Interreg CENTRAL EUROPE

Co-funded by the European Union

H2CE

D.2.1.3

Report on the testing of a strategic decision-support tool

Version 1

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1. H2CE Project

H2CE addresses the challenge of integrating hydrogen solutions and renewable energies into the regional energy transition. Today, existing information and support focuses on the needs and perspectives of project owners and of the industry, treating public authorities as (passive) framework condition instead of understanding their expertise and authority as a further means to pro-actively support change.

H2CE aims at empowering public authorities and administration in Central Europe (CE) to integrate hydrogen proactively and sustainably into regional planning and development. This will lead to an acceleration of hydrogen infrastructure ramp-up and a more efficient use of available funds. The main results of the project will be mechanisms to empower regional decision makers to support a hydrogen-based energy transition, the initiation of a cross-regional & transnational network of H2-ready regions, and the implementation of a digital collaboration platform.

In this scope, the WP2 aims at Increasing the understanding of challenges, potentials and solutions for the cross-regional and cross-sectoral transition of regional energy systems among energy utilities, public authorities, planning departments and regional SMEs in all H2CE partner regions.

In the specific, the deliverable presents the results of the testing of a digital GIS platform developed within the H2CE project, which aims to integrate hydrogen into regional energy transition strategies. It outlines the methodology adopted, the GIS system prototype, and the evaluation results from pilot regions in Veneto and Styria (D2.1.1). Additionally, it analyzes the Energy Cells model in Lübben (D2.1.2), designed to optimize the use of local energy resources and reduce CO_2 emissions. The report also provides guidelines for the transferability of the GIS model and Energy Cells to other territorial contexts, with a particular focus on scalability opportunities and the technological and economic barriers associated with hydrogen production and distribution.

2. GIS-based tool developed in Veneto and Styria Region

2.1. Results

The tools provide a data-driven approach to hydrogen infrastructure planning, offering decision-makers a strategic platform to evaluate hydrogen production, demand, and distribution at different territorial scales.

1. Potential and Added Value of the GIS Tool

The GIS tool demonstrates significant potential in supporting hydrogen-related policies by enabling:

- Territorial mapping of hydrogen potential: Identifying optimal locations for hydrogen production, storage, and distribution based on spatial data.
- Integration with renewable energy sources: Supporting the alignment of hydrogen production with solar, wind, and hydroelectric energy resources.
- Scenario simulation and predictive modeling: Analyzing different hydrogen development pathways to support long-term planning and investment decisions.
- Optimization of the transport and distribution network: Identifying strategic locations for refueling stations, pipelines, and logistics hubs.
- Environmental and social impact assessment: Analyzing potential impacts of hydrogen infrastructure on ecosystems, air quality, and community acceptance.

The tool leverages Geographic Information Systems (GIS) to optimize infrastructure investments, ensuring an efficient and sustainable transition toward a hydrogen-based energy system.

2. Usability and Key Functionalities

The GIS tool is designed to be accessible and user-friendly, supporting a broad range of users, from technical experts to policymakers. Key usability features include:

- A web-based platform: Allows real-time access to spatial data, eliminating the need for complex installations.
- Interactive decision-making dashboard: Enables policymakers to configure different hydrogen adoption scenarios and visualize their impact.
- Advanced geospatial analytics: Supports real-time data querying, sector-specific analysis, and territorial comparisons.
- Multi-layer data integration: Combines industrial consumption, mobility patterns, population distribution, and existing energy networks into a unified planning interface.
- Customization and scalability: The system is designed to accommodate new datasets and evolving policy priorities, ensuring long-term adaptability.

Through these features, the tool provides a flexible decision-support system that can help authorities optimize investments and coordinate stakeholders in the hydrogen sector.

3. Scalability and replicability in other contexts

One of the most significant aspects of this project is its scalability, making it a valuable model for other regions planning to integrate hydrogen into their energy strategies.

Key factors enabling scalability:

- Common methodology: The GIS tool was developed using a shared approach between Veneto and Styria, allowing it to be adapted to different territorial contexts.
- Interoperability: The system is built with modular and interoperable architecture, enabling integration with other GIS platforms and national energy strategies.
- Transferable data framework: The methodology used to collect, structure, and visualize data can be applied to other regions, industries, or transport networks.
- Adaptability to policy frameworks: The tool can incorporate different regulations, incentives, and energy strategies across various jurisdictions.
- Cross-sector application: While focused on hydrogen, the GIS-based approach can be extended to other renewable energy sources, urban planning, and climate adaptation policies.

Potential Applications in Other Regions:

1. Expanding to other European regions with hydrogen ambitions.
2. Adapting the tool for industrial clusters requiring hydrogen integration.
3. Supporting cross-border energy corridors and hydrogen distribution networks.
4. Integrating with smart city initiatives for sustainable mobility planning.

2.2. Adaptive Handbook based on the results of the GIS Tool

OBJECTIVE: a tool to support decisionmaker to evaluate the transition toward H2

RESULTS: From Actual fuel consumption is it possible to see the effect of fuel shift toward H2, both on numerical and geographical basis

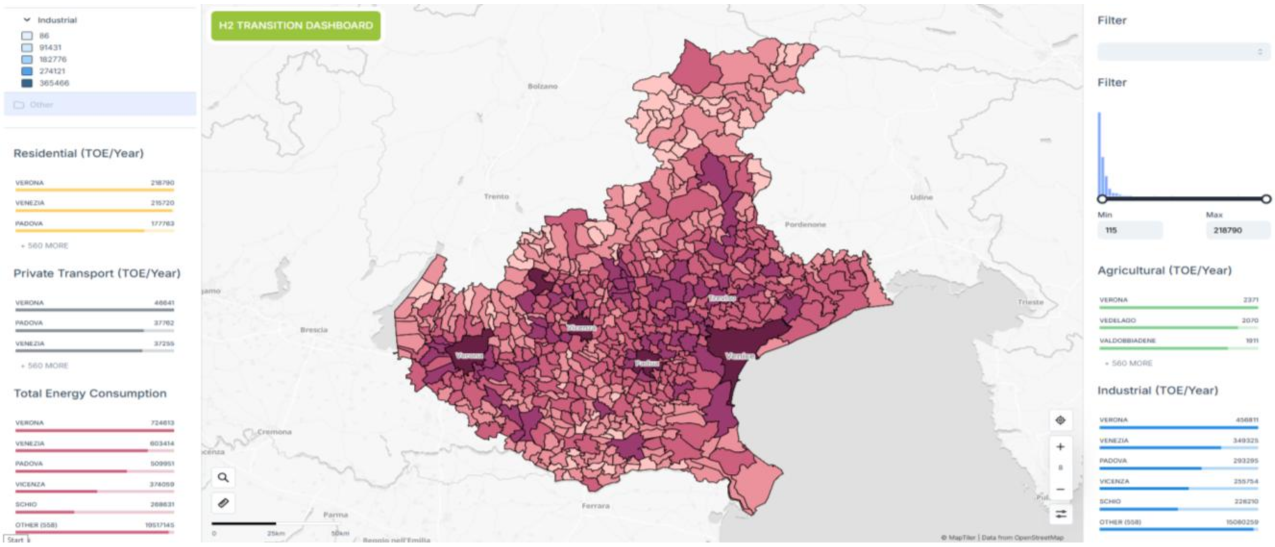
SIMULATION TOOL: The effects of the transition are modulated by a Policy Selector input based on H2 shift on each specific energy sources

RATIONALE: The tool is based on two dashboards and one simulation tool:

- Actual Fuel Consumption Dashboard
- Policy selector input
- H2 Transition Dashboard

Data Output Units: Outputs on numerical and geobased basis are expressed in three different units:

- H2 ton /year
- TOE / Year (Total Equivalent Energy)
- CO2 Savings / Year



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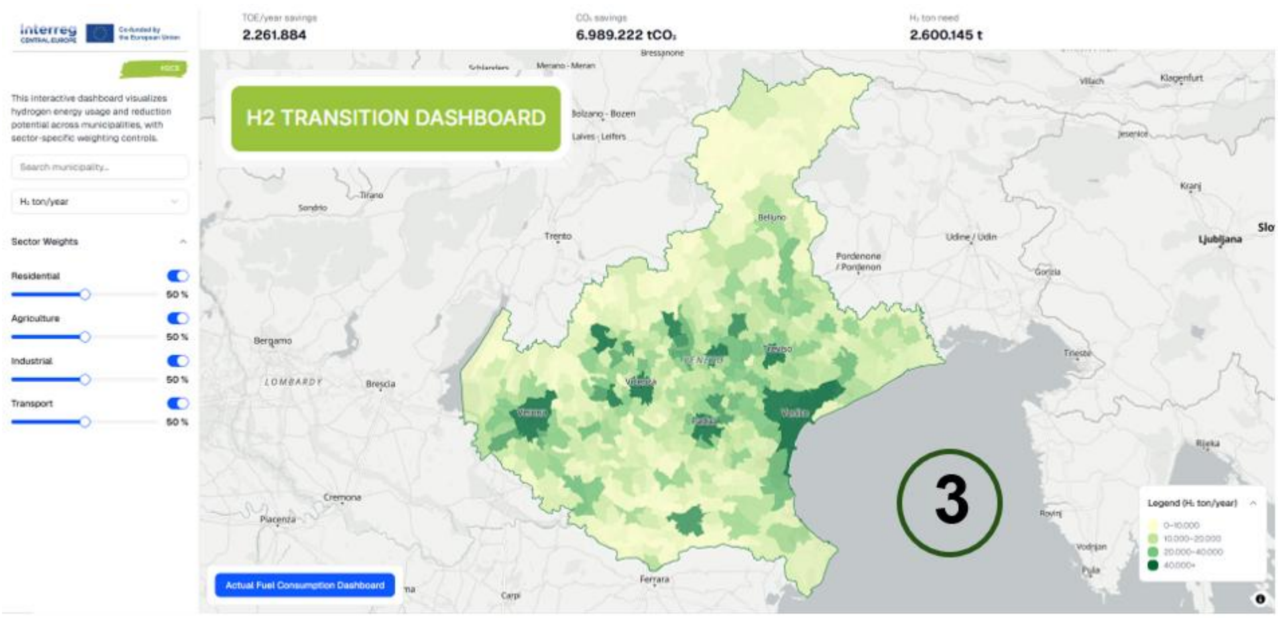
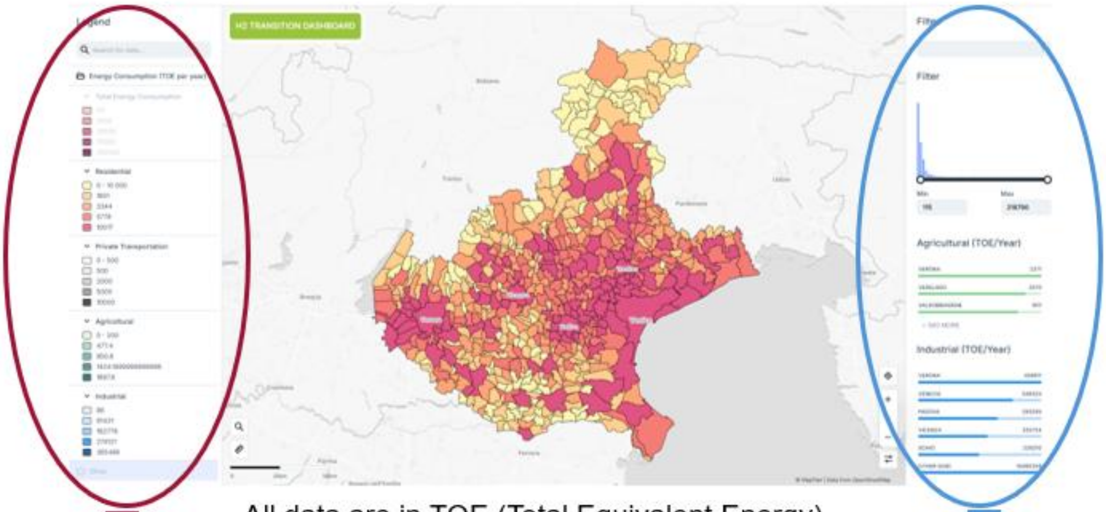
Policy selector input



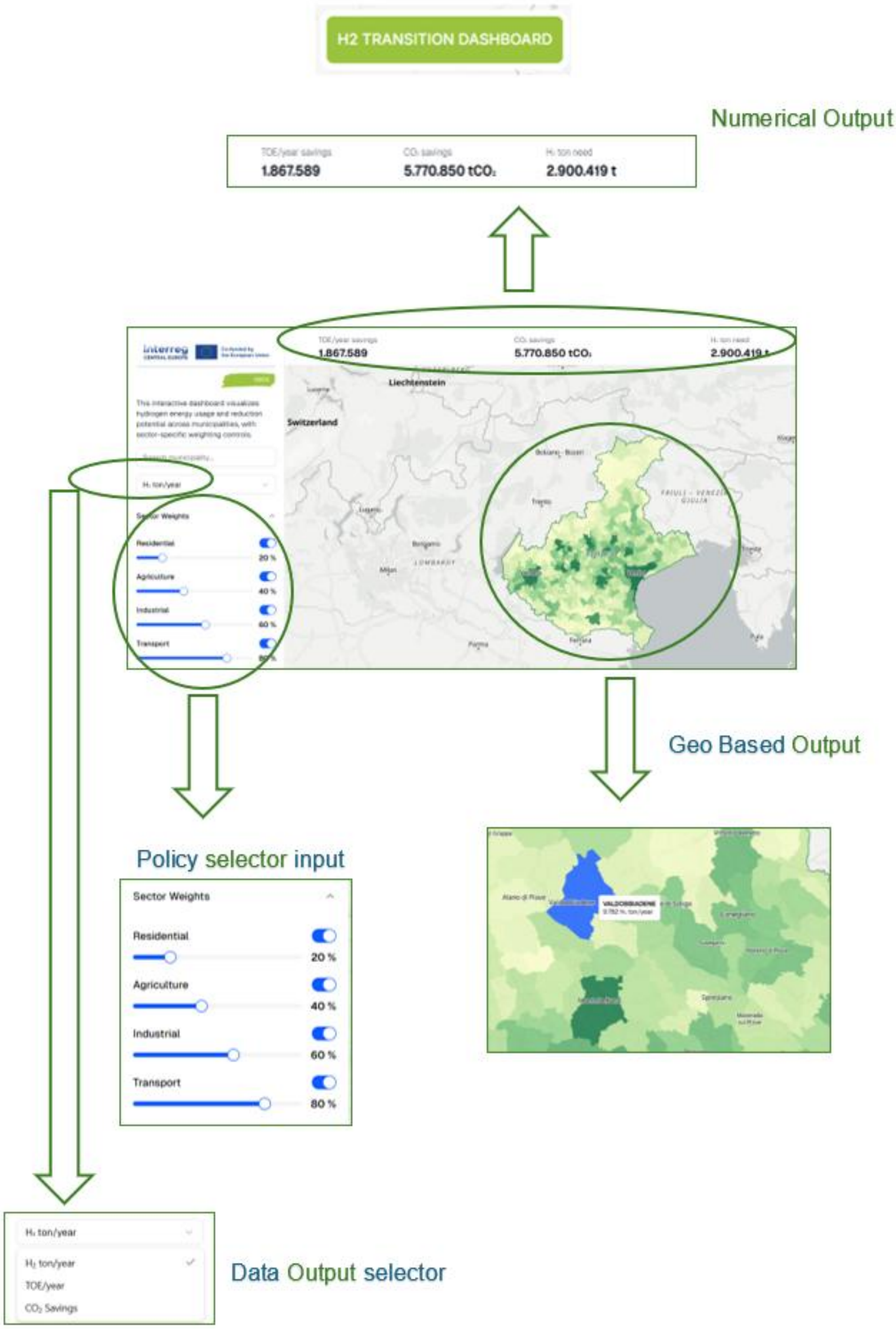
Actual Fuel Consumption Dashboard



All data are in TOE (Total Equivalent Energy) per Year

DATA SELECTION MENU

DATA FILTER MENU


H2 TRANSITION DASHBOARD
Numerical Output
TOE/year savings
1.867.589
CO2 savings
5.770.850 tCO2
H2 ton need
2.900.419 t
Geo Based Output
Policy selector input
Sector Weights
Residential
20 %
Agriculture
40 %
Industrial
60 %
Transport
80 %
H2 ton/year
TOE/year
CO2 Savings
Data Output selector

2.3. Scalability and transferability

1. Defining the Context and Objectives

Objective: Identify regional needs and define the role of GIS in hydrogen planning

Operational Steps:

- Map the territorial context:
  - Analyze local, national, and European energy and climate policies.
  - Review existing decarbonization strategies.
- Define the strategic objectives of the GIS tool:
  - Support decisions on hydrogen production, storage, and distribution sites.
  - Identify key demand sectors (industry, transport, residential, etc.).
  - Create development scenarios based on territorial data.
- Engage stakeholders:
  - Public authorities and local administrations.
  - Industry and energy companies.
  - Universities and research centers.
  - Local communities and associations.

Expected Output:
Initial planning document with clear objectives and a project roadmap.

2. Data Collection and Organization

Objective: Create a structured database with the necessary information for GIS analysis.

Operational Steps:

- Identify primary and secondary data sources:
  - **Energy data**: industrial consumption, transport, residential demand, renewable energy distribution.
  - **Infrastructure data**: transport networks, pipelines, production and distribution facilities.
  - **Geospatial data**: territorial maps, administrative boundaries, environmental constraints.
  - **Economic and social data**: industrial growth, population distribution, demographic trends.
- Standardize and integrate data into GIS:

- Convert data into compatible formats (TOE, hydrogen ton equivalent).
- Ensure quality and consistency across different datasets.
- Create a centralized database accessible to project partners.

Expected Output:
GIS database organized with thematic layers for spatial analysis.

3. Development of the GIS Tool and Spatial Modeling

Objective: Create a GIS platform to analyze hydrogen development scenarios.

Operational Steps:

- **Define the structure of the GIS tool:**
  - Select GIS software (e.g., Atlas, QGIS, ArcGIS).
  - Configure interfaces and visualization dashboards.
- **Build the geospatial model:**
  - Map current and future hydrogen demand.
  - Analyze territorial compatibility for new hydrogen facilities.
  - Simulate scenarios for expanding the distribution network.
- **Integrate interactive functionalities:**
  - Query data by sector and geographic area.
  - Predictive analysis tools based on GIS models.
  - Dashboards to visualize CO_2 savings and environmental impacts.

Expected Output:
Beta version of the GIS tool with analysis and simulation functionalities.

4. Testing and Validation of the GIS Tool

Objective: Ensure that the tool provides accurate and useful data for decision-making.

Operational Steps:

- **Test with experts and public decision-makers:**
  - Engage key stakeholders to test functionalities.
  - Gather feedback on usability and reliability.
- **Verify data quality:**
  - Compare results with real consumption data and forecasts.
  - Optimize GIS models based on test results.

- **Improve and debug the system:**
  - Fix any discrepancies in the data.
  - Add functionalities requested by users.

Expected Output:
Final version of the GIS tool ready for implementation.

5. Implementation and Use for Territorial Planning

Objective: Integrate the GIS tool into regional development strategies.

Operational Steps:

- **Train end users:**
  - Organize workshops with public administrators and businesses to use the tool.
  - Create operational guidelines for data consultation.
- **Integrate into decision-making processes:**
  - Support planning of new hydrogen plants.
  - Analyze investment and funding opportunities.
  - Develop energy policies based on GIS data.
- **Monitor and continuously update the system:**
  - Periodically collect new data to update the system.
  - Assess the impact of decisions made using the GIS tool.

Expected Output:
Fully operational GIS tool used in regional planning processes.

3. Energy Cells Model in Luebben

3.1. Results

The energy system in Lübben has been analysed with the open plan tool. The idea was to analyse possible solutions for decarbonisation. The demand profile of the Region of Lübben is dominated by private households. The highest obstacle to take is the decarbonization of the heating sector in the region. The lack of industry using high temperature process makes the utilization of waste heat impossible. Therefore, other technologies must be used in order to meet the demand.

The region has high potential for renewable energy production with wind and solar. The electricity grid has limited capacity. Therefore, utilising the potential of renewable energies needs to happen with local consumption through sector coupling of the electricity and heating sector. The goal is to achieve climate neutrality by 2045 according to the German national law.

Electricity supply

The high potential for renewable energies in the region allows for complete self-sufficiency. There is also the possibility to sell energy via the electrical grid.

Sector coupling

About 62 % of the decentral heat demand is to be met with heat pumps, allowing to utilize the high potential for renewable energies. Biogas used in boilers makes up for the other 38 % to fulfil the the demand. For the central demand in the heating grid of Lübben a combination of a heat pump and a combined heat and power plant (chp). The electrical power of the chp can be used to power the heat pump. The use of a heat storage allows for more flexibility.

Comparing of central and decentral demand

The comparison of the centralized and decentralized demand shows significant differences in their value. The demand in the heating grid is about 2,5 % of the decentralized demand. Since the differences are so high, the optimization does not show optimal results for the central heat supply. The Sankey shows a branch called “heat_central_excess” that is bigger than the central heat demand. Excess energies are energies that the system produces but is not able to distribute and therefore qualifies as excess. Usually excess energy is meant to be as low as possible, but since the values of the decentralized demand are way higher, the excess energy is relatively small compared to the total demand. A more detailed analysis of the centralized heating demand needs to be made.

3.2. Adaptive Handbook based on the results of the Energy Cells Model

(SEE the full Handbook in the Annex 1)

3.3. Scalability and Transferability

The energy system in Lübben shows various results that can be transferred to other regions in Central Europe.

Heat demand as a challenge for future energy systems

The energy transition in the heating sector poses an enormous challenge for regions. The energy demand in this sector usually exceeds the demand for electrical energy by far. In many regions, the current heat demand is covered by natural gas. In the future, it cannot be assumed that this demand cannot simply be replaced by biogas due to the lower availability. Current research shows, the heat pump is the cheapest way to supply heat. However, using heat pumps changes the required infrastructure because the performance of the heat pump is highly dependent on the temperature difference. For example, it is more efficient to emit room heat through underfloor heating instead of smaller radiators, which have to reach a significantly higher temperature to heat a room. In the majority of the housing stock, these infrastructure needs are not met. The same applies to heating networks. Currently, many heating networks operate with high temperatures, which reduce the efficiency of heat pumps in a central supply. In order to make the heat supply cheap and environmentally friendly in the future, an expansion of the infrastructure and renewable energies is indispensable.

Sector coupling and intelligent systems

The energy supply of the future works by coupling different sectors. Because many sectors are showing countercyclical demand patterns, synergies are to be expected here. Likewise, flexibility in processes must be increased to counter the fluctuation of renewable energies. This requires smart systems that can control processes according to the generation profile of renewable energies.

Role of hydrogen in the energy system

In regions such as Lübben without foreseeable hydrogen demand, hydrogen plays a subordinate role in the energy system. The region does not have any industrial processes for which the application of hydrogen is an option. The use in other sectors, such as the heating sector, is also not economically competitive.

However, due to the high potential for renewable energies, the production and export of hydrogen is an economically viable solution. The connection to the European Hydrogen Backbone thus opens economic opportunities for such regions.

Barriers to hydrogen production

The optimization shows that the use of hydrogen in the energy system is not economical based on the assumptions made. However, it also shows that the production of hydrogen is too possible and economical if the purchase price is sufficient. If a region cannot do without hydrogen due to economic

processes, regional production is a good addition. The simulation also shows large surpluses of electrical energy for the year 2045. The decarbonization of energy systems requires the expansion of renewable energies. Because the expansion of electricity grids is a complex project, the use of energy surpluses for hydrogen production can prevent RE plants from having to be shut down to prevent grid overloads.

To use these energy surpluses electrolysers and other technical equipment for producing and storing hydrogen must get cheaper to create a viable business case.

4. Testing of strategic decision support tools

4.1. Methodology

The validation and testing activity presented in this chapter was designed to evaluate the usability, relevance, and transferability of the two decision-support tools developed within the H2CE project:

- The GIS-based platform, piloted in the Veneto Region and developed to support hydrogen planning at territorial scale
- The Energy Cells Model, tested in the city of Lübben (Germany), which focuses on local energy system optimisation through sector coupling and decentralised production

The methodology was defined and coordinated by Unioncamere del Veneto as part of a shared framework for transnational validation. It was developed with the aim of involving real stakeholders—outside of the project partnership—and gathering informed feedback on the tools' applicability to diverse regional contexts. The process was conceived as a pilot action, with the potential to be replicated in future initiatives or territorial energy planning processes.

The validation activity followed a structured three-step approach, combining training, testing, and interactive feedback.

<u>Step 1 - Stakeholder involvement and activation</u>

Each project partner was invited to identify and involve one or more relevant stakeholders from their territory. The target was to ensure a diverse set of participants, including:

- Local and regional public authorities (technical or political)
- Energy and environmental agencies
- Utilities and infrastructure operators
- Research institutions or academic experts

Stakeholders were selected based on their potential interest in adopting or adapting the tools within real decision-making processes. The goal was not only to "showcase" the tools, but to activate a preliminary reflection on their practical value, their policy relevance, and the conditions for possible implementation.

Step 2 – Online training and live demonstration

An online workshop was organised to provide a shared testing environment for all invited stakeholders. The session was structured around three main moments:

Introductory framing: the objectives of the session, the rationale behind the tools, and the methodological reference provided by the H2CE Handbook on testing and transferability were presented.

Tool demonstration: a live demo of the GIS platform developed by Unioncamere del Veneto was conducted, using the actual web-based interface. This demonstration showed the core functionalities of the platform, including:

- Data visualisation at municipal scale
- Filtering by sector and energy source
- Simulation of hydrogen development scenarios
- Estimation of CO_2 emissions reduction and fossil fuel displacement

A short presentation of the Energy Cells Model tested in Lübben followed, with focus on its application to the local heating sector and on the logic of sector coupling.

Feedback and interaction: participants were invited to express their views through live polling (via Mentimeter). The questions covered:

- Overall usability and accessibility of the GIS tool
- Relevance of different functionalities for their specific contexts
- Potential obstacles to adoption (e.g., data gaps, technical capacity, political prioritisation)
- Perceived domains of application and interest in follow-up

The use of live polls ensured a dynamic interaction and allowed for a first layer of structured, comparable feedback across participants and countries.

Step 3 – Consolidation of inputs and reporting

Following the session, all collected inputs were analysed by Unioncamere del Veneto. The feedback was categorised by stakeholder type and country, and interpreted in relation to the goals of the testing process:

- Identifying which functionalities were perceived as most useful
- Understanding where barriers might lie (technical, institutional, financial)
- Mapping potential domains of application (energy, climate, mobility, etc.)
- Assessing the overall transferability of the tools

The findings of this analysis are presented in the following section and form the basis for final recommendations on how to improve the tools, increase their accessibility, and support their future replication.

4.2. Results of the testing

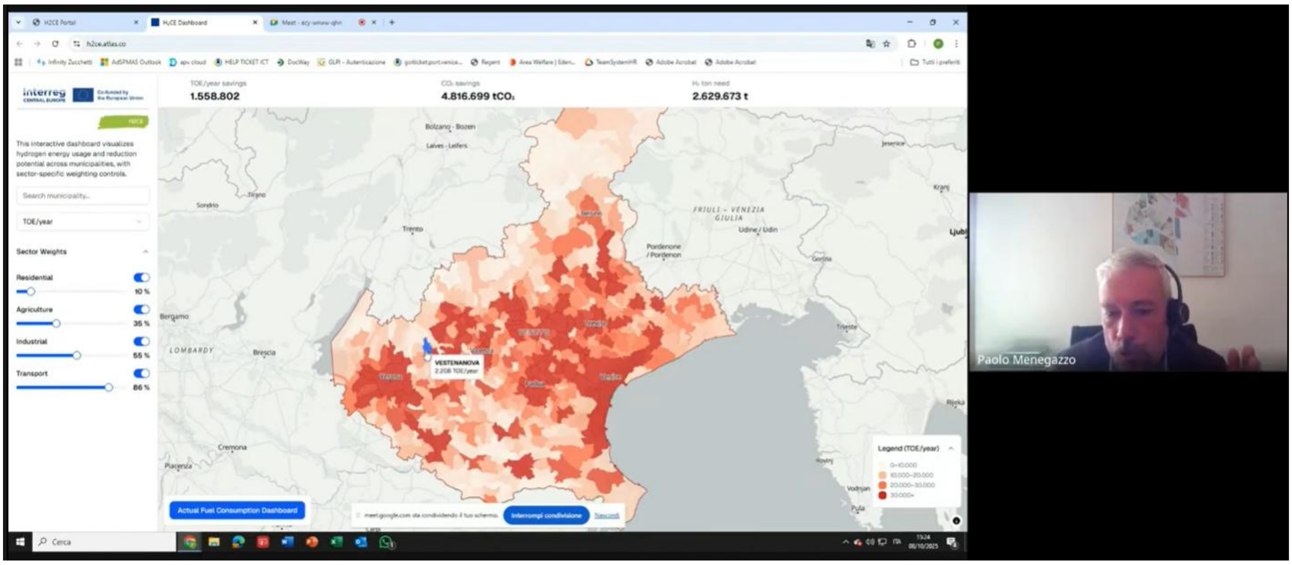
The testing session took place on 8 October 2025, from 15:00 to 16:00 CET, as an online workshop open to external stakeholders invited by the H2CE project partners.

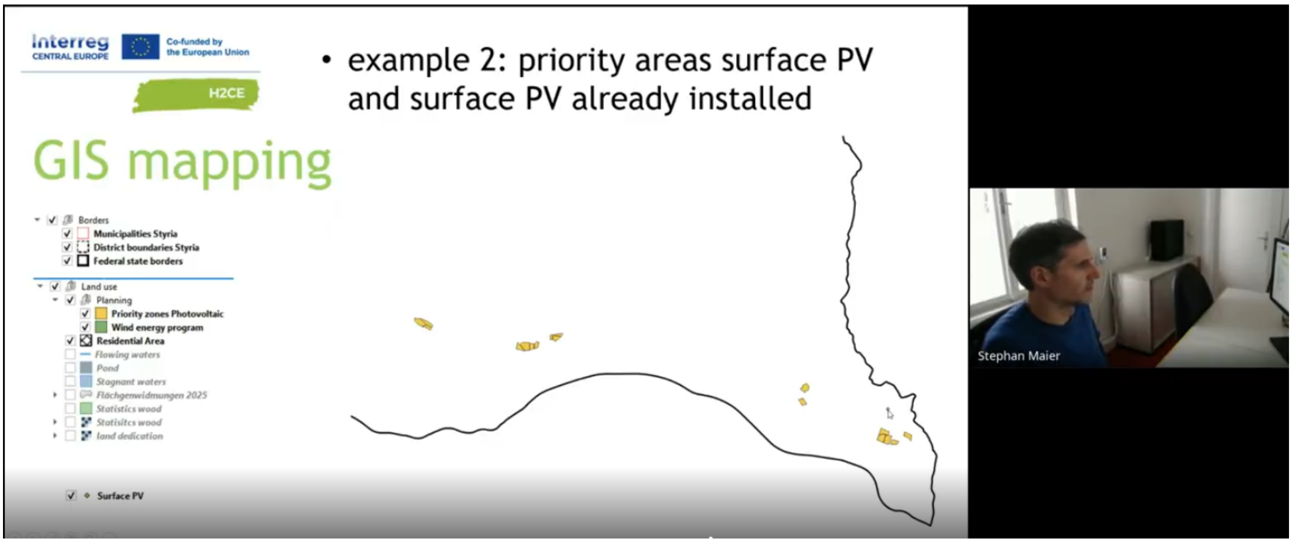
The event was coordinated by Unioncamere del Veneto, with the participation of other partners involved in the development of the tools, namely the Energy Agency of Styria and Stadt- und Überlandwerke Lübben.

The structure of the session followed the methodology described in section 4.1 and included:

- A general introduction to the H2CE project and testing objectives
- A live demonstration of the GIS Platform developed for the Veneto Region and Styria
- A presentation of the Energy Cells Model tested in Lübben

A real-time interactive survey using the Mentimeter platform, where participants were asked to provide structured feedback on the tools.




Interreg
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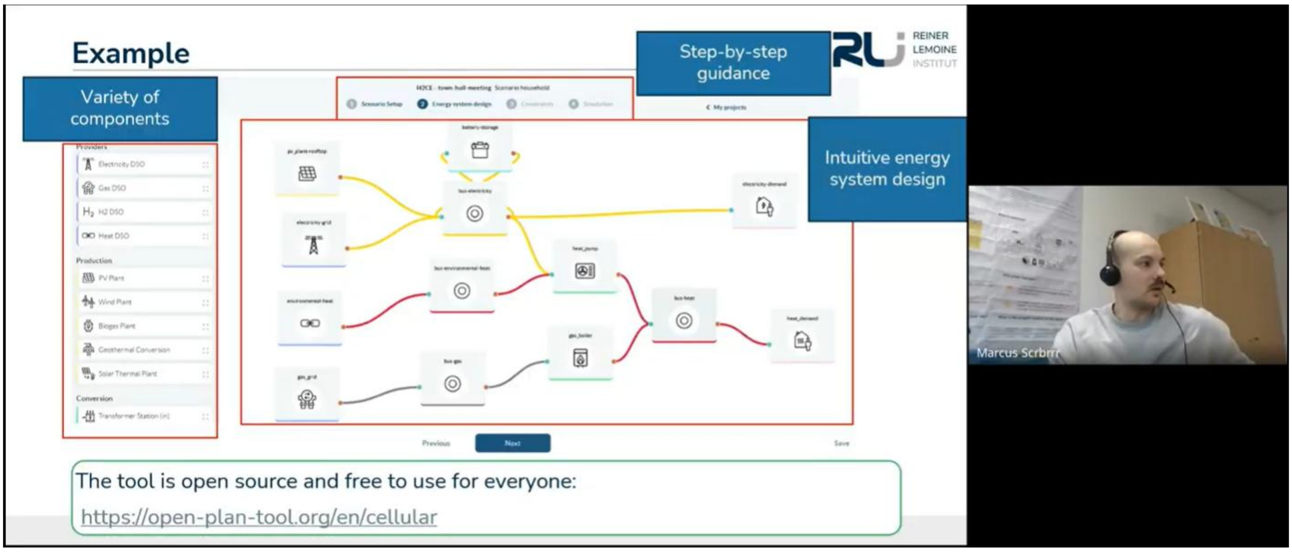
H2CE
GIS mapping
• example 2: priority areas surface PV and surface PV already installed
Borders
Municipalities Styria
District boundaries Styria
Federal state borders
Land use
Planning
Priority zones Photovoltaic
Wind energy program
Residential Area
Flowing waters
Pond
Stagnant waters
Flächgenwidmungen 2025
Statistics wood
Statisitcs wood
land dedication
Surface PV
Stephan Maier


Example
Variety of components
Step-by-step guidance
REINER
LEMOINE
INSTITUT
Intuitive energy system design
Providers
Production
Conversion
Previous
Next
The tool is open source and free to use for everyone:
https://open-plan-tool.org/en/cellular
Marcus Scrbrrr

Participants

A total of 27 participants from 18 organizations took part in the workshop, representing a diverse range of organisations and territorial contexts. Below is a summary of their profiles:

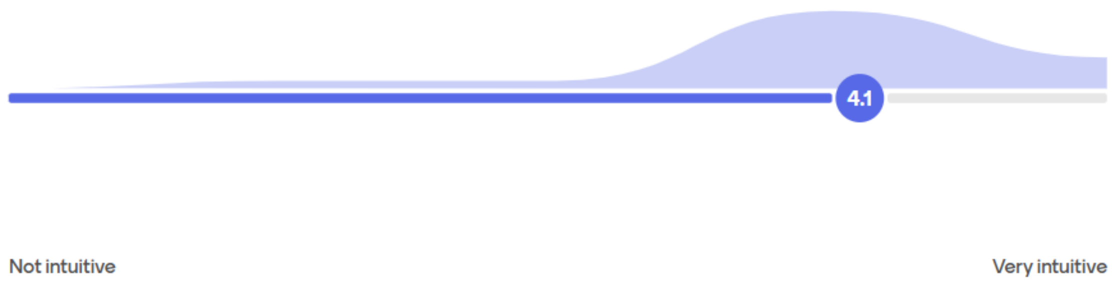
Participants came from several countries within the Interreg Central Europe area, including Italy, Austria, Germany, Poland, Slovenia and Croatia.

ORGANIZATION	COUNTRY	TYPE	DESCRIPTION
Energy Agency of Styria	Austria	Energy/environmental agency	Regional agency promoting energy efficiency, renewable energy and climate strategies.
Energy Institute Hrvoje Požar	Croatia	Energy/environmental agency	National energy institute for research, policy and strategic planning.
Bürgerinitiative Neue Energie - Hydrogen for Falkensee	Germany	NGO or non-profit organisation	Citizens' initiative promoting hydrogen and renewable energy awareness.
PROOH2V e.V.	Germany	NGO or non-profit organisation	Association promoting hydrogen mobility and regional cooperation in Northern Germany.
STRATECO OG	Austria	Private company	Consultancy and project management firm specialized in regional development and innovation.
Green Wind Innovation GmbH & Co. KG	Germany	Private company	Private enterprise active in renewable energy and hydrogen projects.
Greenwind	Germany	Private company	Company developing wind and hydrogen energy solutions.
Spilett new technologies GmbH	Germany	Private company	Consultancy and innovation company in technology transfer and EU projects.
Port of Venice - Strategic Planning Department	Italy	Public utility or infrastructure operator	Public entity managing strategic development and infrastructure planning of the Venice Port.
Landkreis Havelland	Germany	Regional or local public authority	Local district administration involved in sustainable territorial development.
WFBB - Brandenburg Economic Development Corporation	Germany	Regional or local public authority	Public regional development agency supporting innovation and business growth in Brandenburg.
REG Regional Development Company	Germany	Regional or local public authority	Regional development company supporting municipalities and local projects.

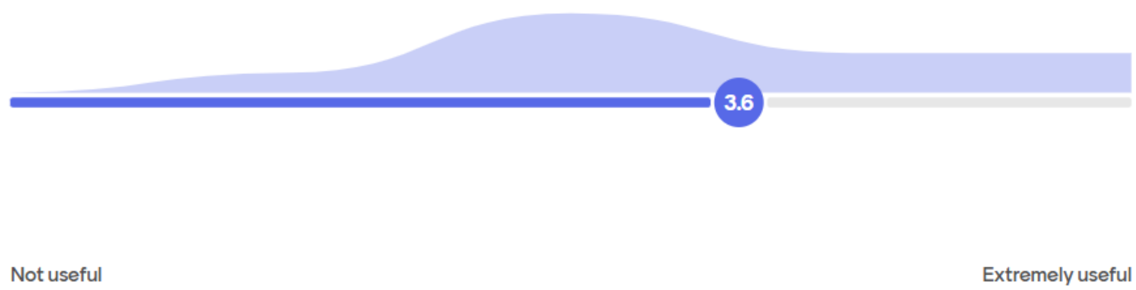
Northwest Brandenburg			
City of Zagreb	Croatia	Regional or local public authority	Municipal administration responsible for urban and environmental policies.
Joint Spatial Planning Department Berlin-Brandenburg	Germany	Regional or local public authority	Cross-regional planning body coordinating spatial and territorial development policies.
4ward Energy Research GmbH	Austria	Research centre or university	Applied research company focused on energy transition and digitalisation.
Reiner Lemoine Institute	Germany	Research centre or university	Non-profit research institute focused on sustainable energy systems and mobility.
ITL Foundation (Institute for Transport and Logistics)	Italy	Research centre or university	Foundation supporting research and innovation in sustainable transport and logistics.

Key Results from the Live Polling

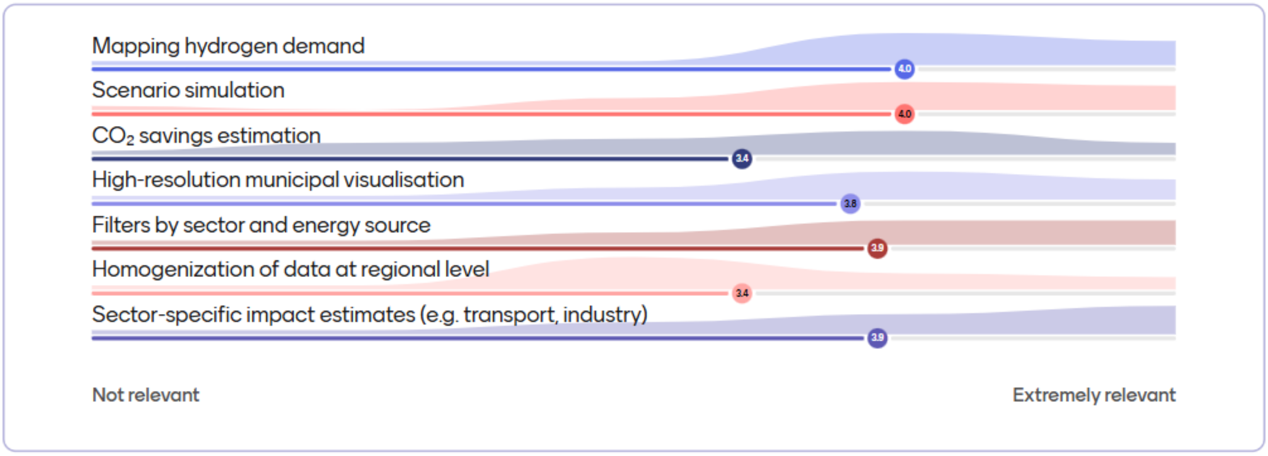
Usability: How intuitive did you find the dashboard and basic functionalities?



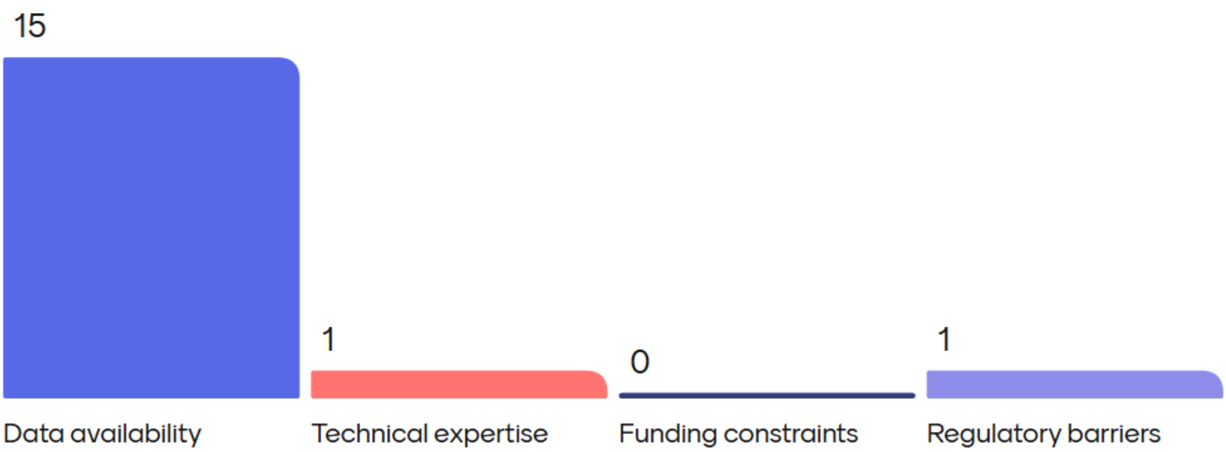
Usefulness: How useful do you think this tool is for supporting strategic decisions on energy/hydrogen planning?



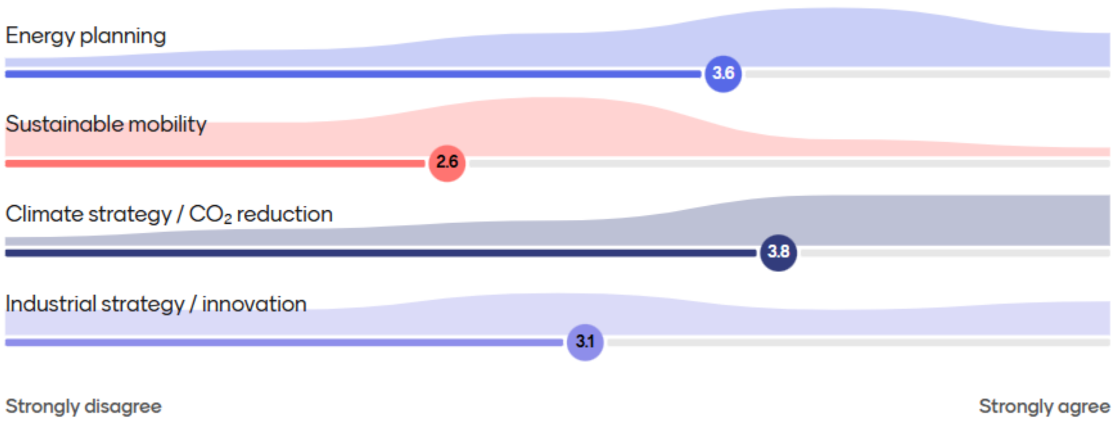
Most Relevant Functionality: which of the following functionalities did you find most relevant?



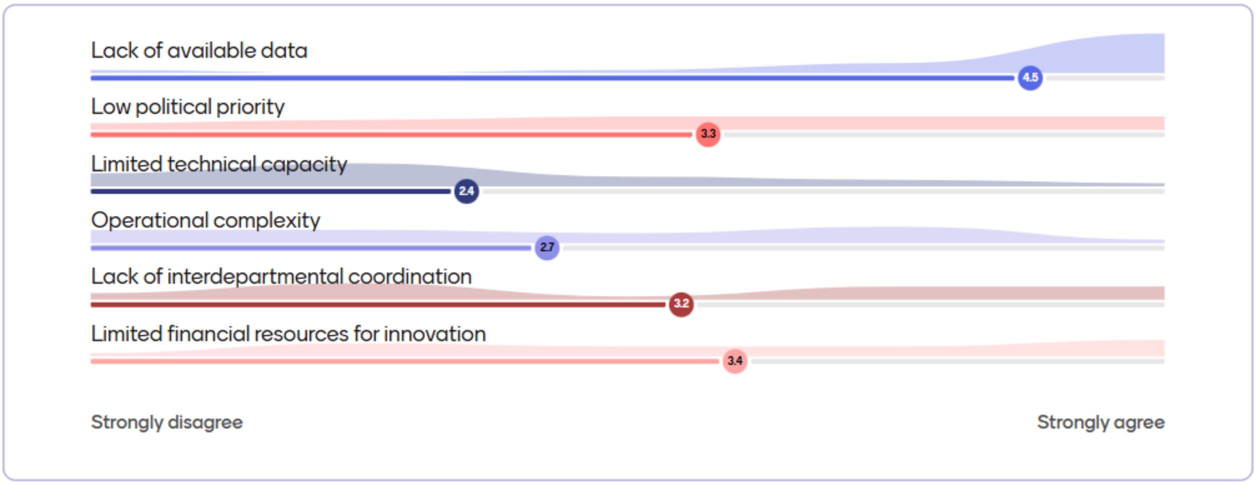
Transferability: what are the biggest challenges to adapting this tool locally?



<u>**Transferability:**</u> in which domain would this tool be most relevant in your context?



<u>**Barriers:**</u> which factors could hinder the adoption of such a tool in your organisation or territory?



5. Conclusions

The analysis and testing carried out within the H2CE project demonstrate how the GIS platform and the Energy Cells Model can serve as strategic tools for energy planning and the transition towards a hydrogen-based system. The GIS platform, tested in the pilot regions of Veneto and Styria, has proven to be an effective decision-support tool, providing a detailed view of hydrogen infrastructure by integrating territorial, environmental, and economic data. Its advanced modeling and simulation capabilities enable policymakers and planners to evaluate different hydrogen development scenarios, optimizing investments and implementation strategies.

The Energy Cells Model in Lübben, on the other hand, provides a concrete example of how local energy solutions can be optimized to support decarbonization, particularly in the heating sector. The integration of renewable energy production, local consumption, and storage systems highlights the potential of regional energy transition strategies. The Lübben experience also emphasizes the importance of adopting a sector coupling approach, integrating different energy sectors to improve overall system efficiency and reduce energy losses.

One of the most significant findings of the project is the scalability and transferability of these tools to other territorial contexts. The GIS platform, with its modular and interoperable approach, can be adapted to different regional configurations, allowing public authorities and administrations to design hydrogen development plans tailored to local needs. Similarly, the Energy Cells Model can be replicated in regions highly dependent on fossil fuels, providing concrete solutions for the gradual decarbonization of the energy sector.

The adoption of these tools by other regions could bring significant benefits:

- Optimization of infrastructure planning: ocal administrations could use the GIS platform to identify the most suitable areas for hydrogen production, distribution, and utilization, minimizing environmental impact and maximizing energy network efficiency.
- Better integration of renewable energy sources: the ability to simulate development scenarios allows for strategic planning of hydrogen use alongside other energy sources, promoting a more sustainable use of local resources.
- Support for public policies and investment decisions: by providing detailed analyses and reliable forecasts, these tools can facilitate access to funding for energy transition projects, guide policy decisions, and attract private investors.
- Reduction of emissions and improvement of air quality: the use of hydrogen in strategic sectors such as transportation and urban heating could significantly contribute to CO_2 emissions reduction, improving the quality of life for citizens.

General Observations from the testing

The testing session confirmed that the GIS Platform is a valuable and well-structured tool, appreciated for its accessibility, sectoral detail, and scenario-based approach. Participants showed strong interest in:

- Using the tool as a support for decision-making at regional level
- Integrating it into climate and energy strategies
- Exploring its adaptability to local datasets and planning frameworks

The feedback collected will inform the final refinement of the tools and serve as the basis for future replication efforts in other Central European regions.

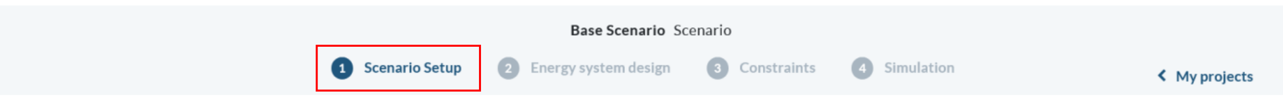
ANNEX1: Handbook on seeting up Energy Cells Model

In order to use the energy cells model an account has to be created. Visit https://open-plan-tool.org and sign up with a mail address.

2.1. Step 1: Scenario Setup

In the *open_plan* [2]tool, four steps need to be conducted. These steps are shown in a progress bar at the top of the screen:

- Scenario Setup: define the basic settings of your scenario,
- Energy System Design: choose and set up energy system components,
- Constraints: add rules or limitations,
- Simulation: run and analyze your scenario.

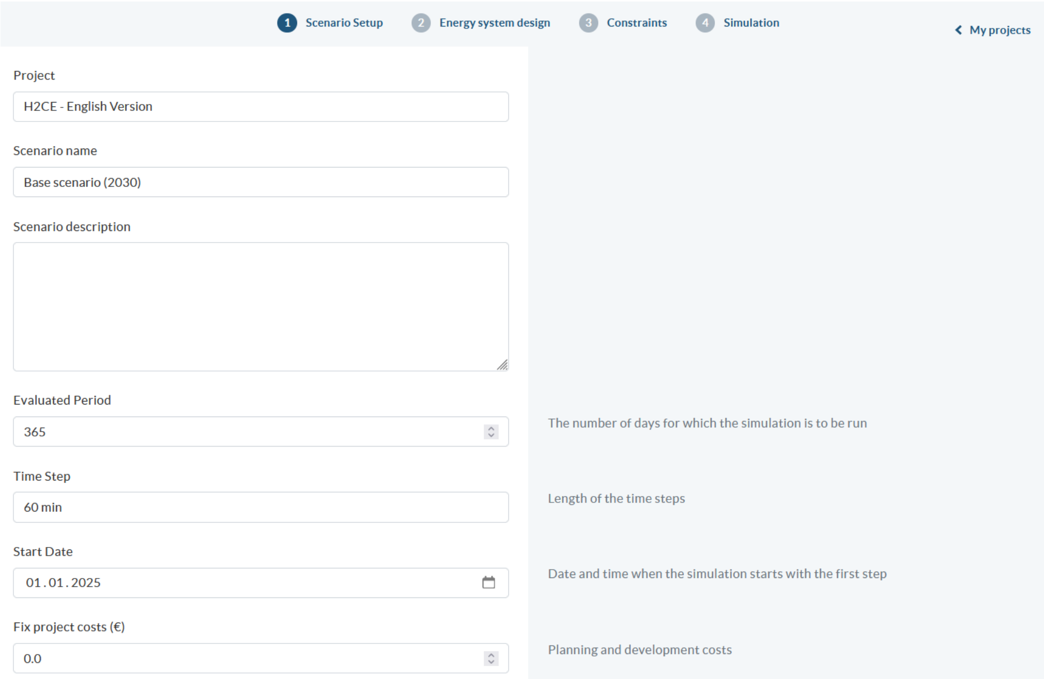


In the first step, the scenario setup must be defined in detail. This involves assigning a name and description to the scenario, which helps differentiate it from others. You also need to specify an evaluation period, indicating the number of days the simulation will cover, and select a start date for the simulation. The starting date is critical for aligning the system with time series data and ensuring accurate results. Additionally, a limit for planning and development costs can be set, which accounts for the initial expenses

[2] Go to: https://open-plan-tool.org

of the project. These parameters help shape the scenario and provide the necessary inputs for the next steps.

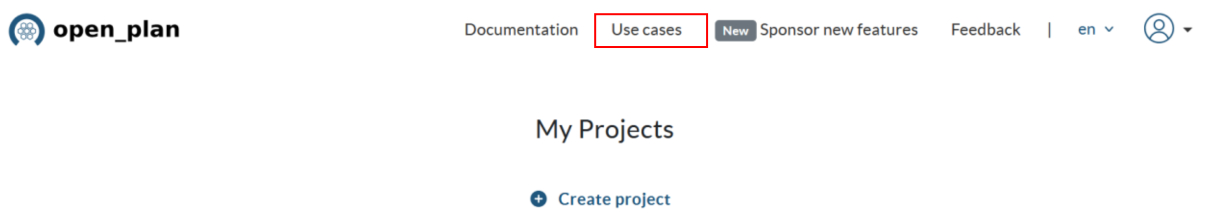
One crucial step is to save your changes after configuring any energy component. Before closing the application, don't forget to click the "Save" button, as parameters will only be stored if saved explicitly!



2.2. Step 2: Energy System Design

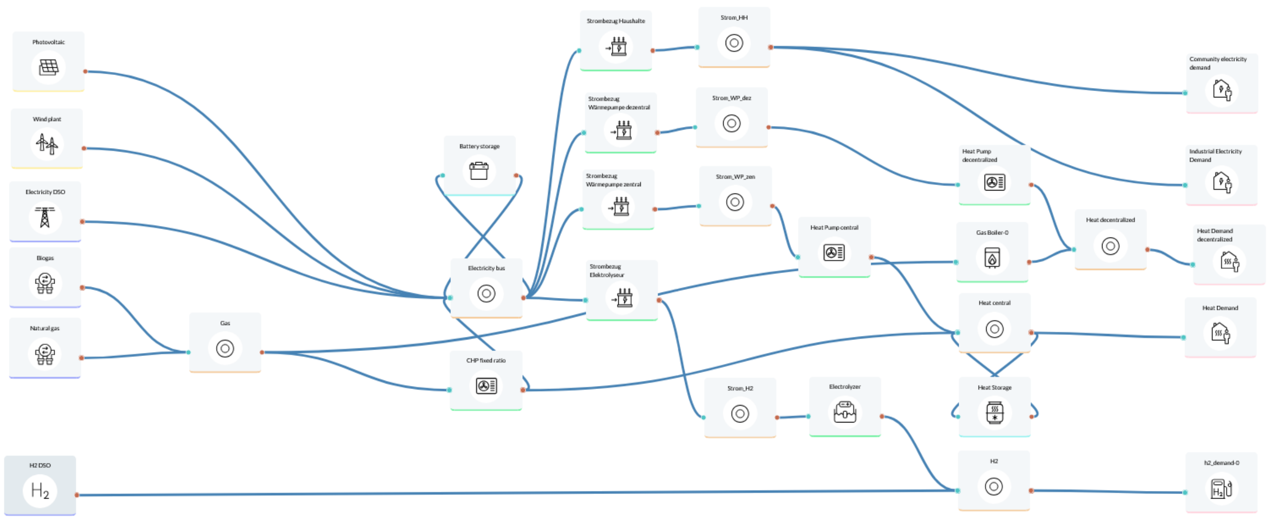
Once the scenario setup is completed, the next step is to define the energy system design. This involves configuring the layout and parameters of the energy system, ensuring that the design aligns with the project goals. At this stage, you could refine the system by adjusting the pre-configured components or adding new elements as needed. Since this can take a lot of time, there is a scenario called the basic scenario, which offers a pre-designed layout of an energy system, making it a convenient starting point.

2.2.1. The Base Scenario



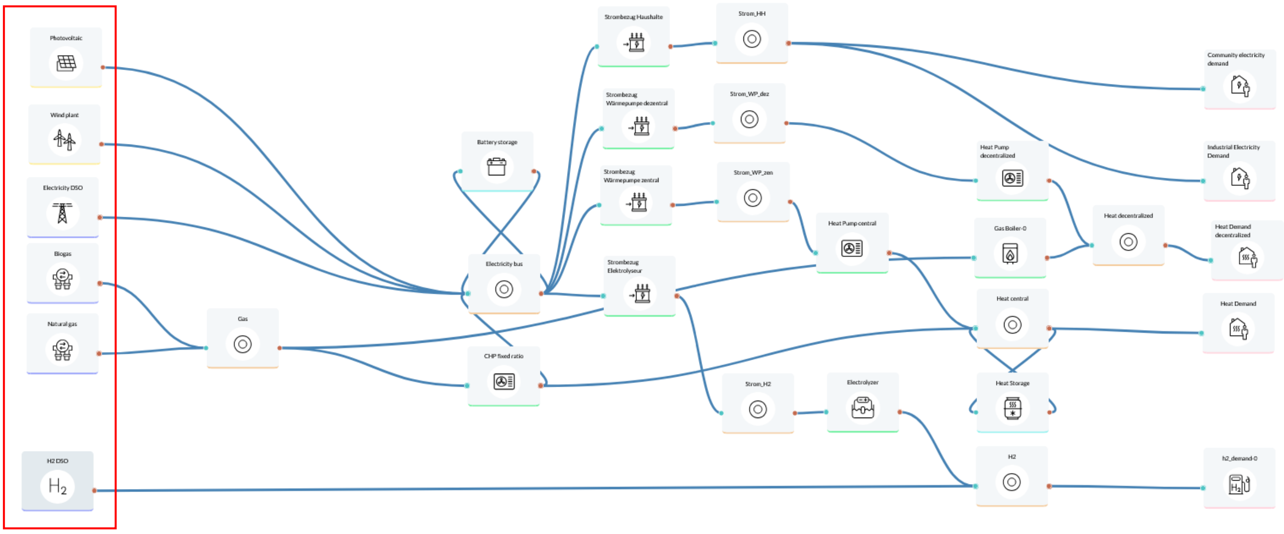
The base scenario is available in the "Use Cases" section. It can be accessed by simply opening and importing the scenario. The scenario can be imported under ‘Use as a project template’. You find it then under your own projects as a scenario, which can be used as a template for your own simulations.

All essential energy components are already pre-configured, eliminating the need to design the system from scratch. This allows you to focus on customizing and analysing the system rather than building it from the start.



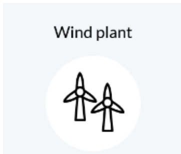
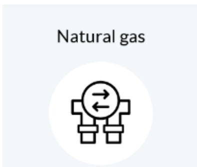
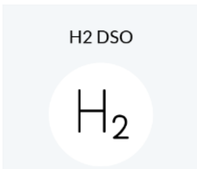
The system design graph in *open_plan* shows all key components and their connections within the energy system. It includes energy sources such as PV, wind power, and gas, as well as storage units like batteries and hydrogen storage. Energy flows are visualized through lines, connecting sources, converters (e.g., heat and power plants, boilers, heat pumps), storage units, and demand sectors (like households, industry, and district heating). This setup illustrates how electricity, heat, and hydrogen are produced, stored, and consumed across the system. It helps users understand the structure and interactions. Subsequently, each section of the system will be described.

2.2.2. Energy supply



The system is structured to allow the selection of different components as energy supply options at the beginning, including photovoltaics (PV), wind energy, electricity purchase, biogas, hydrogen, and natural gas. By double-clicking on a component, you can access and customize its economic and technical parameters in detail. If certain components are not required, they do not need to be deleted; simply leave their parameters incomplete, and they will be excluded from the simulation. The technical parameters for energy components include various settings such as efficiency, capacity, operational limits, and more. It is important to carefully define these values, as they directly impact the system's performance in the simulation. Always ensure that each parameter aligns with your project goals and technical constraints.

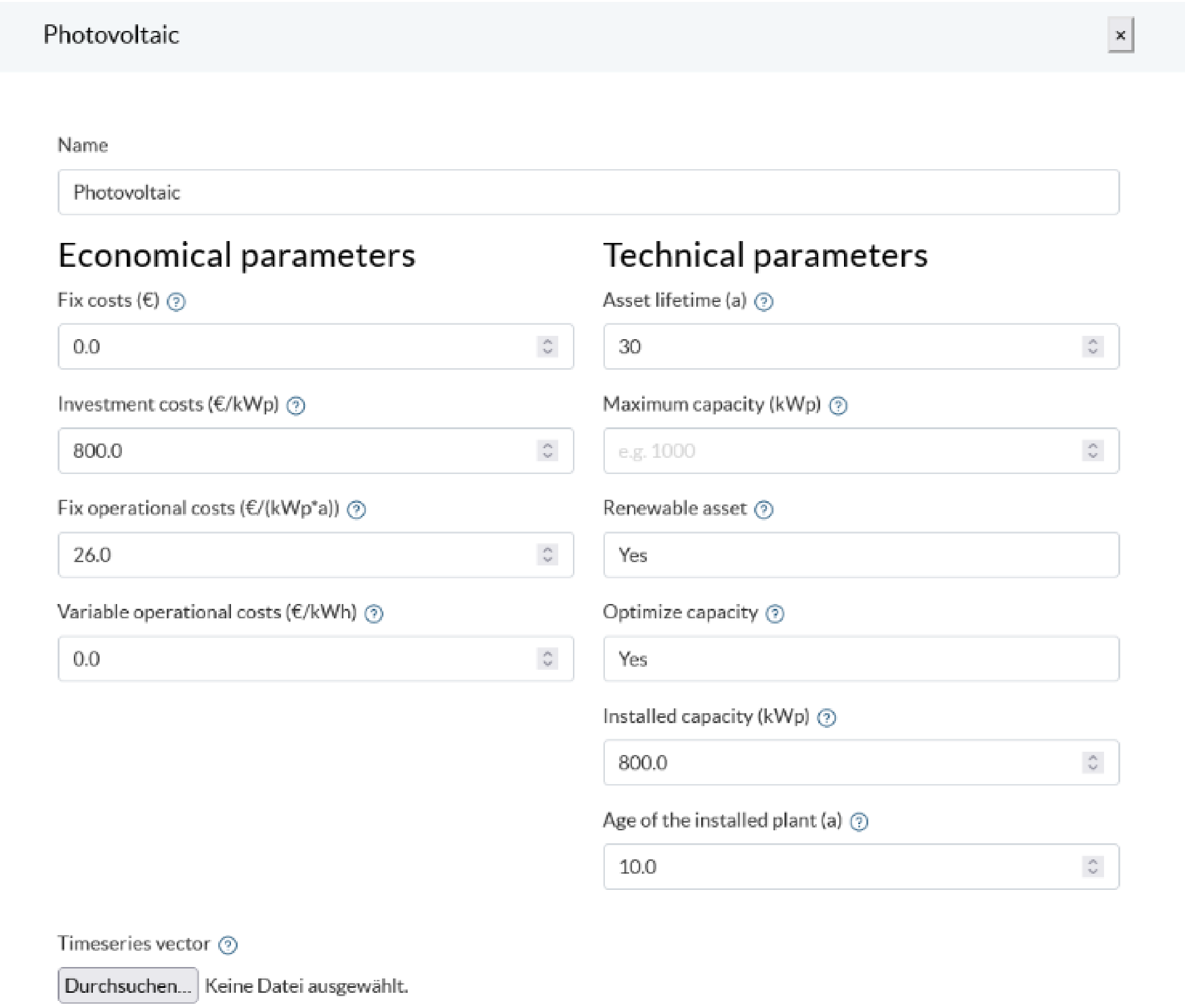
In the table below, you find the different energy components that provide the energy supply.

Energy supply options	
Photovoltaic	
Wind plant	
Electricity DSO ➔ Representing the electricity grid	
Biogas	
Natural gas	
H2 DSO ➔ Representing an external h2 supply	

The subsequent sections describe how the individual parameters for the various energy components can be filled in.

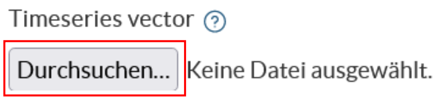
2.2.3. Photovoltaic

To configure the photovoltaic system in the interface, you need to fill in the *economical parameters* and *technical parameters* fields, ensuring that each field reflects the specifics of your project.



Begin by entering the *economical parameters*. For fixed costs, put in costs associated with the system that remain constant over time. This could be costs like approval, or planning that are not dependend on the installed capacity. If there are no such costs, you can leave this at "0". In the *investment costs* field, specify the cost per kilowatt-peak (kWp) for installing the system. For example, in this simulation the installation costs €800 per kWp, so you enter "800.0". *Fixed operational costs* should reflect annual maintenance or similar expenses based on the installed capacity, while *variable operational costs* represent expenses that depend on energy production. If *variable costs* are negligible, set this value to "0.0".

Next, proceed to the *technical parameters* section. The *asset lifetime* is already set to 30 years, which represents a typical photovoltaic system's operational lifespan. This value can remain unchanged unless your project has a different estimated lifetime. If your system has a *maximum capacity*, enter it in the corresponding field; otherwise, leave it blank. The *renewable asset* field is pre-set to "Yes", confirming that the system qualifies as a renewable source, and this does not need to be modified. Similarly, *optimize capacity* is pre-selected to "Yes", allowing the system to determine the optimal capacity for simulation purposes. For the *installed capacity*, enter the current capacity of your system, such as "800.0" for an 800 kWp system. Finally, input the system's age in years in the *age of the installed plant* field, for instance, "10.0" if the system has been operational for ten years. Many fields, such as *asset lifetime*, *renewable asset*, and *optimize capacity*, are pre-configured with default values that are appropriate for most projects. But you can change them if necessary.



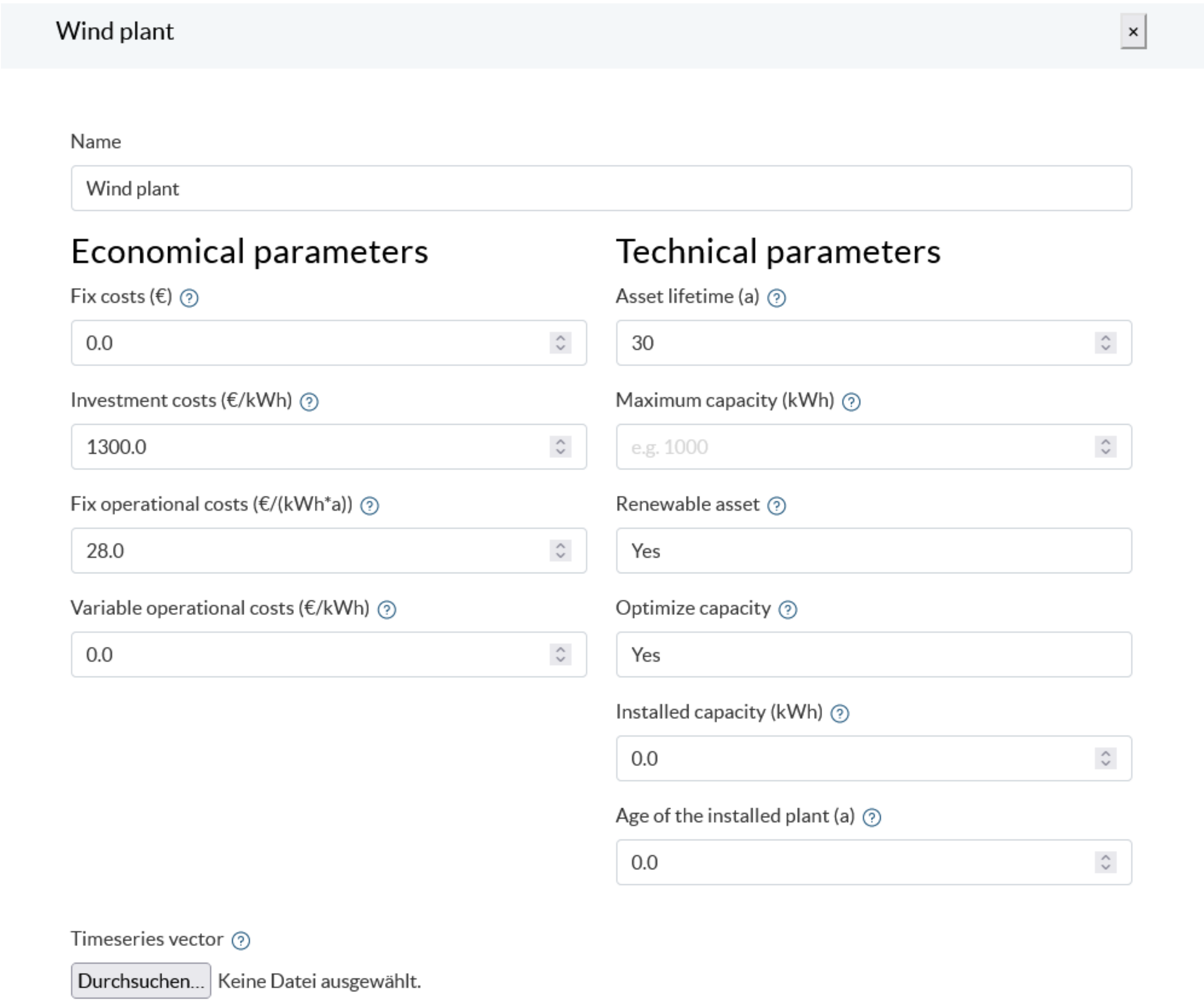
If you have specific time-series data for the system, such as weather patterns or energy demand, upload the file in the *Timeseries vector* section. A platform where you can find specific timeseries data is *Renewables.ninja*[3]. It is an open-source platform designed to simulate the hourly energy output of solar and wind power systems at any global location. The tool allows users to create and analyse renewable energy projects by combining detailed meteorological data with models of energy generation systems.

Users can input data through various formats, including manual data entry or file uploads in CSV or JSON formats. Input categories include project-specific information such as location and economic parameters, technical specifications of energy systems, and constraints like renewable energy targets or autonomy levels. The simulation results are then presented in structured outputs, covering key performance indicators, technical capacities, and economic analyses. These outputs enable users to evaluate the efficiency and cost-effectiveness of their renewable energy systems.

[3] The website is available at https://www.renewables.ninja/.

2.2.4. Wind plant

Following the photovoltaic system configuration, setting up a wind plant in the tool requires similar attention to both *economical parameters* and *technical parameters*, but with considerations specific to wind energy.


Wind plant ×

Name
Wind plant

Economical parameters
Fix costs (€)
0.0
Investment costs (€/kWh)
1300.0
Fix operational costs (€/(kWh*a))
28.0
Variable operational costs (€/kWh)
0.0

Technical parameters
Asset lifetime (a)
30
Maximum capacity (kWh)
e.g. 1000
Renewable asset
Yes
Optimize capacity
Yes
Installed capacity (kWh)
0.0
Age of the installed plant (a)
0.0

Timeseries vector
Durchsuchen... Keine Datei ausgewählt.

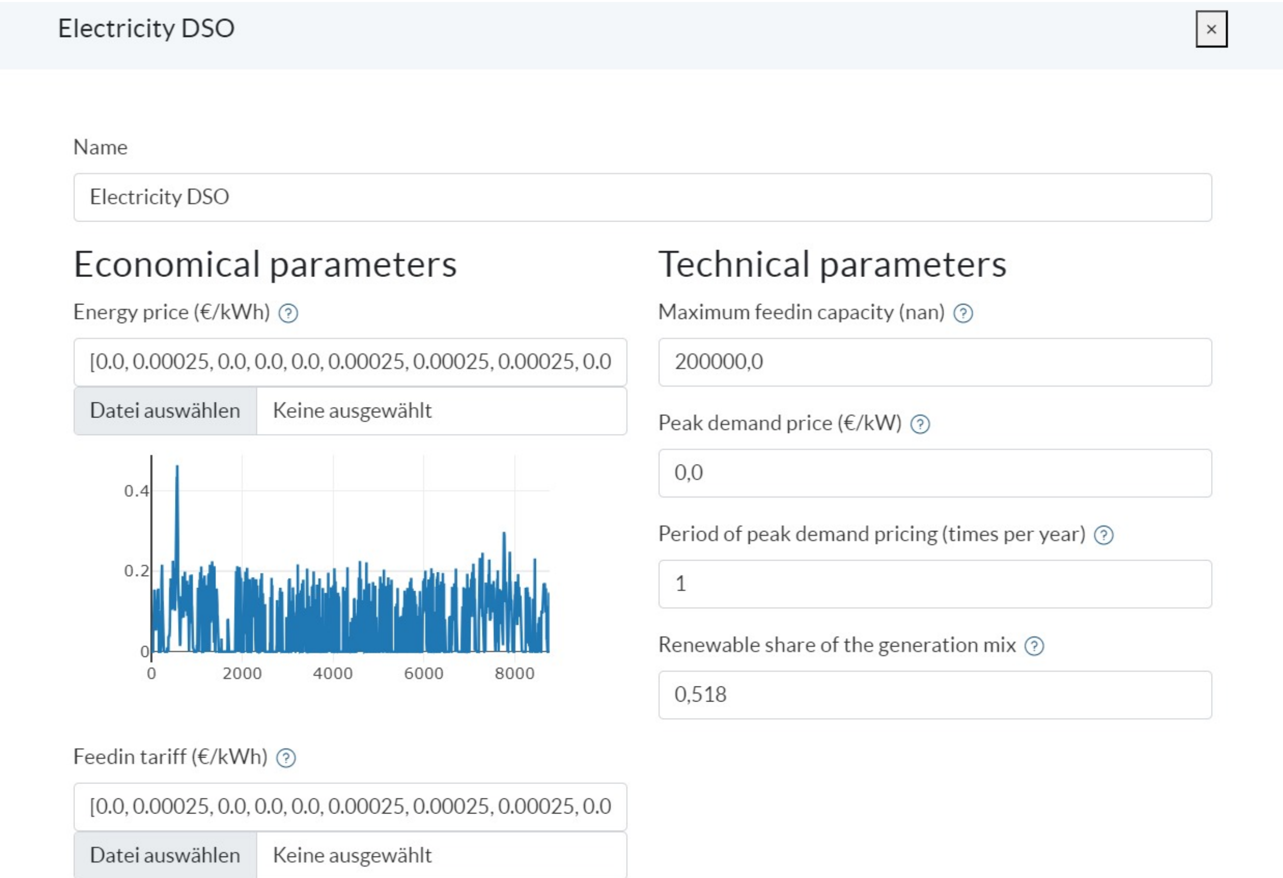
For the *economical parameters, fixed costs (€)* should only be entered if there are one-time expenses that are not dependent on system size, such as administrative fees. If none apply, this field can remain at "0". The *investment costs (€/(kWp))* reflect the capital required to install wind turbines, typically higher than for photovoltaics. Input the relevant value here. For the example of Lübben the value was "1200.0", which means that the cost is €1,200 per kWp. *Fixed operational costs (€/(kWp*a))* capture recurring annual expenses for maintenance and operations, while *variable operational costs (€/(kWh))* account for production-related costs.

In the *technical parameters*, the *asset lifetime* defaults to 30 years, reflecting the typical lifespan of wind turbines, and usually does not need adjustment. If the wind plant has a maximum capacity, input the value in the *maximum capacity (kWp)* field. The *renewable asset* field remains pre-set to "Yes," as wind energy is inherently renewable. Similarly, the *optimize capacity* field is already set to "Yes," ensuring the tool optimizes turbine capacity during simulations for maximum performance.

If time-series data specific to the wind plant is availabe, such as wind speed or historical energy production[4], it can be uploaded under the timeseries vector section.

Since default assumptions for fields like *asset lifetime*, *renewable asset*, and *optimize capacity* are already in place, they typically do not require changes.

2.2.5. Electricity DSO



Setting up the electricity DSO helps to model energy prices, feed-in tariffs, and technical constraints relevant to electricity distribution.

In the *economical parameters*, the *energy price (€/kWh)* field allows you to input a time series of electricity prices. You can either input values directly in the table or upload a data file if detailed time-dependent price data is available. The graph below this field visualizes the provided energy price data. Similarly, the *feed-in tariff (€/kWh)* field accepts a time series of tariffs for energy fed back into the grid. This data is

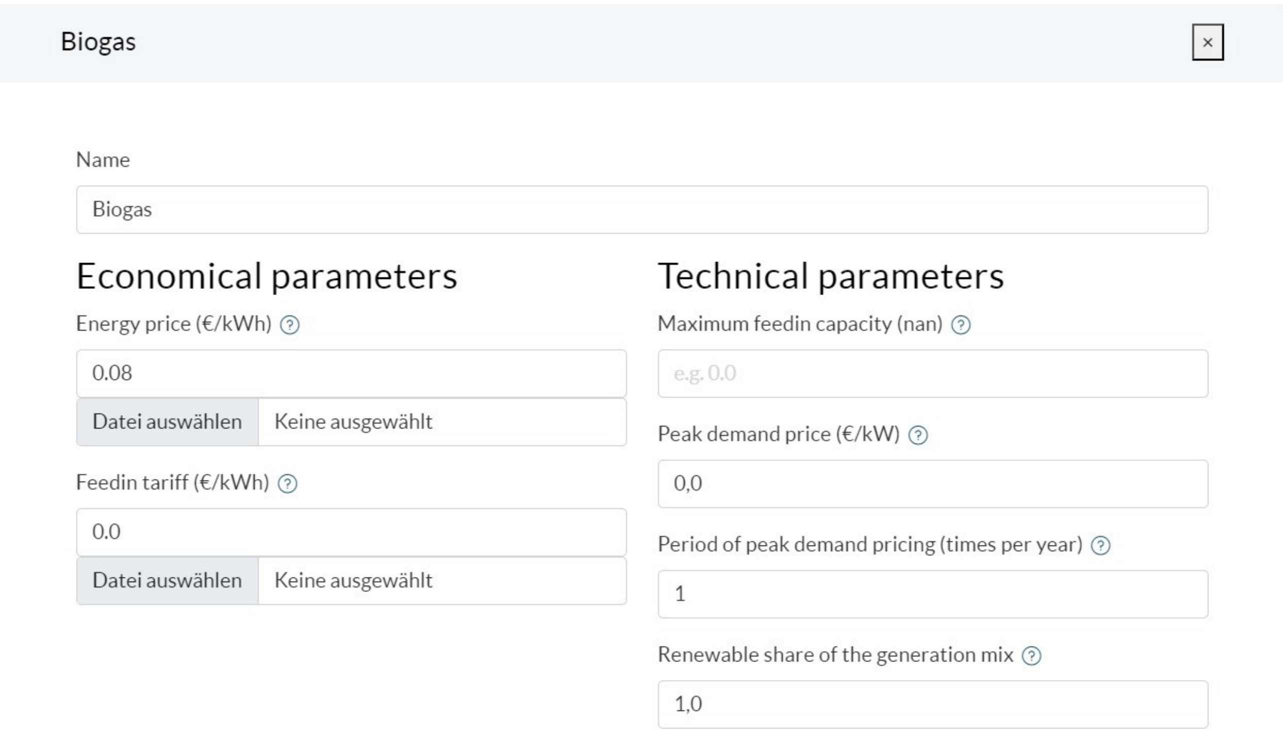
[4] Which often can be found at *Renewables.ninja*.

critical for assessing revenues from exporting excess energy to the grid. You can enter this data directly or upload a file containing the feed-in tariff structure.

Under the *technical parameters*, the *maximum feed-in capacity (kW)* defines the upper limit on the amount of energy that can be fed back into the grid at any given time. For example, in Lübben, the limit is set to "200000.0," which represents the capacity constraint imposed by the distribution network. The *peak demand price (€/kW)* field is used to define costs incurred during peak demand times. If peak pricing does not apply, this value can remain at "0.0." The *period of peak demand pricing (times per year)* field specifies how often peak demand charges occur annually.

The *renewable share of the generation mix* represents the proportion of electricity in the grid that originates from renewable energy sources. The value in the example is "51.8 %" but must be adjusted to reflect the conditions of the national or regional electricity network. By completing these fields accurately, you enable the tool to simulate interactions with the electricity grid, assess potential costs or revenues, and incorporate grid constraints into the overall energy system model.

2.2.6. Biogas

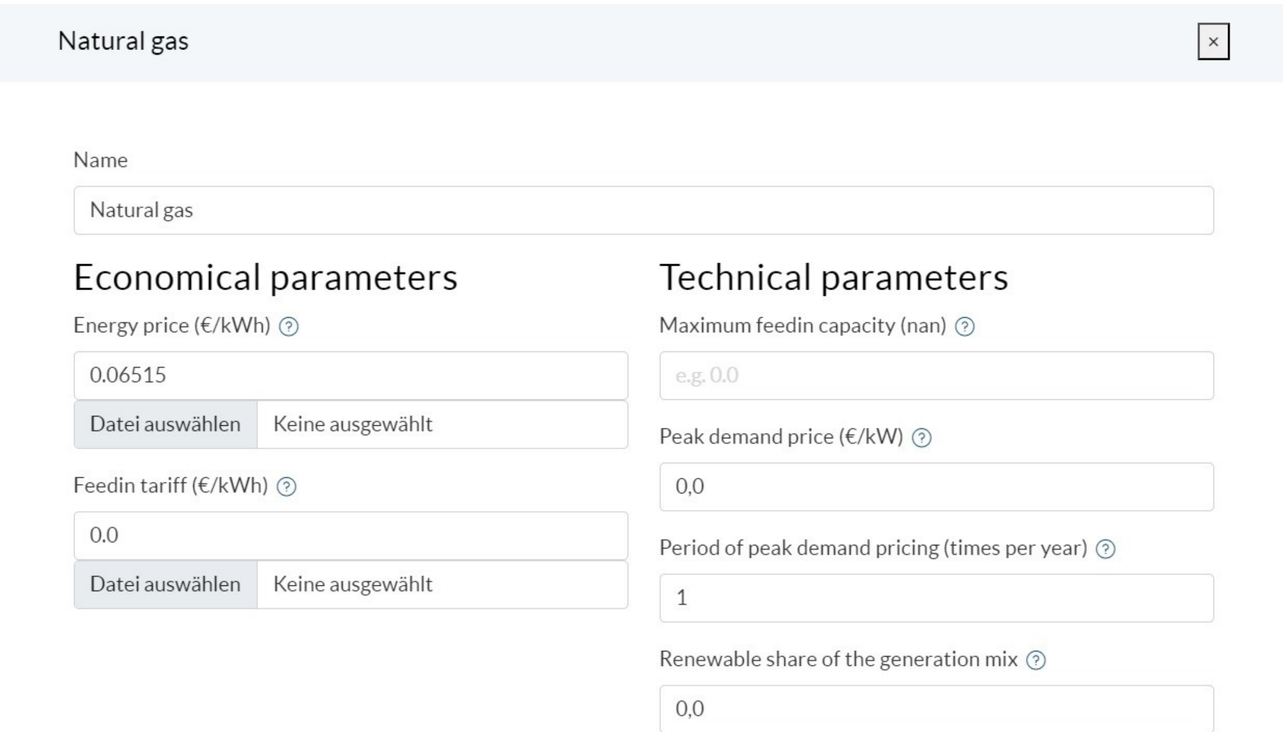


To configure a biogas system within the tool, the setup involves inputting economical parameters and *technical parameters* to accurately model costs, revenues, and system constraints. This section is similar to the electricity DSO configuration but specific to biogas energy production.

For the *economical parameters*, the *energy price (€/kWh)* represents the cost of electricity generated from biogas. For instance, if the price is €0.08 per kWh, this value should be entered directly into the field. If dynamic pricing applies, you can upload a time-series dataset by selecting the "Select file" option. The *Feed-in tariff (€/kWh)* field indicates the revenue per kWh of electricity fed into the grid. If biogas electricity is not eligible for feed-in tariffs or if the tariff is zero, you can leave this at "0.0". Similarly, time-series data for feed-in tariffs can be uploaded if available.

The *technical parameters* section requires details such as the *maximum feed-in capacity (kW)*, which defines the upper limit on the amount of biogas-generated electricity that can be fed into the grid. If there is no specific limit, this field can be left blank. The *peak demand price (€/kW)* captures costs incurred during peak demand times; if there are no peak charges, this value can be left at "0.0". The period of *peak demand pricing (times per year)* field specifies how often peak demand charges apply annually, with a default value of "1" representing once per year. Finally, the *renewable share of the generation mix* is pre-filled with "1.0" (100%), reflecting that biogas is fully renewable. This value typically does not need to be adjusted unless specific project details require it.

2.2.7. Natural gas

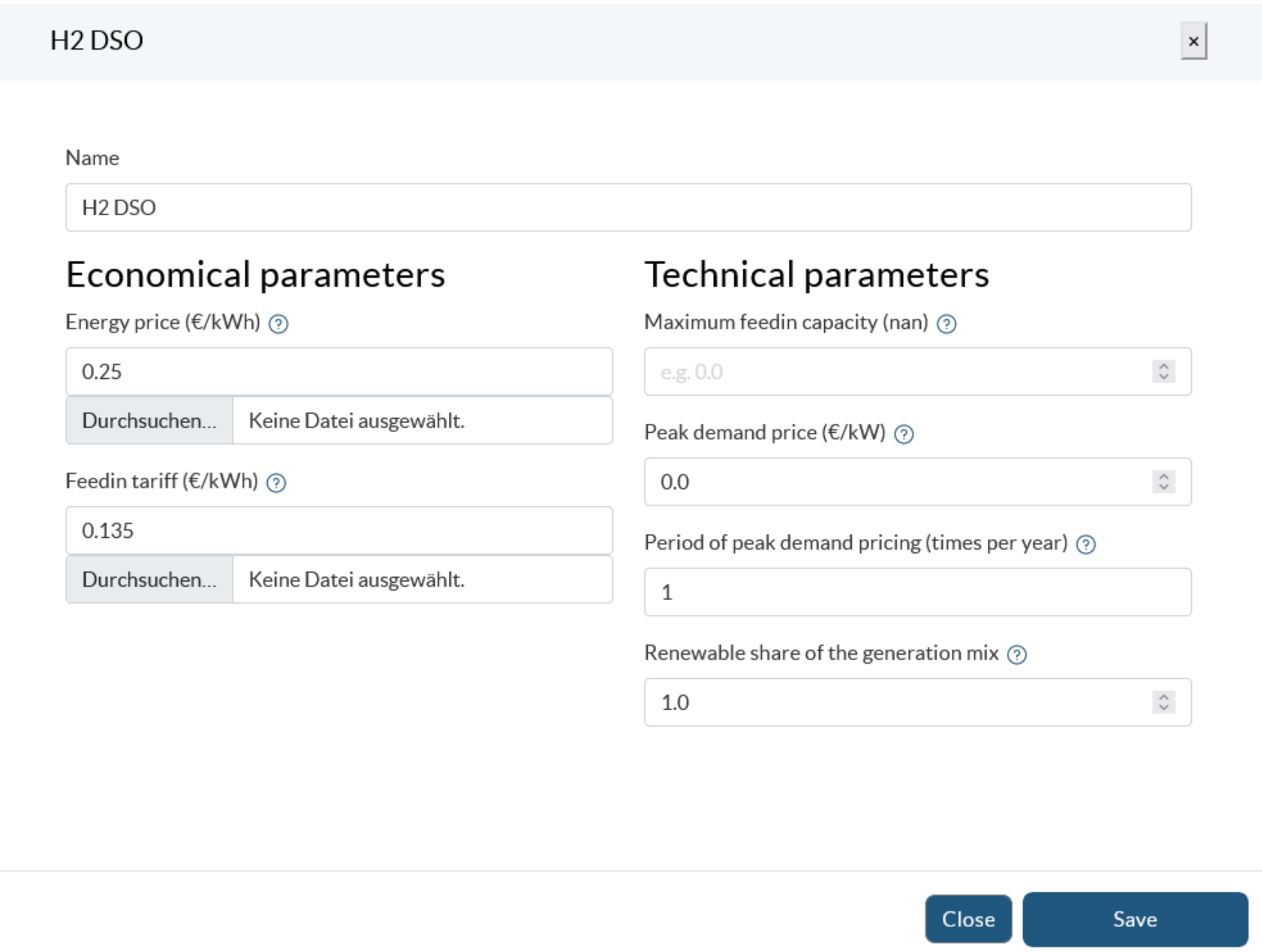


Like the other energy components, the natural gas system is divided into *technical* and *economic parameters*. These inputs capture the costs and constraints associated with natural gas as an energy source.

In the *economical parameters*, the *energy price (€/kWh)* field captures the cost of purchasing natural gas energy. For instance, if the price is €0.06 per kWh, enter this value directly. If the price fluctuates over time, you can upload a detailed time series by using the upload option ("Select file"). Similarly, the Feed-in tariff (€/kWh) field allows you to input the revenue earned per kWh when exporting energy to the grid.

The *technical parameters* start with the m*aximum feedin capacity (kW)*, representing the maximum energy output that can be fed back into the grid. This field can be left blank if no limit applies. The Peak demand price (€/kW) accounts for costs during times of high energy demand; if this is not relevant, it can remain at "0.0". The Period of peak demand pricing (times per year) is set to "1" by default, meaning peak pricing applies once annually, but this can be adjusted based on project requirements. Lastly, the Renewable share of the generation mix is set to "0.0," since natural gas is a non-renewable energy source.

2.2.8. H2 DSO



In this section, the H2 DSO system is the final energy component that needs to be configured.

For the *economical parameters*, the *energy price (€/kWh)* represents the cost of hydrogen energy. You should replace it with the cost of hydrogen per kWh relevant to your project. If the cost fluctuates, a timeseries another dataset can be uploaded using the "Select file" option. The f*eedin tariff (€/kWh)* defines the revenue from feeding hydrogen-based energy into the grid. For this setup, it is set at 0.135, but you can adjust it to your scenario. Like the energy price, time-series data can also be uploaded from *Renewables.ninja* for the dynamic pricing.

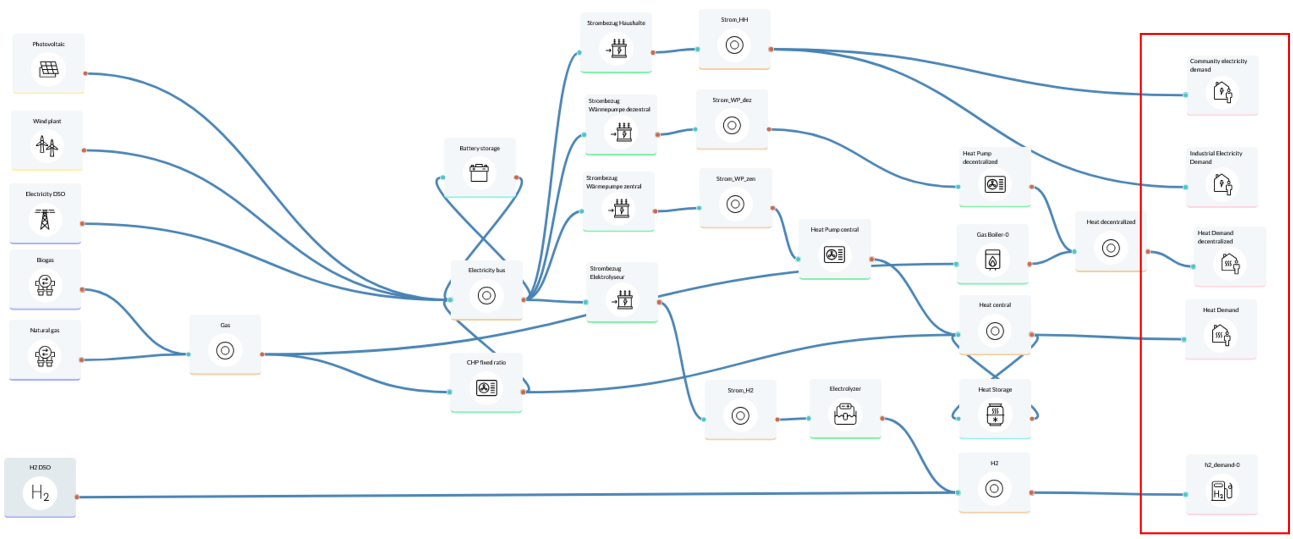
In the *technical parameters*, the *maximum feed-in capacity (kW)* sets an upper limit for the energy amount fed into the grid. If there is no limit, leave this field blank. The *peak demand price (€/kW)* accounts for charges during high-demand periods, set here at 0.0 but adjustable based on project-specific conditions. The period of peak demand pricing (times per year) defaults to "1," indicating annual application, which can be modified if needed. Lastly, the renewable share of the generation mix is set to 1.0, meaning in this example that the hydrogen source is fully renewable. This value typically does not require modification unless your hydrogen source includes non-renewable components.

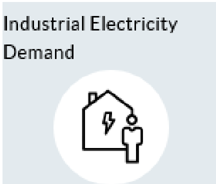
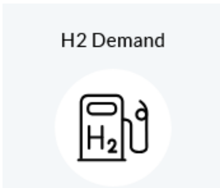
2.3. Taxes (Conversion and Storage)

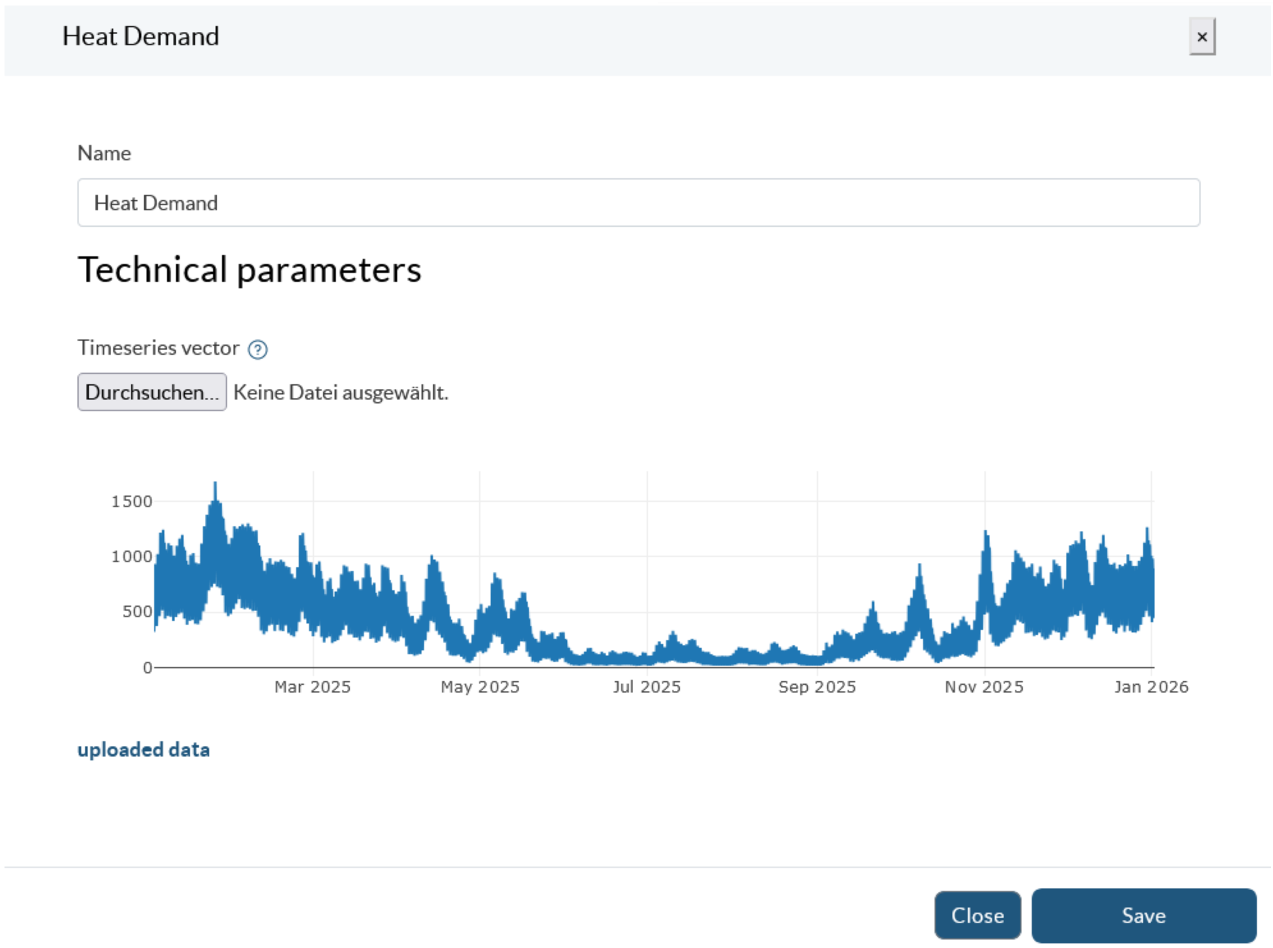
If wanted, adjustments can also be made to conversion energy components. These components enable the transformation of one form of energy to another, and their parameters can be tailored to specific requirements. Similarly, taxes and additional economic factors can be configured for a more detailed financial analysis.

2.4. Demand

The demand section focuses on defining the energy needs across various sectors to ensure the system reflects real-world requirements. These needs are divided into key areas such as household electricity consumption, industrial power requirements, decentralized heating, and, where applicable, hydrogen demand. Each of these categories must be addressed by uploading appropriate data files that provide detailed time-series information.

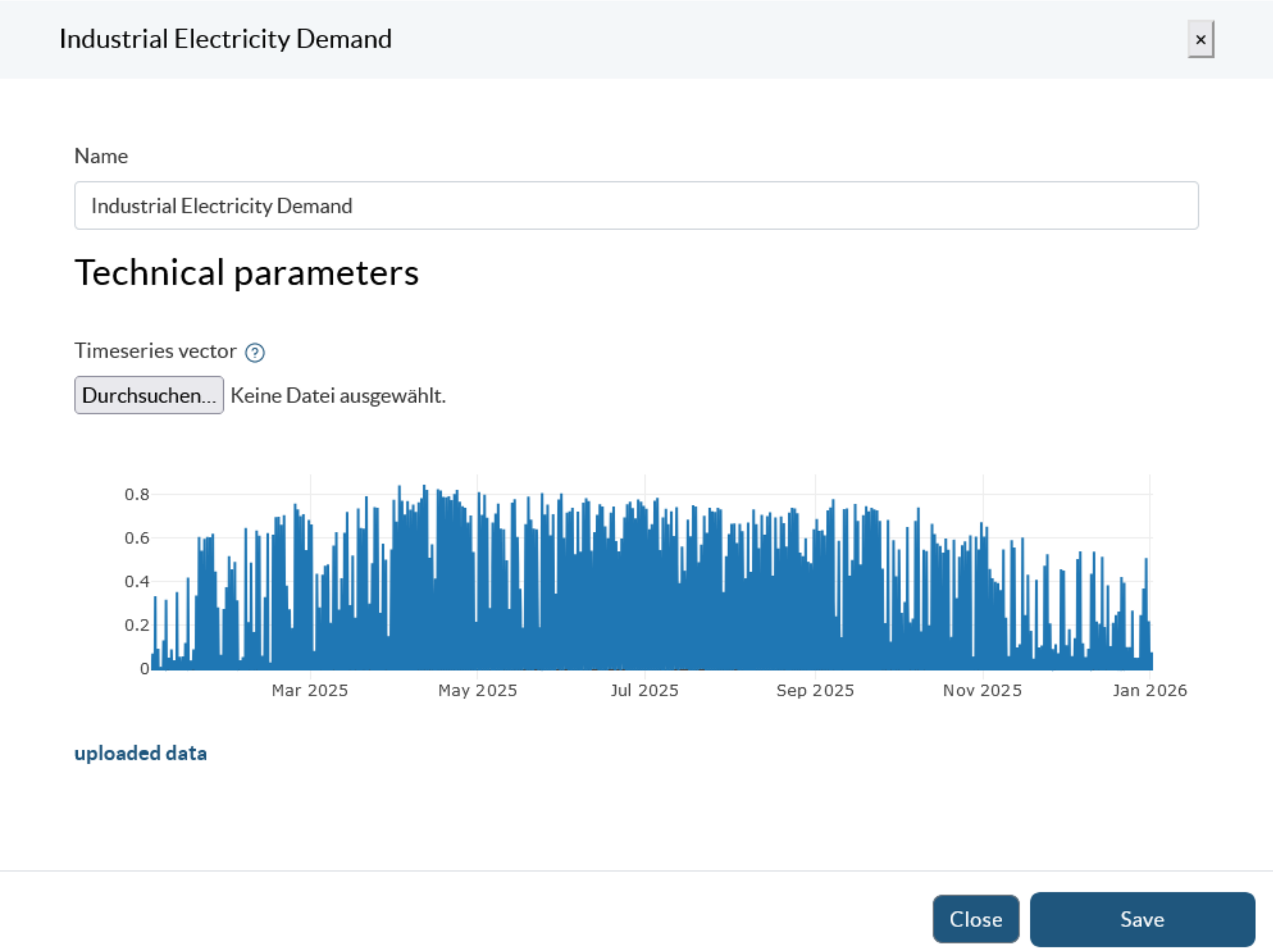


Community Electricity Demand	
Industrial Electricity Demand	
Heat Demand decentralized	
Heat Demand	
H2 Demand	



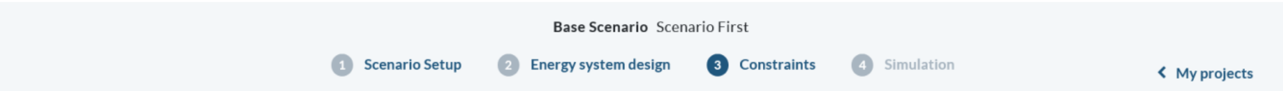
For example, for *heat demand*, you should input the actual time-series data reflecting the energy demand for heating over time. The graph above represents the *energy demand (in kWh)* over one year and shows the seasonal fluctuations based on heating needs. To add the needed data, click on the "Search" button to select your file, and upload the time-series data for your heat demand.

These timeseries can be provided by local energy and heat suppliers. In case there is no real-life data available the heating demand can be estimated based on regional temperature data. An example of such an estimation can be found at *renewable ninjas*.

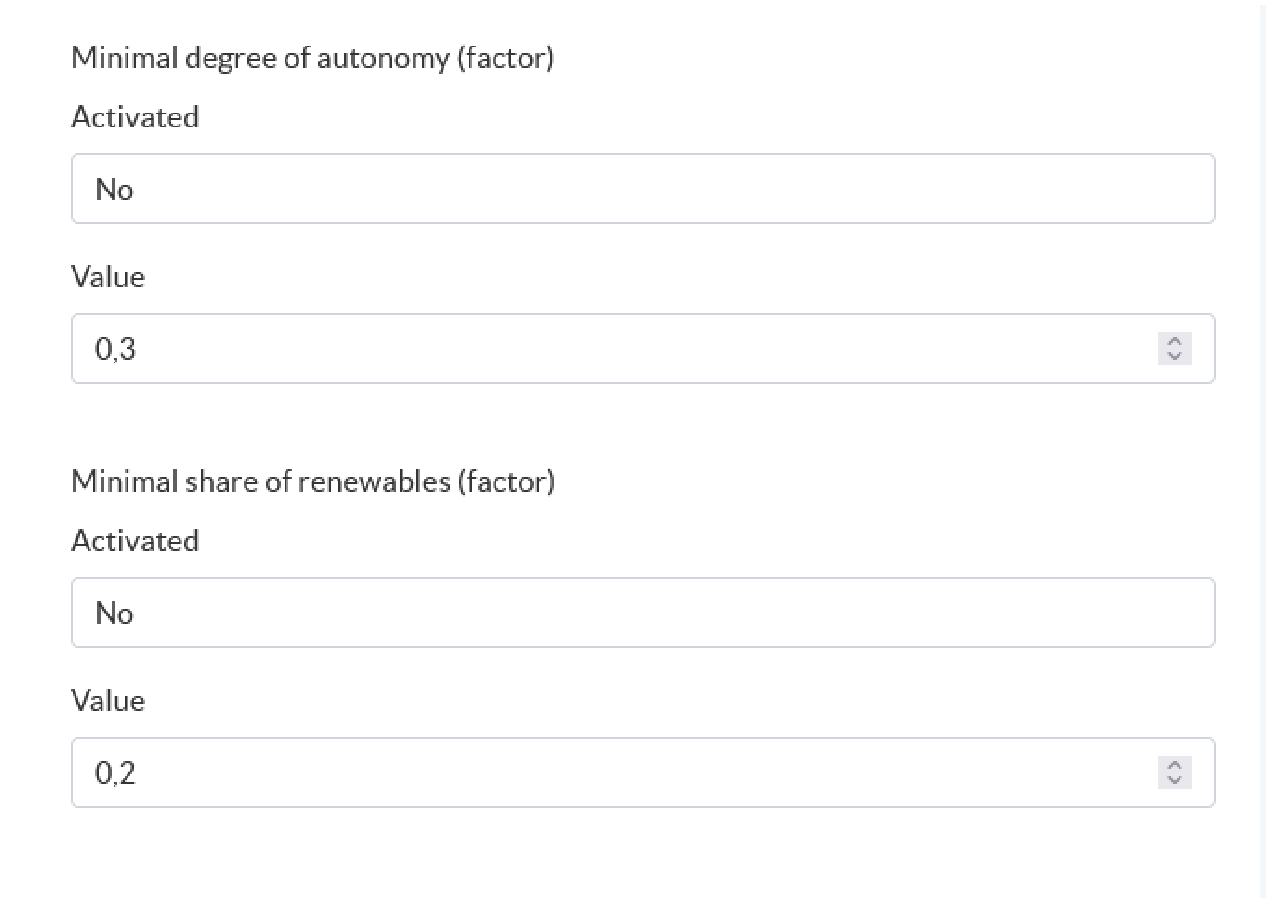


The same goes for the *Industrial Electricity Demand*. Similarly, you will input the data related to electricity usage in the industrial sector. You will upload the time-series data that shows the electricity consumption for industrial activities if given. Again, click the “Search" button to browse and select the appropriate file containing your time-series data. Once uploaded, click on "Save" to store the data in the system.

2.5. Step 3: Constraints



Once all the required details for the energy system have been provided and saved, you can proceed to define the constraints in the next step.

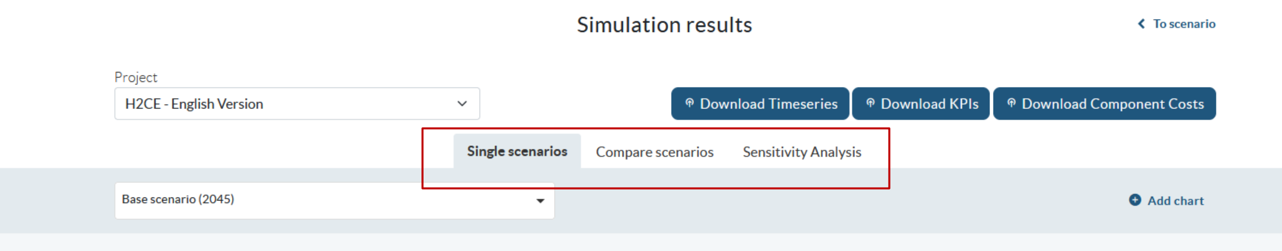


This section allows you to configure constraints related to the *minimal degree of autonomy* and the *minimal share of renewables* for your energy system. For the m*inimal degree of autonomy*, the parameter controls the percentage of energy demand that must be met by local generation sources rather than external imports. If activated, you can set a target using the *value* field, which is currently pre-filled with 0.3, representing 30%. To activate this constraint, switch the *activated* field to "Yes." The *minimal share of renewables* defines the proportion of energy supply that must come from renewable sources. The corresponding *value* field is pre-filed with 0.2, indicating 20%. Again, to enforce this requirement, change the *activated* field to "Yes." Both parameters give you the choice to control the system's sustainability and autonomy.

2.6. Step 4: Simulation Results

The simulation results can be accessed after the simulation is done. You can also directly access them via the main page.

2.6.1. Results overview



When starting the *Simulation result* page, you can select three different modes. You can either look at the results for one scenario or you can compare the results for two scenarios. The functionality *sensitivity analysis* is not yet implemented and, therefore will lead to an error.

The results overview shows:

- Degree of autonomy: The degree of autonomy shows the dependencies on external energy sources. The higher the autonomy, the lower the independence.
- Levelized costs of electricity equivalent: Shows the energy cost per unit (kW_el_equ)
- On-site energy fraction: The amount of energy that is locally produced and used in the region.
- Renewable factor: The relative amount of energy produced renewably, including external energy sources.
- Renewable share of local generation: The relative amount of energy produced renewably in the region.

After the results overview the energy model is displayed again. There is also an overview of all the timeseries of the components.

2.6.2. Timeseries

The timeseries of components can be accessed in different ways.

- Via the energy system: The timeseries of components can be accessed by clicking on the components in the displayed energy system. More detailed information on the component attributes is shown there.
- Via the timeseries per sector: *open_plan* sorts the timeseries by the sector. The possible sectors are heat, electricity, gas, and hydrogen. All components generating, distributing, and storing energy in a specific sector are displayed in the diagram.
- Via the download: Downloading the timeseries gives excess to the data per timestep. The data is sorted in energy production, energy conversion, energy storage, and energy consumption. Downloading is suitable for more detailed analysis.

3. Possible Analysis for Regions

There are many different analyses which can be done for a region. Depending on the current state of strategic development a region can use different simulations to analyse the energy system and make strategic decisions. Here are some examples:

3.1. Renewable energies

Open_plan gives the possibility to quantify the amount of renewable energies needed to fulfil the demand in certain fields. This kind of calculation is suitable for smaller energy systems like houses and streets but can be transferred to regional Energy Systems. The simulation can be started like this:

- Energy system: Build your energy system or use the example energy system from Chapter 2.2. Ensure that all renewable energies you included in the system have the selection at o*ptimize Capacity* set to “yes”. If your region has limitations on the installation of renewable energies, you can set a maximal capacity for every component.
- Constraints: The constraints should be set to the desired share of renewable energies. If the share is less than 100%, a connection to the electricity grid or another source of energy needs to be added. By increasing the share of renewable energies in multiple scenarios iteratively, the results show that the energy system is changing and adapting. This can be useful to understand the impact of laws regarding decarbonization.
- Simulation and results: When the simulation is finished, the results show the installed and optimized capacity of renewable energies.

3.2. Technology selection

A crucial question for many regions is which technology or combination of technologies is the most suitable and cheapest to meet their demand with the resources they have. The energy system developed in Chapter 2.2 shows many different technologies meet the demand in different sectors. The optimization can find the cheapest combination of technologies for the energy system.

- Energy system: For this analysis set the selection *optimize capacity* to *no* and the *installed capacity* to the regional available capacity to represent the local energy system. All components for energy conversion and storage will automatically be set to be optimized when importing the scenario from Chapter 2.3.
- Constraints: If regionally produced renewable energies should be preferred, the minimal degree of autonomy needs to be adjusted.
- Results: The results now show the optimized capacity of all components. The sankey diagram gives an overview over the energy system and the technologies used to fulfil the different demand sectors.