URBAN TRANSITIONS MISSION

CLEAN HYDROGEN MISSION

Urban Transitions & Clean Hydrogen Missions

GUIDEBOOK Clean Hydrogen in cities

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01.
Challenge

Most of the hydrogen produced today is obtained from fossil fuels, creating emissions that are harmful to the climate. In recent years, hydrogen and particularly low carbon and renewable hydrogen has gained momentum. Clean hydrogen is increasingly recognised as one of the main energy carriers in the global transition to sustainable energy systems, particularly because of its potential to decarbonise energy-intensive sectors, such as heavy industry and shipping.

The use of clean hydrogen as a feedstock in industry and as a fuel for transport and industrial applications is rapidly growing. Since the mid-2010s, integrated hydrogen projects spanning the entire hydrogen value chain, from production to end use, have started emerging, creating an increasing number of what is most commonly referred to as “Hydrogen Valleys” or “Hydrogen Hubs”.

As more and more cities scale their efforts to become climate neutral, local governments require more information, knowledge and tools to analyse, and plan the future of their energy systems. Clean hydrogen can play an important role in these transformations: this guide aims to showcase the potential of clean hydrogen in supporting cities in the energy transition, to present best practice examples of integrated hydrogen projects, and to share recommendation on dos and don’ts, as well as possible application of clean hydrogen in cities.

02.

Urban Transitions and Clean Hydrogen Missions: joining forces for decarbonizing cities with clean hydrogen

The Urban Transitions (UTM) and Clean Hydrogen (CHM) Missions are collaborating to support cities in the UTM cohort to have a better understanding of hydrogen technologies and their possible successful application in an urban context. This cooperation helps build know-how on deploying clean hydrogen technologies and accelerate the deployment of hydrogen demonstrations projects worldwide.

CHM's goal is to catalyse international collaborations in research and innovation to support the growth of a global clean hydrogen value chain, to make clean hydrogen attractive, affordable and accessible to all. CHM has three main objectives: 1. advance research and innovation through collaborative research to create clean hydrogen demand for hard to decarbonize applications in mining, construction, agriculture, rails, marine and aviation, 2. support the implementation of 100 hydrogen hubs/valleys on all five continents, and 3. provide capacity building to increase the skilled hydrogen workforce, especially in emerging market and developing countries.

Cities can explore clean hydrogen to reduce emissions, drive sustainable economic growth, and support the transition to net-zero energy systems. Cities can support and contribute to the development of clean Hydrogen Valleys, serving as hubs where production, distribution, and utilization converge to create integrated ecosystems. By incorporating hydrogen technologies into public transport, logistics, and urban industries, cities can decarbonise their activities. This fosters innovation and supports the growth of a sustainable hydrogen economy.

Cities can also enable the establishment of Hydrogen Valleys by fostering collaboration among stakeholders, including businesses, research institutions, and policymakers. Their role is especially critical in developing countries, where urban areas act as gateways for emerging markets.

Additionally, cities are vital for engaging the community and building the skilled workforce needed to support the hydrogen economy. Through education programmes, public-private partnerships, and innovation hubs, urban areas can nurture expertise and promote the widespread adoption of hydrogen technologies. By promoting supportive policies and local hydrogen projects, cities are also reinforcing global efforts to make clean hydrogen accessible and affordable. In doing so, they are bridging the gap between local needs and international ambitions, ensuring the success of a sustainable hydrogen economy.

The guide is addressed to local policymakers and city technical staff, and it is dedicated to cities wishing to embark on the clean hydrogen journey and launch first pilot projects. This guide aims to help cities better understand the benefits and possible challenges of clean hydrogen applications in the urban context and to contribute to the development and implementation of hydrogen projects and strategies. Sharing real life examples and lessons learned from Cascais (PT), Miami Dade County (US), Aberdeen (UK) and Kobe (JP), this publication explains how to get started with clean hydrogen.

Hydrogen as catalyst for CO2 emissions reduction in Miami-Dade County

Local utility Florida Power & Light Company is pursuing its Real Zero goal of eliminating carbon emissions from its power generation operations by 2045. This involves replacing natural gas with clean hydrogen. The plan calls for increasing the share of renewable energy from 46% (2025) to 89% (2045) and reducing the share of fossil fuels from 35% to 0%. Nuclear energy will be used to provide extra generation.

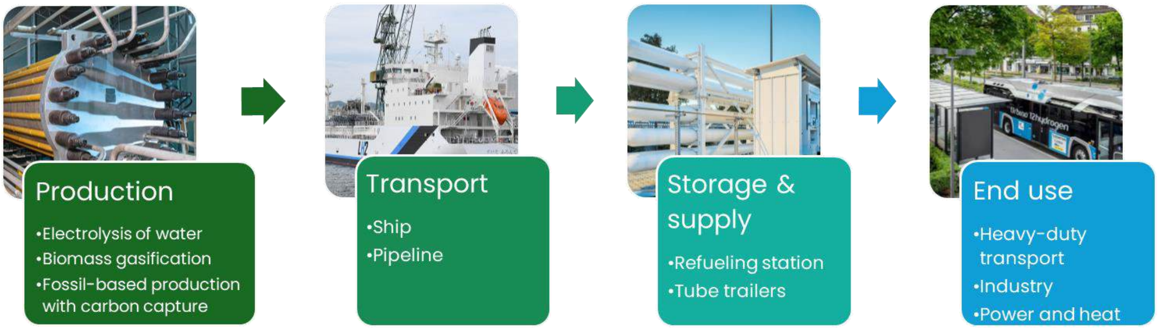
To make hydrogen viable in the long term, Miami-Dade County sees the following actions as essential: the establishment of a national H_2 market in the United States, the decrease of the hydrogen production cost to around $1/kg, and the development of H_2 applications in the heavy goods vehicle and aviation sectors.

03.

Clean Hydrogen: value chain, main technologies and applications

As of today, hydrogen **production** is mainly obtained via steam reforming process (SMR). The hydrogen produced by this process is usually referred to as *grey hydrogen* because of the associated high greenhouse gas (GHG) emissions linked to its production. SMR is a mature production process in which methane (CH_4) from natural gas is heated with steam to produce a mixture of carbon monoxide (CO) and hydrogen (H_2). It accounts for more than 90% of the total volume of hydrogen produced annually and represents almost 1 gigatons of CO_2 emissions (out of the 35-36 gigatons of CO_2 emitted annually).

The remaining volume of hydrogen is generated with few or no GHG emissions. There are different technologies for producing low-carbon hydrogen, also referred to as *clean hydrogen* or *green hydrogen*. The most widely used technology is water electrolysis, which breaks down the molecule of water (H_2O) to extract hydrogen (H_2) using an electric current. To be considered low-to-no emission, the energy used must be either renewable (solar or wind) or nuclear. Hydrogen can also be produced from the gasification of biomass, and in some cases low-carbon hydrogen can be obtained using conventional methods such as SMR, by capturing and storing the carbon produced during the transformation process (also called *blue hydrogen*).
It should be noted that there is no uniform definition of clean hydrogen throughout the world. Under the revised Renewable Energy Directive (RED III) in the European Union, low-carbon hydrogen is defined as a fuel that achieves at least 70% reduction in greenhouse gas (GHG) emissions compared to a baseline fossil fuel. The comparison is based on lifecycle greenhouse gas emissions, including the emissions from the production, transport, and use of the hydrogen. It compares the total GHG emissions associated with the hydrogen's entire lifecycle to the lifecycle GHG emissions of fossil hydrogen or natural gas (often used as the baseline). The 70% reduction in emissions reflects the differences in emissions between hydrogen produced from fossil fuels and hydrogen produced using renewable or low-carbon energy sources.



Once produced, hydrogen needs to be **transported** to the demand clusters. Here too, several options are possible. For long-distance transport, hydrogen is transported by ship from its country of production to the main seaports in the form of liquefied hydrogen or derivatives such as ammonia. Once unloaded, it is generally compressed into gas and transported by pipeline to the main centres of demand.

For hydrogen to become an intrinsic part of an integrated energy system, it is essential that **storage** units are present to provide buffer functions and thus enhance security of supply. Various solutions exist, ranging from short-term surface storage in tanks to seasonal underground storage in aquifers and depleted gas fields. Hydrogen is often **supplied** to end customers in tube trailers. If hydrogen is used as a transport fuel, refuelling stations are built to supply commercial vehicles, heavy vehicles such as lorries, trains and even boats. Compared with electric refuelling stations, hydrogen ones offer the advantage of much shorter refuelling times.

Hydrogen can be **used** in different sectors, such as transport, industry, power and heat. It is expected to play a key role in the decarbonisation of high-emission sectors that are challenging to address through other means, such as long-haul transport (aviation, maritime), and heavy industry (steel, glass, chemical). For cities, hydrogen can be a particularly viable option for the transport sector - used as fuel for buses, lorries transporting freight, commercial vehicles, logistics equipment, trains and taxis. Whilst not yet widespread, it may also be used in residential buildings for power and heat purposes.

For more Information on clean hydrogen technologies and applications, readers are invited to visit the website of the European Hydrogen Observatory managed by the Clean Hydrogen Partnership (https://observatory.clean-hydrogen.europa.eu), and to consult the factsheets produced by the International Energy Agency's Hydrogen Technology Collaboration Programme (https://www.ieahydrogen.org/why-hydrogen/) as well as the education materials developed by the Hydrogen and Fuel Cell Technologies office of the US Department of Energy (https://www.energy.gov/eere/fuelcells/increase-your-h2iq).

04.

Hydrogen Valley & integrated H_2 project in a city: key preparatory steps

The Mission Innovation Hydrogen Valley Platform (https://h2v.eu/), a joint initiative by the Clean Hydrogen Joint Undertaking and the Clean Hydrogen Mission (CHM), provides an inventory of Hydrogen Valleys (HVs) deployed worldwide. By summer 2024, the platform encompassed 98 Valleys, with detailed information per Valley on the partners involved, costs, the volume of H_2 produced and the technologies constituting the value chain. There five main steps to follow to launch a Hydrogen Valley or an integrated hydrogen project in a city:

1. **Identify, connect and work with the economic development players** (e.g. chamber of commerce, economic and territorial development agency) in the region or city who have knowledge of the local context and can support the hydrogen project,

2. **Assess the local production potential, as well as current and future H_2 needs** of the city and the region, investigating sectors that could use clean hydrogen and assessing the potential for emissions reductions and return on investment. Evaluate the production potential based on local energy sources to ensure integrated planning. Detailed planning of the transport and storage system is usually only necessary when large quantities of hydrogen are involved. For small-scale projects, production often takes place close to demand, so there is no need for a dedicated transport (and storage) infrastructure,

3. **Contact energy utilities and project developers** willing to develop H_2 production facilities, **work with potential users** across sectors (e.g. transport operators, industrial players, energy utilities) to support them in their hydrogen transition, **engage and consult with the local community** to ensure buy-in and acceptance,

4. **Identify a portfolio of public and private funding** that can be used to build a solid business case benefiting all parties involved,

5. Encourage **all project partners to jointly design their activity in a cross-sectoral approach and carry out a feasibility study** as a prerequisite to making an investment decision.

Once the final investment decision is taken, the project can be kicked-off. Typically, the project is divided into three consecutive phases, each lasting approximately two years:

1) an initial phase of technical studies to prepare the ground for the technical pilots;
2) a second step, also called the demonstration phase, during which all the equipment is tested and various experiments are carried out to evaluate the technologies under different operative conditions;
3) a final phase of economic and environmental analysis to assess the impact of the running hydrogen project, in order to draw conclusions and plan the next stage of the hydrogen project. This phase is key to support the region in further advancing toward a fully integrated hydrogen economy.

A Hydrogen Valley also includes cross-cutting activities such as communication and dissemination, networking and training, which are necessary to increase public acceptance, enable the valley to develop, and provide a skilled workforce. Please note that the project work plan provided here is an example. Different models may be followed based on the project's objectives and the partners involved.

Twin cities project of Aberdeen (UK) and Kobe (Japan)

H_2 Twin Cities is an initiative under the US Government Clean Energy Ministerial (CEM) where two or more cities can apply to receive support, either in the form of a fixed amount of money or in-kind support. This is aimed at supporting the execution of the work scope including municipal partnerships, as well as the development of training tools and activities to encourage community participation. Aberdeen (UK) and Kobe (Japan) were the two cities selected in 2022 and will collaborate for a minimum of five years to accelerate their transition into hydrogen-based societies.

The partnership between Aberdeen and Kobe will focus on sharing best practice regarding fuel cell vehicles, decarbonising ports using hydrogen, and using hydrogen in residential areas. Furthermore, it will facilitate personal exchanges and joint research at government and university level, and create a network to develop a strong supply chain in both cities.

More information on the twin cities programme can be found here: https://www.energy.gov/eere/h2twincities/h2-twin-cities .

05.

Success factors for integrated hydrogen projects

Cities wishing to explore clean hydrogen applications as part of their energy transition need to consider the following key elements in their planning to maximise their success:

- **Project structuring and partnership development**: mapping the hydrogen value chain, identifying stakeholders to be involved and technologies to be integrated at each step, is the essential starting point for any successful project. This process can be started by identifying offtake opportunities, then setting up efficient and low-cost clean hydrogen production and finally developing the midstream part of the value chain, including transportation and storage. Workshops and regular meetings involving all key stakeholders (e.g. energy utilities, transport operators, port authorities, technology providers, research Institutes, public authorities) are needed to establish a clear project structure and co-create the development of the initiative. Once a more detailed map of the project value chain is available, it is essential to collect clear commitments from the partners engaged – e.g. declarations of intent, letter of intent, memorandum of understanding, electricity/hydrogen transport/purchase contracts – as a basis for the launch of a feasibility study.
- **Project's business case:** constructing detailed business cases for the project as a whole and for the different steps of the value chain (production, transport, distribution & storage, end use) will help check and ensure the economic viability of the project. Business models and plans must be drawn up, taking into account the private and public sources of funding identified for the project.
- **Financing:** developing bankable project financing concepts is essential to take a final investment decision. This includes obtaining a clear understanding of existing regulatory and fiscal landscape - project developers will have to navigate complex regulatory frameworks and the landscape of regional, national and supranational subsidies.
- **Political backing and buy-in:** it is crucial that the project receives support from public authorities and that the project developers work hand-in-hand with local governments. This will increase public acceptance, motivate partners to join the hydrogen project and might unlock public funding necessary to derisk private investment and obtain a viable business case. The hydrogen project can also

have a positive influence on local and national clean hydrogen development and roll-out policies, and early alignment between local, regional and national plan is essential to fully reap the benefits of these projects

The success factors highlighted in this chapter are based on an analysis of best practice carried out by the Clean Hydrogen Partnership in collaboration with hydrogen project developers. For more information, readers are invited to read the report "Making it happen Hydrogen Valleys – Progress in an evolving sector" published in June 2024 (available here) and visit the Mission Innovation Hydrogen Valley Platform (https://h2v.eu/) to have more details on individual projects.

Bus powered by hydrogen in the Portuguese city of Cascais

Cascais is a town located on the west coast of Portugal and an increasingly popular tourist destination. In 2021, the city acquired two hydrogen fuel cell powered buses manufactured in Portugal by Caetano Bus, a Toyota subsidiary, and a mobile refueling station was installed by PRF Gas Solutions. In 2023 it has increased the fuel cell bus fleet to four and intends to finish 2028 with 10 fuel cell buses.

For urban transit, hydrogen as fuel has several advantages, namely it allows short refueling times and longer ranges. The construction of Portugal's first fixed hydrogen refuelling station started September 2024 in Cascais. This station will replace the existing portable station and will supply clean hydrogen to both heavy duty and light commercial vehicles at 350 and 700 bar respectively. The station will incorporate on-site hydrogen production using electrolysers powered by renewable sources. With a production capacity of 389 kg per day, it is now on the last phase of construction and will start normal operation in the first quarter of 2025.

06.

Establishing a fertile ground for hydrogen applications in urban areas through collaboration and finance

Hydrogen projects are complex undertakings, requiring developers to master the entire project lifecycle - from concept to commissioning, operation and maintenance to future scale-up. As highlighted in the previous chapter, project developers play an important role in the design and implementation of integrated Hydrogen Valley and projects.

The Clean Hydrogen Mission is one of several international initiatives seeking to accelerate the development of hydrogen projects and valleys worldwide. In recent years, programmes have been set up to fund Hydrogen Valleys and provide support to project development. Project developers are encouraged to explore these as a start:

UNIDO - Global Programme for Hydrogen in Industry (GPHI): the programme aims to provide crucial support to developing countries in their efforts to achieve net-zero industrial development through the production and use of clean hydrogen. The programme aims to create employment opportunities, improve skills, mobilise investment, ensure energy security and enable developing countries to participate in global hydrogen trade. More information available here.

UNIDO – Accelerate-to-Demonstrate (A2D) Facility: this initiative provides grant funding to support the implementation and operation of hydrogen demonstration project in developing countries. This programme is funded by the UK government and grants of up to $5 million are awarded to individual winning projects. More information available here.

The Hydrogen Valley platform of the Clean Hydrogen Mission and Clean Hydrogen Partnership: this online platform aims to share best practices and promote large-scale uptake of Hydrogen Valleys. The platform features a world map of Hydrogen Valleys (98 as of January 2025), individual profiles of Hydrogen Valley projects, tools for data, analysis & visualization and a resources centre containing links to other platforms and reference reports. To visit the platform, click here.

Developers looking for more information to set up an integrated hydrogen project can contact the Clean Hydrogen Mission team at: EC-MI-CLEAN-HYDROGEN-MISSION@ec.europa.eu

07.

Getting started: 10 questions to ask yourself

1. Knowledge of clean hydrogen and associated technologies - Do you have a clear understanding of what an integrated hydrogen project is, and what technologies are available and needed to make it a reality in your context?

2. Existing studies and regional strategies - Has a preliminary study on the production and use of clean hydrogen already been carried out at city or regional level, and has a national or regional clean hydrogen strategy already been developed? Are there any hydrogen-related projects in the region and can you connect with existing initiatives to leverage synergies?

3. Policies and funding programmes overview - Are there any public policies and funding programmes in your city/region/country supporting clean hydrogen projects?

4. Skilled workforce availability – Does your local authority have staff with experience of developing and/or supporting a clean hydrogen project? Do you work already with partners or professional project developers who could support the city's staff?

5. Assessment of hydrogen demand – Do you have a clear overview of potential local demand, and what sectors could benefit from clean hydrogen production? Are any industrial companies, energy utilities or transport operators in your city/region interested in clean hydrogen applications to decarbonise their activities?

6. Estimation of hydrogen production – Are there enough renewable energy sources and water resources available in your town/region that could be used to produce clean hydrogen by electrolysis of water? Do you already have an integrated plan for your city?

7. Planning of hydrogen transport and storage– Transport and storage of hydrogen is expensive. Are there any gas pipelines in your city/region that could be repurposed to transport clean hydrogen from production to demand centres? Are there any industrial partners in your region with hydrogen storage units that can be integrated into a larger system?

8. Mapping partnerships - Are the stakeholders in your city and region, such as economic development players, research bodies, technology suppliers, industrial players, energy companies and associations, willing to take part in a H_2 project?

9. Building political support – Does your city support the implementation of clean hydrogen projects? Can your city play a catalytic role in mobilizing joint efforts to implement an integrated H_2 project?

10. Identifying Research and Innovation funding programmes (although other funding sources might exist, Hydrogen Valleys very often grow from an initial R&D project.) – Are there any regional, national or supranational R&I funding programmes (e.g. small-scale and large-scale Hydrogen Valley calls from the Clean Hydrogen Partnership) that allow you to submit a proposal for your clean hydrogen project?

About the Urban Transitions Mission (UTM)

Launched at COP26 under the framework of Mission Innovation (MI), the Urban Transitions Mission (UTM) is a joint effort by GCoM, the European Commission, and Joint Programming Initiative Urban Europe. It offers an urban net-zero transition framework that builds on the knowledge and expertise of a Global Innovation Alliance of supporting partners and organizations together with the first-hand experience of cities. Through the Urban Transitions Mission, cities will strengthen their net-zero visions, scale action, and accelerate implementation.

The Mission will work with a cohort of 50 ambitious cities worldwide to demonstrate integrated pathways towards holistic, people-centred urban transitions built around clean energy and innovative net-zero carbon solutions. By 2030, these pathways will be validated by a group of 250 cities and inspire cities across world regions on their journey towards decarbonisation.

About the Clean Hydrogen Mission (CHM)

The Clean Hydrogen Mission (CHM) aims to increase the cost-competitiveness of clean hydrogen by reducing end-to-end costs from production to end-use to a tipping point of $2/kg by 2030. The Mission also seeks to prove clean hydrogen's viability for hard-to-abate sectors, such as heavy industry and long-distance freight. Research, development, demonstration, and scale-up investments are crucial to achieving these objectives.

The Mission collaborates with partners worldwide to identify and support large-scale integrated "Hydrogen Valleys" across the globe. These valleys serve as hubs for clean hydrogen production and utilization and pave the way for the creation of an hydrogen economy on a global scale.