Scaling up hydrogen investment

How public authorities can use partnering models to deliver projects

European Investment Bank
The EU bank

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1. Introduction

Hydrogen has the potential to decarbonise a variety of sectors including power, the heating and cooling of buildings, transport and industry. It is expected to play a key role in sectors and applications that are difficult to electrify. Examples include heavy-duty transportation and industrial processes requiring high-grade heat, as well as the power sector, where it could serve as a means to store energy from variable renewable energy sources over daily, weekly or seasonal time frames.

The European Union's Hydrogen Strategy[1], adopted in July 2020, identifies the significant investments required to bolster the clean and low-carbon hydrogen sector until 2030. Similarly, the Fit for 55[2] package and the REPowerEU[3] plan — launched by the European Commission in July 2021 and May 2022, respectively — provide policy initiatives and targets for the development of the hydrogen ecosystem. Private sector investors are increasingly considering investing in hydrogen projects. Despite the perceived challenges and risks, the market for these projects is growing[4]. Nevertheless, in order to reach the European Commission's targets, substantial public support will be needed[5] to develop, accelerate and deliver hydrogen projects.

Projects considered to be part of the green and low-carbon hydrogen ecosystem are those aiming to develop or deploy infrastructure or assets for hydrogen production, storage, transmission and/or use. The projects must feature hydrogen produced through means that ensure it is associated with no or limited emissions of greenhouse gases[6]. Reflecting the tendency for hydrogen production and use to be closely integrated, project types within the hydrogen ecosystem generally cover more than one value chain component.

Public authorities have an important role to play in scaling up the hydrogen ecosystem. First, they need to ensure that enough demand for hydrogen applications is generated at the local, regional and national level. This demand is necessary in order to attract investment in the generation of supply (hydrogen production). To do this, legal and regulatory interventions are necessary, together with the creation of incentives for hydrogen use. Second, because hydrogen production and distribution are costly, public authorities need to take on some of the investment costs and associated risks. This is key to avoiding the valley of death (the critical initial phase that every new business or technology, such as hydrogen, is faced with until it becomes commercially self-sustainable). With this goal in mind, public contracting authorities may need to contribute to the development of hydrogen-related infrastructure and decide how to best use the limited public funds that they have in order to maximise support for this new ecosystem.

[1] European Commission (2020). A hydrogen strategy for a climate neutral Europe, COM (2020) 301 final. Available online at https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[2] European Commission (2021). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, COM(2021) 550 final. Available online at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN

[3] European Commission (2022). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: REPowerEU Plan, COM(2022) 230 final. Available online at https://eur-lex.europa.eu/resource.html?uri=cellar:fc930f14-d7ae-11ec-a95f-01aa75ed71a1.0001.02/DOC_1&format=PDF

[4] European Commission and European Investment Bank (2022). Unlocking the hydrogen economy – stimulating investment across the hydrogen value chain: Investor perspectives on risks, challenges and the role of the public sector, EIB. Available online at https://www.eib.org/attachments/publications/unlocking_the_hydrogen_economy_en.pdf

[5] ibid

[6] This report uses the CertifHy definitions of green and low-carbon hydrogen. For more information please refer to https://www.certifhy.eu/

About this report

This report has been developed with public contracting authorities in mind. Whereas public support for hydrogen projects can come in various forms, here the focus is placed on project delivery solutions that involve private sector partnering models. The aim of the report is to serve as a compass for contracting authorities wishing to navigate the ever-expanding and changing hydrogen project delivery landscape. To this end, it offers practical information and guidance on why and how such projects — which often span different value chains — can be delivered through partnering models.

Methodology

The study informing this report comprised desk research, project case studies and interviews with stakeholders in the hydrogen ecosystem. The starting point was to outline the boundaries of this ecosystem and describe its value chains and their components. This mapping made it possible to identify a large number of possible project types, which were subsequently narrowed down based on numerous criteria. The analysis then focused on project types that were most suitable for public sector support via the use of private sector partnering models. Ultimately, the six project types deemed most promising based on a list of additional criteria were studied in detail, with a view to both suggesting the most suitable partnering model for their type, and exploring other relevant project structuring characteristics (risk allocation, value for money, bankability, etc.). This report presents a high-level summary of these findings. Individual guides on each one of these six project types contain a much more detailed version of this information.

Structure of the report

Section 2 presents partnering models suitable or available for hydrogen projects. Section 3 contains a brief discussion of the main risks affecting these projects. Section 4 lists the types of projects within the hydrogen ecosystem that would lend themselves to partnering solutions following the use of relevant filters and criteria. Section 5 then presents the six most promising project types together with the criteria that led to their selection. This section also contains summaries of the findings from the detailed analysis of each project type, including information on their optimal partnering model, key stakeholders and funding sources. The final section provides suggestions for next steps.

2. Partnering models

Partnering models differ in terms of the support required from the public authority and the allocation of responsibilities and risks to the public and the private sector sides of the partnership. Only five existing partnership models were found to be available and/or suitable for projects within the hydrogen ecosystem. The names and brief descriptions of these models are shown in Table 1. Public contracts, licensing and government intervention limited to the granting of subsidies fall outside the scope of this study.

Table 1 — Five main partnering models in the hydrogen ecosystem

Availability-based contract	The public authority makes periodic payments to the private partner that are linked to the infrastructure being available for use and the defined services being delivered. Payments to the private partner will start only once the construction phase is complete and service delivery has begun. Risks associated with operating the infrastructure are mainly transferred to the private partner, with the notable exception of user-demand risk. The private partner finances the capital and maintenance expenditure but the public sector retains some control over the infrastructure as well as ownership.
Concession	The public authority retains some control over the specification, installation, operation and use of the infrastructure. The risks associated with operating the infrastructure (including user-demand risk) are typically transferred to the private partner, although risk allocation in a concession contract can be tailored to specific circumstances. The private partner finances the capital and maintenance expenditure, with or without subsidies, guarantees or other financial support from the public authority. It also collects and retains user revenues from multiple end users, with or without sharing with the public authority.
Build-operate-transfer (BOT)/ build-own-operate (BOO)	The public authority grants the right to develop and operate a facility for a certain period to a private company, in what would otherwise be a public sector project. In a build-operate-transfer project, the private company finances, constructs and operates the facility commercially for the project period, after which it is transferred back to the authority. Revenues are often obtained from a single offtake purchaser, such as a utility or government, which purchases project output from the project company. The build-own-operate variant corresponds to the case where the private partner retains the ownership of the asset at the end of the contract, instead of transferring it back to the public authority.
Operating lease	An operating lease is an agreement to use and operate an asset without the transfer of ownership. The key difference between an operating lease and a finance lease is that in the former, the asset is returned to the owner at the end of the lease period, whereas in a finance lease, ownership of the asset is generally transferred to the operator at the end of the lease term. The advantage of an operating lease relative to a finance lease, from the point of view of the operator, is that the asset owner bears the risks involved with obsolescence and residual value.
Joint venture	The public authority and private partner create a joint venture company through which they share control of the infrastructure. The risks are shared by the parties according to their stakes in the joint venture. The model is flexible on financing arrangements, which might come from one or both parties or from a separate third party. User revenues are also collected by and shared between the parties according to their stakes.

Partnering model suitability criteria

There are many possible reasons why a given infrastructure project may be suitable for delivery through a partnering model that involves private sector participation. In general, such models are a means for governments and public entities to deliver a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance. A public entity may wish to involve private parties in procuring public assets or services for the following reasons:

- Value for money: Involving private investors can help ensure that projects are as financially viable as possible, therefore limiting the amount of public support required.

- Technical limitations: The public entity may not have the technical skills or the personnel required to oversee the design, construction and operation of a given infrastructure asset, and involving a private operator may help address these limitations.

- Budgetary constraints: Public entities have limits to their borrowing capacity, and are generally constrained as regards large capital expenditures.

Additionally, partnering models are generally well-suited to delivering essential public infrastructure assets or services in the presence of implementing conditions such as the following:

- Lack of viability without public support: When projects are not viable without public support, the use of partnering models may provide a solution. Public infrastructure assets that enjoy natural monopoly status are a typical case of such projects.

- Externalities: When there is a positive externality associated with procuring a given infrastructure project, the public authority has an interest in developing the project. For instance, the market price for public transportation services often does not reflect the full costs and benefits to society. Public transportation generally leads to significant benefits in the form of decreased greenhouse gas emissions and lower congestion in cities, compared to private transportation. Municipalities therefore have an interest in procuring public transportation services.

- Opportunity for risk transfer: Certain risks, such as construction risk, are usually better handled by the private sector and partnership models offer the means for this transfer to take place. On the other hand, private investors may be averse to certain risks, such as demand risks. When appropriate, such risks could be retained by public entities under a partnering model. This is even more pronounced in cases of public authorities that are developing projects requiring a continuous and reliable source of green and low-carbon hydrogen.

3. Risks

Projects in the green and low-carbon hydrogen ecosystem face a number of risks that should be allocated to the parties that are most suited to managing and mitigating them. Allocating the risks to each of the parties is a key determining factor for the selection and design of the optimal partnering model.

Demand risks

Demand risk is critical in the development of green and low-carbon hydrogen production projects. To a degree, this risk may be mitigated through offtake agreements signed with interested parties, supporting industrial, transport and other applications. Nevertheless, developers of hydrogen production projects could be left exposed to default or bankruptcy on the part of their customers. The lack of liquidity on hydrogen markets leads to hydrogen producers having high risk exposure.

On the contracting authority side, there are numerous local applications where hydrogen-related services could be beneficial. These include, for instance:

- Decarbonising public transport: Switching city buses and non-electrified rolling stock to hydrogen use.
- Decarbonising municipal vehicle fleets: Switching waste collection vehicles, snow removal vehicles and other municipal vehicles to hydrogen use.
- Decarbonising heating in buildings: District heating networks previously powered by fossil fuels could be converted to run on hydrogen.

Promoting a local hydrogen economy has many indirect benefits to regional authorities as well. For example, decarbonising road transport is directly linked to better air quality in cities. Hydrogen production can also make it possible to secure high shares of variable renewable energy production, given the flexibility it provides to the power system.

As a result, regional authorities have a sustained interest in procuring green and low-carbon hydrogen and incentivising local use.

Project-on-project risks

When projects grow beyond the scope of a single integrated facility, significant technical concerns emerge that go beyond the uncertainty of commercial supply and demand dynamics. For example, one key risk for blue hydrogen production facilities stems from the possible unavailability of CO_2 transport and storage services. Such unavailability may lead to temporary halts to production. Offtakers relying on the hydrogen outputs could then be negatively affected and request compensation on the basis of the offtake agreement. At the same time, operating the facility without any carbon capture could negatively affect public support for the project.

Regional authorities can play a role in coordinating such investments to ensure that all the value chain components are developed on schedule. They can also structure the compensation mechanisms that address the unavailability of any given value chain component, whether this occurs due to a delay in developing the required infrastructure or operational unavailability. This enables cascading project-on-project risks to be better mitigated.

Design risks

Most of the projects in the green and low-carbon hydrogen ecosystem involve assets with a long operational lifespan that should address not just today's needs but also those of the energy system in ten or 20 years' time. However, in the absence of a fully fledged hydrogen market, project developers will only tend to address immediate local needs and design facilities accordingly. Long-term forecasts of future needs are thus required to make today's investments as impactful and future-proof as possible. Contracting authorities can play an important role in soliciting stakeholder opinions, tracking and anticipating policy framework changes, and integrating scenarios for technology development to derive credible and comprehensive forecasts of future needs in order to optimise the design of these facilities.

Regulatory and policy risks

Policy decisions directly and indirectly affect projects along the entire length of the green and low-carbon hydrogen value chain. Public authorities can support the emergence of a local green and low-carbon hydrogen ecosystem in a number of ways. For example, consumer incentive schemes can lead to greater adoption of hydrogen fuel cell vehicles or higher rates of connection to district heating networks.

Additionally, when public authorities decide to participate in projects that use a partnering model, they can provide guarantees to project developers concerning the supporting policy framework, and can also help with the coordination of planning and permitting processes.

Lastly, these authorities can also structure funding and subsidy opportunities. Subsidy schemes at the national or regional level can play a role in businesses' decisions to convert current fossil-powered applications to hydrogen.

Structuring investments in a coordinated approach

Contracting authorities have a key role to play in structuring green and low-carbon hydrogen investments with a coordinated approach, thereby mitigating a series of key project risks including project-on-project risks, input supply and output demand risks, design risks and more. The European Commission Hydrogen Strategy[7], foresees the emergence of so-called hydrogen valleys in the coming decade, as an intermediate step prior to the development of a fully fledged European Union-wide hydrogen economy. Regional and municipal governments — as well as public utilities, public transport companies and other public entities — are expected to drive and coordinate investments in these hydrogen valleys.

Hydrogen valleys would host entire value chains, including all stages from production to application, including transmission and storage infrastructure, as well as upstream supporting components such as clean energy production. In practice, many individual projects will tend to be self-contained in the starting phase of the green and low-carbon hydrogen ecosystem. For example, hydrogen-powered public transport vehicles are often procured as a single comprehensive solution including not only the supply and maintenance of the vehicles, but also the supply and distribution of green and low-carbon hydrogen to refuel them.

Regional authorities can apply this risk mitigation strategy to an entire regional value chain. Doing so can build resilience, as key infrastructure components such as refuelling infrastructure can be designed to address the needs of multiple applications, on top of reaching decarbonisation objectives.

[7] European Commission (2020). A Hydrogen Strategy for a climate neutral Europe. Available online at https://ec.europa.eu/commission/presscorner/api/files/attachment/865942/EU_Hydrogen_Strategy.pdf.pdf

4. Hydrogen project types relevant to partnering

Starting from the fullest possible version of the hydrogen ecosystem, a number of filters and criteria were used to identify the types of project that would be relevant to partnering solutions. This process involved analysing public policies for hydrogen, reviewing upcoming national hydrogen project pipelines and using the partnering model suitability criteria presented in section 2. The analysis only considered technologies that are likely to be deployed by 2030 (those that could significantly contribute to scaling up the ecosystem in the near to medium term).

Figure 1 presents the subset of the green and low-carbon hydrogen ecosystem that is relevant to partnering solutions.

Figure 1 Subset of the hydrogen ecosystem that is relevant to partnering solutions

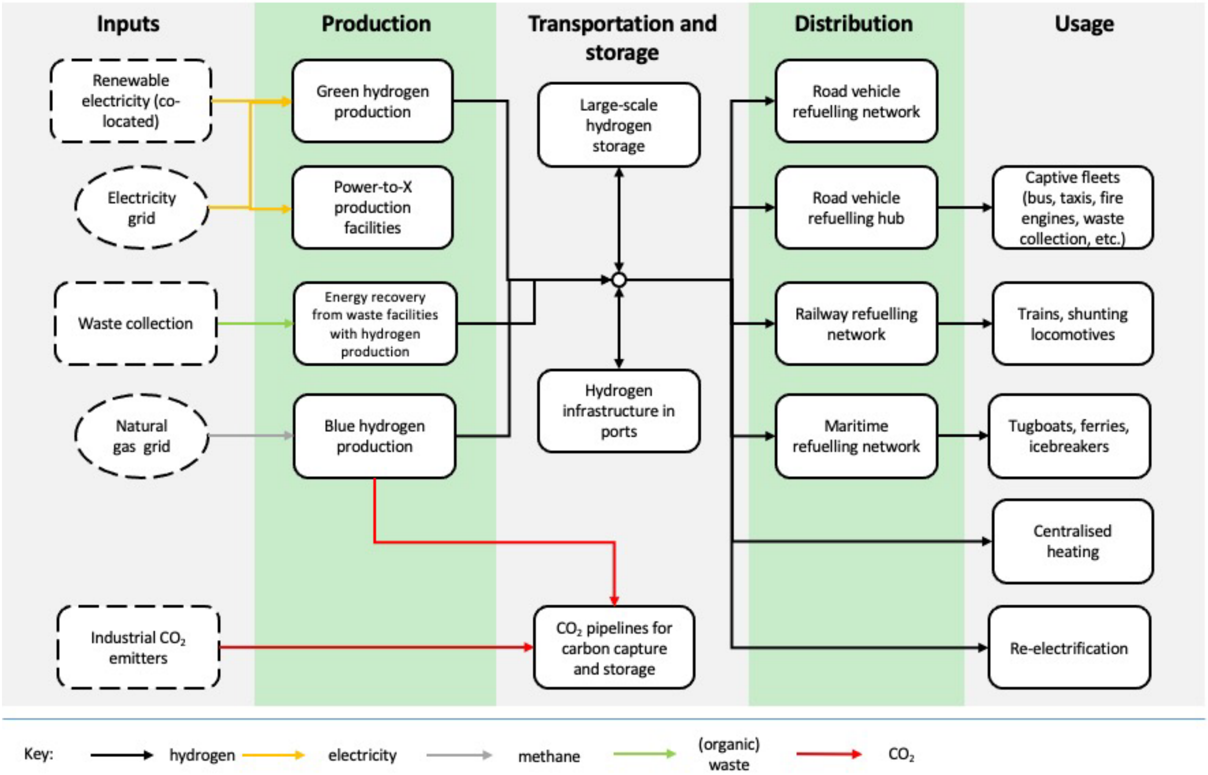


Table 2 presents the main types of projects that could be delivered through some form of partnering model. In preparing this list no assumption was made about the type of partnering model that could be used for each project type.

Table 2 — Types of hydrogen projects relevant to partnering models

Project type	*Relevance to partnering models*
Development of green hydrogen production facilities powered by renewable electricity	A reliable supply of green and low-carbon hydrogen is essential to the development of the hydrogen economy. The use of green hydrogen in applications such as industry, transport, power and buildings will result in positive externalities, notably in the form of reduced greenhouse gas emissions. However, there are significant market risks associated with investments in hydrogen production because hydrogen is currently not traded as a commodity. Price support will be necessary to attract investments (such as through contracts for difference — CfDs), but may not be sufficient. Through a partnering structure, public entities may guarantee that they will take a share of the hydrogen produced by a given facility, for example to supply a municipal public transport network. This arrangement would help address market risks.
Hydrogen production from waste	Local public entities with an interest in securing a supply of low-carbon hydrogen may consider supporting the emergence of local hydrogen value chains.

Project type	*Relevance to partnering models*
	Hydrogen production from waste is linked to the provision of public services, namely the management of residual waste, including waste from agriculture, forestry, wastewater treatment and municipal solid waste.
Development of blue hydrogen production facilities, coupled with carbon capture and storage (CCS)	Some hydrogen value chains will require the capture and storage of CO_2 emissions in order to qualify for the production of green and low-carbon hydrogen. These include, most importantly, blue hydrogen production from steam methane reforming (SMR) coupled with CCS. Blue hydrogen production projects represent approximately 15% of green and low-carbon hydrogen projects expected to be developed in the European Union by 2030, by number of projects[8].
Development of other power-to-X production facilities	Public entities may consider participating in the development of other power-to-X production facilities as a means of ensuring security of supply and of supporting the emergence of local hydrogen and synthetic fuels value chains. These conversion technologies that turn electricity into carbon-neutral synthetic fuels, such as methanol, ammonia, or synthetic kerosene (among others), can be deployed through partnering models.
Development of CO_2 pipelines for CCS	Developing CO_2 pipelines and storage capacity will be a key enabler of blue hydrogen production capacity. Due to the high cost of pipelines, they should ideally address the needs of multiple facilities to ensure sufficient volumes are transported and stored. CO_2 pipelines are a form of local natural monopoly. Public entities have an interest in supporting these projects as they can result in significant positive externalities in the form of reduced greenhouse gases.
Development of dedicated hydrogen storage facilities	Storage facilities will be key components within local, regional, national and international hydrogen grid networks. Public entities with a strategic interest in securing a stable supply of low-carbon hydrogen may consider participating in partnering models integrating local green hydrogen production and storage, thus de-risking these investments whose business cases are highly uncertain. Potential examples of such projects include the storage of hydrogen to address the needs of applications where significant public support is expected due to positive externalities, such as public transport.
Development of terminalling, bunkering, storage and grid connection facilities in ports	Most EU seaports remain under public ownership, either by national or local authorities. They provide a range of services to their users, either directly or through private operators. In the latter case, the contractual relationship with the operator will generally be structured as a partnering model. Due to the economics of hydrogen production, seaports are expected to play a significant role as energy hubs. More specifically, the international trade in hydrogen is expected to grow significantly, connecting regions with low renewable energy cost with industrialised regions with high energy and feedstock needs.
Road vehicle refuelling networks and hubs	Vehicle refuelling infrastructure along motorways and on public roadways in cities (such as electric vehicle chargers) is often managed by public authorities via concessions granted to private operators. The limited deployment of hydrogen fuel cell electric vehicles (FCEV) is currently a barrier to the development of hydrogen refuelling stations (HRS), which in turn limits the attractiveness of these vehicles. In addition to vehicle technology, ensuring sufficient coverage of hydrogen refuelling stations would help level the playing field for hydrogen fuel cell electric vehicles and such partnering models for these stations are emerging in some jurisdictions (for example, Germany).
Maritime refuelling networks	Refuelling stations for maritime hydrogen applications will be located in seaports, which are generally under public ownership in the European Union. They are expected to be developed through partnering models involving the seaport authority and private operators given their natural monopoly status.
Railway refuelling network	Rail networks are natural monopolies and are usually developed and operated by a state-owned company or government agency. The associated refuelling stations required to operate hydrogen-powered trains are typical service facilities that could be delivered through a partnering model.
Deployment of vehicle fleets powered by hydrogen or hydrogen conversion products	Many of the projects aiming to deploy fleets of vehicles powered by hydrogen or hydrogen conversion products (such as methanol or ammonia) involve the provision of public services and are characterised by the existence of significant positive externalities. Such fleets/services are: • City buses — public transportation • Ships — tugboats, ferries and icebreakers providing public services • Railway — public transportation • Waste collection • Fire engines • Taxi fleets Projects of this type could thus be delivered through partnering models.

[8] The European Clean Hydrogen Alliance (2021). The European Clean Hydrogen Alliance: Overview of projects collected. Available online at https://prod5.assets-cdn.io/event/6779/assets/8375992644-bc85860f7c.pdf

Project type	*Relevance to partnering models*
Centralised heating	District heating systems are a form of local natural monopoly, as they require high capital costs to establish a network-based asset. Based on these characteristics, partnering models could also be suitable.
Re-electrification	Most supply and demand forecasts foresee a limited role for re-electrification via hydrogen until 2030. Additionally, the rate of return of hydrogen storage and re-electrification projects will depend on market demand for seasonal storage, itself largely determined by the rate of deployment of renewable energy and other local conditions. Nevertheless, where seasonal flexibility needs would be best met through re-electrification via hydrogen, public support may help accelerate private investment in such facilities. An example of partnering model in this field has already emerged.

Table 2 demonstrates the vast opportunities for using partnering models to deliver projects in the hydrogen ecosystem. In section 5, this long list is narrowed down to a set of six project types that are the most promising and relevant to partnering in the short to medium term.

5. Partnering to deliver hydrogen projects

To determine to most promising types of projects with respect to partnering models, those presented in Table 2 were further screened against the following high-level qualitative suitability criteria:

- Size: Does the size of a typical project of this type justify the use of a partnering model, taking into account the high transaction costs it entails, relative to conventional project delivery?

- Replicability: Is the project type widely applicable across the European Union, or will it only lead to a handful of projects?[9]

- Risks: Are projects of this type affected by risks that may be mitigated thanks to the public sector's intervention through a partnering structure?

A final, ad hoc selection criterion was the existence of regulatory/policy risk affecting transition technologies and their applications. In the case of the hydrogen ecosystem, such transition technologies are those related to the production of blue hydrogen. In order to avoid the risk of creating stranded assets (assets that lose value or turn into liabilities before the end of their expected economic life), all project types related to blue hydrogen were not considered any further.

With the use of these criteria, six project types were chosen for detailed exploration. In these project types a distinction is made between a core asset — the main target for investment — and auxiliary assets that would be developed as additional value chain components. These types are:

- Green hydrogen production (core) combined with a road vehicle refuelling hub (auxiliary) and H_2-powered road vehicle fleets (auxiliary) related to the provision of public services (public bus transport, waste collection, firefighting services, etc.)

- Energy recovery from waste, resulting in the production of hydrogen

- Hydrogen infrastructure in ports

- Road vehicle hydrogen refuelling stations network

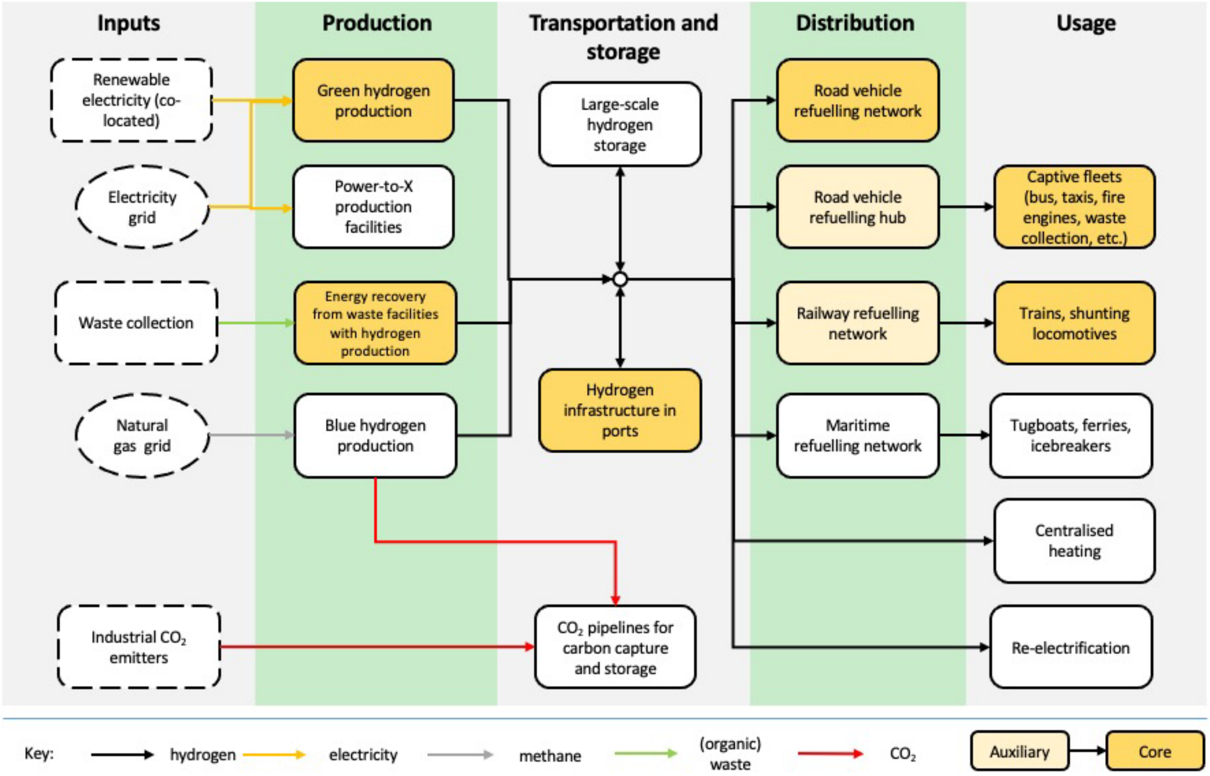
- H_2-powered road vehicle fleet (core) related to the provision of public services (public bus transport) combined with a road vehicle refuelling hub (auxiliary) and green hydrogen production (auxiliary)

- H_2-powered rail multiple units (core) combined with railway refuelling infrastructure (auxiliary) and green hydrogen production (auxiliary)

These selected project types are shown schematically in Figure 2 with core and auxiliary assets appropriately shaded.

[9] In this study, very large or mega, one-of-a-kind projects (such as the pan-European H_2 pipeline backbone), which may be good candidates for some form of partnership model but would require specific feasibility studies, have not been considered.

Figure 2 Schematic representation of selected project types



The following sub-sections present summaries of the detailed analysis of these project types and contain information on their proposed optimal partnering model, their key stakeholders and their expected sources of funding.

5.1. Green hydrogen production

Green hydrogen is produced via electrolysis of water, powered by renewable and low-carbon electricity, and thereby does not result in significant CO_2 emissions. Green hydrogen production has significant indirect benefits as well: electrolysers can absorb excess renewable energy production when high production (such as high wind events) coincides with low demand, a situation that is becoming increasingly frequent with the growing penetration of renewable energy sources in the power grid.

Due to high cost of electrolysers and related equipment as well as relatively high electricity input costs, green hydrogen is still significantly more expensive than natural gas. Nevertheless, new renewable energy capacity is being developed at increasingly low prices, meaning that the developers do not require subsidies to compete in electricity markets. In addition, the accelerated growth of green hydrogen production capacity is driving down the cost of electrolysers through economies of scale.

Optimal partnering model

The optimal partnering model for a green hydrogen production facility, coupled with an auxiliary hydrogen refuelling hub for public service provision road vehicles, would be a ***build-own-operate (BOO) model*** combined with an offtake agreement between the contracting authority and the private partner.

The contracting authority would be the main hydrogen offtaker, while allowing for commercial operations outside of the offtake agreement. This would secure the supply of green hydrogen at a predictable price with guaranteed volumes, thereby mitigating the hydrogen supply risks related to operating a fleet of hydrogen-powered vehicles.

In parallel, the hydrogen offtake agreement would guarantee a volume of demand and an acceptable rate of return to the private partner, securing the investment's bankability[10].

Because producing fuels is not a public service, ownership of the facility would remain with the private partner, including after the end of the contract, which would be tied to the facility's expected lifetime.

Key stakeholders

The main stakeholders involved in a partnering arrangement for a green hydrogen production facility are the following:

- The contracting authority, whether a regional or municipal government, or other
- Private partners
- Upstream clean energy companies, where the clean energy facilities feeding green hydrogen production are tendered separately
- Hydrogen users, including for example public transport operators

Project funding

Project revenues will come from sales of green hydrogen, as well as grants, where relevant. Depending on the agreement between the contracting authority and the private partner, these sales may be exclusively carried out under the terms of an offtake agreement, or they could combine both on-contract and off-contract sales.

5.2. Energy recovery from waste, resulting in the production of hydrogen

Energy recovery from waste (EfW) is defined as the conversion of waste products into energy such as heat, power, electricity or fuel. Waste streams can include municipal solid waste, agricultural and forestry waste, sludge from wastewater treatment plants, etc. The carbon intensity of hydrogen production from waste largely depends on the biomass source: while value chains leveraging forestry residues are considered eligible for low-carbon certification, this may not be the case for municipal solid waste[11].

Two main technologies are used to produce hydrogen from waste:

- Gasification — thermo-chemical processing of waste at high temperatures, in the presence of controlled amounts of oxygen, to produce heat and a mixture of hydrogen and carbon monoxide called syngas
- Pyrolysis — thermal processing of waste at medium-high temperatures to produce syngas

Hydrogen production from waste would be relevant for contracting authorities in densely populated areas with limited access to renewable energy sources, as a means to guarantee some degree of energy security. The most immediate application would be to provide fuel for a fleet of waste collection vehicles, whose fuel consumption could represent between 2% and 10% of the facility's output[12]. Even after accounting for waste collection fuel use, the remaining hydrogen could support public transport in the region.

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[10] Public authorities can grant other forms of support to green hydrogen, such as price or revenue guarantees. Nevertheless, the offtake agreement solves both demand-side risks for production projects and supply-side risks for hydrogen applications, and is therefore likely to be the optimal solution where there is a need for hydrogen supply linked to the provision of public services.

[11] Certifhy (2017). Definition of Green Hydrogen, outcome & scope LCA analysis. Available online at https://www.certifhy.eu/images/media/files/CertifHy_-_definition_outcome_and_scope_LCA_analysis.pdf

[12] Calculation based on industry averages for conversion efficiency, distance travelled per tonne of waste collected, and fuel consumption by distance for fuel cell waste collection vehicles.

Optimal partnering model

The optimal partnering model for an energy recovery from waste facility producing hydrogen would be a ***concession model***, with exclusivity guarantees on waste supplies provided to the private partner. It is possible that energy (hydrogen) sales for such facilities will comprise a greater share of total revenues than electricity and heat revenues for a traditional incineration facility. As a result, the private partner will rely more on hydrogen revenues, and will be more sensitive to hydrogen demand risk. The private partner is therefore likely to require a hydrogen offtake agreement.

Key stakeholders

The main stakeholders involved in a partnering arrangement for an energy recovery from waste facility producing hydrogen are the following:

- Waste management authorities
- Waste collection companies
- Private partners
- Hydrogen offtakers

Project funding

Project revenues will come from two main streams, namely gate fees[13] and sales of hydrogen. In the absence of an offtake agreement, the private partner is likely to heavily discount expected revenues from hydrogen sales in its financial appraisal, resulting in higher gate fees. High hydrogen prices, which are likely to be prevalent in the early stages of the green and low-carbon hydrogen economy, could result in excess revenues that would have to be shared with the contracting authority.

5.3. Hydrogen infrastructure in ports

Ports may host a variety of hydrogen infrastructure assets, reflecting their unique and varied role within the green and low-carbon hydrogen ecosystem. Ports across Europe are a key link in the energy supply chain, host energy-intensive industry clusters, and serve as multimodal logistics hubs. As a result, ports are expected to see significant investments in infrastructure projects that: 1) are linked to import value chains; 2) serve industry clusters; and 3) serve the transport sector. Such projects are:

- Hydrogen terminalling facilities: Ports are a significant entry point for the European Union's fossil fuel imports and have a key role to play in low-carbon hydrogen import value chains.
- Hydrogen production facilities: Many European ports host industrial clusters with high potential for blue hydrogen production. Ports are also a natural target for green hydrogen production due to their proximity to offshore wind power generation.
- Hydrogen pipelines: Industry clusters located in ports require an affordable and reliable means of transporting energy and chemical products, with pipelines being particularly suitable for this task.
- Hydrogen refuelling stations, possibly multimodal, with the goal of addressing energy needs in road, rail and maritime transport.

This report focuses in particular on local hydrogen pipelines as they are a fundamental part of the hydrogen ecosystem. Without them, other facilities potentially developed and operated by private investors cannot function.

To create a local hydrogen economy, port authorities are supporting the development of hydrogen pipelines serving industrial facilities based in the port area. While gas transmission system operators (TSOs) are already working on national (as well as European Union-wide) hydrogen transmission networks, local hydrogen pipeline networks in ports are special. They require not only more immediate

[13] A gate fee is the payment treatment facilities charge waste disposers to accept their waste.

attention, but also a tailored approach because they serve a dual purpose: to bring imported or locally produced hydrogen to port-based industrial consumers, and to bring hydrogen to market by connecting to the broader network.

Optimal partnering model

The optimal delivery model will likely depend on the contracting authority's main objectives for this infrastructure. A ***joint venture*** partnership between the port authority and the national gas transmission system operator would reflect their combined interests at a local, regional and national level.

Two options would then exist for project development: a *corporate finance* or a *project finance* approach. In the first, the participating companies would develop the project on their own balance sheets. In the second, a two-tier model would be used. The port authority and a national gas transmission system operator would form a joint venture company (first tier), which would act as a contracting authority procuring the infrastructure through a design, build, finance and maintain model (second tier). While the project finance approach brings higher transaction costs, it should also result in benefits due to its competitive approach to financing.

Key stakeholders

The main stakeholders involved in a partnering arrangement for local pipeline infrastructure in ports are the following:

- The port authority
- The national gas transmission system operator
- Private partners
- Infrastructure users (producers and consumers of hydrogen, and energy trading companies)

Project funding

Project revenues will come from user charges for the services (fees charged to the infrastructure users in proportion to the use they make of the pipeline). The European Commission's proposal for a Recast EU Regulation on Gas and Hydrogen Networks (COM/2021/804 final) foresees a regulated environment for hydrogen pipeline networks with a transparent tariff structure based on an entry/exit approach by 2030. It is likely that discrete assets like local pipeline networks in ports would be regulated according to the same rules as the broader transmission and distribution grids. However, until 2030, hydrogen network operators will be granted a regulatory holiday, allowing for negotiated arrangements instead of regulated fees.

5.4. Road vehicle hydrogen refuelling stations network

Hydrogen refuelling stations (HRS) coupled with locally produced green hydrogen could be a key solution for the energy transition. They could help shift economic gains away from extractive economies abroad, leading to added value for the EU economy alongside positive climate impacts.

In addition to vehicle technology, establishing a fuelling station network is critical to the uptake of new hydrogen-powered vehicles. Hydrogen fuel cell electric vehicles (FCEVs) can be refuelled in three to five minutes at a hydrogen refuelling station, meaning that their refuelling times are comparable to traditional internal combustion engine (ICE) vehicles.

Optimal partnering model

The optimal partnering model for this type of infrastructure will likely be a ***concession***, although details will depend on contracting authority objectives and local conditions. Under a concession model, the public authority can structure its support in numerous ways and fine-tune it based on the specific needs of the parties.

Similarly to production, fuel distribution is not considered a core public service. Consequently, the role of public authorities will be limited, both in scope and in time. Contracting authorities will likely have to support hydrogen refuelling station operators, such as when high wholesale hydrogen costs cannot be passed on to consumers, or where locations with low traffic cannot generate sufficient cash flows to ensure the required return on investment. Authorities will also have to regulate the market, in order to, among other things:

- Ensure that private partners do not make windfall profits.
- Ensure that public support measures are tied to the provision of truly green and low-carbon hydrogen.

Additionally, the requirement to develop hydrogen refuelling stations along the TEN-T road network[14] is a significant determinant of the partnering model that will be adopted. The TEN-T road network mostly comprises highways, for which fuel stations are often foreseen on rest areas, whose operations are managed through concession agreements. As the focus for hydrogen in transport shifts to heavy-duty road transport, contracting authorities are increasingly likely to seek means to integrate hydrogen refuelling stations into existing on-highway concessions.

Key stakeholders

The main stakeholders involved in a partnering arrangement for a hydrogen refuelling station network are the following:

- The contracting authority, for example a regional authority, a municipality, or a federation of public authorities
- Hydrogen fuel cell electric vehicles users, including both those providing public services such as public transport and municipal waste collection, as well as private users such as logistics companies and individuals
- Hydrogen suppliers, especially where the project does not foresee integrated (green) hydrogen production facilities
- Private partners

Project funding

Project revenues will be derived from fuel sales to hydrogen fuel cell electric vehicle users. The bankability of the project will depend on the ability to generate sufficient demand from captive fleets. To this end, public authorities may subsidise the purchase of hydrogen fuel cell electric vehicles but also the hydrogen fuel costs for public transport operators and other stakeholders delivering public services, guaranteeing cost parity with fossil fuel alternatives.

5.5. H_2-powered road vehicle fleet

Hydrogen-powered road vehicle fleets can serve multiple public service needs, with public transport and municipal waste collection being two prime examples. Many public authorities in the European Union have been delivering these services with varying degrees of private sector participation, through contracts awarded via competitive bidding. This has important implications for the structure of the market.

In a non-competitive market, the public authority usually procures vehicles directly, and has exclusivity on the provision of the relevant public service. This brings certainty on the use of the vehicles over their entire life cycle. In a liberalised market, private operators may also be delivering these services either in whole or in part. However, these vehicle operators may require subsidies to cover part of their

[14] Revision of the Directive on the deployment of alternative fuels infrastructure. 2021. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698795/EPRS_BRI(2021)698795_EN.pdf

operating costs. As a result, a liberalised market is likely to see contracting authorities procuring the vehicles and putting them at the disposal of private operators.

The partnering model discussed below applies to the procurement of new vehicles, regardless of the degree of liberalisation of the market.

Optimal partnering model

Contracting authorities aiming to procure new vehicles have two options: outright purchase and leasing. The former does not imply a partnership agreement and is a purely public or private project, depending on the nature of the contracting authority. The latter, in the form of ***operating leases,*** can provide significant benefits to contracting authorities seeking to replace internal combustion engine vehicles with hydrogen fuel cell electric vehicles, relative to outright purchase:

- Operating leases help free up capital.
- The lease can be structured to include maintenance and repair services; this is particularly relevant in the case of hydrogen fuel cell electric vehicles given the innovative nature of the technology, and means that the private partner should be better positioned to take responsibility for repairs and maintenance.
- Under an operating lease, the private partner remains the owner of the assets at the end of the contract, thereby removing all end-of-life risks for the contracting authority.

Operating leases for hydrogen fuel cell electric vehicles can be structured in a flexible manner (the lease can cover the full vehicle, or just the fuel cell and associated battery). This flexibility allows contracting authorities to purchase vehicles at prices comparable to existing internal combustion engine models, with the lease covering just the fuel cell and battery. This also makes it possible to allocate only the more sensitive risks to the private partner.

Key stakeholders

The main stakeholders involved in a partnering arrangement for a fleet of hydrogen-powered road vehicles are the following:

- The contracting authority, for example a regional authority, a municipality, a federation of public authorities, or a publicly-owned public transportation or waste management company
- The private partners, including original equipment manufacturers, fuel cell and electric powertrain companies, and hydrogen refuelling station solution providers
- The hydrogen fuel cell electric vehicle operators

Project governance would rely on a number of agreements under the responsibility of the contracting authority. However, the market is currently unwilling to provide all-in-one solutions that would include the provision of hydrogen fuel cell electric vehicles, refuelling infrastructure, and (green) hydrogen fuel production in a single contract.

Project funding

Project revenues will be derived from a combination of user fees, collected on behalf of the contracting authority, and public support, depending on the extent to which the provision of public service is subsidised. Fees can include fares paid by passengers on public transport, charges levied on households for waste collection, fees for mandatory municipal waste bags, etc.

5.6. H_2-powered rail multiple units

Hydrogen fuel cell powertrains could be deployed to replace existing diesel powertrains in multiple unit trains. Multiple unit trains differ from their locomotive-hauled counterparts in that the former have tractive power in all cars whereas the latter use one or more dedicated locomotives to provide tractive power, in combination with unpowered carriages. While locomotive-hauled trains are used to transport either passengers or freight, multiple units are commonly used for regional passenger rail transport. They are therefore the core asset needed to offer passenger rail transport under a public service contract on the non-electrified part of the network.

As part of the EU Fourth Railway Package, 2023 is the deadline by which national and regional public authorities in Member States must begin using competitive tendering procedures to award public service contracts for passenger rail transport. In a liberalised environment, railway undertakings can expect to win concession contracts for up to 15 years, compared to asset lifespans that are double this. In addition, even in a liberalised market, railway undertakings may require subsidies to cover operating costs. As a result, a liberalised market is likely to see contracting authorities — usually a public transport authority controlled by the regional government — procuring rolling stock and making it available to the railway undertakings. Conversely, in a non-competitive market, the incumbent monopolistic operator is likely to procure trains directly and has the exclusivity on the provision of the relevant service. The partnering model discussed below applies to the procurement of new rolling stock, regardless of the degree of liberalisation of the market.

Optimal partnering model

Contracting authorities aiming to procure new fuel cell multiple units have two main options: outright purchase and leasing.

As in the case of hydrogen-powered vehicle fleets, ***operating leases*** can provide significant benefits to contracting authorities seeking to replace diesel multiple units with fuel cell equivalents. More specifically, on top of freeing up capital and assigning repair and maintenance risk to the private partner, under an operating lease the private partner remains the owner of the assets at the end of the contract. Although this would theoretically remove all end-of-life risks for the contracting authority, it may not be a feasible option as there is no secondary market for fuel cell multiple units, and the public service contracts are of a much shorter duration than the economic life of the rolling stock. As a result, the allocation of residual value risks will be a key element of the partnering agreement. For projects to be bankable, it is likely that the public transport authority (or the incumbent railway undertaking, where markets are not liberalised) will have to take on a share of residual value risks.

Key stakeholders

The main stakeholders involved in a partnering arrangement for a fleet of fuel cell multiple units are the following:

- The public transport authority
- The railway undertakings
- The private partners, including original equipment manufacturers, fuel cell and electric powertrain companies, and hydrogen refuelling station solution providers
- The rolling stock leasing company

Project funding

Project revenues will be similar to those in hydrogen-powered vehicle fleets. Revenue streams will comprise user fees collected by the railway undertaking and public support, whether paid as compensation for a public service provided or as a subsidy.

6. Next steps

The hydrogen ecosystem is still in a nascent state. Whereas certain parts of the ecosystem are more technologically and commercially mature than others, fully integrated solutions and industrial-scale roll-out are still not possible. This may change, but will require both public and private stakeholders to play their part.

To help establish a healthy and vibrant hydrogen economy, public intervention is needed in order to overcome both the valley of death funding gap on the supply side and high switching costs (costs incurred for replacing current end-use technologies with hydrogen) on the demand-side. Public authorities and national governments have a role to play in working towards these goals, as do public policy banks such as the EIB.

Creating the right legal and regulatory environments and bearing some of the development risks by channelling public support to the parts of the ecosystem that need it most are crucial steps that must be taken.

Equally important is the way that public support is lent to such projects. Partnering models can make use of such public support under contractual arrangements that aim to allocate risks to public and private parties in a way that creates value for money and capitalises on their individual strengths.

Finally, suitable project appraisal methodologies and financial solutions are critical for the development and scaling of the hydrogen ecosystem. Not all hydrogen-related projects will be economically viable compared to other alternative technologies and not all projects will be able to attract private financing to move forward. This is another reason why public support — for the right projects — is key.

This report presents practical (albeit high-level) information and guidance on the use of partnering models in the hydrogen ecosystem. Developing the legal/regulatory environment as well as project appraisal and financing solutions for hydrogen projects are important topics for further work. They are, however, outside the scope of this report.

Individual reports for each of the six project types summarised above are available on request from the EIB's advisory services. These individual reports elaborate further on the information provided above, and:

- Identify the objectives pursued by the public partner.
- Detail the argument for the choice of the proposed partnering model.
- Develop the conditions of value for money and bankability underlying the structuring of the partnership.
- Specify the optimal allocation of key risks to the two partners.
- Present, where available, an existing case study of the use of a partnering model for that particular project type.

This report and the six individual project type guides are not intended to replicate or substitute for professional advisory services (such as legal, financial or technical services) that a public authority may need in preparing, procuring and delivering hydrogen projects. The EIB is actively involved in the financing of the hydrogen ecosystem and its advisory services are available to assist public authorities in translating their hydrogen ambitions into concrete investment solutions and transforming their hydrogen strategy into operational project delivery plans.

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