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H2YDEA

Boosting the hydrogen transition in the Atlantic Area ports

Deliverable D 5.2.1

Methodology for the qualification of case studies

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EXECUTIVE SUMMARY

The purpose of deliverable D5.2.1, *"Methodology for the qualification of case studies,"* is to define a unified approach for assessing the case studies prepared by HYDEA partners as part of activity 5.2, *"Technical, economical, environmental and social assessments for each case study."* This deliverable supports the broader objectives of Work Package 5, which focuses on developing case studies, business models, and a Decision Support Tool (DST). Within this framework, the evaluation of each case study aims to identify relevant hydrogen applications in ports and assess their potential contribution to the decarbonation strategies of the participating ports.

This document sets out a shared structure and methodological basis for conducting these evaluations. It offers guidance intended to ensure that activity 5.3, dedicated to business model development, is informed by consistent performance indicators. It also supports the development of the DST under activity 5.4, whose goal is to provide a practical tool to assist port authorities and stakeholders in selecting the most suitable hydrogen technologies.

To achieve this, the deliverable introduces a common evaluation framework built around a core set of Key Performance Indicators (KPIs) to be applied across all case studies. Additional site-specific indicators may be included when relevant, particularly when they can contribute to refining the DST. The KPI categories cover four main dimensions:

- Technical performance
- Economic feasibility
- Environmental impact
- Social considerations

Although this methodology provides an overarching structure, its application must be adapted to each individual case study to account for diverse local conditions, technological contexts, and economic constraints.

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ABBREVIATIONS AND ACRONYMS

APDL	Administração dos Portos do Douro, Leixões e Viana do Castelo SA = Port of Leixões port authority
APS	Autoridad Portuaria de Sevilla (Port of Seville)
CAPEX	CAPital EXpenditures = investment cost of a project
DST	Decision Support Tool
FC	Fuel Cells
FEM	France Energies Marines
H_2	Hydrogen
H2X	A technology that transforms hydrogen in electricity and heat for multiple uses
ITG	Centro Tecnologico Nacional
KPI	Key Performance Indicator
NUI	National University of Ireland
OPEX	OPerational EXpenditures = operationnal cost of a project
UPORTO	University of Porto

1 Introduction

The HYDEA project aims at accelerating the development and integration of green hydrogen-based technologies in the Atlantic Area port with the goal of decarbonizing ports activities, and improve energy efficiency.

As such, the definition of hydrogen use cases in ports is developed in Work Package 5 with the objective of evaluating which hydrogen based solution can be incorporated in port activities. Further to the identification of relevant case studies for each port partner of the project in previous activities, the objective of activity 5.2 is to progress towards practical implementation of the selected solution with the development of case studies, evaluating the interest of several green-hydrogen based solutions for port operations

To achieve this, this deliverable introduces a common evaluation framework built around a core set of Key Performance Indicators (KPIs) to be applied across all case studies. Additional site-specific indicators may be included when relevant, particularly when they can contribute to refining the DST. The KPI categories cover four main dimensions:

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- Social considerations

2 Case studies definition

Based on the outputs of D.4.4.1 "*Opportunities of H_2 application in HYDEA ports*", each partner has selected the use case that was the more in line with its expertise and projected interest and proposed a case study based on their specific context.

The case studies selected by the HYDEA partners cover the complete value chain of hydrogen from production to end uses, such as Onshore Power Supply, decarbonation-oriented retrofitting, H_2 as a fuel for vehicles and port equipment and H_2 as a fuel for vessels.
A synthesis of the case studies and of their geographic repartition is available below.

N°	Use Case	Case study	Country	Partners
1	H_2 FC application for vehicles and equipment	H_2 as a fuel for dumper retrofit	Spain	ITG
2	Hydrogen based fuels for vessels	H_2 as a fuel for vessels	Spain	ITG
3	H_2 based electrical production for port consumption: onshore power supply	Onshore Power Supply	Spain	APS

4	Production of H_2 from marine and other renewables energies	H_2 production involving marine renewables	France	FEM, BrestPort
5	Production of H_2 from marine and other renewables energies	H_2 production through steam methane reforming	France	BrestPort, H2X
6	Equipment retrofit and dedicated H_2 equipment for logistics	Retrofitting and decarbonizing key port energy consumers (tugboat, cranes, etc.)	Portugal	APDL, UPORTO
7	Import/Export of H_2, ammonia and/or methanol	Import/Export of H_2-based energy vector (methanol)	Portugal	APDL, UPORTO
8	H_2 storage, distribution and infrastructure	H_2 refuelling station	Ireland	HIVE/NUI

The generic frame of each case study has been developed within activity 5.1, with a first definition of the scope of each case study, the objective of the hydrogen-based technology and a provisional timeline to implement it.
The evaluation of the case studies by Activity 5.2 has the following objectives:

- Provide technical details for the implementation of the case study
- Assess the performance of the solution proposed by the case study (compared to a reference scenario whenever possible) on 4 topics:
    - Technical performance and progress
    - Economical evaluation
    - Environmental performances
    - Social evaluation

To establish a shared evaluation framework, this document outlines the methodology and key recommendations for assessing each case study. It also specifies the essential Key Performance Indicators that must be produced as evaluation outputs. These results will subsequently support the development of the Decision Support Tool created under activity 5.4 of this work package.

3 Evaluation methodology

Whenever possible, the case study developed with hydrogen-based technology should be compared to a "reference case" corresponding to a business-as-usual technology. In that sense, the reference case should preferably include the current state solution (usually fossil-fuel based). If other hypothetic solutions are also investigated, they can be included as well in the comparison exercise. For instance, case studies #7 and #8 may want to establish the CO2 emissions for a fossil-fuel consumption that would be equivalent to the consumption of methanol or H2 distributed.
The comparison of the economic and environmental performances between the different scenarios is particularly recommended as well.

For example, for the FC application for trucks, the case study based on hydrogen-powered fuel cell should be compared to the use of a conventional diesel truck.

3.1 Technical evaluation

The technical evaluation of the case study aims at defining the technical requirements needed for the implementation of the solution within an identified timeframe.

The common KPI for the technical performances of the hydrogen-based solution are:

- Technology Readiness Levels (TRLs, Figure 1) of the corresponding hydrogen-based solution before and after the HYDEA project
- Annual volume of H_2 produced/imported/delivered/consumed (depending on the case study type)

Additional recommended indicators include:

- TRL of each technical component required to realize the case study, before and after the HYDEA project
  List of the key infrastructure modifications required for the port (i.e. operational shifts required to switch from conventional to hydrogen based technology)
- Main technical challenges required to deploy the solution
- Include safety considerations and recommendations (or possibly in the environmental and social assessment)

In the case HYDEA did not lead to significant TRL progress in the case study considered, or if TRL steps are not relevant for your case study, precisely describe the technological bottlenecks that were addressed during the project, and how the actions taken during HYDEA paved the way to the next step of technical maturity of the technology.

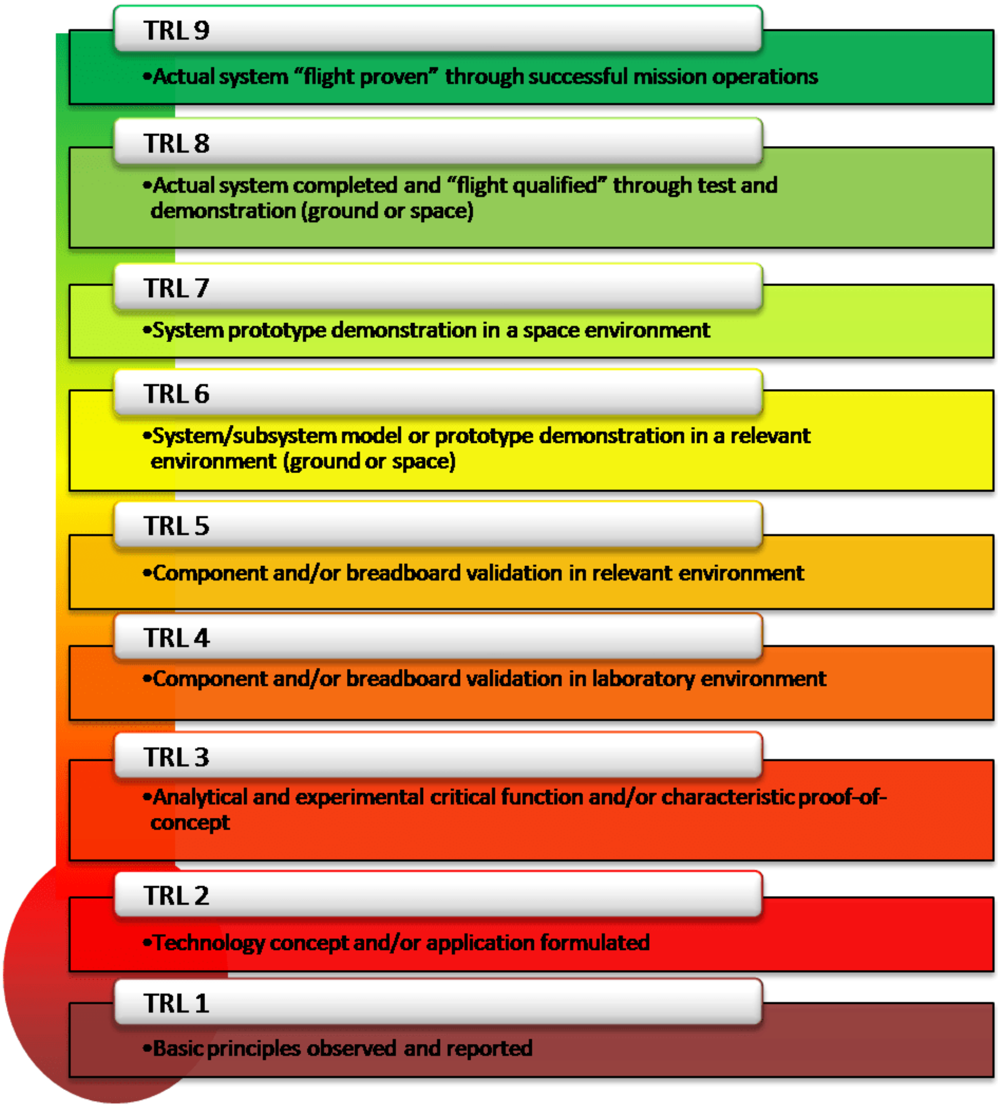

Figure 1 : Technology Readiness Levels - NASA definition (source: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/)

For example, for hydrogen production from renewable energies, typical outputs of the technical evaluation should be:

- *500 ktH_2 produced per year: 70% from offshore wind and 30% from solar panels.*
- *TRL of the hydrogen-based technology is 4-5 for solar panels and 5 for offshore wind although demonstration of this case study is not planned in the scope of HYDEA project.*

Additional case-specific indicators include:

- Capacity factor of the hydrogen-based solution per year to identify the viability of it.
- Etc.

3.2 Economic performance

Using the results of the technical assessment and the available data, each case study is also assessed from an economic point of view.

The common KPI for the economic performances of the hydrogen-based solution are:

- CAPEX: Capital Expenditures corresponding to the initial investment costs for the development and initialisation of the hydrogen-based solution. A breakdown of the CAPEX of the different elements involved in the case study, rather than an overall CAPEX, is recommended.
- OPEX: Operational Expenditures corresponding to the operation costs of the implementation of the solution during its design life
- Total Cost of Ownership (TCO) = CAPEX + OPEX
- For production-oriented case studies, Levelized Cost of Electricity / Levelized Cost of Hydrogen assessment is necessary
- For consumption-oriented case studies, including retrofitting, the energy consumption costs by the (possibly retrofitted-) technology should be assessed
- For storage/import/export case studies, the estimated cost of import/export operations (port handling operation for example) and the storage cost of the hydrogen-based technology should be assessed.

Comparison of the economic KPI of the hydrogen-based solution with the “reference case” (business-as-usual case) is highly recommended.

Additional recommended indicators, strongly recommended for the case studies that will feed business models, include:

- Levelized Cost of Hydrogen/Levelized Cost of Electricity
- Internal Rate of Return (IRR) of the solution, provided that the case study includes a financial breakdown, would help feeding the business model’s step
- Net Present Value (NPV) of the solution corresponding to the difference between the present value of cash inflows and the present value of cash outflows over a specific period of time
- Electrical consumption and cost
- Overview of foreign financial investments injected in the local economy
- Assess the environmental taxes reduction

For each case study, the use of robust economic hypothesis is recommended to establish the economic performance of the hydrogen-based solution. For some case studies however, the maturity of the hydrogen-based solution developed is not sufficient to get access to the hypothesis needed for a robust economic evaluation. In that case, the use of values extracted for the scientific literature or other study reports is recommended. A non-exhaustive list of some bibliography that can feed the economic case study evaluation is:

- International Energy Agency report: -https://www.iea.org/reports/the-future-of-hydrogen
- Other European projects on hydrogen-based solutions. For example:

- Clean Hydrogen Partnership's Study on hydrogen in ports and industrial coastal areas by Deloitte.
- NREL study Hydrogen Infrastructure Analysis for Port Applications
- …

3.3 Environmental evaluation

A core pillar of the HYDEA project is the environmental validation of green hydrogen for port decarbonization. Beyond economic factors, each case study must analyze the environmental trade-offs of the proposed solution compared to the status quo. While a comprehensive Environmental Impact Assessment is out of the scope of the present work, the study must provide a clear qualitative or, whenever possible, quantitative evaluation of the solution's ecological impact to ensure its overall acceptability.

The common KPI for the environmental performances of the hydrogen-based solution are:

- (Avoided) Green House Gas (GHG) emissions and corresponding CO2-equivalent value compared to the reference case
- Electrical consumption
- Land use: surface required , mandatory if land artificialisation is necessary
- Water consumption

Comparison of the GHG of the hydrogen-based solution with the "reference case" is highly recommended.

In addition, the environmental evaluation shall discuss how the solution can qualitatively affect the environment:

- Air quality (reduce SOx, NOx, Particulate Matter and other pollutants)
- Water releases (brine, warm water, etc)
- Chemical releases (anti-fouling paints, chemical/fuel spills, etc)

Additional performance parameters can include, when relevant:

- Captured CO2
- Noise level reduction compared to regular diesel/LNG engines
- Cleaner/safer workspace (no toxic fumes)

For GHG emissions estimate, the source of the emission factor should be mentioned in the bibliography of the case study evaluation. For this evaluation, the use of national database is preferred to ensure the accuracy of the evaluation. In the absence of existing database, the following database can be used:

- International Energy Agency Emissions factors datasets: https://www.iea.org/data-and-statistics/data-product/emissions-factors-2025
- GHG protocol databases: https://ghgprotocol.org/life-cycle-databases

- For France for example, Base Carbone® database shall be used.

3.4 Social evaluation

The case study is finally expected to bring specific social benefits compared to business as usual solutions. Industrial zones disproportionately affect, usually lower-income, fence-line neighbourhoods. Implementing green-hydrogen solution in ports decouples industrial activity from local air pollution and socially secures a port's "license to operate" while fostering a just transition. Reskilling workers for hydrogen infrastructure transforms traditional labor into high-tech "green-collar" roles, ensuring long-term community support.

The common KPI for the social evaluation of the hydrogen-based solution are:

- Employment (highly recommended indicator): Number of jobs needed to operate/maintain the H_2-based solution compared to current jobs for the reference case technology
- Assess public outreach opportunities:
    - Build knowledge on hydrogen production/usage
    - Increase public awareness
- Relations with local residents:
    - New job opportunities
    - Reduce pollutions of all kinds (air quality, noise)
    - 24/7 ports operation thanks to reduced noise pollution
    - Improved air quality (safer working environment)

Table 1. Example of social evaluation for FC power solution

TOPIC	HYDROGEN-BASED SOLUTION	REFERENCE SCENARIO
	FC powered terminal tractor	**Conventional diesel terminal tractor**
Employment	10 drivers for the operation 2 skilled-technicians for the maintenance X engineers for the development of the solutions 1 additional contract for safety considerations (ATEX areas for hydrogen storage / container swap)	10 drivers for the operation 2 mechanics
Qualification	Additional training needed for hydrogen handling	-
Social acceptability	Air quality improvement Noise reduction	Pollution

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