H2MA

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Input paper

On planning specifications and requirements for setting up green H2 mobility routes

Activity 1.2

April, 2023

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Short description

H2MA brings together 11 partners from all 5 Interreg Alpine Space EU countries (SI, IT, DE, FR, AT), to coordinate and accelerate the transnational roll-out of green hydrogen (H2) infrastructure for transport and mobility in the Alpine region. Through the joint development of cooperation mechanisms, strategies, tools, and resources, H2MA will increase the capacities of territorial public authorities and stakeholders to overcome existing barriers and collaboratively plan and pilot test transalpine zero-emission H2 routes.

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- PP3 EUROMETROPOLE DE STRASBOURG (FR)

CONTENT

EXECUTIVE SUMMARY

The aim of the document is to support the implementation of Activity 1.2 "Study visits on planning specifications and requirements for setting up green H2 mobility commercial and urban routes, to improve partners and stakeholders' coordination and implementation capacities". To that end, it provides:

- thematic background on the planning specifications and requirements for setting up green H2 mobility routes for both commercial long-distance transportation (e.g. trucks and trains) and urban (e.g. buses).

- operational guidelines for the organisation and successful implementation of two study visits in Bavaria and Strasbourg, including implementation and dissemination plans and templates for the communication of the events.

The input paper is structured as follows:

Section 1 provides a brief description of the Activity A1.2.

Section 2 provides thematic background on basic components of hydrogen infrastructure and on technical, economic and safety specifications and requirements during the planning phase of HRS that serve a) buses, b) trucks and c) trains.

Section 3 offers operational guidelines for the organisation and the successful implementation of the two study visits in Bavaria and Strasbourg including a thematic agenda, and implementation and dissemination plans.

Annex A includes a Participants list Template

Annex B provides a Feedback Form Template for Evaluation

Annex C provides an Input form for reporting (to be filled by organising partners)

Annex D includes two Invitation Templates

1. INTRODUCTION

Fossil fuel-powered transportation has an adverse impact on the environment and air quality, contributing to the climate change and lowering the overall quality of life of European communities. To that end, EU countries are taking action to promote the transition of the sector to alternative fuels in order to curtail its environmental footprint. In this context, green hydrogen constitutes a significant pathway to decarbonizing the transportation sector. In particular, hydrogen has the potential to significantly reduce greenhouse gases in hard-to-electrify areas (e.g. heavy-duty trucks, buses, planes and ships) and can provide a more comfortable, emissions free driving experience. With this objective in mind, territorial public authorities and stakeholders across the Alpine region share the need to mitigate the environmental impact of long-haul commercial transportation and support the transnational deployment of H2 mobility infrastructure for freight and passenger transport.

1.1 Activity 1.2

Activity 1.2 concerns two study visits in Bavaria (organized by ITALCAM) and in Strasbourg (organized by EMS and PVF) to provide hands-on knowledge to the participants on planning requirements needed for integrating green H2 in a) urban transportation, focusing on buses and b) commercial long-distance transportation, focusing on trucks and trains.

In this context, the Input paper, prepared by EMS, aims to enhance partners' thematic knowledge and ensure the successful organisation of the study visits. It therefore comprises a thematic background on planning specifications and requirements for setting up green H2 mobility commercial and urban routes and operational guidelines to ensure the successful implementation of the activity.

Subsequently, ITALCAM and EMS will each draft a study visit report that summarizes the main results and lessons learnt from the study visits, focusing on key planning specifications and technical, economic and safety requirements that were identified during each study visit.

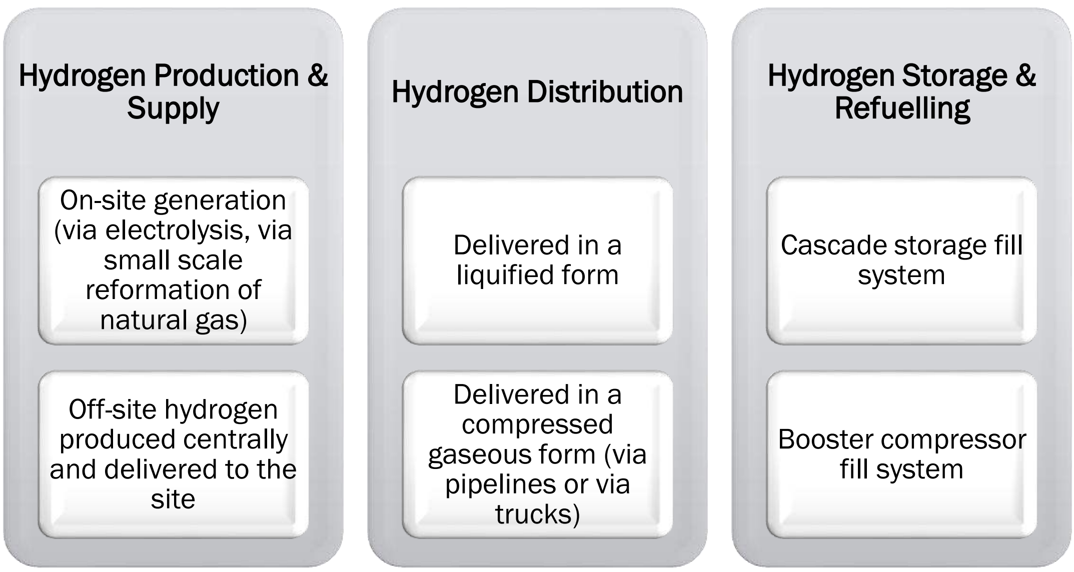
2. THEMATIC BACKGROUND

This section aims to familiarise partners and stakeholders with planning requirements and specifications for H2 infrastructure to facilitate the study visits in Bavaria and Strasbourg. It discusses the components of hydrogen refuelling infrastructure, identifies several technical, economic and safety issues crucial to the design and installation of HRS and provides an extensive analysis of different HRS configurations (for Fuel Cell Electric Vehicles, Fuel Cell Electric Buses, heavy-duty trucks and trains).

2.1 Basic components of hydrogen refuelling infrastructure

Hydrogen infrastructure consists of three main components: i) production and supply, ii) distribution and iii) storage and refuelling. HRS represent the third component but their design must take into account the other two, since their location and type (on-site versus off-site) are directly dependent on the territorial H2 production and distribution infrastructure.

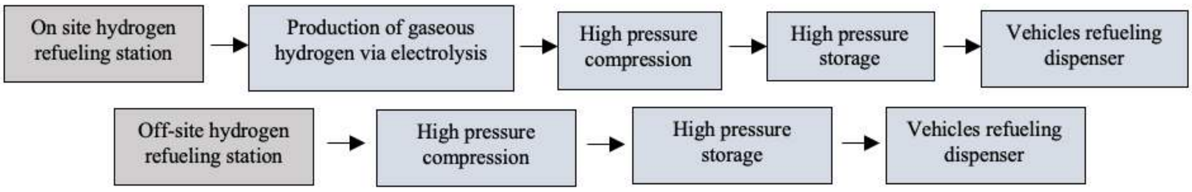
Figure 1 Main components of hydrogen refuelling infrastructure



2.1.1 Hydrogen production and supply

Hydrogen can be produced through various methods, e.g. from fossil fuels by steam reforming of natural gas, biomass gasification, or through water electrolysis. The most sustainable option is by using electricity from renewable energy sources (such as wind and solar) as this process does not involve any GHG emissions. The hydrogen produced through this process is referred as green hydrogen. The selection of the optimal production method is based on the availability of resources and cost-effectiveness criteria. It can be produced on-site and stored in the HRS until fuelling (requiring a HRS with on-site hydrogen production capacity) or, more commonly, it is produced centrally and then delivered to the HRS. Below, the hydrogen supply chain from production to refuelling for both types of HRS (on-site and off-site production) is presented.

Figure 2. Hydrogen supply chain for on-site and off-site production HRS.



2.1.2 Hydrogen distribution

For off-site HRS, hydrogen distribution can take place:

a) in gaseous form:
   - via pipelines
   - via compressed hydrogen (gaseous) tube trailers,

b) in liquified form:
   - via liquid hydrogen trailers and tank trucks.

Although hydrogen pipeline transport is technologically mature, and the transport costs are similar to those of Compressed Natural Gas (CNG), most hydrogen is still produced in an industrial production facility that is in closed proximity to demand sites. For process metal piping at pressures up to 7,000 psi (48 MPa), high-purity stainless steel piping with a maximum hardness of 80 HRB is preferred. This is because higher hardness is associated with lower fracture toughness, so, stronger, higher hardness steel is less safe.

In this context, the European Hydrogen Backbone (EHB) initiative has developed a plan for a dedicated EU-wide hydrogen pipeline infrastructure, based on existing and new pipelines in 28 countries. **By 2030** hydrogen infrastructure pipeline network is expected to reach a total length of approximately **28,000 km**.

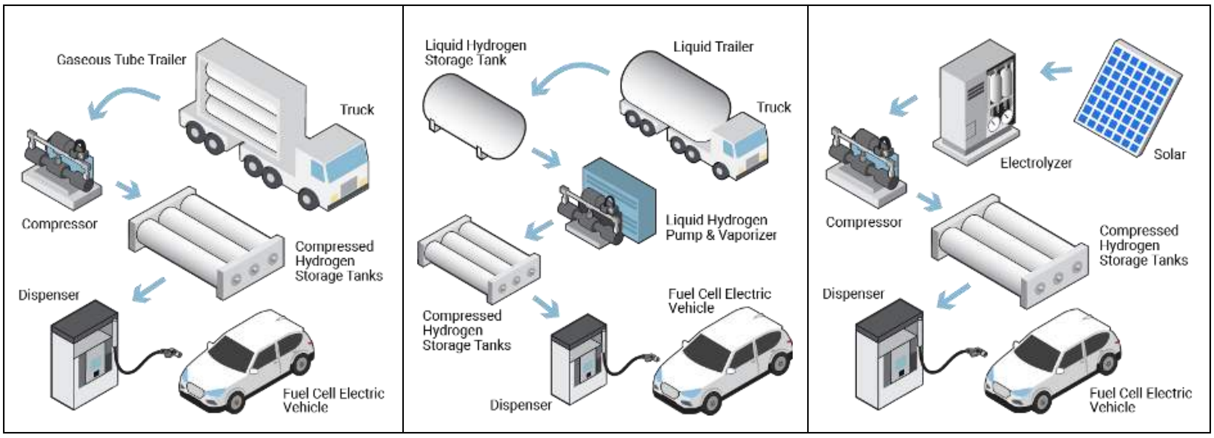
2.1.3 Hydrogen storage and refuelling

Storing **hydrogen in liquid form** requires cryogenic temperatures because the boiling point of hydrogen at one atmosphere pressure is **−252.8°C**. Storage of **hydrogen as a gas** typically requires **high-pressure tanks at 350–700 bar** (5,000–10,000 psi). Also, depending on the vehicles an HRS aims to serve, a compressor is needed to discharge pressure at 350 bar when refuelling heavy-duty trucks and at 700 bar when refuelling passenger vehicles.

Finally, the station must have dispensers that are capable of dispensing hydrogen at high flow rates, typically between 40 and 60 kg/min, to accommodate the refuelling needs of urban buses and heavy-duty trucks. The dispenser is chosen based on the type of vehicle that will be refuelled and the rate of refuelling.

Compared with single-stage hydrogen storage refuelling, **cascade storage refuelling has more advantages** and significantly reduces cooling energy consumption. In the cascade system, the parameters of cascade storage tanks are critical, especially the initial pressure and volume. A cascade storage system works in the following way: Fuel dispenser A draws hydrogen from tank A, while dispenser B draws fuel from hydrogen tank B. If dispenser A is over-utilized, tank A will become depleted before tank B. At this point dispenser A is switched to tank C. Tank C will then supply dispensers A and B and tank A until tank A is filled to the same pressure as tank B and the dispensers are disconnected, after which the control system will close the control valves to switch to its former state.

Figure2. HRS variations with gaseous delivery, liquid delivery and on-site production



Source: California Fuel Cell Partnership

2.2 Requirements and specifications during the HRS planning phase

Although technical aspects of hydrogen refuelling stations design are becoming increasingly standardised, a certain level of site-specific planning is required. In particular, the planning and design of HRS must take into account a number of technical specifications and requirements related to:

a) The site in question and the type of station to be hosted (e.g. stand-alone vs. hosted vs. fully integrated station)[1]

(b) The type of vehicles it aims to serve (passenger vehicles filling at 700 bar versus buses filling at 350 bar)

(c) Safety measures that need to be taken

[1] Stand-alone stations are independent facilities that provide fuel or charging services without any other associated services, like a convenience store or car wash. Hosted refuelling stations are located on the premises of another business or property, for example, on the property of a supermarket, a logistics depot or a car dealership that provides electric charging services. Fully integrated refuelling stations combine multiple services into one location, such as a convenience store, car wash, and auto repair services, fast food restaurants or shopping centers.

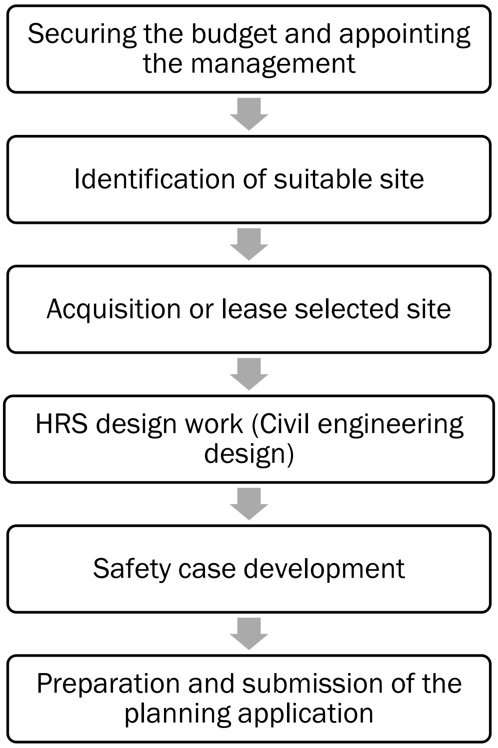
(d) Financial considerations (costs and time to repayment)

(e) Civil engineering constraints and finally,

(f) The paperwork required.

Therefore, HRS planning should usually follow a series of steps, which are summarised below.

I. Securing the budget and appointing the management



Securing the budget and appointing the management of the project is the first step in planning. Developing a sound business plan and a comprehensive project budget will help attract investors and ensure capital if needed. Usually this step also involves the identification of the primary partners tasked with delivering the HRS: a project manager, planning/design consultants, and contractors (for civil engineering, landscaping, etc.) that could have a specific role in planning and installation phase.

II. Identification of suitable site

Identifying the optimal site for the installation of an HRS is potentially the most challenging part of the process. It involves two steps: Identifying the general area where the station needs to be located and finding a specific site where it can be built. As the deployment of Fuel Cell Electric Vehicles (FCEVs) is still limited, it is necessary to plan the location of the stations efficiently in order to serve the maximum number of potential customers and ensure the financial viability of the stations. A number of models for the optimization of HRS allocation have been studied since late last century, however the most prevalent models for HRS location planning can be categorized into the following two major types: **a) location-allocation solutions**; and **b) flow-demand solutions**. The first type of HRS location planning aims to minimize the distance between facilities and customers. The second type analyses refuelling demands based on traffic flows. Nevertheless, as will be further demonstrated below, HRS location planning may take additional parameters into account depending on the type of vehicles it intends to serve.

HRS fall into two broad categories in terms of siting: standalone and hosted stations. Standalone HRS are installed on sites with no or limited other facilities and are typically unmanned. Heavy duty trucks Hosted HRS are installed on forecourts and can be further

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categorised as non- integrated or fully integrated. These types of station also tend to be self-service but are in close proximity to other business operations, hence are not unmanned in the same sense as standalone HRS.

III. Acquisition or lease of the selected site

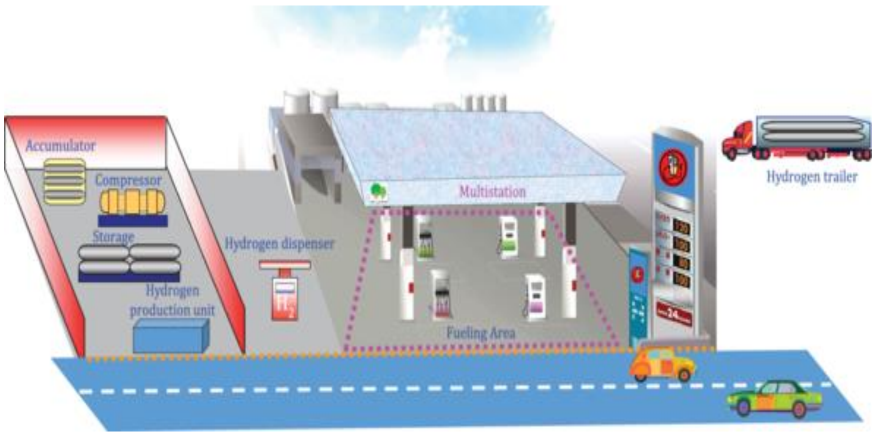
HRS suppliers do not typically own sites suitable for HRS installation and must therefore purchase the land or enter into agreements to lease it. In this regard, owners and operators of existing service stations could also potentially participate in a joint project as partners.

IV. HRS Design

Most HRS are based on a modular arrangement, with three principal components:

i. **The main skid**, housing any on-site production equipment, the hydrogen compressor, control equipment, and a small amount of high-pressure storage.
ii. **Bulk hydrogen storage** – bottles / tubes / vertical tanks. Bottles of compressed hydrogen offer insufficient storage capacity for most HRS. Vertical tanks around 20m high are being installed in a number of HRS in Germany. These are preferred over tubes when space is at a premium as they offer a lower footprint solution.
iii. **Hydrogen dispenser** (which may include pre-cooling equipment depending on distance from the main skid). This is generally the only part of the station that is publicly accessible.

Figure 3. HRS infrastructure visualisation



Like any other filling stations, HRS need to adopt a customer focused design, namely to take into consideration the look and feel of the station (ergonomics), as well as the **ease of access** and use (e.g. ensure that vehicles can be refuelled with filler caps on both sides). It is also necessary to develop a layout that fits within the site constraints and respects all relevant safety distances. When designing an HRS station, consideration must be given to practical issues, such as on how vehicles will navigate the station, how delivery vehicles will have safe and secure access to refuelling at the station (a process that takes up to an hour) and how maintenance activities will be carried out regularly.

V. Safety case development

Last but not least, the station's design must take into consideration all safety requirements and provisions to ensure that the HRS will operate safely. Most of the technical specifications and provisions in relation to safety are now standardised, as for example in [ISO SO 19880-1:2020 Gaseous hydrogen – Fuelling stations](), and they focus on the areas of fire explosion protection, handling of hazardous goods, waste water disposal, water and environmental protection. The development of a risk management plan during the HRS planning helps identify potential risks and hazards in order to mitigate them during the HRS design and installation phase (e.g. by installing fire suppression systems, obtaining explosion-proofed electrical equipment, leak detectors, ventilation systems). Provision should also be made for the implementation of a safety management system which will address any hazards and risks in a timely manner.

VI. Preparation and submission of the planning application

Preparing and submitting the planning application to the local planning authority is usually the last step of the planning phase. The process varies from country to country, but generally the application is submitted to the local or national government agency responsible for land use planning and development. A full application may include: a cover letter, a site plan, the station's layout drawing, elevation drawings, safety distance plan, design and access statement, planning statement, impact assessment (on traffic, noise, other environmental impact), photographs and proof of payment of the application fee.

2.3 Planning requirements for HRS serving heavy-duty trucks

A fuel cell truck is an electric vehicle that includes both a fuel cell system and batteries. Fuel cells generate onboard power from hydrogen to recharge the batteries providing the entire daily power needs of the truck. The remaining truck components (chassis, electric drive, etc.) are common across all electric trucks. Fuel cell electric trucks are ideal for applications requiring high usage, heavy payloads, and long range, such as transport and distribution trucks but also, waste, cement, mining and utility trucks. In particular, fuel cell trucks have the potential to significantly reduce greenhouse gas emissions if hydrogen is produced using electricity from renewable energy sources. Nevertheless, a widespread adoption of fuel cell heavy-duty trucks would need to be accompanied by a large scale-up of hydrogen infrastructure to ensure the production and distribution of the required quantities of green hydrogen.

With regards to refuelling patterns and HRS network design, heavy-duty trucks share a number of similarities with buses, such as storage at 350 bars, but they also exhibit important differences. Whereas buses typically return to base at the end of the day and can be quickly refuelled at a centralized hydrogen refuelling station at one of the city's depots, heavy-duty trucks require a much more spatially extended HRS network. Moreover, they typically carry much heavier loads and have greater fuel needs.

Therefore, although the design steps for a hydrogen station do not vary in terms of its components from one vehicle to another, there are a number of considerations that must be taken into account when stations aim to serve mainly heavy-duty trucks.

Key parameters to consider include:

1. The ability to refuel at 350 bar which means that hydrogen storage and dispenser must be adapted to this pressure.
2. The amount of hydrogen storage capacity. Fuel cell heavy-duty trucks are typically much larger and heavier than fuel cell passenger vehicles; they have much larger fuel tanks and higher hydrogen consumption, hence requiring more hydrogen to operate. Inevitably this can potentially have significant implications with regards to the optimal hydrogen storage capacity of the HRS, although the exact requirement will depend on the expected average hydrogen demand.
3. The location of the station should be suitably chosen to support long-range road transportation. This places certain requirements in terms of their placement and the maximum distance between the hydrogen stations, in line with the TEN-t network regulation.
4. Fleet-based medium and heavy-duty trucks (Class 4 to 8 and >6t) present the lowest barriers to entry for hydrogen. These trucks, typically operated by large logistics companies, often return to base at the end of the shift and can be quickly refuelled at a centralized hydrogen refuelling station at the depot.
5. Similarly to every HRS other ergonomic considerations must also be taken into consideration, including the safe movement of the vehicles within the station or the location of the valves dispensing the hydrogen.

Real-world examples

A recent study commissioned by the European Fuel Cells and Hydrogen Joint Undertaking (FCH JU) foresees the deployment of up to 100,000 Hydrogen Fuel Cell heavy-duty trucks, as well as up to 1,500 hydrogen refuelling stations (HRS) beyond 2030, with hydrogen powered trucks set to become the cornerstone for achieving CO_2 reduction targets. To date, several fuel cell demonstration projects have been carried out under different European programmes and shown technological readiness. Yet, economic considerations (including hydrogen prices) remain the bottleneck of full commercialization. Some of these projects are listed below.

i) H2 Share (2017-2020)

The H2 Share project ("Hydrogen Solutions for Heavy-duty transport Aimed at Reduction of Emissions in North-West Europe") funded under Interreg North-West Europe program, developed and tested one 27-ton rigid truck run on hydrogen and one flexible low energy mobile refueler. The H2-Share truck was built by VDL and completed demonstration at

BREYTNER Zero-emission Transport, ABC-Logistik, Colruyt Group (in Brussels and Dole) and DHL.

ii) H2HAUL (2019-2024)

H2Haul ("Hydrogen Fuel Cell Trucks for Heavy Duty Zero Emissions Logistics") is project co-financed by the Fuel Cell and Hydrogen Joint Undertaking (FCH JU). It aims to deploy 16 zero-emission fuel cell trucks at four sites. In addition, new high-capacity hydrogen refuelling stations will be installed to provide reliable, low carbon hydrogen supplies to the trucks.

iii) H2PORTS (2019-2024)

H2PORTS (Implementing Fuel Cells and Hydrogen Technologies in Ports) is a project funded under HORIZON 2020. It will demonstrate new fuel cell technologies in the port terminals of Valencia. More specifically, it will develop and test three prototypes, i) a reach stacker powered by hydrogen, ii) a yard tractor equipped with a set of fuel cells and iii) a mobile HRS to provide the fuel.

2.4 Planning requirements for HRS serving hydrogen trains

A hydrogen train is an electric train powered by hydrogen fuel cells. Similar to passenger cars and heavy-duty trucks, this technology works by using a fuel cell to convert hydrogen into electricity, which is then used to power the train's electric motors. The adoption of green hydrogen trains is an important step toward decarbonizing the transportation sector. However, as is the case of fuel cell trucks and buses, the development and implementation of hydrogen technology in trains requires significant investment in infrastructure.

The refuelling process in trains is also similar to that of the rest FCEVs. Trains are refuelled at the HRS, which store hydrogen in large tanks and dispense it into the train's fuel cell system. However, since trains travel on a fixed-route, refuelling can be done on a programmed basis at a railway station. From this perspective, the design of HRS network for trains is more similar to that of urban buses, which takes place along their route, rather than heavy-duty trucks.

Real-world hydrogen train examples

There are currently several green hydrogen trains operating in Europe. Some of them are listed below.

i) The Alstom Coradia iLint in Germany

The Alstom Coradia iLint is the first hydrogen-powered passenger train in commercial service in the world. It was launched in Bremervörde, Lower Saxony, Germany, in 2018 and currently operates in various lines across Germany. The fuel cell system allows the train to emit only steam and condensed water while in service and operate with low noise levels that improve both operator and passenger comfort. The Coradia iLint has also been successfully tested in Austria, the Netherlands, Poland and Sweden.

ii) The HydroFLEX train in the United Kingdom

The Hydroflex train is a prototype hydrogen-powered train, developed by a consortium of UK companies, which is set to be in operation in 2024. During the pilot phase, it made a 25-mile round trip through Warwickshire and Worcestershire, reaching speeds of up to 80km. Its next phase is to move the hydrogen tanks, fuel cell and battery out of a carriage and store them underneath the train.

2.5 Planning requirements for HRS serving hydrogen city buses (Fuel Cell Electric Buses)

A fuel cell electric bus (FCEB) is an electric urban bus that includes both a hydrogen fuel cell and batteries/capacitors. The fuel cell provides the energy for the vehicle operation, whilst the batteries/capacitors are able to provide additional power to the motor when required. By using a fuel cell in conjunction with a battery, the size of each can be optimized based on the specific operational needs. The fuel cell power unit in the bus generates electricity through an electrochemical reaction that leaves only water and heat as by-products, so there are no local emissions. All the energy required to operate the bus is provided by the hydrogen stored in it. Since, hydrogen offers a higher energy density compared to electrical storage systems such as batteries, it allows a greater range compared to systems where batteries are used as energy storage.

FCEBs have significant operational flexibility. They have relatively long range (> 300 km) and limited refuelling needs and do not require additional on-street infrastructure or city permits, other than hydrogen refuelling stations (HRS) at the bus depots. In addition, refuelling takes approximately 7 minutes for a typical fill-up, while designs are being developed that allow less than 5 minutes. Overall, FCEBs are zero-emission vehicles with a performance comparable to convention buses in terms of traction, speed and acceleration, while in addition being completely silent.

Technical difference between HRS for cars and buses

The design and construction of hydrogen refuelling stations is not a completely new challenge since a growing number of HRS already exist in Europe; these were initially built in the context of demonstration pilots and later became fully operational. Nevertheless, most of these HRS provide hydrogen to a relatively small number of passenger vehicles and/or buses. HRS that are intended to cover the needs of bus fleets with a significant number of FCEBs, will potentially require different design specifications.

In particular, refuelling a large number of buses, with a typical storage tank size of 30 – 50 kg of hydrogen, requires considerably more hydrogen than passenger vehicles that usually carry approximately 5 kg of hydrogen, potentially leading to higher hydrogen storage capacity requirements.

Another important difference is that the on-board hydrogen storage for buses typically **requires lower pressures than the passenger cars.** Two standard dispensing pressures have been adopted globally, **350 bar for buses and 700 bar for cars**. The lower pressure level (350 bar) provides several advantages. Firstly, it allows the use of lower specification and, in some cases less complex, components both for the bus and the HRS infrastructure. **This reduces costs and increases the overall reliability of the technology**. Secondly, compressing hydrogen up to 350 bar requires less energy than compressing up to 700 bar. Furthermore, the available standards for hydrogen refuelling of passenger vehicles prescribes the precooling of hydrogen to -40°C when being refuelled at a 700-bar pressure. This precooling, which requires additional equipment and energy, **is not necessary for the refuelling of hydrogen at 350 bar pressure**.

Moreover, hydrogen buses are often subject to uniform scheduling by bus companies, with fixed daily refuelling times and fixed driving routes. Since buses generally cover 150 – 300 km range daily, hydrogen buses typically require one refuelling per day. The relatively low refuelling requirements have direct implications for the size and refuelling capacity of the stations and make planning for supplying the station (in case of off-site hydrogen production supply), and maintenance work easier.

Economic considerations

The various HRS concepts (on-site and off-site production) presented earlier are suitable for all types of vehicles, namely for cars, buses and trucks. However, the optimal configuration will depend on the quantity of buses that each station is expected to serve. Existing HRS have been designed to cover the refuelling needs of only a small number of buses; however, the wider adoption of hydrogen in urban mobility will require the deployment of HRS with considerably higher refuelling capacity (several tons per day). These new planning requirements are expected to lead to changes in the individual HRS and the HRS network design, in order to address refuelling needs and ensure the economic viability of hydrogen infrastructure.

Real-world applications in European HRS

Below are presented some real-world applications.

i) Trailer Delivery of Gaseous Hydrogen in London, UK (2010-2015)

The hydrogen fuel and refuelling facilities for a fleet of 5 buses operating in London by Transport for London were provided via liquid hydrogen trucks, which was then considered the most cost-effective option as the hydrogen was produced by Air Products in the Netherlands and then transported across the Channel. A novel liquid hydrogen tanker was used to dispense high-pressure hydrogen into banks of hydrogen cylinders at a filling station. This vehicle was able to supply high-pressure hydrogen to London's filling station, thereby minimising the use of compressors. This technology could fill a bus from empty in less than ten minutes on average.

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ii) Electrolysis-Based Fuelling Station in Oslo, Norway

In June 2016, Oslo announced it would reduce the city's carbon emissions 50% by 2020 and 95% by 2030. Ruter, the public transport authority in the region, supported this initiative by ensuring that all public transport in Oslo run on renewable energy by the end of 2020.

The hydrogen refuelling station for the first five fuel cell buses deployed in Oslo by operator Ruter was owned and operated by Air Liquide Norway. Hydrogen was generated from water via electrolysis that utilized exclusively renewable sources, using two HySTATTM 60 electrolyzers provided by Hydrogenics Corporation. The hydrogen station had at the time a generating capacity of 250 kilograms per twenty-four-hour period to refuel five buses with 35 kilograms each. The refuelling pressure was 350 bar and all five buses were filled within a two-hour period overnight.

iii) An HRS installed within the public transport company's depot in Bolzano, Italy (2021)

SASA Bolzano has been operating Mercedes hydrogen buses since 2013, as the company took part in the EU funded project CHIC. In 2021, it purchased 12 new Solaris Urbino hydrogen buses, that will be refuelled by a hydrogen refueling station installed within the public transport company's depot. This HRS will be co-financed by the Province of Bolzano and the EU-funded project MEHRLIN. Thanks to this latest supply, Bolzano features today one of the largest fuel cell bus fleets in Europe and the first in Italy.

3. OPERATIONAL GUIDELINES FOR THE ORGANISATION AND SUCCESSFUL IMPLEMENTATION OF TWO STUDY VISITS IN BAVARIA AND STRASBOURG

A study visit aims to help the participants gain hands-on knowledge from organisations with thematic expertise on the topic of interest. As part of activity A.1.2, H2MA partners will participate together with relevant stakeholders in two visits in Augsburg, Germany and in Strasbourg, France. The purpose of these two visits is to gain practical knowledge of the steps to be followed in the design and deployment of an HRS network, with a focus on i) trains and heavy-duty trucks (Augsburg) and ii) urban buses (Strasbourg). Exposure to real design requirements and the challenges that may arise during the design process is expected to increase the knowledge of all participants and support the planning of the hydrogen supply network in the Alpine regions. This section offers operational guidelines for the successful implementation of the two visits, preparing participants for the topics to be discussed and proposing a dissemination strategy that also includes a set of communication activities to support its implementation.

3.1 Selection of the study visits locations

In the context of this activity, the following sites were chosen to host the study visits.

The first is Augsburg in Bavaria, Germany, with the participation of the Hydrogen Centre Bavaria (H2.B). The second study visit will take place in Strasbourg, France and will include the visit of the R-Hynoca HRS.

3.1.2 Study visit in Augsburg, organized by ITALCAM

The study visit in Bavaria will include presentations by the Hydrogen Centre Bavaria (H2.B) and three on-site visits: the first to Quantron AG company, the second to Green Hydrogen Technology GmbH and the last to the University of Augsburg.

Hydrogen Centre Bavaria (H2.B)

The Hydrogen Centre Bavaria (H2.B) is an initiative in Bavaria, Germany, focused on advancing research and development in the field of hydrogen and fuel cells. It was founded in 2014 by the Bavarian Ministry of Economic Affairs, Energy and Technology, and is a collaboration between academic institutions, research centres and industry partners. The H2.B aims to promote the use of hydrogen as a clean and sustainable energy carrier, with a focus on developing and implementing innovative technologies for energy storage, mobility, and industrial applications. It also supports the training and education of a new generation of experts in the field of hydrogen and fuel cells. The centre conducts research on hydrogen production, storage, transport and utilisation in a variety of sectors, such as transportation, industry, and the energy sector. The H2.B also provides a platform for collaboration between industry, research, and government institutions to accelerate the development and deployment of hydrogen technologies.

QUANTRON AG

Quantron AG is a German company that specialises in the development and production of commercial vehicles with electric and hydrogen fuel cell drive systems. The company was founded in 2019 and is based in Augsburg, Germany. Quantron offers a range of electric and hydrogen commercial vehicles, including vans, trucks and buses. Since 2020 they offer the 44-tonne Energon truck with a fuel cell that runs on hydrogen. These vehicles are designed to be environmentally friendly, quiet, and cost-effective, while also meeting the needs of commercial customers. In addition to developing and producing its own vehicles, Quantron also provides customised solutions for its customers to understand their specific requirements and provide tailored solutions that meet their needs.

Quantron's mission is to help accelerate the transition to sustainable mobility and reduce emissions in the commercial vehicle sector. The company aims to be a leader in the development of innovative and sustainable transportation solutions.

The company is funded by the Free State of Bavaria.

Green Hydrogen Technology GmbH

Green Hydrogen Technology GmbH developed a new way of producing green hydrogen, which allows industrial, utility and municipal companies to produce it on an industrial scale. The technology uses sewage sludge, plastic and wood waste as feedstocks.

Research group of H2.UniA of the University of Augsburg

The research group of H2.UniA of the University of Augsburg is an interdisciplinary network of chairs and working groups within the University of Augsburg.

Their focus is to bundle expertise and exchange regarding research on relevant topics of hydrogen technology and to make a significant contribution to the implementation of the energy transition and the European, National and Bavarian Hydrogen Strategy and Climate Alliance.

3.1.1 Study visit in Strasbourg, organized by EMS and PVF

The study visit in Strasbourg will include the visit of R-Hynoca station which will open in 2023. The project is being carried out by Hynoca, a joint venture created by Haffner Energy, a company specialising in the development of green energy plants, based in Vitry-le-François (Marne), and Réseaux-Gaz de Strasbourg (R-GDS), a mixed economy company based in Strasbourg. It will produce hydrogen using thermolysis of locally sourced biomass, heated to 400 degrees and then steam cracking of the gas. Once operational, the unit will produce up to 720 kg/day of H2 syngas called Hypergas, to supply the local transport industry as it transitions from fossil fuels to clean energy.

The production unit will be located in the Plaine des Bouchers business park in Strasbourg, close to the R-GDS plants and represents an investment of 6 million euros. The R-Hynoca technology is environmentally friendly, as the fuel is derived from local forest scrap and potentially from waste biomass. The goal of R-Hynoca is to recover 100% of the processed resources in the form of various combustible gases (mainly green hydrogen) and a solid residue that can be recovered, biochar. In collaboration with the Carnot MICA Institute in Mulhouse, the R-Hynoca project aims to characterise this biochar as a biological improver for agricultural land. Finally, the R-Hynoca project plans to produce Hypergas, a renewable synthetic gas that can be used in an urban heating network. The R-Hynoca plant will be the first industrial demonstration plant of this technology.

The station's characteristics

- The first high-capacity hydrogen station in Strasbourg
- 1 Dual pressure refill station 350-750 bas
- 720 kg of green hydrogen distributed per day
- 1 refuelling interface for pressurized hydrogen cylinders ("tube trailers")
- Innovative project for low-carbon mobility

Photo 1. Photorealistic picture of the station

Source: https://tinyurl.com/4duycdjv

Overview of the construction of the R-Hynoca station

Milestone 1: Laying the ground

On Monday 16 November 2021, the dump trucks, excavators, bulldozers and other compactors of the GCM company went into action in the Rue du Doubs to prepare the platforms for the SKID-1 installations (R-Hynoca test phase). This first phase involves digging up an inhomogeneous site to prepare for the laying of various foundations, traffic lanes and technical networks.

Milestone 2: Delivery and installation of the SKID-1 components on the R-HYNOCA site

Thursday 17 February, the R-HYNOCA project reached a second major milestone with the arrival of the two SKID-1 modules at the R-GDS site in Strasbourg, after a smooth journey from Vitry-le-François. This first installation will be used to carry out operational tests of the process for the production of hydrogen from biomass. The teams successfully unloaded the equipment and positioned it precisely on the invert.

Milestone 3: The invert of the SKID-1 is laid

The assembly work on SKID-1 is complete. One of the next crucial stages is the first hot biomass injection, which will allow the thermochemistry of the process to be tested under real conditions before the evaluation and trial operation phase of the installation. These qualification tests will make it possible to verify the contractual performance and stability of the process. This is another decisive milestone before the transition to the industrial stage.

The H2MA project is co-funded by the European Union through the Interreg Alpine Space programme

3.2 Study visits agenda

The purpose of the two study visits is to gain hand-on knowledge on planning specifications and requirements for HRS infrastructure intended to serve a) trains and heavy-duty trucks (Augsburg) and b) urban buses (Strasbourg). This section provides the thematic areas that are expected to be addressed in the course of the study visits. However, these are not final and are subject to modifications and/or updates based on partners' feedback. Three distinct thematic areas have been identified for the study visits. Each of them comprises some indicative topics that can be further explored in the context of presentations during the site visits.

a) Technical specifications

This section will aim to guide participants through the necessary technical specifications and requirements of an HRS. This includes, inter alia a) the currently available arrangements pertaining to the supply of the station, b) storage options, c) the necessary specialized equipment for refuelling fuel cell vehicles and d) ergonomic specifications for the design and construction of the station.

b) Economic aspects

This section will aim to discuss economic aspects and challenges during the hydrogen station planning, deployment and operation phases. Participants are expected to a) discuss planning aspects (e.g. station location and size) that play a key role to the financial viability of the stations, b) gain knowledge on securing funding for HRS projects (including state subsidies and aid), and c) discuss investment costs and procedures for the purchase of the necessary equipment.

c) Safety requirements

The third section focuses on the safety measures and standards to be followed in the implementation of HRS projects. Participants will discuss a) safety guidelines and regulations on safety standards, b) implementation challenges, c) safety measures in the visited HRS, and d) risk management plans developed during the planning and deployment of the stations.

3.3 Implementation Plan

To facilitate the successful implementation and evaluation of the visits, the following actions are envisaged, to be undertaken from the organising partners (ITALCAM, EMS, PVF):

1. Finalisation of the study visits' agenda
2. Selection of stakeholders to be invited in the study visits
3. Confirmation of attendance from stakeholders
4. Transportation arrangements during the visits
5. Arrangement of networking activities (coffee breaks, lunches, dinners according to hour)

6. Overnight accommodation arrangements
7. Evaluation of the study visits (during/after each study visit) by all participants
8. Collection of notes, videos and photographs to be included in the Study visits reports.

Finalisation of the study visit's agenda

To facilitate knowledge sharing, the study visits should ideally include oral presentations and Q&As sessions. In line with the thematic objectives and purpose of each study visit, organising partners should set a thematic agenda and ensure that the proposed topics for study are covered.

Selection of participants

A list of important regional stakeholders has been provided in the H2MA Application Form. Nevertheless, project partners are expected to identify and invite those stakeholders that are the most thematically relevant to the topics that will be addressed during the visits. Indicatively, but not limited to, these stakeholders can include energy agencies, truck fleet operators, refuelling station operators, public authorities and thematic experts. Project partners have the freedom to expand this indicative list if they deem it conductive to increasing the overall impact of the study visits. For the communication with prospective attendees, **two invitation templates** are annexed at th end of this document (**Annex 4**).

Confirmation of attendance of external participants

Setting a date by which all invitees will confirm their attendance would help in better organising the study visits. **Annexe 1** provides a **template for the list of participants** to be completed by the organising partner.

Transportation arrangements during the visits

Depending on the number of participants and the structure of each visit, transportation arrangements should be made. These may involve transport to and from a meeting point, or from one location to another. Also, if there is a lunch at the end of the day which is also recommended for networking purposes, transportation to that event should be provided, especially if it is in a location not accessible by public transport. To that end, the organising partners are expected to identify the optimal arrangement, after inquiring about and ascertaining any mobility impairments or special needs of the participants.

Networking activities

Networking is an important aspect of the activity, as it will facilitate cooperation among partners and open up new opportunities for collaboration with invited stakeholders. To that end, it would be advisable for organisers to plan common events, such as a dinner or coffee break, to allow informal discussions on the topics addressed in the study visits.

Overnight accommodation arrangements

Irrespective of whether the visit takes place in one or two days, overnight accommodation arrangements should be made, as many partners and stakeholders will be travelling from other countries. For this reason, organising partners should consider including a list with suggestions for overnight accommodation. The possibility for all partners to stay in one place should be considered as it would provide an opportunity to extend the discussions and networking beyond the duration of the visit.

Evaluation of the study visits by all participants

Time should be set aside for all participants to evaluate the visit. Any such evaluation should address the relevance, effectiveness, and transferability of the empirical knowledge gained during the study visits. It is recommended, to hand out the evaluation forms and let the participants fill them in at the end of the study visit. In cases that this is not possible, the organizing partners should send the evaluation forms by email within 3 working days. An indicative **Feedback form (Evaluation Template)** has been attached at the end of this document (**Annex 2**).

*Collection of notes, photos and videos during the study visit (**only for organising partners**)*

Using the attached **Input form** (**Annex 3**), organising partners are expected to document the key discussion points and conclusions of the study visits to facilitate the preparation of the lessons learnt reports. In addition to the input form, organizing partners are advised to document written presentations or any other document presented or distributed and discussed during the study visit. Finally, all participants and especially organising partners are encouraged to take videos and photos to enrich the report with both content and visual material.

3.4 Dissemination Plan

Partners are advised to organise a dissemination campaign in order to support the implementation of the study visits and valorise their results and lessons learnt. The campaign should start before the study visits and extend beyond the completion of the study visits. The following target groups have been identified, however organizing partners are free to add more:

- Public authorities and policy makers
- Green hydrogen producers
- Truck and bus fleet operators
- Energy and infrastructure agencies
- Fuelling station operators

Below are some steps that could be undertaken to raise awareness on the visits and their results.

Before the study visits - Send invitations to identified stakeholders - Announce the study visits in the project's and partners' website and social media - issue a press release for the study visit to the local media **During the study visits:** - Take pictures and other visual material to upload on the website - Ask partners to post texts, videos and photos related to the study visit, while tagging the project (e.g. #H2MA, #H2MA_studyvisits, #Interreg_Europe) **After the study visits** - Disseminate the results via the project's website, newsletter and social media accounts - Share the study visits reports with a broader audience of stakeholders, including those not invited or able to attend

3.5 Summary reports

To conclude H2MA activity A1.2, ITALCAM and Eurométropole de Strasbourg will deliver two summary reports, one for each study visit. The reports will present the discussions, conclusions and lessons learnt from the study visits and will be used, inter alia, by project partners as a means of diffusing the lessons learnt within their organisations and to promote storytelling. For this purpose, **Annex 3** provides an **Input form** for reporting to be filled by organising partners after each visit.

ANNEX A - PARTICIPANTS LIST TEMPLATE

Annex A provides a template for the list of participants to be completed by the organising partner.

The participants attending the study visit will register their name and the name of the organisation they represent, so that a complete list of territorial stakeholders that participated in the study visit can be obtained. This will also help in providing contact details for future references and actions which may be needed. This annex presents a template of the study visit's registration form:

Participants list template:

Name/Surname:	
Organisation/Business/Institution:	
Email:	
Comments:	

ANNEX B - FEEDBACK FORM TEMPLATE (EVALUATION TEMPLATE)

Participants should evaluate the implementation of each study visit, after its completion, using the feedback form provided in ANNEX B. If necessary, partners can modify the form as they see fit, in order to ensure the evaluation process of the presentations and discussions that took place in each study visit.

The qualitative aspect will additionally focus on the:

- study visit organisation
- thematic areas addressed
- relevance of discussions topics to the participating organisations' operations
- transferability of lessons learnt

The following template corresponds to the feedback form that attendees will complete to carry out the study visit's evaluation process. The form evaluates the study visit in terms of the discussion topics, as well as the relevance and applicability of the case studies presented. EMS is welcome to modify it.

EVALUATION FORM				
H2MA Activity A1.2 – "Study visits on planning specifications and requirements for setting up green hydrogen mobility routes"				
Organised by				
Name:				
Organisation:				
Please answer the following questions, relevant to different aspects of the study visit, by rating on a 1 to 5 scale.				
How would you rate the study visit's overall organisation?				
1	2	3	4	5

☐	☐	☐	☐	☐
Do you think that the time allocated for each topic was sufficient?				
1	2	3	4	5
☐	☐	☐	☐	☐
How would you rate the quantity of information received during the study visit on planning specifications for green H2 refuelling stations?				
1	2	3	4	5
☐	☐	☐	☐	☐
How would you rate the quality of information received during the study visit on planning specifications for green H2 refuelling stations?				
1	2	3	4	5
☐	☐	☐	☐	☐
How relevant to your organisation's operations were the topics addressed?				
1	2	3	4	5
☐	☐	☐	☐	☐
Knowledge gained in the study visits can facilitate policy recommendations and improvements				
1	2	3	4	5
☐	☐	☐	☐	☐
The study visit as a whole was appropriate and productive				
1	2	3	4	5
☐	☐	☐	☐	☐

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Are there any issues related to the thematic areas of the study visits that have not been addressed? Please briefly describe them.
Do you have any suggestions for the organisation of future study visits?

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ANNEX C - INPUT FORM FOR REPORTING

Annex C provides an Input form to be filled by organising partners after each study visit. Information provided will be used, along with other presentations

STUDY VISIT INPUT FORM	
H2MA Activity A1.2 – "Study visits on planning specifications and requirements for setting up green H2 mobility commercial and urban routes, to improve partners and stakeholders' coordination and implementation capacities"	
Name of the person filling the questionnaire:	
Affiliation:	
Name of the Location:	
Date of Visit:	
Purpose of the visit (Thematic focus):	
SUMMARY OF THE STUDY VISIT	
Please indicate the places you have visited and provide information on the host	
Please provide any relevant information and knowledge shared by the host during the visit (not including any oral presentations held in an organised manner). This may indicatively include information on the premises, important dates, the plans and goals of the hosting organisations.	
Please provide information on the presentations held during the visits (including names, titles, themes discussed and duration)	

Please attach or share any written or visual resources that has been handed out during the study visit (presentation texts, brochures, videos etc.)
Please provide information on the participants' questions and points of view during the discussions and Q&As sessions (if applicable) that took place in the study visit.
Please write down any personal observations you consider important
Please indicate any implementation challenges (if any)
Please provide an overall assessment of the visit
Please attach or share any photos, videos or recordings taken during the study visit

ANNEX D - INVITATION TEMPLATES

Annex D provides two Invitation Templated for the Study Visits in Bavaria and Strasbourg to be adapted accordingly by organising partners.

Your Recipient's Name
123 Anywhere Street
Any City 12345

Dear XXX,

As part of the H2MA Interreg Alpine Space project, the Italian-German Chamber of Commerce is organising a study visit in XXX and we would like to invite you to join us. The aim of this visit is to gain hands-on knowledge on planning specifications and requirements for green hydrogen infrastructure with a particular focus on the construction of HRS serving urban buses. Such a visit will bring together numerous stakeholders from within and beyond the H2MA consortium in order to facilitate cooperation and explore new opportunities for development and growth.

H2MA Interreg Alpine Space project comprises 11 partners from all 5 Interreg Alpine Space EU countries (SI, IT, DE, FR, AT), with the goal to coordinate and accelerate the transnational roll-out of green hydrogen infrastructure for transport mobility in the Alpine region. In this respect, your interest and involvement in the project's activities may prove to be mutually beneficial.

We would be delighted to welcome you during this study visit. A thematic agenda will be sent to you shortly to help you prepare for the activity.

Sincerely,

Your Name/Affiliation/signature

Your Recipient's Name
123 Anywhere Street
Any City 12345

Dear XXX,

As part of the H2MA Interreg Alpine Space project, the Eurometropolis of Strasbourg and the Pôle Vehicule du Futur are organising a study visit in XXX and we would like to invite you to join us. The aim of this visit is to gain hands-on knowledge on planning specifications and requirements for green hydrogen infrastructure with a particular focus on the construction of HRS serving urban buses. Such a visit will bring together numerous stakeholders from within and beyond the H2MA consortium in order to facilitate cooperation and explore new opportunities for development and growth.

H2MA Interreg Alpine Space project comprises 11 partners from all 5 Interreg Alpine Space EU countries (SI, IT, DE, FR, AT), with the goal to coordinate and accelerate the transnational roll-out of green hydrogen infrastructure for transport mobility in the Alpine region. In this respect, your interest and involvement in the project's activities may prove to be mutually beneficial.

We would be delighted to welcome you during this study visit. A thematic agenda will be sent to you shortly to help you prepare for the activity.

Sincerely,

Your Name/Affiliation/signature

Interreg Alpine Space
Co-funded by the European Union
H2MA