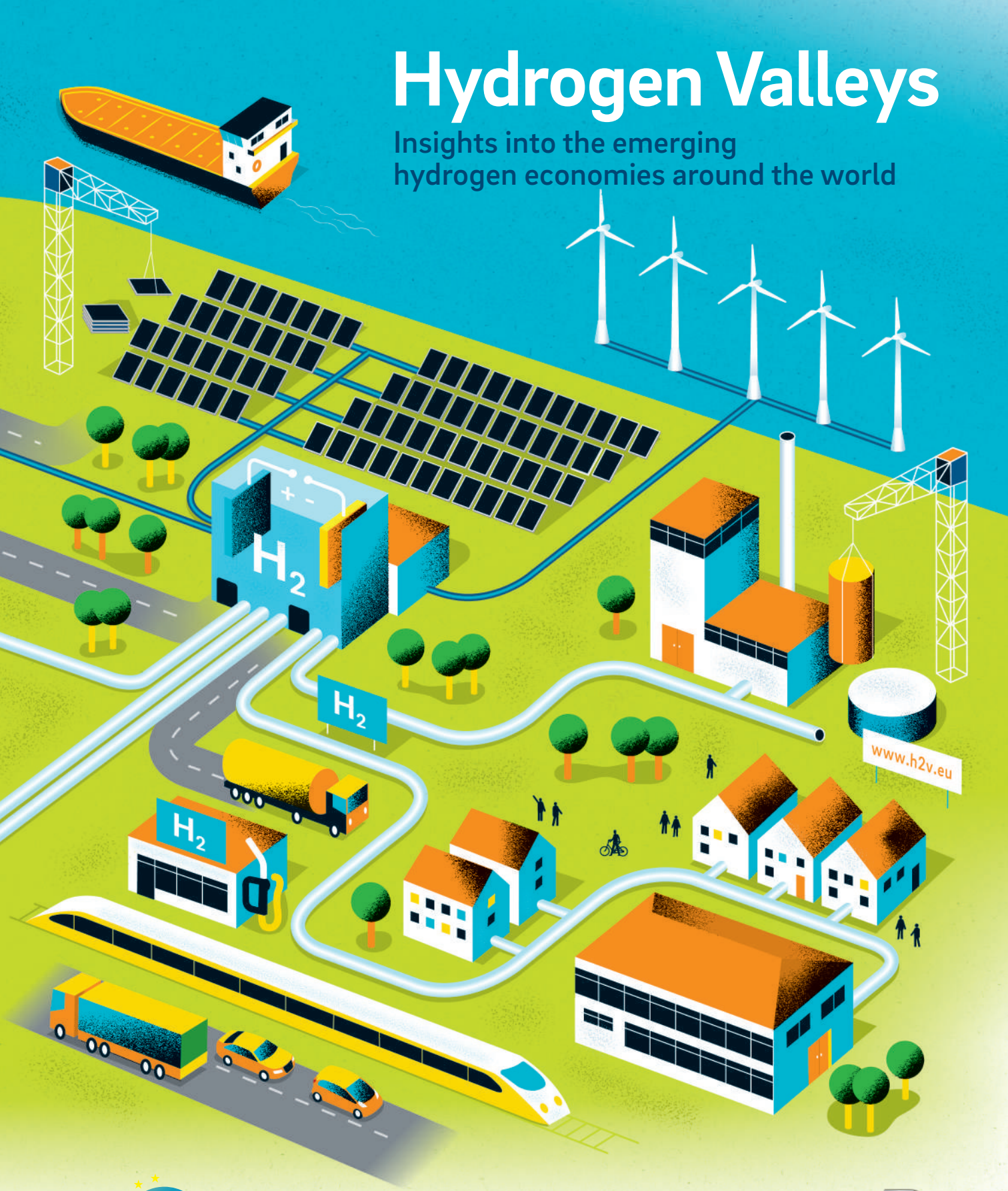
Hydrogen Valleys

Insights into the emerging hydrogen economies around the world



FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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Abstract

Clean hydrogen is universally considered an important energy vector in the global efforts to limit greenhouse gas emissions to the "well below 2°C scenario", as agreed by more than 190 states in the 2015 Paris Agreement. Hydrogen Valleys – regional ecosystems that link hydrogen production, transportation, and various end uses such as mobility or industrial feedstock – are important steps towards enabling the development of a new hydrogen economy.

This report has been issued during the setup of the "Mission Innovation Hydrogen Valley Platform" (www.h2v.eu) which was commissioned by the European Union and developed by the Fuel Cells and Hydrogen Joint Undertaking. The global information sharing platform to date already features 30+ global Hydrogen Valleys with a cumulative investment volume of more than EUR 30 billion. The projects provide a first-of-its-kind look into the global Hydrogen Valley project landscape, its success factors and remaining barriers. This report summarizes the findings and presents identified best practices for successful project development as well as recommendations for policy makers on how to provide a favourable policy environment that paves the way to reach the Hydrogen Valleys' full potential as enablers of the global hydrogen economy.

List of abbreviations

AEM	Anion Exchange Membrane
AIB	Association of Issuing Bodies
ALK	Alkaline
ATR	Auto-Thermal Reformer
CCfD	Carbon Contracts for Difference
CC(U)S	Carbon Capture, (Utilisation) and Storage
CEF	Connecting Europe Facility
CO_2	Carbon Dioxide
EU	European Union
FCH	Fuel Cells and Hydrogen
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
GHG	Greenhouse Gases
GHR	Gas Heated Reformer
GW	Gigawatt
H_2	Hydrogen
IC8	Mission Innovation's Innovation Challenge 8 – 'Renewable and Clean Hydrogen'
IPCEI	Important Projects of Common European Interest
LOHC	Liquid Organic Hydrogen Carrier
PEM	Proton Exchange Membrane
PV	Photovoltaic
SMR	Steam Methane Reforming
SOEC	Solid Oxide Electrolyser Cell

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Executive summary

Hydrogen is universally considered an important energy vector for combating climate change. It enables the decarbonisation of hard-to-abate sectors such as fuel or feedstock and, moreover, holds vast potential for industrial development and job creation. Its benefits are also acknowledged through the many dedicated national hydrogen strategies that have been published globally in recent years. Simultaneously, the emergence of a hydrogen market economically stimulates regions where hydrogen is produced and associated technologies are deployed by creating new jobs and showcasing the regions as environmental forerunners.

Hydrogen Valleys have started to form first regional "hydrogen economies", as bottom-up stepping stones in the development of the new hydrogen economy overall. Over the past several years, the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) has been setting up, in collaboration with European cities and regions, so-called Hydrogen Valleys – a concept that aims to enable the emergence of locally integrated hydrogen ecosystems for climate change mitigation and regional economic development. Hydrogen Valleys typically comprise a multi-million EUR investment, spread across a defined geographic scope and covering a substantial part of the value chain, from hydrogen production, storage and transport to its end use in various sectors (industry, mobility, energy). Over the past few years, Hydrogen Valleys have gone global, with new projects emerging worldwide.

This report provides insights into the most advanced Hydrogen Valleys globally. The findings are based on data gathered during the development of the Mission Innovation Hydrogen Valley Platform (www.h2v.eu) by the FCH JU, a global information sharing platform set up under the Innovation Challenge 8 'Renewable and Clean Hydrogen' of Mission Innovation and funded by the European Commission. The data on the platform and in this report comes out of a comprehensive survey conducted among 30+ Hydrogen Valleys globally providing cumulatively more than 2,500 datapoints on their projects. Complemented by best practice interviews with selected Hydrogen Valleys, the platform and this report provide a first-of-its-kind look into these projects.

The Hydrogen Valley landscape is growing, is increasingly driven by the private sector and gravitates towards archetypical project setups. Hydrogen Valleys will significantly mature over the 2020s, due to an increasing number of projects overall and because announced projects themselves grow in size and complexity (e.g. by hydrogen production volume, planned investment). While in the earlier phases of hydrogen deployment, projects were mostly driven by public authorities or public-private initiatives, today more than 50% of projects are led by the private sector, which views projects as strategic investments in a new business area. In addition to that, Hydrogen Valleys are gravitating towards archetypical value chain setups where different foci promise near-term commercial business cases. Three typical setups observed are (i) local, smaller-scale and mobility-focused projects, (ii) local, medium-scale and industry-focused projects, as well as (iii) large-scale and international export-focused projects.

Five factors are particularly key for the successful project development of Hydrogen Valleys. A Hydrogen Valley not only needs a convincing project concept with a hydrogen value chain coverage that leverages local assets (e.g. abundant renewable energy sources) and addresses local needs (e.g. the decarbonisation of local industrial production),

1) The IC8 is co-led by Australia, Germany and the European Commission. http://mission-innovation.net/our-work/innovation-challenges/renewable-and-clean-hydrogen/

it also needs to develop a viable business case that links competitive clean hydrogen production with the off-takers' willingness to pay. Here, obtaining public support and/or funding (potentially from multiple sources) that closes any remaining funding gaps is still vital. During project development, effective partnering and stakeholder cooperation that ensures continuous commitment from all parties involved is essential, as is getting political backing from policy makers and support by the general public.

There are four prominent barriers to the development of Hydrogen Valleys – yet they're not insurmountable. The first and most prominent barrier is securing funding. Among the methods used by Hydrogen Valleys to overcome this challenge, creating awareness about the technology at funding entities, initiating proactive dialogues about funding criteria and remaining flexible regarding the potential adaptation of the project concept to tailor it to public funding requirements proved to be particularly successful. Second, Hydrogen Valleys also see securing off-take commitments for clean hydrogen as a key barrier. Investing time in credible investment plans complemented by talks with as many potential off-takers from various sectors as possible are among the best practices mentioned to reach the required off-take quantities. Third, in order to secure private funding, Hydrogen Valleys relied on a structured development approach, early involvement of off-takers and equity partners that de-risk the project as well as early feedback from the lending community. Involving local private investors might additionally be attractive for locally anchored Hydrogen Valleys. Lastly, to mitigate technological readiness and technological performance barriers, it proved to be essential for Hydrogen Valleys to remain flexible regarding the project's general direction. This could also lead to adding other applications into the project's portfolio. Moreover, best practices also involve ensuring efficient operation and maintenance, for example by procuring maintenance services directly from the equipment supplier or trusted third parties.

A fifth barrier is still regulatory provisions: Four recommendations for policy makers. The policy landscape is growing increasingly favourable for Hydrogen Valleys globally, but barriers still exist regarding permitting and regulation affecting Hydrogen Valleys directly as well as indirectly, for example as the respective policy affects conventional competitors or off-takers. Almost 40% of Hydrogen Valleys still see regulatory provisions as a challenge. In order to facilitate their emergence further, policy makers should focus on the following priorities: (i) having a clear vision of the country's future hydrogen economy in a national hydrogen strategy that sets the framework for Hydrogen Valley development, (ii) creating a regulatory environment conducive to their development, (iii) closing the gaps in permitting procedures and (iv) acting as local matchmakers to enable the setup of Hydrogen Valleys.

Hydrogen Valleys will unfold their full potential globally towards the middle of the decade and the Mission Innovation Hydrogen Valley Platform seeks to contribute to this effort. In the years to come, all Hydrogen Valleys currently featured on the Mission Innovation Hydrogen Valley Platform will reach the implementation phase and ultimately go into operation. In addition, 70% of Hydrogen Valleys also indicated that they intend to expand their activities beyond the current scope. Moreover, Hydrogen Valleys will continue to move towards commercial maturity and thus remain beacons of the hydrogen economy that pave the way for the full roll-out of a global market by showcasing its potential on an increasing scale. The Mission Innovation Hydrogen Valley Platform will support these activities by being the go-to website for up-to-date information on Hydrogen Valleys' project development globally and by serving as a project incubator as well as collaboration enabler between mature Hydrogen Valleys.

Synthèse

L'hydrogène est universellement considéré comme un vecteur énergétique important de lutte contre le changement climatique. Il permet la décarbonisation dans des secteurs dont les émissions sont difficiles à réduire, tels que la mobilité ou l'industrie, et possède en outre un vaste potentiel de développement industriel et de création d'emplois. Ses avantages sont également reconnus par les nombreuses stratégies nationales dédiées à l'hydrogène, publiées ces dernières années à l'échelon international. Parallèlement, l'émergence d'un marché de l'hydrogène stimule économiquement les régions de production d'hydrogène et de déploiement des technologies associées, en créant de nouveaux emplois et en présentant les régions comme des pionnières de l'environnement.

Les Hydrogen Valleys ont commencé à former les premières "économies de l'hydrogène" régionales, premières étapes dans le développement de la Nouvelle Économie de l'Hydrogène. Ces dernières années, la Fuel Cells Hydrogen Joint Undertaking (FCH JU) a été mise en place en collaboration avec les métropoles et les régions européennes, sous le nom de "Hydrogen Valleys". Ce concept vise à permettre l'émergence d'écosystèmes à hydrogène intégrés localement en faveur de la réduction du changement climatique et du développement économique régional. Les Hydrogen Valleys se composent généralement d'un investissement de plusieurs millions d'euros, réparti selon un périmètre géographique défini et couvrant une part substantielle de la chaîne de valeur, allant de la production, du stockage et du transport d'hydrogène jusqu'à son usage final dans divers secteurs (par exemple l'industrie, la mobilité ou l'énergie). Ces dernières années, les Hydrogen Valleys ont acquis une dimension internationale, avec l'émergence de nouveaux projets dans le monde entier.

Ce rapport donne un aperçu des Hydrogen Valleys les plus avancées à l'échelle du globe. Les résultats reposent sur les données collectées au cours du développement de la Mission Innovation Hydrogen Valley Platform (www.h2v.eu) par la FCH JU, une plateforme de partage d'informations établie dans le cadre de l'"Hydrogène Renouvelable et Propre" (Innovation Challenge 8)[1] de la Mission Innovation et financé par la Commission européenne. Les données de la plateforme et du présent rapport proviennent d'une enquête exhaustive réalisée auprès de plus de 30 Hydrogen Valleys dans le monde, fournissant en cumulé plus de 2 500 points de données sur leurs projets. Accompagnés d'entretiens sur les pratiques exemplaires avec une sélection d'Hydrogen Valleys, la plateforme et le présent rapport fournissent le premier aperçu de ce type sur ces projets.

Le paysage des Hydrogen Valleys se développe, sous l'impulsion accrue du secteur privé et s'articule autour de créations d'archétypes de projets. Les Hydrogen Valleys vont sensiblement arriver à maturité au cours des années 2020, du fait de l'augmentation du nombre global de projets, et parce que les projets annoncés eux-mêmes gagnent en importance et en complexité (par exemple en termes de volume de production d'hydrogène, de prévisions d'investissement). Alors que dans les premières phases du déploiement de l'hydrogène, les projets étaient essentiellement portés par les autorités publiques ou les partenariats public-privé, aujourd'hui, plus de 50 % des projets sont dirigés par le secteur privé qui considère les projets comme des investissements stratégiques dans un nouveau domaine commercial. Par ailleurs, les Hydrogen Valleys s'articulent autour de l'établissement d'archétypes de chaînes de valeur, où différents centres d'intérêt promettent des justifica-

1) L'IC8 est co-dirigé par l'Australie, l'Allemagne et la Commission européenne. http://mission-innovation.net/our-work/innovation-challenges/renewable-and-clean-hydrogen/

tions commerciales à court terme. Les trois configurations classiques observées sont les suivantes : (i) projets locaux, à petite échelle et axés sur la mobilité, (ii) projets locaux, de taille moyenne et axés sur l'industrie, et (iii) projets à grande échelle tournés vers l'exportation internationale.

Cinq facteurs sont particulièrement essentiels pour le succès des Hydrogen Valleys. Une Hydrogen Valley ne nécessite pas seulement un concept de projet convaincant avec une couverture de la chaîne de valeur hydrogène qui tire parti des actifs locaux (ex : sources d'énergie renouvelables abondantes) et qui répond aux besoins locaux (ex : la décarbonisation de la production industrielle locale). Elle doit également mettre au point une étude de cas viable qui associe la production compétitive et propre d'hydrogène à la volonté de payer des acheteurs. Ici, l'obtention du soutien et/ou du financement public (probablement issu de sources multiples) qui comble les éventuels déficits de financement subsistants est crucial. Au cours du développement du projet, l'efficacité du partenariat et la coopération des parties prenantes qui assurent un engagement permanent de toutes les parties en présence sont essentiels, ainsi que l'obtention du soutien politique des décideurs et de l'adhésion du grand public.

Il existe quatre obstacles majeurs au développement des Hydrogen Valleys, qui ne sont toutefois pas insurmontables. Primo, l'obstacle le plus important est la garantie du financement. Parmi les méthodes utilisées par les Hydrogen Valleys pour surmonter cette difficulté, la sensibilisation des organismes de financement à la technologie, l'engagement d'un dialogue proactif sur les critères de financement et la flexibilité concernant l'adaptation potentielle du concept du projet pour l'ajuster aux exigences du financement public ont été nettement couronnés de succès. Secundo, les Hydrogen Valleys considèrent également les engagements d'achat d'hydrogène propre comme un obstacle majeur. Le temps consacré à des plans d'investissement crédibles, ainsi que les discussions avec autant d'acheteurs potentiels des divers secteurs que possible, figurent parmi les pratiques exemplaires mentionnées pour atteindre les quantités d'achat requises. Tertio, afin d'assurer le financement privé, les Hydrogen Valleys se sont fondées sur une approche de développement structurée, la participation en amont des acheteurs et des partenaires financiers qui réduisent les risques du projet, ainsi que les réactions précoces des prêteurs. La participation des investisseurs privés locaux pourrait en outre s'avérer attractive pour les Hydrogen Valleys implantées localement. Enfin, pour réduire les obstacles liés à la maturité technologique et aux performances technologiques, il est essentiel pour les Hydrogen Valleys de rester flexibles concernant la direction générale du projet. Cela pourrait également se traduire par l'ajout d'autres applications au portefeuille de projet. Par ailleurs, les pratiques exemplaires impliquent également de garantir l'efficacité du fonctionnement et de la maintenance, par exemple en obtenant les services de maintenance directement auprès du fournisseur d'équipement ou de tiers de confiance.

Un cinquième obstacle persiste sous la forme des dispositions réglementaires : quatre recommandations destinées aux décideurs. Le paysage politique est de plus en plus favorable aux Hydrogen Valleys à l'échelle mondiale ; toutefois, des obstacles persistent au sujet des autorisations et de la réglementation concernant directement et indirectement les Hydrogen Valleys, par exemple dans la mesure où la politique en question affecte les concurrents ou les acheteurs traditionnels. Presque 40 % des Hydrogen Valleys considèrent encore les dispositions réglementaires comme une difficulté. Afin de faciliter davantage leur émergence, les décideurs

devraient se concentrer sur les priorités suivantes : (i) avoir une vision claire de la future économie hydrogène du pays dans le cadre d'une stratégie hydrogène nationale qui détermine le cadre du développement des Hydrogen Valleys, (ii) créer un cadre réglementaire favorable à leur développement, (iii) combler les lacunes dans les procédures d'autorisation et (iv) agir en tant qu'intermédiaires locaux pour permettre l'établissement des Hydrogen Valleys.

Les Hydrogen Valleys vont atteindre leur potentiel à l'échelle du globe vers le milieu de la décennie et la Mission Innovation Hydrogen Valley Platform cherche à contribuer à cet effort. Dans les années à venir, toutes les Hydrogen Valleys figurant actuellement sur la Mission Innovation Hydrogen Valley Platform vont atteindre la phase de mise en œuvre et en définitive la mise en service. En outre, 70 % des Hydrogen Valleys ont également indiqué leur intention d'étendre leurs activités au-delà du cadre actuel. Par ailleurs, les Hydrogen Valleys vont continuer à évoluer vers la maturité commerciale et donc à servir de repère à l'économie hydrogène, préparant la voie au déploiement total sur le marché mondial en révélant son potentiel de manière croissante. La Mission Innovation Hydrogen Valley Platform va soutenir ces activités en constituant le site Web de référence pour les informations actualisées sur le développement du projet des Hydrogen Valleys à l'échelon mondial et en servant d'incubateur de projet et de facilitateur de collaboration entre les Hydrogen Valleys matures.

1 Hydrogen Valleys as a stepping stone towards the new hydrogen economy

Hydrogen is universally considered an important energy vector in the global efforts to limit greenhouse gas (GHG) emissions to the "well below 2°C scenario", as agreed by more than 190 states in the 2015 Paris Agreement. With its versatility, it can contribute to the decarbonisation of a wide range of sectors including heavy industry, long-haul and heavy-duty transport as well as energy – i.e. the sectors that are generally considered "hard to decarbonise" and where meaningful GHG emission reductions are yet to be achieved. Moreover, not only can hydrogen contribute to curbing global warming, it can also cut local emissions from burning fossil fuels such as nitrogen oxide, sulphur dioxide as well as particulate emissions, ultimately leading to an overall increase in quality of life.

The combination of these factors as well as the European ambition to be the first climate neutral economy by 2050 have led the European Union and many of its Member States to adopt ambitious hydrogen strategies. In July 2020, the European Commission published its own hydrogen strategy, including ambitious goals of 6 gigawatts (GW) of installed electrolyser capacity by 2024 and 40 GW by 2030 within the European Union.

At the global level, Mission Innovation (a global initiative of 24 countries and the European Commission working to reinvigorate and accelerate global innovation in clean energy with the objective of making it widely affordable) recognized hydrogen's multiple roles in the energy transition:

"Hydrogen is a promising [...] energy carrier with multiple uses and the potential to play an essential part in achieving deep cuts in emissions and improved security and resilience of the global energy system at scale."

To advance the emerging new hydrogen economy, i.e. the use of clean hydrogen to decarbonise the aforementioned sectors, governments have started to implement supporting polices and regulations. In addition to such "top down" measures, specific projects need to create the new hydrogen market from the "bottom up". Here, increasing focus is placed on regionally integrated hydrogen ecosystems, so-called hydrogen hubs, hydrogen clusters or "Hydrogen Valleys".

Over recent years, the Hydrogen Valley concept has emerged as a firmly established term in the European funding and collaboration landscape. Building on the FCH JU Regions and Cities Initiative launched in 2017, a "European Hydrogen Valleys partnership" (EHV) was created under the "Smart Specialisation for Industrial Modernisation" framework of the European Commission. The partnership supports the setup of joint hydrogen projects between the 30 participating European regions and increases the visibility for fuel cell and hydrogen applications at European level. In parallel, the FCH JU awarded two European regions dedicated funding of more than EUR 25 million to pursue their tailor-made Hydrogen Valley concepts, besides the FCH JU's extensive regular funding activities of many more Hydrogen Valleys that are also present in this study.

This report, commissioned by the European Commission and developed by the FCH JU under Mission Innovation's Innovation Challenge 'Renewable and Clean Hydrogen', marks the end of the most recent European efforts to advance the Hydrogen Valley concept globally – the creation of a global online platform. The platform (www.h2v.eu) provides information for project developers, policy makers and industry representatives alike on the most ambitious Hydrogen Valleys around the world. It offers insights into the Valley's fundamentals, technologies used, project development and financing activities as well as associated hurdles and barriers the projects experience along the way. Further-

more, selected best practice interviews complement the most comprehensive data collection on Hydrogen Valleys ever conducted. This report summarises the main findings of the quantitative and qualitative analyses that were made possible thanks to the comprehensive primary data that the platform helped collect.

1.1 THE BACKGROUND: WHAT MAKES A "HYDROGEN VALLEY"

Although Hydrogen Valley concepts are always adapted to cater to specific regional circumstances and the overall objectives of a project, there are common characteristics of what constitutes a Hydrogen Valley: → A

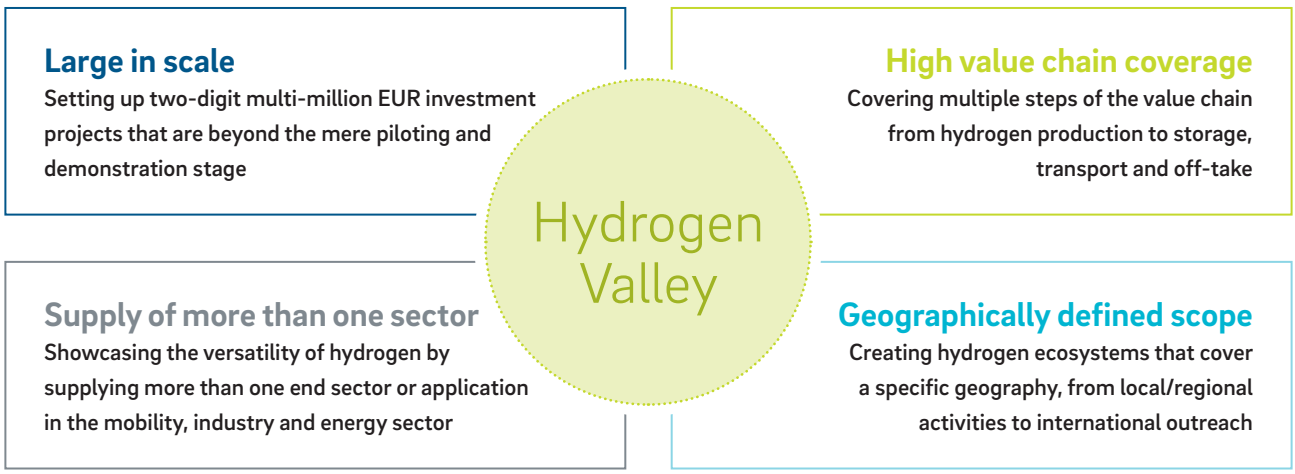
→ **Large in scale:** The project scope goes beyond mere demonstration activities and entails at least a two-digit multi-million EUR investment. It typically also includes several subprojects that make up the larger Valley "portfolio".

→ **A clearly defined geographic scope:** Hydrogen Valleys are hydrogen ecosystems that cover a specific geography. Their footprint can range from a local or regional focus (e.g. a major port and its hinterland) to a specific national or international region (e.g. a transport corridor along a major European waterway).

→ **Broad value chain coverage:** Across their geographic scope, Hydrogen Valleys cover multiple steps in the hydrogen value chain, ranging from hydrogen production (and often even dedicated renewables production) to the subsequent storage of hydrogen and distribution to off-takers via various modes of transport.

→ **Supply to various end sectors:** Hydrogen Valleys usually showcase the versatility of hydrogen by supplying ideally several sectors in their geography such as mobility, industry and energy end uses. Thus, Hydrogen Valleys are ecosystems or clusters where various final applications share a common hydrogen supply infrastructure.

A: What makes a Hydrogen Valley



Source: FCH 2 JU, Inycom, Roland Berger

1.2 THE BIGGER PICTURE: HYDROGEN VALLEYS AND THEIR ROLE IN THE EMERGING HYDROGEN ECONOMIES

Ursula von der Leyen, President of the European Commission, underlined the pivotal role of Hydrogen Valleys in her State of the Union Address at the European Parliament Plenary in September 2020:

> "I want [...] to create new European Hydrogen Valleys to modernise our industries, power our vehicles and bring new life to rural areas."

Strong statements like these underline the importance of the concept to European policy makers – not only as an enabler of the energy transition but also as a means of future economic development in European regions. Moving beyond mere piloting and demonstration activities, Hydrogen Valleys are the pioneers of this market and ultimately the stepping stone towards the full roll-out of a new hydrogen economy – and the industrialisation of the associated technologies simultaneously.

With their integrated approach, Hydrogen Valleys pave the way for the setup of the first regional 'mini hydrogen economies' by combining or pooling supply and demand, often with long-term off-take agreements, thus contributing to the market development bottom up. As a result, the project's investments get de-risked and the concept becomes viable.

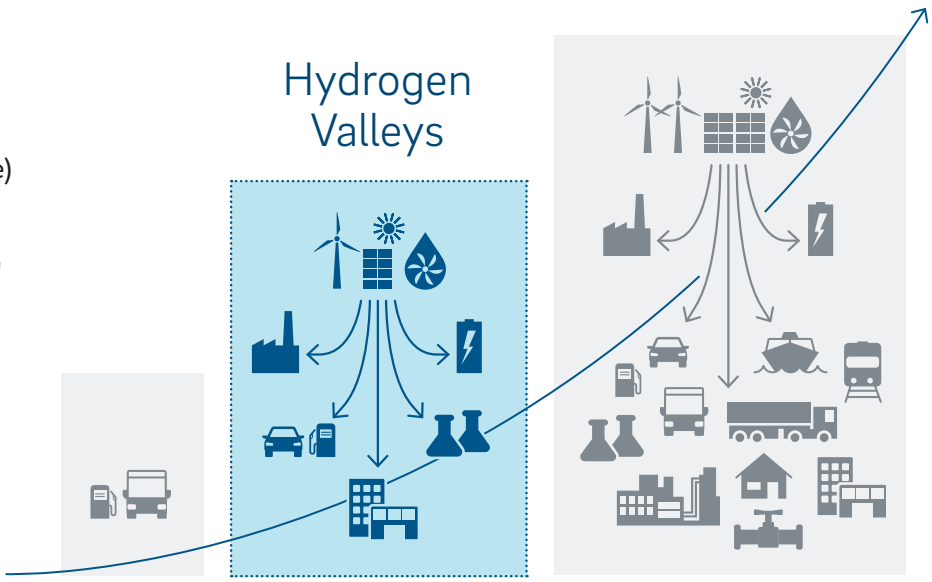
The information collected during the development of the Mission Innovation Hydrogen Valley Platform confirms the two-fold strategic relevance of Hydrogen Valleys as climate change mitigators as well as developers of a new industry. More than 75% of the more than 30 Hydrogen Valleys involved in the project indicate that reaching climate goals is the main underlying driver for the development of the project. At the same time, more than 50% also state that an industrial policy strategy and job retention as well as creation are additional factors. Thus, the resulting global potential from taking advantage of these mutually beneficial factors is substantial. → B

Drawing on the substantial experience gathered through the work of the FCH JU in setting up Hydrogen Valleys over recent years, the Mission Innovation Hydrogen Valley Platform strives to provide leadership and inspiration to project developers globally to incentivise the creation of more Hydrogen Valleys around the world and hence enable the global hydrogen economy.

B: Hydrogen Valleys as a stepping stone towards a new hydrogen economy

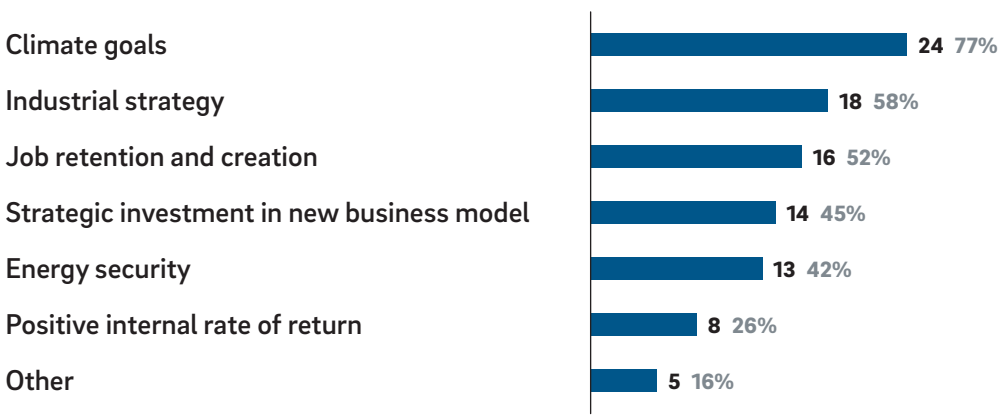
THE TOPIC

- → Next-generation market development
- → Integrated (and larger-scale) projects covering more and more of the value chain – "mini hydrogen economies"



THE UNDERLYING DRIVERS

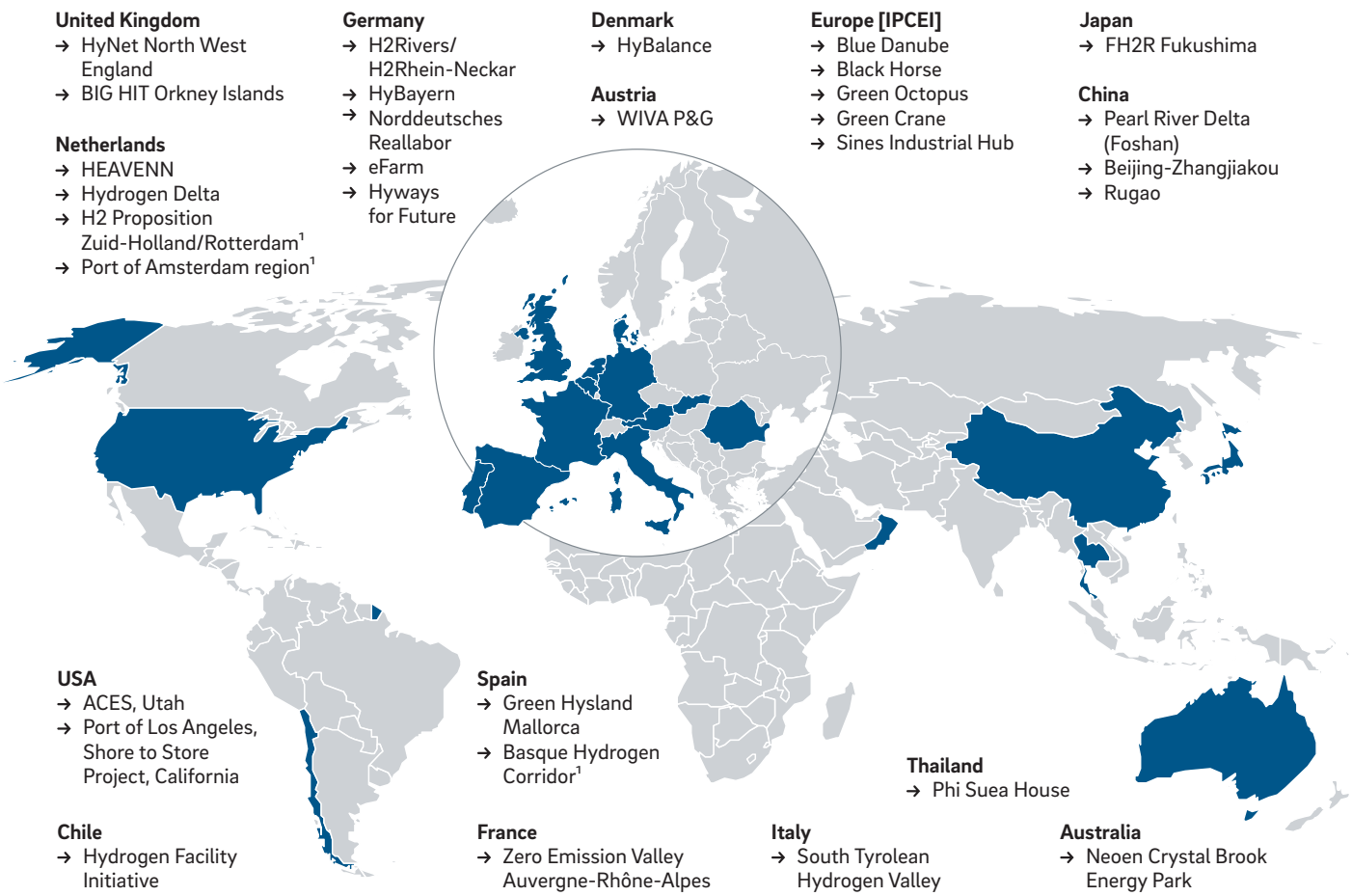
Question: "What are the main drivers for your project?" (n=31)[1]



Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible

C: Hydrogen Valleys on the Mission Innovation Hydrogen Valley Platform (as of May 31, 2021)



Source: FCH 2 JU, Inycom, Roland Berger

1) Projects that recently joined the platform; not included in the aggregate data analyses presented in this report

2 The commonalities and the diversity of Hydrogen Valleys around the world

The Mission Innovation Hydrogen Valley Platform features a selection of the most ambitious Hydrogen Valley projects around the world and shares first-hand project information based on a comprehensive survey. More than 30 projects provided more than 2,500 datapoints, on topics ranging from fundamentals such as investment and production volumes, technologies deployed to project development and financing activities as well as hurdles and barriers along the way. → C

The following chapter first provides a synopsis of the collected data to create an understanding of the current Hydrogen Valley project landscape. Following the synopsis, it outlines the common global trends and emerging archetypes in the sector.

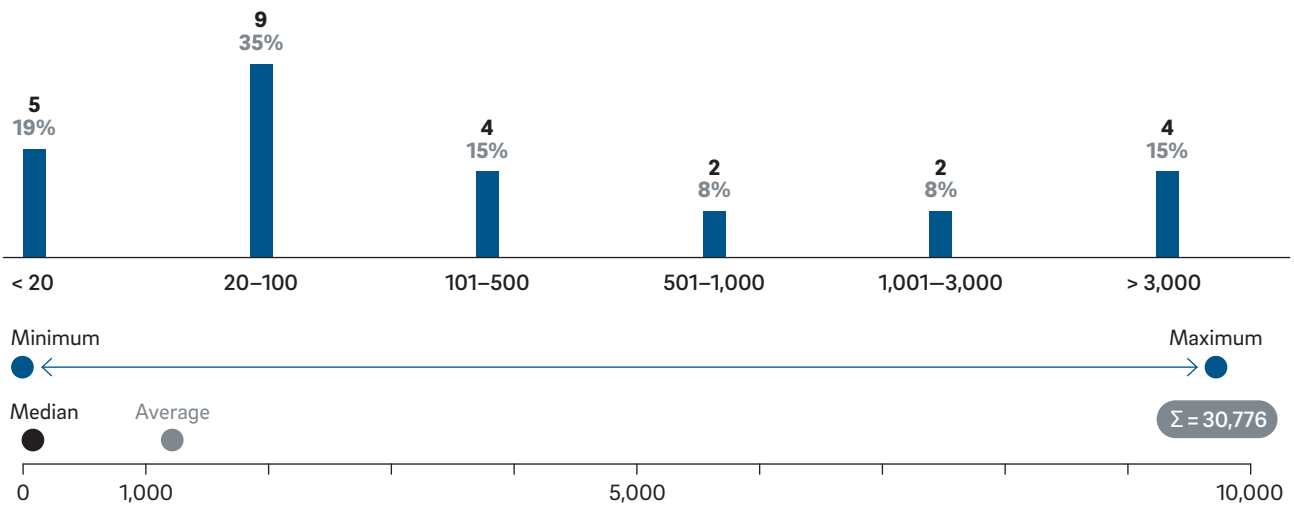
2.1 THE PROJECTS AS THEY STAND TODAY: PROJECT FUNDAMENTALS, VALUE CHAIN COVERAGE AND DEPLOYED TECHNOLOGIES

Geographic spread: While the Hydrogen Valley concept is undoubtedly "going global", it for now remains "Eurocentric" in many ways. Of the 32 Hydrogen Valleys that participated in the survey, 65% are European, 13% are in the Americas and 22% are Hydrogen Valleys in the Asia-Pacific region.

Investment: In line with general market development and following the ambitious targets set by governments, integrated hydrogen projects include growing investments: About 25% of the Hydrogen Valleys analysed have an investment volume below EUR 50 million, 45%

D: Project investment volumes

Question: "What is the investment volume over the project lifetime [EUR m]?" (n=26)



Source: FCH 2 JU, Inycom, Roland Berger

have an investment volume between EUR 50 and 500 million and the remaining 30% indicated an investment volume above EUR 500 million. This distribution shows that most projects have an investment volume below EUR 100 million with several outliers beyond the EUR 1,000 million mark. The cumulative investment volume of all Hydrogen Valleys on the Mission Innovation Hydrogen Valley Platform amounts to more than EUR 30 billion. → D

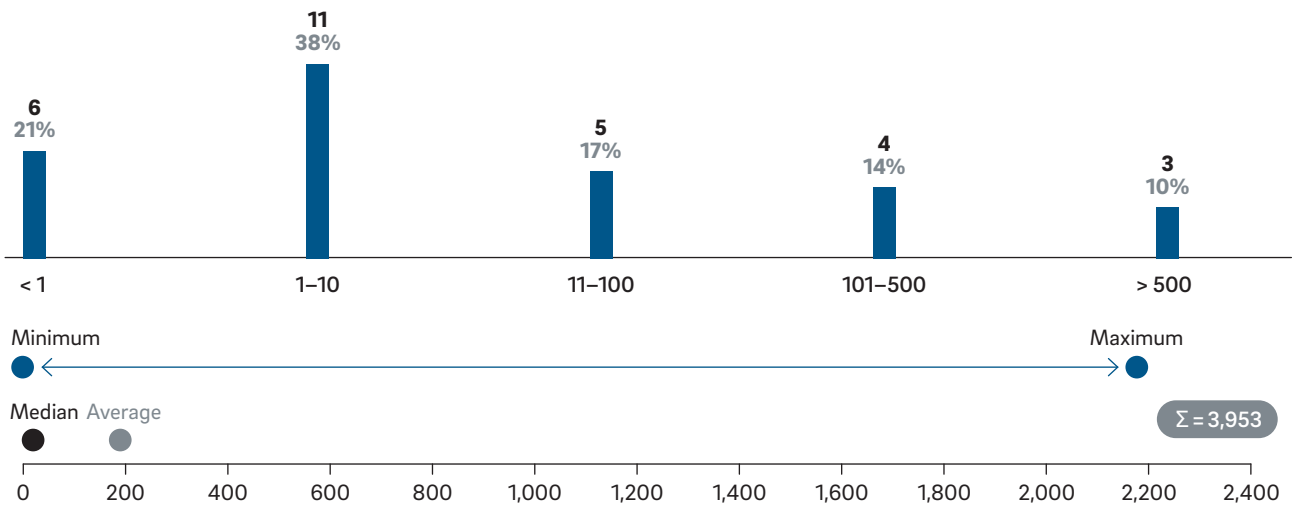
Value chain coverage: Corresponding to the archetypical concept of a Hydrogen Valley, the projects cover large parts of the hydrogen value chain. Almost all Hydrogen Valleys engage in hydrogen production and about 85% also cover storage or conversion of hydrogen as well as subsequent transport. On top of that, half of the Hydrogen Valleys also produce the needed primary energy for hydrogen production by deploying renewable energy technologies.

The Hydrogen Valleys on the platform also provided insights into the respective technologies for each value chain step, which will be presented below. As most of the Hydrogen Valleys are still under development and have not reached the implementation phase yet, the answers are a snapshot of their current technology decision. It is important to highlight that the technological setup can still be subject to change at a later point in time.

Upstream/production: Most of the projects are located around the lower end of the distribution with several

E: Project production volumes

Question: "How much hydrogen is produced within the project per day [tons]?" (n=29)



Source: FCH 2 JU, Inycom, Roland Berger

large outliers beyond the 500 tons mark. This is in line with our initial analysis of the investment volume distribution. About 20% of Hydrogen Valleys produce below one ton of hydrogen per day, while 40% produce between one and ten tons per day. The remaining 40% produce more than ten tons per day with a maximum production of more than 2,000 tons per day. The cumulative production volume of all Hydrogen Valleys amounts to almost 4,000 tons per day – almost 1.5 million tons per year. → E

One reason for the high diversity in production and investment volumes is the differing project timelines. More than 85% of Hydrogen Valleys are still in various project development phases, while less than 15% of the projects have been fully implemented. A lot of projects that are further along in their project development tend to be smaller projects compared to the Hydrogen Valleys whose project ideas have been formulated only in the last year and are currently only in the feasibility stage. For the underlying trend analysis, please refer to chapter 2.2.

Looking closer at the value chain and the deployed technologies upstream, hydrogen is mostly produced via electrolysis, with Proton Exchange Membrane (PEM) being the most common technology used by almost 80% of Hydrogen Valleys globally. However, due to the multitude of applications, a significant share of Hydrogen Valleys deploys additional production technologies simultaneously, such as alkaline electrolysers (42% of all Hydrogen Valleys) or blue hydrogen production via steam methane reforming (SMR) and carbon capture, utilisation and storage (CC(U)S) (10% of Hydrogen Valleys). Little more than 10% of Hydrogen Valleys also take advantage of byproduct hydrogen. Ten projects also deploy solar photovoltaic (PV) panels to produce the required electricity for electrolysis, whereas five projects also investigate electricity production from onshore wind. A less prevalent role is played by hydropower and offshore wind, each with one Hydrogen Valley deploying the technology respectively. → F

Midstream: The Hydrogen Valleys also engage in storing and transporting hydrogen (around 85% of Hydrogen Valleys), especially in its compressed gaseous form via cylinders, which is one of the most mature technologies used for small-scale distribution today. Moreover, 30% of Hydrogen Valleys also store the produced hydrogen in salt caverns, which is used in case of long-term and large-scale storage needs in larger projects. Liquefied hydrogen, liquid organic hydrogen carriers (LOHC) and ammonia are also planned to be deployed, although to a somewhat lesser extent. Furthermore, many Hydrogen Valleys deploy several transport technologies in parallel, for example pipeline and trucks, as they often comprise various subprojects with highly varying use cases. The most common transport technology is trucking (80% of Hydrogen Valleys) followed by pipelines (58%) and ship (20%). When transporting hydrogen by truck and pipeline, the majority of projects transport compressed gaseous hydrogen. When transported by ship, two out of three projects transport the hydrogen via LOHC. → G

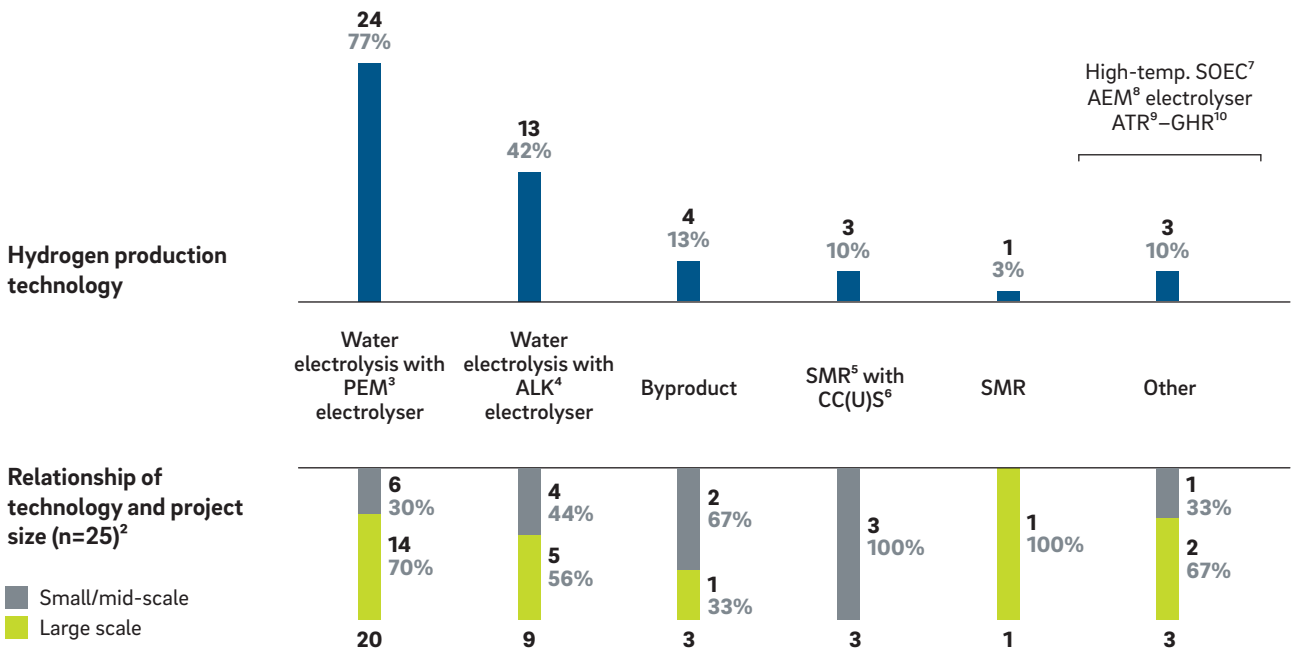
Downstream: Looking at the hydrogen end use, more than 65% of Hydrogen Valleys supply more than one end sector, reflecting the Valleys' integrated and multi-purpose character. The mobility segment is most prevalent in the Hydrogen Valley sphere, with more than 80% of Hydrogen Valleys supplying it. Within the segment, the focus is mostly on buses, cars and trucks. The prevalence of mobility applications likely stems from the legacy of the first hydrogen demonstration projects in Europe, which were typically centred around buses, refuelling stations and car fleets. These developments were driven by the comparatively high willingness to pay in this segment due to highly taxed conventional fuels, which resulted in a favourable business case. Additionally, the higher visibility of hydrogen fleets among the general public served as a showcase element of the technology for early initiatives.

Recently there has been an ongoing shift in the market, away from mobility centred projects to Hydrogen Valleys that see mobility only as an add-on that is beneficial for their business case. Now, there is a visible trend towards shifting the main activities to other sectors. More than 50% of Hydrogen Valleys (plan to) supply the energy sector and/or industry segments. These projects typically tend to be larger in scale and thus are looking for substantial, large volume off-takers, which can only be found outside the mobility sector.

Within the energy sector, Hydrogen Valleys typically focus on the supply of stationary fuel cells (e.g. applications in residential heating, back-up or prime power), but also blending into the gas grid, as clear

F: Hydrogen production technology

Question: "What and how much technology do you use/intend to use along the value chain?" – Hydrogen production (n=31)[1]



1) Multiple answers possible; other production options available in the survey were not selected;
2) Small/mid-scale: Production ≤ 10 t/day; large scale: Production > 10 t/day; 3) PEM=Proton exchange membrane; 4) ALK=Alkaline; 5) SMR=Steam methane reforming; 6) CC(U)S=Carbon capture, utilisation and storage; 7) SOEC=Solid oxide electrolyser cell; 8) AEM=Anion exchange membrane; 9) ATR=Auto-thermal reformer; 10) GHR=Gas heated reformer

Source: FCH 2 JU, Inycom, Roland Berger

regulations for the injection begin to emerge globally. Looking at the industry supply of Hydrogen Valleys, they typically serve a variety of segments, which highlights once more the broad range of hydrogen applications. The most typical sectors, however, are the chemicals industry (e.g. clean hydrogen as a feedstock for ammonia production) and refineries (e.g. clean hydrogen for desulphurisation and hydrocracking of hydrocarbons). These sectors still almost exclusively use grey hydrogen in their production processes, which gets directly produced on-site via SMR. New industry uses of hydrogen have been on the rise as well, especially in the CO_2-intensive steel industry, which is shifting towards the usage of hydrogen to decarbonise its steel production. Moreover, e-fuels plants are also a growing segment to which clean hydrogen from Hydrogen Valleys is supplied. → H

The use of technologies along the value chain differs by project size. For instance, 45% of projects that deploy alkaline electrolysers are large-scale projects with a daily production volume above 10 tons of hydrogen, while only 30% of projects using PEM are of this size. Moreover, liquefied hydrogen and LOHC as well as storage in salt caverns play a significantly bigger role in the large-scale segment compared to compressed gaseous hydrogen stored in cylinders. Similar results can also be found when looking at transportation, as pipelines and ships become more important compared to trucks in the large-scale segment. → F

2.2 COMMON THEMES AND EMERGING PROJECT ARCHETYPES: REAFFIRMING KEY HYPOTHESES OF THE NASCENT NEW HYDROGEN ECONOMY

A set of common trends are currently shaping the global Hydrogen Valley landscape, as revealed by the survey data as well as ten dedicated best practice interviews with selected Hydrogen Valleys:

→ **First trend:** With the market evolving, Hydrogen Valleys will mature over time. Towards the middle and second half of the decade, projects will get more numerous, bigger and more complex.
→ **Second trend:** Hydrogen Valleys are increasingly driven by private initiatives (rather than the public sector) that view a given project opportunity as a strategic investment in a new business area.
→ **Third trend:** Hydrogen Valleys are gravitating towards three archetypical value chain setups that promise near-term commercial business cases.

First trend: With the market evolving, Hydrogen Valleys will mature over time. Towards the middle and second half of the decade, projects will get more numerous, bigger and more complex.

The very early movers in the market used to be small-scale projects with a project volume below EUR 50 million. From 2017 on, mid-scale projects started being developed, while large-scale projects with an investment volume above EUR 500 million only picked up speed in the last two years, as shown in figure I showing the start dates for project development as well as the planned project finalization. In 2017, Hydrogen Valleys with an estimated investment volume of EUR 250 million began their project development, while investment volume quadrupled to almost EUR 1 billion in 2018, followed by an eighteen-fold increase to more than EUR 18,000 million in 2019. → I

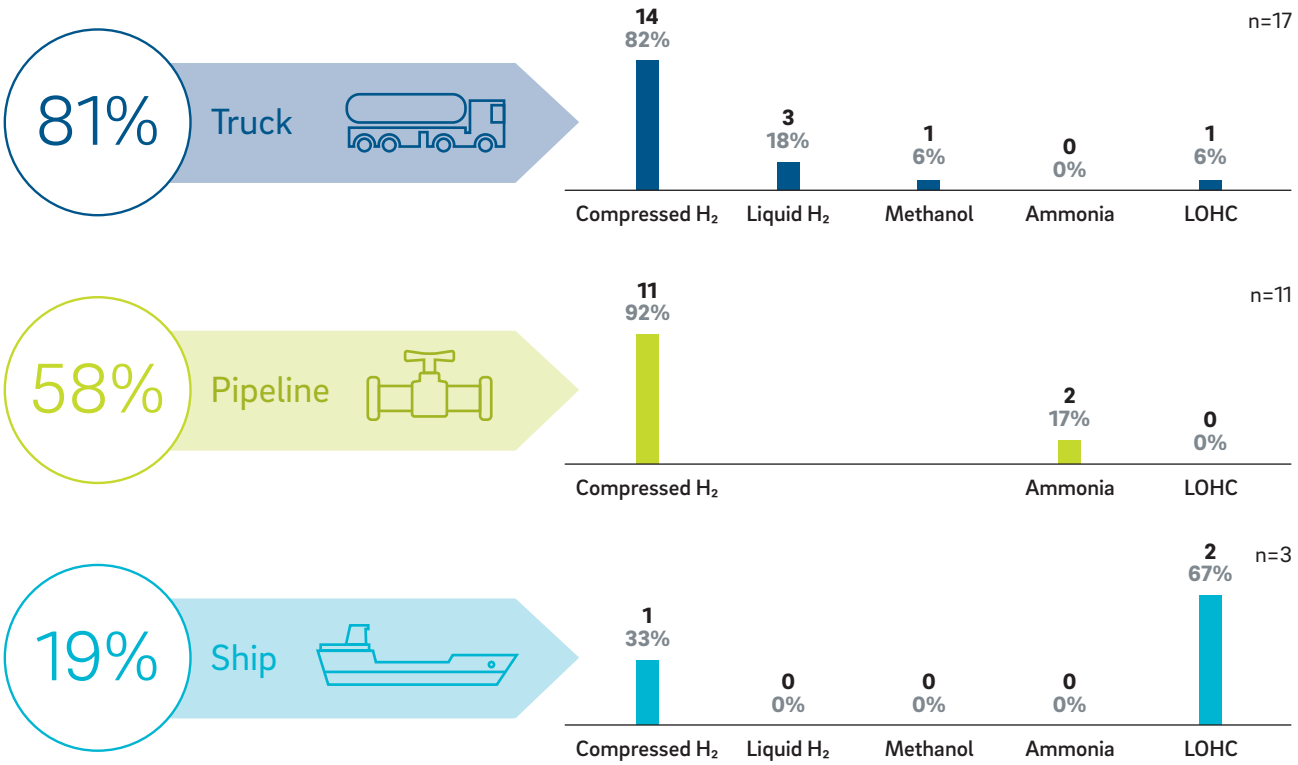
Production volumes are also picking up speed, from below 5 tons of hydrogen production per day by projects that started in 2017 to almost 1,450 tons per day by projects that began their project development in 2019 – also an eighteen-fold increase from 2018 to 2019. Thus, both planned production as well as investment volumes are growing at similar rates in the market. However, due to the increasing geographical scope of Hydrogen Valleys, projects' capital intensity keeps

increasing for additional equipment besides hydrogen production technology. This might eventually lead to a temporary and partial decoupling of the growth rates of investment and production volume, at least in some projects.

Two conclusions are important: First, the project volumes are picking up speed and second, the number of projects is growing at a near exponential pace. Moreover, larger projects with higher hydrogen production volumes tend to supply larger-scale off-takers in energy and industrial segments. More than 85% of large-scale projects beyond EUR 500 million of investment volume supply the industry sector, while more than 60% of them also supply the energy and mobility sector.

G: Modes of hydrogen transport

Question: "What mode(s) of transport do you use? (n=26)[1]

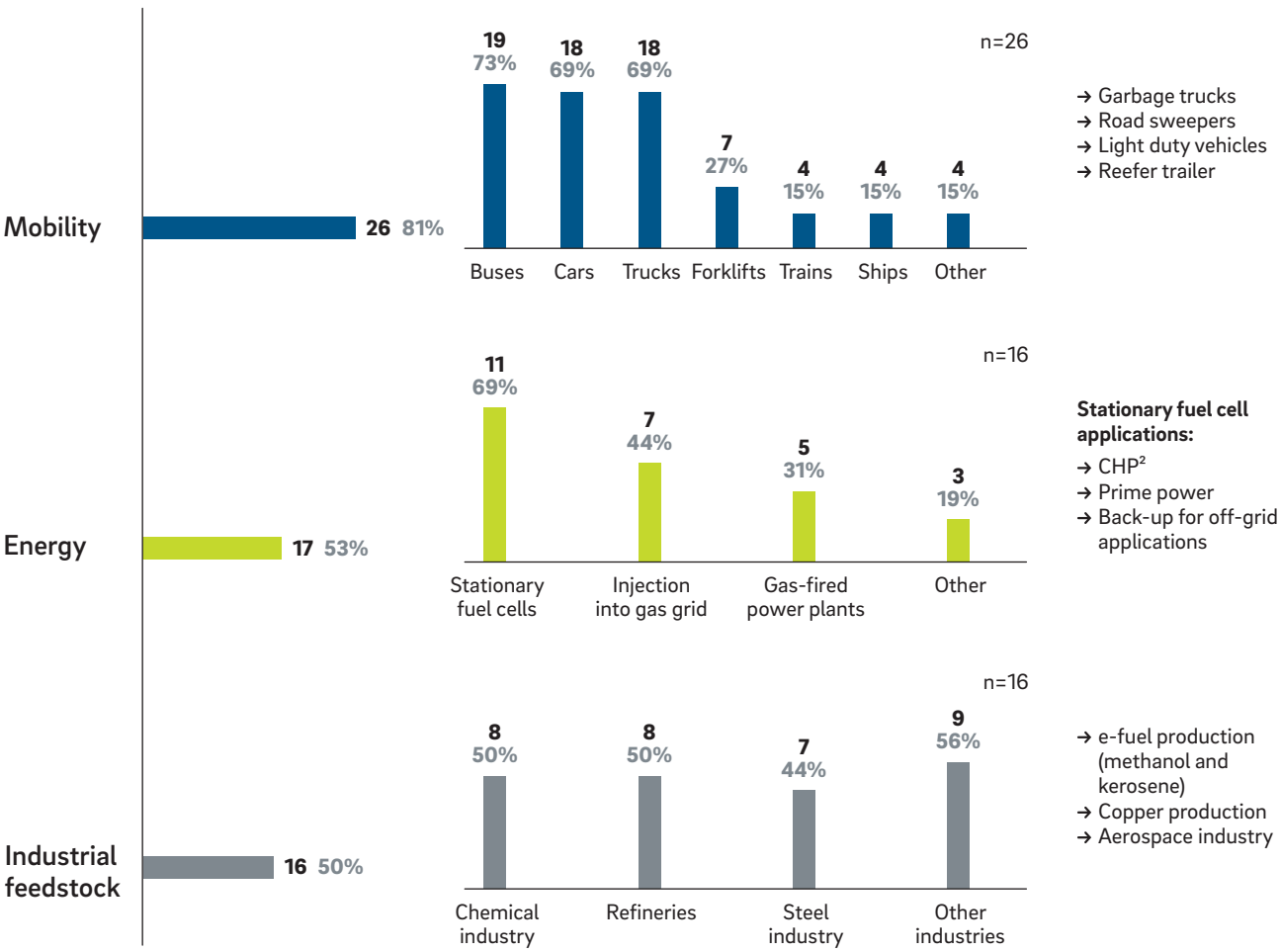


Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible

H: Hydrogen end uses

Question: "Which application does your production go into and how much does this make up?" (n=32)[1]



Other uses (selection):

→ Garbage trucks
→ Road sweepers
→ Light duty vehicles
→ Reefer trailer

Stationary fuel cell applications:

→ CHP[2]
→ Prime power
→ Back-up for off-grid applications

→ e-fuel production (methanol and kerosene)
→ Copper production
→ Aerospace industry

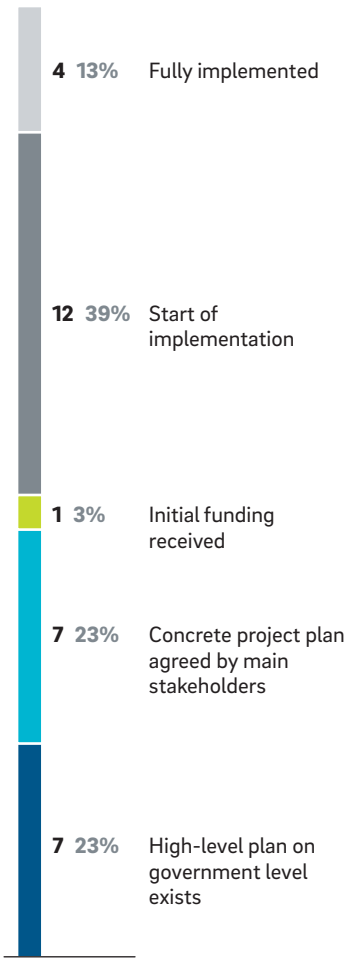
Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible; 2) Combined heat and power

Project statuses and timelines

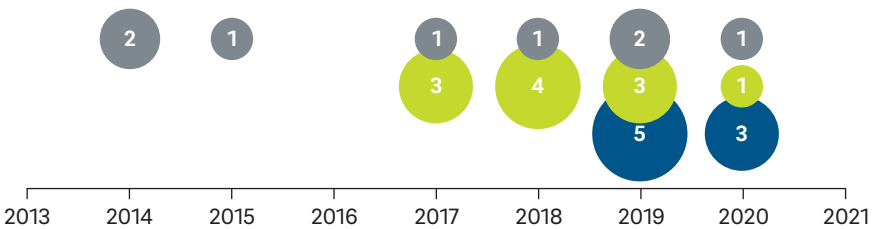
CURRENT STATUS

Question: "What is the current status of the project?" (n=31)



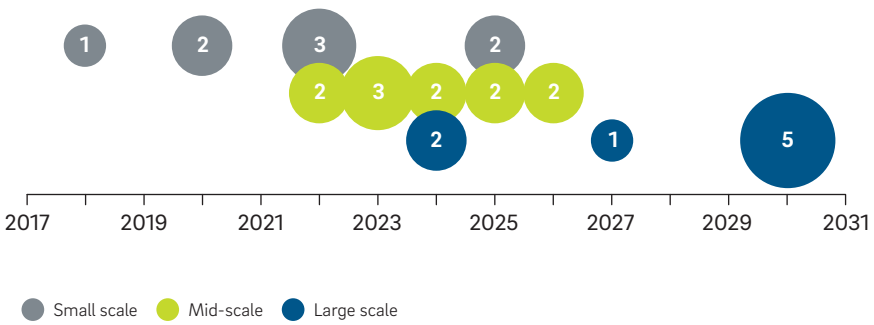
PROJECT START

Question: "What is the start date of project preparation?" (n=27)[1]



PROJECT FINALIZATION

Question: "What is the date of project finalization?" (n=25)[1]



Source: FCH 2 JU, Inycom, Roland Berger

1) Small scale: Investment < EUR 50 m; mid-scale: Investment EUR 50–500 m; large scale: Investment > EUR 500 m

Second trend: Hydrogen Valleys are increasingly driven by private initiatives (rather than the public sector) that view a given project opportunity as a strategic investment in a new business area.
Especially in Europe, hydrogen projects have long been mostly initiated and led by public authorities and stakeholders from research and academia. Over the last two years, the landscape has shifted towards private enterprises as lead entities. More than 50% of Hydrogen Valleys surveyed for this report are led by private companies. Among large-scale projects, the share of private companies is even bigger (70%) – signs of a maturing market with more and more profitable investment cases. → J

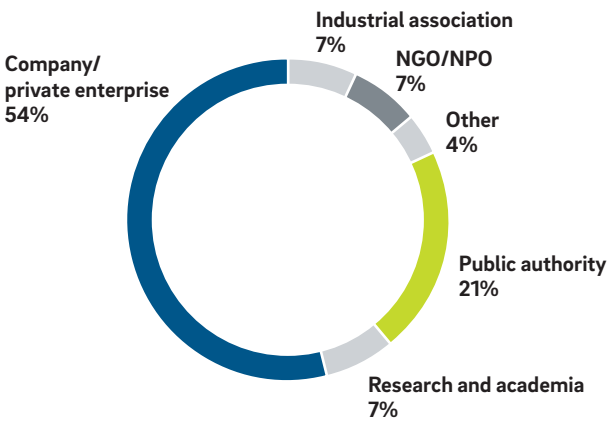
The underlying project drivers of Hydrogen Valleys confirm this trend: More than 45% of Hydrogen Valleys see their project as a strategic investment in a new business model, while 25% are even driven by a (potentially) positive internal rate of return. The best practice interviews validated this view: newly emerging Hydrogen Valleys are starting to be commercially driven, already in some cases without any public funding support. In the field of integrated projects, the hydrogen market has already become more attractive for the private sector and is poised to become even more so in the years to come.

Third trend: Hydrogen Valleys are gravitating towards three archetypical value chain setups that promise near-term commercial business cases.
Three archetypical value chain setups are representative of the current project landscape: → K

ARCHETYPE 1: Locally integrated, smaller-scale producers and consumers of hydrogen with a focus on mobility applications. These projects typically comprise locally anchored Hydrogen Valleys that produce and consume the hydrogen within a region. They usually involve many (i.e. dozens of) local stakeholders and are often led by public-private partnerships or regional public authorities. They have often organically grown from previous single-application demonstration projects and expanded their mobility focus over the past years in a step-by-step approach, e.g. from first uses of a few fuel cell buses in public transport with the associated refuelling infrastructure towards larger semi-captive fleets of buses, cars and trucks. At their core, they aggregate consumption volumes from different (mobility) users and share hydrogen supply as well as distribution infrastructure, such as refuelling stations. The Valleys are often driven by a combination of factors: reaching climate goals, lowering local emissions of pollutants and creating a new industry within their region to create jobs and increase its overall attractiveness.

J: Lead entity of the Hydrogen Valleys during project preparation

Question: "What kind of stakeholder is the lead entity in the preparation phase?" (n=28)

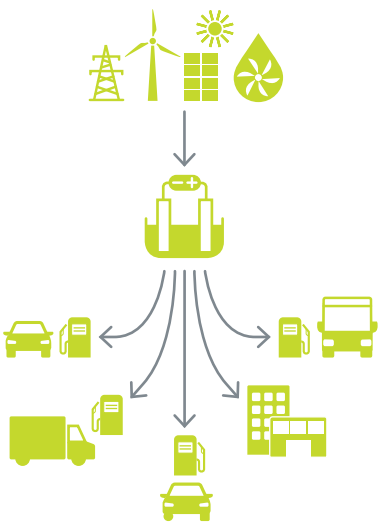


Source: FCH 2 JU, Inycom, Roland Berger

K: Hydrogen Valley archetypes

Archetype 1:

Local, small-scale & mobility-focused

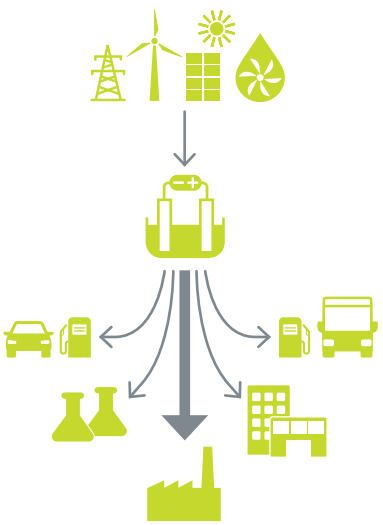


- Local (green) hydrogen production projects serving mobility applications (esp. semi-captive fleets of buses, cars, trucks, etc.)
- Key focus is on aggregating consumption volumes and sharing refuelling infrastructure (e.g. HRS)
- Legacy of mobility/electrolyzer demo projects
- Mostly led by public-private initiatives

Examples: Hyways for Future (Germany), Zero Emission Valley Auvergne-Rhône-Alpes (France), Hydrogen Valley South Tyrol (Italy)

Archetype 2:

Local, medium-scale & industry-focused



- Local (green or blue) hydrogen production projects centered around 1-2 large off-takers as "anchor load" (industry or energy sector, e.g. refineries), smaller mobility off-takers as add-on
- Making use of existing infrastructure around industrial plants, often replacing grey H_2 supply
- Mostly led by private sector

Examples: Basque H_2 Corridor (Spain), Advanced Clean Energy Storage (USA), HyNet North West England (UK)

Archetype 3:

Larger-scale, international and export-focused

- Large-scale projects with low-cost (green or blue) production, ultimately aiming for long-distance hydrogen transport to large off-takers abroad (but typically starting with local supply)
- Focus on connecting supply and demand internationally
- Mostly led by private sector

Examples: Eyre Peninsula Gateway (Australia), Blue Danube (IPCEI), Green Crane (IPCEI)

Source: FCH 2 JU, Inycom, Roland Berger

ARCHETYPE 2: Locally integrated, medium-scale producers and consumers of hydrogen with a focus on industrial feedstock. While valleys of this archetype also produce and consume their hydrogen locally (green or blue), the off-take focus is on one or more larger off-takers as "anchor loads", typically from the industry or energy sector (e.g. refineries). These off-takers create the initial critical demand for clean hydrogen – and thus present the project opportunity overall. This archetype leverages existing infrastructure around industrial plants (e.g. existing equipment and permits for industrial-scale energy supply, hydrogen compression, storage or local transportation). In a first step, clean hydrogen merely replaces grey hydrogen production. Other end-use applications, e.g. from mobility, may be added to the industrial demand, thereby benefitting from synergies in hydrogen supply. Projects are often driven by tightening regulations on large-scale CO_2 emitters that begin to turn to clean hydrogen as a progressively more attractive clean fuel. The projects are often led by private initiatives, either the off-taker itself or companies that want to tap into the new business potential of industrial clean hydrogen supply.

ARCHETYPE 3: Large-scale hydrogen production and international export focus. This emerging project archetype focuses on large-scale, low-cost (and mostly green) hydrogen production and storage, ultimately aiming for international, long-distance transport to off-takers abroad. The main motivation of these Hydrogen Valleys is to bridge the geographic gap between regions with favourable conditions for green hydrogen production and the future global hydrogen demand centres that are located elsewhere. They typically focus on large-scale off-takers from the industry and energy sector to commercially de-risk the necessary upstream and midstream investments. However, they typically follow a phased project implementation logic that initially includes smaller-scale supply for local off-takers near the place of production. These projects are often driven by private-sector initiatives and are still at earlier stages of their project development as they have been recently emerging globally (and often still await some public funding or supporting regulation). The main driver for project developers is to tap into the new long-term business potential of becoming competitive international hydrogen suppliers.

The three identified archetypes have complementary effects for the hydrogen market. While the first archetype establishes local hydrogen infrastructure and builds acceptance within the population, the second archetype enables the local scale-up of the market and reaps the benefits of hydrogen at a larger-scale by decarbonising the industry and energy sector. The third archetype increases the overall geographic coverage of hydrogen products and services while tapping into the most cost-efficient hydrogen potential.

In the short to mid term, it is reasonable to expect that due to the limited local green hydrogen production potential in some Hydrogen Valleys, archetypes will interconnect and create interfaces between the as-yet isolated initiatives. This will be more obvious in regional blocks with traditionally strong infrastructure links and bonding policies (e.g. the European Union). This will provide an additional push for the hydrogen market and will establish the necessary infrastructure and interconnection for the economy to reach maturity.

3 Elements of successful project development

Chapter 3 of this report analyses key factors for successfully developing Hydrogen Valleys. Based on the insights derived from the Hydrogen Valley survey, chapter 3.1 dives into the identified key success factors when setting up a Hydrogen Valley. Chapter 3.2 identifies and analyses the associated barriers and provides complementary insights on how to overcome them based on the experiences reported by selected Hydrogen Valleys during ten best practice interviews. → L

3.1 **PROJECT INCEPTION**: SETTING UP A HYDROGEN VALLEY

→ **First key success factor:** A convincing project concept with a value chain coverage and technology choices that leverage local assets and address local needs

→ **Second key success factor:** A viable commercial structure that enables first real business cases for developers (incl. any public funding)

→ **Third key success factor:** Public-private financing from multiple sources that includes enough public funding to close all gaps

→ **Fourth key success factor:** Partnering and stakeholder cooperation that covers the entire project scope and ensures continuous commitment from all parties involved

→ **Fifth key success factor:** Political backing and buy-in of the general public for smooth and continuous project development

First key success factor: A convincing project concept with a value chain coverage and technology choices that leverage local assets and address local needs

Regardless of the lead entity of a prospective Hydrogen Valley, the first step towards developing a successful project is to set up a convincing project concept. As highlighted in previous chapters, successful Hydrogen Valleys always cater to the specific needs and assets of a region. Therefore, local circumstances must be analysed thoroughly, and the project concept must match with these conditions. For example, these needs and assets may concern local emission reduction targets, structural changes in the economy that need to be faced, or an abundance of renewable energy or a strong industry in the respective region.

Matching the conditions in the potential Hydrogen Valley region with the archetype characteristics might be a first step towards shaping an attractive Hydrogen Valley concept. Archetype 1 tends to be driven by local decarbonisation needs, either resulting from ambitious climate goals or high local pollution levels as a side effect of fossil fuel use. Hydrogen Valleys falling into the category of archetype 2 are often driven by increasing regulatory pressure on the off-taker in the region and its need to decarbonise. Moreover, the possibility to create new value and supply chains in the regions, thus creating and retaining jobs that would otherwise be lost due to structural changes in the economy, is often an additional factor for both archetypes. By contrast, archetype 3 is driven by the abundance of renewable energy sources in the region and the resulting potential to export hydrogen at low cost to other regions with higher demand.

Consequently, irrespective of the need in the specific region, there are best practices in how to approach them and set up a convincing concept. Beyond that, based on the experience of the Hydrogen Valleys on the platform, it has proven to be beneficial to engage with policy makers early on to get approval for the concept. Sharing a common vision of the future of the region concerned that is also reflected in the project concept as well as subsequent collaboration is key to obtaining further support during project development and financing phases later on.

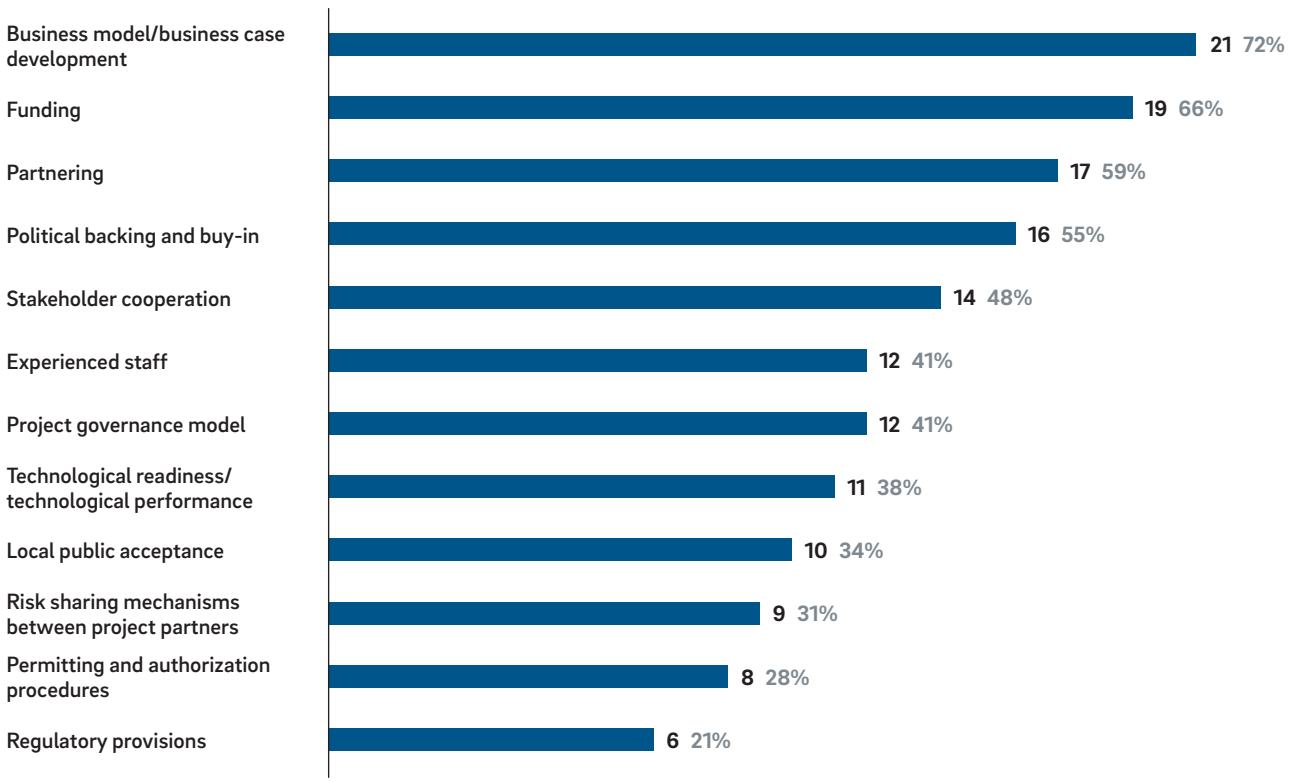
Second key success factor: A viable commercial structure that enables first real business cases for developers (incl. any public funding)

After an initial project concept has been set up, Hydrogen Valleys typically go through a more detailed feasibility and business case analysis including a detailed assessment of the project cost (capital and operating expenditure based on requests for quotation). All these analyses combined help assess the economic attractiveness of the project from various angles (e.g. local cost of supply of green hydrogen, total cost of ownership of hydrogen-based transport), quantify funding needs and thus ultimately the project's competitiveness compared to other offerings and alternative solutions.

Looking at existing Hydrogen Valleys under development today, they have average green hydrogen costs of 6–7 EUR/kg. Thus, the majority of Hydrogen Valleys are not yet cost competitive in all sectors – especially in the industry segment where the effective willingness to

L: Key success factors for the project development

Question: "What are the key success factors for the preparation phase?" (n=29)[1]



Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible

pay is determined by the on-site production cost of grey hydrogen (typically 1–1.50 EUR/kg without effective CO_2 pricing). The analysis shows that there are three major cost drivers: → M

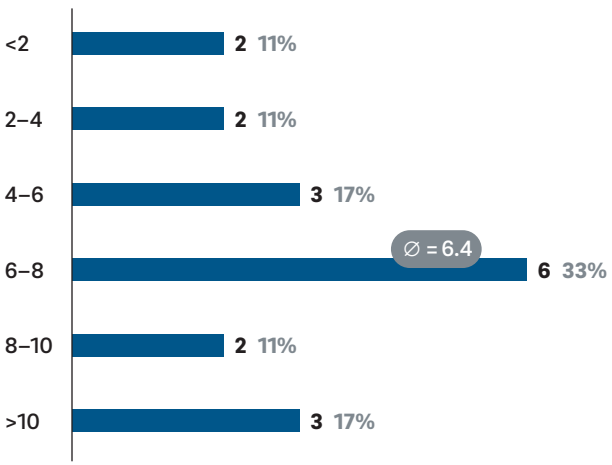
→ **Geography:** Hydrogen Valleys located in regions with abundant supply of renewable energy sources naturally have a lower cost of green hydrogen. Primary energy production and hydrogen production via water electrolysis are the major cost drivers within the Hydrogen Valley value chain. Nevertheless, four Hydrogen Valleys are already able to achieve costs below 4 EUR/kg and two projects even report costs below 2 EUR/kg.

→ **Project timelines:** Hydrogen Valleys that have already started implementation or that have already been fully implemented report higher hydrogen costs. All Hydrogen Valleys that report costs of 8 EUR/kg and above are already in the implementation phase. This confirms the observed technology cost reductions in recent years and indicates that Hydrogen Valleys are on a path to competitiveness irrespective of their geography. At the same

M: Average green hydrogen cost and competitiveness assessment

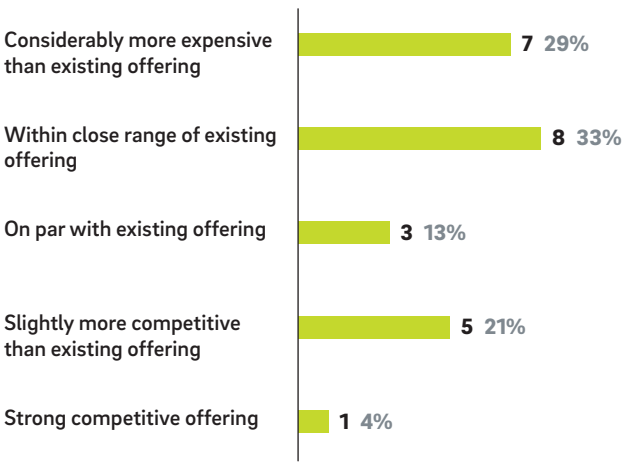
AVERAGE COST OF GREEN HYDROGEN

Question: "What is your (anticipated) average cost of green H_2 [EUR/kg]?" (n=18)



OVERALL COMPETITIVENESS

Question: "How competitive are your (anticipated) products compared to offerings based on conventional technology?" (n=24)



Source: FCH 2 JU, Inycom, Roland Berger

time, it is important to highlight the need for accurate feasibility studies that reflect real costs including all necessary equipment prior to implementation.

→ **Project scale:** Hydrogen Valleys with large investment volumes tend to report lower costs than smaller projects. The median hydrogen cost of large-scale projects with an investment volume above EUR 500 million is between 4–6 EUR/kg, while the median of smaller projects is between 6–8 EUR/kg, reflecting expected economies of scale and resulting cost reductions.

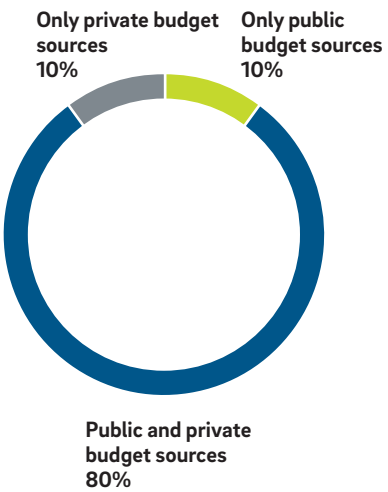
Signs of a maturing hydrogen market, thus conducive to a viable business case, are also visible in the projects' assessment of their competitiveness. While the majority still self-assesses as being less competitive than the conventional offering they need to compete with, an increasing share of Valleys (>35%) see themselves as on par or even more competitive. → M

It is important to highlight that competitiveness is highly dependent on the sector in which the Hydrogen Valleys operate. Although large-scale projects on average report lower hydrogen cost, their self-assessment is not

N: Main budget sources and public funding shares

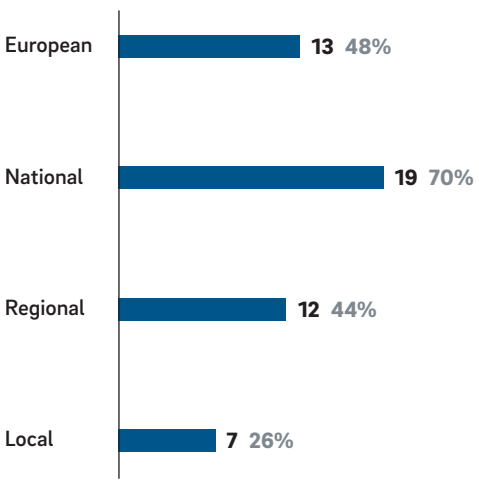
MAIN BUDGET SOURCES

Question: "What are the main sources for your budget?" (n=30)



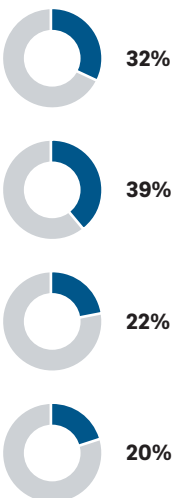
PUBLIC FUNDING SHARES

Share of projects with respective public funding (n=27)[1]



PERCENTAGE OF BUDGET FUNDED

Average % of budget funded by respective public institution (n=16)



Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible; as a share of all projects with (partial) public funding

as positive as the assessment of smaller projects. While more than 55% of large-scale projects above EUR 500 million state that they are considerably more expensive than the conventional offering, only below 30% of smaller projects report this to be true. This is likely an indication that large-scale Hydrogen Valleys compete in sectors where cost competition is intense and conventional hydrogen production costs via SMR are the benchmark, e.g. in the industry segment. Mobility-focused Hydrogen Valleys, which also tend to be smaller, have a better competitive position versus the incumbent heavily taxed fossil fuels. Ultimately, the landed hydrogen supply cost must match the willingness to pay of the main off-takers in the Valley. Either the suppliers have to find off-takers that are willing to pay their price and/or off-takers have to source hydrogen at their target price level. It might also be attractive for industry-focused Hydrogen Valleys to integrate supplying the mobility segment into their project to improve the overall business case.

Moreover, the valley needs a viable commercial structure, i.e. a combination of different business models (e.g. hydrogen production and supply, operation of refuelling stations, operation of hydrogen fuel cell vehicle fleets). The associated contractual relationships (e.g. hydrogen purchase agreements) need to be clear and together enable the de-risking of the entire Hydrogen Valley project.

Third key success factor: Public-private financing from multiple sources that includes enough public funding to close all gaps

According to the survey, nearly all Hydrogen Valleys (ca. 90%) still rely – at least partially – on public funding. Thus, searching and applying for public funding support schemes makes up a substantial part of the preparation phase and is the major success factor for the Valleys in the financing phase. So far, only 10% of Hydrogen Valleys are completely privately financed. → N

In Europe specifically, national and EU-level funding plays a major role in getting projects off the ground. 85% of all European Hydrogen Valleys receive national funding, while 65% receive European funding, e.g. from the FCH JU or the Connecting Europe Facility (CEF). For European Hydrogen Valleys it is common to have several public funding sources in parallel, particularly national or regional co-funding complementing European funding sources.

Looking at funding shares, European Valleys – if they receive the respective public funding – receive on average 39% of their budget through national public sources. Where they receive European funding, they receive on average 32% of their budget through that source. Regional and local co-funding have significantly lower funding shares. Hydrogen Valleys in the Asia-Pacific region also receive public funding, although funds tend to come from local and regional public entities. However, due to the relatively small dataset, explanations relating to public funding are limited for regions other than Europe.

A different picture emerges when looking at funding sources for the project preparation, i.e. setting up the project, the partner consortium and the funding for the implementation and operations phase of the project. During that phase, more than 40% of Hydrogen Valleys indicated that they have only private budget sources at hand. An additional 25% have access to both private and public funding. Moreover, the larger the projects tend to be, the more they rely on private funding for this phase. This confirms that the Hydrogen Valleys that are under development today are already driven to a large extent by private stakeholders.

A deep dive into the associated hurdles when securing both public and private funding can be found in chapter 3.2.

Fourth key success factor: Partnering and stakeholder cooperation that covers the entire project scope and ensures continuous commitment from all parties involved

Successfully creating a broad, yet manageable partner consortium for the project is also one of the major success factors according to the project developers. The majority of Hydrogen Valleys have more than 10 stakeholders from all sides involved and 40% of Hydrogen Valleys even report having more than 15 stakeholders. Thus, the establishment of successful governance mechanisms becomes key for the overall project (e.g. concerning joint project development work, joint decision making, joint communication activities).

Looking at the entire dataset of Hydrogen Valleys, more than 70% have a dedicated governance mechanism in place, with most of them being established at very early planning stages. Two thirds of the Hydrogen Valleys set up a working group for the project, while one third created a dedicated project company. Moreover, 30% of Hydrogen Valleys that have an established mechanism have two or more governance mechanisms simultaneously in place. Large-scale projects with an investment volume above EUR 500 million all have a dedicated governance mechanism as they also tend to have even more stakeholders involved (13 compared to 11 on average). → 0

When analysing the intersection of governance mechanisms and competitiveness, our data shows that 38% of Hydrogen Valleys organized as a project company self-assess as being on par with or more competitive than the conventional offering, while only 17% of Hydrogen Valleys organized as a working group claim to be so. This could indicate that a tightly organized consortium with an official legal structure is able to develop particularly successful projects, although other factors certainly play into it as well, such as the preference for a certain mechanism in various geographies.

The importance of a governance mechanism for effective partnering also becomes clear when looking at specific best practices for project development:

→ **Talks with many potential partners:** When setting up the consortium, it is vital to enter into talks with as many potential long-term partners as possible early on. This increases the flexibility to choose perfectly matching partners later in the project development and contributes to the project's visibility in various related sectors, such as technology suppliers or hydrogen users. For a deep dive on securing long-term off-take agreements, please see chapter 3.2.

> "The key learning for emerging Hydrogen Valleys is to build a growing network along the value chain very early on and to keep investing in the collaboration of stakeholders."
>
> — Hyways for Future, Germany

→ **Dedicated project manager(s):** Involving the necessary human resources to manage the consortium is key to the project's future progress. Due to the high number of stakeholders usually involved in the setup of a Hydrogen Valley, successful and efficient stakeholder management becomes critical for the project's development.

→ **Clear rules and delegation of responsibilities within the consortium:** The establishment of a governance mechanism from the beginning with clear rules and guidelines for the project consortium is important to guarantee an efficient kick-off of the project. It ensures the commitment of each partner to their respective responsibilities and establishes a common understanding of the tasks to be carried out by each partner involved.

"Since the commercial setup, it has been of great importance to have a dedicated and agreed governance mechanism in place. It is vital that all shareholders commit to their respective responsibilities in the company. For this reason, we advise putting very clear and transparent governance rules in place from the very beginning to ensure successful cooperation."
— ZEV, France

Fifth key success factor: Political backing and buy-in of the general public for smooth and continuous project development

Another major success factor mentioned by Hydrogen Valleys is the political backing for the projects from policy makers at regional (and national levels) as well as the support of the general public in the regions. Best practice valleys highlight the importance of early engagement – not only with policy makers, but also regulators, environmental agencies as well as the local community – to align on project objectives and general scope – and thus create trust in the project from the beginning. In many successful valleys, external stakeholders thereby become multipliers for the Hydrogen Valley and might even bring additional potential partners to the table.

Moreover, early engagement of policy makers often helps public funding, as Hydrogen Valleys can collect information on upcoming opportunities for funding and the prerequisites to receive it and adjust their projects accordingly. It also creates a win-win situation as policy makers profit from information on the ground, which ideally also leads to them addressing potential policy barriers quickly and effectively.

The local community is especially important in locally embedded projects (archetype 1 and 2) that directly affect local living conditions, e.g. by implementing new public transport technologies or car sharing services. These applications need to be accepted and used by the community. Thus, getting in contact with the local population and highlighting the benefits of the projects early on is essential.

"First, regionally focused Hydrogen Valleys need to ensure that the general public, which includes not only political decision makers but rather more importantly local residents, understand the needs and objectives of the project. Raising awareness of the importance of hydrogen use as well as demonstrating its regional added value to the people is the first step in creating a functioning Hydrogen Valley." — eFarm, Germany

3.2 BREAKING DOWN PROJECT BARRIERS: EXISTING HURDLES FOR HYDROGEN VALLEYS TODAY AND WAYS TO OVERCOME THEM

The successful project inceptions today are still accompanied by common challenges and hurdles that Hydrogen Valleys face (to varying degrees). These barriers fall into three categories: First, obtaining funding for the projects, both public and private. Second, hurdles directly related to the successful setup of a project, such as the business case, technological readiness and successful governance. And third, external factors impacting the project, such as regulatory provisions, political backing and local acceptance of the general public. → P

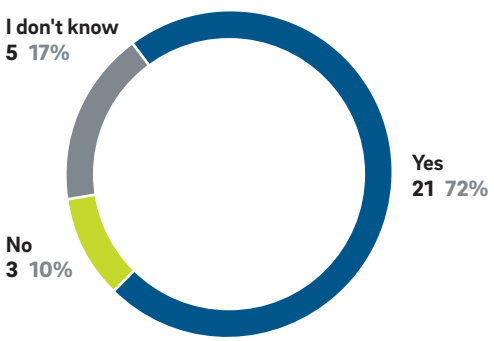
Still, the most prominent hurdles for Hydrogen Valleys today are related to successful funding and an overall viable business case for the project. 50% and 43% of Hydrogen Valleys respectively mention these factors as a barrier. Especially obtaining public funding, off-take commitments and private funding are the most common challenges for Hydrogen Valleys in this respect, but technological readiness and regulatory provisions also get mentioned frequently. The following chapter picks up on these top hurdles and provides a synopsis of successful actions undertaken by Hydrogen Valleys to overcome them:

- **First barrier:** Securing public funding
- **Second barrier:** Securing off-take commitments
- **Third barrier:** Securing private funding
- **Fourth barrier:** Mitigating technological readiness and technological performance

0: Governance mechanisms

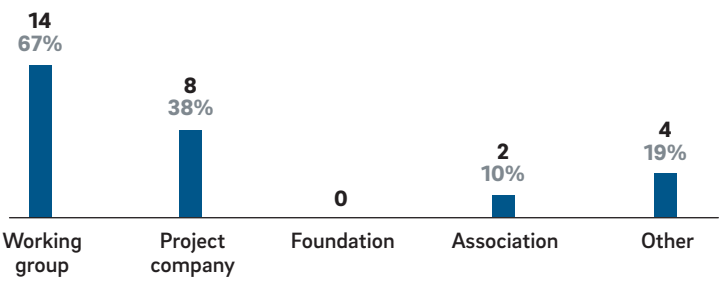
GOVERNANCE MECHANISM

Question: "Do you have a formal and dedicated governance mechanism in place?" (n=29)



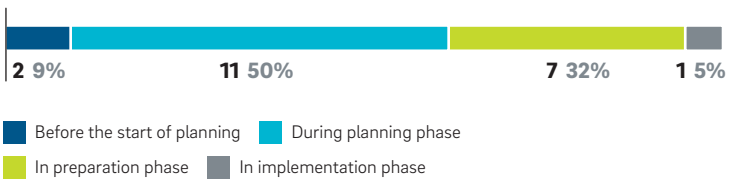
TYPE OF GOVERNANCE MECHANISM

Question: "What kind of governance mechanism do you have in place?" (n=21)[1]



TIME OF ESTABLISHMENT

Question: "At what time in the project did you establish the governance mechanism?" (n=22)



Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible

For an analysis of the policy landscape and associated regulatory hurdles, please refer to chapter 4.

First barrier: Securing public funding

For the majority of Hydrogen Valleys (59%), obtaining public funding is still a major hurdle for their project and at the same time the key to the project's realisation. Nevertheless, many Hydrogen Valleys on the platform successfully managed to secure public co-funding from different entities and different levels of government for their projects. The following insights are the collective lessons learned from these Hydrogen Valleys.

→ **Creating awareness about the technology among funding entities.** Building up internal knowledge on the functioning of funding entities and public application procedures in order to be able to raise awareness of the technology among funding entities proved to be essential, especially when the funding programmes were not specifically designed for the funding of hydrogen technologies. Hydrogen Valleys reported that local authorities managing funds were inexperienced with regards to the technology and its associated benefits. By informing the local authorities on the project's potential, they were able to increase their formerly low public funding support by substantial amounts.

"We invested in advanced training on European public funding laws for our core team. In addition and for more complex funding applications, we sought targeted external expertise (e.g. [legal] consulting services) in order to deal with the local administration responsible for funding or with EU-level funding programmes – and thus to be better prepared for the next funding programme."

— Hydrogen Valley South Tyrol, Italy

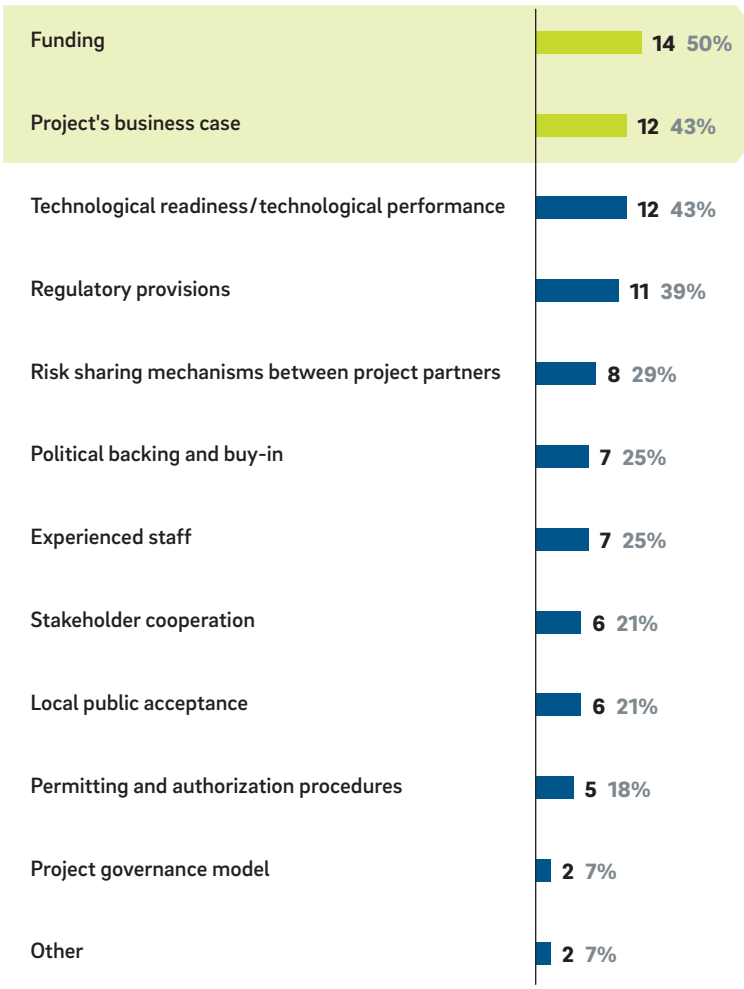
→ **Initiating proactive dialogues with potential funding entities while maintaining flexibility on the project developer's side.** Hydrogen Valleys highlighted the importance of proactive and collaborative dialogues with a broad set of potential funding entities. This allowed for the subsequent alignment of the respective Hydrogen Valley concept with the entities' funding priorities. To achieve this, however, enough flexibility on the project developer's side is essential. If achieved, projects can become tailor-made with specific subparts catering to each respective funding programme.

→ **Leveraging funding entities as multipliers.** Hydrogen Valleys reported that having the support of one public entity enabled them to get in touch with more public entities willing to fund additional parts of the Valley. They were thus able to approach additional resources quite easily by being referred from one entity to the next.

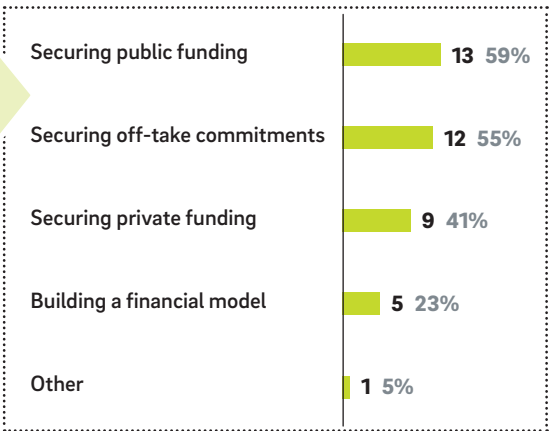
"For regional or local public co-funding, it can be beneficial for hydrogen projects to leverage already successfully established access to public funding. Meaning that an already positive and strict evaluation at European level, such as that of the FCH JU, can be used to convince regional or local decision makers to shorten their evaluation process." — HEAVENN, Netherlands

P: Main barriers in the preparation and financing phase

Question: "What are the main preparation hurdles that you have to overcome?" (n=28)[1]



Question: "What are the main financing hurdles that you have to overcome?" (n=22)[1]



Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible

→ **Managing the funding process with the necessary resources.** Application processes for public grants are very resource intensive. Hence, the Valleys highlighted that having the respective resources at hand to coordinate the application process and manage the many stakeholders involved proved to be essential. Moreover, being able to manage and maintain the momentum in a project consortium over a longer period including breaks, for example the waiting period after the submission of application materials or after an unsuccessful funding call, is also vital for the projects to reach the implementation stage.

"It is worthwhile taking a broad and inclusive perspective on potential funding sources. It pays off to look at different ministries, agencies, programmes, etc., analyse their policy agendas and funding priorities – and ultimately maintain enough flexibility to shape a hydrogen valley project in a way that secures broad political buy-in."

— Living Lab Northern Germany, Germany

Second barrier: Securing off-take commitments

Securing off-take commitments has been identified as the number two hurdle in the financing phase for Hydrogen Valleys (55%). Getting the commitment from off-takers to buy clean hydrogen, especially with a long-term agreement, is one of the most important steps to de-risk the entire value chain of a project and specifically the substantial upstream investments needed to produce it.

→ **Making upfront investments.** A convincing project development is required to kick off commercial discussions with potential off-takers. This results in a need for upfront investments from the project developer to signal their willingness and project development competence to the market. This includes conducting feasibility studies, front-end engineering work and reporting on progress in permitting processes or testimonials of political and public support, among other things.

"Technical and economic credibility comes first. A full de-risking of a large-scale project which ultimately aims at securing binding off-take commitments requires, first of all, a convincing project development concept as an 'entry ticket' to meaningful commercial discussions."

— ACES, USA

→ **Entering into discussions with many potential off-takers.** Talking to a large number of potential off-takers and keeping them up to speed with the project's overall development also proved to be vital to achieve required off-take agreements. Due to the urgency of climate mitigation and the recognized potential of the industry today, policies are shifting in favour of clean hydrogen at a rapid pace in many geographies worldwide. Hence, potential off-takers that might not have seen the need to decarbonise and shift to clean hydrogen today might have an urgent need tomorrow.

→ **Entering into discussions with off-takers from various sectors.** Due to the dynamic developments in the market today, it is also beneficial to approach off-takers from different sectors, as clean hydrogen will become competitive at different points in time compared to the conventional applications used in the respective segment. Clean hydrogen is already price competitive in some sec-

tors today, for example in the mobility segment. Thus, including off-takers from these segments might complement and de-risk the overall project further and contribute to reach the required off-take quantity.

Third barrier: Securing private funding

Although significant shares of the budget are covered through public sources, substantial parts of the budget also need to come from private sources. Most Hydrogen Valleys thus receive private equity funding through the participating private stakeholders in the project. Hydrogen Valleys also use debt to varying degrees when financing their projects, ranging from shares of below 30% to more than 80%. Getting a Hydrogen Valley to a bankable stage, thus making it attractive to private and public institutional investors, is one key element needed to realize the growing ambitions of the projects.

→ **Setting up a structured project.** The bankability of a Hydrogen Valley is determined in its project preparation stage. A structured project development approach is the starting point and therefore all activities mentioned in this chapter ultimately contribute to a project's bankability. This includes setting up a convincing project concept, conducting environmental, economic and technical feasibility studies as well as installing an adequate project structure and overall good governance and leadership. Moreover, risks need to be allocated efficiently and de-risking must be pursued as far as possible.

→ **Involving off-takers and equity partners that support the commercial de-risking early on.** A key takeaway from interviews with solely privately funded projects was to include off-takers and other counterparts that lead to an overall de-risking of the commercial structure early in the project development. Setting up contracts with long-term off-takers of the hydrogen is the major contributing factor to de-risk a Hydrogen Valley by substantial amounts, particularly necessary for capital-intensive upstream investment.

"Our key learning for other and future projects is to build up contracts that involve off-takers and counterparts that de-risk the commercial structure of the project; without them, bankability cannot be achieved, and private funding will be difficult." — CEOG, French Guiana

→ **Receiving early feedback from potential investors and financiers.** Moreover, a Hydrogen Valley also mentioned the advantage of getting an infrastructure fund on board during the project development. Funds not only provide capital during a capital-intensive phase but can also contribute significantly in terms of project development know-how, which further helps the projects reach the bankability stage. Early feedback is thus beneficial for the project's ultimate bankability.

→ **Local private funding.** In the case of a locally anchored project developer setting up a Hydrogen Valley in its own region, it proved best to include only private funding from local companies and banks. This in turn helped to create more local acceptance for the project and enhance the credibility of the developer's intentions to the general public. In including local and regional policy makers very early in the project development and gaining their support, they were also able to introduce a favourable clause in the public funding commitments, which helped the off-takers of the project claim additional costs from the local governments, thus further improving the business case.

Fourth barrier: Mitigating technological readiness and technological performance

40% of Hydrogen Valleys identified technological readiness as a hurdle to developing their projects. If that question had been asked a few years prior, the share would have certainly been much higher. Over recent years, substantial piloting and demonstration activities along the entire hydrogen value chain have taken place and improved the technological readiness of electrolysers, refuelling stations and also end applications such as buses and cars significantly. Today, other hurdles have become more pressing according to the Hydrogen Valleys. However, technological readiness still plays a major role in successfully implementing and operating a Hydrogen Valley.

→ **Ensuring flexibility of the project concept.** Technological readiness also includes the availability of products and services on the market. Several Hydrogen Valleys reported having difficulty in procuring light-duty vehicles for their Hydrogen Valleys as there is not enough supply on the market currently. The mitigation strategy involved expanding procurement efforts to heavy-duty vehicles to reach the needed utilization factor for the refuelling stations in the project. However, suppliers will need to scale up their production in the short term to maintain market momentum.

→ **Ensuring efficient systems integration, commissioning, operation and maintenance.** While the availability of hydrogen technology and applications is one factor, another major factor includes the efficient systems integration, commissioning, operation and maintenance of the technologies deployed. Another mitigation strategy of the Hydrogen Valleys to avoid lengthy maintenance times was to ensure procurement of technical equipment with fast and reliable maintenance services included – either provided directly by the supplier or by trusted third parties.

"First, we identified key factors on technological risk mitigation: ensuring the possibility of e.g. fast and reliable maintenance and repairing services from suppliers or from trusted third parties. For that reason, we implemented a reserve fund for the project to be able to react effectively to potential hurdles and delays, such as technical or financial trouble experienced by an essential equipment supplier." — HEAVENN, Netherlands

4 A policy landscape that allows for Hydrogen Valleys to emerge

Looking at the main hurdles when developing a Hydrogen Valley, adverse or missing regulations still remain a pertinent point. Over a third of projects still see it as a critical barrier, indicating that – while the regulatory environment for the use of hydrogen and fuel cells has improved globally – some work remains to be done. Encouragingly for the sector, when asked specifically what the main regulatory hurdles are, Hydrogen Valleys also frequently confirm that regulatory provisions are not a barrier for them anymore. Their regions or countries now provide a more opportune environment for their project and already have some well-designed policies and permitting procedures in place. → P

Nevertheless, regulatory barriers still exist. For European Hydrogen Valleys, for example, nearly half of all valleys surveyed see regulation as a critical obstacle to project development. The following chapter 4.1 provides a synopsis of the mentioned hurdles and regulatory provisions along the three following dimensions: permitting, policies directly affecting Hydrogen Valleys and policies indirectly affecting Hydrogen Valleys. This will serve as a background for chapter 4.2, which presents a set of policy recommendations to support the successful development of Hydrogen Valleys globally. → Q T

4.1 THE POLICY LANDSCAPE: EXISTING HURDLES AND KEY REGULATORY PROVISIONS FOR HYDROGEN VALLEYS

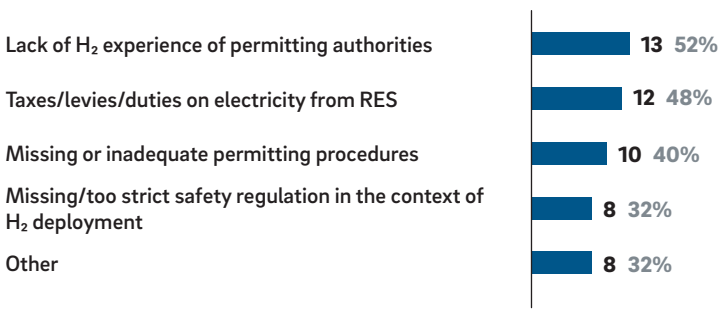
Permitting

Permitting topics are the major regulatory hurdle for project developers of Hydrogen Valleys. Looking deeper, several factors are in play: First, the lack of experience of permitting authorities. Many local and regional authorities are not used to authorizing permits for hydrogen infrastructure (e.g. electrolysers, storage tanks, grids, refuelling stations) or end-use applications, which typically complicates and prolongs the project development process. More than half of Hydrogen Valleys see this as a hurdle. Second, the permitting procedures themselves are often missing or in some way inadequate for Hydrogen Valleys, which 40% cite as an additional barrier. → Q

Only 50% of Hydrogen Valleys in the survey indicate that they have clarity on all required permitting procedures, which confirms a lack of experience on both

Q: Main regulatory barriers

Question: "What are the main regulatory hurdles that you have to overcome?" (n=25)[1]



Other hurdles
(selection of quotes from survey):

"Legal uncertainty around RED II article 27 (e.g. additionality and other criteria)"

"Acceptance of scope 3 cross-border CO_2-emission reduction projects"

"Grid connection fees"

Source: FCH 2 JU, Inycom, Roland Berger

1) Multiple answers possible

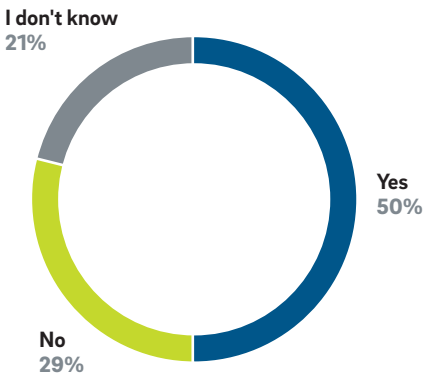
sides, on the authorities' side regarding the hydrogen technologies and on the project developers' side regarding the permitting procedures. Nevertheless, about 60% of Hydrogen Valleys confirm having already obtained a major construction, deployment or operating permit. Consequently, many Hydrogen Valleys will enter and move along or into the permitting stage in the upcoming months and years and authorities will need to provide efficient solutions to facilitate the emergence of projects and ultimately enable the deployment goals set out in the various hydrogen strategies. → R

A positive indicator for future permitting processes is the data on permitting timelines: Hydrogen Valleys tend to need less time than they initially plan for obtaining major construction and deployment permits. The median planned time for the permits is 12 to 18 months, whereas the median amount of time actually needed is between 6 and 12 months.

R: Permitting activities

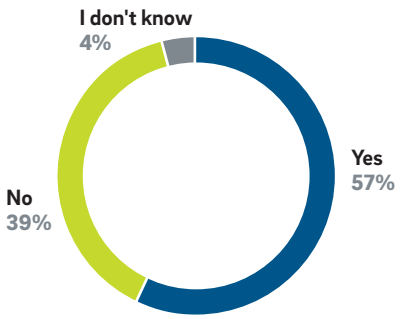
PERMITTING PROCEDURES

Question: "Do you have clarity on all required permitting procedures?" (n=28)

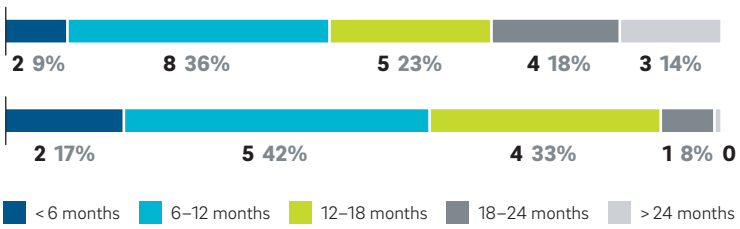


MAJOR CONSTRUCTION OR DEPLOYMENT PERMITS

Question: "Have you already obtained any major construction or deployment permit?" (n=28)



TIME NEEDED TO OBTAIN PERMIT



Source: FCH 2 JU, Inycom, Roland Berger

Policies and regulation directly affecting Hydrogen Valleys

Almost 50% of Hydrogen Valleys see taxes, levies and duties on electricity from renewable energy sources as a key barrier to developing their project. As electricity is the major input factor and operational expenditure in green hydrogen production, regulations affecting the power price are policies that directly impact the business case of the projects. The same holds true for midstream and downstream-related regulations, for example regarding hydrogen injection into the gas grid. → Q

Funding programmes are also part of the regulatory environment that help Hydrogen Valleys directly by enabling the closing of the remaining funding gap and thus making the business case viable. Many Hydrogen Valleys mention public funding schemes as key regulatory provisions for their projects. Among the funding schemes mentioned are Important Projects of Common European Interest (IPCEI), the FCH JU programme, the Connecting Europe Facility (CEF) as well as the Just Transition Fund and the LIFE programme. Non-European Hydrogen Valleys especially mention grants from local governments, e.g. from California or South Australia, as key regulatory provisions.

Moreover, hydrogen strategies from regional to supranational level also play a decisive role in signalling political commitment for hydrogen. Many projects highlight the positive influence of these strategies and recognize the resulting political support from local and national ministries as essential. → S

Policies indirectly affecting Hydrogen Valleys

Hydrogen Valleys are not only impacted by direct regulations but are also dependent on the regulations targeting the conventional (i.e. fossil fuel) technologies and applications they compete with. As the majority of Hydrogen Valleys operate in multiple sectors simultaneously, they are concerned with a variety of regulations that influence the cost of their conventional competitors. The development of additional or stricter environmental regulations for these technologies is equally as important for the emergence of Hydrogen Valleys as it is to provide effective regulation for their own operation. For example, European Hydrogen Valleys mention the legal uncertainty regarding the implementation of the Renewable Energy Directive ("RED II") and the resulting hesitation of potential off-takers as a barrier. Moreover, regulation affecting the price for CO_2 and the European regulations around clean vehicles are identified as key regulatory provisions as well.

By implementing these policies – not only the regulations around conventional energy carriers and Hydrogen Valleys themselves but also national and regional hydrogen strategies as well as funding programmes mentioned by the Hydrogen Valleys as key provisions for their development – the policy landscape will progressively become more favourable for Hydrogen Valleys globally. → S

4.2 BREAKING DOWN REMAINING POLICY BARRIERS: KEY RECOMMENDATIONS FOR POLICY MAKERS

From the above elements, a general picture of a favourable regulatory and policy environment emerges that tends to facilitate the development of Hydrogen Valleys. The following policy recommendations lay out what policy makers should prioritise when aiming to actively stimulate the Hydrogen Valley landscape in their country and support project developers.

Recommendation 1: A clear vision of the country's future hydrogen economy in a national hydrogen strategy that sets the framework for Hydrogen Valley development

For Hydrogen Valleys to be successfully developed, project developers will benefit from a clear understanding of the country's overall strategy regarding the future role of hydrogen and the country's envisaged hydrogen value

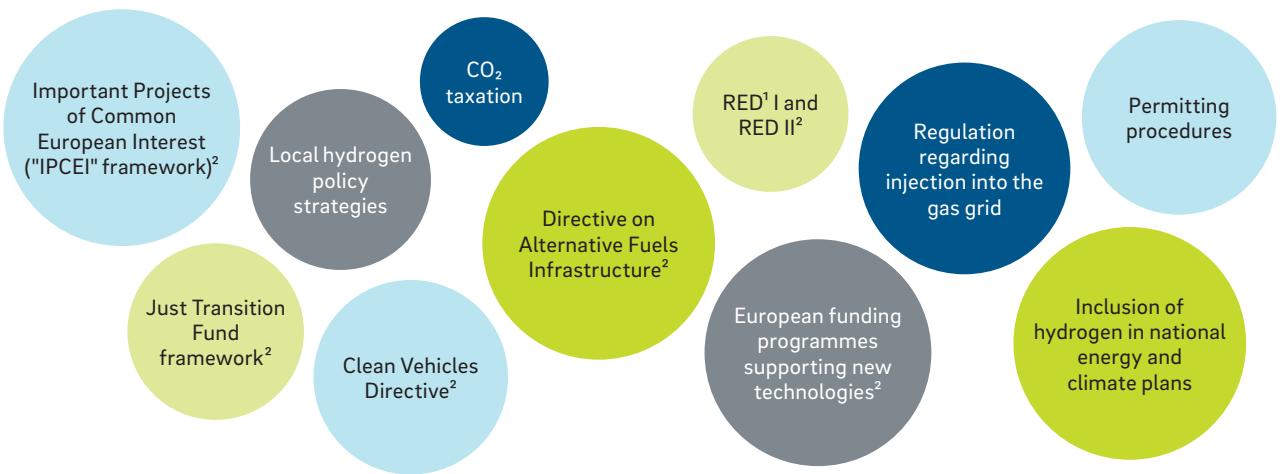
chain (e.g. domestic production vs. imports, transportation infrastructure, main sectors for clean hydrogen usage). This also includes questions regarding the favoured hydrogen colours, e.g. blue vs. green hydrogen production, and especially how the preferences will evolve over time. All of the above will give Hydrogen Valleys more business certainty for designing their project as well as their medium to long-term investment planning.

Moreover, countries need to establish clarity regarding their position in a globally evolving hydrogen market. What is a given country's strategic aspiration, e.g. to become a production centre, an import gate or a transportation and storage hub? Answering this question will involve sector studies and strategies to project long-term needs for hydrogen (including structural import requirements) as well as assessments on whether there might be a possibility to export hydrogen due to favourable conditions for production. The boundaries set by these strategies will give Hydrogen Valleys the required orientation to set up a convincing project concept that is in line with the country's capacities and needs – and meets the government's expectations as well as those of potential public support schemes.

After the determination of long-term possibilities and needs, countries will ideally set ambitious goals for deployment of hydrogen technologies. This signals the commitment of policy makers to the technology and further incentivises potential Hydrogen Valley developers to pursue projects. The formulated goals should ide-

S: Key regulatory provisions

Selection of quotes from Hydrogen Valleys globally



Source: FCH 2 JU, Inycom, Roland Berger

1) RED=Renewable Energy Directive; 2) Quotes refer to European legislation and/or programmes

ally be specific, time-bound, quantitative (e.g. planned electrolyser capacities by 2025/2030, number of hydrogen refuelling stations by 2025/2030) and allow for effective monitoring of national progress.

Recommendation 2: A regulatory environment conducive to the development of Hydrogen Valleys

To ultimately help more Hydrogen Valleys emerge and be successfully developed, a supportive regulatory environment needs to be in place that creates business certainty and adequate incentive and support schemes. Four key aspects are particularly important from a Valley point of view:

→ **Regulation enabling the (industrial) off-take of clean hydrogen.** As outlined in chapter 3, securing off-taker commitments is a key success factor for a Hydrogen Valley project's de-risking and one of the crucial enablers of its implementation. As clean hydrogen today competes with much cheaper (and CO_2-intensive) grey hydrogen and other fossil fuels, especially in industries with large-scale hydrogen demand today and/or tomorrow (e.g. refining, fertilizer production, steel production) as well as high grade heating needs, regulators need to incentivize the off-take of clean hydrogen by helping bridge the effective cost gap. This can be achieved for example by creating effective CO_2 pricing schemes at high enough levels, implementing quotas for the use of clean commodities in certain industries or offering Carbon Contracts for Difference (CCfD) for large-scale, clean hydrogen off-takers. CCfDs are a policy instrument hedging both contributing parties to the contract against lower (or higher) CO_2 prices in the future and thus reducing uncertainty on the part of the industry over investing in innovative and clean technologies and at the same time avoiding unnecessary compensation with taxpayers' money.

→ **Regulation enabling clean hydrogen production.** Simultaneously, the production of clean hydrogen needs to be supported. In the case of green hydrogen, electrolyser operators in many geographies require grid access to obtain the required level of operating hours year round in order to produce hydrogen at a reasonable cost. This is especially the case for Hydrogen Valleys with local production (archetype 1 and 2) that are not in regions with an abundant supply of renewables and a beneficial mix of various, complementing, intermittent renewables.

Therefore, the exemption from taxes or levies on the grid electricity consumed is highly beneficial to the business case of Hydrogen Valleys for hydrogen supply and would also further foster the market for green corporate power purchase agreements. In the future, electrolysers could also provide demand side or general ancillary services to the power grid. Moreover, the use of electrolysers could also contribute to limiting the curtailment of renewable energy by transferring energy from the power to the gas grid.

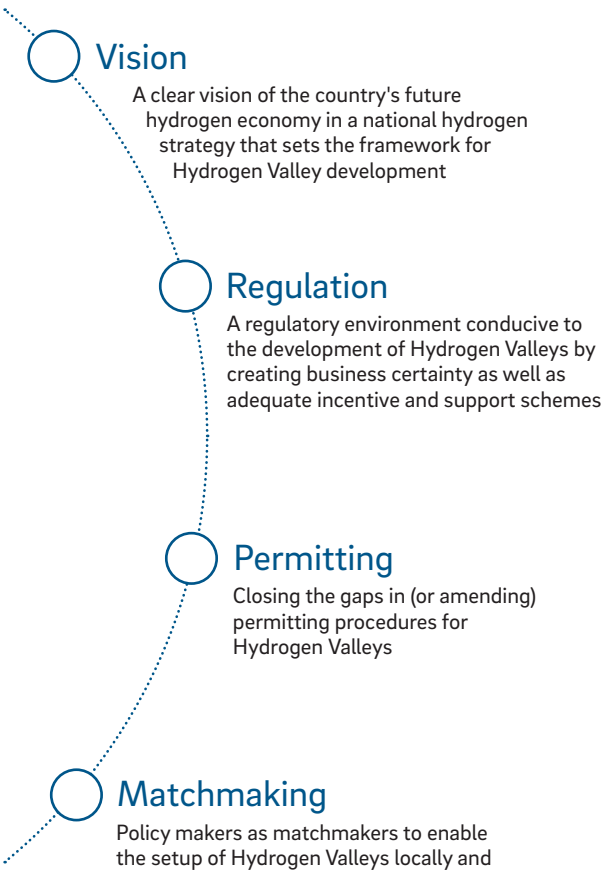
Additional and temporary investment subsidies for the deployment of electrolyser capacities further contribute to favourable business cases in the short and medium term (as electrolyser cost will come down) and thereby close the funding gap in comparison to grey hydrogen or alternative technologies. Dedicated funding programmes specifically targeting Hydrogen Valleys in supporting the setup of local hydrogen value chains and integrated hydrogen ecosystems also contribute to the concept's success.

→ **Regulation enabling the development of regulated business models in hydrogen transport.** As Hydrogen Valleys have been emerging and expanding over the years and are now starting to form "mini hydrogen economies" including the transport and storage of hydrogen over longer distances, policy makers also need to address the regulatory gaps and needs in the midstream part of the

value chain. Specifically, governments need to start to enable the development of regulated business models that could potentially concern all elements of the future hydrogen value chain with prospective "natural monopolies" – where regulated asset bases will likely be most economically efficient. In the mid term, this may include the injection of hydrogen into the natural gas grid, the operation of hydrogen pipelines (retrofitted or newly built) or the operation of hydrogen storage facilities. For this goal – and to enable global supply chains – transnational cooperation between policy makers is required to create a level playing field for all stakeholders and transport technologies and thus facilitate cross-border supply. Here, Hydrogen Valley projects can become the testbed and first real-life cases of new regulated business models.

→ **Closing the gaps in standardisation of hydrogen use along the value chain.** Creating a level playing field goes hand in hand with the setup of internationally harmonised codes and standards related to hydrogen, its production, distribution and use, which is especially important for Hydrogen Valleys that intend to export hydrogen (archetype 3). When standardisation bodies close the existing gaps, e.g. regarding the definition of hydrogen colours, or policy makers decide on clean hydrogen's possibility to contribute to certain environmental quota, the entire hydrogen supply chain needs to be considered. First steps have been taken by the European CertifHy project, funded by the FCH JU, that developed a roadmap for a European-wide hydrogen infrastructure for Guarantees of Origin of green and low-carbon hydrogen. The next phase of the project until 2023 involves the establishment of harmonised Guarantees of Origin schemes across Europe in collaboration with the Association of Issuing Bodies (AIB). Moreover, due to rapid technological developments, existing standards in the sector need to be revised regularly as well.

T: Four main policy recommendations



Source: FCH 2 JU, Inycom, Roland Berger

Recommendation 3: Closing the gaps in (or amending) permitting procedures for Hydrogen Valleys

In the upcoming months and years, the Hydrogen Valleys on the Mission Innovation Hydrogen Valley Platform that are still at the planning stage will enter implementation and many more Hydrogen Valleys and other hydrogen-related projects will start to emerge. This will set the overall hydrogen economy on a path to exponential growth – partly due to the many hydrogen strategies that are emerging globally and the ongoing and growing support of the technology as policy makers globally recognize its potential. Standardised, effective and fast permitting procedures are key to maintaining market momentum and ensuring a fast, reliable and safe scale-up of the sector. Hence, the setup of permitting jurisdiction and efficient procedures as well as the clarification of existing processes should be the focus of policy makers globally.

For the closing of existing gaps in permitting processes and the adaptation of existing ones, a partnership-based approach between authorities might be mutually beneficial. Moreover, international cooperation including sharing best practices and lessons learned between policy makers globally might create additional value. Beyond that, Hydrogen Valleys might also profit from the consolidation of jurisdiction and expertise in certain dedicated authorities, for example at the national level, instead of having local or state-level authorities managing the process. This might prove to be conducive to their development, especially in the short term, until sufficient capacity building on the side of regional authorities has taken place. Developing the required knowledge and skillset within authorities should therefore be another focus of policy makers.

Recommendation 4: Policy makers as matchmakers to enable the setup of Hydrogen Valleys locally and stimulate the sector overall

Policy makers, especially local and regionally anchored policy makers, are well connected stakeholders within their regions. This makes them ideally suited to act as matchmakers for Hydrogen Valley project developers that want to engage in hydrogen production and are looking for local off-take. By connecting project developers with potential off-takers in the region that seek to decarbonise, reduce air pollution or that want to tap into new business potential, e.g. an e-fuels plant, policy makers can ultimately enable the Hydrogen Valley to get off the ground. Simultaneously, project developers can engage with respective authorities early-on in the development of a Hydrogen Valley and bring them to the table to discuss possibilities and requirements in the event that the project seeks to apply for public funding.

Another matchmaking possibility is to conduct "idea contests" or "calls for expressions of interest" to develop specific Hydrogen Valley concepts for selected regions. This could be the case if a region with a specifically urgent need to decarbonise or to improve local air quality is identified. In providing a structured way for project developers to participate and share their ideas for the region, policy makers can select the most promising option from the best candidate, also in terms of maximising local value creation.

5 What's next for Hydrogen Valleys?

In the upcoming years, Hydrogen Valleys will continue to play an ever more integral part in building further momentum in the market. New Hydrogen Valleys will be developed increasing the coverage of hydrogen products and services globally. Moreover, existing Hydrogen Valleys will enter operation, expand their scope and start collaborations with neighbouring Valleys. They will also further mature commercially and will contribute to local acceptance by raising awareness and showcasing the potential of a green hydrogen economy. → U

5.1 THE BIGGER PICTURE (AGAIN): HYDROGEN VALLEYS' MARKET ROLE IN THE YEARS TO COME

Entering implementation and operation as well as facilitating the emergence of new Hydrogen Valleys

Hydrogen Valleys will continue to play an integral part in building further momentum in the market globally. The Hydrogen Valleys represented on the Mission Innovation Hydrogen Valley Platform comprise a total investment volume of more than EUR 30 billion covering more than 20 countries worldwide. Only little more than 10% of Hydrogen Valleys have entered operations so far. In the upcoming five years and beyond, the bulk of the remaining projects will enter the implementation phase and will thus contribute significantly to the further industrialisation of the industry. These forerunners can also contribute to the emergence of new Hydrogen Valleys in new markets and geographies. More Hydrogen Valleys will emerge globally building on the knowledge and experience of existing projects.

Tapping into expansion and collaboration

70% of Hydrogen Valleys indicated that they plan to expand their activities beyond the currently envisioned scope. This includes scaling up activities, but also tapping into new applications. Moreover, Hydrogen Valleys also plan to expand their geographical scope by merging with neighbouring projects. Therefore, the next phase for Hydrogen Valleys will lead to transnational or even international collaborations to exploit synergies and provide the product and service to a widening geography.

Moving towards commercial maturity

Hydrogen Valleys will further mature commercially and pioneer more mature and innovative de-risking and financing models in their project development. Already, commercial structures and financing models are becoming more sophisticated in projects, e.g. with limited-recourse project financing appearing in first Hydrogen Valleys that is backed by long-term take-or-pay agreements for hydrogen off-take and transportation. Competitiveness of Hydrogen Valleys will further improve globally as technology costs decrease and conventional fossil-fuel technologies become more expensive due to tightening regulations. This trend will likely go hand-in-hand with a growing interest of the financial community in direct project investments.

Representing lighthouse projects of the new hydrogen economy

Hydrogen Valleys will remain essential as bottom-up creators of local acceptance and awareness of the importance of hydrogen for the clean energy transition. Through local value creation, additional job creation, the improvement in air quality and the resulting visibility, Hydrogen Valleys will be able to pave the way for the full roll-out of a global market by showcasing its potential on an increasing scale. A global market will also provide an opportunity to generate income for renewable resource abundant, low-income economies with otherwise limited natural resources. → V

5.2 THE ROLE OF THE MISSION INNOVATION HYDROGEN VALLEY PLATFORM:
THE PLATFORM AS INFORMATION PROVIDER, PROJECT INCUBATOR AND GLOBAL COLLABORATION ENABLER

The Mission Innovation Hydrogen Valley Platform wants to become an enabler for the hydrogen economy worldwide. The platform to date already comprises the most ambitious and advanced projects in the market globally – a unique opportunity to leverage their insights and initiate conversations – not only among themselves, but also with project developers that are just getting started as well as policy makers worldwide. Through a collaborative approach and exchanging best practice, the sector will benefit as a whole and the hydrogen economy will come one step closer to maturity. These objectives will be achieved through several lines of action:

The platform as information provider

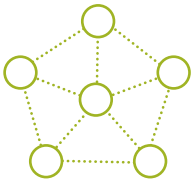
The platform to date already offers the most comprehensive data collection on Hydrogen Valleys worldwide, fully accessible to the public. More than 30 Hydrogen Valleys globally put extensive efforts into answering the in-depth survey and additionally provided insights via best practice interviews. This shows the global willingness for sharing information and thus helping other project developers, industry representatives and policy makers alike understand key success factors, alongside key challenges and how to face them effectively.

U: Hydrogen Valleys in the years to come

Vision: Hydrogen Valleys will play an integral part in building further momentum in the market

"More of the same"

Hydrogen Valleys can help develop first H_2 projects in new markets and geographies



Connected Valleys

Connecting existing Hydrogen Valleys (e.g., NL and DE) can enable the market

Towards a commodity

Pioneering more mature and innovative de-risking and financing models

A green hydrogen future

Raising awareness and social acceptance at local and regional level

Source: FCH 2 JU, Inycom, Roland Berger

The next steps involve putting more emerging Hydrogen Valleys on the platform, thus further increasing the data quantity and quality on the platform. Some subsections of the survey have not been put on the platform yet as sufficient data has not been available so far. Next steps would therefore involve improving the database, especially regarding economic and environmental impact for additional display on the platform.

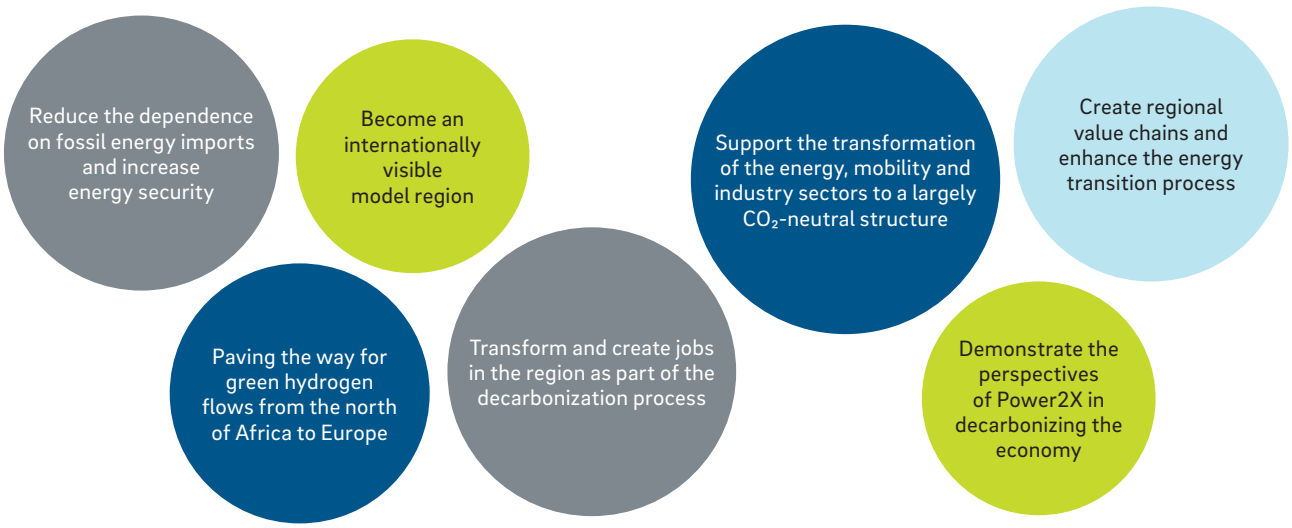
In order to remain the main source of up-to-date information regarding Hydrogen Valleys, the data on the platform will need to be updated regularly. The vast majority of Hydrogen Valleys on the platform are still being developed, thus changes in the project setup occur almost inevitably and projects will gather more insights along the way on how to manage a Valley effectively. Staying in touch and updating the data will therefore remain key for the platform.

The platform as global collaboration enabler between Hydrogen Valleys

During the development of the platform, regular exchanges between the Hydrogen Valleys selected took place. The exchanges, and especially the feedback on the future functionalities of the platform, showed the key role for global collaboration between Hydrogen Valleys and the opportunity that arises from this platform.

V: Additional project benefits

Selection of quotes from Hydrogen Valleys globally



Source: FCH 2 JU, Inycom, Roland Berger

As previously stated, the importance of collaboration for Hydrogen Valleys as well as the sector overall was also highlighted during our best practice interviews: the immediate next steps for mature Hydrogen Valleys on the platform involve collaboration across projects.

Therefore, the platform could serve as a facilitator of exchanges between Hydrogen Valleys by starting to initiate conversations between projects from the same region but subsequently also international conversations. The goal should be to explore potential synergies of Hydrogen Valleys, e.g. between a renewable resource abundant Hydrogen Valley and a Hydrogen Valley that pursues the scale-up of their hydrogen use in various end sectors but has limited clean hydrogen production potential of its own. The platform could thus provide a space for collaboration between project developers – but not limited to that: once two potential Hydrogen Valleys have agreed on exploring tangible and concrete ways of collaboration, policy makers in the Mission Innovation member countries could join the conversation and offer additional support and guidance, e.g. regarding funding opportunities in the Hydrogen Valleys' home countries. Moreover, policy makers in the affected countries could align on their support offered for the Valleys' future collaboration. Thereby, the platform could become a central matchmaking point for existing Hydrogen Valleys on the platform seeking to expand and collaborate across projects.

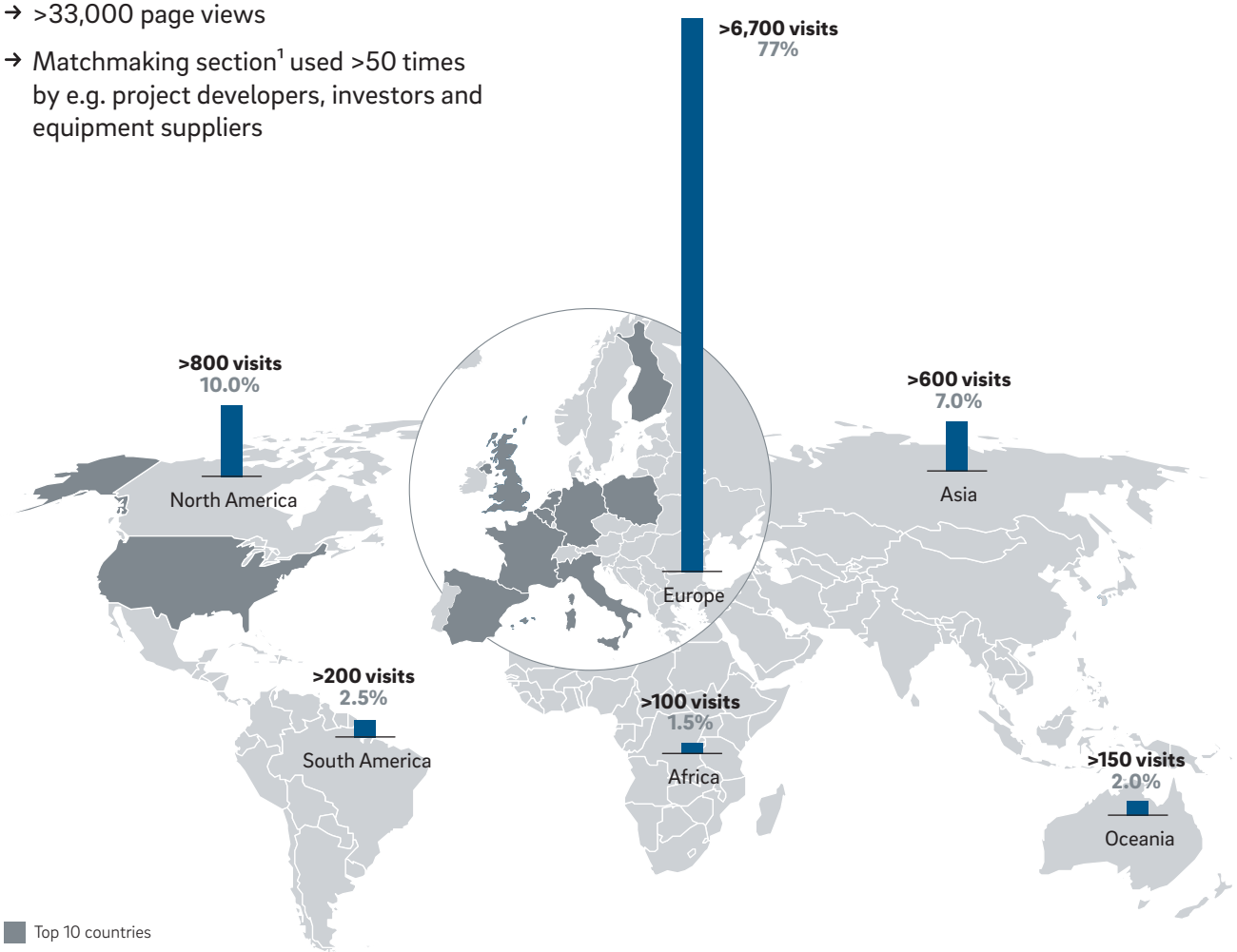
The platform as Hydrogen Valley incubator

The platform can become a project incubator through the facilitation and initiation of new Hydrogen Valleys around the world. To date, the platform already offers the possibility for project developers, companies, regional authorities as well as the general public to reach out to Hydrogen Valleys on the platform. During the first weeks after the launch, the matchmaking part of the platform has already been used extensively with more than 50 submissions. Particularly, other entities who develop hydrogen projects and are at earlier stages of their project development reached out to Hydrogen Valleys of their choice with their questions. This clearly shows the need of emerging projects for guidance and input from more experienced developers. Moreover, potential investors also used the matchmaking section extensively, thus confirming the need for a single point of information on ongoing hydrogen projects. → W

Next steps could involve the expansion of these activities to target and bring on board younger and less mature projects. For example, it would be possible to provide initial workshops on the setup of Hydrogen Valley concepts on the platform. Moreover, additional best practices on the platform specifically targeting the topic of project conceptualisation and how to gather initial support could be of additional help. Lastly, additional knowledge and insights from the FCH JU's "Project Development Assistance for Regions Initiative" could be leveraged and shared for a global audience on the platform.

W: Use of the Mission Innovation Hydrogen Valley Platform since its launch

- → Total number of visits: >8,600
- → >33,000 page views
- → Matchmaking section[1] used >50 times by e.g. project developers, investors and equipment suppliers



Source: Matomo (14:00 CET, March 15, 2021), FCH 2 JU, Inycom, Roland Berger

1) The matchmaking section provides the opportunity to contact Hydrogen Valleys represented on the Mission Innovation Hydrogen Valley Platform

6 Conclusion

The results presented in this report, which have been obtained throughout the setup of the Mission Innovation Hydrogen Valley Platform, highlight once more the importance of Hydrogen Valleys, not only for the hydrogen sector but also the success of the energy transition overall. As Hydrogen Valleys have already started to form first regional "hydrogen economies", they act as bottom-up stepping stones in the development of the new hydrogen economy. The results also show that the Hydrogen Valley concept is expanding and will significantly mature over the 2020s, due to an increasing number of projects overall and because announced projects themselves are growing in size and complexity.

For the successful development of a Hydrogen Valley, five factors proved to be particularly key. A Hydrogen Valley not only needs a convincing project concept with a hydrogen value chain coverage that leverages local assets (e.g. abundant renewable energy sources) and addresses local needs (e.g. the decarbonisation of local industrial production), it also needs to develop a viable business case that links competitive clean hydrogen production with the off-takers' willingness to pay. Here, obtaining public support and/or funding, (potentially from multiple sources) that closes any remaining funding gaps is still vital. During project development, effective partnering and stakeholder cooperation that ensures continuous commitment from all parties involved is essential, as is getting political backing from policy makers and support from the general public.

Nevertheless, barriers for the projects still exist, but they are not insurmountable. The best practice interviews with project developers globally brought attention to the fact that projects were indeed able to address all barriers Hydrogen Valleys highlighted as most prevalent, namely obtaining public and private funding, securing off-take commitments as well as managing technological readiness. Yet most Hydrogen Valleys still (at least partially) rely on public funding support to close the competitive gap to conventional technologies. A clear vision of a country's future hydrogen economy as well as the global setup of conducive regulations, harmonised standards as well as transparent and efficient permitting procedures is thus highly critical for the success of Hydrogen Valleys and the sector in general.

Hydrogen Valleys will unfold their full potential globally towards the middle of the decade. In the years to come, all Hydrogen Valleys currently featured on the Mission Innovation Hydrogen Valley Platform will reach the implementation phase and ultimately operation. In addition, 70% of Hydrogen Valleys also indicated that they intend to expand their activities beyond the current scope. Moreover, Hydrogen Valleys will continue to move towards commercial maturity and thus remain lighthouses of the hydrogen economy. The Mission Innovation Hydrogen Valley Platform seeks to contribute to these activities by providing the go-to website for up-to-date information on Hydrogen Valleys' project development globally and by serving as a project incubator for emerging Hydrogen Valleys as well as collaboration enabler between mature projects.

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