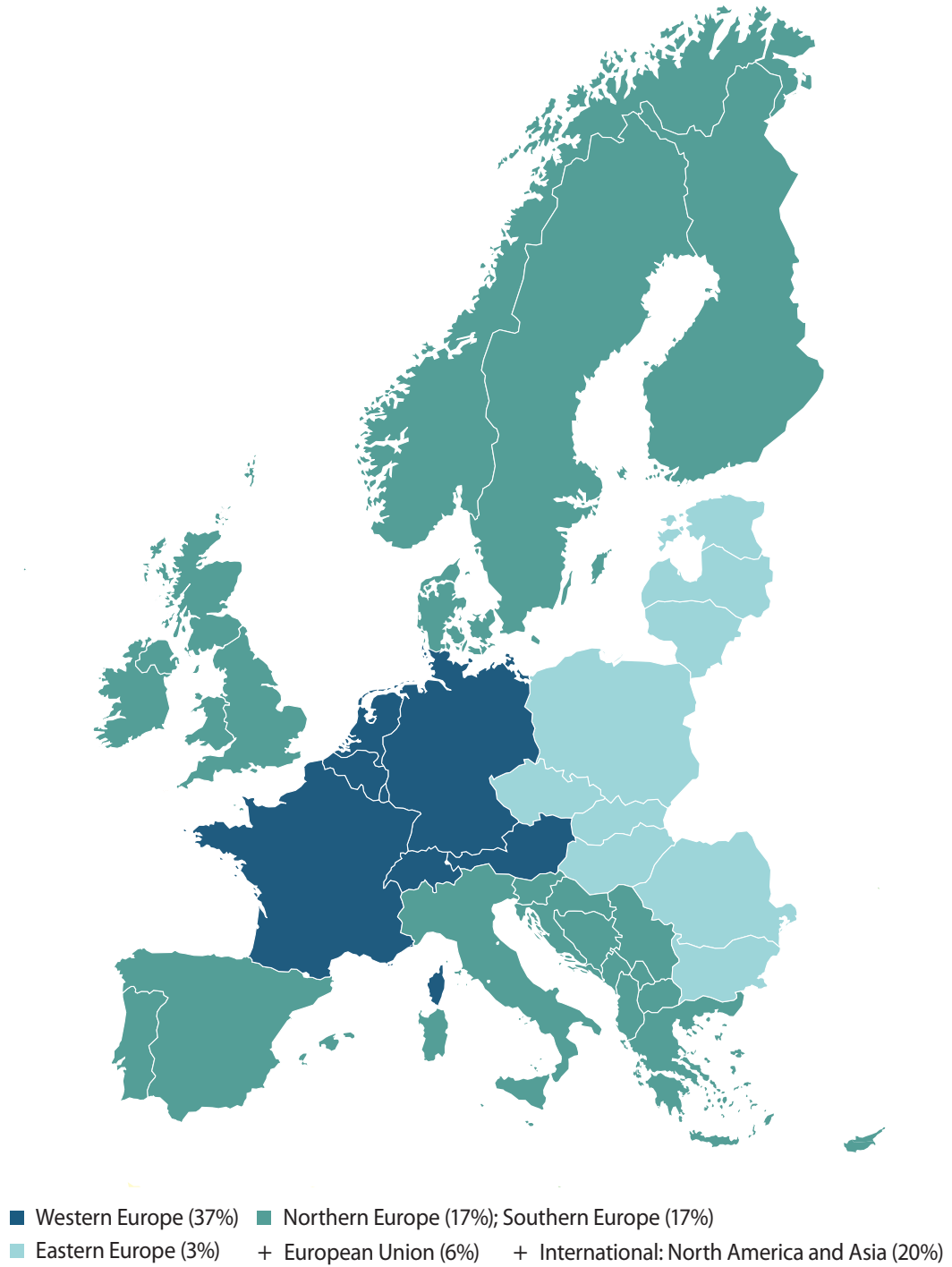
Figure 1a: Sample Description – Type and Geography of Investors Interviewed

Breakdown of participants by specialisation



¹Transport, storage and distribution.

Figure 1b: Sample Description – Type and Geography of Investors Interviewed
Breakdown of companies across geographies



HYDROGEN — STATE OF PLAY

European investors expect hydrogen to play a key role in decarbonising EU economies, especially in energy-intensive sectors where decarbonisation has been particularly challenging. Hydrogen’s unique properties can enable sustainable energy innovation.

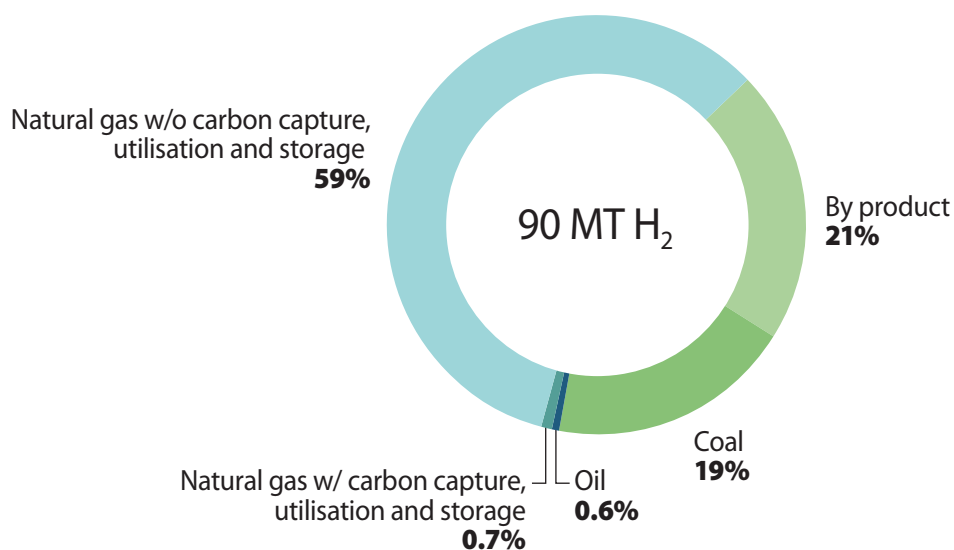
Hydrogen is the most abundant chemical substance in the universe. When isolated in its pure form (dihydrogen, or H₂), it has a number of physical properties that make it useful in contexts where energy needs to be used, stored or transferred. Hydrogen combustion does not produce CO₂ or any other greenhouse gas. Hydrogen is already in use in sectors such as petrochemical refining and fertiliser production. In the future, hydrogen could also play a useful role in decarbonising energy-intensive industrial sectors such as steel production and act as a buffer for intermittent renewable power sources. Hydrogen can also provide energy for fuel cell electric vehicles and decarbonise heating applications.

Production Methods

Today, the vast majority of hydrogen is produced via methods that release carbon emissions (“grey” hydrogen) from coal or natural gas-based processes — as Figure 2 illustrates.

Importantly, alternative methods exist to produce the molecule with limited or near-zero emissions. For example, the process of electrolysis can separate hydrogen from water and, if based on renewable electricity, can produce renewable hydrogen without emitting carbon (i.e. “green” or “renewable” hydrogen). To date, renewable hydrogen production remains expensive in most cases and dependent on the availability and cost of renewable electricity.

Figure 2: Overview of global hydrogen production sources in 2020; source: IEA (International Energy Agency)¹



Source: IEA. All rights reserved

¹ <https://iea.blob.core.windows.net/assets/e57fd1ee-aac7-494d-a351-f2a4024909b4/GlobalHydrogenReview2021.pdf>

Another method of low-carbon hydrogen production (i.e. “blue” hydrogen) utilises existing fossil-based production processes, while capturing most of the emissions. Nevertheless, there are concerns about the sustainability of this type of hydrogen, since investing in this technology could “lock in” carbon-intensive infrastructure and crowd out the rapid scale-up of green hydrogen².

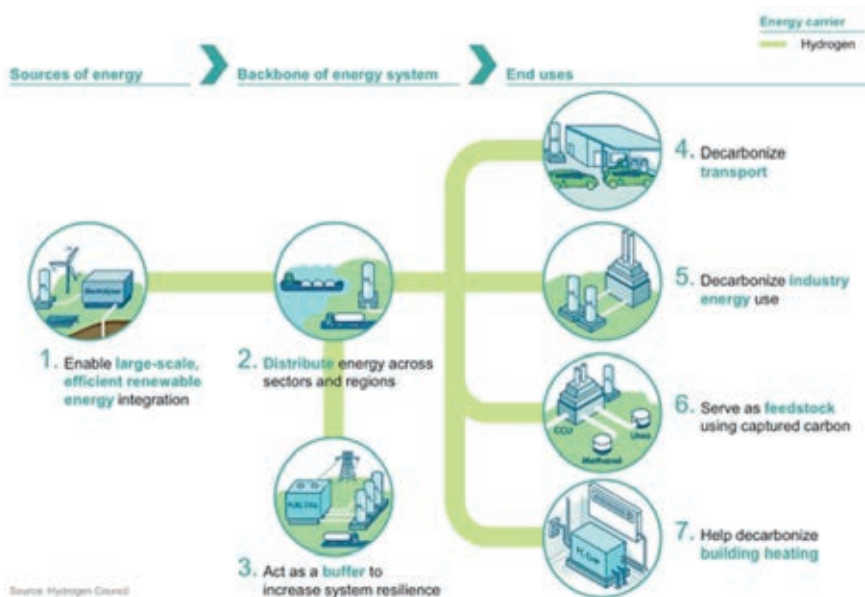
Terminology

Following the terminology used by the market representatives consulted throughout this report, the term “low-carbon hydrogen” encompasses green hydrogen (also referred to as “renewable” or “clean”) and low-carbon blue hydrogen (i.e. fossil-based hydrogen with carbon capture).

Green Deal Objectives

Given its physical properties as an energy carrier, hydrogen is expected to play a key role, alongside renewables, in Europe’s energy transition. For instance, hydrogen is emerging as a solution to decarbonise certain hard-to-abate industrial processes such as the production of chemicals or steel, and also long-distance or heavy transport applications where range and refuelling times matter. Hydrogen could also play a role in the power sector and support certain heating applications. The key uses of hydrogen are summarised in the figure below.

Figure 3: Overview of hydrogen applications; source: Hydrogen Council



Source: Hydrogen Council

In order to realise this potential and contribute to the objectives of the European Green Deal for carbon neutrality by 2050, substantial investment will be required to scale up hydrogen infrastructure and promote further innovation. This should help to lower costs and facilitate the adoption of hydrogen across the energy system.

² See: <https://climateanalytics.org/publications/2021/why-gas-is-the-new-coal/>

To achieve the European Union's hydrogen strategy, €24-42 billion of investment will be needed by 2030 in European electrolyser capacity alone.

EU Hydrogen Strategy Targets

The EU hydrogen strategy recognises the importance of developing a clean hydrogen economy and aims to install six gigawatts of electrolyser capacity by 2024, scaling up to a total of 40 gigawatts by 2030. To achieve these goals, Europe will need to invest a cumulative amount of €24-42 billion in electrolysers alone by 2030. Together with the additional investment that will be required in renewable energy capacity, transportation and storage infrastructure and hydrogen applications, the total funding required by 2030 is in the range of hundreds of billions of euros. Future regulation could also further stimulate demand and increase funding needs in the hydrogen sector.

By mid-century, the cumulative investment needed in hydrogen production capacity in the European Union could be as high as €470 billion. The funding committed to hydrogen projects today, however, remains relatively low due to a number of hurdles and uncertainties, in terms of economic competitiveness, regulatory clarity, financing availability and lack of supply chain maturity among others.

Project Development and Investment State of Play

Particular efforts at EU level towards the development of hydrogen projects have been ongoing since the launch of the EU hydrogen strategy. The European Clean Hydrogen Alliance was launched to mobilise players across the hydrogen value chain for the development of a pipeline of projects. In November 2021, a list of 750 projects was released as a result of the work of Alliance members, comprising production, midstream and application-level projects across Europe.

In parallel, a process to identify **Important Projects of Common European Interest (IPCEI)** was launched in December 2020 to identify major projects and provide a basis for public support that goes beyond normal state aid limitations. Work is still ongoing to select projects and allocate funds.

Some of the projects emerging from these initiatives are large-scale, cross-value chain projects involving several regions or countries. Such ambitious developments are important because they present an opportunity to create more viable end-to-end hydrogen ecosystems. Some of these have been labelled "**lighthouse**" projects. While the challenges described in this report apply just as well to these large and complex developments, attention to their success is critical for the mainstream development of hydrogen at scale.

Overall, project promoters have announced more than €130 billion of investment in hydrogen in the European Union to date. However, out of the 23 gigawatts of electrolyser capacity to be installed by 2030, only 350 megawatts (less than 2%) are linked to projects that are currently underway or for which a final investment decision has been made.

The environment for financing investment in hydrogen remains challenging due to a number of issues. Given these challenges and the magnitude of the investment required to develop a hydrogen economy in the European Union, it is crucial to understand the perspective of investors and the factors that will help allocate market financing to hydrogen projects and increase the impact of public resources dedicated to hydrogen's development. The following chapters detail the market's feedback on these issues and views on potential solutions.



KEY INTERVIEW FINDINGS

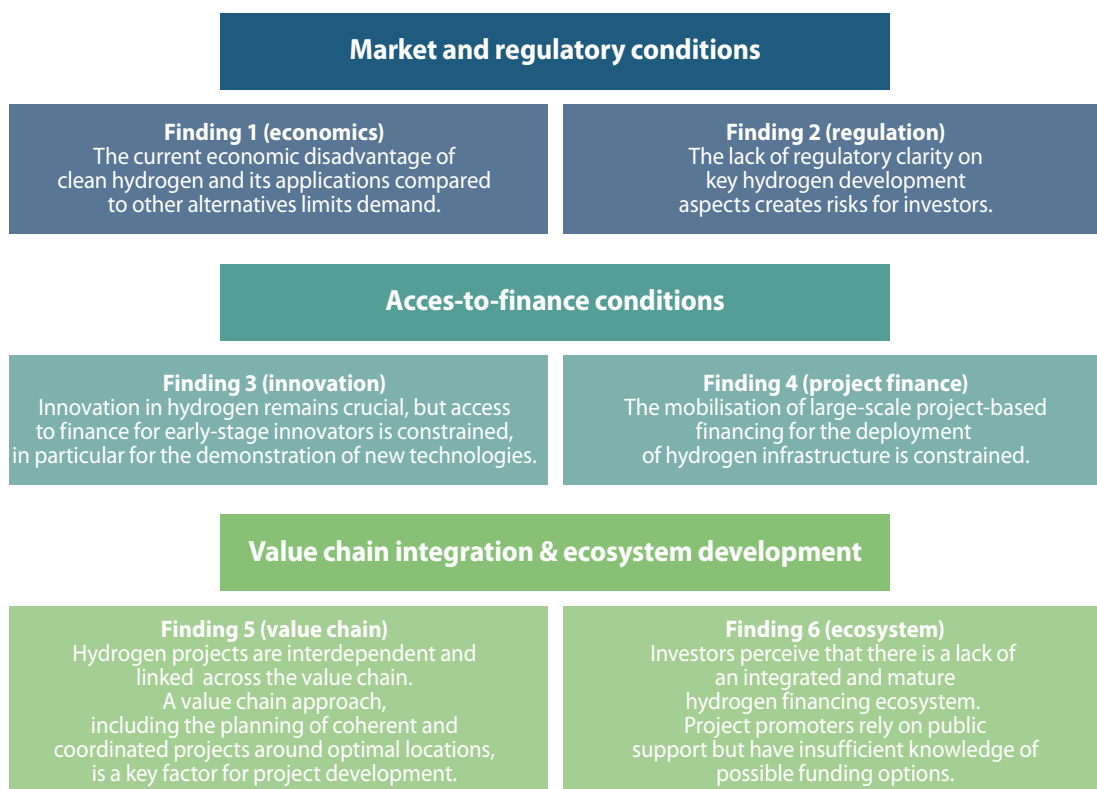
Investor interest in hydrogen has risen substantially in recent years but investment activity in renewable and low-carbon hydrogen projects has been constrained by a combination of risks and challenges. If unaddressed, these could hinder the investment and project development needed to achieve the targets of the European Green Deal and the European Union's hydrogen strategy.

All 46 investors consulted in this study acknowledged the potential of hydrogen and its importance as an investment opportunity. The majority of investors consulted have already announced specific internal initiatives or developed strategies to approach this opportunity.

At the same time, investor feedback also clearly underlines that significant risks and challenges exist and need to be addressed in order to make investment possible.

Based on the consultation, this report focuses on the key forces that are at work across six key findings:

Figure 4: Overview of findings across key dimensions



The following sections provide details on each of the six findings.

CHALLENGING ECONOMIC CONDITIONS

Finding 1

The current economic disadvantage of low-carbon hydrogen and its applications compared to other alternatives limits low-carbon hydrogen demand.

The main barrier to the hydrogen market's development is the fact that low-carbon hydrogen and its applications are currently relatively expensive compared to existing alternatives. Without compensating mechanisms, the current cost gap (or "green premium") of low-carbon hydrogen limits investors' ability and willingness to invest in projects.

Optimising resources across the value chain to bridge the cost gap

The economics of hydrogen were equally cited by the majority of investors, including early-stage players considering investment in hydrogen technologies, as the main barrier to investment. This economic disadvantage can be attributed to the lack of economies of scale; higher production, transport, storage and application costs; and the insufficient monetisation of avoided carbon emissions. The current cost gap for the production, transport and use of low-carbon hydrogen is thus the primary constraint to making hydrogen business models work. Indeed, investor feedback indicates that the economic gap, which reduces returns on investment, is present across practically all areas of the low-carbon hydrogen value chain:

- The production of renewable and low-carbon hydrogen remains more expensive than existing grey hydrogen production approaches. In the case of renewable hydrogen, this cost differential is mainly attributable to the cost of clean electricity and the cost of electrolyser equipment.
- Limited access to low-cost means for transporting and storing hydrogen through pipelines, liquefaction, or hydrogen carriers adds substantially to the final cost of hydrogen.
- Across applications, the lack of scale and maturity of technologies also keeps costs high. For example, the use of hydrogen in steelmaking is found to add significant costs to the process and the cost of fuel cell vehicles also remains higher than existing alternatives.

The relatively high costs associated with hydrogen are prompting some investors to seek partnerships for their first projects. The high costs also encourage promoters to locate projects close to abundant, low-cost sources of renewable energy and in proximity to customers in order to lower or avoid transport costs. These measures, however, are often still insufficient to overcome the economic gap for initial deployment initiatives.

Investors demand a supportive ecosystem

The view of the investors consulted is that a robust support ecosystem is indispensable to bridge the hydrogen cost gap. This is seen as critical to supporting the adoption of hydrogen technologies, especially in the early stages of growth. Investors called for clearer public support mechanisms that create long-term visibility and positive returns, enabling them to approve projects based on their financial and economic merits.

While bridging the economic gap is a key consideration, many players also pointed to the need for measures that level the playing field in a way that is consistent with the European Union's aim of reducing carbon emissions, for instance through some form of carbon levy that would help put a value on the positive externalities of lower-carbon hydrogen initiatives.

Investors also commented on the incomplete and fragmented offering of public support mechanisms for hydrogen projects. Schemes differ greatly between sectors and regions, or are in some cases non-existent. This calls for more integration of public support, including from a value chain management perspective.

Lastly, investors pointed out the lack of financial support for operating costs among available instruments. In the case of hydrogen, a lack of financial support for operating costs can be particularly challenging because production of the molecule is in certain cases reliant on operating expenditure (for instance, purchasing grid electricity to power electrolyzers) versus capital expenditure (for instance, building dedicated renewable infrastructure for the same purpose).

Scaling must be accelerated to decrease costs

While the economic gap is a significant short-term obstacle, investors recognise the potential impact for economies of scale to drive down costs over time, as well as the need to collaborate closely with other players across the value chain in the development of large-scale projects. This type of multi-party collaboration is primarily aimed at ensuring more efficient infrastructure deployment than would otherwise be achievable.

Furthermore, significant cost reductions can only be achieved through industrialisation and through the expansion of production capacity. However, investors agreed that the current levels of industrialisation and production capacities are insufficient to achieve the deployment targets set out in the EU hydrogen strategy.

There is a need for demand-creation mechanisms

Compounding the challenge, hydrogen business models often need to be integrated into complex value chains. As a result, investors fear that projects may not be viable in the near term without broad adoption and demand for hydrogen across the full value chain. For investors, this calls for measures to boost demand for hydrogen and market uptake of products produced with hydrogen versus more carbon-intensive production methods.

High valuations create barriers to entry

Beyond project economics, high capital market valuations in the hydrogen space indicate strong market demand for innovation. High valuations have been mentioned as a barrier to entry for smaller venture capital investors, who find it difficult to come up with such funding. Investors also expressed concerns about the potential for market valuation corrections in the sector, which could disrupt the current momentum and discourage further investment activity.

NEED FOR SUPPORTIVE REGULATION

Finding 2

A lack of regulatory clarity on key hydrogen development aspects creates risks for investors.

The hydrogen sector depends on multiple regulatory frameworks across the value chain and throughout European regions, on which investors lack clarity. A supportive and streamlined regulatory framework could increase investor confidence.

More than half of the investors interviewed, including all the participating venture capital investors, mentioned the importance of a supportive and streamlined regulatory framework and regulatory transparency. Because of the complexity of the hydrogen value chain, it is important to have clarity on the future regulatory treatment of hydrogen.

Regulatory issues have a direct economic impact on hydrogen projects, making the planning of large-scale hydrogen projects difficult for investors. Key points raised by market players include:

EU taxonomy

EU taxonomy developments are still ongoing. In the case of hydrogen, some technical and methodological uncertainties remain. In addition, the question of taxonomy compliance vs. public support eligibility still remains open for investors.

Guarantees of origin

A legal framework is needed for guarantees of origin linked to the carbon content of hydrogen production methods. This would help to monetise a green premium for clean hydrogen.

Additionality requirements

There are uncertainties related to additionality requirements for renewable energy (how much dedicated renewable energy infrastructure should be added alongside hydrogen production projects). The general requirement for additional renewable energy appears to be well understood by investors but uncertainties remain nevertheless — in terms of both emission calculation approaches and specific criteria used to define what is to be considered as additional renewable energy. Investors also pointed to a lack of an integrated strategy on sector coupling between hydrogen and electricity.

Technical and safety standards

There is a lack of clarity related to technical and safety standards, particularly for the transport and storage of hydrogen (e.g. standardisation of storage and dispensing pressures).

State aid

State aid rules constrain the ability of the public sector to effectively bridge the economic gap between hydrogen and existing alternatives.

Investors look for a harmonised approach at the European level

In line with the above comments, investors also expressed concerns about the lack of harmonisation of support mechanisms and policies across the European Union potentially triggering uneven economic conditions for investors in different locations. Such differences could create complexity for players operating across multiple countries and limit the proper functioning of cross-border hydrogen markets. Early-stage investors pointed to relevant case studies from abroad, in particular California's Low Carbon Fuel Standard (LCFS), which includes grants, matching public funds, a credit system, auctions and hydrogen project development targets.

The question of renewable versus low-carbon hydrogen

The question of carbon content and eligibility for support measures stands out as critical for many investors. The investors consulted included companies interested in investing in renewable hydrogen only, as well as technology-agnostic companies (i.e. those interested in investing in renewable and low-carbon hydrogen).

Ten out of the 11 early-stage investors were open to investing in both renewable and non-renewable hydrogen, depending on market developments and economics. Of the 35 late-stage investors, 57% were technology-agnostic, while 43% indicated they would invest in green hydrogen only. The vast majority of investors looking into green hydrogen only were developers of renewable energy or of renewable hydrogen technologies.

In all cases, interest in investing in various forms of hydrogen was closely linked to questions of regulatory clarity.

IMPORTANCE OF INNOVATION FINANCE

Finding 3

Innovation in hydrogen remains crucial, but access to finance for early-stage innovators is constrained, particularly for new technology demonstration projects.

There is an economic need for R&D investment

The economics of hydrogen, where scale alone may not be sufficient to bridge the economic gap, require innovation that would facilitate larger-scale deployment at a lower cost. Investors agreed that innovation in hydrogen remains critical for the success of the EU hydrogen strategy and the European Green Deal. The investors consulted highlighted the need for innovation and R&D at the hydrogen production stage, where disruptive technologies that could optimise the economic aspects of hydrogen production are sought.

This need for innovation calls for action at the earliest stages of the development cycle, where grant-type and research support funding can be deployed. Significant opportunity exists here and there is a perception that hydrogen is falling behind in comparison to groundbreaking developments in other fields.

A concentrated venture capital market

The venture capital scene for hydrogen is concentrated, with a limited number of European funds focused on hydrogen and corporate venture capital players dominating the space. Many venture capital investors remain cautious with respect to innovative business models requiring significant capital expenditure and real world project deployment to meet development and valuation milestones (as opposed to often more scalable valuation milestones that can be achieved in information and communication technologies or life sciences).

The venture capitalist and corporate venture capitalist investors consulted mentioned a number of investment constraints. These include the high capital expenditure requirements of hydrogen demonstration projects; the high valuation of start-ups, which limits their ability to invest; the geographical limitations of European public mandates, which can inhibit cross-border projects with countries outside the European Union; and the need for research and development that could bring new players and innovations that would lower the cost of hydrogen to market.

Demonstration projects need funding

In this context, obtaining financing for commercial-scale demonstration projects with ticket sizes often in the tens of millions of euros can be even more challenging. Indeed, these projects consolidate most of the risks generally associated with hydrogen development (economic gap, regulatory uncertainty, etc.) and add a layer of innovative technology deployment to bring project risks largely beyond the thresholds of many investors. These difficulties for hydrogen innovators are compounded by the economic and regulatory challenges described previously, which add significant uncertainty to the business and commercial outlook of early-stage investments.

To overcome such constraints, more needs to be done to ensure the availability of a robust offering of risk capital to European hydrogen innovators, while also making sure that financial instruments for demonstration projects meet the needs of innovative hydrogen project developers.

CHALLENGING PROJECT FINANCE CONDITIONS

Finding 4

The mobilisation of large-scale project-based financing for the deployment of hydrogen infrastructure is constrained.

Financing conditions for hydrogen infrastructure projects remain challenging because of the many risks associated with such projects, including a paucity of demonstrations from which lenders can draw experience. For demonstration projects, large capital expenditure requirements relative to the risk profile are a further constraint.

Similar to the wind and solar energy sectors a few years ago, the hydrogen sector requires a significant ramp-up in the deployment of projects across all areas of the value chain. Greater scale would generate industrial improvement processes and bring about cost reductions in a virtuous development cycle.

Investors' ability to finance hydrogen projects on a senior, non-recourse basis, which is essential for the scale-up of the sector, is constrained by the perception of significant residual risks. In the case of project finance for demonstration projects, early-stage investors are particularly constrained by the

large capital expenditure requirements and their perception of better investment opportunities in other parts of the decarbonisation agenda, such as the bioeconomy, renewables, or electrification, where investment requirements may be more modest.

For potential project financiers, the key residual risks cited include the offtake price, duration and volume risk, as well as technology, operational and counterparty credit risks.

Offtake price:

- Fluctuating natural gas prices affect the price of hydrogen directly (as an input factor for blue hydrogen) and indirectly as a competitor in some applications.
- Regulatory uncertainty over the valuation of avoided carbon emissions makes it challenging to rely on the portion of revenue attributable to such schemes.
- Even in the case of the existing EU Emissions Trading System (ETS), investors voice concerns over the lack of long-term visibility. In some cases, entirely new certificate schemes could be required to crystallise revenue streams for hydrogen project developers.

Offtake duration:

- Hydrogen buyers are constrained by industrial investment cycles. Buyer offtake commitments are typically limited to five to ten years, while the economic life of hydrogen production or industrial assets, which influences the desired maturity of financing for project developers, lies in the 20 to 30-year range.

Offtake volume:

- Commercial commitments by buyers of hydrogen or buyers of end products based on hydrogen tend to be limited in terms of volume. Hydrogen project developers struggle to present predictable revenue and cash flow outlooks for their projects. As a result, the debt capacity of projects is constrained by their amount of predictable cash flow.

Technology maturity and scale-up risk:

- While certain technologies are mature (e.g. alkaline electrolysis), there is little experience of their industrial deployment on a commercial scale within complex integrated business models (e.g. combining intermittent renewable energy to deliver firm volume commitment to offtakers). This creates significant uncertainty for some potential financiers, although others stated that such risks were not significant and could be managed through contractual arrangements.

Operational risk:

- Investors cite a number of operational risks, such as uncertainties related to the technical performance and efficiency of hydrogen equipment (e.g. load factors, conversion efficiency, leakage) but also in the useful life and reliability that can be expected from such assets given their limited track record (e.g. electrolyser stack lifetimes). The question of maintenance beyond an initial period of activity has also come up as a particular uncertainty. Such factors could impact maintenance and operational expenditure and worsen the credit profile of projects.

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Counterparty credit risk:

- Hydrogen projects necessarily involve multiple firms with expertise in different areas such as equipment manufacturing, renewable energy, engineering and other technical services. Feedback from developers and financiers indicates that the relatively small size of some hydrogen equipment suppliers is a concern because such companies are less able to provide creditworthy warranties to their project contribution.
- Offtakers for hydrogen may also be less than robust in terms of creditworthiness, which could exacerbate the challenge for financiers to render projects bankable.

Risk mitigation approaches to mobilise the balance sheets of private funding providers

Some of the aforementioned risks could be mitigated and allocated to the various parties within project structures. For example, operational risks, cost overruns and maintenance issues could be structured under engineering, procurement and construction wrap contracts, which define the responsibilities of contractors and the risks they would bear. Such contracts could, for example, also allow for a portion of core technology and performance risks related to the still-to-be-tested performance of large-scale electrolysers to be allocated. Performance guarantees from project partners could be another way to mitigate project risks. These could cover aspects such as efficiency, capacity, output pressure, purity, noise, load following, oxygen production, output availability, or water-related aspects.

Risk allocation to the private partners around the table is likely to have its limits, however, as some private partners may not have the creditworthiness to provide guarantees, or the risk appetite. This calls for new risk mitigation mechanisms to enable private investors to participate in the rollout of hydrogen projects (e.g. offtake guarantees, auctions). Such measures would likely be needed until market conditions are achieved for hydrogen and until there is a sufficient track record of projects to give comfort to senior financiers under normal project conditions.

The magnitude of the investment required for such a scale-up (several hundred billion euros by 2050) cannot rest on public support alone. To develop hydrogen projects on the right scale, it is vital to mobilise the balance sheets of large banks and providers of project finance. Such financing, when available, is generally cheaper and helps improve the return prospects for project developers and encourage further project development.

IMPORTANCE OF VALUE CHAIN AND ECOSYSTEM

Finding 5

Hydrogen projects are interdependent and linked across the value chain. A value chain approach, including the planning of coherent and coordinated projects around optimal locations, is a key factor for project development.

Value chain coordination is required to achieve the timely development of the market

Key segments within the hydrogen value chain spanning production, transport, storage and end applications are highly dependent on each other. Investors lack clarity on hydrogen cluster locations and express a clear need for planning visibility and intra-value chain coordination.

Value chain complexity stands out in conversations as a critical constraint for project development. Investors often compare hydrogen with renewable energy projects in this respect, contrasting how much more complexity needs to be managed in the case of hydrogen to arrange the end-to-end business models. In this context, investors realise that location can be a significant success factor for hydrogen projects as proximity to cheap, adequate renewable energy or to hydrogen users can make a significant difference to the economics of projects. The importance of coordination across multiple areas and segments of the value chain is thus perceived as critical.

Supporting projects with selective end uses and locations

Interviewees suggested the need for a coherent value chain approach, with planning and identification of the winning use cases for hydrogen (e.g. steel, chemicals), which could be the investment focus for public spending. They expressed the need for such market coordination while urging caution to avoid overregulation in terms of sector selectivity. Some of the most promising investment areas/use cases mentioned by the investors interviewed also included new production methods (e.g. methane pyrolysis, waste-based hydrogen production), transport and storage, mobility for large vehicles (e.g. truck, aircraft and bus fleets) and infrastructure upgrades (e.g. pipeline coatings).

International value chain coordination

Given the location requirements for the cost-efficient production of low-carbon hydrogen, there will inevitably be a need to transport it across borders. This makes international collaboration a vital issue. Interviewees expressed the need for cooperation across the value chain (e.g. gas companies transporting hydrogen in their gas pipes). One industrial player consulted summarised the situation by saying: “From a European perspective I’d really wish for a collaborative and harmonised approach. [...].....a cross-border type of approach.”

IPCEI exemplifies European project support coordinated across the value chain

Investors interviewed specifically mentioned positive case examples from the European Clean Hydrogen Alliance or Important Projects of Common European Interest (IPCEI). They highlighted the comprehensive approach of these instruments that fund projects from supply to demand. In addition to such existing, well-functioning mechanisms, investors raised the need for a coordination ecosystem/entity connecting players from across the value chain to strategically plan investment in key hydrogen infrastructure. This finding was particularly strong among smaller early-stage investors which, given their size, usually lack global industry visibility compared to large industrial players.

Finding 6

Investors believe there is a lack of an integrated and mature hydrogen financing ecosystem. Project promoters rely on public support but have insufficient knowledge of possible funding options.

The offer of financing solutions and public support for hydrogen is complex and constantly evolving. This market consultation found that most promoters do not have a full understanding of how to optimally combine multiple sources of public and private financing to assemble workable financing structures for their projects.

Promoters often fall back on public support requests without necessarily considering the full range of blended financing options that may be available to them and could potentially result in finance structures that deliver returns and projects with a lower total use of scarce grant resources. This is especially true for cases where residual project risks limit financing possibilities from traditional private financing providers, and promoters lack the knowledge and access to innovative fuel blending schemes.

Beyond this, the financing industry has picked up significant interest in hydrogen as a business opportunity, even if the hydrogen financing ecosystem today remains immature. Most interactions with financing players indicate that the actual investment track record, and therefore the risk management lessons learnt, remain limited. In response, a number of proactive investors have joined open collaboration initiatives among project developers and other financing players in order to enhance knowledge sharing, develop ex ante assessments and discuss risks within project archetypes.

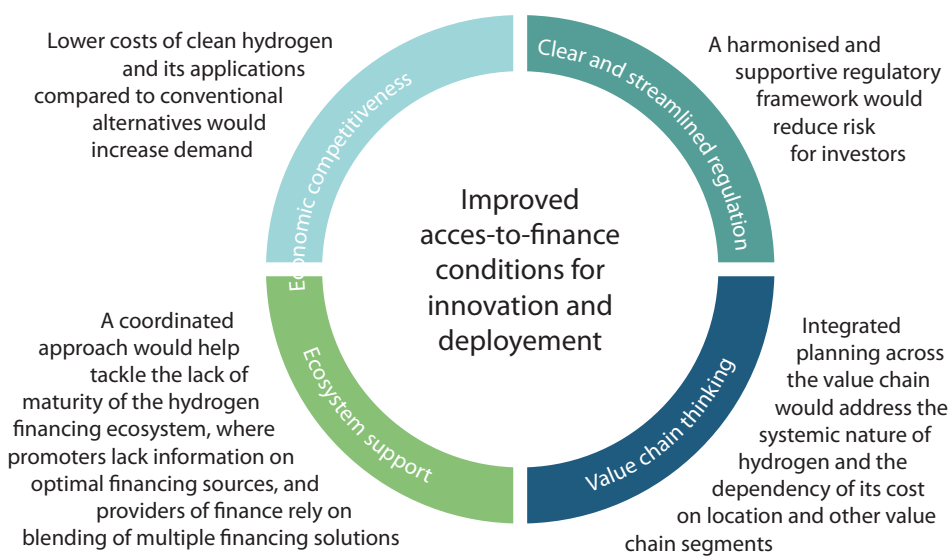


RECOMMENDATIONS

Unlocking the hydrogen market requires action to improve the market and regulation, access to finance, and value chain integration with ecosystem support.

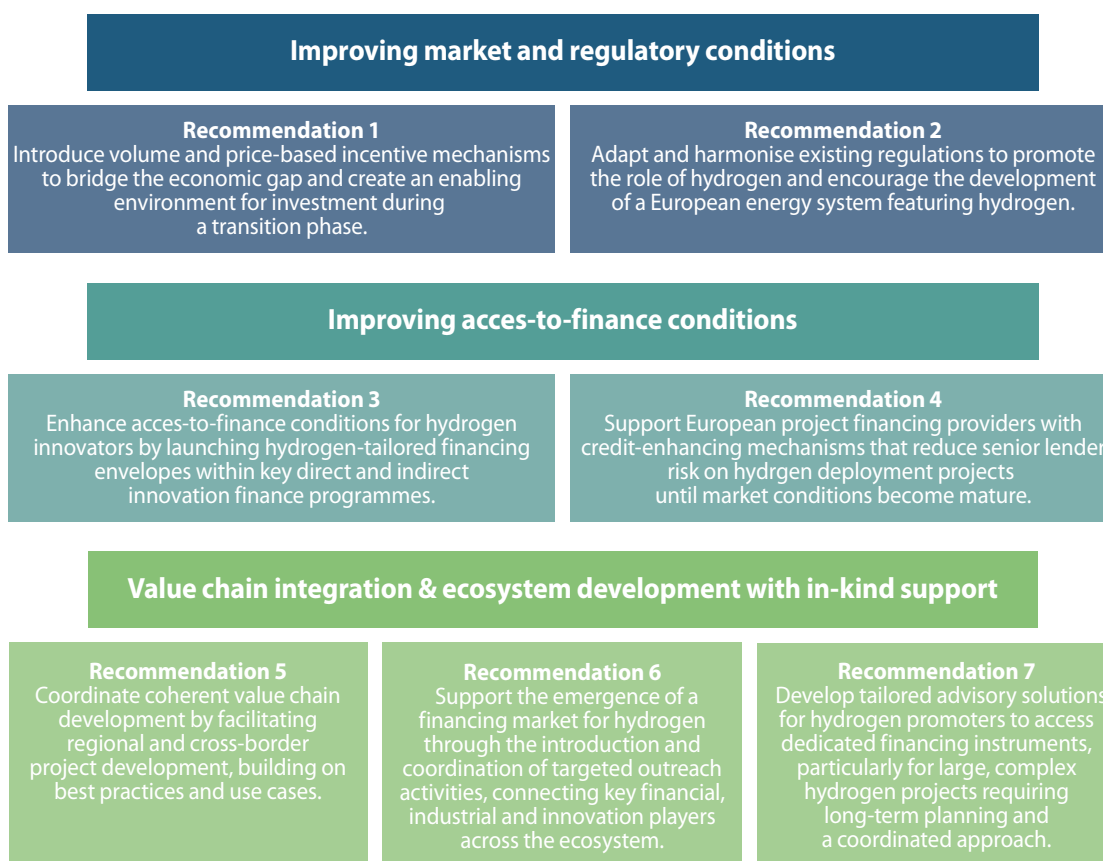
The key findings of the consultation of 46 investors can be summarised in terms of four main forces that could improve the conditions for accessing finance for the innovation and deployment of hydrogen technologies: economic competitiveness, clear and streamlined regulation, a value chain approach, and ecosystem support — as summarised in Figure 5 below.

Figure 5: Key forces required to increase investor funding for hydrogen innovation and projects



Feedback from the participating investors included a number of recommendations for improving access-to-finance conditions for the hydrogen economy, which have been structured along the lines of the key themes in Figure 6 below.

Figure 6: Summary of recommendations across the regulatory, access-to-finance and advisory support dimensions



Note: The market feedback around recommendations 1 and 2 on economic and regulatory aspects has been shared with the European Commission. Given the extensive scope and complexity of these aspects, and the rapidly evolving policy landscape, these particular proposals have not been fully fleshed out in the context of this report. Rather, this document focuses in more depth on recommendations 3-7 which apply directly to the financing community, and therefore also the European Investment Bank, as well as those hydrogen projects seeking finance.

IMPROVING MARKET AND REGULATORY CONDITIONS

ECONOMICS

Recommendation 1

Introduce volume- and price-based incentive mechanisms to bridge the economic gap and create an enabling environment for investment during a transition phase.

Given the economic pressure on hydrogen projects, the hydrogen industry needs targeted programmes to ensure a reasonable return on investment for initial commercial projects, especially during the early stages of the hydrogen market's development. Ideally, mechanisms should evolve as the market develops and ultimately be phased out as market conditions improve.

Early projects will provide the market with experience and help accelerate learning curves and cost reductions, which over time would reduce the need for market support mechanisms. In the medium term, a transparent, pan-European market would require more ambitious tools that target new sectors and innovations.

Potential support mechanisms discussed with investors include the following:

- Carbon contracts for difference
- Guaranteed offtake (potentially combined with a price floor at the end of commercial contracts)
- Feed-in tariffs
- A European clearing house or market-making mechanism
- Auctions
- Green public procurement.

Among the various initiatives or support measures proposed, the concept of market-making platforms stands out in particular for its potential to create supportive market conditions for both producers and users of hydrogen. For example, the H2 Global funding instrument launched in Germany received positive feedback from many participants. Through it, producers of hydrogen may be able to obtain more visibility on offtake over time and in terms of volume and price. Users requiring price visibility and stability in supply would also benefit from the platform. Such market-making or “switchboard” mechanisms could also be considered on a European scale to provide support for the emergence of producers and users of green hydrogen across the continent.

REGULATION

Recommendation 2

Adapt and harmonise existing regulations to promote the role of hydrogen and encourage the development of a European energy system featuring hydrogen.

Improving the regulation of hydrogen is a complex yet critical issue to facilitate investment and the development of the sector. While the full extent of potential regulatory improvements could not be derived from this consultation, the following topics were raised in investor interviews:

- Need to finalise efforts of defining a hydrogen taxonomy that removes the uncertainties surrounding what type of hydrogen may be considered compliant and/or eligible for public support
- Opportunity for market regulations to promote the use of excess renewable energy for electrolyzers
- Potential for a guarantee of origin or virtual pan-European certificate market
- Potential hydrogen blending quotas for midstream infrastructure
- Need for enabling standards and legal frameworks for midstream and storage (e.g. safety and pressure standards)
- Opportunity to promote the deployment of hydrogen and CO₂ pipelines through consistent third-party access to regulated infrastructure with standardised contracting across Europe
- Potential for regulated asset base model for midstream infrastructure, and facilitating market trading mechanisms (equivalent to gas clearing houses)
- Potential sectoral consumption quotas for large hydrogen consumers (e.g. ammonia, petrochemicals) in the short term and for new sectors in the medium to long term
- Exploration of how future EU ETS allowances could enable investment
- Potential for carbon border tax
- Potential relaxation of state aid rules during market launch phase and eligibility for state aid rules

IMPROVING ACCESS-TO-FINANCE CONDITIONS FOR HYDROGEN PROMOTERS

INNOVATION

Recommendation 3:

Enhance access-to-finance conditions for hydrogen innovators by launching hydrogen-tailored financing envelopes within key direct and indirect innovation finance programmes.

Innovation is critical to market development. Therefore, it is important for innovators to obtain funding so that an established market can form and the technology to scale up can be developed. Some recommendations for financing frameworks for hydrogen innovators, informed by market feedback and the EIB's own experience, are described below.

European Innovation Council

The first step to improving access to finance for innovators would be to increase the availability of funding for early-stage ventures involved in hydrogen. This could be achieved, for example, by launching hydrogen-related calls under the European Innovation Council (EIC) programme, which would provide a combination of grants and equity to eligible candidates. EIC blended funding would also help protect Europe's strategic interests in this innovative sector.

Innovation Fund

Similarly, leveraging the Innovation Fund will be key to promote the rollout of further innovation in the hydrogen sector. The Innovation Fund is already seen by players as one of the key tools to promote new technology deployment. Maintaining sufficient focus on hydrogen technologies in the scope of eligibility criteria will be important. Aligning potential grants, in terms of quantity and structure, to the needs of individual promoters may be another factor to consider. Finally, maintaining sufficient project development assistance for projects requiring support to obtain the grants will also contribute to overall potential impact.

Fund-of-funds

Another way to provide early-stage support would be to allocate dedicated equity resources for venture capital intermediaries to encourage indirect financing of hydrogen ventures and the setting-up of dedicated hydrogen venture capital funds or strategies within established generalist funds. The latter solution could draw on lessons learnt from the artificial intelligence and blockchain investment platform set up with the European Investment Fund to provide targeted financing.

Finance for higher-risk demonstration projects

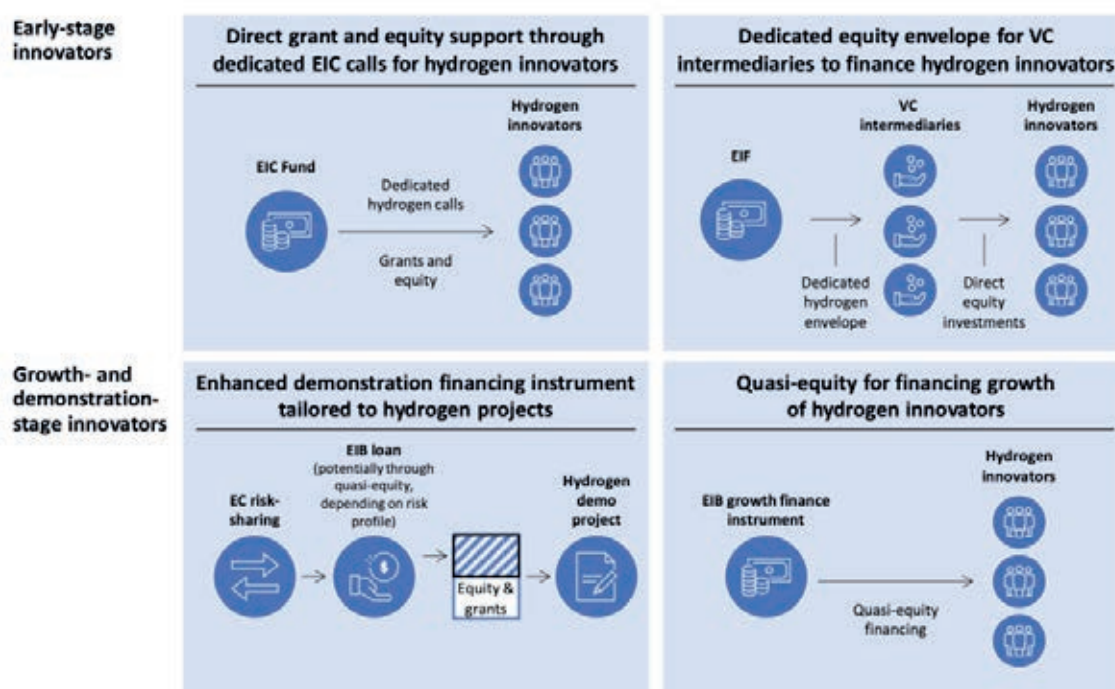
Supporting innovators in their growth stage and for the deployment of demonstration projects is equally important. For hydrogen demonstration projects, a blended finance resource drawing on lessons learnt from the InnovFin Energy Demonstration Projects facility should be made available, ideally with adjustments catering to the specific needs of hydrogen projects. Such adjustments could include:

- Implementing risk-sharing mechanisms to allow for the absorption of offtake risks (volume, price, duration), technology scale-up risks and operational risks, which are still expected to be high in initial innovative demonstration projects.
- Ensuring flexibility in terms of loan tenor to help match the long economic life of hydrogen assets.

Thematic growth finance

For hydrogen innovators seeking growth funding, dedicated support could also be introduced by enhancing quasi-equity investment resources to provide long-term, less dilutive risk capital to eligible companies to help further their development (potentially backed by European Commission risk-sharing mechanisms).

Exhibit 1: Potential financing support for hydrogen innovators



PROJECT FINANCE

Recommendation 4:

Support European project financing providers with credit-enhancing mechanisms that reduce senior lender risk on hydrogen deployment projects until market conditions become mature.

One or more specific tools should be created to absorb the previously described risks, which are currently hindering project finance providers from providing low-cost senior financing to hydrogen projects and thereby preventing project developers from structuring and launching attractive investment projects.

Based on market feedback and the EIB's own experience, such credit-enhancing mechanisms could take multiple forms. The following proposals were mentioned in the consultation:

- A first-loss guarantee providing a risk cushion to lenders, facilitated by the European Commission, export credit agencies or national public sources.
- A liquidity facility or a contingent loan scheme triggered under certain events, with risk-sharing from appropriate public sources (e.g. European Commission or European Investment Bank).
- A conditional grant enhancing the project capital structure based on loan approval.

- A subordinated loan resource structured to absorb first losses after equity holders and before senior lenders, with risk-sharing from appropriate public sources (e.g. European Commission).

First-loss guarantee

A first-loss guarantee would act as a direct financing enabler, whereby a guarantee from an appropriate public funding source (e.g. European Commission, a national programme or export credit agency) would be made available in support of senior project lenders to eligible projects, subject to pre-defined parameters. This could be an attractive option for senior lenders as it would reduce their risk exposure where it is highest. When projects are successful, the public guarantee would not be called and therefore would not result in an actual draw on public resources. Such an instrument could stimulate the early rollout of new technologies, subject to phasing out as the need for public support diminishes.

Conditional grants

A conditional grant scheme could also make lending easier if it were made available to eligible hydrogen projects on the condition that they obtain a loan from agreed implementing partners. A conditional grant could be designed to cover certain agreed costs (capital or operating expenditure) specific to hydrogen projects. This would help to reduce the overall amounts to be financed by debt and improve the debt service coverage ratio of the project, all other things being equal. This could follow the model of the Connecting Europe Facility programme's Blending Facility, where eligible mobility projects can apply for a portion of the costs of mobility assets to be financed if approved for a loan by the European Investment Bank or another implementing partner.

Liquidity facility

A liquidity facility could provide a buffer to senior lenders for the phasing of project cash flows, helping reduce risks related to temporary deviations from predicted cash flows. It could be triggered under certain debt service or operational performance scenarios, e.g. project cash flow shortfalls or a reduced senior debt service capacity. The facility would bring additional cash into the project when triggered, which could then be used to cover the project's expenses, including senior debt service. Such a resource could be relevant in cases where liquidity risks, rather than debt service capacity, need to be addressed. Given the high risk, this financing resource would require risk-sharing support from public sources.

Contingent loans

Contingent loans are loans structured in such a way that certain terms and conditions (interest, grace period, repayment, amortisation schedule, etc.) are dependent/contingent on certain trigger events or milestones. Contingent loans are normally structured upfront, e.g. by linking repayment conditions to certain milestones. Such loans could be beneficial to hydrogen projects to help mitigate some of the underlying risks. For example, repayment flexibility could be introduced to deal with project execution risk, or technology performance risk. Such financing resources would require risk-sharing support from public resources.

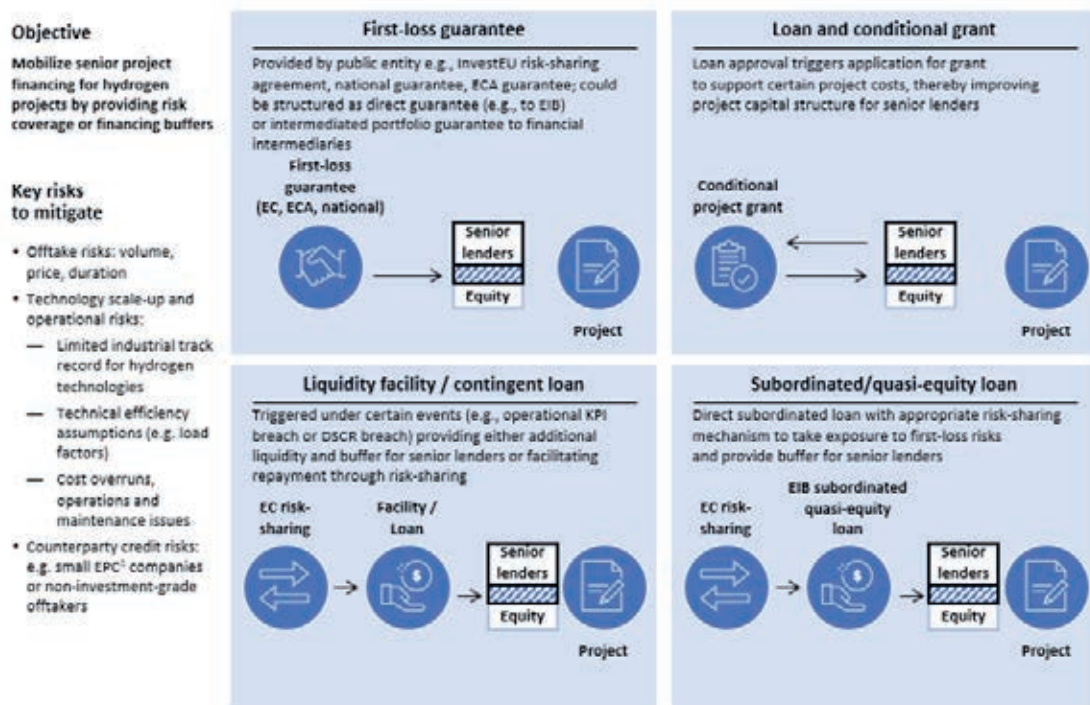
Subordinated loans

A subordinated loan could help facilitate senior financing by providing a buffer in the capital structure and reducing the probability of default for senior lenders in the event of cash flow shortfalls. If implemented by the European Investment Bank, such subordinated loans could bring signalling

benefits that would further encourage senior lender intervention. Given the high risk exposure, this action may require significant risk-sharing coverage from public sources to be effective. It should also be designed with sufficient structuring flexibility so as to enable the implementing partner to also finance the project at senior levels in parallel to the subordinated tranche, subject of course to normal measures to manage potential conflicts of interest.

To conclude, credit-enhancing mechanisms similar to those outlined above could provide a buffer to investors, facilitating the entry of senior lending into project structures as well as enticing institutional investors into this nascent market. Such support could stimulate further investment, which would then spur innovation and the formation of a stronger market base.

Exhibit 2: Potential credit-enhancing mechanisms for hydrogen projects



² Engineering, procurement and construction



SUPPORTING VALUE CHAIN INTEGRATION AND ECOSYSTEM DEVELOPMENT

VALUE CHAIN AND ECOSYSTEM

Recommendation 5

Coordinate coherent value chain development by facilitating regional and cross-border project development, building on best practices and use cases.

Interviewees expressed the need for the alignment and optimisation of projects across the value chain in order to develop the different dimensions of successful hydrogen ecosystems in parallel. Such coordination could include the identification of relevant projects, the screening of potential winning use cases and, where relevant, the potential prioritisation of public spending. Investors also cautioned against overregulating in terms of sector selectivity to avoid picking winners. This presents an opportunity for public organisations (including the European Commission) to set up open collaboration initiatives, public-private partnerships, as well as working groups or expert panels that promote sector collaboration around key projects while encouraging a deeper understanding of the evolving market, economic, regulatory and environmental contexts.

Such initiatives could foster the development of pockets of demand around key clusters (e.g. industrial or mobility-related). Around such hubs where demand would be aggregated, hydrogen production and transport could be planned on a more significant scale to support lower costs and improved economic soundness for projects. The allocation of public spending could be considered in a way that would optimise consistent developments across the value chain.

It is noted that the ongoing Important Projects of Common European Interest process already aims to address this issue through the identification of projects by Member States and the prioritisation and matchmaking of shortlisted candidates.

Recommendation 6

Support the emergence of a financing market for hydrogen through the introduction and coordination of targeted outreach activities, connecting key financial, industrial and innovation players across the ecosystem.

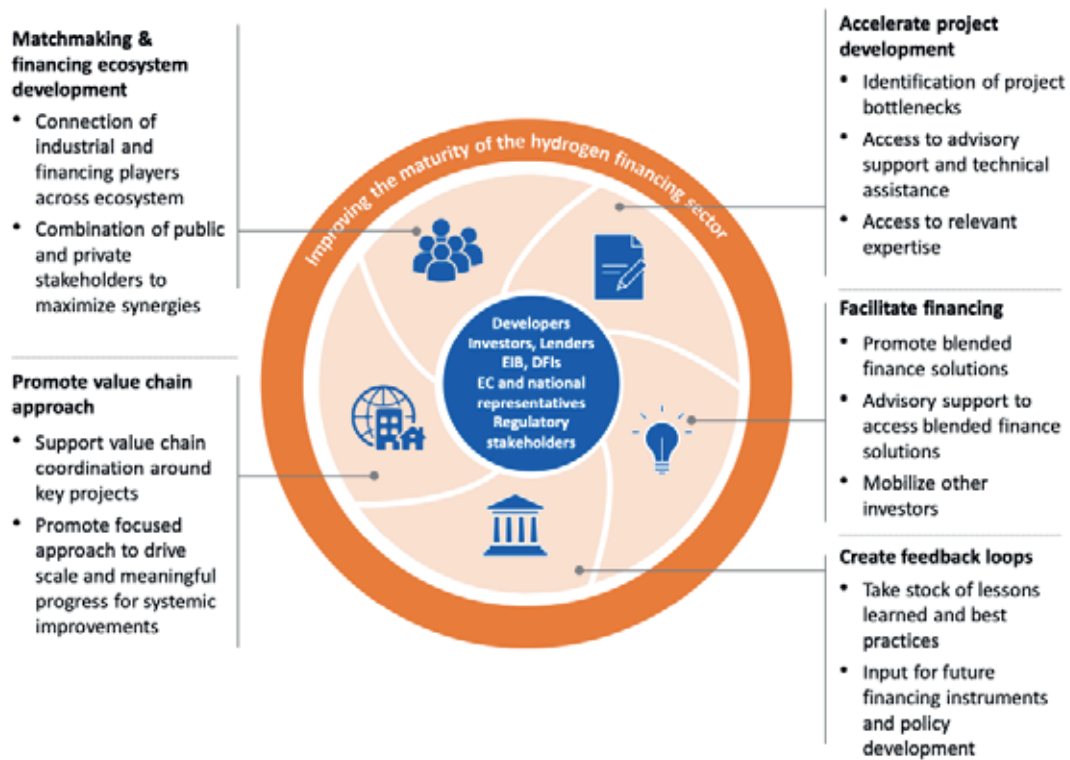
Hydrogen finance labs to help the emergence of a hydrogen financing sector

Targeted initiatives to develop the financing ecosystem for hydrogen could disseminate information about the optimal blended financing solutions available, connect players to their peers and potential partners, and offer a platform for the exchange of best practices.

This proposal draws on the EIB's recent experience in the space sector, where Space Finance Labs were created to achieve similar objectives. These have helped to bring the sector into the mainstream and improve financing players' understanding of the key risks and opportunities. In practice, a series of Hydrogen Finance Labs could be launched, either as stand-alone initiatives or in synergy with existing sector outreach initiatives (e.g. in the context of the Clean Hydrogen Partnership). Such a forum could gather players on the industrial front with public finance providers, such as the EIB, serving as a coordination mechanism between industrial developers and financiers.

This initiative would aim to complement existing market outreach activities through a more targeted approach, connecting carefully identified project developers with key providers of financing and helping enhance trust and understanding in a beneficial way. Case studies of successful financing and lessons learnt could be shared to facilitate future credit risk decisions. The grouping could also reflect on constraints to the financing of projects and contribute ideas for the development of future financing resources.

Figure 7: Dimensions of a potential Hydrogen Finance Labs ecosystem to support hydrogen



Recommendation 7

Develop tailored advisory solutions for hydrogen promoters to access dedicated financing instruments, particularly for large, complex hydrogen projects requiring long-term planning and coordination.

Hydrogen projects are likely to require specific blended finance solutions that have the ability to absorb some of the underlying project risks. To help deploy these instruments in relevant projects, market feedback and the EIB experience indicate a need for targeted support from finance experts to help navigate the evolving offering of financing products. Such support would also help promoters position themselves for the right offering. Given the complexity and often long time-to-market times of hydrogen projects, the advisory resources should be sized and designed accordingly.

Advisory support could also extend to hands-on project development assistance, particularly in the case of large, complex projects involving multiple players and value chain segments. In such contexts,

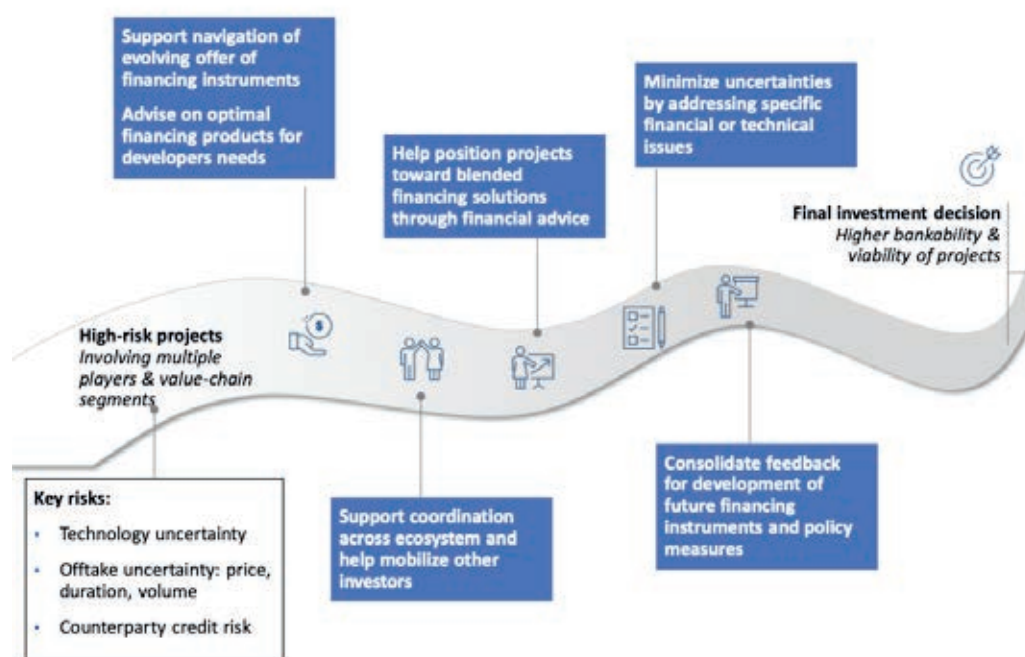
the contribution of a neutral advisory partner could act as a catalyst and accelerate projects to facilitate certain decisions or project development activities. This type of assistance is already being provided under the Innovation Fund’s PDA (project development assistance) programme, under the New Entrants’ Reserve NER 300 PDA programme and could be further expanded in the coming years under the new InvestEU Advisory Hub.

Based on the EIB’s experience, such development assistance could be particularly relevant for large and complex hydrogen projects establishing new business models for which there are few precedents. For example, IPCEI projects, or the key “lighthouse” hydrogen projects could benefit. Due to the high risks, such projects may in the near term lie beyond the frontier of what is normally considered bankable. To help these projects, advisory support should also contribute to clear financial signalling and guidance to promoters and their partners to assist in adapting their operational and funding strategies accordingly.

Advisory support can help address key uncertainties in the development of projects, by offering ways to test and arbitrate between certain financing, economic or technical alternatives that may ultimately impact the economic viability and bankability of projects. For example, advisory support packages could make it possible to explore how demand could be aggregated around hydrogen production centres, how hydrogen could be integrated into renewable energy projects as a power storage solution, or how mobility ecosystems could be structured. Based on this, such projects could obtain potential financing faster. Through such support, promoters would be better placed to also seek commensurate public support or guarantees to achieve bankability.

Integrated, comprehensive support instruments that encompass the entire value chain will be needed to bring down investment barriers, catalyse investment, and enhance collaboration between financiers and hydrogen sector companies. All of these are vital components for the ambitious 2030 targets to be met and the hydrogen ecosystem to mature.

Exhibit 3: Advisory support to bring high-risk projects to a final investment decision — EIB experience



CONCLUSION AND NEXT STEPS

The potential of hydrogen and the investment opportunities it represents are clearly recognised by the investment community. Virtually all players consulted through this study are planning or have already made investments in the hydrogen sector. The current momentum for hydrogen is palpable in most investor conversations.

However, significant challenges need to be addressed to create the conditions for the large-scale deployment and financing of hydrogen projects. Economic and regulatory conditions would need to improve further in order to mobilise the full financing needed to meet the ambitious EU targets. In this context, financing risks would need to be appropriately mitigated, while the nature of the hydrogen sector also calls for a coherent value chain approach to ensure coherent development of the various parts of the ecosystem.

This report provides a basis for both financiers and policymakers to assess these challenges as they pursue hydrogen investment opportunities. The European Investment Bank's Advisory Services, which have authored this study, will continue to work both with their partners at the European Commission and with the project promoters that they advise to ensure hydrogen financing needs are well understood and to help in the development of appropriate instruments that are equal to the challenges of the European Union's ambition.

Readers and hydrogen promoters who would like to explore financing options with the European Investment Bank are invited to reach out to the Innovation Finance Advisory division at innovfinadvisory@eib.org or to one of the authors directly.



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Unlocking the hydrogen economy — stimulating investment across the hydrogen value chain

Investor perspectives on risks, challenges and the role of the public sector