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D5.3: H2 AIRCRAFT-AIRPORT COMPATIBILITY CHECKLIST AND H2 MASTERPLAN STRUCTURE FOR FUTURE REPLICATION

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Project coordinator: Virginie Pasquier, Project Manager Environment / Energy, ADP

Tel: +33 7 88 35 16 07

E-mail: virginie.pasquier@adp.fr

Project website address: www.olga-project.eu

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APPROVALS

	Name	Company	Date	Visa
Coordinator	Virginie PASQUIER	ADP	30/07/2026	OK
WP Leader	Massimo CORRADI Elena BRANCHINI	SEA	30/07/2026	OK
Task Leader	Blandine LANDFRIED	ADP	29/07/2026	OK
Quality Manager	Melike RIOLLET	LUP	31/07/2026	OK

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List of Abbreviations

AB	Advisory Board
ACI	Airport Council International
ADR	Aerodromes
AMC	Acceptable Mean of Compliance
ANS	Air Navigation Service
APU	Auxiliary Power Unit
ASTM	American Society for Testing and Materials
ATM	Air Traffic Management
BEV	Battery Electric Vehicle
bioNGV	bio- Natural Gas Vehicle
CA	Consortium Agreement
CAGR	Compound annual growth rate
CDG	Paris-Charles de Gaulle airport
CLJ	Cluj Airport
CNG	Compressed Natural Gas
CS	Certification Specification
DG-DEFIS	Directorate-General for Defence, Industry and Space
EASA	European Aviation Safety Agency
EC	European Commission
EIGA	European Industrial Gases Association
ENAC	Ente Nazionale per l'Aviazione Civile (Italian Civil Aviation Authority)
EPC	Engineering Procurement and Contract
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
(P)(H)EV	Plug-In hybrid Electric Vehicle
GHG	greenhouse gas
GPU	Ground Power Unit
(G) (L) H2	(Gaseous) (Liquid) Hydrogen
GSE	Ground Service Equipment
H2020	Horizon 2020
HEFA	Hydroprocessed Esters and Fatty Acids



IATA	International Air Transport Association
ICPE	Installation Classée pour la Protection de l'Environnement
IEA	International Energy Agency
IFR	Instrument Flight Rules
IP (R)	Intellectual Property (Rights)
IR	Implementing Rule
ISO	International Organization for Standardization
JIG	Joint Inspection Group – Aviation Fuel Supply Standards
LCA	Life Cycle Assessment
LTO	Landing and Take-off
MXP	Malpensa airport
MRV	Measurement, Reporting and Verification
NFPA	National Fire Protection Association
NGV	Natural Gas for Vehicle
NPA	Notice of Proposed Amendment
OEM	Original Equipment Manufacturer
PAX	Passenger
PC	Project Coordinator
PMC	Project Management Committee
PPE	Programmation Pluriannuelle de l'Energie (French Multiannual Energy Program)
PtL	Power to Liquid
R&D	Research and Development
RES	Renewable Energy Source
RFFS	Rescue and Fire Fighting Service
SAF	Sustainable Aviation Fuel
SC	Steering Committee
SERA	Standardised European Rules of the Air
SFEC	Stratégie Française pour l'Energie et le Climat (France's energy and climate strategy)
SMS	Safety Management System
SNBC	Stratégie Nationale Bas-Carbone (French National Low-Carbon Strategy)
TRL	Technology Readiness Level
VTOL	Vertical Take-Off and Landing



WG	Working Group
WP	Work Package
WPL	Work Package Leader
ZAG	Zagreb airport



1 Executive summary

1.1 Context and objectives

In 2020, Airbus announced its ambition to bring a hydrogen-powered commercial aircraft to market by 2035 to contribute through this energy vector to air transport decarbonisation¹.

The introduction of this new aircraft technology requires airports to prepare for it by understanding the challenges involved in terms of hydrogen supply chain, integration of hydrogen infrastructure and facilities within their boundaries, H2-aircraft operations, and potential changes to applicable regulation.



Figure 1 : Airbus ZEROe aircraft

Source: www.airbus.com

In WP5 dedicated to energy and hydrogen topics, the task *WP5.2. H2 Airport Design – Paris Case study* aims to propose master planning guidelines towards H2 use for aviation uses (mostly Liquid-Hydrogen aviation) and ground uses at airports, by developing an overall integrated “hydrogen airport master-planning”. It also aims at enabling key learnings dissemination and thus preparing the pattern for airport community to be H2-ready.

The task promotes a holistic approach of hydrogen topic covering both H2 regulation for airports and integration of H2 airside and landside infrastructures and facilities at airports addressing the whole value chain (production, transportation, liquefaction, storage, distribution, refuelling).

Concerning the analysis of H2 regulation for airports, the goal is to identify the EU Regulation – concerning airport organization, operations and design - that could be impacted by the introduction of H2 on airports to feed the gap analysis and to then engage in dialogue with the EU authorities, such as EASA.

Concerning the integration of H2 airside and landside infrastructures and facilities at airports, the goal is to determine the perspectives of H2 uses at airports, propose associated H2 supply chain and evaluate how to adapt airport infrastructures to accommodate H2 operations.

The master planning study is developed through a case study: Paris-CDG Airport. Studies have also mainly focused on the impacts in terms of master planning and hydrogen infrastructure requirements

¹ It should be noted that only renewable or low-carbon hydrogen makes sense for the decarbonization of airport activities and air transport. Therefore, all the following considerations relating to hydrogen refer to renewable or low-carbon hydrogen.



associated with the introduction of Airbus's ZEROe aircraft fleet, as it is this fleet, in the projected market forecast, that is likely to have the greatest impact in terms of master planning at airports.

Note : In February 2025, Airbus announced that the entry into service of the ZEROe aircraft, initially planned for 2035, would be delayed. These delay assumptions came too late in the OLGA study cycle to be incorporated. Therefore, all sizing assumptions for this masterplanning study are based on the ZEROe aircraft being marketed from 2035 onwards. The conclusions of the studies presented in this report will remain usable once the schedule delay has been specified.

1.2 Scope of work and achievements

1.2.1 Work performed and main results achieved

For hydrogen-powered aviation to be successful, it is essential to understand the implications for airports. Significant infrastructure development is required, and new regulations and procedures are needed to enable the aircraft to operate safely. In addition, liquid hydrogen presents many challenges, including the need to operate at cryogenic temperatures of -253 °C.

Regarding the study of hydrogen facilities and infrastructure development, the OLGA project focuses on realizing the first level of airport design (= masterplan) and prefeasibility studies using Paris-Charles de Gaulle airport as case study. The work performed takes a long-term perspective, with gaseous hydrogen infrastructure to supply ground mobility applications and gaseous hydrogen aviation and liquid hydrogen infrastructure to supply liquid hydrogen powered aircraft.

The study initially clarified the hydrogen demand for ground mobility and aviation, the timing of the ramp-up of hydrogen and the quantities of hydrogen involved for CDG and the other OLGA Airports. It then focused on identifying the various possible logistics chains that would be suitable for each phase. Finally, the integration of hydrogen infrastructure at Paris-CDG to meet the various uses and different time phases was characterized.

The masterplan and pre-feasibility studies showed that, in the maturity phase, up to 700 tons of hydrogen per day will be needed at Paris-CDG. To meet this need, a plant covering more than 20 hectares will be required to liquefy and store the necessary hydrogen. This plant could also



accommodate a part of hydrogen production through electrolysis (~30T/day) while most of the hydrogen will be transported to the airport in gaseous form via hydrogen transport networks.

The study concluded with a basic design for a hydrogen plant distributing 700 tons of hydrogen per day.



Figure 2 : Basic design for a hydrogen plant distributing 700 t of liquid hydrogen per day

Source: Groupe ADP and Air Liquide

The study also contains the H2 Masterplan replication guidelines for Zagreb Airport.

Regarding the analysis of the impact of introducing hydrogen on the airport regulatory framework, to prepare a first level of airport design (= masterplan), the work performed focuses on analyzing European regulations that apply directly or that may have an impact on airport authorities in terms of organization, operations management, or design.

Thus, the regulations studied are:

- Basic Regulation EU n° 1139/2018 and Commission Regulation EU n° 139/2014. Indeed, aerodromes concerned by LH2 aircraft targeted in WP5.2 are aerodromes within the scope of the EASA regulation which are certified in accordance with these EU regulations;
- The common rules of the air and operational provisions regarding services and procedures in the air (Standardized European Rules of the Air: Regulation SERA 923-2012);
- Texts describing the measures applicable to the storage and transport of dangerous goods on airport;



-
- Doc 9284 Technical instructions, ICPE regulations on installations classified for environmental protection, since liquid hydrogen can be considered as a regulated dangerous good stored on airport.

The analysis consists in identifying the regulatory articles or their application that could be affected by the introduction of hydrogen at airports.

The analysis carried out by ADP Hydrogen Project Manager and ADP Compliance Monitoring entity shows that:

- it is necessary to introduce a clear definition of the energies or energy carriers used to power aircraft into the texts and define if hydrogen can be included in the term “fuel” used in the texts;
- only few articles need to be modified, but many airports authorities' procedures, which are operationally or organizationally based on regulation, will need to be clarified to incorporate the specific characteristics of hydrogen.

The document also includes EASA comments on the analyzed European regulations

1.2.2 Partners involved

The three main actors involved in the study are: Groupe ADP (ADP), Air Liquide (AL) and the Service Technique de l'Aviation Civile (STAC). Their roles are complementary to each other.

Groupe ADP (ADP), as an airport operator and designer:



- Analyses airport regulation framework;
- Provides airport characteristics and expertise in airport regulation, operations and design;
- Defines airport requirements / constraints for the implementation of H2 infrastructure at airport;
- Provides feasibility studies about hydrogen infrastructures design and implementation on airports.

Air Liquide (AL), as one of the world leaders in gases, technologies, and services for industry:



- Provides technology drivers on the various elements of the H2 supply chain;
- Builds infrastructure deployment scenarios and conceptual design for the supply of airports;



- Provides feasibility studies about hydrogen infrastructures design and implementation on airports.



The **Service Technique de l'Aviation Civile (STAC)**, as technical department from the DGAC (French National Civil Aviation Authority), provides expertise in airport regulation and operations.

EASA has been consulted to review the analysis of the European Regulation applicable to airports.

The methodology to estimate hydrogen volumes required for aviation at the OLGA fellow airports: Milan Malpensa Airport (Italy), Cluj-Napoca Airport (Romania), Zagreb Franjo-Tuđman Airport (Croatia) has been shared with **SEA, CLUJ** and **MZLZ**.

Airbus as advisory board member provides information about the estimated hydrogen aircraft ramp up at Paris-CDG airport.

1.3 Deviation from the original objectives

The studies conducted and the deliverable enable the initial objectives to be met concerning the analysis of the regulation framework applicable for airport design and operations and the design of airport facilities to accommodate H2 facilities for ground uses and aviation.

Concerning LH2 (liquid hydrogen) infrastructure design, some information shall remain confidential and thus cannot be included in this deliverable because the dissemination level is public. This document contains a general layout of a LH2 plant (3D plot plan) integrated at a generic airport and, in section 4.3.4, a high-level description of the LH2 plant at a main Hub Airport modelled on Paris-CDG needs.

In addition, it should be noted that detailed H2-aircraft / airport compatibility (verification of trajectories and safety margins around the aircraft in motion and at the parking position, study of the compatibility of the pavement structure with the forces generated by the aircraft, service road design for new emergency vehicles, specific refuelling area, etc.) could not be studied within this task because of the lack of an H2 aircraft detailed design. At the time of preparing this report, from 2021 until 2025, Airbus was still in the pre-feasibility study phase of two aircraft designs: the Turbopan and



the Turboprop, all powered by hydrogen; only in 2025 they decided to focus on the Turbofan (the fuel cell-powered ZEROe) detailed design.

As a consequence of the above the aircraft/airport compatibility checklist could not be developed and submitted to EASA.

1.4 Links with other OLGA projects

In OLGA, the task *WP 3.3. Low-carbon airside mobility infrastructure* aims at carrying out a feasibility study to integrate an airside multi-energy station (bioNGV and H2) at Paris-CDG airport. This station is an example of functional facilities that are intended to be integrated into the master plan of an "H2-ready" airport.

In addition, the output of the present deliverable can be used as input for task *8.1.2: Green Energy at Airport - project certification scheme* aimed at defining methodological standard which lists the required steps an airport must follow to become H2-ready.

The document will also be carefully revised by SEA, in order to consolidate its strategy to become an H2 ready airport. At the time of writing this document, the WP5.3 Green hydrogen production in Malpensa was forced to stop at the design phase because of the impossibility to implement the mandatory requirements imposed by the Italian Firefighters Department.



2 Introduction

The urgent need to reduce greenhouse gas emissions has prompted the aviation industry to explore innovative solutions to minimize its environmental footprint. In 2020, kicked by Airbus' ZEROe aircraft project, hydrogen² has emerged as a promising candidate for decarbonizing short and medium haul aviation offering the potential for zero emission flight operations. Hydrogen, as a disruptive technology, is one of the four pillars enabling carbon neutrality in aviation by 2050, as highlighted in all roadmaps for the aviation sector.

The ambition of several aircraft manufacturers, including Airbus, Zero Avia, and Beyond Aero, is to enable the advent of commercial hydrogen aviation within the next decade.

Airports must therefore prepare without delay to meet the challenge of hydrogen logistics and operations.

Airports offer numerous opportunities for the gradual deployment of hydrogen: initially for ground mobility applications—heavy-duty vehicles, taxi fleets, aircraft ground support equipment—and then for aviation applications, initially for general and regional aviation and subsequently for short- and medium-haul aviation. In this sense, airports have many advantages that will enable them to become hydrogen hubs and act as catalysts for the development of hydrogen in the regions where they are located. The coordination and synergies of hydrogen use at airports and in their surrounding areas must be considered in the discussions and planning of stakeholders. Indeed, the development of hydrogen uses for industry and land mobility, which will reach maturity before the widespread deployment of hydrogen-powered aircraft, will benefit the large-scale use of hydrogen at airports: development of initial infrastructure, cost optimization through infrastructure sharing (production, transport), and a better understanding of safety issues and societal acceptability. Conversely, the development of hydrogen uses for airport infrastructure and, more broadly, the aviation sector, could in the long term benefit the growth of land-based mobility and, by extension, river and maritime transport. The deployment of hydrogen in airports, in both gaseous and liquid forms, will thus lead to a completely new organization of the value chain and organizational and infrastructure adaptations at airports.

Turning airports into hydrogen hubs requires a deep analysis of the hydrogen market perspectives, the hydrogen supply chain and how the new hydrogen facilities can be integrated on the airport.

² It should be noted that only renewable or low-carbon hydrogen makes sense for the decarbonization of airport activities and air transport. Therefore, all the following considerations relating to hydrogen refer to renewable or low-carbon hydrogen.



These elements then lead to the integration of hydrogen deployment issues into the long-term airport's master plan, which is the preliminary step in long-term airport development planning. In addition, the transition to hydrogen-powered aviation requires comprehensive analysis and adaptation of regulation applicable to airports both in terms of organization, operations and design to ensure safety and operational feasibility.

Based on the case study of Paris-CDG airport, this report presents the key learnings from the pre-feasibility study conducted to enable the integration of hydrogen at airports.



3 The master plan as a tool for long-term planning of airport development

3.1 What is a masterplan?

The International Civil Aviation Organization's (ICAO) Airport Planning Manual (Doc 9184) presents an airport masterplan as the planner's conception of the ultimate (long-term) development of an airport. It effectively presents the research and logic from which the airport plan was developed [...]. It is a guide for development of physical facilities of an airport aviation and non-aviation uses [...] ». The FAA, Federal Aviation Administration, define an airport master plan as a "comprehensive study of the airport and typically describes short, medium, and long-term plans for airport development".

The ICAO Airport Planning Manual gives few recommendations to be followed. The airport masterplan shall:

- contain a program of prioritized tasks, including a progressive implementation plan;
- be periodically reviewed in accordance with current and future airport traffic;
- be drafted using a consultative and collaborative approach with the various stakeholders, in particular aircraft operators;
- consider land use and environmental regulatory measures.

An Airport Master Plan (not enforceable against third parties) is a major document which:

- sets out the major features of the airport's long-term development (runways, division into major zones, ground access, air traffic) based on a traffic study, a program and a facility plan;
- aims at translating the airport's strategic development vision into reality. It looks to the foreseeable future, while preserving the flexibility needed to respond to changing industry and regulatory conditions. It must be regularly revised;
- is a support document that facilitates the internal coordination of projects. It serves as a basis for studies, enabling short-term projects to be carried out without compromising the airport's medium- and long-term potential.

The initiation / opportunity phase marks the beginning of a project where the needs for airport development are identified, often supported by preliminary high-level opportunities studies. This leads to the planning phase, which involves the development of the airport master plan. This comprehensive plan includes an inventory of existing conditions, forecasting future aviation demand, determining facility requirements, evaluating development alternatives, considering environmental impacts, developing a financial plan and creating an implementation strategy.



The planning phase is closely followed by the feasibility study phase and then by the design phase, which involves the detailed design and engineering of the projects and the preparation of construction documents.

An airport Master Plan should not be considered neither as a project nor as a regulatory document. It primarily occurs in the planning phase but influences decisions and actions throughout the entire project lifecycle.



Figure 3 : Macro-phasing of an airport project

Source: Groupe ADP

3.2 Process to prepare a master plan to make an airport H2-ready

Integrating a requirement into an airport master plan requires following a step-by-step process/checklist. Figure 4 shows the several steps followed to study the integration of H2 facilities in airport master plan.

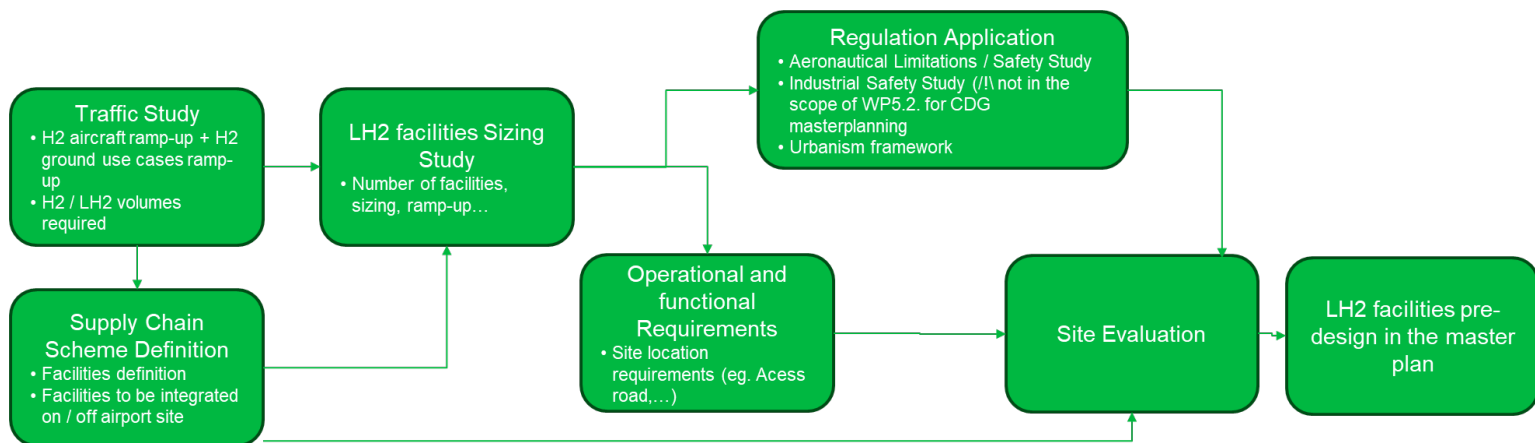


Figure 4 : Process/checklist to prepare a master plan to make airport H2 ready

Source: Groupe ADP

Traffic study: The objective of a traffic study is to assess the future demand and ramp up scenarios for hydrogen aircraft and ground use. This will help to estimate the volume of (L)H2 required at different timeframes and horizons and fine tune the road map established.



Supply chain definition for ground mobility and for aviation: Airports should study among the several possible H2/LH2 supply chain the most adapted to the H2 volumes requirements and ramp-up. This leads to shortlisting the facilities (hydrogen production, storage and distribution) that will be located on site (at the airport) and off site.

LH2/H2 facilities study: Combining the traffic study and the H2/LH2 supply chain definition, airport seconded by a H2 specialist can finalize the scale and number of facilities needed. Airport should then plan the land reservation needed for the production, storage, and distribution of H2 and LH2.

Site Evaluation: Once all the above requirements have been verified, the site assessment will enable the suitability of potential sites to be evaluated and the preferred option to be selected.

LH2 Facilities Pre-Design in the Master Plan: Finally, airports will have to integrate the LH2 facilities into the overall airport Master Plan. This will start by drafting the first LH2 facilities ensuring that these drafts and allocated surfaces are incorporated into the airport's long term master plan.

Operational and functional requirements: Airports must specify the functional needs and location criteria for each facility including the accessibility (access roads, proximity to terminals or to other facilities...). One criterion is also the operational requirements such as safety measures, security measures, operating hours and maintenance schedules to ensure that the location is compatible with these constraints

Regulation and standards application : Once the facility design study has been completed, the airport must take into account all safety regulations and standards, both in terms of aviation safety, airport development (noise protection plan, aviation and radio frequency easement plans, urban planning regulations) and industrial safety³ (e.g. assessment of impact distances to calibrate the distance, where applicable, from other areas and buildings) so that the studied location complies with these requirements.

³ Studies relating to industrial safety are out the scope of this study.



4 H2 master planning: Paris-Charles de Gaulle airport case study

This chapter illustrates the application of the process/checklist described in Chapter 3 to the case of Paris-Charles de Gaulle airport and aims to describe the reservations necessary in the master plan to accommodate hydrogen equipment for ground mobility and aviation.

4.1 Traffic study and assessment of hydrogen demand

Section 4.1 is composed of three parts. The first one focuses on CDG, it illustrates: i) the landside and airside H2 needs considering the energy mix as suggested by the French government based on future traffic assumptions and consumption projections by vehicle type; and ii) the LH2 needs for aircrafts refueling in CDG based on the traffic projections considering the Airbus ZEROe consumption available. The first part also contains an analysis of the ramp-up of (L)H2 at CDG. The second part maps the European traffic growth and additional hydrogen powered aircrafts projects and the related LH2 market study in Europe. The third part hypothesizes the LH2 needs for OLGA fellow airports based on the traffic projections considering the LH2 market study in Europe in the previous section.

4.1.1 Case study of Paris-Charles de Gaulle airport

4.1.1.1 Hydrogen required for ground mobility uses

4.1.1.1.1 Landside mobility energy mix

This paragraph addresses the energy needs associated with the ground transportation of passengers, staff and goods on the landside of the airport, and therefore light vehicles and heavy goods vehicles. As rail transport is already electric, no changes are planned for the rail sector.

ADP mobility workshops have conducted studies on changing needs and modal split.

The energy mix projections for landside mobility are determined by applying the national assumptions defined, thanks to the French National Low-Carbon Strategy (SNBC-Stratégie Nationale Bas-Carbone) which targets carbon neutrality by 2050 (see Figure 5) and the French Multiannual Energy Program (PPE- Programmation Pluriannuelle de l'Energie). These two documents are part of France's energy and climate strategy (SFEC – Stratégie Française pour l'Energie et le Climat), promoted by the French government.



Energy market share in the vehicle fleet				Fleet consumption in 2015, 2030 and 2050			
	2015	2030	2050		2015	2030	2050
Car				Car			
fuel (gasoline or diesel)	100%	76%	5%	fuel (gasoline or diesel) (L/100km)	6,8	5	3,3
Electric	0%	16%	94%	Electric (kWh/100km)	17,8	16,3	13,6
plug-in hybrid	0%	8%	1%	Heavy Goods Vehicle			
Heavy Goods Vehicle				Fuel (diesel)(L/100km)	33,9	29,4	21
diesel	100%	86%	24%	Natural Gas (kg/100km)	27,0	22,4	15,1
Natural gas	0%	12%	51%	Electric (kWh/100km)	197	168	126
Electric & hydrogen	0%	2%	25%	Light Commercial Vehicle			
Light Commercial Vehicle				Fuel (diesel) (L/100km)	8,9	7,3	3,9
diesel	99%	87%	23%	Natural Gas (kg/100km)	6,3	5,2	2,6
Natural gas	0%	2%	9%	Electric (kWh/100km)	24,0	22,8	18,5
Electric	1%	11%	68%				

Figure 5 : Energy consumption assumptions for the French vehicle fleet

Source : SNBC – Stratégie Nationale Bas Carbone – 2020

The energy mix for heavy goods vehicles (proportion of electric battery and hydrogen fuel cell) is not detailed in the French government's reference documents. This energy mix can be refined on the basis of the assumptions defined by the International Energy Agency in its report Net Zero by 2050 - A Roadmap for the Global Energy Sector - IEA.

Figure 3.23 ► Global share of battery electric, plug-in hybrid and fuel cell electric vehicles in total sales by vehicle type in the NZE

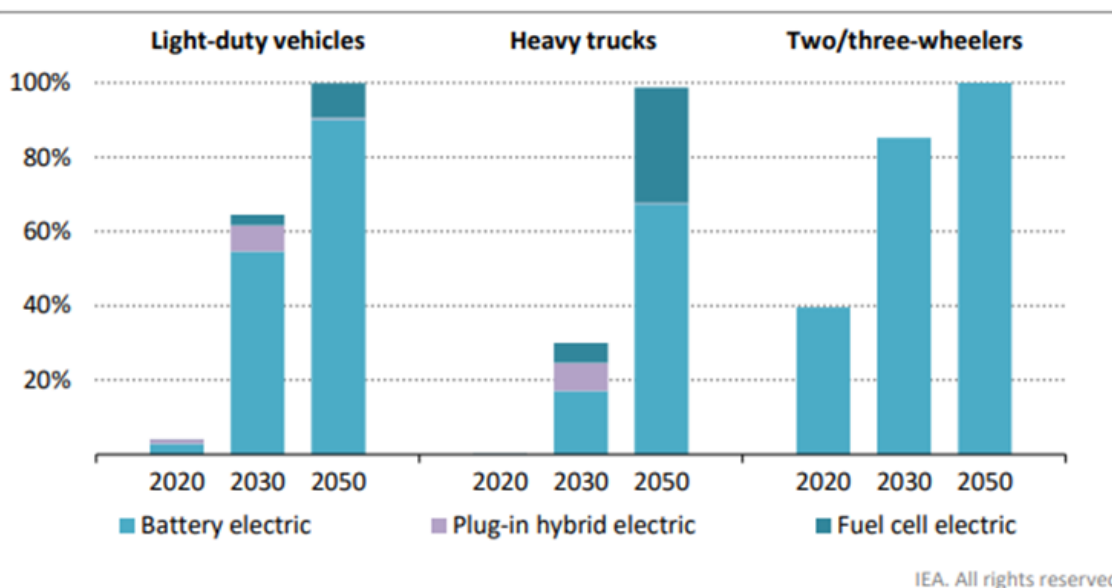


Figure 6 : Assumptions on the market share of different electric vehicle technologies (IEA scenario)

Source: Zero by 2050 - A Roadmap for the Global Energy Sector - IEA



These data lead to the following estimates for the French energy mix for light vehicles and heavy goods vehicles:

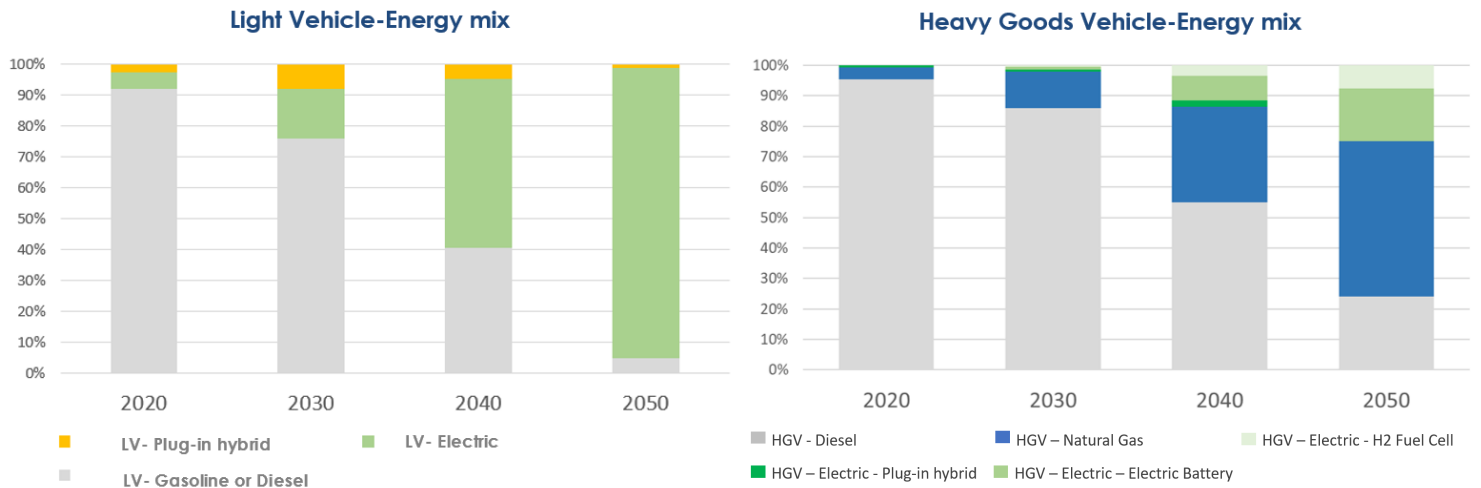


Figure 7: Forecast energy mix for light and heavy vehicles in France

Source: Groupe ADP study based on the combination of above-mentioned studies

The above projections, combined with the strategies of heavy vehicle manufacturers (trucks and buses), allow the team responsible for preparing this document to make **the hypothesis that the decarbonization of ground mobility on the landside is based on the following levers:**

- Light vehicles: massive electrification (and could have hydrogen fuel cell for ride hailing services and taxis);
- Buses and coaches: mixed electrification using batteries and hydrogen fuel cells, with an intermediate step using natural gas. Most of urban network buses will be electrified;
- Trucks: mostly natural gas and biofuels, with some battery and hydrogen fuel cell electrification.

4.1.1.1.2 Airside mobility energy mix

This section deals with airside mobility uses: GSE – Ground Service Equipment, passenger shuttles, freight vehicles and equipment.

This study is an initial approach and does not consider specific vehicles (fire trucks, sweepers and degreasers, winter maintenance equipment - snow removal, de-icing machines, etc.) because there are fewer of them than there are ground handling vehicles, and it is likely that specific maintenance vehicles for aeronautical areas will use biofuel instead.



To assess the energy mix, the study focused on determining the volume of different types of vehicles and the nature of the associated energy (diesel, electricity, hydrogen, biofuel, bio natural gas) by 2030, 2040 and 2050, by:

- Considering an increase in the number of vehicles to keep pace with traffic growth;
- Applying different decarbonisation vector assumptions according to the type of vehicle, based on information communicated or published by ground handlers and manufacturers.

The assumptions made are that the decarbonisation of ground handling vehicles is based on the following levers:

- Light vehicles + light GSE: electrification;
- Buses: a combination of battery electrification and hydrogen fuel cells, with a transition thanks to natural gas;
- Heavy-duty vehicles + heavy GSE: mainly use of hydrogen (fuel cell), with a transition thanks to biodiesel.

Proportion of vehicles / GSE by motorization type in 2018							Potential for greening by 2030 (proportion of vehicles / GSE)						Potential for greening by 2040 (proportion of vehicles / GSE)						Potential for greening by 2050 (proportion of vehicles / GSE)					
DIESEL	ELECTRIC	GAS	LPG	HYBRID	GAZOLINE	TOTAL	DIESEL	ELECTRIC	H2	BIOFUEL	NATURAL GAS	TOTAL	DIESEL	ELECTRIC	H2	BIOFUEL	NATURAL GAS	TOTAL	DIESEL	ELECTRIC	H2	BIOFUEL	NATURAL GAS	TOTAL
61%	25%	1%	4%	1%	8%	100%	3%	79%	3%	10%	5%	100%	0%	81%	6%	7%	6%	100%	0%	81%	9%	4%	6%	100%

Figure 8: Proportion of ground handling vehicles by type of energy used

Source : Groupe ADP

4.1.1.1.3 H2 quantities required for landside and airside ground mobility

Assumptions about the energy mix for ground mobility need to be combined with traffic assumptions and consumption projections by vehicle type to characterise hydrogen volume requirements.



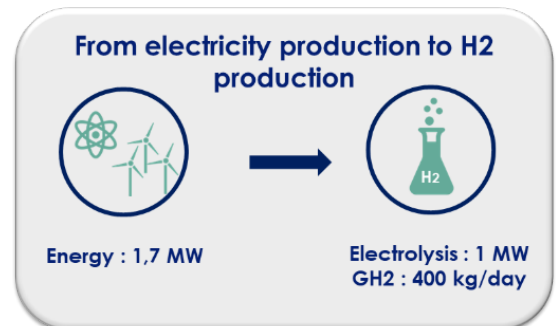
Usage	Consumption	Average level of use	Estimated daily consumption
Bus	9 kg H2 / 100 km	200 km / day	18 kg H2 / day
Heavy truck	9 à 12 kg H2 / 100 km	300 km / day	21 à 36 kg H2 / day
Refuse Collection Truck	10 kg H2 / 100 km	100 km / day	10 kg H2 / day
Light Duty Vehicle	1 à 1,5 kg H2 / 100 km	200 km / day	2 à 3 kg / day
Car	0,9 kg / 100 km	200 km / day	1,8 kg / day
Forklift			0,5 kg / day
Luggage tractor			5 kg / day
Luggage belt			15 kg / day
Freight loader			15 kg / day

Figure 9: Estimated H2 consumption by type of vehicle

Source : summary produced by Groupe ADP based on public literature on the subject

The estimated ramp-up for GH2 required for ground mobility (air side and land side) is:

- By 2025-2026: ~from 300 kg / day to 400 kg / day;
- By 2027 – 2028: up to 2 T / day;
- By 2030: up to 4 T / day;
- By 2035-2040: up to 8 – 10 T / day.



A 400 kg H2/day Refueling Station enables the refueling of :

10 buses + 15 heavy trucks

or

- 10 buses + 20 forklifts+ 10 light duty vehicles + 10 heavy trucks



4.1.1.2 Hydrogen required for hydrogen-powered aviation

4.1.1.2.1 Airbus-ZEROe aircraft project applied in CDG use case

The ZEROe project was launched in 2020 and when studies began within OLGA project, in 2021, Airbus was exploring the feasibility of three aircraft designs, powered by liquid hydrogen combustion propulsion systems: the Turboprop, the Turbofan, the Blended-Wing Body.

After investing in research into both hydrogen combustion and hydrogen fuel cell technology, Airbus determined in 2025 that fuel cells are the most promising option for a future hydrogen-powered aircraft. However, Airbus' research into the other concept resulted in valuable insight into hydrogen combustion systems, and Airbus does not rule out further investment into this technology in the future.

Source : [Hydrogen / Airbus](#)



Figure 10: Three ZEROe concepts, Airbus

Source : [Airbus' new zero-emission concept aircraft - H2GreenTECH](#) and <https://www.airbus.com/innovation/zero-emission/hydrogen/zeroe.html>

Within this study, market forecast takes into account the Turboprop and the Turbofan concepts.

It has to be highlighted here that in February 2025, Airbus announced that the entry into service of the ZEROe aircraft, initially planned for 2035, would be delayed. These delay assumptions came too late in the OLGA study cycle to be incorporated. Therefore, all sizing assumptions are based on the ZEROe aircraft being marketed from 2035 onwards.



Traffic projections for hydrogen-powered aircraft should enable two key parameters to be determined for the design of hydrogen facilities:

- LH2 daily volume to be distributed and stored;
- Maximum instantaneous LH2 flow.

The diagram below illustrates the process followed to estimate requirements at Paris-Charles de Gaulle Airport and a set of assumptions.

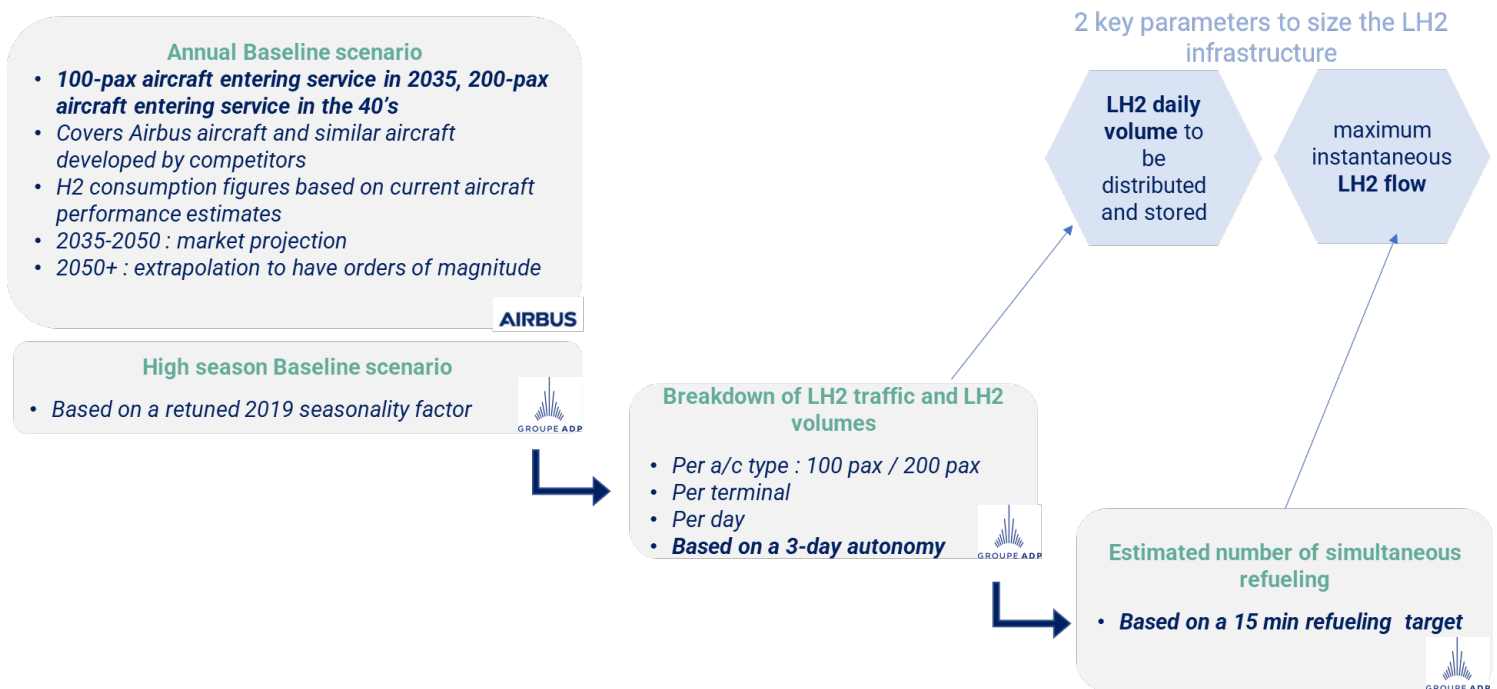


Figure 11: Process to estimate the LH2 daily volume and LH2 flow at CDG

Source: Groupe ADP

The traffic and liquid hydrogen consumption assumptions presented are based on two scenarios:

- The Average Day Scenario is the annual traffic baseline scenario averaged per day. It is based on Airbus's high annual market penetration scenario (launch of a 100-passenger module in 2035 and a 200-passenger module in 2038) (market data between 2035 and 2050 / linear extrapolation between 2050 and 2060);
- The Max Day scenario (summer or high season baseline scenario) is based on the average day adjusted by a standard traffic seasonality factor. Infrastructure sizing is based on this scenario.



The assumptions regarding hydrogen storage autonomy (3 days of autonomy) and flow rate (15-minute refuelling target) were defined by ADP based on current practices for comparable kerosene-powered aircraft. The aim of this study is to prepare an airport master plan able to preserve airlines and airport full performance, including in terms of turnaround time. **These assumptions are not binding on Airbus.**

LH2 volume required in CDG

From this set of assumptions, ADP, Airbus and AL have estimated the ramp up of ZEROe aviation and LH2 needed from 2035 to 2050+ at Paris-CDG:

- **2035 – 2040: ~from 30 T to 50 T of LH2 per day.** In this phase, 10% of short- and medium-haul flights are planned as H2 flights;
- **2040 – 2050: a few hundred T (~300 to 500 T) of LH2 per day** in the middle of the decade;
- **2050+: up to 700 T of LH2 per day.** More than 50% of short- and medium-haul flights departing from Paris could be powered by hydrogen.

As of 2035, the estimated LH2 volumes required, thanks to Airbus contribution, cover Airbus aircraft and similar aircraft developed by competitors. Thus, the graph below shows the ramp-up in liquid hydrogen requirements at Paris-CDG.

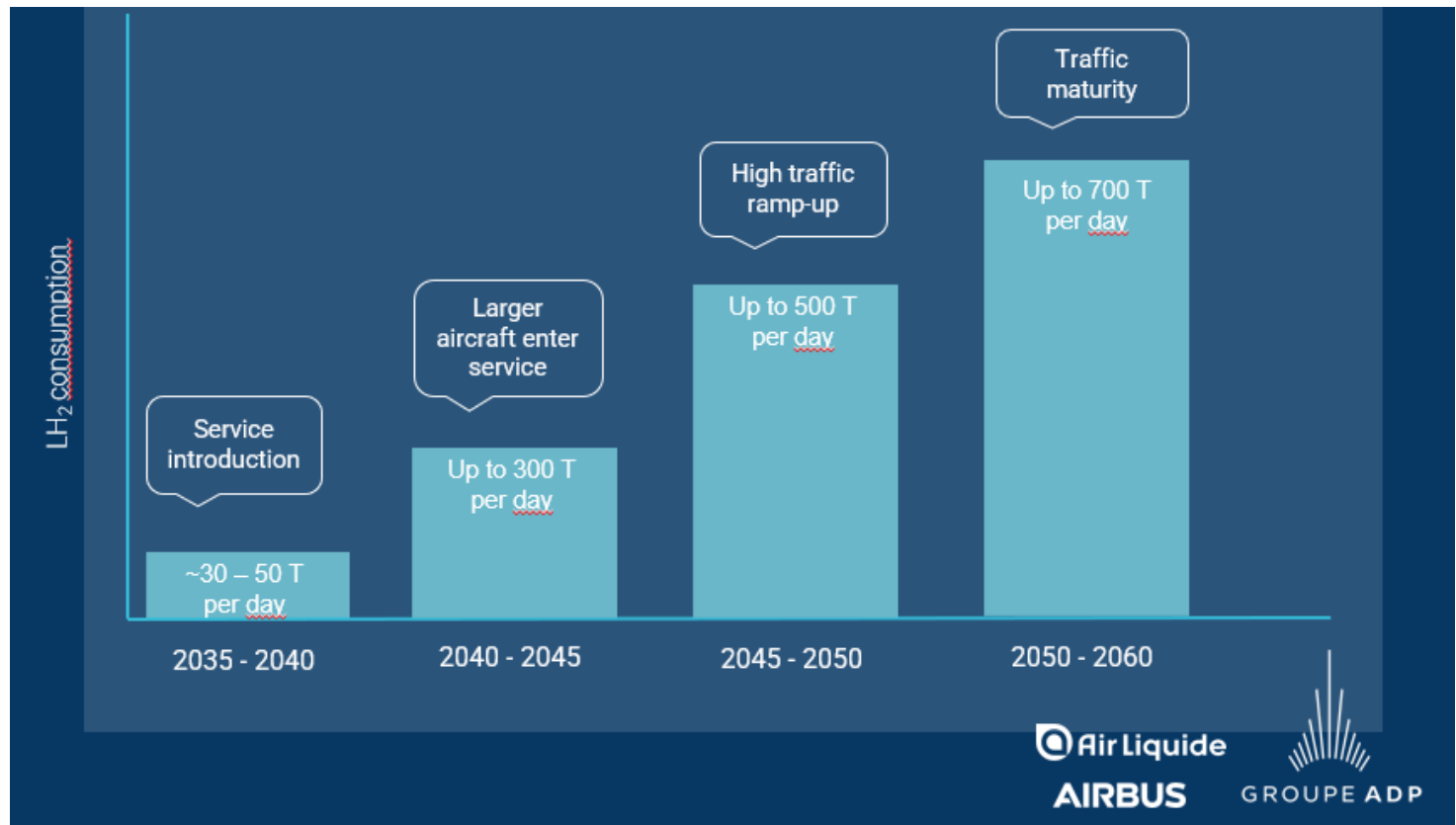


Figure 12: LH2 ramp-up at Paris-CDG
Source: Groupe ADP, Air Liquide, Airbus

To obtain a more detailed overview, ADP has broken down LH2 2050+ demand by terminal at Paris-CDG. This breakdown is based on traffic growth forecasts (number of flights, aircraft types, range of destinations served, etc.). This breakdown is also important to assess instantaneous LH2 flow rate by airside sector.

CDG Terminal distribution	Average day 2050+	Max day 2050+
Terminal 1	70 t/d	85 t/d
Terminal 2	440 t/d	535 t/d
Terminal 3	55 t/d	65 t/d
TOTAL	565 t/d	685 t/d

Table 1: LH2 daily demand per terminal starting from 2050
Source: ADP



Estimates of hydrogen consumption lead to an estimated **storage requirement of 2,100 tons in 2050+** based on a 3 days autonomy as defined in Figure 11: Process to estimate the LH2 daily volume and LH2 flow at CDG.

In 2050+, AL has estimated the electric power and energy needed in Paris-Charles De Gaulle and Paris-Orly, based on the LH2 need hypothesized.

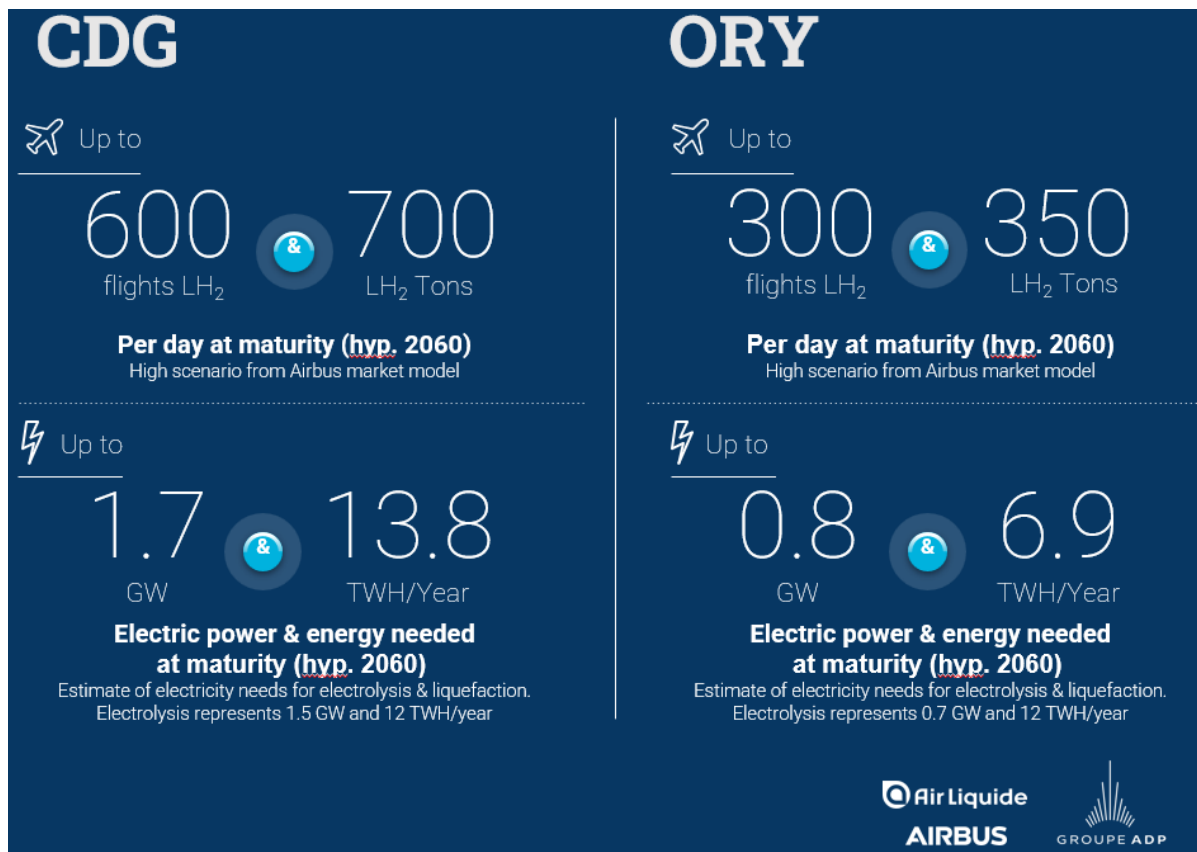


Figure 13: Electric power and energy needs for the LH2 daily volumes required at Paris-Charles de Gaulle and Paris-Orly by 2050+

Source: Groupe ADP, Air Liquide, Airbus

Maximum instantaneous LH2 flow in CDG

To determine the maximum instantaneous LH2 flow rate, ADP conducted a study to determine the number of aircraft refuelled simultaneously in CDG on a typical day. This number is estimated in 5-



minute increments based on the daily traffic sheet and assuming that LH2 refuelling is seamless compared to kerosene refuelling (same duration and same timing during aircraft turnaround time).

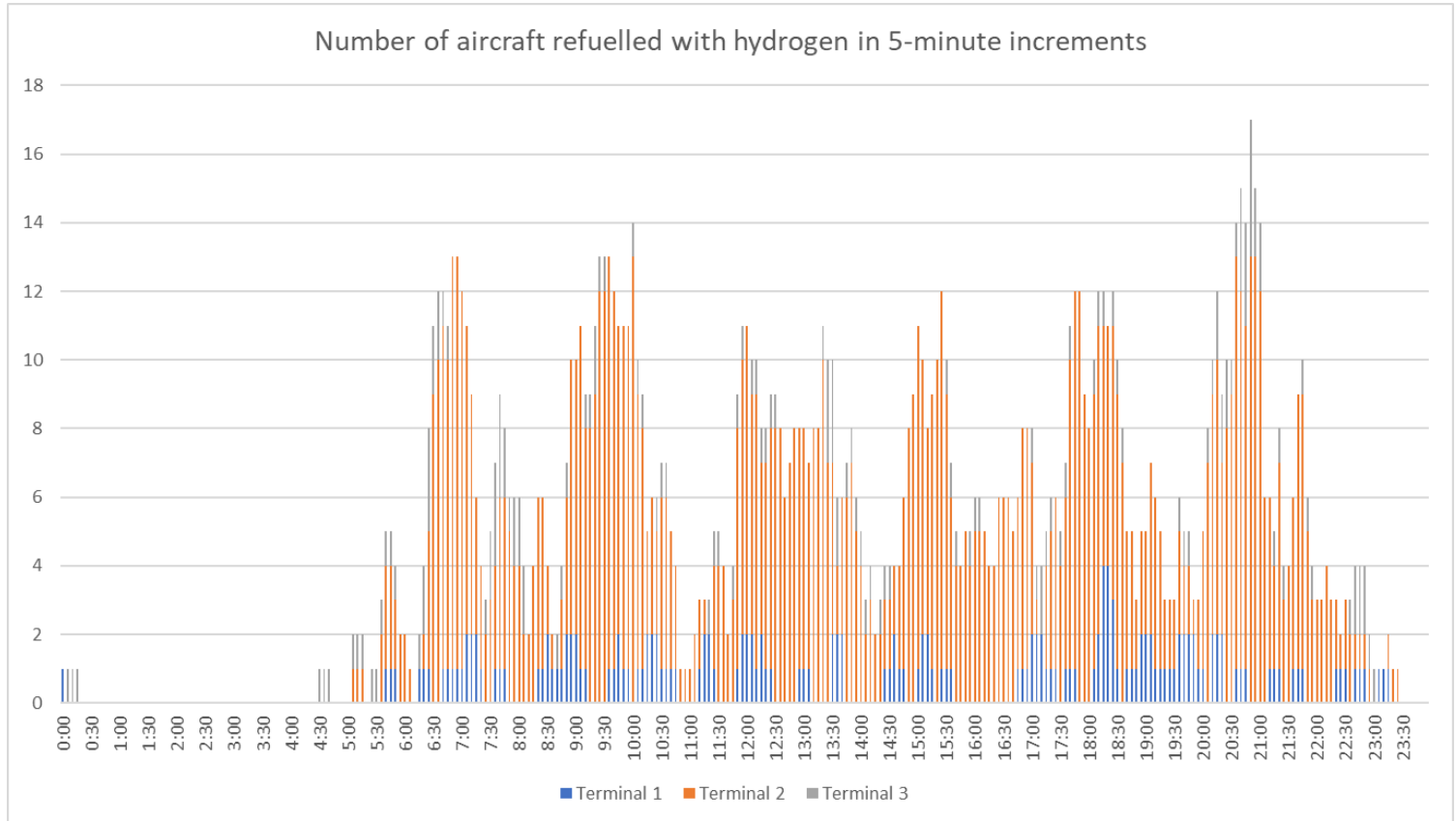


Figure 14: Number of aircraft refuelled with LH2 in CDG in 5-minute increments in 2050+

Source: Groupe ADP

4.1.1.2.2 H2 quantities required for hydrogen-powered aviation in Paris-CDG

Due to the limitations on range and passenger capacity of aircraft powered by hydrogen gas, it is estimated that hydrogen gas aviation will not develop at Paris-CDG. This type of aviation is more suited to regional airports or airports operating medical transport services.

It has to be highlighted here that, to decarbonize aviation, besides being used to power propulsion systems, hydrogen constitutes one of the elements required to produce eSAF (Synthetic Sustainable



Aviation Fuel or PtL, Power to Liquid). The requirements outlined below in Figure 15 do not consider the hydrogen requirements for the volumes of eSAF that will be distributed.

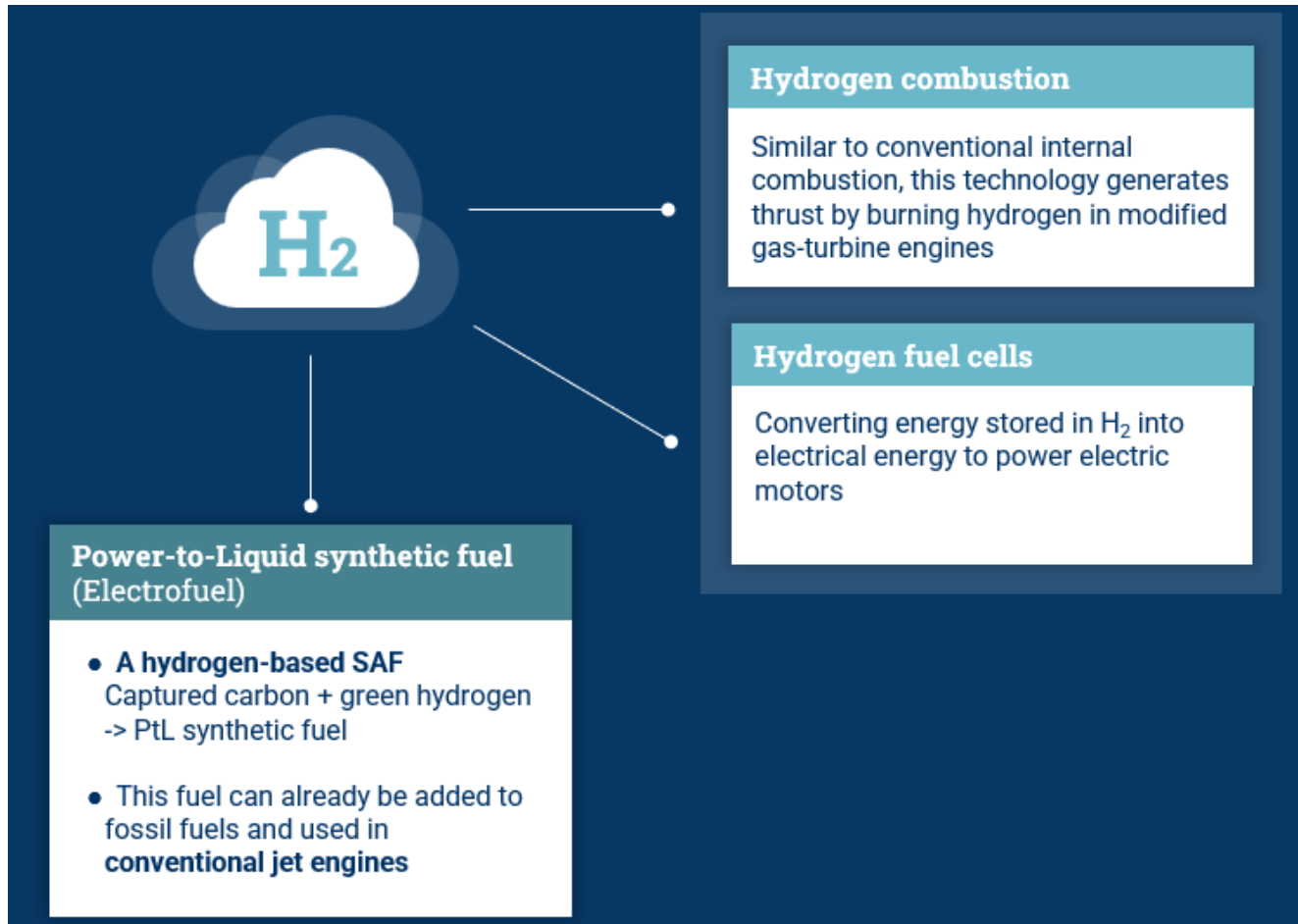


Figure 15: H₂, a lever to decarbonise Air Transport

Source: from Airbus picture

4.1.1.3 The ramp-up of hydrogen at Paris-CDG airport: the major timeframes

In summary, to cover the needs related to ground and aviation uses, three main phases of hydrogen ramp-up at Paris-CDG are identified:

- The emergence phase (from 2025):
 - To meet the initial needs of ground operations and mobility (heavy goods vehicles, light commercial vehicles, buses, ground handling vehicles, GPUs, aircraft loading platforms, wide-body aircraft tow trucks, baggage carts, etc.);



- To serve the first hydrogen-powered aircraft for general and regional aviation (from 2028);
 - o The deployment phase (from 2035 until 2040):
- To support the increasing expansion of ground use and general and regional aviation;
- To meet the initial needs of short/medium-haul aircraft powered by liquid hydrogen (cryogenic, maintained at a temperature of around -253°C);
 - o The consolidation phase (between 2040 and 2060), when hydrogen-powered short/medium-haul aircraft reach maturity.

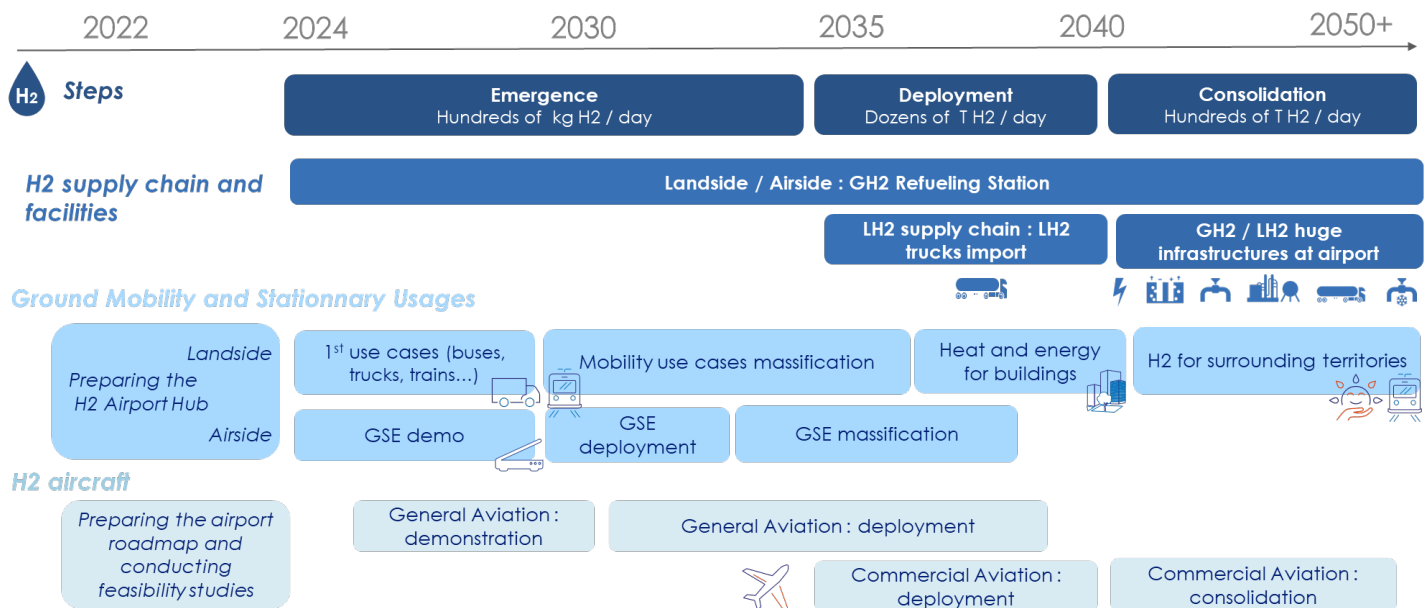


Figure 16 : Hydrogen ramp-up at Paris-CDG Airport

Source: Groupe ADP - Hydrogen: roadmap for Paris airports

4.1.2 Mapping of traffic growth and other hydrogen-powered aircraft projects in Europe

4.1.2.1 Traffic growth in Europe

Traffic growth is based on data from Eurocontrol⁴, which produces traffic forecast studies by major European region. Two main Eurocontrol traffic scenarios will be considered for this study:

⁴ Eurocontrol is a pan-European, civil-military organisation dedicated to supporting European aviation



- a high scenario, characterized by strong economic growth in a globalized world, with intense investment in technology supporting sustainable aviation growth;
- a baseline scenario, as the one which is the most likely to occur, with moderate economic growth, with regulation reflecting environmental, social, and economic concerns to address aviation sustainability. It follows current trends.

ECAC	IFR flights						
	2019		2050			2050/2019	
	Total (million)	Avg. daily (thousands)	Total (million)	Avg. daily (thousands)	Extra flights/day (thousands)	Total growth	AAGR
High scenario	11.1	30.4	19.6	53.6	23.2	+76%	+1.8%
Base scenario			16.0	43.7	13.4	+44%	+1.2%
Low scenario			13.2	36.2	5.8	+19%	+0.6%

Figure 17 : Estimated annual IFR (Instrument Flight Rules) flights in 2050 (high, base, low scenario)

Source: Eurocontrol

4.1.2.2 Mapping of other hydrogen powered aircraft projects

Although in Europe, Airbus and its ZEROe aircraft project (100% hydrogen-powered aircraft) is the most promising way to lay the foundations for large-scale hydrogen aviation, it is interesting to take a broader perspective by also looking at business and general aviation. In fact, several manufacturers are working on projects that are expected to enter service before 2035, i.e. before the Airbus aircraft goes on sale.

Manufacturers' roadmaps make eclectic use of different energy vectors to decarbonize aviation. Some manufacturers are relying on the use of hydrogen for hybrid or hydrogen-powered aviation:

- **Hybrids**, with aircraft using electric power and sustainable fuels developed by VoltAero.



VoltAero Cassio 330, Cassio 480 & Cassio 600 - Electric-hybrid and Hydrogen-hybrid engine - Passengers: 4/5 seats for Cassio 330, 6 seats for Cassio 480 and 10/12 seats for Cassio 600 - Range: 200 to 1 200 km

- **Hydrogen**, thanks in particular to the conversion and retrofit of regional aircraft, with technologies developed by Universal Hydrogen, ZeroAvia and Beyond Aero.

Universal Hydrogen*	ZeroAvia	Beyond Aero's One BYA-1
- Hydrogen engine - Passengers : 56 seats - Range: 1 000 km - Certification horizon: 2025	- Hydrogen engine - Passengers: 90 seats - Range: 1 900 km - Certification horizon: 2027	- Hydrogen engine - Passengers: 4 to 8 seats - Cruise speed: 575 km/h - Range: 1 500 km - Certification horizon: by 2029
*Cessation of business in 2024		

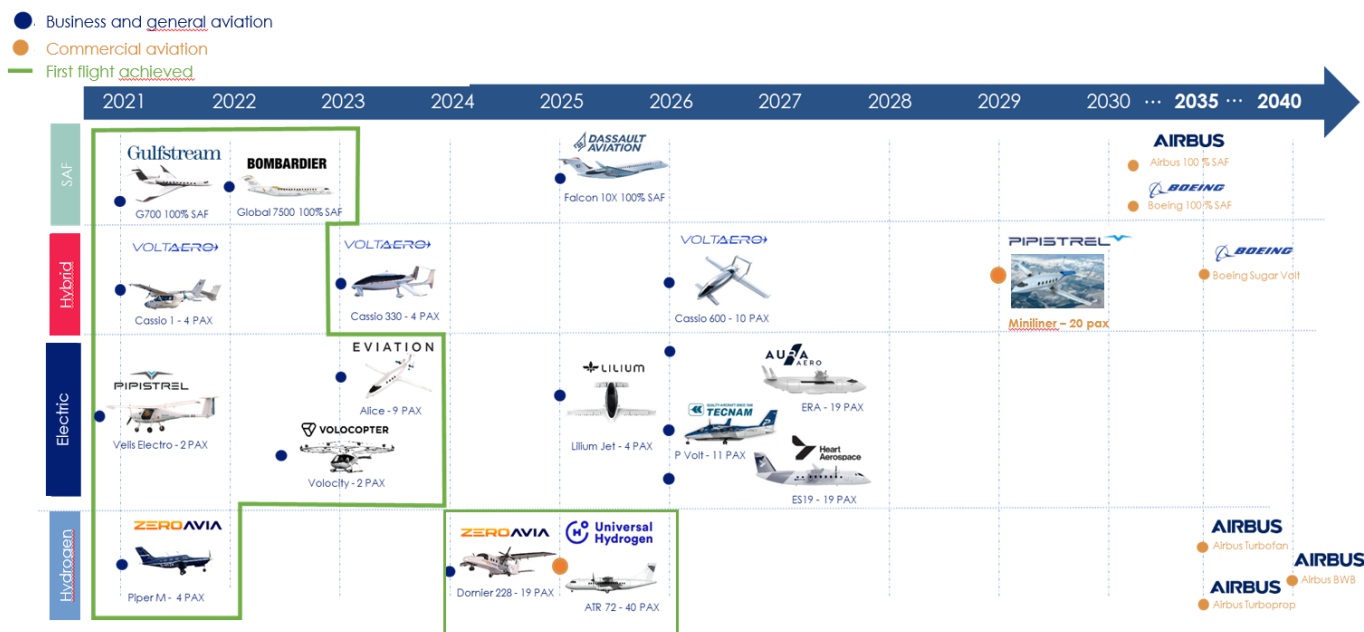


Figure 18: Roadmap for manufacturers in business and general aviation (established in 2023)

Source: Groupe ADP from public data

4.1.2.3 Mapping of LH2 aircraft market in Europe

The actual public studies are commonly based on a single aisle (narrow body) aircraft with an average of 150 passengers' capacity, for the horizon 2050:



-
- According to Destination 2050 Roadmap⁵ (2021), the total energy demand for hydrogen powered aviation in Europe (flights inside Europe below 2000 kilometers) is estimated to be 3,7 Mt of LH2 in 2050;
 - Waypoint 2050 report from IATA and Hydrogen-powered aviation study, commissioned in 2020 by Clean Sky 2 and Fuel Cells & Hydrogen 2 Joint Undertakings, merge on the "efficient decarbonization scenario" forecasting the worldwide demand of LH2 in 2050 as an average of **40 MtH2/year**. This scenario assumes that all new deliveries of 100-200 seat aircraft in 2042 and in subsequent years are from hydrogen powered aircraft. This represents about 20 % of the global aviation energy demand in 2050. Clean Sky 2 projects therefore an estimation of 1500 kg of LH2 per flight. The other scenario in Hydrogen-powered aviation, called "maximum decarbonization scenario" estimates the demand of LH2 in 2050 up to **135 MtH2/year**. In this scenario, all aircraft for ranges of up to 10,000 kilometers would start to be replaced by hydrogen aircraft after 2028-2038. However, these assumptions do not seem realistic considering the technological roadmaps;
 - The ICAO LTAG-TG (Long Term Global Aspirational Goal-Technical Goals) give an estimation of the LH2 aircraft penetration for the narrow-body aircraft following an efficient decarbonization scenario and a maximum decarbonization scenario.

These reports set out assumptions for estimating the share of hydrogen-powered medium-haul aircraft by 2050 and the average fuel consumption of a hydrogen-powered aircraft.

⁵ The DESTINATION 2050 roadmap developed by Royal Netherlands Aerospace Centre (NLR) and SEO Amsterdam Economics and commissioned by A4E, ACI EUROPE, ASD, CANSO Europe and ERA shows an ambitious decarbonisation pathway for European aviation.

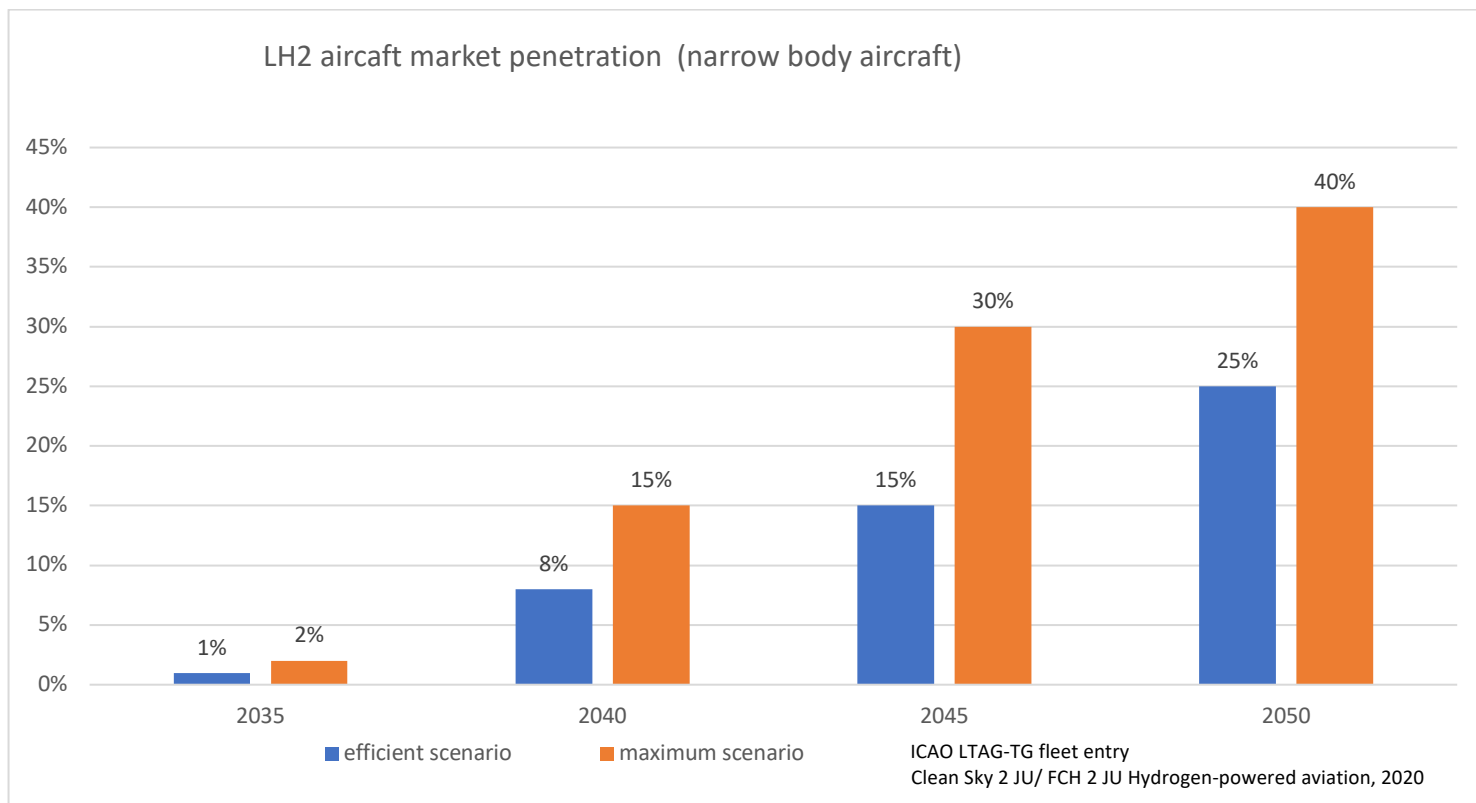


Figure 19 : LH2 aircraft market penetration (narrow body aircraft) in Europe by 2050

Source: Groupe ADP based on ICAO LTAG-TG and Clean Sky 2 JU/ FCH 2 JU Hydrogen-powered aviation, 2020

4.1.3 Focus on aviation LH2 requirements for OLGA fellow airports

This paragraph deals with the estimation of hydrogen for aviation at the OLGA fellow airports: Milan Malpensa Airport (Italy), Cluj-Napoca Airport (Romania), Zagreb Franjo-Tuđman Airport (Croatia).

To assess future hydrogen volumes required, the first step is to estimate the air traffic (aircraft movements). As the airports of Paris Charles de Gaulle, Milan Malpensa, Zagreb and Cluj are very unequal in terms of aircraft movements, hydrogen requirements will be different, and the most adapted hydrogen supply chain may not be the same either.

Air traffic forecast

Air traffic forecast is estimated from projected air traffic growth rates relative to the traffic data analyzed.

With reference to Millan Malpensa Airport data analyzed, it must be highlighted that:

- in 2019 a record growth was recorded in traffic compared to the previous years. This increase was largely driven by the so called “Bridge Operation” during which, from Jul 27th until October 27th, Linate was closed for renovation works: this resulted in significant flight relocations from Linate to Malpensa;
- in 2023, Milan Malpensa Airport consolidated its post-pandemic recovery, marking the return of traffic volumes to pre-pandemic levels.

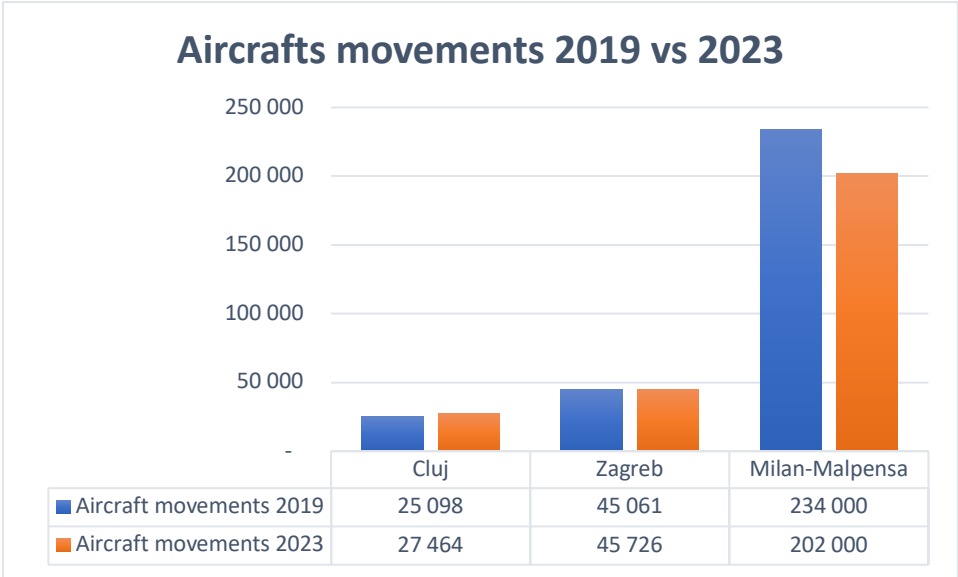


Figure 20 : OLGA fellow airports - aircraft movements 2019 vs 2023
Source: Groupe ADP based on data provided by OLGA fellow airports

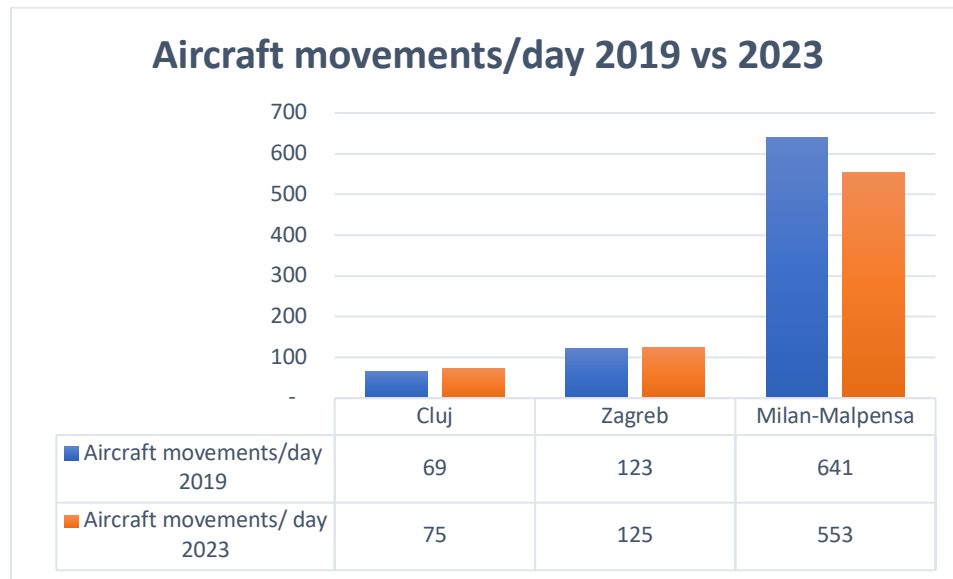


Figure 21 : OLGA fellow airports – daily aircraft movements 2019 vs 2023

Source: Groupe ADP based on data provided by OLGA fellow airports

LH2-powered aircraft ramp-up at OLGA fellow airports

Combining the previous set of air traffic data with the hypotheses and forecast of the aircraft market penetration percentage in figure 19 (section 4.1.2.3) allows the estimation of the hydrogen-powered aircraft traffic and associated hydrogen volumes required at OLGA fellow airports:

- Milan Malpensa (Italy) represents significant potential for the development of liquid hydrogen aircraft. With almost $\frac{3}{4}$ of narrow body flights, this represents between 60,000 to 120,000 LH2 flights per year by 2050. Daily demand is estimated between 200 and 400 tons of LH2 per day by 2050;
- Cluj-Napoca (Romania) has a potential for hydrogen aviation thanks to its regional airport profile. Indeed 100% of its commercial flights are operated by narrow-body aircraft. Daily demand is estimated to be between 30 and 60 tons of LH2 per day by 2050;
- Zagreb Franjo-Tudman (Croatia) has an important potential for hydrogen aviation deployment because of the 95% market-share of narrow body aircraft. Daily demand is estimated to be between 50 and 100 tons of LH2 per day by 2050.

The tables below provide an estimation of the LH2 needs in the 3 different airports for the years 2035, 2040, 2045 and 2050, calculated on the aircraft market penetration percentage in Figure 19



(section 4.1.2.3) based on the study carried out in 2020 by ADP on ICAO LTAG-TG and Clean Sky 2 JU/ FCH 2 JU Hydrogen-powered aviation. The results vary in terms of daily LH2 aircraft movements and consequent daily LH2 needs.



Horizon 2035		AAGR 2023-2029	Total Growth 2023-2029	Aircraft Movements OLGA Airports 2019	Aircraft Movements OLGA Airports 2023	Estimated Aircraft Movements OLGA Airports 2029	Estimated aircraft movement horizon 2035	Parts of narrow bodies aircraft flights	LH2 aircraft market penetration (narrow bodies aircrafts) 2035	Estimated annual LH2 aircraft movement horizon 2035	Estimated daily LH2 aircraft movement horizon 2035	Average daily LH2 demand (1,2 t/ flight)
Italy- Milan Malpensa	High	5,2%	26,3%	234 000	202 000	255 031	292 367	73%	2%	4 286	12	14
	Base	3,4%	13,7%			229 620	255 177		1%	1 870	5	6
Croatia- Zagreb Franjo- Tuđman	High	5,4%	27,0%	45 061	45 726	58 089	63 141	95%	2%	1 200	3	4
	Base	3,8%	16,1%			53 070	55 884		1%	531	1	2
Romania- Cluj- Napoca	High	5,7%	31,2%	25 098	27 464	36 023	37 964	100%	2%	759	2	2
	Base	4,1%	19,8%			32 911	33 680		1%	337	1	1

Figure 22 : Estimated hydrogen needs at airports - Horizon 2035

Source: ADP

Horizon 2040		AAGR 2023-2029	Total Growth 2023-2029	Aircraft Movements OLGA Airports 2019	Aircraft Movements OLGA Airports 2023	Estimated Aircraft Movements OLGA Airports 2029	Estimated aircraft movement horizon 2040	Parts of narrow bodies aircraft flights	LH2 aircraft market penetration (narrow bodies aircrafts) 2040	Estimated annual LH2 aircraft movement horizon 2040	Estimated daily LH2 aircraft movement horizon 2040	Average daily LH2 demand (1,2 t/ flight)
Italy- Milan Malpensa	High	5,2%	26,3%	234 000	202 000	255 031	329 702	73%	15%	36 251	99	119
	Base	3,4%	13,7%			229 620	280 734		8%	16 462	45	54
Croatia- Zagreb Franjo- Tuđman	High	5,4%	27,0%	45 061	45 726	58 089	68 193	95%	15%	9 717	27	32
	Base	3,8%	16,1%			53 070	58 697		8%	4 461	12	15
Romania- Cluj- Napoca	High	5,7%	31,2%	25 098	27 464	36 023	39 904	100%	15%	5 986	16	20
	Base	4,1%	19,8%			32 911	34 449		8%	2 756	8	9

Figure 23 : Estimated hydrogen needs at airports - Horizon 2040

Source: Groupe ADP



Horizon 2045		AAGR 2023-2029	Total Growth 2023-2029	Aircraft Movements OLGA Airports 2019	Aircraft Movements OLGA Airports 2023	Estimated Aircraft Movements OLGA Airports 2029	Estimated aircraft movement horizon 2045	Parts of narrow bodies aircraft flights	LH2 aircraft market penetration (narrow bodies aircrafts) 2045	Estimated annual LH2 aircraft movement horizon 2045	Estimated daily LH2 aircraft movement horizon 2045	Average daily LH2 demand (1,2 t/ flight)
Italy- Milan Malpensa	High	5,2%	26,3%	234 000	202 000	255 031	367 038	73%	30%	80 712	221	265
	Base	3,4%	13,7%			229 620	306 291		15%	33 677	92	111
Croatia- Zagreb Franjo- Tudman	High	5,4%	27,0%	45 061	45 726	58 089	73 245	95%	30%	20 875	57	69
	Base	3,8%	16,1%			53 070	61 511		15%	8 765	24	29
Romania- Cluj- Napoca	High	5,7%	31,2%	25 098	27 464	36 023	41 844	100%	30%	12 553	34	41
	Base	4,1%	19,8%			32 911	35 218		15%	5 283	14	17

Figure 24 : Estimated hydrogen needs at airports - Horizon 2045

Source: Groupe ADP

Horizon 2050		AAGR 2023-2029	Total Growth 2023-2029	Aircraft Movements OLGA Airports 2019	Aircraft Movements OLGA Airports 2023	Estimated Aircraft Movements OLGA Airports 2029	Estimated aircraft movement horizon 2050	Parts of narrow bodies aircraft flights	LH2 aircraft market penetration (narrow bodies aircrafts) 2050	Estimated annual LH2 aircraft movement horizon 2050	Estimated daily LH2 aircraft movement horizon 2050	Average daily LH2 demand (1,2 t/ flight)
Italy- Milan Malpensa	High	5,2%	26,3%	234 000	202 000	255 031	411 840	73%	40%	120 751	331	397
	Base	3,4%	13,7%			229 620	336 960		25%	61 748	169	203
Croatia- Zagreb Franjo- Tudman	High	5,4%	27,0%	45 061	45 726	58 089	79 307	95%	40%	30 137	83	99
	Base	3,8%	16,1%			53 070	64 888		25%	15 411	42	51
Romania- Cluj- Napoca	High	5,7%	31,2%	25 098	27 464	36 023	44 172	100%	40%	17 669	48	58
	Base	4,1%	19,8%			32 911	36 141		25%	9 035	25	30

Figure 25 : Estimated hydrogen needs at airports - Horizon 2050

Source: Groupe ADP



4.2 Hydrogen facilities for ground mobility

Section 4.2 leverages on the H2 needs derived from the traffic study in section 4.1.

It defines the supply chain in CDG for H2 ground mobility and hypothesizes the space allocation together with the land side and air side facilities connected to it.

4.2.1 Supply chain for ground mobility

Two types of supply chains can be organised, depending on the size of the stations and their capacity to be supplied with hydrogen:

- Scheme 1: The station is moderate in size (< 2 tons/day) and can be supplied with hydrogen from off-site production. Thus, GH2 can be imported to the airport by tube trailers. At the airport, a combined "refueling station" delivers equipment for the compression, storage, and distribution of GH2.
- Scheme 2: The station is significant in size (> 2 tons/day) and can be supplied with hydrogen from on-site production (economically viable). GH2 can be on site produced through electrolysis. A storage facility is required upstream the combined "refueling station".



Figure 26 : Supply chains for GH2 for ground mobility

Source: Groupe ADP



To choose the most appropriate hydrogen supply chain, both the H2 quantities and the supply capacity must be considered.

4.2.2 Facilities for landside mobility

The traffic study showed that hydrogen is used for landside mobility in the following ways:

- GH2 for light vehicles used by private ride hailing and taxi services;
- GH2 for trucks used for transporting goods.

Hydrogen facilities for ride hailing services and taxis

In Paris, the decarbonization of taxis involves the use of gaseous hydrogen since 2019.

A 350 and 700 bars GH2 H2 refueling station is operated at Paris-CDG.

The H2 refueling station for taxis is around 2,000 m² and is in the immediate vicinity of the taxi rank.



Figure 27 : H2 refuelling station for taxis at Paris-CDG Airport

Source: Google Earth

Hydrogen facilities for trucks



GH2 refueling stations for trucks should preferably be installed in the airport area where the largest flows of goods are concentrated. At Paris-CDG, this is the freight area. Ideally, the station should be easily accessible from the main road network and, if possible, from the public road network nearing the airport. Depending on the congestion of its private road network, the airport manager may decide, in consultation with the station operator, to grant public access to the station, including for hydrogen-powered heavy goods vehicles not operating directly at the airport.

Based on the rate of growth in demand, the following installations at Paris-CDG are hypothesized:

- By 2030: a H2 distribution station to ensure efficient fueling of heavy goods vehicles in the freight area, as they will be the first users of hydrogen;
- By 2040: a second H2 station will be needed to supply heavy goods vehicles (including buses and coaches). It will need to be positioned at the heart of the hub (to spread the supply) and be easily accessible from and to the business park.

To optimize the land allocated to the hydrogen refueling station, it is recommended that:

- H2 refueling stations be mixed with other energy vectors (such as gas or electricity). Distributing several types of energy in such a way as to be resilient in the event of different market penetration of one of these energy vectors.
- H2 refueling stations are dual-status landside/airside stations.

A mixed H2/ natural gas (or electric) and dual-status refueling station requires a land area of around 7,000 m²-8,000 m². If the H2/ natural gas stations are to be specific to the landside, **a land reservation of 5,000 m² per station is required.**

4.2.3 Facilities for airside mobility

The traffic study showed that hydrogen can be used for airside mobility for some ground handling vehicles as GPUs, aircraft loading platforms, wide-body aircraft tow trucks, baggage carts.

Given the rate of growth in demand, the following requirements are estimated:

- By 2030: a H2 distribution station offering 2 pits, as well as a mobile distribution capacity (bundle);
- By 2040: a second H2 distribution station offering 2 spots, as well as mobile distribution capacity (bundle).

Ideally, the station should be located near ground handling vehicles parks.



To optimize the land allocated to the hydrogen refueling station, it is recommended that:

- H2 refueling stations be mixed with other energy vectors (such as gas or electricity). Distributing several types of energy in such a way as to be resilient in the event of different market penetration of one of these energy vectors.
- H2 refueling stations are dual-status landside/airside stations.

A mixed H2/ natural gas (or electric) and dual-status refueling station requires a land area of around 7,000 m²-8,000 m². If the H2/ natural gas stations are to be specific to the airside, **a land reservation of 4,000 m² per station is required.**

To supply ground support equipment that could not be refilled at the GH2 refueling station (ex: limited access to very heavy equipment such as towing vehicles or push-back vehicles), it is recommended to equip the station with mobile refueling facility. Thus, GH2 can be supplied to the vehicle park from the refueling station through "bundles".

4.2.4 Focus on the project of GH2/Natural Gas refueling station in the freight area of Paris-CDG

As mentioned in paragraph 4.2.2, a GH2 refuelling station has been planned in the freight area of Paris-CDG to serve trucks. To optimise the land required, this station is planned to be a multi-energy refuelling station located on the landside / airside border. Thus, this station will also be able to refill airside vehicles and ground service equipment.

The feasibility study for the implementation of this station has been entrusted to Engie Solutions and is the subject of WP 3.3 of the OLGA project. The feasibility study is documented in the deliverable D3.3 Feasibility study for the multi-energy station airside.

Covering an **area of approximately 9,000 m²**, this station plans to ramp up the volumes of Natural Gas and GH2 distributed.

For GH2 the phases considered are:

- Phase 1: Refuelling capacity: 5 T/day (~200 trucks)
- Phase 2: On-site production capacity: 2 T/day, 5 MW + Refueling capacity: 5 T/day
- Phase 3: On-site production capacity: 4 T/day, 10 MW + Refueling capacity: 5 T/day



Figure 28 : GH2 and Natural Gas refuelling station in the freight area of Paris-CDG Airport – Feasibility study
Source: Engie Solutions

4.3 Hydrogen facilities and infrastructures for aviation

Section 4.3 leverages on the LH2 needs derived from the traffic study in section 4.1. The deployment and the consolidation phases considered in this section correspond to CDG deployment and consolidation phases, i.e. the ones starting, respectively, in 2035 and between 2050 and 2060, as defined in Figure 16 in section 4.1.1.3 “The ramp-up of hydrogen at Paris-CDG airport: the major timeframes”.

The supply chain for H2 and LH2 aviation at a generic European airport are defined, together with the H2 facilities and infrastructures required for LH2 deployment phase at a generic European airport and in Paris-CDG.

4.3.1 Supply chain for aviation

The supply of hydrogen to airports presents unique challenges and opportunities compared with the supply of kerosene fuel.

4.3.1.1 For general and regional aviation using gaseous hydrogen

The ramp-up of compressed hydrogen gas aircraft will be supported by logistics chains requiring modest airport infrastructure.



Several airport supply chains are possible:

- End-to-end truck logistics chain: aircraft refueling by tanker trucks supplied from factories located outside the airports;
- Fixed hydrogen refueling stations – refilled by tube trailers or backed by on-site production – on dedicated aircraft refueling areas. This model seems suitable for general aviation, but less so for regional commercial aviation, where optimizing turnaround time is an important criterion for profitability.

For general and regional aviation using gaseous hydrogen, the supply chain is similar to the one described for ground mobility.

4.3.1.2 For regional and short/medium-haul aviation powered by liquid hydrogen

For European airports, four LH2 supply chain models are suitable for transporting and storing hydrogen at airports:

Scheme 1: LH2 imported by trucks from external plants outside the airport

LH2, produced at remote plants, is transported to the airport by transport trucks (tractors + tanks). These LH2 tanks are then stored at one or more locations at the airport. Airport tractors, adapted to the traffic constraints of the airport area and the specific requirements of refueling, are used to tow the tank for the aircraft refueling.

This scheme:

- avoids fixed intermediate storage of LH2 and intermediate transfers, which are significant sources of inefficiency in LH2 handling;
- is flexible and does not require significant space or major investment at the airport;
- is suitable for small/medium-sized airports or during the deployment phase of LH2 flights. The limiting factor is then the large number of lorries required, resulting in high transport/logistics costs and potential traffic congestion in the vicinity and at airports.

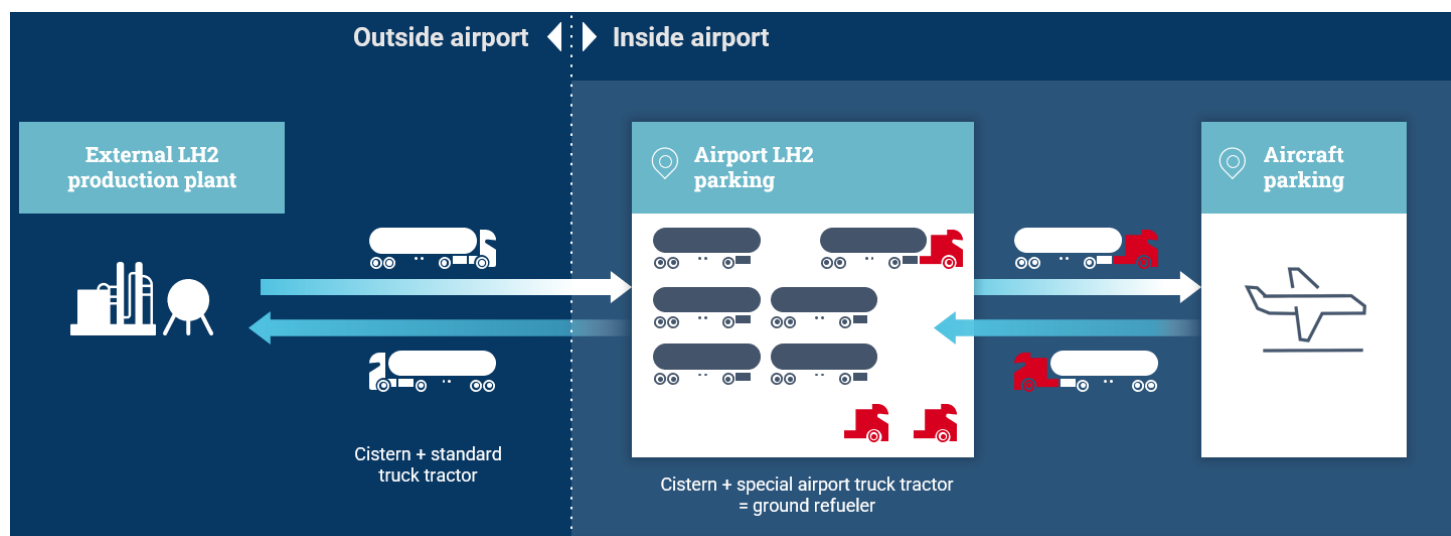


Figure 29 : End-to-end truck supply chain to refill aircraft

Source: Groupe ADP and Air Liquide

Consequently, when LH2 requirements increase, other supply chains can be considered.

Scheme 2: GH2 imported by pipelines to the airport

The gaseous hydrogen is produced outside the airport and transported by pipeline to the airport before being liquefied and stored at the airport. The LH2 is finally distributed to the aircraft.

Scheme 3: Import of low-carbon electricity and water to the airport and production of hydrogen at the airport

Hydrogen is produced by water electrolysis at the airport, then liquefied and stored at the airport, before being distributed to the aircraft.

Scheme 4: Import of LH2 by ship to the airport

The hydrogen is produced off the airport site, then shipped to the airport in liquid form. This option applies only to coastal or river airports.

Schemes 2 and 3 appear to be complementary:



-
- The scheme 3 certainly requires the transmission of large amounts of electricity to airports, but in return it secures part of the on-site production and eliminates the need for a GH2 transport network.
 - The scheme 2 could be adopted at a later stage, to limit the impact on land and the need for on-site electrical power. This option is subject to the deployment of a GH2 transport network in the area.

In schemes 2, 3 and 4, two ways of distributing liquid hydrogen to aircraft are possible according to the LH2 needs hypothesized in this deliverable:

- when the volume of LH2 remains limited, refueling by truck (tractor + tanker);
- when the volume increases (several hundred tons per day), distribution through an LH2 pipeline system. The LH2 would be put on board (connection between the hydrogen pipeline and the aircraft tank) by “hydrogen tanker” vehicles.

The definition of the distribution method is specific to each airport. Truck refueling is operationally possible up to a certain truck flow. The LH2 pipeline system may be economically viable below a certain pipe length and above a certain volume of LH2 to be distributed.

The illustration below (Figure 30) shows the three most plausible scenarios for regional and short/medium-haul aviation powered by liquid hydrogen.

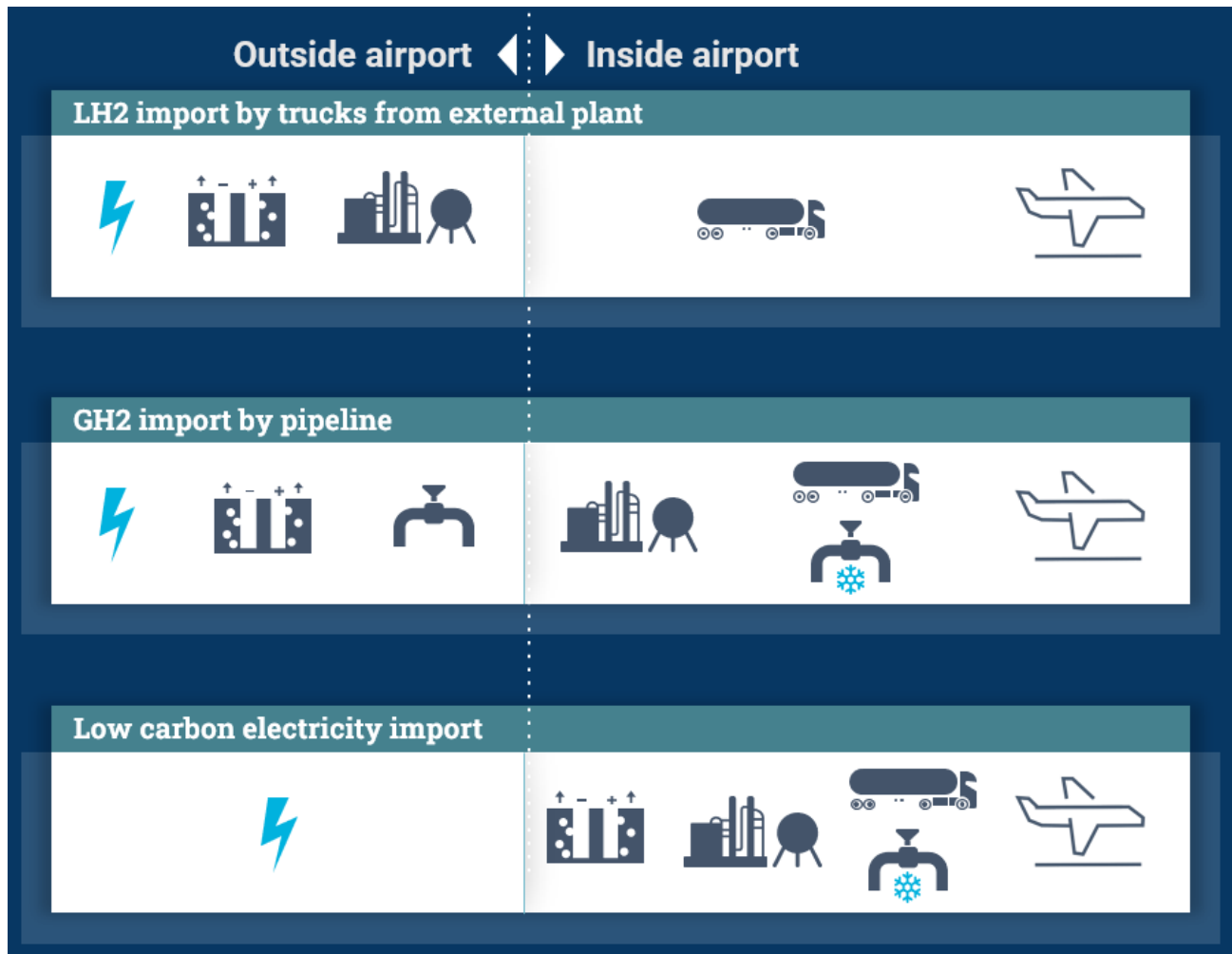


Figure 30 : Hydrogen supply chains for LH2 aviation

Source: Groupe ADP and Air Liquide

Other logistics models remain possible, but large-scale deployment is less likely for air transport:

- Other methods of hydrogen production besides electrolysis at the airport can also be explored, but more likely as a supplement than as the primary source of production.
- Transporting hydrogen in the form of ammonia or methanol is also a possible option.

4.3.2 H2 facilities and infrastructures required for LH2 aviation deployment phase (LH2 volumes required by aircraft up to ~30 T /day to 50 T / day)



A hydrogen truck supply chain is planned for requirements inferior to 30-50 tons LH₂/day (see Figure 29: End-to-end truck supply chain to refill aircraft).



Figure 31 : Hydrogen refueling through a hydrogen truck

Source: Airbus

The space required to organize this hydrogen supply chain was sized on the following assumptions:

- a LH₂ truck cistern has a capacity of 4T of LH₂. Thus up to 25 cisterns (considering a 3 days of storage as hypothesized for the Paris-CDG use case – see figure 11 “*Process to estimate the LH₂ daily volume and LH₂ flow at CDG*”) are stored every day;
- the flow rate study, developed for the CDG use case in section 4.1.1.2.1 “*Airbus-ZEROe aircraft project applied in CDG use case*” has shown that there could be up to 5 simultaneous refuelings. Thus 6 (considering a margin) of special airport truck tractor are required.

To enable the organization of the hydrogen supply chain by truck, a **1-hectare plot of land** (in one of more areas) must be reserved for the storage of liquid hydrogen cisterns and the parking of special airport truck tractor. The plot must be located in the airside (controlled access zone for air transport), close to a safety checkpoint (if possible, as close as possible to the future airport hydrogen plant) and at a sufficient distance from a public building.



The location of these areas will have to be the subject of a safety study, given the hydrogen storage involved.

At airports where hydrogen volumes are set to increase beyond this 30 – 50 T/day threshold, and where on-site liquefaction and storage infrastructures are planned, the land required for these cisterns and trucks is not necessarily destined to disappear. Indeed, these areas could then be used:

- for hydrogen distribution trucks between the airport storage plant and the aircraft, for airports not equipped with a hydrogen hydrant network;
- to ensure a "mix-mode" for hydrogen distribution at airports ultimately equipped with a hydrogen hydrant network, i.e. to ensure truck refueling of aircraft some stands not yet equipped with this hydrogen hydrant network;
- to ensure robustness in the event of malfunction and/or maintenance of the hydrogen hydrant network, at airports ultimately equipped with a hydrant network.

4.3.3 H2 facilities and infrastructures required for LH2 aviation consolidation phase (LH2 volumes required by aircraft above ~30 T /day to 50 T / day)

The facilities installed at the airport for requirements above of 30-50 tonsLH2/day are:

- hydrogen production (electrical transformers, H2 production systems such as electrolysis)- optionally, depending on the strategy defined by the airport - to satisfy all or part of the LH2 requirements;
- hydrogen liquefaction - to satisfy daily requirements, including peak demand;
- storage of liquid hydrogen - to cover peak demand and for a period that depends on each airport's strategy (3 days hypothesized for the Paris-CDG use case – see figure 11 “Process to estimate the LH2 daily volume and LH2 flow at CDG”);
- loading bays for cisterns and airport trucks to refuel aircraft (in nominal mode for airports with a truck-based distribution system, in mixed or degraded mode for airports with a distribution network).

The graphs below illustrate the proportion of these different functionalities in a hydrogen plant at an airport and the surface required following the size of the airports.

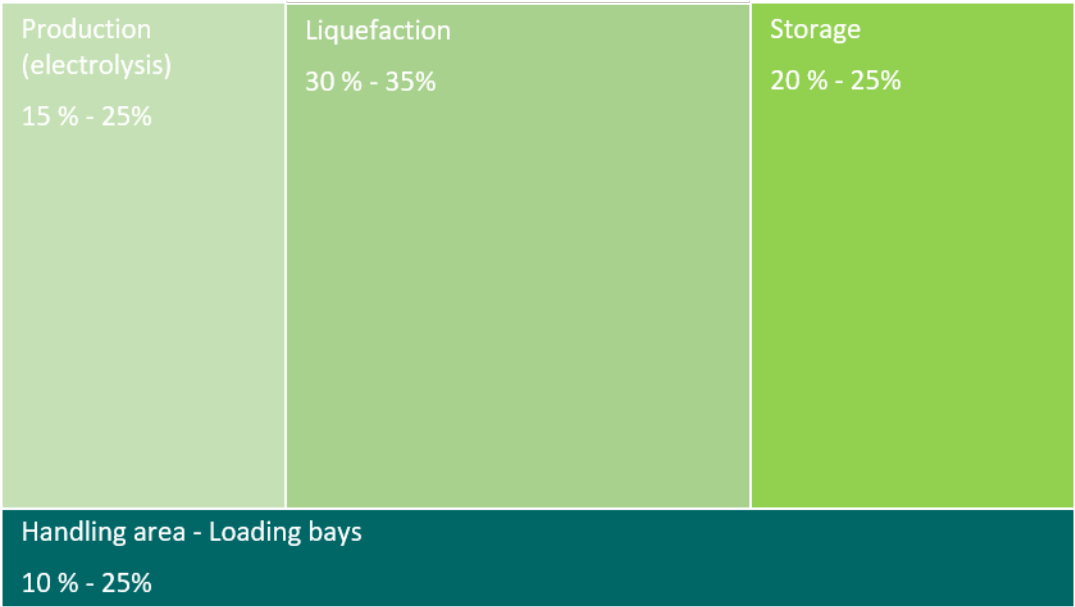


Figure 32 : Hydrogen plant at airports -Surfaces required by the several functionalities
Source: Groupe ADP and Air Liquide

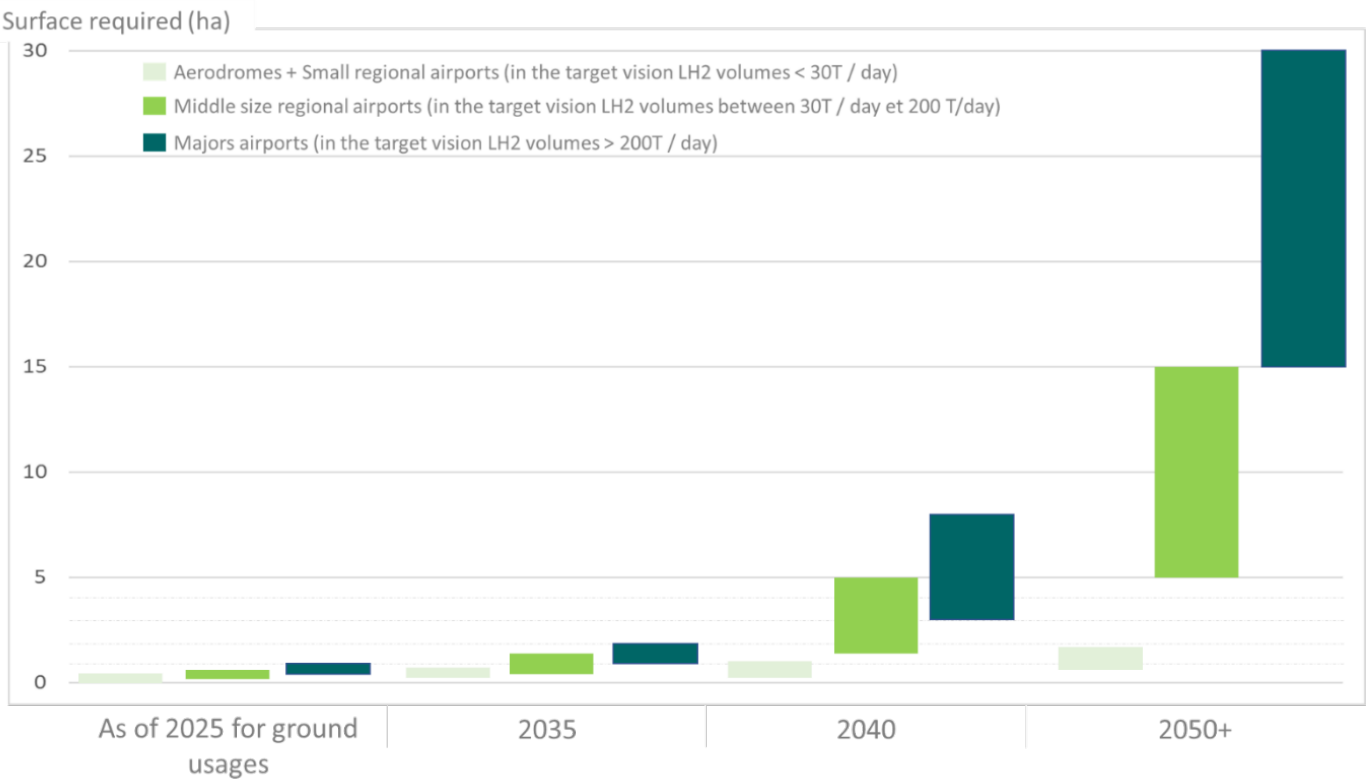




Figure 33 Hydrogen plant at airports -Estimation of global surfaces required

Source : Groupe ADP and Air Liquide

4.3.4 H2 facilities and infrastructures required for LH2 aviation consolidation phase in CDG (LH2 volumes required by aircraft above ~30 T /day to 50 T / day)

According to the results of the studies in sections 4.3.1, 4.3.2 and 4.3.3 at Paris-CDG airport, the facilities installed at the airport would then be:

- **Partial hydrogen production** (through electrolysis) : covering ~30 tonnes/day;
- **Hydrogen liquefaction: 700 tons/day** (covering demand until 2060 – maximum day);
- **Liquefied hydrogen storage: 2,100 tons** (assumption: 3 days' autonomy in summer);
- Hydrogen distribution to aircraft via a **pipeline distribution network**, partially backed up by cistern truck refuelling.

Prefeasibility studies show that, for reasons of land and investment optimization, **the optimum scenario is to install a central infrastructure (plant) for the whole airport**, rather than setting up liquefaction/storage units close to each terminal.

For hydrogen production

Outside of the OLGA project, ADP has conducted feasibility studies with the electricity transmission network operator and the gas transmission network operator in France. These studies have shown that, at first glance, there are no technical restrictions to considering all or part of hydrogen production at Paris-CDG.

However, with a view to pooling infrastructure at the regional level, the GH2 imported by pipelines to the airport seems to be the most suitable option for Paris-Charles de Gaulle airport for a long-term vision. The gaseous hydrogen is produced outside the airport and transported by pipeline to the airport before being liquefied and stored on the airport.

To ensure minimum resilience in the event of failure, hydrogen production facilities for approximately 30 tonnes per day may be provided.



For hydrogen liquefaction and storage

Liquefaction will be carried out in units capable of processing 50 tonnes of LH2 per day. For Paris-CDG, 14 units (or trains) are required.

The storage units can store either 50 tonnes (bundle) or 350 tonnes (sphere). For Paris-CDG, the preferred choice is 6 spheres of 350 T.

Approximately 0.2 GW of electrical power will be required for the liquefaction and storage process. Thus, in addition, several transformer stations are planned to be installed.



For hydrogen distribution

The distribution of hydrogen in the target vision is envisaged via a pipeline network (or hydrant system network) serving all medium-sized aircraft stands.

This hydrogen hydrant system would need to use a cryogenic pipeline to transport liquid hydrogen from the storage location to the aircraft stands. This system needs to be capable of distributing liquid hydrogen at $-253\text{ }^{\circ}\text{C}$. In addition, the system must be able to handle the boil-off of hydrogen generated by transporting hydrogen from the hydrant to the aircraft tanks. The hydrogen hydrant system envisaged in this study consists of a looped hydrant system which would keep liquid hydrogen flowing while limiting boil-off and a return pipe for hydrogen gas boil-off.

The gaseous hydrogen could be re-liquefied for aircraft use or utilised for other applications, such as to refill fuel cells for gaseous hydrogen ground mobility.

Hydrogen hydrant system requires further investigation.

The hydrogen would be loaded into the aircraft (at the junction between the hydrogen pipeline and the aircraft's tank) by 'hydrogen servicing' trucks.

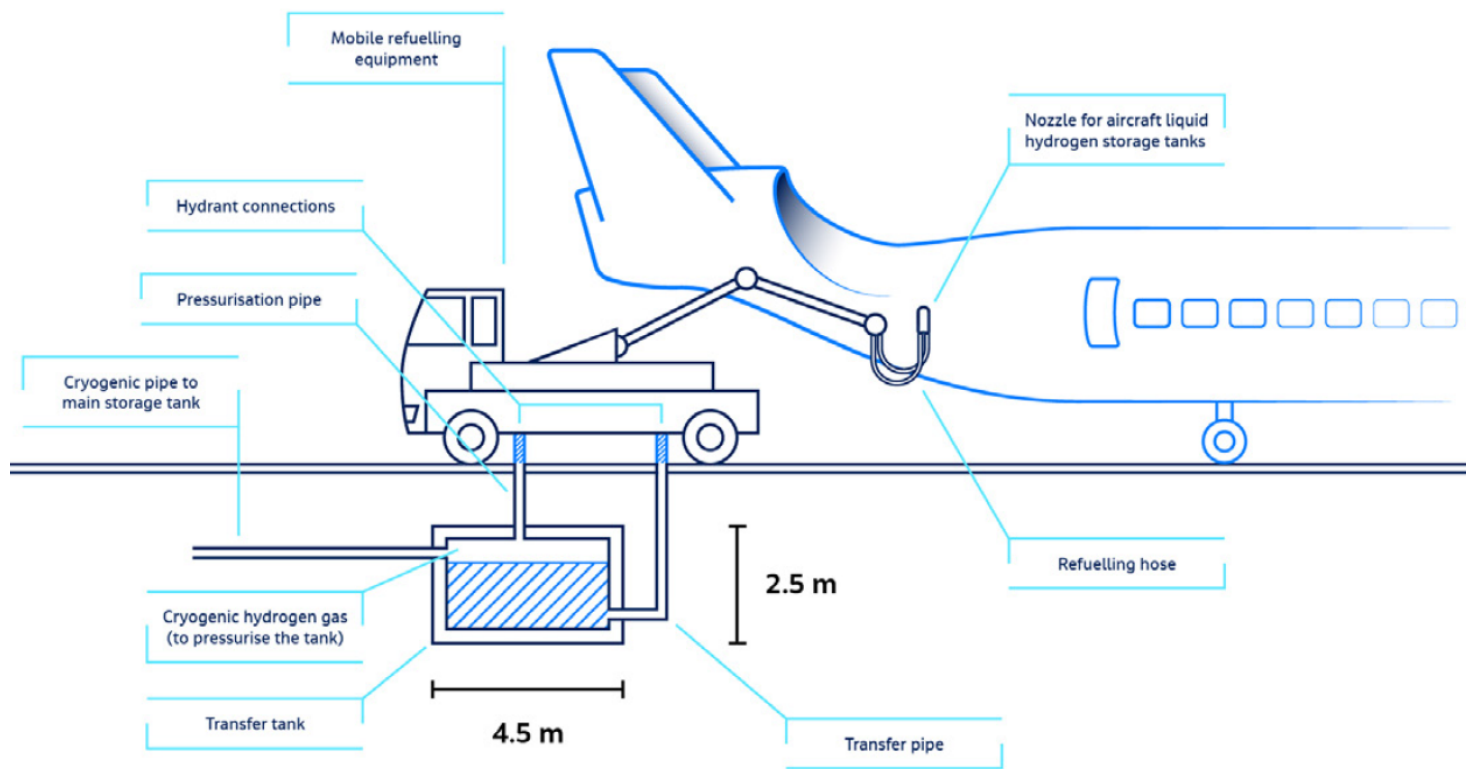




Figure 34 : Illustration of LH2 into plane concept

Source: Aerospace Technology Institute – FlyZero - Hydrogen Infrastructure and Operations (FZO-CST-POS-0035), from Jacobs

One or more plots covering an area of 1.5 hectares are required for the hydrogen refuelling activity. This area includes offices, car parking and parking for 'hydrogen servicing' trucks. The plot must be located in the airside.

This plot for 'hydrogen servicing' trucks may be located near the plot reserved for LH2 cisterns trucks (see section 4.3.2). This would reduce its overall footprint in the event of shared activities.

Furthermore, positioning the plot for 'hydrogen servicing' trucks near the plot for 'Jet fuel servers' could also optimise the total area dedicated to energy loading, allowing the areas dedicated to each use to be gradually adjusted according to emerging energy needs and the proportion of needs.

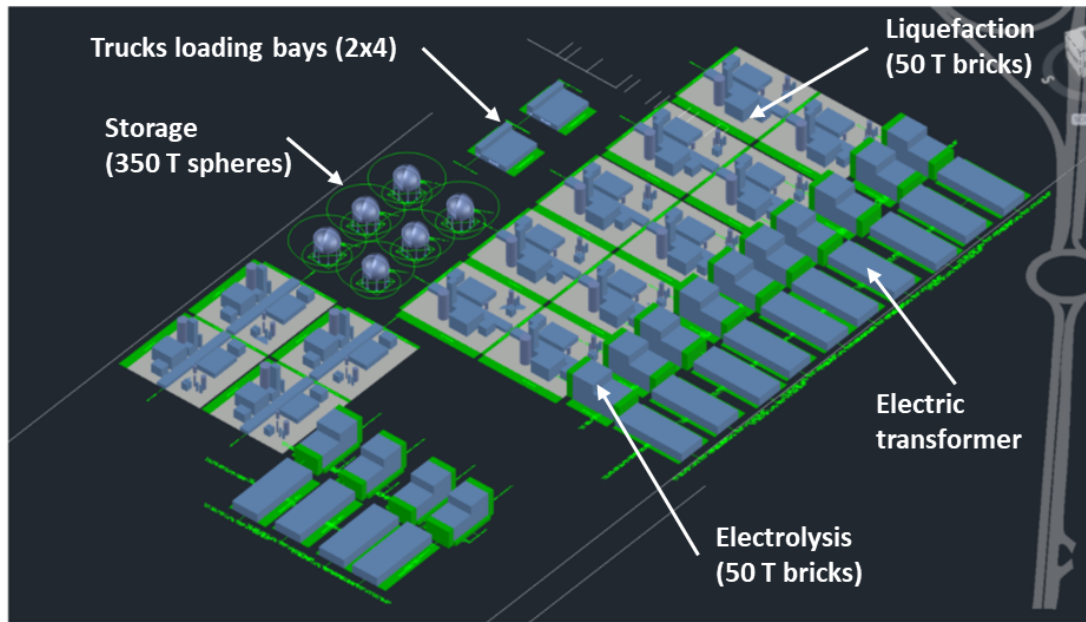


Sizing and layout of the plant

The sizing of the central hydrogen plant requires a **land reservation of around 20 hectares** on the outskirts of the airport and, if possible, on the airport's land. Its operation requires electrical power of around 220 MW.

In this scenario, this 20-hectare area would make it possible to be resilient:

- in the event of the installation of electrolyzers in the plant, if all or part of the hydrogen were eventually produced at the airport;
- to absorb residual growth potential in the hydrogen aircraft market between 2060 and 2070;
- for a hydrogen storage/distribution facility - of a few dozen tons - for ground usages within the airport or for the neighbouring areas.



Central plant characteristics:

- Electrolysis : up to 700T/d (up to 14 trains of 50T/d)
- **Liquefaction : 700T/d** (14 trains of 50T/d)
- **Storage : 3 days = 2100 T** (6x350T spheres)
- Trucks loading bays (2x4) – sizing considering LH2 pipe distribution
- Implantation to ease constructability in several phases & maintenance

Figure 35 : Composition of a 700-tonne-per-day liquid hydrogen plant

Source: Groupe ADP and Air Liquide



Figure 36 : Basic design for a hydrogen plant distributing 700 t of liquid hydrogen per day

Source: Groupe ADP and Air Liquide

4.4 Roadmap for studies and development of hydrogen infrastructure at an airport

The deployment of infrastructure at airports will need to be gradual to be closely aligned with the volumes of hydrogen distributed. As a result, this deployment may involve progressive deployment based on capacity modules or "capacity bricks" and extend over a long period of time.

The main phases of infrastructure deployment are:

- An opportunity / advisability / pre-feasibility study phase: assessment of the volumes of hydrogen required over time and the uses to be served, and definition of appropriate logistics plans (particularly based on the volumes of H2 and the volumes of inputs required);
- A feasibility phase: challenges and feasibility of integrating the infrastructure at airports, reserving space on the site plan (and, if necessary, identifying land to be acquired), securing inputs (connection to the electricity and water networks for the required volumes, assessment of water stress where applicable, connection to the hydrogen gas transport network);
- A detailed design study phase, including obtaining the necessary authorizations and permits;



-
- A building (construction) phase.

The diagram below (Figure 37) highlights the major phases in the deployment of hydrogen infrastructures at airports, with progressive deployment based on capacity brick (where A, B, C, ..., X represent the years in which bricks A, B, C, ...X are commissioned):

- The opportunity study phase is conducted for the project as a whole, with a target outlook for needs beyond 2050. This phase lasts approximately 2 years;
- From the outset of the opportunity study, identifying the land—and, in particular, the airport's ability to carry out the project within its right-of-way—is essential. Indeed, the project's location will be a key input for conducting the feasibility study. Furthermore, if the airport does not have the capacity to accommodate the hydrogen facilities identified in the feasibility study on its own property, it must promptly begin searching for land outside the airport's right-of-way but in close vicinity to the airport. Land acquisition can take up to 10 years under adverse scenarios;
- Following the opportunity study, the detailed feasibility study will begin. It is estimated to take between 4 and 5 years, primarily due to the necessary studies for connecting to either the electrical grid (in the case of hydrogen production at the airport) or the hydrogen gas network (in the case of transporting hydrogen gas to the airport for on-site liquefaction). The detailed feasibility study should clearly define the timeline for the design, implementation, and commissioning of the various "capacity bricks" that will make up the plant, in line with the target vision 2050+. In parallel with these technical studies, economic analyses will be required to determine the business model for the detailed design, construction, and operation of the hydrogen infrastructure;
- In parallel with the feasibility study, the documentation related to the environmental and safety permitting processes must be prepared. This step also continues during the detailed design phase;
- Once the general feasibility phase is complete, the detailed design studies, followed by the building phase, for the various "capacity bricks" can proceed one after another. The sequence depends on the commissioning schedule that has been determined.

For airports that will have hydrogen infrastructure (such as production and/or liquefaction/large-volume storage) – H2 requirements > 30 to 50 tonnes/day – the deployment phase for an initial factory module (design + construction) is estimated to take at least 10 years. It is also essential to consider the processes involved in reserving land, obtaining authorisations (environmental, aviation safety) and connecting to input networks (electricity, gaseous H2 transport, water).



The development of hydrogen infrastructure at airports will require infrastructure planning on a larger territorial scale (electricity production, electricity networks, hydrogen and water transport networks). This, combined with the length of infrastructure deployment cycles, requires large European airports to assess their future hydrogen needs and the challenges of integrating this energy vector into their platforms as soon as possible, and for these needs to be incorporated into national roadmaps, in coordination with energy companies, gas and electricity network operators (low-carbon electricity production, electricity network, gas network) and airlines and aircraft manufacturers.



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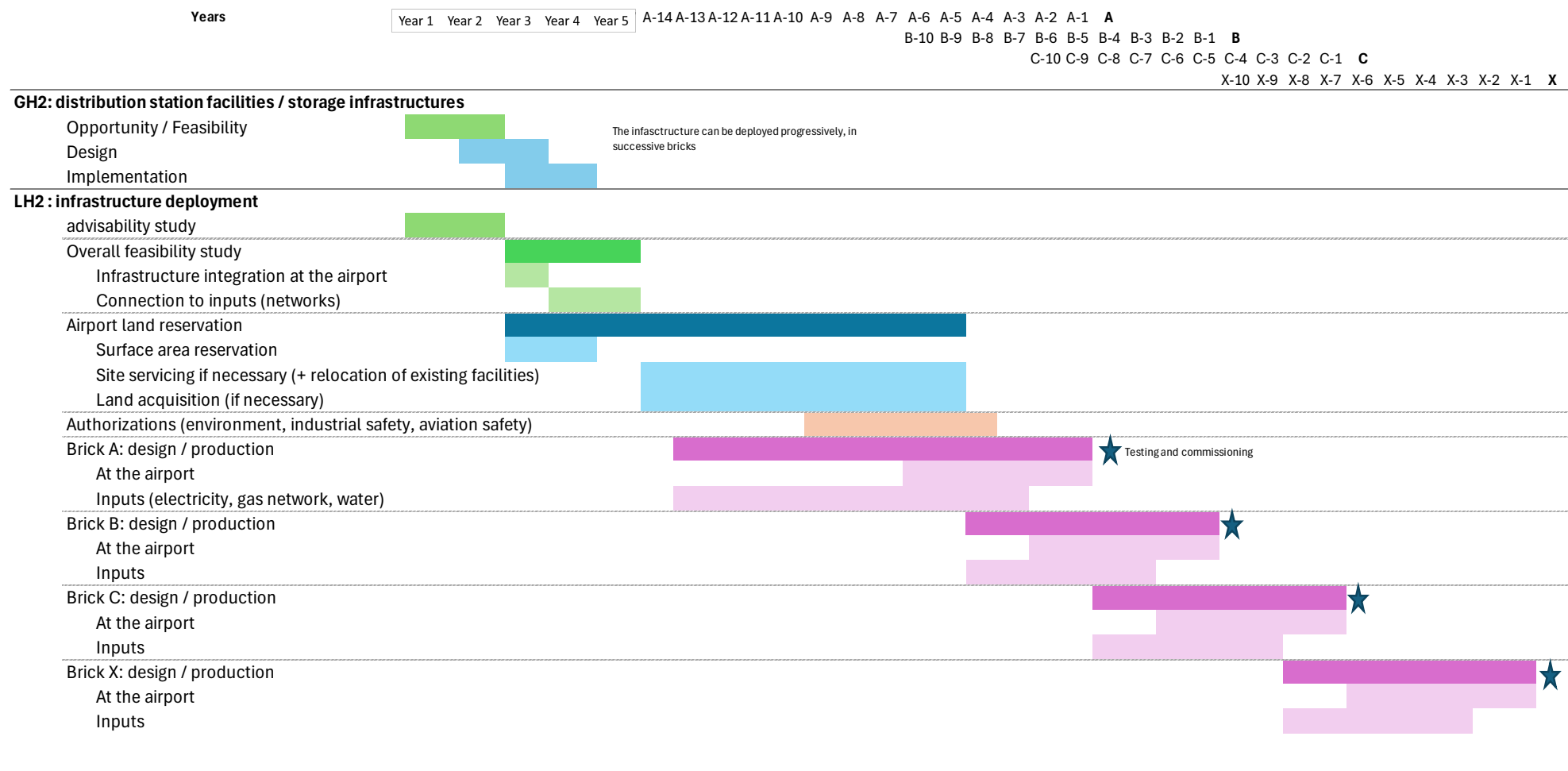


Figure 37 Hydrogen infrastructure roadmap at large airports

Source: Groupe ADP



4.5 H2 masterplanning Replication: Zagreb Airport Case Study

4.5.1 Lack of hydrogen production in Croatia

Two supply options:

- Road transport by LH2 trailers (initial implementation phase, ~30–50 t/day, 2035–2045)
 - Becomes uneconomical above ~30–40 t/day;
 - LH2 trailers (capacity 4–6 t per unit) would need to come from external hubs (e.g. Rotterdam, Antwerp, or Germany – distance 800–1200 km);
 - This implies 5–10 trailers per day even for modest demand, increasing transport costs (fuel, ADR-certified drivers for cryogenic substances) and dependence on road infrastructure (congestion on A3/A4 motorways, adverse weather conditions);
 - Risk of delivery delays, potentially disrupting flight operations.
- Pipeline supply (later phase, >50 t/day, post-2045)
 - The North Adriatic Hydrogen Valley (NAHV) project targets first kilograms of green hydrogen by 2026, with planned capacities in Croatia of ~1,000 tonnes/year (out of >5,000 tonnes/year for the entire valley);
 - Plinacro or an NAHV partner would need to extend a GH2 pipeline to the airport boundary (or at least proximity, e.g. 5–10 km) by 2030–2032.

Transition to pipeline supply requires 5–10 years of construction; if not initiated between 2026–2030, ZAG would remain dependent on road transport, significantly limiting scalability for Airbus ZEROe operations.

4.5.2 Land take by development phases (trailers first, pipelines later) with strict safety distances

- Initial phase (trailers, up to ~30–50 t/day):
 - Required land area: approx. 1–2 ha for trailer parking, loading bays, and specialized tractors (airside zone);
 - Safety distances (min. 50–100 m from public buildings/terminal, 15–30 m between trailers, 60 m venting distance) significantly constraints in the available locations.
- Later phase (pipeline-based system, >50 t/day):
 - Required land area: approx. 3–6 ha for a central facility (liquefaction, storage, pipeline interface);



- Safety distances: 75–150 m from occupied buildings (e.g. terminal), 60 m venting/refueling zone – total land requirement may reach 8–10 ha;
- Pipeline integration would require underground or above-ground routing through airside areas, increasing costs (cryogenic materials, boil-off management) and leakage risks;
- Dedicated explosion protection studies would be required and formally approved by competent authorities.

4.5.3 Hydrogen aircraft refueling under safety distance constraints

- Trailer-based refueling:
 - Aircraft turnaround refueling must be fast (15–30 minutes), but LH2 requires strict procedures (cryogenic connectors, purging, leak detection, etc.);
- Pipeline-based refueling:
 - Hydrant system (looped cryogenic pipeline): LH2 supplied to stands and transferred via servicing vehicles;
 - Better suited for large volumes (faster refueling, reduced boil-off), but requires pump stations and re-liquefaction systems for boil-off gas.

4.5.4 Summary of key challenges for LH2 infrastructure implementation at ZAG

- LH2 import logistics challenges and dependence on external supply sources and future projects;
- Limited land availability and conflicts with existing airport masterplans;
- Significant investment required for staff training and certification, as well as procurement of specialized LH2 transport, handling, and safety monitoring equipment;
- Stringent safety requirements substantially increasing implementation costs;
- Dual civil–military airport status, further complicating implementation due to the need for approvals from the Ministry of Defence.



4.6 Operational challenges at airports

In addition to the issues of layout and integration of hydrogen equipment and infrastructure discussed above, operational challenges will need to be considered at airports.

Indeed, the current overall level of operational performance (aircraft operations, aircraft turnaround times, airport operating costs for fleet operations, quality of service to users) must be maintained as much as possible. In this regard, the coexistence and increasing complexity of managing a greater number of utility flows and energy carriers, with new handling constraints specific to each carrier, must be addressed. First and foremost, the increase in airport traffic, as well as the supply of new energies, may require significant operational and infrastructural adaptations.

More specifically, the use of hydrogen introduces new operational constraints such as:

- monitoring and managing H2 leaks on aircraft;
- managing aircraft tank vents;
- ensuring the safety of aircraft tank filling operations;
- maintaining H2 tanks.

These operational constraints will need to be addressed in close collaboration with aircraft manufacturers. The impact of the introduction of new energies on airport operations, particularly hydrogen, is closely linked to the design of the associated solutions developed for aircraft. The most significant effects on operations, and even more so on airport infrastructure, need to be taken into account from the aircraft system design phase onwards. At the same time, an assessment and management of residual constraints must be planned and monitored in order to anticipate the necessary adaptations.



5 Airport Regulation Analysis

The use of hydrogen, in both liquid and gaseous form, is not widespread at airports today, and the current regulatory framework is not necessarily suited to its large-scale deployment. Different types of regulations apply to the installation and operation of hydrogen equipment at airports: **aviation and airport regulations and industry regulations, norms and standards**.

Industry regulations, norms and standards are numerous and come from a variety of sources (European directives relating to industrial sites and facilities, Code de l'Environnement in France, ISO or EUROCAE committees, specialised organisations such as JIG or EIGA, public organisations such as NFPA, etc.). These texts specify the obligations and recommendations regarding the design and operation of industrial sites, in particular the requirements to be complied with in terms of industrial safety and security⁶. Some of them also cover both the management and organisation of aircraft ground handling and the design and operation of airport equipment.

Aviation regulations are generally based on ICAO's Standards and Recommended Practices and adapted by the local aviation authorities (EASA in Europe). These regulations deal with a wide range of air transport topics, such as the sharing of responsibilities between air transport operators, aircraft certification, Air Traffic Management (ATM), flight crew training and certification, aerodromes...

In Europe, the *European Union Aviation Safety Agency* (EASA) is the **authority in aviation safety**. Its mission is to ensure the safety and environmental protection of air transport in Europe. For this purpose, it draws up common regulations and standards to ensure the highest possible level of safety, while ensuring uniform application throughout Europe.

Figure 38 illustrates, in a non-exhaustive manner, the interconnection between the various texts in the case of a French airport operating hydrogen-powered vehicles and aircraft.

⁶ Studies and researches relating to industry regulations, norms and standards are out the scope of this study.

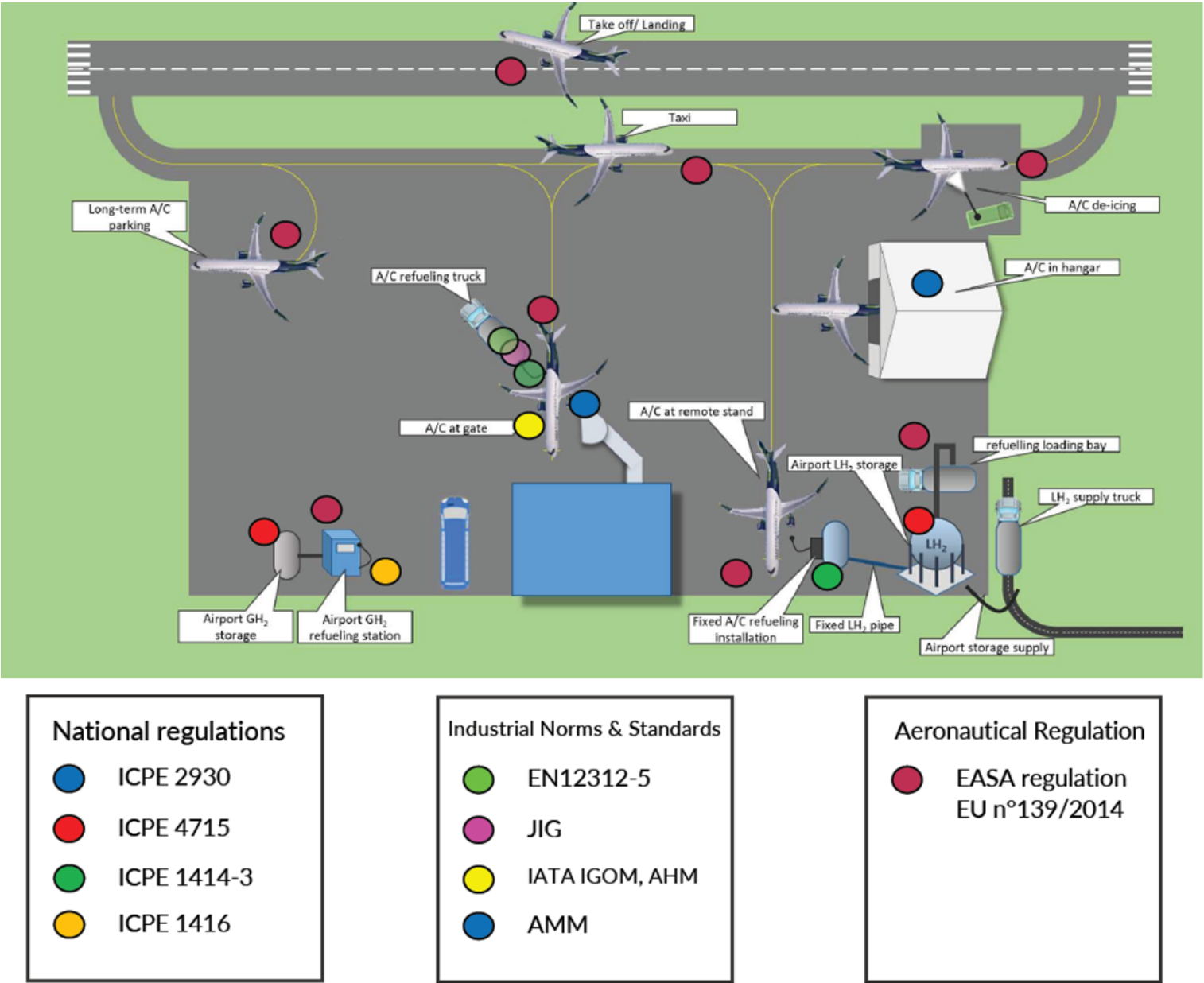


Figure 38 : Scope of the requirements relating to industrial process applicable on an EU aerodrome (non-exhaustive list of examples)

Source: published in FEUILLE DE ROUTE -Article 301- décarbonation de l'aérien, based on the work of Airbus WG7 outcomes, focusing on accommodation of the new H2 aircraft during a whole airport stay (runway operations, taxiing, aircraft stand operations, de-icing, maintenance) through a normative / regulation prism

⁷ WG which gathers experts from airports (including ADP), H2 industry (Air Liquide), French Civil Authorities, GSE manufacturers – Airbus is Advisory Board member of OLGA project



According to the WP5.2 description in the DoA., to prepare an airport master plan, the first step is to focus on regulations applicable to airport authorities and dealing with general airport operations and design and to determine if these regulations could be **impacted by the introduction of liquid hydrogen on aerodromes**.

Regulations analysed are targeting:

- airport operators' responsibilities in terms of organisation, operations and design. Aerodromes concerned by H2 aircraft targeted in WP5.2 are aerodromes within the scope of the EASA regulation. They are certified accordance with the "aerodromes" Basic Regulation EU n°1139/2018 and Commission Regulation EU n°139/2014;
- the common rules of the air and operational provisions regarding services and procedures in the air (Standardized European Rules of the Air: Regulation SERA 923-2012);
- the liquid hydrogen to be considered as a regulated dangerous good and stored on airport platforms (Doc 9284 Technical instructions, ICPE regulations on installations classified for environmental protection).

The current analysis was conducted by ADP and the conclusions do not prejudice the work that will be carried out by aviation and airport regulatory authorities.

5.1 Analysis of EU regulations applicable to organisation, operations and design of aerodromes - EU N° 1139/2018 and EU N° 139/2014

5.1.1 Analysis framework

Basic Regulation (EU) n° 1139/2018

[Regulation EU n° 1139/2018](#), or the Basic Regulation, is a heading text which establishes the legal basis for the creation of EASA, defines EASA's competences and defines the scope of the common aviation safety requirements. To this end, the Basic Regulation empowers the European Commission to adopt implementing and delegated rules detailing how the essential requirements of the Basic Regulation are to be met and regulating the subjects within its scope, in particular airworthiness, aircrew licensing, environmental compatibility in relation to products, aircraft operations including



third country operators, ATM/ANS including air traffic controller licensing, aerodromes and ground handling, and unmanned aircraft.

3 relevant parts – related to WP 5.2. - of the Basic Regulation have been analysed:

- The *section IV AERODROMES*: This section is composed of 7 articles and aims to give the basic rules and essential requirements for aerodromes certification, safety equipment, and protection of aerodrome surroundings.
- *Annex VII Essential requirements for aerodromes* explains the legal basis requirements for the infrastructure and equipment inside the aerodrome, the operations and management giving the aerodrome operator's responsibilities, and requirements in the surroundings of the aerodrome.
- *Book1 – Certification Specifications (CS)* that establishes rules and specification for aerodrome design.

Regulation EU n° 1139/2018, in addition to the above, under point “Whereas: 2) a high and uniform level of environmental protection should be ensured”, encourages, in the spirit of the law, the use of green H2.

Commission Regulation EU n° 139/2014

The regulation n°139/2014, linked to the Basic Regulation 1139/2018, defines requirements about the management, certification and operations of aerodromes in EU states. It is composed as follows:

- Annex I – Definitions, that contains all the definitions of the terms used in annexes II, III, IV.
- Annex II – Authority Requirements, that establishes requirements for the Competent Authorities responsible for the certification and oversight of aerodromes and aerodrome operators. **This section is not analysed in WP5.2 since these requirements are not directly applicable to aerodromes.**
- *Annex III - Organisation Requirements (Part ADR.OR.)*, that establishes the requirements to be followed by an aerodrome operator subject with respect to its certification, management, manuals, and other responsibilities.
- *Annex IV - Operations Requirements (Part ADR.OPS.)*, that establishes the requirements for aerodrome data, aerodrome operational services, equipment and installations, aerodrome maintenance and apron management operations.

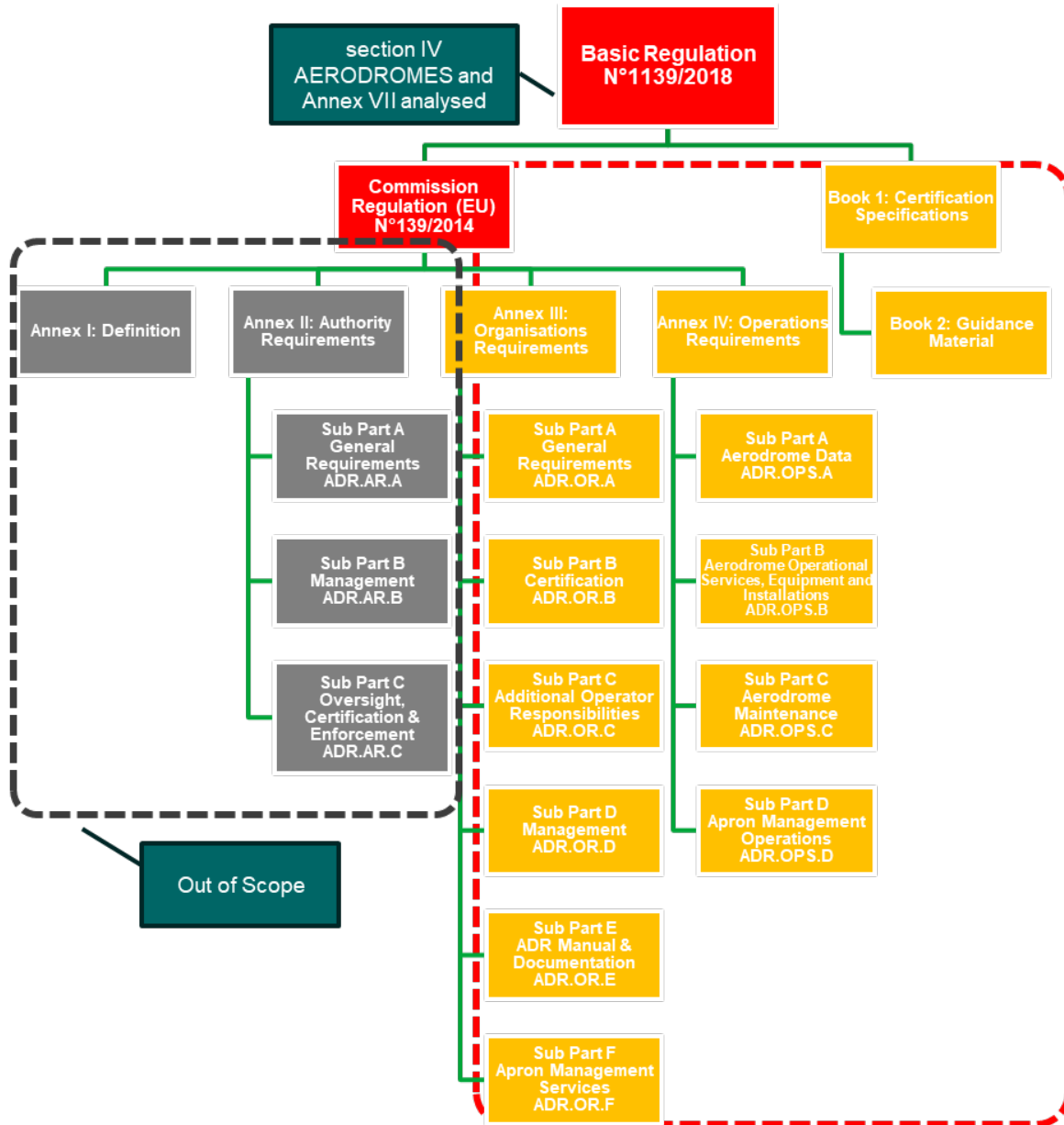


Figure 39: Regulatory framework of the Basic Regulation n° 1139/2018 and the Commission Regulation n° 139/2014 – Texts analyzed in WP 5.2

Methodology for regulation analysis

ADP - Hydrogen Project Manager and Compliance Monitoring entity - have held several working sessions to screen these regulations.

The Implementing Rules (IR) and the Certification Specifications (CS) that constitute the aforementioned texts have been analysed according to 2 questions:



- May the introduction of H2 have an impact on the way article / IR (Implementing Rules) / CS (Certification Specifications) is applied at aerodromes (without requiring a change in the wording of the article / IR / CS or the associated AMC (Acceptable Means of Compliance)?)
- Does the introduction of H2 require changes to the wording of the article / IR / CS?

5.1.2 Analysis outcomes of Regulation EU N° 1139/2018, defining EASA's competences and the scope of the common aviation safety requirements

From the Basic Regulation (EU) n°1139/2018, **section IV - AERODROMES** and **Annex VII- essential requirements for aerodromes** have been analysed.

Among the 7 articles that constitutes the **section IV AERODROMES**, **4 articles** may be impacted by the introduction of H2 at airports:

- **Article 33, Essential requirements**
 - There should be no need to change the wording of the regulation, but safety-related H2 aerodrome equipment, activities related to H2 operations and H2 ground handling, may have to comply with the essential requirements related to Annex VII mentioned in article 33.
- **Article 34, Aerodrome certification**
 - There should be no need to change the wording of the regulation, but the new aerodrome certification may include details on H2.
- **Article 35, Safety related aerodromes equipment**
 - There should be no need to change the wording of the regulation, but the certification of safety equipment will apply to RFFS foams, which must therefore be certified for the treatment of (L)H2 fires.
- **Article 39, Delegated powers**
 - There should be no need to change the regulation, but the certification of safety equipment will apply to RFFS foams, which must therefore be certified for the treatment of (L)H2 fires.

The **Annex VII** deals with essential requirements for aerodromes. **4 articles** are particularly relevant and potentially impacted by the introduction of (L)H2 at airports:

- **Annex VII, 2. Operations and management**



- **2.1. Responsibilities of the aerodrome operator:** There is no need to change the regulation.
- **2.2. Management systems:** There is no need to change the regulation. It will be essential to Incorporate (L)H2 activities within the scope of the SMS (Safety Management System) (in the same way as fuel supply, as it is currently the case).

➤ **Annex VII, 4. Ground handling services**

- There should be no need to change the regulation, but there is a need to integrate the new (L)H2 supply activity for ground handlers.

➤ **Annex VII, 6. Others**

- There should be a need to analyse more deeply this regulation. It may be necessary to define if an aircraft operator should ensure or not that the diverted airport selected to divert a (L)H2 aircraft is compatible with (L)H2 operating procedures.

Regulatory requirements applicable to European aerodromes			LH2 impact Analysis / ADP	
Text identification				
Standard level	short title	article	Impact LH2	Need to change regulation
Basic Regulation (section ADR)	Articles	article 33	yes	no
Basic Regulation (section ADR)	Articles	article 34	yes	no
Basic Regulation (section ADR)	Articles	article 35	yes	no
Basic Regulation (section ADR)	Articles	article 36	no	no
Basic Regulation (section ADR)	Articles	article 37	no	no
Basic Regulation (section ADR)	Articles	article 38	no	no
Basic Regulation (section ADR)	Articles	article 39	yes	no
European regulations	Annexe VII	2,1	yes	no
European regulations	Annexe VII	2,2	yes	no
European regulations	Annexe VII	4	yes	no
European regulations	Annexe VII	6	yes	no

Figure 40: Regulation UE N° 1139/2018 results impacted in the way they are applied by airports due to the introduction of (L)H2.



5.1.3 Analysis outcomes of Regulation n°139/2014- Certification Specifications from Book 1, defining design rules for aerodrome

206 CS from [Book 1 \(Certification Specifications\)](#) have been analysed. **Only 4** might have a link to H2 operations, infrastructures, and facilities (see column "Impact LH2" in Figure 41 below). None would need to be completed or changed (see column "Need to change regulation" in Figure 41 below) :

CS.ADR.DSN	LH2 Analysis	
	Impact LH2	Need to change regulation
CS ADR-DSN.E.355 Strength of aprons	Yes	No
CS ADR-DSN.F.370 Isolated aircraft parking position	Yes	Unsure
CS ADR-DSN.T.900 Emergency access and service roads	Yes	No
CS ADR-DSN.T.905 Fire stations	Yes	No

Figure 41 : CS (=Certification Specification) impacted in the way they are applied by airports due to the introduction of (L)H2

The list below describes the Certification Specification (CS) that may be affected by the introduction of hydrogen, either in their formulation or in their application in terms of airport design:

- **CS ADR-DSN.E.355 Strength of aprons**
 - An apron should be protected against fuel leakage with a specific surface protection, or a product incorporated in the mass of the bituminous concrete. With the introduction of LH2, and despite the properties of LH2 which makes it quickly dispersible, it may be necessary to assess the effects of LH2 spraying on the strength of the apron pavement.
- **CS ADR-DSN.F.370 Isolated aircraft parking position**
 - It may be necessary to assess whether the minimum distance of 100m is acceptable for the isolation of (L)H2 aircraft. It may be necessary to change the regulation if the distance were to be greater than 100m.
- **CS ADR-DSN.T.900 Emergency access and service roads**



- The design of service roads for emergency vehicles may need to be reviewed for (L)H2 aircraft requiring special equipment.

➤ **CS ADR-DSN.T.905 Fire stations**

- The implementation of (L)H2 at airports may be affected if new RFFS facilities are required. However, the design regulations are unlikely to be amended.

Current design regulations and possible future developments allow for a master plan exercise on the integration of hydrogen facilities. However, in order to fully take into account the regulations on master plan design, aircraft manufacturers must first be able to provide detailed aircraft designs (length, wingspan, tank positioning, H2 volume carried, wheelbase, etc.) so that the authorities and airports can also study the consequences in terms of aircraft taxiing, aircraft stands sizing, specific requirements for emergency services, etc.

5.1.4 Analysis outcomes of Regulation EU n° 139/ 2014- Implementing Rules (IR) from Annex III and IV, defining organisation and operations requirements for aerodrome operator

[124 IR from Annex III \(Organisation Requirements – OR\) and Annex IV \(Operations Requirements – OPS\)](#) have been analysed. Among them, **33 IR** may be impacted in the way they are applied by airports due to the introduction of H₂ (see column "Impact LH2" in Figure 42 below). Among them, the content of **only 4** of them might need to be adapted or changed in terms of content to take H₂ into account (see column "Need to change regulation" in Figure 42 below).



	LH2 Analysis	
	Impact LH2	Need to change regulation
ADR.OPS.A.005	Yes	No
ADR.OPS.A.057	Yes	Yes
ADR.OPS.A.060	Yes	No
ADR.OPS.B.003	Yes	No
ADR.OPS.B.005	Yes	No
ADR.OPS.B.010	Yes	Yes
ADR.OPS.B.015	Yes	No
ADR.OPS.B.035	Yes	No
ADR.OPS.B.036	Yes	No
ADR.OPS.B.037	Yes	No
ADR.OPS.B.050	Yes	No
ADR.OPS.B.055	Yes	Yes
ADR.OPS.C.005	Yes	No
ADR.OPS.D.001	Yes	No
ADR.OPS.D.010	Yes	No
ADR.OPS.D.015	Yes	No
ADR.OPS.D.040	Yes	Unsure
ADR.OPS.D.055	Yes	No
ADR.OPS.D.060	Yes	Yes
ADR.OPS.D.065	Yes	No
ADR.OR.B.015	Yes	No
ADR.OR.B.025	Yes	No
ADR.OR.B.035	Yes	No
ADR.OR.B.040	Yes	No
ADR.OR.C.005	Yes	No
ADR.OR.C.040	Yes	No
ADR.OR.D.010	Yes	No
ADR.OR.D.015	Yes	No
ADR.OR.D.017	Yes	No
ADR.OR.D.020	Yes	No
ADR.OR.D.025	Yes	No
ADR.OR.E.005	Yes	No
ADR.OR.F.065	Yes	No

Figure 42 : IR (=Implementing Rules) impacted in the way they are applied by airports due to the introduction of (L)H2



The list below describes the Implementing Rules (IR) that may be affected by the introduction of hydrogen, either in their formulation or in their operational application:

➤ **ADR.OPS.A.005 Aerodrome data**

- There should be no need to change the content of the IR, but it may be necessary to introduce the elements specific to (L)H2 in the AIP (Aeronautical Information Publication) in its existing form.

➤ **ADR.OPS.A.057 Origination of NOTAM**

- In reference to (b)(9): the term fuel does not include LH2. It can be replaced, for example, by "aircraft energy" to make the fuel generic and not specific to "Fuel". EASA has already submitted in January 2024 a NPA (Notice of Proposed Amendment). It is suggested to replace in the SERA the term "fuel" by "fuel/energy": "The term "fuel/energy" should cater for both typical fuel and any other type or source of energy used for aircraft propulsion, including but not limited to electrical energy stored in batteries" + "Hydrogen may also be used as fuel for fuel cell applications, which generate electricity that is used to generate propulsion."

➤ **ADR.OPS.A.060 Reporting of surface contaminants**

- There is a potential consideration of (L)H2 in the case of physio-chemical characteristics with specific impacts on pavements, compared with conventional kerosene.

➤ **ADR.OPS.B.003 Handover of activities – provision of operational information**

- Concerning Handover activities, ADP liability is limited to its own personnel. For the dissemination of operational information, it will be done via existing third-party communication processes.

➤ **ADR.OPS.B.005 Aerodrome Emergency Planning**

- The aerodrome emergency plan should consider situations specific to (L)H2.

➤ **ADR.OPS.B.010 Rescue and firefighting services (RFFS)**

- The current RFFS management and operating methods do not consider the (L)H2 specificities. Reference scenarios would need to be defined to assess the impact on the sizing, resources, methods and training of RFFS services (all components of OPS.B.010).

➤ **ADR.OPS.B.015 Monitoring and inspection of movement area and related facilities**



- There should be a need to incorporate, when appropriate, the characteristics of surface damage specific to LH2 for personnel in charge of inspections. For instance, on CDG airport, FLYCO is responsible for daily operational inspections and facilities management department of specific technical visits.
- **ADR.OPS.B.035 Operations in winter conditions**
 - Further investigation would have to be carried out to analyse the potential impact of water vapor emissions from LH2 aircraft on surveillance and surface decontamination or de-icing procedures, to be created for modification of the winter planning.
- **ADR.OPS.B.036 Operations on specially prepared winter runways**
 - Linked with ADR.OPS.B.035, it should have to be analysed based on the consequences of the potential release of water and/or steam from LH2 combustion engines.
- **ADR.OPS.B.037 Assessment of runway surface condition and assignment of runway condition code**
 - The operational implementation, depending on the severity of winter conditions, could be adapted (e.g. frequency assessment) to the consequences of water and/or water vapor discharge in the case of engines using LH2 combustion.
- **ADR.OPS.B.050 Operations in adverse weather conditions**
 - Ground staff procedures may have to consider the LH2's particularities and the dedicated safety measures to be implemented during degraded weather situations, compared with those existing for the handling of current aircraft (e.g. refueling stop in the event of a thunderstorm).
- **ADR.OPS.B.055 Fuel quality**
 - This IR does not cover (L)H2. This IR may have to include aircraft energies that are not fuels (consideration of "fuels" such as (L)H2).
 - There is a need to further check whether changes are required to the control actions under the responsibility of the aerodrome operator whether the scope of the aerodrome operator's responsibility, as defined in the IR, is still appropriate.
 - The references relating to the fuel controls to be acquired by the aerodrome operator, as per GM, need to be further updated with respect to what has already been planned.
- **ADR.OPS.C.005 General (aerodrome maintenance)**



- This IR is applicable to the (L)H2 infrastructure/equipment perimeter run directly by the aerodrome operator. If the infrastructure and equipment belong to the aerodrome operator, they are covered by the ADR (aerodrome) regulations.
- **ADR.OPS.D.001 Apron management safety related activities**
 - The aircraft refueling procedures should consider the specific features of the (L)H2.
 - It may be appropriate to discuss with the aircraft manufacturer whether to highlight a focus on the procedures related to release time and taxi time (interval between refueling and take-off), aiming at facilitating the maintenance of the LH2 temperature, which could be more demanding in pre-take-off. This could involve other norms such as ADR.OPS.D.060 Aircraft refueling or ADR.OR.D.025 Coordination with other organisations if ATS provider manage part of apron / ground movement.
- **ADR.OPS.D.010 Coordination of aircraft entry to/exit from the apron**
 - For new facilities that will be used with (L)H2 aircraft, it may be appropriate to distinguish them from those that use 'standard fuel'.
- **ADR.OPS.D.015 Management of aircraft movements on the apron**
 - Depending on the aircraft, (L)H2's aircraft might have new procedures including the movement of the aircraft on the apron. This point will have to be checked in the frame of the aircraft-airport checked based on the aircraft manual.
- **ADR.OPS.D.040 Aircraft departure from the stand**
 - Some equipment specific to the (L)H2 may have to remain on the apron when the aircraft leaves the apron.
- **ADR.OPS.D.055 Jet blast precautions**
 - LH2 aircraft may have to be the subject of specific blast studies to be considered by aerodrome operator.
- **ADR.OPS.D.060 Aircraft refueling**
 - The text does not consider the use of other fuels such as (L)H2. Aircraft refueling procedures may have to consider the particularities of LH2. The regulation may have to be adapted and new procedures on the aerodrome established.
- **ADR.OPS.D.065 Engine test**



- The IR may not require a change, but the procedures should consider the engine test requirements of LH2 aircraft, where applicable.
- **ADR.OR.B.015 Application for a certificate/ ADR.OR.B.025 Demonstration of compliance / ADR.OR.B.035 Continued validity of a certificate / ADR.OR.B.040 Changes**
 - In Paris CDG/LBG/ORY airports are already certified under EU regulation n°139/2014. The inclusion of (L)H2 may require the implementation of several modifications regarding procedures which involves this IR.
- **ADR.OR.C.005 Aerodrome operator responsibilities**
 - With the introduction of (L)H2, the aerodrome operator must comply with the section (d): *" If an unsafe condition develops at the aerodrome, the aerodrome operator shall, without undue delay, take all necessary measures to ensure that those parts of the aerodrome found to endanger safety are not used by aircraft."*
- **ADR.OR.C.040 Prevention of fire**
 - The IR would not require a change, but the procedure should consider of the (L)H2's ignition characteristics.
- **ADR.OR.D.010 Contracted activities**
 - It would have to be further examined depending on the airport. The contracted activities might be different from the Paris-CDG case, as well as the needs of the airport. As example, several airports subcontracted the RFFS activities which is not the case in Paris-CDG airport.
- **ADR.OR.D.015 Personnel requirements**
 - With reference to (f), training of the relevant personnel in the characteristics of (L)H2 in accordance with their duties should be taken into consideration. This IR is linked to ADR.OR.D.017.
- **ADR.OR.D.017 Training and proficiency check programs**
 - Training for relevant (internal) staff on the characteristics of (L)H2 in relation to their duties should be included in the training programme.
 - A (L)H2 module should be included in the SMS (Safety Management System) training provided to autonomous staff, as well as in training session to get a driving licence on the apron and manoeuvring area (known as 'runway permits').
- **ADR.OR.D.020 Facilities requirements**



- This requirement covers all dangerous goods and may therefore be applied to (L)H2 with evolution for aerodromes operators.
 - In reference to GM1 ADR.OR.D.020 (b) *personnel protective equipment*: it would be necessary to provide adapted equipment to the personnel working with (L)H2. For instance, Personal Protective Equipment must not be a source of static electricity (antistatic footwear, electrostatic dissipative protective and work clothing).
- **ADR.OR.D.025 Coordination with other organisations**
- Airport authorities should ensure that third-party company working on the aerodrome comply with the new (L)H2 safety procedures.
- **ADR.OR.E.005 Aerodrome manual**
- There would be a need to describe in the aerodrome manual the elements relating to (L)H2 in the same way as those described for conventional fuels.
- **ADR.OR.F.065 Personnel requirements**
- The training of apron management service personnel may cover the characteristics of the (L)H2 according to their missions. To be linked with ADR.OR.D.017

As a main outcome of the analysis IR related to organization and operations, we can conclude that:

- it is necessary to introduce a clear definition of the energies or energy carriers used to power aircraft into the texts and define if hydrogen can be included in the term “fuel” used in the texts. For information, in early 2024, EASA published a Notice of Proposed Amendment (NPA) relating to VTOLs, which explicitly proposes amending the SERA regulation and adding the term ‘energy’ to the term ‘fuel’ to take into account all types of energy or energy carriers. In this NPA, it is interesting to note that hydrogen is considered a fuel.⁸

⁸ Abstract from "EASA - Notice of Proposed Amendment 2024-01 in accordance with Article 6 of MB Decision 01-2022" – pages 18 and 19 : "[...] The energy used for aircraft propulsion comes from various sources and is of various types. A frequently used type of energy in aviation is derived from processing (in a piston or turbine engine) hydrocarbon-based fuels that include gasoline (leaded or unleaded), diesel, avgas, JET A-1, and JET B. Hydrogen may also be used as fuel for fuel cell applications, which generate electricity that is used to generate propulsion. However, as current technologies already use other sources of energy for aircraft propulsion, such as stored electrical energy, the typical term ‘fuel’ has become restrictive and no longer covers emerging technologies. Therefore, a broader, combined term is introduced to accommodate new types of energy, other than fuel, used for aircraft propulsion purposes. The term ‘fuel/energy’ should cater for both typical fuel and any other type or source of energy used for aircraft propulsion, including but not limited to electrical energy stored in batteries. [...]”.



- only few articles need to be modified, but many airports authorities' procedures, which are operationally or organizationally based on regulation, will need to be clarified to incorporate the specific characteristics of hydrogen.

5.2 Analysis of the Standardised European Rules of the Air - Regulation SERA 923-2012

The SERA or **Standardised European Rules of the Air** is the European Union regulation setting the common rules of the air and operational provisions relating to air services and procedures. Those that may be related to operations at an aerodrome are analysed here.

2 Implementing Rules may be impacted by the way they are applied due to the introduction of (L)H2.

SERA 923/2012	LH2 Analysis	
Article	Impact LH2	Need to change regulation
SERA.8012	yes	no
SERA.11012	yes	?

Figure 43 : IR from SERA 923-2012 impacted by the way they are applied on airports due to the introduction of (L)H2

Within "section 8 Air traffic control service", SERA.8012 *Application of wake turbulence separation* should be analysed by aircraft manufacturers to determine if LH2 aircraft must have specific procedures of separation in air. In the case of special separation needed for LH2 aircraft, **this could also impact take-off and landing procedures, and thus runways capacity.**

The second IR that may be impacted by the introduction of (L)H2 is in "section 11 Interference, emergency contingencies and interception" with SERA.11012 *Minimum Fuel and Fuel Emergency*. It is relevant to determine if the term fuel oil is too restrictive. It may be more appropriate to use more generic term like "Energy/Combustible".



5.3 Analysis of applicable regulations for Dangerous Goods

Liquid hydrogen must also be considered under the regulation as a **regulated dangerous good** that can be **stored** on the airport (eg. hydrogen capsules), and not just as a propulsion source in aircraft. Although this material is intended for use as a means of propulsion and not as a commercial cargo, its nature qualifies it as a dangerous good.

The only aeronautical safety regulatory requirement applicable to aerodrome operators issued from regulation n°139/2014 in this context is:

IR.ADR.OR. D.020 "Facilities requirements":

(a) The aerodrome operator shall ensure that adequate and appropriate facilities are available to its personnel or personnel employed by parties with whom it has contracted for the provision of aerodrome operational and maintenance services.

(b) The aerodrome operator shall designate appropriate areas at the aerodrome to be used for the storage of dangerous goods transported through the aerodrome, in accordance with the Technical Instructions.

The technical instructions, Doc 9284 Technical instructions of the ICAO, is a **guidance document** relating solely to the air transport of regulated dangerous goods, **not to their possible storage** on an aerodrome by its operator, as is ICAO Annex 18.

In France, the regulation relating to Classified Facilities for Environmental Protection (ICPE – Installations Classées pour la Protection de l'Environnement), and more specifically the rule n°4715, defines conditions and quantities of hydrogen that can be stored in some buildings. A number of those ICPE regulations will be applied with the introduction of (L)H2 on airports and can have an impact on organisations, operations, and design. But in the context of this report, only aeronautical rules have been analysed and ICPE regulations which is about safety and industrial risks are out of this scope.

Any regulations related to the use of buildings should be further studied to determine the regulatory requirements applicable within this perimeter.

5.4 Analysis of additional national regulations

5.4.1 Analysis of additional French regulations

French aerodromes are also subject to national laws and regulations that supplement European regulations. These are divided into 3 parts: the laws, which constitute the legislative part of the French



Transport Code, Book III "Aerodromes"; the Decrees ("décrets"), which constitute the regulatory part of the French Civil Aviation Code, Book II "Aerodromes"; and finally, the Orders ("arrêtés"), which cover various areas such as infrastructures, operating conditions, wildlife hazard prevention, RFFS, etc.

Decree dated by June 9th, 2021, on aerodrome movement area inspections, runway surface condition assessment and runway surface condition reporting. It is suggested to incorporate when appropriate, the characteristics of potential surface damage specific to (L)H2 for personnel in charge of pavement inspections.

Decree dated by January 18th, 2007, on RFFS (Airport Rescue and Fire Fighting service) is a critical part of the regulation which is subject to changes. Indeed, the current RFFS management and methods do not consider the particularities of (L)H2. The aim would be to define reference scenarios to assess the impact on the sizing, resources, methods, and training of RFFS services (all components of the decree).

Decree dated by January 23rd, 1980, and decree dated by December 12th, 2000, on Refueling on aerodromes do not consider the precaution to be taken when refuelling aircraft using LH2 as fuel.

Decree dated by July 10th, 2006 on Aerodrome manual must describe the elements relating to LH2 in the same way as those described for conventional fuels.

5.4.2 Analysis of additional Italian Regulations

The national regulatory framework includes the **Ministerial Decree of June 30, 2011**, issued by the Ministry of the Interior, which establishes safety provisions for refueling (adjacent stands constraints, passenger and vehicle escape routes). A review of the Decree is required, which will require a very long time.

Additional regulatory elements from the National Civil Aviation Authority (ENAC) in Italy are:

- ENAC regulation regarding the "Management of aviation fuel depots..." rev. n° 1 of March 24, 2025, which requires the airport operator to own the aviation fuel storage and distribution infrastructure. This, on the one hand, facilitates the choice to adopt hydrogen as an airport fuel, but requires the airport operator to make additional efforts in terms of costs and expertise;
- ENAC regulation regarding the "Protection of the territory from risks generated by aeronautical activities" rev. n° 0, also dated March 24, 2025, which involves risk assessments for the location of Dangerous Goods storage areas.



Given the above, to date, in Italy, the hydrogen master planning process requires parallel consideration of the supply chain definition, operational and functional requirements (for both GH₂ and LH₂) and the regulatory framework, allowing for feedback between activities, to proceed realistically.

An alternative approach established by ENAC to address new, non-standard infrastructure or operational models, is the concept of a sandbox. Within an ENAC-approved sandbox, the initial introduction of H₂ would be possible, anticipating the national regulatory timeframe.

Due to the absence of national regulations, in parallel to the sandbox, a continuous dialogue with the Italian Firefighter Department must be engaged.

5.5 EASA Evaluation of the Regulation Analysis

Teams in charge of certification and aerodromes in EASA have provided an evaluation of the regulation analysis proposed above.

5.5.1 Clear terminology—"fuel/energy"

EASA can agree to make minimal changes sometime in the long-term to EU ADR Regulation as proposed in the draft OLGA report to better clarify that also hydrogen can be considered as fuel. Since the changes are needed in a distant future from now, EASA declared that they have no immediate plans to introduce such changes in upcoming rulemaking tasks.

The OLGA report shows few IRs where the current text assumes "fuel" means kerosene; hydrogen (LH₂/GH₂) needs explicit inclusion to avoid ambiguity in NOTAMs, AIP content, refuelling rules, fuel quality, and emergency declarations. Proposed edits—e.g., replacing "fuel" with "fuel/energy" and explicitly listing hydrogen. EASA supports those changes they are high level and clarify Implementing Regulations (i.e. rules). However, the change is not urgent and can be done in the next 5 to 10 years.

5.5.2 Regulation 139/2014 – Organisation and Operations Requirements

The following changes could be made in an upcoming RMT (Rule Making Task) over the next years. Since hydrogen aircraft are still a very long time away from realisation EASA advises there is **no hurry to make any changes now.**



➤ **ADR.OPS.A.057 Origination of NOTAM**

- In reference to (b)(9): the term fuel does not include LH2. It can be replaced, for example, by "aircraft energy" to make the fuel generic and not specific to "Fuel". EASA has already submitted in January 2024 an NPA (Notice of Proposed amendment). It is suggested to replace in the SERA Regulation the term "fuel" by "fuel/energy": "The term "fuel/energy" should cater for both typical fuel and any other type or source of energy used for aircraft propulsion, including but not limited to electrical energy stored in batteries" + "Hydrogen may also be used as fuel for fuel cell applications, which generate electricity that is used to generate propulsion."

➤ **ADR.OPS.B.055 Fuel quality**

- This Implementing Rule does not cover (L)H2. This IR may have to include aircraft energies that are not fuels (consideration of "fuels" such as (L)H2).
- There is a need to further check whether changes are required to the control actions under the responsibility of the aerodrome operator whether the scope of the aerodrome operator's responsibility, as defined in the IR, is still appropriate

➤ **ADR.OPS.D.040 Aircraft departure from the stand**

- Some equipment specific to the (L)H2 may have to remain on the apron when the aircraft leaves the apron.

➤ **ADR.OPS.D.060 Aircraft refueling**

- The text does not consider the use of other fuels such as (L)H2. Aircraft refueling procedures may have to consider the particularities of LH2. The regulation may have to be adapted and new procedures on the aerodrome established.

EASA agrees that there is no need to make changes in operational or procedure and Safety Management System rules. They agree with the "*Wait and see*" attitude, as mentioned in this report.



Hydrogen introduces distinct ignition, cryogenic, and plume/water-vapor behaviors requiring specific procedures, training, and emergency planning. The report identifies concrete IRs where operators' manuals, training, apron management, winter ops, jet blast precautions, surface inspection, and rescue and firefighting might have to be amended in the distant future. However, those changes should be carefully assessed before agreeing to change the regulations and/or AMC/GM :

- ADR.OR.D.017 (Training & proficiency)
- ADR.OR.E.005 (Aerodrome Manual)
- ADR.OPS.B.005 (Emergency planning)
- ADR.OPS.B.010 (RFFS)
- ADR.OPS.D.001/ADR.OPS.D.010/ADR.OPS.D.015/ADR.OPS.D.055/ADR.OPS.D.60 (Apron management, jet blast, refuelling) Such updates enable safe operations as hydrogen trials are scale, consistent with the report's gap analysis.

5.5.3 Regulation 139/2014 – Design specifications (CS ADR-DSN)

Major changes should be **deferred until data from OEM** (original equipment manufacturers) becomes available.

The report concludes that only **four** CS items might be affected and *none* requires immediate textual change. Instead, they need validation once OEMs release hard aircraft data (tank position, wheel loads, geometry, refuelling interface, blast profiles):

- CS ADR-DSN.E.355 (Apron strength & resistance to cryogenic spray)
- CS ADR-DSN.F.370 (Isolated aircraft stand—100 m sufficiency for LH₂?)
- CS ADR-DSN.T.900 (Service roads for specialized emergency vehicles)
- CS ADR-DSN.T.905 (Fire stations & facilities).

Given uncertainty (e.g., LH₂ spill/spray impacts on pavements; separation distances), a data-driven revision later is prudent. Meanwhile, operators can address these via local risk assessments and AMC/GM guidance.



5.5.4 Dangerous goods & industrial rules

Recommendation is to keep within non-aerodrome scope but align interfaces.

The report notes LH₂ storage is governed mainly by industrial safety legislation (e.g., ICPE in France), not 139/2014. Harmonization at EU level is desirable, but that sits outside EASA aerodrome CS/IR. For 139/2014, ensure ADR.OR.D.020 (Facilities for dangerous goods) references hydrogen storage locations and PPE specifics, and coordinate with national industrial frameworks.



6 Conclusion and outlook

Airports, with their own energy transition challenges, combined with those of their surrounding areas and all stakeholders in the airport and air transport ecosystem, have many assets that enable them to be catalysts for the development of hydrogen both in their countries and in the areas where they are located.

Airports must begin their transformation into 'hydrogen hubs' capable of distributing hydrogen in very large quantities and at a competitive cost.

This transformation into 'hydrogen hubs' requires adapting energy supply chains to guarantee the security of supply of these new energies, from production to distribution at airport platforms, through the integration of new airport infrastructure, by taking into account new operational challenges, by evolving the regulatory and normative framework, and through forward-looking management of employment and skills.

The regulatory texts studied as part of this project are those relating to airport operations and design that may be linked to master plan studies. Of all the texts studied, the analysis carried out shows that only few articles need to be modified, but many airports authorities' procedures, which are operationally or organizationally based on regulation, will need to be clarified to incorporate the specific characteristics of hydrogen.

More generally, when looking at the regulatory framework applicable to hydrogen in Europe, it clearly emerges that there is currently no harmonisation of industrial rules for the construction and operation of hydrogen equipment at European level. This lack of harmonisation is very detrimental to the future deployment of hydrogen aviation. It prevents the definition of standardised components that can be used at any European airport, increases costs by forcing manufacturers to follow different rules and procedures depending on the country and region, and hinders long-term planning capabilities due to a lack of clarity and visibility on the evolution of the regulatory framework. Harmonising rules and procedures will be a powerful lever for competitiveness for France and Europe in the deployment of airport hydrogen ecosystems.

Associations such as Hydrogen Europe and the Hydrogen Council are raising awareness of this issue by pushing for greater harmonisation at European level.

In 2022, the European Commission, specifically the Directorate-General for Defence, Industry and Space (DG-DEFIS), formed an alliance called AZEA (Alliance for Zero Emission Aviation), with the main objective of removing obstacles to the emergence of electric and hydrogen aviation. One of the



alliance's working groups, led by EASA, will be dedicated to analysing the state of the art in regulations and establishing a roadmap for implementing the standards and regulations needed to regulate airport operations incorporating new energies.

The master plan study carried out for Paris-Charles de Gaulle and the associated pre-feasibility studies have shown that the physical integration of a hydrogen logistics chain and associated infrastructure appears to be possible.

However, to ensure the successful introduction of hydrogen aviation and the preparation of airports at a large scale, other success factors have been identified:

- Access to hydrogen at a competitive cost, thanks to the development of a large-scale economy and the introduction of support mechanisms for infrastructure development to maintain a fair competitive balance between airports and airlines at European and international level;
- Harmonization at the national and European levels of an economic model allocating investment to airports to maintain a competitive balance between airports and airlines;
- Synchronising the roadmaps of the various players in the value chain - regulatory authorities (ICAO, EASA, Standardization entities, etc.), aircraft manufacturers, airports, airlines, energy providers (upstream, midstream, downstream) - to plan the development of the necessary infrastructure in France and even Europe, and at airports, in line with the roadmap of users. Particular attention needs to be paid to the availability of primary energies (volumes, definition criteria);
- A shared and coordinated roadmap between European airports (initially those in the core network defined by the trans-European transport network regulation) to ensure synchronized preparation of a network of airports equipped and capable of operating hydrogen-powered aircraft;
- Each airport should be aware of the challenges it faces (both its own and those of its local area) in terms of hydrogen development, the development of a supply chain and the integration of infrastructure on its site, so that the necessary land can be reserved as of now;
- Carrying out research and development projects and safety studies on aircraft/airport interfaces specific to hydrogen (aircraft operations and refueling at aircraft stations in co-activity, liquid hydrogen distribution systems);
- the management of regulatory and normative issues at national level, with a view to standardization at European and international level, with the identification of an entity responsible for steering the development of the regulatory and normative framework;



- Forward planning for employment and skills, and preparation of large-scale training (standardization of training programs at national level) for personnel working at airports (relevant government departments, emergency services, airport operators, ground staff, airlines);
- National-level management of social acceptability issues surrounding the large-scale introduction of hydrogen in urban areas;
- Integration of the potential impact on airport infrastructure into the design of H2 aircraft solutions to minimize operational impacts and investment and operating costs for the deployment of disruptive energies.



7 Annexes

7.1 Task description included in the Grant Agreement

WP 5.2 H2 Airport Design – Paris Case study (ADP; AL, STAC, EASA, SEA, CLUJ, MZLZ) (M1 – M54)

This task aims to develop an overall integrated “Hydrogen airport master-planning” and to enable key learnings dissemination and thus preparing the pattern for airport community and for replicating such masterplan (to be developed for Paris environment) even in the other OLGA replication airports. ADP, with the support of AL and STAC and under Airbus advisory, promotes a holistic approach of hydrogen topic covering (i) H2 regulation for aviation, (ii) H2 airside and landside infrastructures, (iii) H2 operations and (iv) hydrogen-powered aircraft-airport compatibility, and addressing the whole value chain (production, transportation, liquefaction, storage, distribution, refuelling).

(i) H2 regulation and safety for aviation aspects: will be studied also thanks to Airbus WG⁹ outcomes, focusing on accommodation of the new H2 aircraft during a whole airport stay (runway operations, taxiing, aircraft stand operations, de-icing, maintenance) through a normative / regulation prism and tends to define the required adjustments of airport and H2 regulation frame. As output of this WG, for WP5.2., ADP assesses the impacts of the regulatory frame evolution on its operations and infrastructures.

(ii) (iii) H2 airside and landside infrastructures - H2 operations aspects: ADP and AL study the design and the implementation of H2 infrastructures on both landside and airside. The study takes a long-term perspective, with gaseous H2 infrastructure to supply mobility, logistic and GSE applications and liquid hydrogen infrastructure to supply aircraft. As outputs: - ADP and AL, (i) define the main possible schemes for hydrogen chain supply on airports to fuel aircraft and other local H2 users and (ii) determine the most relevant patterns for H2 distribution on the airside to serve aircraft; - ADP, with AL and STAC support, prepares the master planning of hydrogen infrastructure at CDG until 2035/2040. To ensure that H2 facilities will be properly sized and located to refuel hydrogen-powered aircraft at CDG, Airbus provides the necessary support to assess the hydrogen needs and technical and operational characteristics of these H2aircraft.

(iv) Hydrogen-powered aircraft and airport compatibility aspects: relying on learnings from the studies mentioned above, ADP leads a working group which gathers ADP, Airbus, AL, STAC and airlines and which defines the check-list of all verifications an airport operator has to point out before operating a hydrogen-powered aircraft.(D5.3). This checklist will be reviewed by EASA to ensure airport safety stakes are well screened and shared.

⁹ WG which gathers experts from airports (including ADP), H2 industry (Air Liquide), French Civil Authorities, GSE manufacturers – Airbus is AB advisory Board



8 References

French Aviation Decarbonization Roadmap, March 2023

In this report, paragraphs 4.3. and the outlook contained in the conclusions chapter are based on study findings produced by ADP as part of a national regulatory exercise. Indeed, in 2022, ADP was designated as co-rapporteur for the French Aviation Decarbonization Roadmap (Feuille de Route de Décarbonation de l'Aérien, published in March 2023), especially for sections related to the adaptation of airport infrastructure to new energies.

The elaboration of French Aviation Decarbonization Roadmap was managed under the supervision of the French Government, since it is a document legally required by the Loi Climat et Résilience – Article 301. [Proposition de feuille de route décarbonation transport aérien.pdf](#)

Other study reports on hydrogen development at airports

Over the past five years, several consulting firms, associations and consortiums have published studies on the deployment of hydrogen, including its development at airports. These studies, which run parallel to the one described here and carried out as part of the OLGA project, can reinforced some conclusions of the study led by ADP.

Among these other study reports, those that can be cited are:

- Integration of Hydrogen Aircraft into the Air Transport System: an airport operations and infrastructure review, ACI and Aerospace Technology Institute, 2021. Groupe ADP, Air Liquide and Airbus have been contributors.
- Hydrogen infrastructure and operations – Airports, airlines and airspace, Aerospace Technology Institute, March 2022
- Airports as Catalysts for Decarbonization, Jacobs, 2022