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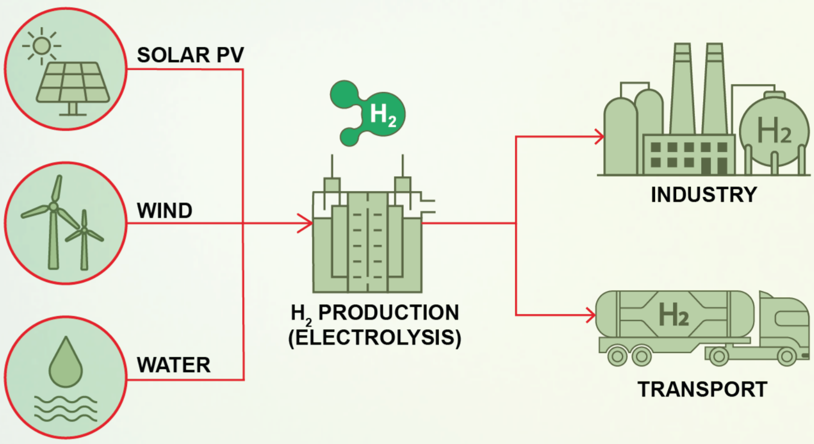
DE INVESTIGAÇÃO

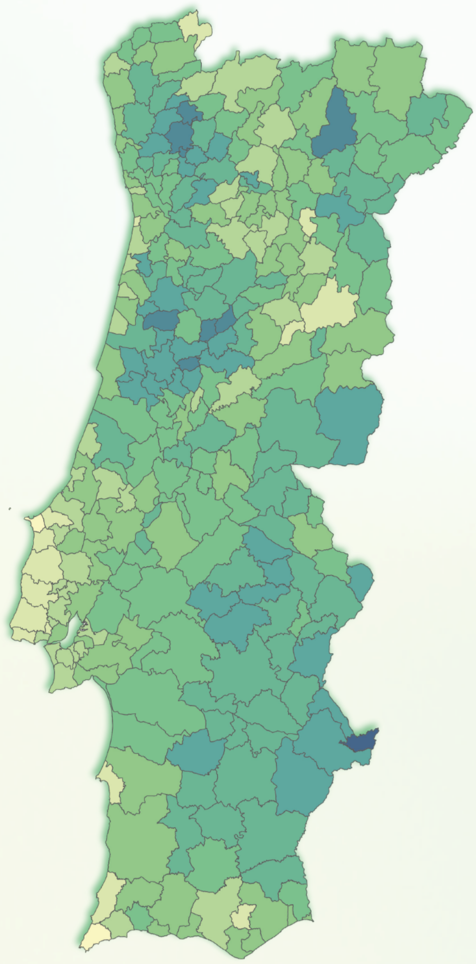
Geospatial Hydrogen Cost Calculator

LNEG-H_2PTMap

Geospatial Green Hydrogen Cost Assessment for Portugal

Municipality-level LCOH, renewable electricity and water resource analysis





LNEG-H_2PTMap
Geospatial Hydrogen Cost Calculator

Technical report
June 2026

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Title

LNEG-H_2PTMap - Geospatial Hydrogen Cost Calculator

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PRR Plano de Recuperação e Resiliência
REPÚBLICA PORTUGUESA
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Nomenclature

AEP	Annual electricity production
AHP	Annual hydrogen production
AHP_{nom}	Annual nominal hydrogen production - as specified by manufacturer
ALK	Alkaline electrolyser
AMM	Ammonia
ANTRAM	The National Association of Freight Transport Companies
CAPEX	Capital expenditures
DECEX	Decommissioning expenditures, or end-of-life costs
DTMN	A four-digit code for territorial Division of Municipalities
E-PRTR	European Pollutant Release and Transfer Register
ERSAR	Entidade Reguladora dos Serviços de Águas e Resíduos
GHG	Greenhouse gas
GIH	Global horizontal irradiation
H_2	Hydrogen
HICP	Harmonised index of consumer prices
HRS	Hydrogen refuelling station
HVO	Hydrotreated vegetable oil
IEA	International Energy Agency
IMT	Institute for Mobility and Transport
IPPC	Integrated Pollution Prevention and Control
IRENA	International Renewable Energy Agency
LCOE	Levelised cost of electricity
LCOH	Levelised cost of hydrogen
NECP	National Energy and Climate Plan
NEPS	Number of hours at full capacity (h/year)
O&M	Operation and maintenance
OEM	Original equipment manufacturers
OPEX	Operational expenditures
$OPEX_{fix}$	Annual fixed operational expenditures
$OPEX_{var}$	Annual variable operational Expenditures
P2X	Power-to-X
PEM	Proton exchange membrane electrolyser
PR	Performance ratio
PV	Photovoltaic
R&D	Research and development
RES	Renewable energy sources
RO	Reverse osmosis
RRP	Recovery and Resilience Plan
SWRO	Sea water reverse osmosis
WACC	Weighted average cost of capital
WO	Onshore wind

WWSRA	Water and Waste Services Regulatory Authority
WWTPs	Wastewater treatment plants
r	Annual discount rate
$r_{\mathrm{degradation}}$	Annual rate of degradation
t	Year t
t_{f}	Last year of operation of the assets, i.e., end of lifetime year

1 Introduction

The National Laboratory for Energy and Geology (LNEG) presents the first version of the LNEG-H_2PTMap Tool, available through the LNEG geoPortal. This free geospatial calculator enables the rapid estimation of the Levelised Cost of Hydrogen (LCOH) across the 278 municipalities of mainland Portugal. The tool integrates the costs of green hydrogen (H_2) production with the main components of its value chain applicable to the transport and industrial sectors, including storage and distribution to the end user, enabling flexible analyses based on up-to-date reference parameters and local conditions. The LNEG-H2PTMap Tool was developed under the "H_2 Cost Geospatial Simulator" initiative within the framework of the PRR Agenda M-ECO2. This report describes the methodological approach adopted for the development of the tool, including its cost calculation framework, data sources, assumptions, and implementation.

Unlike other hydrogen cost assessment tools, such as the European Hydrogen Observatory's LCOH Calculator, which primarily provide estimates based on country-level datasets, the LNEG-H_2PTMap Tool enables the estimation of levelised hydrogen costs at the municipal level throughout mainland Portugal. To the best of the authors' knowledge, no publicly available tool currently provides municipality-level levelised hydrogen cost estimates covering all municipalities of mainland Portugal. This finer geographical resolution enables the incorporation of spatial variations in key cost determinants, including renewable electricity availability and costs, water sourcing and treatment requirements, and hydrogen transportation distances. Consequently, the tool can reveal cost differences between municipalities that may be obscured when using national or regional averages, thereby supporting more informed investment, planning, and policy decisions.

By capturing these spatial variations at the municipal scale, the tool addresses a concrete need identified by industry stakeholders, investors, researchers, and policymakers for a practical, transparent, and evidence-based decision-support instrument. The LNEG-H_2PTMap Tool facilitates the identification of cost-competitive locations for green hydrogen production, storage, and distribution, thereby supporting strategic planning and contributing to the accelerated, efficient and targeted deployment of the green hydrogen economy in Portugal.

The following sections provide an overview of LNEG and its research units, followed by an explanation of the tool's purpose and the exclusions applied in the LCOH calculation.

1.1 The National Laboratory of Energy and Geology (LNEG) at a glance

The National Laboratory of Energy and Geology, I.P. (LNEG) is a research organisation, which carries out Science in the domains of Energy, Geology and Geological Resources with a view to its application in advanced solutions that allow the leverage of the Portuguese Economy. LNEG is under the tutelage of the Ministry of Environment and Energy of Portugal.

LNEG, under the motto "Building a cleaner, future" has, as Mission, to promote and carry out research, demonstration and knowledge transfer actions, technical and technological assistance and laboratory support for companies, in the domains of Energy and Geology (Decree-Law nr. 129/2014 of August 29).

LNEG's vision is to be a reference institution capable of contributing with excellent solutions for a decarbonised economy. The Values followed by LNEG focus on Excellence, Commitment, People, and Innovation.

In 2010, The National Laboratory of Energy and Geology adhered to the principles of the European Charter of Researchers and the Code of Conduct for the recruitment of researchers. In 2013, LNEG received the right to use the logo of Excellence in Research HR.

LNEG is scientifically organized into two main laboratories: the Laboratory of Energy (LEN) and the Laboratory of Geology and Mines (LGM). Furthermore, there is a transversal research unit named Resource Economics Unit (UER), and various administrative and management supporting units to ensure LNEG's smooth operation (e.g., Strategic Management Unit, Management and Organization Department, and others).

Grounded on the values of Excellence, Commitment, People, and Innovation, LNEG aims to contribute towards building a cleaner and better future.

1.1.1 Laboratory of Energy (LEN)

LEN operates in the areas of renewable endogenous energy resources and energy efficiency. It has the responsibility of developing knowledge about the potential of renewable energy sources (RES) and exploring innovative and strategic technologies to support the optimal use of resources. The accumulated knowledge from its research activity allows it to be in a permanent readiness to support the implementation of public policies and the business sector. LEN is divided into three main units:

- Bioenergy and Biorefineries Unit
- Renewable Energies and Energy Eficiency Unit
- Materials for Energy Unit

1.1.2 Laboratory of Geology and Mines (LGM)

LGM performs permanent functions of the State in the development of geoscientific knowledge of the emerged territory, the continental shelf and deep water zones. It is also responsible for the systematic geological survey of geological risks and resources, including geothermal energy resources, geological storage, namely CO_2, and geological heritage. It performs functions of the National Geological Service. The accumulated knowledge from its research activity allows it to be in a permanent readiness to support the implementation of public policies and the business sector. LGM is divided into four main units:

- Geology, Hydrogeology and Coastal Geology Unit
- Geoscientific Information Unit
- Mineral Resources and Geophysics Unit
- Mineral Technology and Science Unit

1.1.3 Accredited Laboratories

LNEG counts on three accredited laboratories that serve government, industry, and society:

- Laboratory of Biofuels and Biomass

- Laboratory of Materials and Coatings
- Laboratory of Solar Energy

1.1.4 LNEG as a contributor of innovation ecosystems

LNEG is part of five technological infrastructures in which close cooperation is established between public and private partners to foster innovation ecosystems, taking advantage of existing complementary knowledge, equipment, and experimental facilities. These structures are also open to external cooperation. Some of them are listed here:

- BBRI – Biomass and Bioenergy Research Infrastructure;
- C4G – Collaboratory for Geosciences;
- INIESC – National Research Infrastructure for Concentrating Solar Energy;
- NZEB LAB – Research Infrastructure on Integration of Solar Energy Systems in Buildings;
- WindScanner – The European WindScanner Facility.

Collaborative Laboratories (CoLabs) form part of a recent approach of the Portuguese State, and LNEG develops activities within the framework of the following CoLabs:

- CoLAB BIOREF - Collaborative Laboratory for Biorefineries;
- HyLAB - Collaborative Laboratory for Green Hydrogen;
- CECOLAB – Collaborative Laboratory Towards Circular Economy; and
- GreenCoLab – Oceano Verde Association.

Collaborative Laboratories also aim to have a positive effect on qualified and scientific employment in Portugal through the definition and implementation of research and innovation agendas aimed at creating economic and social value.

LNEG is also the Portuguese Geological Survey and is a full member of the European Geological Surveys, EuroGeoSurveys. Also noteworthy is the activity of the three lithotheques managed by LNEG, in which, in addition to 700 thousand meters of drilling cores, more than a hundred geological sections are also available for consultation, as well as thousands of samples, thin sections of rocks and microfossil cells. These provide valuable scientific information to researchers, students, local authorities, organisations, and companies. LNEG also manages the geoPortal of Energy and Geology

The Geological Museum is also an important asset of LNEG, which provides regular public visits to its museological space. Reference collections are also available for consultation and study by researchers, both in Portugal and abroad.

1.2 The Resource Economics Units (UER)

The Resource Economics Unit (UER) operates across the Energy and Geology areas of LNEG. It develops R&D&D (Research, Development and Demonstration) activities and decision-support tools for public policy makers and the private sector in energy and geological resource economics, aiming at carbon neutrality and sustainable resource exploration and use of resources. The unit applies techno-economic and social analytical approaches in the areas of (1) Sustainable energy systems, (2) Use of resources for energy production and consumption, (3) Classification of national geological deposits and energy resources in a global economy, (4) Economic and social impact of the energy transition, and (5) Circular economy, including the design of products, services, systems, and business models. UER is the unit responsible for the creation and maintenance of the LNEG-H_2PTMap tool and serves as an interface for external users.

1.3 Purpose of the LNEG-H_2PTMap Tool

The purpose of the LNEG-H_2PTMap tool - Geospatial Hydrogen Cost Calculator, is to provide a free service for the quick estimation of costs over different components of the hydrogen value chain at municipality level in mainland Portugal. The tool is envisioned to provide flexibility according to the users' needs and to provide reference values based on current trends.

LNEG is actively contributing to reducing the gap between research and the market by supporting innovation. LNEG develops high-added value tools for public use to analyse the value and supply chains associated with hydrogen and closely monitors the exchange of ideas in this emerging area.

1.4 Version

The version of this release is identified as Beta Version 01.2026. Please visit Section 4.1 for more information about contacts and how to submit a bug report or other inquiries.

1.5 Exclusions

The LNEG-H_2PTMap tool version described in this manual excludes the following variables, items, components, parameters, ideas, or dimensions in LCOH calculation:

- Taxes, subsidies or incentives in any form;
- Distribution via pipeline;
- Underground storage in salt cavern;
- The consideration of other co- or by-products like oxygen and their economic leverage or other sustainable fuels that can be produced with green hydrogen, e.g., hydrotreated vegetable oils (HVO) or ammonia (NH_3);
- Credits associated with the reduction of Greenhouse Gas Emissions (GHG).

1.6 Structure of this Document

This document is divided into four main sections. Section 1 presents an introduction of LNEG, the objective of the LNEG-H_2PTMap Tool, and the version control. Section 2 presents the overall LCOH computation methodology and the LNEG-H_2PTMap Tool workflow. Section 3 presents the reference values and scenarios case studies. Section 4 presents information about contacts and how to report Bugs, Suggestions, and Comments. Supplementary details are also provided in the Appendices.

2 Hydrogen Cost Computation Methodology

This section presents the methodology used for the calculation of the levelised cost of hydrogen (LCOH). It starts with the LCOH definition and equation, describes the different modes, scope and value chains considered in the calculation process, and continues with a holistic overview of the corresponding LNEG-H_2PTMap Tool's components implemented in the current version.

2.1 What is a Levelised Cost of Hydrogen?

a The levelised cost of hydrogen (LCOH) is an indicator or metric that has been widely accepted to compare options for projects involving hydrogen or other energy projects, which also serves to assess the competitiveness of such projects. It is also a method that serves to evaluate the costs involved in hydrogen projects throughout their entire lifecycle. Furthermore, it represents the minimum lifetime-averaged selling price of hydrogen in order to have the expected returns.

The LCOH enables policymakers, investors, industrial players, and other economic agents to make better-informed decisions regarding strategies for the promotion of cost-effective, sustainable hydrogen business cases and the subsequent allocation of resources.

The LCOH could be defined as a metric that relates all the expenses over the lifetime of the hydrogen assets, including capital expenditures or investment costs (CAPEX), the operational and maintenance costs (OPEX), and decommissioning expenditures (DECEX) or end-of-life costs, to the production or reference amount of hydrogen. Costs associated with the balance of plant (BoP), including auxiliary systems and internal storage integrated within the electrolysis plant, are considered within the corresponding CAPEX, OPEX, and DECEX categories. The LCOH considers all quantities (costs and amount of hydrogen) discounted over time at an annual discount rate and their contribution from the beginning until the end of the operation, i.e., the lifetime of the project.

The following general formula is used in the LNEG-H_2PTMap tool to compute the levelised cost of hydrogen:

$$\mathrm{LCOH} = \frac{\mathrm{CAPEX} + \sum_{t=0}^{t_f} \frac{\mathrm{OPEX_{fix}} + \mathrm{OPEX_{var}}}{(1+r)^t} + \frac{\mathrm{DECEX}}{(1+r)^{t_f}}}{\sum_{t=0}^{t_f} \frac{\mathrm{AHP}}{(1+r)^t}} \tag{2.1}$$

where the new variables are: fixed operation and maintenance costs - $\mathbf{OPEX_{fix}}$ (e.g., labor, administrative costs, or other costs not dependent on variations of the amount of hydrogen), variable operation and maintenance costs - $\mathbf{OPEX_{var}}$ (e.g., electricity, water for hydrogen production, electrolyser stack replacement, fuel, or other costs dependent on the amount of hydrogen produced, liquefied, stored, transported, or distributed), the discount rate - $\mathbf{r}$, the year of expenditure or hydrogen production - $\mathbf{t}$, where the $\mathbf{t_f}$ corresponding to the final year, and the term **(AHP)** denotes the annual hydrogen production or, depending on the component analysed, the equivalent annual amount of hydrogen stored, transported, or distributed.

Equation 2.1 represents the general equation for the LCOH calculation for any of the components within value chains implemented in the tool. It should be noted that the current version of the tool includes decommissioning expenditure or end-of-life costs - $\mathbf{DECEX}_{tf}$ (i.e., costs associated with dismantling, removal, and site restoration at the end of a project's operational lifetime) in the LCOH calculation for all of the components in the value chain, except "Hydrogen road transport distribution" which refers to the trucks used to deliver hydrogen from the origin to the destination. It is excluded from the DECEX calculation because this component is represented by trucks used for hydrogen delivery, rather than by stationary infrastructure requiring site dismantling and restoration.

The definition of LCOH adopted and presented in Equation 2.1 is equivalent to the Levelised Cost of Electricity - **LCOE**, and therefore the conversion of the LCOH expressed in EUR/kgH_2 could be easily translated to EUR/MWh. This allows easier comparisons between different energy projects beyond hydrogen ones.

2.2 The LNEG-H_2PTMap Tool Overview

The LNEG-H_2PTMap tool - Geospatial Hydrogen Cost Calculator, is an interactive GIS-based simulator providing levelised green hydrogen cost estimations across the entire hydrogen value chain for all 278 municipalities in mainland Portugal (A list of the municipalities is presented in Appendix E. The tool moves beyond basic calculation by integrating geospatial layers to deliver detailed and region-specific LCOH insights through an intuitive mapping interface.

To avoid ambiguity between the overall hydrogen transport value chain and the specific component related to hydrogen distribution via road transport and specifically by truck, the term **"hydrogen road distribution"** is used throughout this report to refer specifically to H_2 road transport component.

The LCOH calculation in the LNEG-H_2PTMap Tool is organised and starts by choosing one of the two distinct operational modes (Figure 2.1):

1. **Reference LCOH for continental Portugal**: This mode provides predefined values for each parameter used in the current version of each value chain;

2. **LCOH with user-specified variables**: This mode allows users to customise the values of the input parameters.

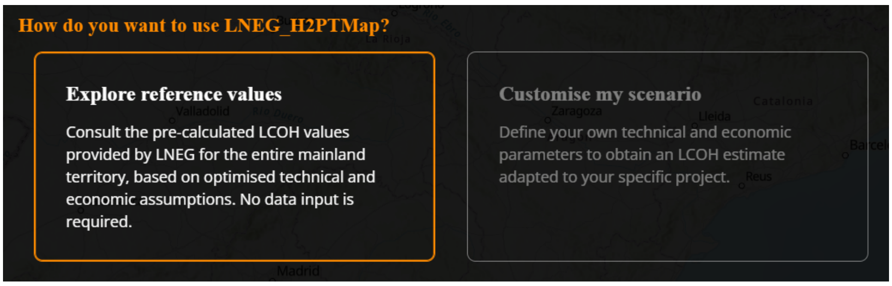

Figure 2.1: Two different modes considered in the LNEG-H_2PTMap Tool.

In each mode, three scope configurations are considered along with their corresponding components, as presented below:

1. **H_2 Production (only) Scope**, which focuses exclusively on the costs associated with green hydrogen production. This configuration is limited to the H_2 production component.
2. **H_2 Transport Scope (Value Chain)**, which considers the full costs associated with hydrogen production, distribution, and delivery to the mobility sector, specifically through hydrogen refuelling stations (HRS). This configuration includes the following components: (i) H_2 production, (ii) H_2 storage, (iii) H_2 road distribution, and (iv) H_2 refuelling stations.
3. **H_2 Industry Scope (Value Chain)**, where the tool analyses the integrated costs of supplying green hydrogen for industrial end-uses. This configuration includes the following components: (i) H_2 production, (ii) H_2 storage, and (iii) H_2 road distribution.

Figure 2.2 shows the three scopes considered in the tool, which can be selected individually to calculate the corresponding LCOH in either Reference mode or Customised mode with user-defined input values.

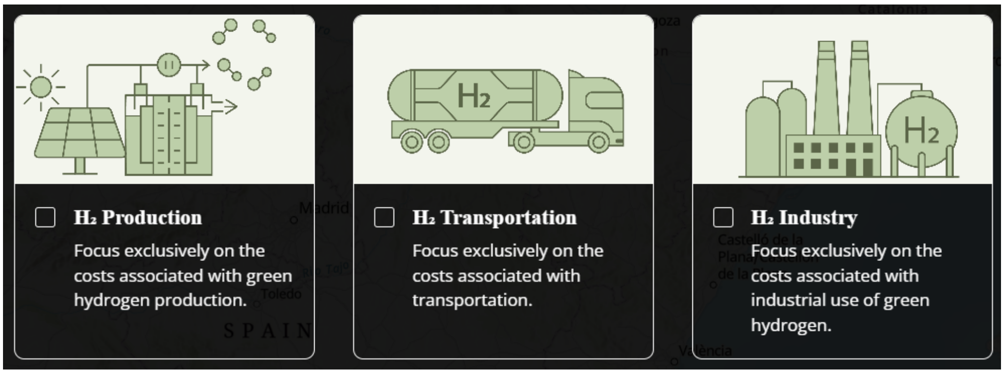

Figure 2.2: Three hydrogen scopes considered in the LNEG-H_2PTMap Tool.

Each path and its corresponding components will be described in more detail in the following sections. Once all required filters, inputs and parameters are completed, the tool processes the data and generates the results. These results can then be explored through tables, graphs and/or map visualisations, depending on the selected mode and scope configuration.

Figure 2.3, shows an overall workflow of the LNEG-H_2PTMap Tool. The hydrogen value chain may be considerably broader than the components currently implemented in the tool. However, project constraints and time limitations have defined the scope of the present version of the LNEG-H_2PTMap Tool.

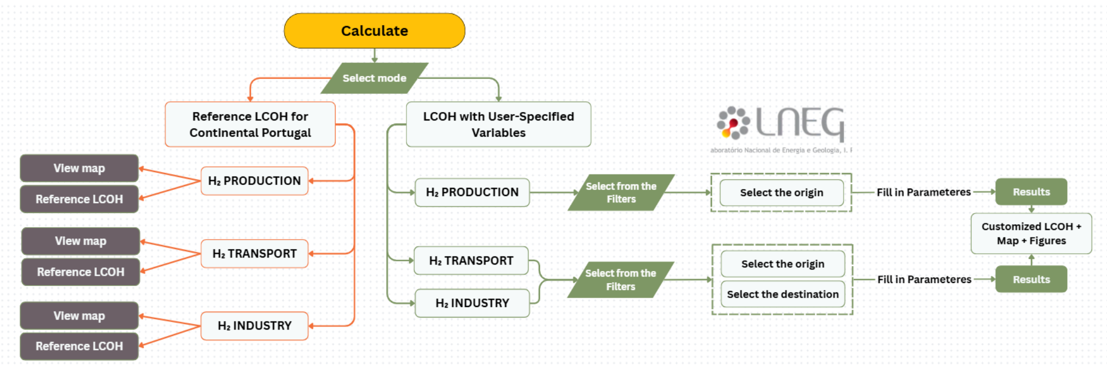

Figure 2.3: Overall workflow of the LNEG-H_2PTMap Tool

2.3 H_2 Production (only) Workflow

Mode and Origin Identification

As illustrated in Figure 2.4, the workflow of the H_2 production (only) scope is structured around a sequential process that begins with the selection of the operational mode, namely reference or customised. Thereafter, the geographical origin, which defines the location of potential hydrogen production sites, is defined as the basis for the assessment; this may be specified either through direct selection of a municipality on the map or via the search bar or drop-down list.

Reference Mode Pathway and Results

In the reference configuration, different scenarios were pre-calculated for continental Portugal. For scenario selection, a set of parameters requires specification via filter selection, namely the electrolyser type (PEM or ALK), water input type (Grid Water, WasteWater, or SeaWater), and the composition of the renewable electricity mix, i.e., Solar PV and Onshore Wind (WO) share (%), selected from predefined options: (a) PV[100%] – WO[0%], (b) PV[75%] – WO[25%], (c) PV[50%] – WO[50%], (d) PV[25%] – WO[75%], and (e) PV[0%] – WO[100%]. The same set of filters is also required for scenario specification in the H_2 Transport and H_2 Industry scopes (value chains).

Once the scenario parameters are selected, the results of LCOH are presented, either for a specific municipality or for all municipalities in mainland Portugal, through a map-based interface, as well as tabular and graphical outputs. The map displays the corresponding LCOH value when the user hovers over a municipality, while the tabular outputs provide additional numerical results, including the LCOH (EUR/kgH_2) values and key cost parameters such as the cost of electricity (EUR/MWh) and the cost of water (EUR/m^3). These results can also be exported for further use. When the municipality is selected, the graphical output illustrates the percentage contribution of the different components of the LCOH.

Customised Mode Pathway and Results

On the other hand, the customised configuration involves a more detailed parametrisation process. Once the origin has been defined, serving as the hydrogen production location, a comprehensive parameter table with default values is presented, allowing the insertion and adjustment of user-defined input values for green hydrogen production conditions. In the customised mode, the results correspond to location-specific LCOH values and are presented for the selected municipality, including the associated electricity cost (EUR/MWh) and water cost (EUR/m^3), along with a graphical breakdown of the LCOH components by cost parameter, enabling detailed analysis and comparison of the selected configuration.

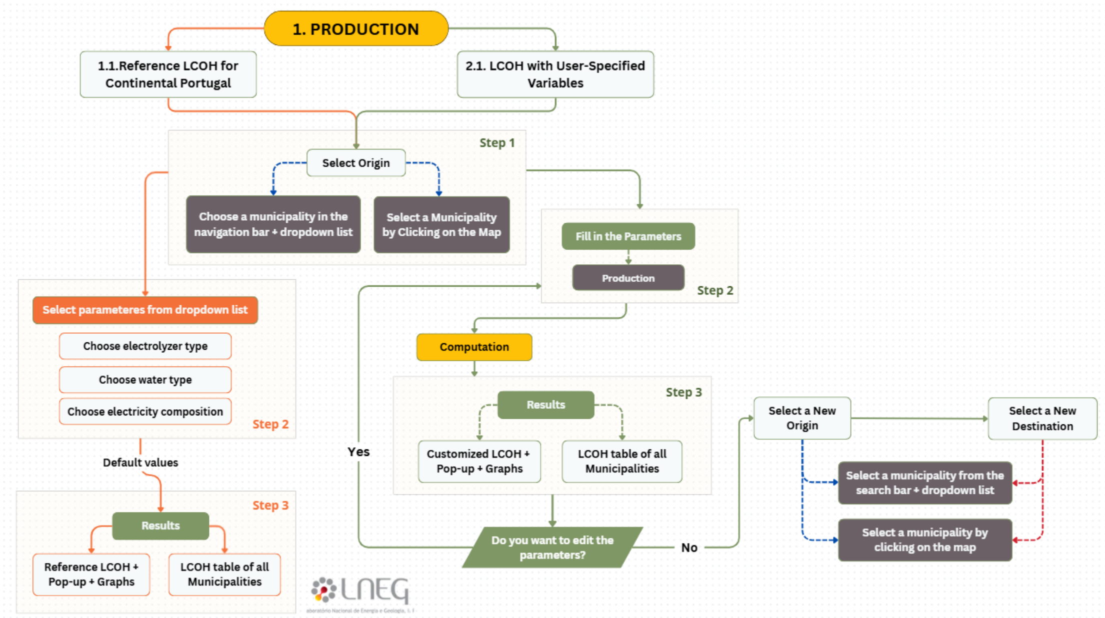

Figure 2.4: H_2 Production (only) scope workflow of the LNEG-H_2PTMap Tool

2.4 H_2 Transport Workflow

Mode, Origin, and Destination Identification

Figure 2.5 presents the H_2 Transport scope (value chain) workflow of the LNEG-H_2PTMap Tool which follows a structured, sequential process beginning with the selection of the operational mode, either reference or customised.

Afterward, with an additional destination-selection step compared with the H_2 Production scope, both the origin and destination municipalities are defined as the basis for the assessment within the H_2 Transport scope. The origin, which defines the location of potential hydrogen production sites, may be specified either by selecting municipalities through the search bar or the drop-down list. The destination, which represents the location where the produced hydrogen is delivered, can be selected using different options, including the search bar, the drop-down list, or direct selection on the map.

Reference Mode Pathway and Results

In the reference configuration, different scenarios were pre-calculated for continental Portugal. For scenario selection in H_2 Transport scope (value chain), the same set of filters used in the H_2 Production scope is required specification via filter selection, namely the electrolyser type (PEM or ALK), water input type (Grid Water, WasteWater, or SeaWater), and the composition of the renewable electricity mix, i.e., Solar PV and Onshore Wind (WO) share (%). The hydrogen delivery distance per dispatch, together with the associated input values, are pre-calculated within the tool. The methodology and assumptions used to obtain these values are described in Appendix D.

Once the scenario parameters are selected, the results of LCOH are presented, either for a specific municipality or for all municipalities in mainland Portugal, through a map-based interface, as well as tabular and graphical outputs. The map displays the corresponding total

LCOH values for the selected origin municipality and all destination municipalities. Total LCOH values for destination municipalities are shown when the user hovers over a municipality, while the tabular outputs provide additional numerical results, including the LCOH (EUR/kgH_2) values and key cost parameters such as the cost of electricity (EUR/MWh) and the cost of water (EUR/m^3). These results can also be exported for further use.

When the user selects a specific destination municipality, either directly on the map or through the corresponding filter in the filters window, tables and graphical outputs for each component of the H_2 Transport value chain are shown. These include the total LCOH (EUR/kgH_2) value, cost parameters such as the cost of electricity (EUR/MWh) and the cost of water (EUR/m^3), and the percentage contribution of the different components to the LCOH, namely H_2 production, H_2 storage, H_2 road distribution, and H_2 refuelling station. This allows a clear visual interpretation of the main cost drivers within the transport value chain. These results can also be exported for further use.

Customised Mode Pathway and Results

In contrast to the reference mode, the customised setting involves a more detailed parametrisation process. Once the origin and destination have been defined, representing hydrogen production and delivery locations, a set of parameter tables is presented, allowing the insertion and adjustment of user-defined input values across all relevant components, including H_2 production, H_2 storage, H_2 road distribution, and H_2 refuelling stations. The H_2 liquefaction component may be optionally enabled, allowing input of user-defined values when required.

Once the required inputs are defined, a computation is executed to estimate the LCOH values and associated parameters specified by the user for the selected transport scope. The results are presented in tabular and graphical form. All inputs and outputs are shown for each component of the H_2 Transport value chain. These results can also be exported for further use.

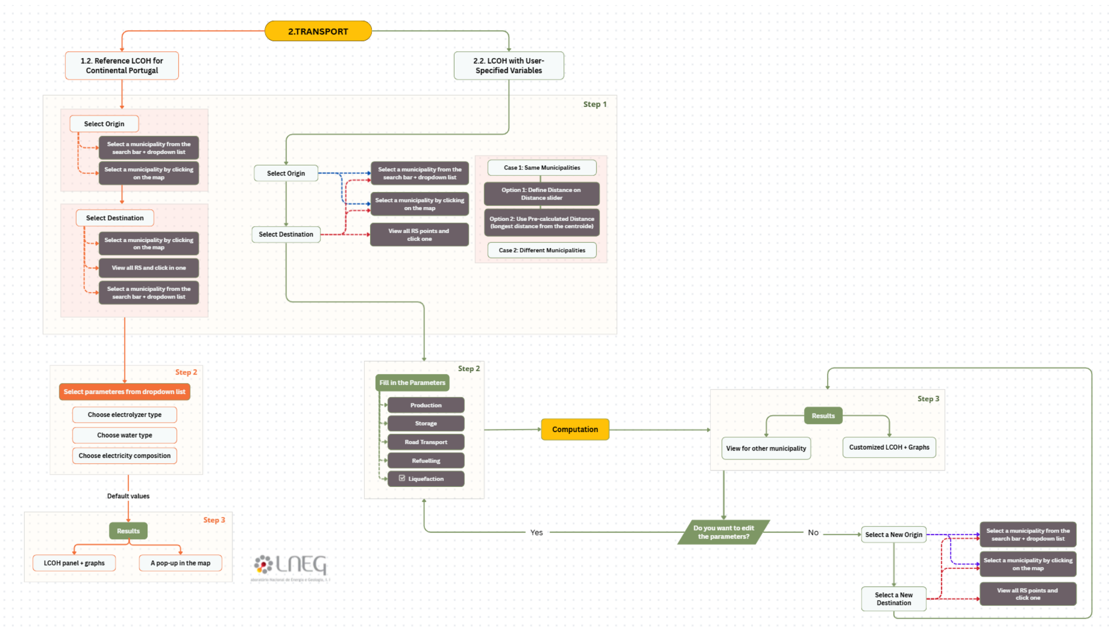

Figure 2.5: H_2 Transport scope (value chain) workflow of the LNEG-H_2PTMap Tool

2.5 H_2 Industry Workflow

Mode, Origin, and Destination Identification

As presented in Figure 2.6, the H_2 industry value chain workflow follows a structured, sequential process beginning with the selection of the operational mode, either reference or customised.

Afterward, with an additional destination-selection step compared with the H_2 Production scope, both the origin and destination municipalities are defined as the basis for the assessment within the H_2 Industry scope. The origin, which defines the location of potential hydrogen production sites, may be specified either by selecting municipalities through the search bar or the drop-down list.

The destination, which represents the location where the produced hydrogen is delivered, can be selected using different options, including the search bar, the drop-down list, or direct selection on the map.

Reference Mode Pathway and Results

In the reference configuration, different scenarios were pre-calculated for continental Portugal. For scenario selection in H_2 Industry scope (value chain), the same set of filters used in the H_2 Production and Transport scopes is required specification via filter selection, namely the electrolyser type (PEM or ALK), water input type (Grid Water, WasteWater, or SeaWater), and the composition of the renewable electricity mix, i.e., Solar PV and Onshore Wind (WO) share (%). The hydrogen delivery distance per dispatch, together with the associated input values considered in the H_2 road distribution, are pre-calculated within the tool. The methodology and assumptions used to obtain these values are described in Appendix D.

Once the scenario parameters are selected, the results of LCOH are presented, through a map-based interface, as well as tabular and graphical outputs. The map displays the corresponding total LCOH values for the selected origin municipality and all destination municipalities. Total LCOH values for destination municipalities are shown when the user hovers over a municipality, while the tabular outputs provide additional numerical results, including the LCOH (EUR/kgH_2) values and key cost parameters such as the cost of electricity (EUR/MWh) and the cost of water (EUR/m^3). These results can also be exported for further use.

When the user selects a specific destination municipality, either directly on the map or through the corresponding filter in the filters window, tables and graphical outputs for each component of the H_2 Industry value chain are shown. These include the total LCOH (EUR/kgH_2) value, cost parameters such as the cost of electricity (EUR/MWh) and the cost of water (EUR/m^3), and the percentage contribution of the different components to the LCOH, namely H_2 production, H_2 storage, and H_2 road distribution. This allows a clear visual interpretation of the main cost drivers within the industry value chain. These results can also be exported for further use.

Customised Mode Pathway and Results

In contrast to the reference mode, the customised setting involves a more detailed parametrisation process. Once the origin and destination have been defined, representing hydrogen production and delivery locations, a set of parameter tables is presented, allowing the insertion and adjustment of user-defined input values across all relevant components, including H_2 production, H_2 storage, and H_2 road distribution. The H_2 liquefaction component may be optionally enabled, allowing input of user-defined values when required.

Once the required inputs are defined, a computation is executed to estimate the LCOH values and associated parameters specified by the user for the selected industry scope. The results are presented in tabular and graphical form. All inputs and outputs are shown for each component of the H_2 Industry value chain. These results can also be exported for further use

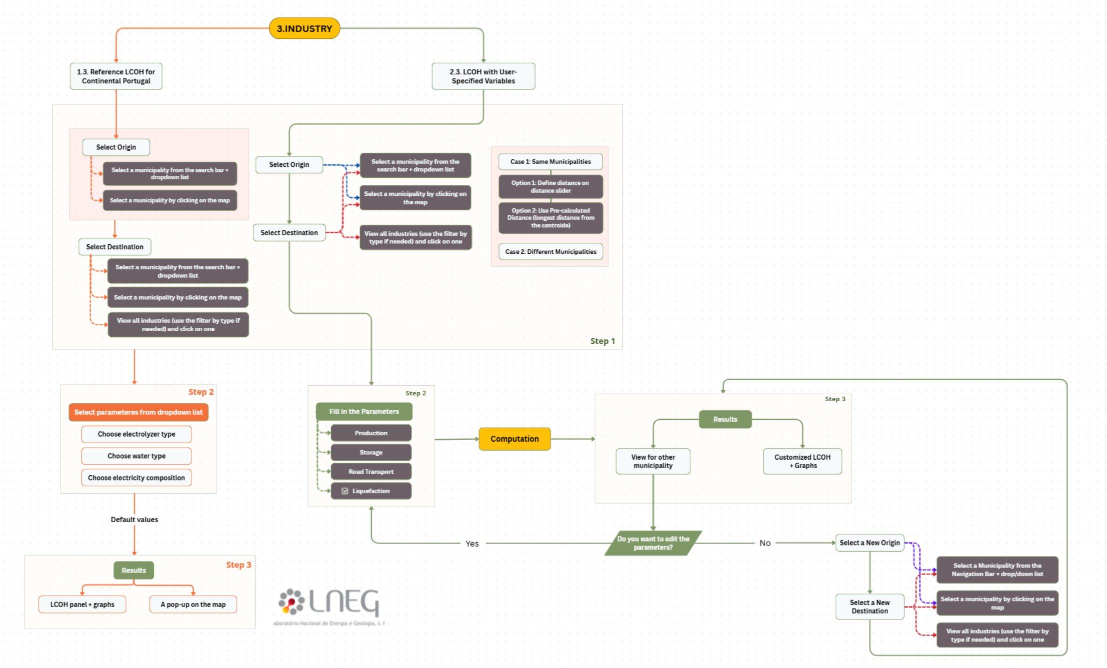

Figure 2.6: H_2 Industry scope (value chain) workflow of the LNEG-H_2PTMap Tool

In the LNEG-H_2PTMap Tool, for each configuration, electricity costs are automatically calculated based on municipality-level average renewable resource availability for solar PV and onshore wind. Water consumption is modelled considering only one water source at a time. The tool provides reference values for all variables used throughout the value chains, with hydrogen production assumptions based on a hypothetical 50 MW water electrolysis plant. Although users can select either ALK or PEM electrolysers, the current version applies an average CAPEX value for the electrolysis plant. Consistent technology performance and lifetime assumptions are adopted across all municipalities for the calculation of electricity and water-related costs.

2.6 Production of Hydrogen Component: *H_2 Production*

The H_2 production component considers a water electrolysis plant and uses Equation 2.1 to obtain a LCOH for hydrogen production.

2.6.1 CAPEX

The CAPEX can be introduced by the users, or default values can be used. The value introduced by the user should not consider the cost of the stack, which is computed internally using the CAPEX input by the user and the percentage of the cost of the stack with regard to the CAPEX (without initial stack costs). Stack replacement costs during the lifetime of the plant are explained in further detail below, as they are considered $OPEX_{var}$ when "incurred" after the start of operations.

2.6.2 OPEX

The OPEX is divided into fixed annual values and variable annual ones. The latter considers the water and electricity consumption for the electrolysis plant, as well as the stack replacement costs over the asset lifetime. Unitary costs of electricity and water are pre-calculated at municipality level and applied according to the selected location and input configuration.

Municipality-Level Electricity considerations

Electricity consumption is also included as part of the variable OPEX of the H_2 production component. In contrast to water, which is selected as a single input source, electricity can be defined as a combination of renewable energy sources. In the current version of the tool, two electricity supply options are considered: solar photovoltaic (PV) and onshore wind (OnW).

The renewable electricity mix can be selected by the user through five predefined composition scenarios: 1) PV[100%]- WO[0%], 2) PV[75%]- WO[25%], 3) PV[50%]- WO[50%], 4) PV[25%]- WO[75%], and 5) PV[0%]- WO[100%]. These scenarios enable the assessment of different renewable electricity supply configurations within the LCOH calculation framework.

The electricity cost is pre-calculated at municipality level and applied according to the selected renewable electricity composition. This approach allows the tool to reflect spatial differences in renewable energy availability and electricity generation cost across mainland Portugal, supporting a more location-specific estimation of the LCOH.

Municipality-Level Water Cost Estimation

Water consumption is included as part of the variable OPEX of the H_2 production component. In the current version of the tool, the user can select one of three water input sources: water from the public grid (Grid Water), treated wastewater (WasteWater), or desalinated seawater (SeaWater). Only one water source can be used at a time. Since water availability, treatment requirements, and tariffs vary across municipalities, the incorporation of location-specific water costs is essential to obtain more representative LCOH results.

The framework adopted to estimate water-related costs was developed at municipality level for mainland Portugal. The three water sources considered reflect different system boundaries, treatment stages, infrastructure requirements, and scenario-specific assumptions. For each water source, the costs over the asset lifetime, including CAPEX, OPEX, and DECEX, as well as the water treatment unit configuration and main assumptions, are detailed in Appendix C.

The specific water consumption of the electrolyser is assumed to be 18 L/kgH_2. This value is within the typical range reported in the literature, namely 10–22 L/kgH_2 [1]. Considering a reference electrolyser capacity of 50 MW and a specific hydrogen production rate of 18 kgH_2/h per MW, the nominal hydrogen production is estimated at 21,600 kgH_2/day. For this reference case, a total water demand of 700 m^3/day, corresponding to 255,500 $m^3/year$, is considered at the electrolyser intake.

For **Grid Water**, the cost is exclusively based on the tariffs charged by water utility operators in each municipality, obtained from Water and Waste Services Regulatory Authority - WWSRA

(*Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR)* [2]). Water abstraction, treatment, transport, and associated energy consumption are assumed to be already incorporated into the tariff applied to the final consumer. Therefore, no additional treatment stages or costs are considered for adapting water quality to electrolysis requirements. The deionisation stage is assumed to be an integral part of the electrolyser system for all water sources and is therefore not detailed within the scope of the water source analysis.

For treated WasteWater, the tariffs associated with wastewater treatment services are also collected for each municipality, but they represent only part of the total cost. These tariffs are assumed to reflect the secondary treatment stages typically carried out in most WasteWater Treatment Plants (WWTPs) in Portugal. Additional treatment stages, namely "ultrafiltration" and "reverse osmosis", are considered to meet the water purity requirements for electrolysis.

The associated additional costs include storage, disposal of water treatment residues, and electricity consumption. The electricity required for these additional treatment stages is assumed to be locally produced using solar photovoltaic and/or onshore wind energy sources, with the same renewable electricity costs applied to the electrolysis unit. Regarding residue disposal, the costs include the transport and management of residues generated from two-stage reverse osmosis, assuming road transportation by truck. Therefore, the final cost estimation considers the tariffs associated with secondary treatment at the WWTP, the costs related to additional treatment through ultrafiltration and reverse osmosis, and the costs associated with residue transport and management.

For **SeaWater**, costs are estimated only for coastal municipalities, resulting in the identification of 51 eligible municipalities. The system boundaries include seawater intake pumping, reverse osmosis desalination, storage, brine discharge, and electricity consumption associated with pumping and desalination processes. Brine discharge costs reflect the cost of a marine outfall. As in the WasteWater scenario, the required electricity is assumed to be locally produced using solar photovoltaic and/or onshore wind energy sources. Two pipeline and outfall length configurations are considered for seawater intake pumping and brine discharge, respectively, with the longer configuration applied to municipalities located within environmentally sensitive areas. In this context, seven classified areas included in the National Atlas of Sustainable Green Hydrogen, developed by LNEG [3], are considered: (a) Rede Nacional de Áreas Protegidas (RNAP), (b) Rede Natura 2000, (c) Reservas da Biosfera da UNESCO, (d) Sítios RAMSAR, (e) Geosites, (f) Reserva Ecológica Nacional, and (g) Reserva Agrícola Nacional.

The results enable a comparative assessment of the influence of different water sources for electrolysis, namely water from the public supply network, treated wastewater, and seawater. However, the use of water from the public supply network in large-scale hydrogen production projects may be constrained by the substantial volumes required. Accordingly, the results associated with the different water-source scenarios should be interpreted primarily on a comparative basis.

Stack replacement costs

Stack replacement costs are computed as a percentage of the CAPEX, excluding the initial stack cost. Both the percentage and CAPEX values are provided by the user. Further details on the stack replacement schedule are provided below.

2.6.3 Regarding the production

Production of hydrogen is adjusted over the year and the lifetime in two complementary ways. The first is associated with the real working hours over one year by applying a mean annual load factor (LF) input by the user. The second is associated with the stack's degradation, a known issue for which manufacturers should provide information about.

Regarding the load factor, the nominal annual capacity of the plant (AHP_{nom}) is multiplied by it. This load factor reflects the equivalent number of hours that the plant works in a given year at the nominal capacity (see Equation 2.2), which is always lower than 1, equivalent to 8760 hours/year.

$$\mathrm{AHP} = \mathrm{AHP}_{\mathrm{nom}} \times \mathrm{LF} \tag{2.2}$$

The stack degradation over time allows for considering the reduction of the total amount of hydrogen produced after the application of the LF. The user indicates the rate of degradation of the stack; otherwise default values apply. Special attention should be paid to the unit of the degradation rate required, which should be expressed annually and not hourly. In other words, every year, including the first, the nominal production of the plant experiences a decrease relative to the previous year in a fraction proportional to the degradation rate (see Equation 2.3). The first year uses as reference the nominal annual production after the application of the LF, while from year two to the lifetime of the plant (n_{lifetime}), the reference value is the previous year. The stack replacement period is specified by the user in hours; once the tool determines the stack replacement period (i.e., specific year(s)), the production is reset, and that year is assumed to have the same production of year one, and the degradation progression rate starts again. A list of the input variables, their definition, and the respective units considered is described in the next subsection.

$$\mathrm{AHP}_i = \mathrm{AHP}_{i-1} \times \left(1 - r_{\mathrm{degradation}}\right), \quad \text{for } i = 2, 3, 4 \ldots n_{\mathrm{lifetime}} \tag{2.3}$$

2.6.4 List of variables for the production component

Table 2.1 presents the variables considered for the production component, along with their corresponding units as used in the tool and brief descriptions.

2.7 Liquefaction of Hydrogen Component: *H_2 Liquefaction*

The H_2 Liquefaction component considers a liquefaction plant and uses Equation 2.1 to obtain a LCOH for liquefaction of hydrogen.

2.7.1 CAPEX

The CAPEX can either be specified by the user or, alternatively, default values can be used.

2.7.2 OPEX

The OPEX is divided into fixed annual values and variable annual ones. The latter considers electricity consumption. The unitary costs of electricity are assumed to be the same as the ones

Table 2.1: Variables for hydrogen production component.

Name	Unit	Description
Electrolyser capacity	MW	Electrolyser nominal capacity in MW
Lifetime of electrolysis plant	years	Lifetime of electrolysis plant per year
Annual discount rate	%/year	Annual discount rate indicated as percentage per year.
Water input type	-	Options: Grid Water, WasteWater or SeaWater
Electrolyser type	-	Options: Alkaline Electrolyser (ALK) or Proton Exchange Membrane Electrolyser (PEM)
Electrolyser stack replacement period	hours	Recommended by manufacturer in hours (of operation).
Mean annual load factor	fraction/year	Number of operational hours divided by the total number of hours in a year (8760 h).
H_2 production capacity	kgH_2/h/MW	Indicated by the manufacturer in the datasheet.
Stack annual degradation rate	%/year	Percentage of stack degradation expected over one year that affects hydrogen production.
CAPEX of electrolysis plant	EUR/kW	Value of capital expenditures of the water electrolysis plant expressed in EUR per kilowatt of total electrolyser plant capacity.
Stack cost	% CAPEX	Stack cost expressed as percentage of CAPEX with values between 0 and 100.
OPEX fixed annual	% CAPEX/year	Annual operational expenditures of fixed costs as percentage of CAPEX per year.
DECEX of electrolysis plant	% CAPEX	Decommissioning Expenditure (end-of-life costs) of electrolysis plant, expressed as a percentage of CAPEX.
Electricity consumption per kgH_2	kWh/kgH_2	Electricity consumption in kWh per kilogram of hydrogen. This quantity is used to estimate the variable portion of OPEX.
Water consumption per kgH_2	l/kgH_2	Water consumption per kilogram of hydrogen, including losses. This quantity is used to estimate the variable portion of OPEX.
PV Solar electricity supply	%	It corresponds to the percentage of electricity supply for electrolysis coming from solar PV generation systems with values between 0 and 100.
Onshore wind electricity supply	%	It corresponds to the percentage of electricity supply for electrolysis coming from onshore wind generation systems with values between 0 and 100.
Offshore wind electricity supply	%	It corresponds to the percentage of electricity supply for electrolysis coming from offshore wind generation systems with values between 0 and 100.
Network electricity supply	%	It corresponds to the percentage of electricity supply for electrolysis coming from the electric network with values between 0 and 100.

specified for the production component.

2.7.3 H_2 amount considered for the LCOH

The H_2 liquefaction plant has a specific capacity in tonnes per day (t/day), which the user can specify. However, in the current version, the quantity considered for the LCOH calculation corresponds to the hydrogen production defined in the production component by the user. The liquefaction component is optional and is only included in the LCOH calculation when it is enabled. It is assumed that all active components within a selected value chain pertain to the same project, and therefore, the total LCOH is computed as the sum of the contributions from each included component. In this way, “compatibility”, ”additivity“, and “comparability” of the LCOH contributions are ensured.

2.7.4 Regarding the lifetime

The lifetime of the liquefaction plant is specified by the user and could be different from that specified in the H_2 Production component. If these values are different, then only the costs of the liquefaction plant “incurred” during the H_2 Production component lifetime are considered. This assumes that a complete project LCOH metric involving various tool components is referenced to the hydrogen production plant.

2.7.5 List of variables for liquefaction component

The Table 2.2 presents the variables considered for the hydrogen liquefaction component, their units as accounted for in the tool, and their description.

Table 2.2: Variables for hydrogen liquefaction component.

Name	**Unit**	**Description**
Liquefaction plant capacity	tH_2/day	Liquefaction plant capacity in tonnes of hydrogen per day
Lifetime of liquefaction plant	years	Lifetime of liquefaction plant
Annual discount rate	%/year	Annual discount rate indicated in percentage per year
Liquefaction plant availability	%	Number of operational hours divided by the total number of hours in a year (8760 h) expressed in percentage with values between 0 and 100
CAPEX of liquefaction plant	MEUR	Total value of capital expenditures of the liquefaction plant expressed in million euros.
OPEX fixed annual	EUR/year	Annual operational expenditures of fixed costs in euros
DECEX of liquefaction plant	% CAPEX	Decommissioning Expenditure (end-of-life costs) of the liquefaction plant, expressed as a percentage of CAPEX.
Electricity annual consumption	MWh/year	Total annual electricity consumption for the liquefaction plant. Designers may express this value in terms of kilogram of hydrogen, then the total value of electricity required in one year may be obtained by multiplying the total kilograms of hydrogen liquefied in one year by the unit electricity consumption per kilogram. This quantity is used to estimate the variable portion of OPEX.

2.8 Storage of Hydrogen Component: *H_2 Storage*

In the current version of LNEG-H_2PTMap Tool, the H_2 storage component considers only high-pressure tank storage (Aboveground). The LCOH is calculated using Equation 2.1.

2.8.1 CAPEX

The CAPEX may be provided by the user or, alternatively, default values can be applied.

2.8.2 OPEX

In this component, the annual OPEX is simplified and expressed as a percentage of the CAPEX input by the user.

2.8.3 H_2 amount considered for the LCOH

The storage system has a specific capacity in tonnes of hydrogen, which the user can specify. However, in the current version, the quantity considered for the LCOH calculation corresponds to the hydrogen production defined in the production component by the user. It is assumed that all active components within a selected value chain pertain to the same project, and therefore, the total LCOH is computed as the sum of the contributions from each included component. In this way, "compatibility", "additivity", and "comparability" of the LCOH contributions are ensured.

2.8.4 Regarding the lifetime

The lifetime of the storage system is specified by the user and might be different than the one specified in the other components. If these values are different, then only the costs of the storage system "incurred" during the H_2 Production component lifetime are considered. This assumes that a complete project LCOH metric involving various tool components is referenced to the hydrogen production plant.

2.8.5 List of variables for storage component

Table 2.3 presents the variables considered for the hydrogen storage component, their units as accounted for in the tool, and their description.

Table 2.3: Variables for hydrogen storage component.

Name	Unit	Description
Storage capacity	tH_2	Storage capacity in tonnes of hydrogen
CAPEX of storage system - tanks, pipes and compressors	EUR/tH_2	Value of capital expenditures of the storage system in euros per tonne of hydrogen. This value must consider tank, pipes and compression system.
OPEX fixed annual	% CAPEX/Year	Annual operational expenditures expressed as a percentage of CAPEX of storage with values between 0 and 100
DECEX of storage system	% CAPEX	Decommissioning Expenditure (end-of-life costs) of the storage system, expressed as a percentage of CAPEX.
Annual discount rate	%/year	Annual discount rate indicated in percentage per year
Lifetime of storage system	years	Lifetime of storage system

2.9 Distribution of Hydrogen - Road Distribution Component: *H_2 Road Distribution*

The H_2 Road Distribution component considers some characteristics of the trailer/truck and selected performance metrics. This component allows for the specification of gaseous or liquid transport. The LCOH is obtained using the Equation 2.1.

2.9.1 CAPEX

CAPEX values can be user-defined or derived from default assumptions within the tool.

2.9.2 OPEX

The OPEX is divided into fixed annual values and variable annual ones. The variable annual OPEX considers the fuel consumption of trailers/trucks.

2.9.3 H_2 volume considered for the LCOH

The quantity used for the calculation of the LCOH in the current version is the amount of hydrogen produced when the H_2 Production is activated. The underlying assumption is that the components active for computation pertain to the same project, and consequently the LCOH of each component is computed as a contribution of the total LCOH. In this way, "compatibility", "additivity", and "comparability" of the LCOH contributions. If only the H_2 road distribution component is activated, then the reference annual amount of hydrogen transported by the trailers/trucks is considered and must be inputted by the user.

2.9.4 Regarding the lifetime

The lifetime of trailers/trucks is usually lower than hydrogen production plants. if the lifetime is shorter than the one specified for the H_2 Production component, then there is a reinvestment in a new trailer/trucks, and only the costs within the lifetime of the H_2 Production are taken into account.

2.9.5 List of variables for road distribution component

The following Table (2.4) represents the variables used to the hydrogen distribution via road transport component, including their corresponding units and descriptions as implemented in the tool.

Table 2.4: Variables for hydrogen road distribution component.

Name	**Unit**	**Description**
CAPEX of truck/trailer	EUR/kgH_2	Value of capital expenditures expressed in euros per kilogram of hydrogen transport capacity for one truck/trailer
Truck/trailer capacity	kgH_2	Transport capacity of one truck/trailer expressed in kilograms of hydrogen
Number of dispatch per day	dispatch/day	Averaged value of dispatch travels per day per truck/trailer expressed as travels per day
OPEX fixed annual	EUR/kgH_2	Annual fixed operational expenditures expressed in euros per kilogram of hydrogen transported
Fuel consumption	EUR/km	Average value of fuel consumption of the truck/trailer fleet expressed in euros per kilometre
Daily mean distance per truck/trailer	km	Averaged daily distance travelled of the truck/trailer fleet expressed in kilometres
Mean number of truck/trailer per HRS	unit/HRS	Averaged value of truck/trailers per HRS
Annual discount rate	%/year	Annual discount rate indicated in percentage per year
Lifetime of truck/trailer	years	Lifetime of truck/trailer

2.10 Hydrogen Refuelling Station component: *H_2 Refuelling*

The H_2 Refuelling station component considers two main types of hydrogen refuelling station (HRS). One that receives gaseous hydrogen and dispatches gaseous hydrogen, and another that receives liquid hydrogen and dispatches gaseous hydrogen. To obtain the LCOH, Equation 2.1 is used.

2.10.1 CAPEX

The CAPEX can be introduced by the user or default values can be used, and it is disaggregated in CAPEX for the HRS not considering the compression system, and the CAPEX associated with the compression system. This has been done recognising that the compression system is an important cost component of an HRS. However, the total cost of CAPEX can be factored into the CAPEX for HRS by the user.

2.10.2 OPEX

The OPEX is divided into fixed annual values and variable annual ones. The latter considers the electricity consumption for the HRS. The unitary costs of electricity are assumed to be the same as those specified for the production component.

2.10.3 H_2 amount considered for the LCOH

The HRS has a specific mean dispatch capacity in kilograms per day, which the user can specify. Nevertheless, the quantity used for the computation of the LCOH in the current version is considered to be the amount of hydrogen produced, when the H_2 Production is activated. The underlying assumption is that the components active for computation pertain to the same project, and consequently, the LCOH of each component is computed as a contribution of the total LCOH. In this way, “compatibility”, “additivity”, and “comparability”of the LCOH contributions are ensured. If only the H_2 Refuelling component is activated, then the reference annual amount of hydrogen to compute the LCOH is the mean dispatch capacity in kilograms per day indicated by the user multiplied by the number of HRS times 365 days times the availability of the HRS.

2.10.4 Regarding the lifetime

The lifetime of the HRS is specified by the user and might be different from the one specified in the other components. If these values are different, then only the costs of the storage system “incurred” during the H_2 Production component lifetime are considered. This assumes that a complete project LCOH metric involving various tool components is referenced to the hydrogen production plant. In the case of HRS, if the lifetime is shorter than the one specified for the H_2 Production component, then there is a reinvestment in a new facility, and only the remaining years until reaching the lifetime of the H_2 Production are considered for accounting costs.

2.10.5 List of variables for HRS component

Table 2.5 presents the variables considered for the hydrogen refuelling station component, their units and their description as accounted for in the tool.

Table 2.5: Variables for hydrogen refuelling station component.

Name	Unit	Description
CAPEX of one HRS	EUR/HRS	Total value of capital expenditures for one HRS
CAPEX of compression system	EUR	Value of capital expenditures expressed in euros per kW of compression system
Electricity consumption	kWh/kgH_2	Electricity consumption in HRS expressed in kilowatts-hour per kilogram of hydrogen dispensed
OPEX fixed annual	EUR/kgH_2	Annual operational expenditures expressed in euros per kilogram of hydrogen dispensed
HRS actual mean dispatch capacity	kgH_2/day	It refers to the effective mean daily amount of hydrogen dispensed per HRS
HRS number for analysis	Unit	Total number of HRS for the analysis
HRS annual availability	%	Number of operational hours divided by the total number of hours in a year (8760 h) expressed as percentage
Annual discount rate	%/year	Annual discount rate indicated in percentage per year
Compressor number per HRS	unit/HRS	Compressor number per HRS
DECEX of HRS	% CAPEX	Decommissioning expenditure (end-of-life costs) of the HRS, expressed as a percentage of CAPEX.
Lifetime of HRS	years	Lifetime of HRS

3 Reference Cases and Values

This section provides the input variables and reference values for the H_2 Production scope, H_2 Transport and Industry scopes (value chains), based on a hypothetical 50 MW water electrolysis plant. The reference configuration assumes that solar photovoltaic (PV) provides 100% of the electricity input, with no contribution from onshore wind (WO), and that Grid Water from the public grid is used as the water source. H_2 liquefaction is excluded from the reference configuration.

The following sections present the reference values adopted for the three scope configurations considered in the LNEG-H_2PTMap Tool, namely H_2 Production, H_2 Industry, and H_2 Transport. For each scope (value chain), the corresponding components and reference values are reported. The methodology used to obtain and apply these values is detailed in Appendices A-F.

3.1 H_2 Production Scope - Reference Case

The H_2 Production scope includes only the H_2 production component. Therefore, the reference values reported in this section refer exclusively to the electrolysis plant. The reference configuration considers a 50 MW water electrolysis plant, Grid Water from the public grid as the water source, and a fully solar PV-based electricity supply, corresponding to PV [100%] - WO [0%]. The plant lifetime is assumed to be 20 years, with an annual discount rate of 6%.

The operational assumptions include a mean annual load factor of 0.6 and an H_2 production capacity of 18 kgH_2/h/MW. Based on the H_2 production capacity and the 50 MW electrolyser, the nominal hourly H_2 production is 900 kgH_2/h. Applying the mean annual load factor of 0.6 results in an average H_2 production of 540 kgH_2/h, corresponding to approximately 12.96 tH_2/day. Considering a storage capacity of 200 tH_2, the storage system can accommodate approximately 15 days of hydrogen production.

Stack degradation and replacement assumptions are also considered. The stack replacement period is defined as 80,000 operating hours, with an annual degradation rate of 1.5%. Stack replacement costs are calculated as 15% of CAPEX, excluding the initial stack cost, allowing the model to represent both production losses and replacement costs over the plant lifetime.

Two electrolyser technologies are assessed under the same reference assumptions. The corresponding reference values for each case are presented in Table 3.1.

3.2 H_2 Industry Scope (Value Chain) - Reference Case

The H_2 industry scope (value chain) considers H_2 production, H_2 storage, and H_2 road distribution. In this configuration, hydrogen is produced at the origin, temporarily stored, and subsequently delivered by truck to the industrial destination. As defined previously, the term H_2 road distribution is used in this report to refer specifically to the H_2 road transport distribution by truck, avoiding ambiguity with the overall H_2 transport value-chain configuration.

The H_2 production component follows the same reference configuration described in the H_2 production value-chain section. Therefore, the production-related input variables and reference

Table 3.1: Reference values for variables considered in H_2 production component.

Variable Name [Unit]	Value	Value
Electrolyser capacity [MW]	50	50
Lifetime of electrolysis plant [years]	20	20
Annual discount rate [%/year]	6	6
Water input type	Grid Water	Grid Water
Electrolyser type	ALK	PEM
Electrolyser stack replacement period [hours]	80000	80000
Mean annual load factor [fraction/year]	0.6	0.6
H2 production capacity [kgH_2/h/MW]	18	18
Stack annual degradation rate [%/year]	1.5	1.5
CAPEX of electrolysis plant [EUR/kW]	1265	1425
Stack cost [% CAPEX]	15	15
OPEX fixed annual [% CAPEX/year]	2.5	2.5
Electricity consumption per kgH_2 [kWh/kgH_2]	55	55
Water consumption per kgH_2 [l/kgH_2]	18	18
PV Solar electricity supply [%]	100	100
Onshore wind electricity supply [%]	0	0
DECEX of electrolysis plant [% CAPEX]	10	10

values are not repeated in this section.The corresponding values for the PEM and ALK electrolysis cases are presented in Table 3.1

For the H_2 industry value chain, the additional components considered are H_2 storage and H_2 road distribution. The reference values adopted for the H_2 storage component are presented in Table 3.2. Considering an average hydrogen production rate of 12.96 tH_2/day and a storage capacity of 200 tH_2, the system can store approximately two weeks of H_2 production.

The CAPEX of the storage system, including tanks, pipes, and compressors, is assumed to be 100,000 EUR/tH_2. The storage system lifetime is assumed to be 30 years, with an annual discount rate of 6%.

Table 3.3 presents the reference values adopted for the H_2 road distribution component. The main techno-economic assumptions of this component include an annual discount rate of 6%, a truck lifetime of 10 years, road distribution capacity, and vehicle-related cost parameters. In the reference case, hydrogen delivery is assumed to occur through three dispatches per week using one truck. The distance travelled by the truck varies according to the selected origin-destination pair. DECEX is excluded from the H_2 road distribution component because the end-of-life dismantling, scrapping, or recycling of trucks is considered outside the boundary of the hydrogen value chain.

Table 3.2: Reference values for variables considered in H_2 storage component.

Variable Name [Unit]	Value
Storage capacity [tH_2]	200
CAPEX of storage system - tanks, pipes and compressors [EUR/tH_2]	100000
OPEX fixed annual [% CAPEX/Year]	2
DECEX of storage system [% CAPEX]	10
Annual discount rate [%/year]	6
Lifetime of storage system [years]	30

Table 3.3: Reference values for variables considered in H_2 road distribution component.

Variable Name [Unit]	Value
CAPEX of truck/trailer [EUR/kgH_2]	1140
Truck/trailer capacity [kgH_2]	1000
Number of dispatch per day [dispatch/day]	0.429
OPEX fixed annual [EUR/kgH_2]	0.06
Fuel consumption [EUR/km]	0.6125
Daily mean distance per truck/trailer [km]	Varies according to the selected origin-destination pair
Mean number of truck/trailer per HRS [unit/HRS]	1
Annual discount rate [%/year]	6
Lifetime of truck/trailer [years]	10

3.3 H_2 Transport Value Chain - Reference Case

The H_2 transport value chain considers H_2 production, H_2 storage, H_2 road distribution, and H_2 refuelling stations (HRS). The H_2 production, H_2 storage, and H_2 road distribution components follow the same reference assumptions and values previously described for the H_2 production value chain and H_2 industry value chain. Therefore, these components are not repeated in this section. The corresponding reference values for H_2 production is presented in Table 3.1, for H_2 storage component in Table 3.2, and for H_2 road distribution component in Table 3.3.

The additional component specific to the H_2 transport value chain is the H_2 refuelling station. The reference values adopted for this component are presented in Table 3.4. The H_2 refuelling station represents the final distribution point where hydrogen is made available for vehicle refuelling. The corresponding techno-economic assumptions include the station capacity, investment cost, fixed and variable operation and maintenance costs, electricity consumption, lifetime, discount rate, and end-of-life cost assumptions.

Table 3.4: Reference values for variables considered in H_2 refuelling station component.

Variable Name [Unit]	Value
CAPEX of one HRS [EUR/HRS]	5000000
CAPEX of compression system [EUR]	0
Electricity consumption [kWh/kgH_2]	3.25
OPEX fixed annual [EUR/kgH_2]	0.5
HRS actual mean dispatch capacity [kgH_2/day]	1000
HRS number for analysis [unit]	1
HRS annual availability [%]	98
Annual discount rate [%/year]	6
Compressor number per HRS [unit/HRS]	2
DECEX of hydrogen refuelling station [% CAPEX]	10
Lifetime of HRS [years]	20

4 How to Report Bugs, Suggestions, and Comments?

This section presents the procedure through which users can report bugs, provide comments, and submit suggestions for improvement.

4.1 Procedure and Contacts

To report problems, bugs or errors associated with the LNEG-H_2PTMap tool, make any suggestions related to possible improvements or changes, or leave any comments (e.g. about the user experience, the ease or difficulty of using the tool, general feedback, questions or any other matter), please write an email to lcoh.lneg@lneg.pt. Please include the words ”Problem”, ”Suggestion”, or ”Comment” in the subject line, optionally followed by a brief description of the main topic or problem.

5 Appendices

This chapter provides supplementary methodological information supporting the development of the LNEG-H_2PTMap tool and the assumptions applied throughout the analysis. It presents a description of the procedures used to collect, process, and integrate the input data, as well as the rationale behind the selection of reference values adopted in the calculations. The purpose of this section is to improve the transparency, traceability, and reproducibility of the methodology by documenting the data sources, processing steps, parameter assumptions, and technical criteria used to define the main inputs of the tool. Where applicable, the appendix also clarifies how specific values were derived from literature, technical reports, databases, or predefined modelling assumptions.

Appendix A

Money Value in Time Approach

All monetary inputs used in the tool were standardised to ensure consistency, comparability, and methodological transparency across the techno-economic calculations. When cost data were reported in USD, values were converted into EUR using historical exchange rate data provided by the European Central Bank (ECB) [4]. The conversion was applied based on the reference year of the original cost value, using the corresponding annual average exchange rate for that year. As ECB exchange rates are expressed as units of foreign currency per euro, the relevant exchange rate relationship was applied to obtain the equivalent value in euros.

When cost values referred to different price years, an inflation adjustment was applied to express all monetary inputs on a consistent price basis. This adjustment was carried out using the Harmonised Index of Consumer Prices (HICP), which provides a harmonised measure of inflation across European countries [5]. HICP was used to update the cost values from their original reference year to the selected price year adopted in the tool, using Equation 5.1. This procedure ensures that all cost parameters are expressed in comparable monetary terms and can be consistently used within the techno-economic assessment.

$$\mathrm{Cost}_{\mathrm{EUR\ 2025}} = \frac{\mathrm{Cost}_{\mathrm{EUR\ 2024}}}{\mathrm{HICP}_{2024}} \times 100 \tag{5.1}$$

where:

- $Cost_{EUR\,2025}$ = inflation-adjusted value
- $Cost_{EUR\,2024}$ = value after currency conversion
- $HICP_{2024}$ = Harmonised Index of Consumer Prices for 2024, (with $HICP_{2025} = 100$)

Appendix B

This appendix provides supplementary methodological information on the estimation of the levelised cost of electricity (LCOE) for solar photovoltaic (PV) and onshore wind (WO) technologies used in the tool. It describes the technical assumptions, reference values, and data-processing steps applied to derive the input parameters required for the LCOE calculation. Particular attention is given to the treatment of capacity factors (CF), number of hours at full capacity (NEPS, h/year), and resource-based limitations, especially for onshore wind, where not all locations may be technically suitable for deployment. The capacity factor calculations were implemented spatially in ArcGIS Pro and aggregated at the municipality level using official administrative boundaries from the*Carta Administrativa Oficial de Portugal (CAOP2025)*, published by the *Direção-Geral do Território* [6]. To ensure spatial consistency across the analysis, all layers used in ArcGIS Pro were projected in the *ETRS89 / Portugal TM06* coordinate reference system. This approach allowed municipality-specific renewable electricity indicators to be derived, reflecting the spatial variability of solar and wind resource availability across mainland Portugal. The appendix also documents the cost parameters, including CAPEX, OPEX, DECEX, discount rate, lifetime, and annual energy production, together with the literature and technical sources used to define these values.

B.1 Solar PV Indicators used in LCOE calculation

This section presents the main input indicators used to estimate the levelised cost of electricity (LCOE). The same LCOE formula is applied to both Solar PV and onshore wind technologies in this report, allowing the electricity generation costs of the two renewable sources to be assessed consistently. The calculation considers CAPEX, OPEX, DECEX, discount rate, asset lifetime, and annual electricity production (AEP), as expressed in Equation 5.2.

$$\mathrm{LCOE} = \frac{\mathrm{CAPEX} + \sum_{t=1}^{t_f} \frac{\mathrm{OPEX}}{(1+r)^t} + \frac{\mathrm{DECEX}}{(1+r)^{t_f}}}{\sum_{t=1}^{t_f} \frac{\mathrm{AEP}}{(1+r)^t}} \tag{5.2}$$

where:

- $CAPEX$ = total installed capital expenditure of the renewable electricity generation system;
- $OPEX$ = annual operating expenditure;
- $DECEX$ = decommissioning expenditure at the end of the asset lifetime;
- AEP = annual electricity production;
- r = discount rate;
- t = year of operation;
- t_f = final year of operation, corresponding to the asset lifetime.

B.1.1 CAPEX - Total Installed Cost

The CAPEX value for Solar PV adopted in the LNEG-H_2PTMap tool corresponds to the European weighted-average of total installed cost for utility-scale Solar PV projects reported by IRENA [7]. After currency conversion and adjustment to the 2025 price basis, the value used in this study is 737.41 EUR_{2025}/kW.

B.1.2 OPEX - Operating Expenditure

The OPEX of Solar PV adopted in the LNEG-H_2PTMap tool is represented as an annual percentage of CAPEX. Based on IRENA [7] cost data, annual operation and maintenance costs for utility-scale Solar PV correspond to approximately 1.9 % of CAPEX per year.

B.1.3 Performance Ratio and Capacity Factor

Solar PV electricity generation depends primarily on the available solar resource and the technical performance of the PV system. In this study, the solar resource was represented by Global Horizontal Irradiation (GHI), expressed in kWh/m^2/year, which represents the total annual solar energy received per unit surface area. The GHI data were provided by LNEG and retrieved from the Global Solar Atlas [8].

For solar photovoltaic systems, the performance ratio (PR) is a key metric used to evaluate and compare the efficiency of the system independently of location-specific solar resource conditions. It represents the ratio between the actual electricity delivered to the grid and the theoretical electricity output expected from the PV modules under standard test conditions. It is expressed in the Equation 5.3:

$$\mathrm{PR} = \frac{E_{\mathrm{grid}}}{H_t \times A \times \eta} \tag{5.3}$$

where:

- E_{grid} = actual electricity delivered to the grid
- H_t = total in-plane irradiation
- A = total PV module area
- η = module efficiency under standard test conditions (STC)

PR is expressed as a percentage, where higher values indicate better system performance. Since unavoidable operational losses occur during PV operation, PR cannot reach 100%. In this study, a PR value of 87% was adopted, based on studies analysing a utility-scale PV park in Portugal [9, 10].

For solar capacity factor calculation, the annual solar resource was converted into equivalent electricity generation using the adopted PR value. The resulting annual output was then normalised by the maximum theoretical annual generation, corresponding to 8,760 operating hours per year. The Solar PV capacity factor was calculated by using the Equation 5.4:

$$\mathrm{CF}_{\mathrm{solar}} = \frac{GHI \times PR}{8760} \tag{5.4}$$

where:

- GHI = Global Horizontal Irradiation (kWh/m^2/year)
- PR = performance ratio (0.87)
- 8760 = total number of hours in one year

This calculation was applied at the municipality level using the corresponding GHI value for each municipality. The resulting solar PV capacity factors were subsequently used as input parameters in the LCOE calculation. To contextualise the resulting values, they were compared with international and national reference indicators. As a reference, IRENA reports a 2024 global weighted-average capacity factor of 17.4% for utility-scale Solar PV, while IEA-PVPS reports an average Solar PV capacity factor of approximately 14.6% for Portugal in 2025. [7, 11]

B.1.4 Discount Rate

The discount rate was represented by the weighted average cost of capital (WACC), consistent with the financial assumptions used in renewable electricity cost assessments. For Solar PV, the European WACC reported by IRENA is approximately 4.2%, reflecting relatively mature market conditions and lower financing risk in Europe. Therefore, a discount rate of 4.2% was adopted for Solar PV in the LNEG-H_2PTMap tool [7].

B.1.5 Electricity Production

Annual Solar PV electricity production was calculated from the installed capacity, the municipality-level capacity factor, and the total number of hours in one year. Therefore, energy – electricity – production varies by municipality according to local solar irradiation conditions. As a national reference, IEA-PVPS reports approximately 8.7 TWh/year of Solar PV electricity generation in Portugal in 2025, with around 6.8 GW of installed capacity. These values support the plausibility of the capacity factor and electricity production assumptions used in the LNEG-H_2PTMap tool [11].

B.1.6 Solar Degradation Rate

A solar PV degradation rate was included in the LCOE calculation to account for the gradual reduction in module performance over the project lifetime. Several degradation-rate assumptions are reported in the literature, reflecting differences in PV technology, module design, operating conditions, climate, and performance assessment methods. For example, Theristis et al. [12] analysed the early-life performance degradation of 834 fielded PV modules, representing 13 module types from seven manufacturers across three climates, showing that degradation rates vary across technologies and operating environments.

Based on this variability, and considering the assumptions adopted in the LNEG-H_2PTMap Tool, a solar degradation rate of 1.5%/year was assumed for the present LCOE maps. This value is within the broader range of degradation rates reported in the literature, which may vary from approximately 0.4%/year to nearly 2%/year depending on module technology and site-specific conditions [12–14]. It should be noted, however, that newer and more advanced solar PV technologies may present lower degradation rates under favourable operating conditions.

B.1.7 DECEX - Decommissioning Expenditure

The Solar PV decommissioning expenditure − End-of-Life costs − was derived from EPRI's utility-scale PV decommissioning cost estimate, which considers labour, equipment, subcontracting, and the salvage value of recoverable materials. Based on this source, net decommissioning costs correspond to approximately 4.8% of CAPEX. Accordingly, a DECEX value of 4.8% of CAPEX was adopted for Solar PV in the LNEG-H_2PTMap tool [15].

Table 5.1 summarises the indicators required for the Solar PV LCOE calculation, based on the parameters and assumptions described above.

Table 5.1: Solar PV indicators used in LCOE calculation.

Indicators	Value	Units
CAPEX	737.41	EUR_{2025}/kW
OPEX	1.9	% CAPEX/year
DECEX	4.8	% CAPEX
WACC	4.2	%
Capacity Factor	17.85	%
Degradation Rate	1.5	%/year
Lifetime	25	years
LCOE	46 - 58	EUR/MWh

B.2 Onshore Wind Indicators used in LCOE calculation

B.2.1 CAPEX - Total Installed Cost

The onshore wind CAPEX value adopted in the LNEG-H_2PTMap tool corresponds to the European weighted-average total installed cost for onshore wind projects reported by IRENA [7]. After currency conversion and adjustment to the 2025 price basis, the value used in this study is 1,570.42 EUR_{2025}/kW.

B.2.2 OPEX - Operating Expenditure

In the LNEG-H_2PTMap tool onshore wind OPEX was represented as an annual percentage of CAPEX. Based on IRENA cost data [7], annual operation and maintenance costs for onshore wind correspond to approximately 2.4% of CAPEX per year. Using the adopted CAPEX value, this corresponds to approximately 37.7 EUR_{2025}/kW/year.

B.2.3 Capacity Factor

Onshore wind capacity factors were estimated from the number of hours at full capacity (NEPS h/year) dataset, expressed in annual full-load equivalent hours (h/year). The NEPS values represent the number of hours during which a reference wind turbine would operate at nominal capacity to produce the same annual energy output. The data were obtained from *LNEG's Atlas of Onshore Wind Potential in Continental Portugal - 2025* [16]. The NEPS values were derived based on the wind-resource assumptions adopted for the onshore technical potential assessment, using a reference wind turbine with a nominal capacity of 3.6 MW, a rotor diameter of 117 m, and a simulation height of 100 m, reflecting modern onshore wind technology assumptions

[17]. The onshore wind capacity factor was calculated by normalising NEPS by the theoretical maximum annual operating time of 8,760 hours, as shown in Equation 5.5:

$$\mathrm{CF}_{\mathrm{wind}} = \frac{NEPS}{8760} \tag{5.5}$$

where:

- $NEPS$ = Number of hours at full capacity (NEPS h/year)
- 8760 = Total number of hours in one year

Suitability limitation for onshore wind deployment

For onshore wind, a minimum NEPS threshold of 2,100 h/year was applied as a resource-based suitability criterion. A municipality was classified as suitable for onshore wind deployment if at least one raster cell within its administrative boundary presented a NEPS value equal to or higher than 2,100 h/year. Conversely, municipalities where all NEPS values remained below this threshold were classified as unsuitable and were excluded from the onshore wind LCOE calculation.

In the LNEG-H_2PTMap tool calculation of onshore wind capacity factors at municipality level is described above. In the tool, the municipality-level onshore wind capacity factors range from approximately 20% to 34%, with an average value of around 25% across suitable municipalities.

As a reference, IRENA reports a 2024 European weighted-average capacity factor of 34% for onshore wind projects [7]. On the other hand, for Portugal, an average national capacity factor of approximately 28.2% can be estimated from APREN data [18], based on reported wind electricity generation and installed wind capacity in 2025. The lower average value obtained in this study is expected because the municipality-level calculation reflects spatially variable wind-resource conditions across mainland Portugal, rather than only high-performing or newly commissioned wind projects. In contrast, the IRENA benchmark refers to recently commissioned onshore wind projects, which are generally located in more favourable wind-resource areas and benefit from newer turbine technologies.

B.2.4 Discount Rate

The discount rate was represented by the weighted average cost of capital (WACC). For onshore wind, IRENA reports a European WACC of approximately 3.7%, reflecting mature capital markets, lower investment risk, and comparatively stable renewable energy policy conditions in Europe. Therefore, a discount rate of 3.7% was adopted for onshore wind in the LNEG-H_2PTMap tool [7].

B.2.5 Electricity Production

Annual onshore wind electricity production was calculated from the installed capacity, the municipality-level capacity factor, and 8,760 annual hours in the LNEG-H_2PTMap tool [11]. Since the wind capacity factors were derived from NEPS values, electricity production varies across municipalities according to local wind-resource conditions. As a national reference, APREN reports 248 wind farms in mainland Portugal in 2024, with 5,819 MW of installed capacity and 14.4 TWh/year of wind generation, corresponding to an average national capacity factor of approximately 28.2%. LNEG further estimates the technical onshore wind potential in mainland Portugal at 15.7 GW, equivalent to 37.13 TWh/year under technical, environmental, and social-acceptance constraints [17, 18].

B.2.6 DECEX - Decommissioning Expenditure

For onshore wind, empirical evidence from the U.S. Department of Energy indicates net decommissioning costs – (End-of-Life Costs) – of 67,000–150,000 USD_{2020} per turbine, based on project estimates from 2019–2021. These values were converted to a per-kW basis and compared with European CAPEX values reported by IRENA. The resulting decommissioning cost corresponds to approximately 1–5% of CAPEX. Accordingly, a DECEX value of 5% of CAPEX was adopted in the LNEG-H_2PTMap tool for onshore wind as a conservative representative assumption [7, 19]

Table 5.2 summarises the indicators required for the onshore wind (WO) LCOE calculation, based on the parameters and assumptions described above.

Table 5.2: Onshore wind indicators used in LCOE calculation.

Indicators	**Value**	**Units**
CAPEX	1570	EUR_{2025}/kW
OPEX	2.4	% CAPEX/year
DECEX	5	% CAPEX
WACC	3.7	%
Capacity Factor	25	%
Lifetime	25	years
LCOE	45 - 78	EUR/MWh

Appendix C

This section presents the methodology used to estimate the unitary water costs per water type, considering the assets' lifetime, to enable comparison across each step of the process.

C.1 Water Cost Methodology

As aforementioned, the water types incorporated in the tool are Grid Water, WasteWater, and SeaWater. Grid Water costs were obtained from the municipalities' water suppliers, WasteWater and SeaWater costs were estimated based on water treatment units and corresponding waste/residues disposal/treatment for designs supplying 700 m^3 as treated water output. Each water type's treatment stages, costs and associated assumptions are described in the following subsections.

The unit water costs (EUR/m^3) for WasteWater and SeaWater were obtained using a similar approach than the one used for the LCOE, i.e., a Levelised Cost of Water ($LCOH_2O$), which can be expressed as shown in Equation 5.6:

$$LCOH_2O = \frac{CAPEX + \sum_{t=1}^{t_f} \frac{OPEX_t}{(1+r)^t} + \frac{DECEX}{(1+r)^{t_f}}}{\sum_{t=1}^{t_f} \frac{AH_2OP_t}{(1+r)^t}} \tag{5.6}$$

where:

- $CAPEX$ = capital expenditure
- $OPEX_t$ = operation and maintenance expenditure in year t;
- $DECEX$ = decommissioning expenditure;
- r = discount rate;
- t = year of operation;
- t_f = final year of the p
- AH_2OP_t = annual water production.

The CAPEX comprises the following main generic components: i) water abstraction/collection, ii) water transport, iii) water treatment, iv) storage, and v) disposal of water treatment waste. Furthermore, OPEX comprises the following main generic components: i) water abstraction/collection, ii) disposal of water treatment waste, iii) electricity (pumping/transport, water treatment, waste treatment, and others), iv) water charges, and v) labour. In addition, DECEX for WasteWater and SeaWater were considered, with 10% and 20%, respectively.

C.1.1 Grid Water

The cost estimation for Grid Water was based on the variable tariffs applied by water supply operators in each municipality to industrial or non-domestic consumers. In Portugal, water services are managed at the municipal level or through inter-municipal systems, while tariffs are regulated and published by the *Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR)* [2]. These tariffs typically include both fixed and variable components, with the latter reflecting the volumetric cost of water consumption.

In this case, the variable, or volumetric, tariff was adopted as the final unit cost of Grid Water (EUR/m^3), as it directly represents the marginal cost associated with water consumption. This approach assumes that the supplied water already complies with the required quality standards and that the tariff structure incorporates the costs associated with abstraction, treatment, transport, and energy consumption. Additional pre-treatment is usually required within water electrolysis plants before the water enters the stack; however, this was considered as part of the balance of plant of the electrolysis unit. The resulting dataset therefore provided a consistent representation of Grid Water costs across 278 municipalities in mainland Portugal.

C.1.2 WasteWater

The WasteWater system considered for the unit water cost estimation includes the main system components, their description, and the associated capital expenditure (CAPEX) and operational expenditure (OPEX), as shown in Table 5.3.

Table 5.3: WasteWater supply system components and associated costs.

WasteWater Components	Description	CAPEX [EUR/m^3]	OPEX [EUR/m^3]
WasteWater Tariff	Includes water abstraction, transport to the WWTP, and the secondary treatment	Vary per municipality	Vary per municipality
Ultrafiltration	Additional treatment	0.956	0.096
Reverse Osmosis	Additional treatment	4.778	0.478
Storage	1000 m^3 storage tank	1.816	-
Waste Disposal[1]	Saline concentrate from reverse osmosis, treated by CIRVER Ecodeal	-	6
Labour	3 daily shifts of 8 h with 2 operators. 1/3 of the labour costs attributed to the processing of water before electrolysis	-	0.393
Transport	Includes the truck rental and fuel cost, with diesel (2 EUR/l)	-	Vary per municipality

[1] Includes treatment component only, and is provided as a contracted service.

Regarding the cost estimation approach, the CAPEX was divided into three components: (1) ultrafiltration, (2) reverse osmosis, and (3) storage. The cost values corresponded to the year 2021 and were subsequently adjusted from EUR$_{2021}$ to a EUR$_{2025}$ price basis to ensure consistency across the techno-economic calculations. Water abstraction and transport to the WWTP were assumed to be zero, as these costs are already accounted for in the WasteWater tariffs. These tariffs, also obtained from ERSAR, represent the baseline secondary treatment provided at WasteWater treatment plants (WWTPs) and were incorporated into the OPEX.

The ultrafiltration process generates a residual stream mainly composed of suspended solids, such as sludge, which can be further treated within the WWTP. In contrast, reverse osmosis produces a saline liquid concentrate containing dissolved contaminants at elevated concentrations. Due to its liquid nature and classification as hazardous waste, the only known entity treating this type of waste in Portugal is *CIRVER Ecodeal – Unidade de Tratamento de Resíduos*.

Transport for waste disposal was assumed to be carried out by truck, using the centroid of each municipality as the reference point and the CIRVER facility in Chamusca, Santarém, as the final destination. The associated transport distances were expressed in kilometres. The total transport cost was estimated as the sum of the truck rental cost and the truck fuel cost, considering diesel as the fuel. A tanker capacity of 25 m^3 per trip was assumed. The number of truck-days required was calculated based on the total daily distance travelled from each municipality to CIRVER, divided by the maximum distance travelled per day. The truck rental cost was then obtained by multiplying the number of truck-days by a unit cost of 175 EUR/day and normalising the result by the daily water volume of 700 m^3/day. The fuel cost was calculated based on the transport distance, assuming a fuel consumption of 0.35 L/km and a diesel price of 2 EUR/L. The resulting daily fuel cost was also divided by 700 m^3/day to express it as a unit cost in EUR/m^3.

Electricity consumption costs were expressed in EUR/MWh/m^3 and calculated by multiplying the unit electricity cost, corresponding to the LCOE of solar PV and/or onshore wind, by the energy consumption associated with each process. Accordingly, the OPEX included: i) ultrafiltration, ii) reverse osmosis, iii) storage, iv) waste disposal, v) labour, vi) transport, and vii) electricity consumption. The electrolyser unit was assumed to be installed in proximity to the WWTP; therefore, no additional transport was included. Table 5.4 presents the electricity consumption expressed in MWh/m^3/day.

Table 5.4: WasteWater electricity consumption.

Energy consumption	Ultrafiltration	Reverse Osmosis	Other (other motors, lighting, etc)
Elect. Pumping_{2025} [kWh/m^3]	72	1680	720
Elect. Pumping_{2025} [MWh/m^3/day]	0.0001	0.0024	0.00103

C.1.3 SeaWater

The SeaWater supply system considered for the unit water cost estimation includes the main components required for SeaWater abstraction, pre-treatment, desalination, storage, and delivery, together with their associated CAPEX and OPEX, as described in Table 5.5.

For SeaWater desalination, the cost assessment was limited to coastal municipalities, resulting in a total of 51 municipalities. For each municipality, the desalination plant was assumed to be located in close proximity to the coastline. Accordingly, SeaWater abstraction was modelled using two intake pipelines, one service line and one reserve line, with nominal diameters of DN500 and DN400, respectively, together with a pumping system. The nominal diameters and the pipeline/outfall lengths were defined using the Algarve desalination project as a reference and were adjusted to ensure consistency with the flow rate considered in this study [20],

The desalination capacity was sized to meet a net water flow of 700 m^3/day. An additional 45% was included to account for losses associated with the reverse osmosis process, resulting in a total intake of approximately 1,550 m^3/day. The resulting brine production from reverse osmosis was assumed to be discharged through a marine outfall with a nominal diameter of DN200.

Table 5.5: SeaWater supply system components and associated costs.

SeaWater Components	**Description**	**CAPEX [EUR/m^3]**	**OPEX [EUR/m^3]**
Pumping Infrastructure	Pump and accessories	0.382	0.204
Abstraction / Collection	Pipelines 2-3 km (DN500 + DN400)	25.70-34.89	0.386-0.523
Fine Screening	Additional treatment	3.345	0.274
Reverse osmosis	Desalinator unit plant with reverse osmosis included	7.796	0.676
Storage	100 and 1000 m^3 tanks	2.088	-
Waste Disposal	Brine from reverse osmosis, disposed by marine outfalls 3-4 km (DN200)	10.44-13.81	0.157-0.207
Labour	3 daily shifts of 8 h with 2 operators. 1/3 of the labour costs attributed to the processing of water before electrolysis	-	0.393
Water Charges	*TRH - Taxa de Recursos Hídricos, Decree-Law n.º 46/2017*	-	0.025

Given the presence of environmentally protected areas along the Portuguese coastline, where infrastructure development is subject to stricter constraints, specific lengths were defined for the seawater abstraction pipelines and marine outfall. For the cost estimation, abstraction pipeline lengths of 2 km and 3 km were considered, while marine outfall lengths of 3 km and 4 km were assumed. The longer configurations were applied to municipalities whose coastline was fully located within protected areas.

As a result, the overall CAPEX of desalinated seawater includes the following elements: i) abstraction, ii) SWRO desalination plant, iii) fine screening, iv) storage, v) waste disposal, vi) abstraction pipelines, and vii) marine outfalls.

Brine residuals were assumed to be treated within the desalination facility prior to discharge. Inspection costs were also accounted for, reflecting the routine monitoring required to ensure operational reliability. Labour costs reflect the personnel required for plant operation, supervision, and maintenance. Regulatory charges correspond to water resource fees, namely the *Taxa de Recursos Hídricos*, which is applied in Portugal to activities involving the use of public water resources. Electricity consumption costs were estimated using the same methodology applied to the wastewater case. Together, these elements represent the OPEX: i) abstraction, ii) SWRO desalination plant, iii) fine screening, iv) waste disposal, v) labour, vi) regulatory charges, vii) abstraction pipelines, viii) marine outfalls, and ix) electricity consumption. The electrolyser unit was assumed to be installed in proximity to the desalination plant; therefore, no additional transport was included. Finally, Table 5.6 presents the electricity consumption expressed in MWh/m^3/day.

Table 5.6: SeaWater electricity consumption.

Energy consumption	**Fine screening**	**Reverse Osmosis**	**Waste treatment**	**Other**	**Pipeline (2km)**	**Pipeline (3km)**	**Outfall (3km)**	**Outfall (4km)**
Elect. Pumping$_{2025}$ (kWh/m^3)	16.8	2800	180	720	0.00014	0.00015	0.0001	0.00014
Elect. Pumping$_{2025}$ (MWh/m^3/day)	0.00002	0.004	0.000257	0.00103	34.514	38.281	26.455	35.74

Appendix D

D.1 Municipality-Level Transport Distance Estimation

Within the H_2 transport and H_2 industry value chains, transport distance represents a key input for the H_2 road transport component, also referred to as H_2 road distribution. A specific methodological approach was therefore developed to estimate the road-based distances between the relevant origin and destination municipalities considered in these value chain configurations.

The methodology distinguishes between two spatial configurations: (1) inter-municipal connections, where the origin and destination are located in different municipalities; and (2) intra-municipal connections, where both points are located within the same municipality. The corresponding procedures are described in the following subsections.

D.1.1 Inter-Municipal Distance Estimation

For connections between different municipalities, distances were calculated using the "Origin–Destination Cost Matrix" tool available in ArcGIS. The analysis mode corresponding to heavy road transport was adopted to represent trucking distances and to reflect typical road-based hydrogen transport conditions. The origin and destination locations were represented using a geographic layer of municipal centroids, generated from the*Carta Administrativa Oficial de Portugal (CAOP)* [6].

To improve the realism of the route modelling, the "Transport Networks of Mainland Portugal 1:200,000" layer, provided by the *Direção-Geral do Território (DGT)* [21], was used as the network dataset. This allowed the existing road infrastructure to be incorporated into the analysis, ensuring that the calculated distances reflected plausible road routes rather than straight-line Euclidean distances.

D.1.2 Intra-Municipal Distance Estimation

For cases where the origin and destination are located within the same municipality, the same road network-based approach could not be applied due to computational limitations associated with the complexity of the analysis. Therefore, an alternative methodology was adopted to estimate the maximum potential transport distance within each municipality. This approach consisted of identifying the maximum straight-line distance fully contained within the municipal boundary.

For this purpose, representative internal points were generated for each municipality, and distances were evaluated between pairs of points located near the municipal boundaries. The maximum identified distance was then adopted as an approximation of the maximum intra-municipal extent. Although this method does not explicitly incorporate the road transport network, it provides a conservative and consistent estimate of internal transport distances, suitable for the spatial resolution and analytical constraints of this study.

Appendix E

Municipalities in Mainland Portugal

As shown in Table 5.7, this section presents the complete list of municipalities in mainland Portugal together with their corresponding DTMN (Territorial Division Code) identifiers, generated from the *Carta Administrativa Oficial de Portugal (CAOP)* [6]. These codes are used for administrative and spatial referencing purposes and ensure consistency in the analysis and processing of geographic and municipal-level data within this study. For all municipality-level calculations performed in this report, this list was used as the reference dataset.

Table 5.7: Municipalities and DTMN codes in mainland Portugal

DTMN	Municipality	DTMN	Municipality
0101	Águeda	1009	Leiria
0102	Albergaria-a-Velha	1010	Marinha Grande
0103	Anadia	1011	Nazaré
0104	Arouca	1012	Óbidos
0105	Aveiro	1013	Pedrógão Grande
0106	Castelo de Paiva	1014	Peniche
0107	Espinho	1015	Pombal
0108	Estarreja	1016	Porto de Mós
0109	Santa Maria da Feira	1101	Alenquer
0110	Ílhavo	1102	Arruda dos Vinhos
0111	Mealhada	1103	Azambuja
0112	Murtosa	1104	Cadaval
0113	Oliveira de Azeméis	1105	Cascais
0114	Oliveira do Bairro	1106	Lisboa
0115	Ovar	1107	Loures
0116	São João da Madeira	1108	Lourinhã
0117	Sever do Vouga	1109	Mafra
0118	Vagos	1110	Oeiras
0119	Vale de Cambra	1111	Sintra
0201	Aljustrel	1112	Sobral de Monte Agraço
0202	Almodôvar	1113	Torres Vedras
0203	Alvito	1114	Vila Franca de Xira
0204	Barrancos	1115	Amadora
0205	Beja	1116	Odivelas
0206	Castro Verde	1201	Alter do Chão
0207	Cuba	1202	Arronches
0208	Ferreira do Alentejo	1203	Avis
0209	Mértola	1204	Campo Maior
0210	Moura	1205	Castelo de Vide
0211	Odemira	1206	Crato
0212	Ourique	1207	Elvas
0213	Serpa	1208	Fronteira
0214	Vidigueira	1209	Gavião
0301	Amares	1210	Marvão
0302	Barcelos	1211	Monforte
0303	Braga	1212	Nisa
0304	Cabeceiras de Basto	1213	Ponte de Sor
0305	Celorico de Basto	1214	Portalegre
0306	Esposende	1215	Sousel
0307	Fafe	1301	Amarante
0308	Guimarães	1302	Baião
0309	Póvoa de Lanhoso	1303	Felgueiras

DTMN	Municipality	DTMN	Municipality
0310	Terras de Bouro	1304	Gondomar
0311	Vieira do Minho	1305	Lousada
0312	Vila Nova de Famalicão	1306	Maia
0313	Vila Verde	1307	Marco de Canaveses
0314	Vizela	1308	Matosinhos
0401	Alfândega da Fé	1309	Paços de Ferreira
0402	Bragança	1310	Paredes
0403	Carrazeda de Ansiães	1311	Penafiel
0404	Freixo de Espada à Cinta	1312	Porto
0405	Macedo de Cavaleiros	1313	Póvoa de Varzim
0406	Miranda do Douro	1314	Santo Tirso
0407	Mirandela	1315	Valongo
0408	Mogadouro	1316	Vila do Conde
0409	Torre de Moncorvo	1317	Vila Nova de Gaia
0410	Vila Flor	1318	Trofa
0411	Vimioso	1401	Abrantes
0412	Vinhais	1402	Alcanena
0501	Belmonte	1403	Almeirim
0502	Castelo Branco	1404	Alpiarça
0503	Covilhã	1405	Benavente
0504	Fundão	1406	Cartaxo
0505	Idanha-a-Nova	1407	Chamusca
0506	Oleiros	1408	Constância
0507	Penamacor	1409	Coruche
0508	Proença-a-Nova	1410	Entroncamento
0509	Sertã	1411	Ferreira do Zêzere
0510	Vila de Rei	1412	Golegã
0511	Vila Velha de Ródão	1413	Mação
0601	Arganil	1414	Rio Maior
0602	Cantanhede	1415	Salvaterra de Magos
0603	Coimbra	1416	Santarém
0604	Condeixa-a-Nova	1417	Sardoal
0605	Figueira da Foz	1418	Tomar
0606	Góis	1419	Torres Novas
0607	Lousã	1420	Vila Nova da Barquinha
0608	Mira	1421	Ourém
0609	Miranda do Corvo	1501	Alcácer do Sal
0610	Montemor-o-Velho	1502	Alcochete
0611	Oliveira do Hospital	1503	Almada
0612	Pampilhosa da Serra	1504	Barreiro
0613	Penacova	1505	Grândola
0614	Penela	1506	Moita
0615	Soure	1507	Montijo
0616	Tábua	1508	Palmela
0617	Vila Nova de Poiares	1509	Santiago do Cacém
0701	Alandroal	1510	Seixal
0702	Arraiolos	1511	Sesimbra
0703	Borba	1512	Setúbal
0704	Estremoz	1513	Sines
0705	Évora	1601	Arcos de Valdevez
0706	Montemor-o-Novo	1602	Caminha
0707	Mora	1603	Melgaço
0708	Mourão	1604	Monção
0709	Portel	1605	Paredes de Coura
0710	Redondo	1606	Ponte da Barca
0711	Reguengos de Monsaraz	1607	Ponte de Lima
0712	Vendas Novas	1608	Valença
0713	Viana do Alentejo	1609	Viana do Castelo
0714	Vila Viçosa	1610	Vila Nova de Cerveira

DTMN	Municipality	DTMN	Municipality
0801	Albufeira	1701	Alijó
0802	Alcoutim	1702	Boticas
0803	Aljezur	1703	Chaves
0804	Castro Marim	1704	Mesão Frio
0805	Faro	1705	Mondim de Basto
0806	Lagoa	1706	Montalegre
0807	Lagos	1707	Murça
0808	Loulé	1708	Peso da Régua
0809	Monchique	1709	Ribeira de Pena
0810	Olhão	1710	Sabrosa
0811	Portimão	1711	Santa Marta de Penaguião
0812	São Brás de Alportel	1712	Valpaços
0813	Silves	1713	Vila Pouca de Aguiar
0814	Tavira	1714	Vila Real
0815	Vila do Bispo	1801	Armamar
0816	Vila Real de Santo António	1802	Carregal do Sal
0901	Aguiar da Beira	1803	Castro Daire
0902	Almeida	1804	Cinfães
0903	Celorico da Beira	1805	Lamego
0904	Figueira de Castelo Rodrigo	1806	Mangualde
0905	Fornos de Algodres	1807	Moimenta da Beira
0906	Gouveia	1808	Mortágua
0907	Guarda	1809	Nelas
0908	Manteigas	1810	Oliveira de Frades
0909	Mêda	1811	Penalva do Castelo
0910	Pinhel	1812	Penedono
0911	Sabugal	1813	Resende
0912	Seia	1814	Santa Comba Dão
0913	Trancoso	1815	São João da Pesqueira
0914	Vila Nova de Foz Côa	1816	São Pedro do Sul
1001	Alcobaça	1817	Sátão
1002	Alvaiázere	1818	Sernancelhe
1003	Ansião	1819	Tabuaço
1004	Batalha	1820	Tarouca
1005	Bombarral	1821	Tondela
1006	Caldas da Rainha	1822	Vila Nova de Paiva
1007	Castanheira de Pêra	1823	Viseu
1008	Figueiró dos Vinhos	1824	Vouzela

Appendix F

F.1 The LNEG-H_2PTMap tool Interface

This Section presents a selection of screenshots from the LNEG-H_2PTMap tool, illustrating its integration within the LNEG geoPortal and highlighting the main interface components available to users. The figures included provide an overview of the tool's homepage, explanatory sections, scenario selection interface, filtering functionalities, geospatial visualisation outputs, and municipality-level result panels.

The purpose of this section is to document the visual structure and operational workflow of the tool, thereby complementing the methodological description provided in the main report. Additionally, it aims to guide users in understanding how to navigate the platform, interpret the displayed information, and effectively interact with the different features available.

F.2 Access to the LNEG-H_2PTMap Tool and Start Interface Overview

When users access the LNEG-H_2PTMap Tool through the "Search" item available in the geoPortal navigation menu, as illustrated in Figure 5.1, they are directed to the tool's initial landing interface (Start tab). This opening screen presents the title of the LNEG-H_2PTMap Tool - Geospatial Hydrogen Cost Calculator, along with a brief introductory description of its purpose and capabilities.

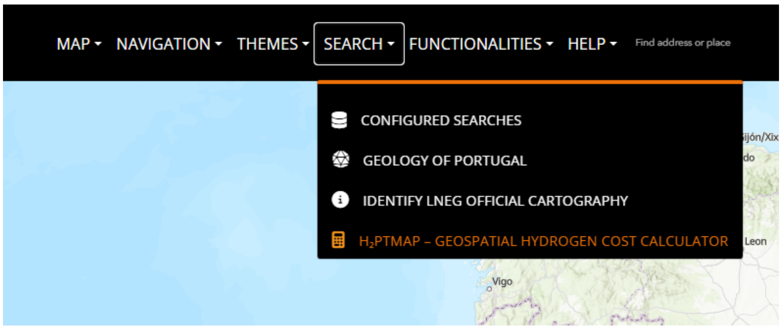

Figure 5.1: Access to the LNEG-H_2PTMap Tool via the geoPortal navigation menu

In particular, it summarises the tool's ability to estimate the Levelised Cost of Hydrogen (LCOH) across mainland Portugal and outlines its core operational structure, including the main workflow steps (mode selection, scope definition, and results visualisation), which are shown in Figure 5.2. This introductory layout provides users with an immediate understanding of the tool's functionality and navigation logic.

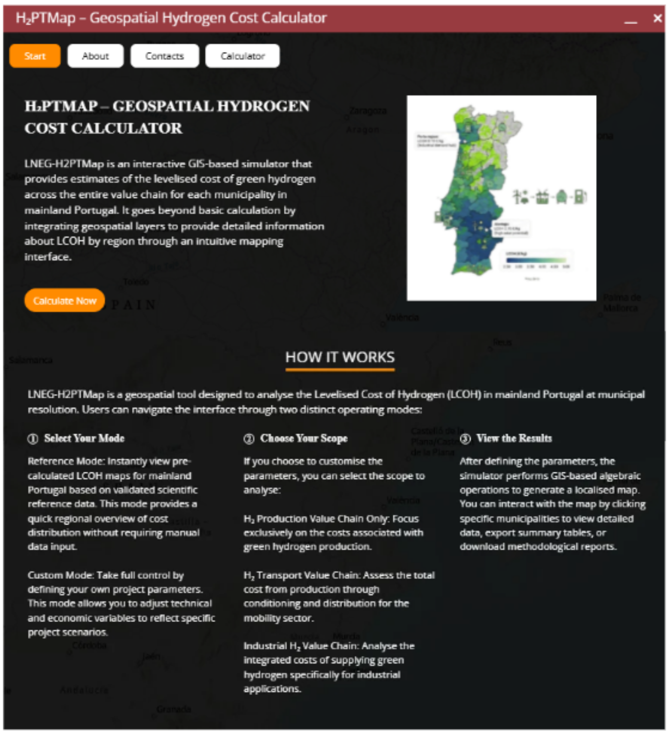

Figure 5.2: Start tab interface of the LNEG-H_2PTMap Tool (Homepage overview)

F.3 About Tab: The LNEG-H_2PTMap Tool Description and Methodological Context

The About section provides a detailed description of the LNEG-H_2PTMap Tool, outlining its purpose, conceptual framework, and development context. As shown in Figure 5.3, this interface explains the role of the tool in estimating hydrogen costs for the H_2 Production, H_2 Transport, and H_2 Industry value chains.

This section also places the platform within its wider scientific and institutional context, emphasizing its development by LNEG and its role in ongoing research initiatives. In addition, it provides access to the methodological documentation supporting the tool, allowing users to further explore the underlying assumptions, methodology, and calculation procedures.

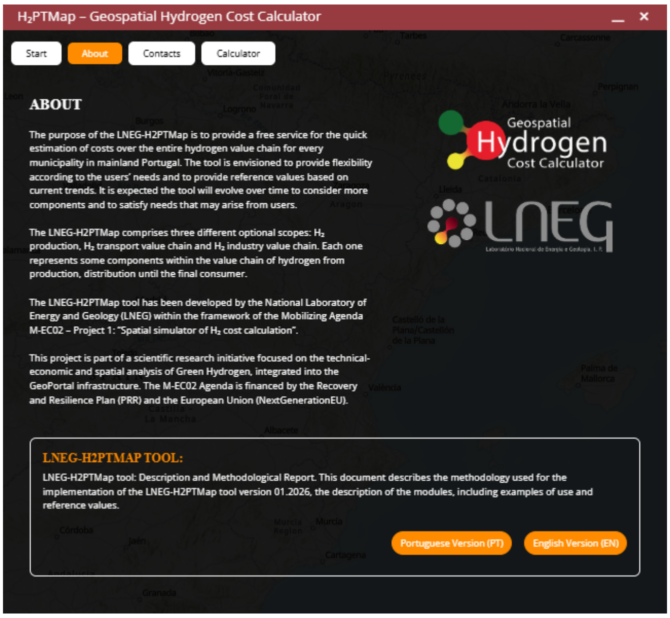

Figure 5.3: About tab interface of The LNEG-H_2PTMap Tool

F.4 Contacts Tab: The LNEG-H_2PTMap Tool Support and Communication Channels

The Contacts section, showed in Figure 5.4, provides users with the necessary information to communicate with the tool development team. This interface includes guidance on reporting technical issues, submitting feedback, and requesting additional information. Users are provided with a range of contact channels, including email, institutional address, and telephone details. This section promotes transparency and facilitates user support, while encouraging user engagement to support the ongoing enhancement of the platform.

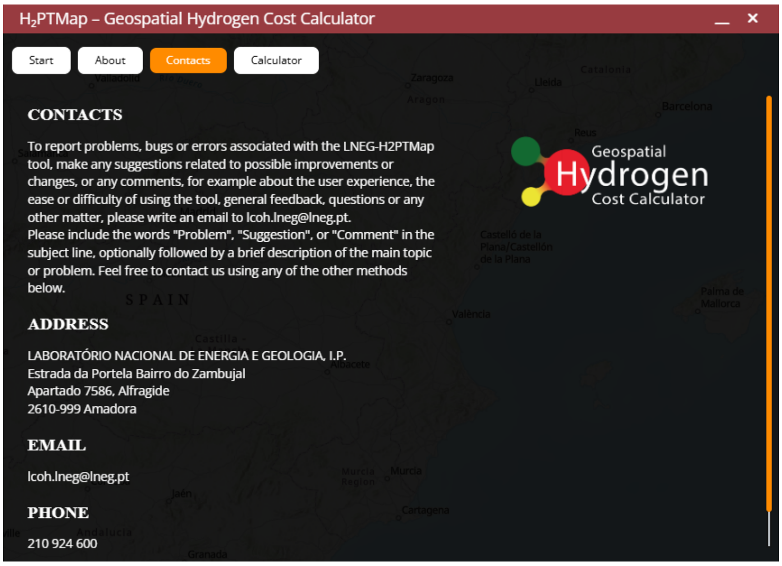

Figure 5.4: Contacts tab interface of the LNEG-H_2PTMap Tool

F.5 Calculator Tab: The LNEG-H_2PTMap Tool Scenario Definition and Scope Selection

The Calculator section represents the core functional component of the LNEG-H_2PTMap Tool, where users define the parameters required for the cost analysis. As shown in Figure 5.5, users can access this section either through the *"Calculate Now"* button on the Start tab interface or by directly selecting the Calculator tab. In both cases, the analysis begins with the selection of the calculation mode, either Reference or Customised. The user then selects the scope of analysis, choosing one configuration at a time: H_2 Production scope, H_2 Transport scope (value chain), or H_2 Industry scope (value chain).

After the scope is selected, the *Calculate* button appears in the right corner of the interface. By clicking this button, the user is directed to the corresponding filters and input parameters associated with the selected value chain configuration. This structured configuration process constitutes the initial step in generating spatially resolved LCOH results, which are further explored through the additional interface options presented in the subsequent sections.

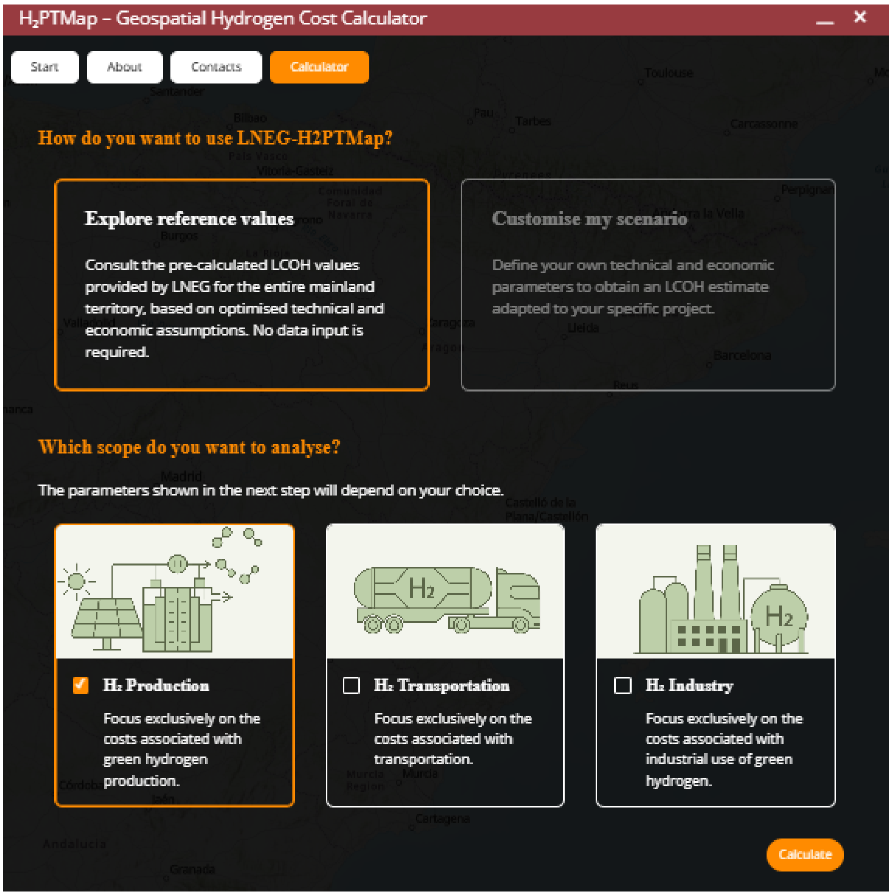

Figure 5.5: Calculator interface of the LNEG-H_2PTMap Tool

F.6 Identify Scenarios and View the Results of The LNEG-H_2PTMap Tool

When the H_2 Production scope is selected in Reference mode and the *Calculate* button is clicked, the user is directed to the corresponding map-based results interface, including the *Filters* panel and the *Identify* results panel, as illustrated in Figure 5.6. In the initial view, the *Identify* panel presents a table with the calculated LCOH values for all 278 municipalities in mainland Portugal, together with the main associated cost parameters. As it is shown above the table, the electrolyser type, water type, and electricity mix used to compute the LCOH in this scenario is mentioned.

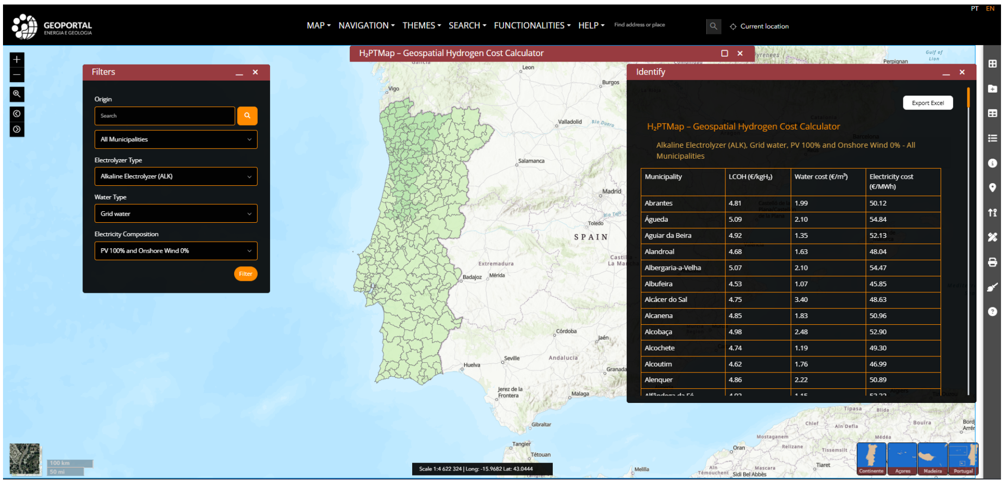

Figure 5.6: Calculator interface showing filtering options, and municipality-level results table of the LNEG-H_2PTMap Tool

The user can then modify the available filters to select one of the 30 pre-calculated reference scenarios and visualise the corresponding spatial results on the map, as well as in the Identify panel. In addition, a specific municipality can be selected as the hydrogen production location, such as Lisbon, providing access to detailed results for the selected municipality, as illustrated in Figure 5.7.

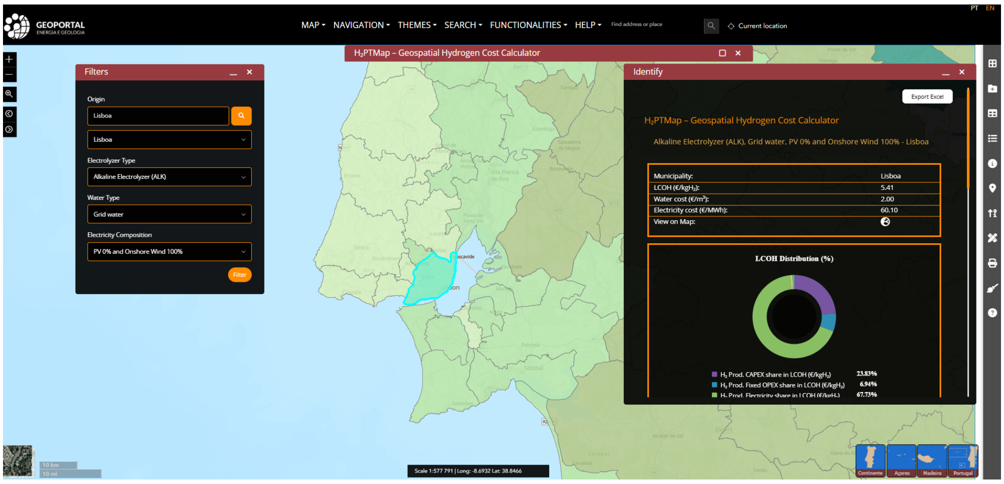

Figure 5.7: Filters and tables interface for H_2 production in Lisbon interface of the LNEG-H_2PTMap Tool

These results include the graphical breakdown of the LCOH components, together with the associated input and output parameters. The selected municipality is also highlighted on the map, allowing the user to spatially identify the chosen hydrogen production location, as illustrated in Figure 5.8.

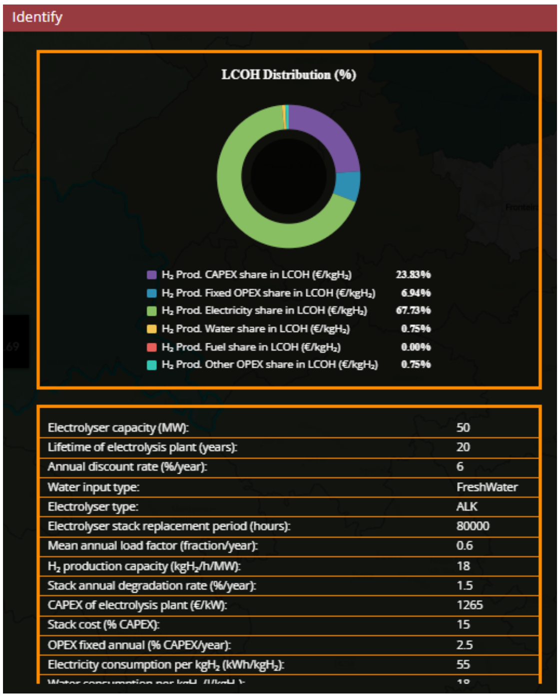

Figure 5.8: Result graphs and tables interface of the LNEG-H_2PTMap Tool

It is important to note that, for all configurations, when the user hovers over a municipality on the map, a pop-up window appears showing the LCOH value calculated according to the selected mode and scope. Figure 5.9 illustrates this functionality using the H_2 Production scope as an example.

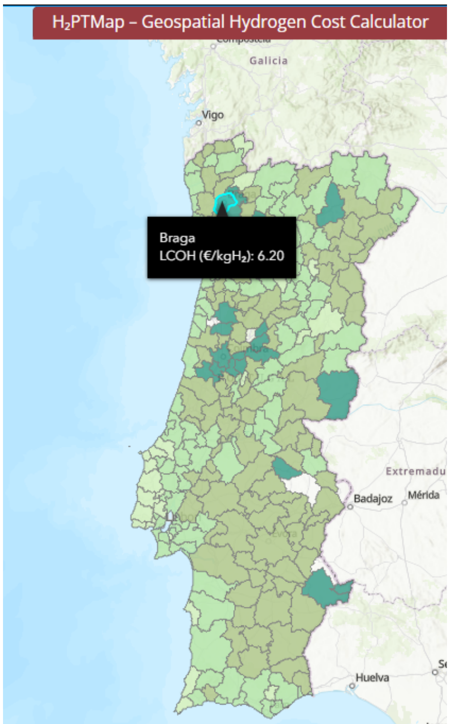

Figure 5.9: Pop-up interface while user hovers over the map in the LNEG-H_2PTMap Tool

The main difference between the H_2 production scope filters and those used for the H_2 Transport and H_2 Industry scopes is the inclusion of an additional destination filter. This parameter can be modified by the user and is used to define the location of the final hydrogen end-user, thereby establishing the origin–destination configuration for the produced hydrogen. In these scopes, the table shown in the *Identify* panel presents pre-calculated results for all destination municipalities from the selected origin, which in this example corresponds to the municipality of Abrantes, as shown in Figure 5.10.

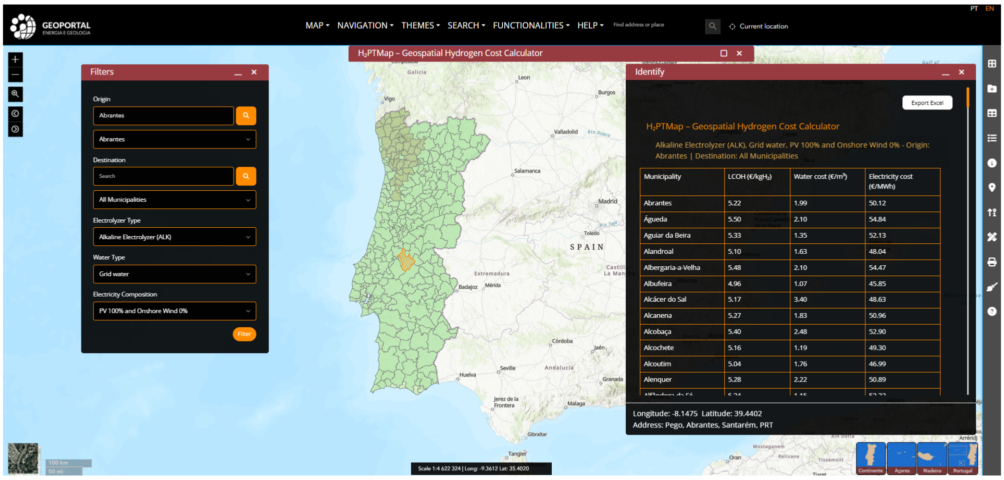

Figure 5.10: Filters and table interface for H_2 Transport and H_2 Industry scopes (value chains) of the LNEG-H_2PTMap Tool

Appendix G

Spatial Identification of Potential Industrial Hydrogen Consumers

The identification of potential industrial hydrogen consumers was based on publicly available data from the European Pollutant Release and Transfer Register (E-PRTR). A dataset comprising approximately 324 potential industrial H_2 consumers was derived from the most recent E-PRTR release, published in February 2026 and reporting industrial activity data for the year 2024 [22].

The location of each potential consumer was defined at the industrial plant level, based on the main industrial activity reported for each facility. The activity classification followed the categories used under the Integrated Pollution Prevention and Control (IPPC) framework, allowing the industrial sites to be grouped according to their main sectoral activity. Table 5.8 presents the activity classifications derived from Annex I to Regulation (EC) No. 166/2006 of the European Parliament and of the Council [23].

Table 5.8: Potential industrial hydrogen consumers identified from E-PRTR, by sector and activity classification.

Type of Potential Consumer	No. of Plants	PRTR Codes
Energy sector	11	1(a), 1(c)
Production and processing of metals	8	2(b), 2(d), 2(e)(i), 2(e)(ii), 2(f)
Mineral industry	14	3(c)(i), 3(c)(ii), 3(e), 3(g)
Chemical industry	5	4(a)(i), 4(a)(viii), 4(b)(ii), 4(c), 4(e)
Waste and wastewater management	42	5(a), 5(b), 5(d), 5(e) 5(f)
Paper and wood production and processing	8	6(a), 6(b)
Intensive livestock production and aquaculture	228	7(a)(i), 7(a)(ii), 7(a)(iii)
Food and beverage sector	2	8(b)(ii)
Other activities	6	9(a), 9(c), 9(e)
TOTAL	324	-

For the purposes of the LNEG-H_2PTMap Tool, the plant-level locations were subsequently translated to the municipality-level. This spatial aggregation enables the tool to represent industrial hydrogen demand consistently with the municipal-level structure used in the cost assessment. As a result, each potential industrial hydrogen consumer is associated with a corresponding municipality, allowing the H_2 Industry value chain to evaluate hydrogen supply configurations between selected production origins and potential industrial demand locations.

Appendix H

Spatial Identification of Potential Hydrogen Refuelling Demand Locations

Potential hydrogen demand locations within the H_2 Transport scope were identified using a dataset of existing fuel refuelling stations across mainland Portugal, which were considered proxies for future hydrogen demand in the transport sector. The dataset was retrieved from the DGEG Geoportal through its ArcGIS Web Application [24], where the thematic layer *"Postos de Abastecimento de Combustível"* (fuel refuelling stations) was selected. This layer provides the geographical distribution of approximately 3,000 fuel refuelling stations throughout mainland Portugal and was therefore used to represent potential locations for future hydrogen refuelling infrastructure in the LNEG-H_2PTMap Tool.

To maintain consistency with the spatial resolution applied in the cost assessment, the individual station data were subsequently aggregated at the municipal level. This aggregation supports the assessment of hydrogen supply chain configurations between selected production municipalities and potential transport demand centres, thereby enabling the estimation of costs across the H_2 transport scope (value chain).

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