Chapter 1
Designing a SHIP Plant

Nowadays the energy costs are very volatile and have been raising dramatically. It is mandatory to secure energy price in an affordable way.

For this reason, thermal solar energy could play a key role. However, this technology is not well known even by engineers. Therefore, an easy-to-use software for presizing a SHIP has been developed in the frame of SHIP2Fair project.

Even if the user is not a solar energy specialist, this tool will answer the following basic questions:

- What is the best technology?
- How much panel surface is needed?
- Which orientation to use?
- What will be the quantity of energy produced?
- At what temperature?
- Do I need a storage? If so, which size?
- How much CO2 will I save?
- What will be the CAPEX? The OPEX?
- What will be the payback time? The ROI? Etc.

The replication tool will answer all these questions.

To this end, basic inputs must be filled by the user:

- the energy demand in terms of quantity and level of temperature
- the use (cooling, heating, …)
- the fluid used in the process (steam, water, air)
- the location
- the space availability

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Chapter 2
How to replicate the results of a demo-site

The Replication Tool is a software developed to assess the techno-economic pre-feasibility of SHIP and to support their design by:

- Evaluation of solar field parameters (sizing, technology, storage requirements, etc.)
- Expected energetic and environmental results (solar fraction, energy savings, avoided GHG emissions, …)
- Preliminary economic figures based on cost-effective solutions.

This tool can combine the data from the solar generation and the process features to provide a first outlook on the SHIP integration within the process and to optimise the system according to the user's needs.

The Replication Tool is a web tool, which allows registered users to run 5 modules in sequence:

- General Information Module
- Solar Mapping Module
- Industrial Process Demand Characterization Module
- Simulation Module
- Solar Integration Module

The user inserts inputs in 3 sections:

- Location of the industrial site
- Assessment of solar radiation and sun position
- Solar field characterisation (area for the collectors, type of installation, corrective factors to reduce the area)

Where to find the replication tool? Create an account here: https://replicationtool.ship2fair.cloud/login

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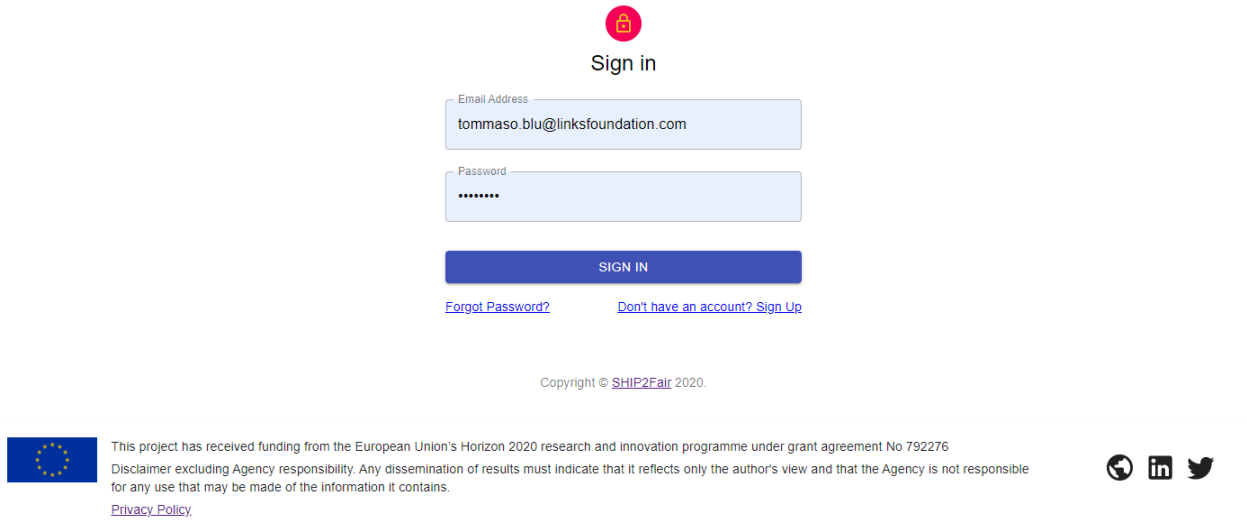
Chapter 3
Example

The homepage uses a minimal layout, providing the user a simple login panel to access the Replication Tool dashboard.



After a successful login, the user accesses the **Projects List** section, which contains:

- The read-only **user's information**
- The list of **existing projects**
- The button "**Create new project**" used to create a new project.

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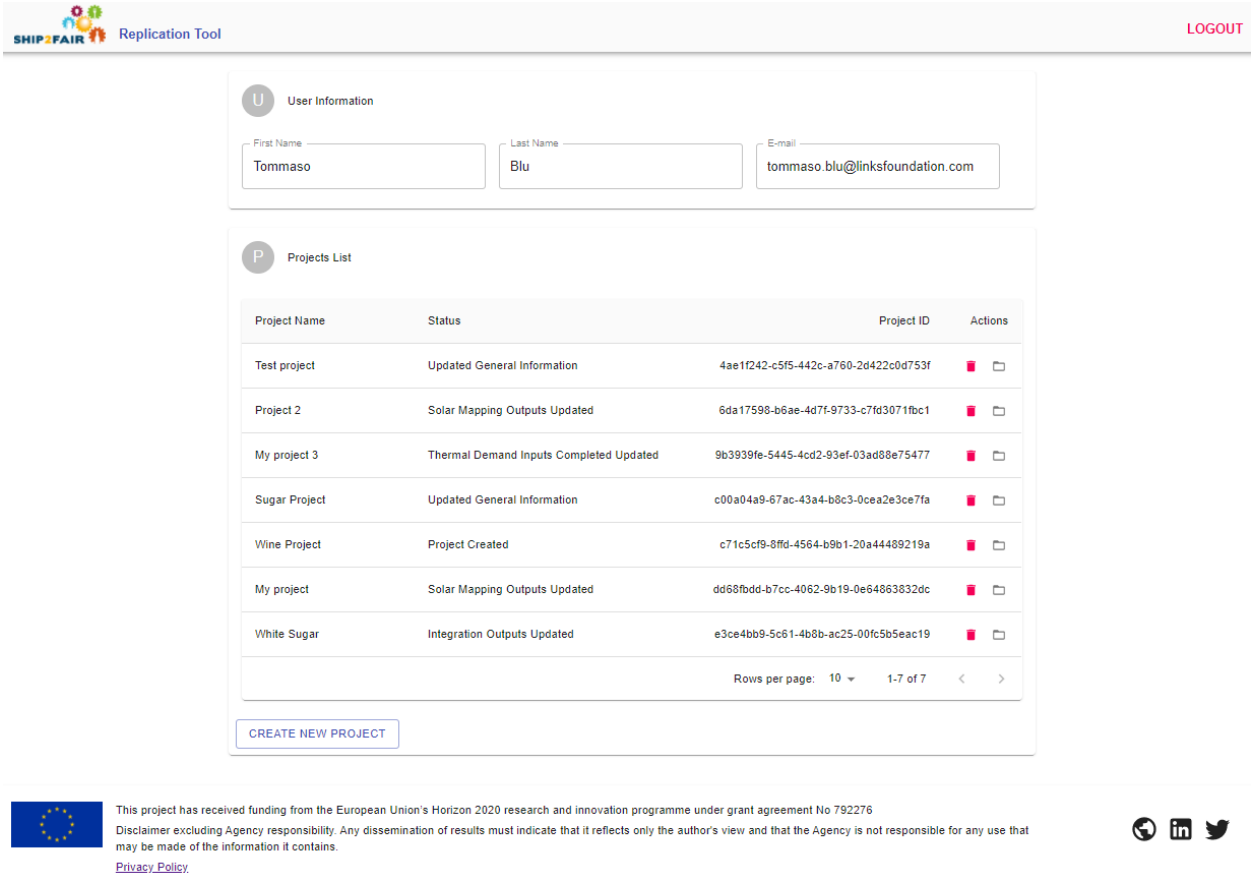

After the user has created a new project or has opened an existing project, the first section "**General information**" is displayed.

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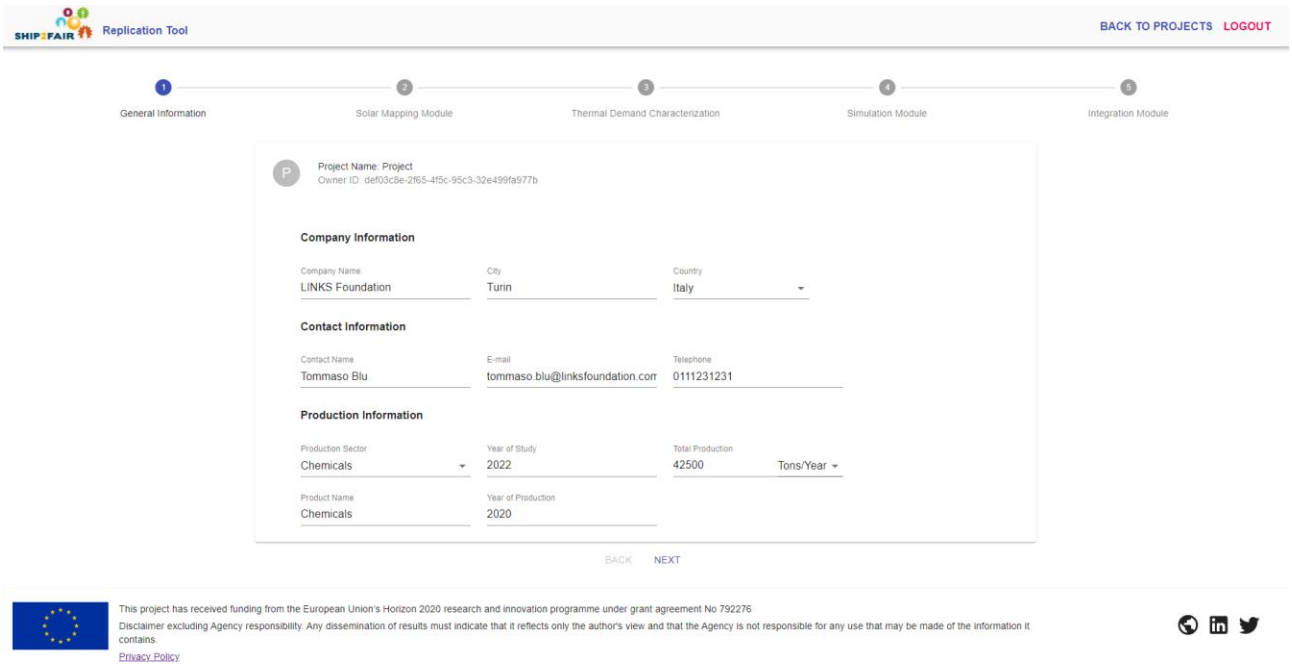
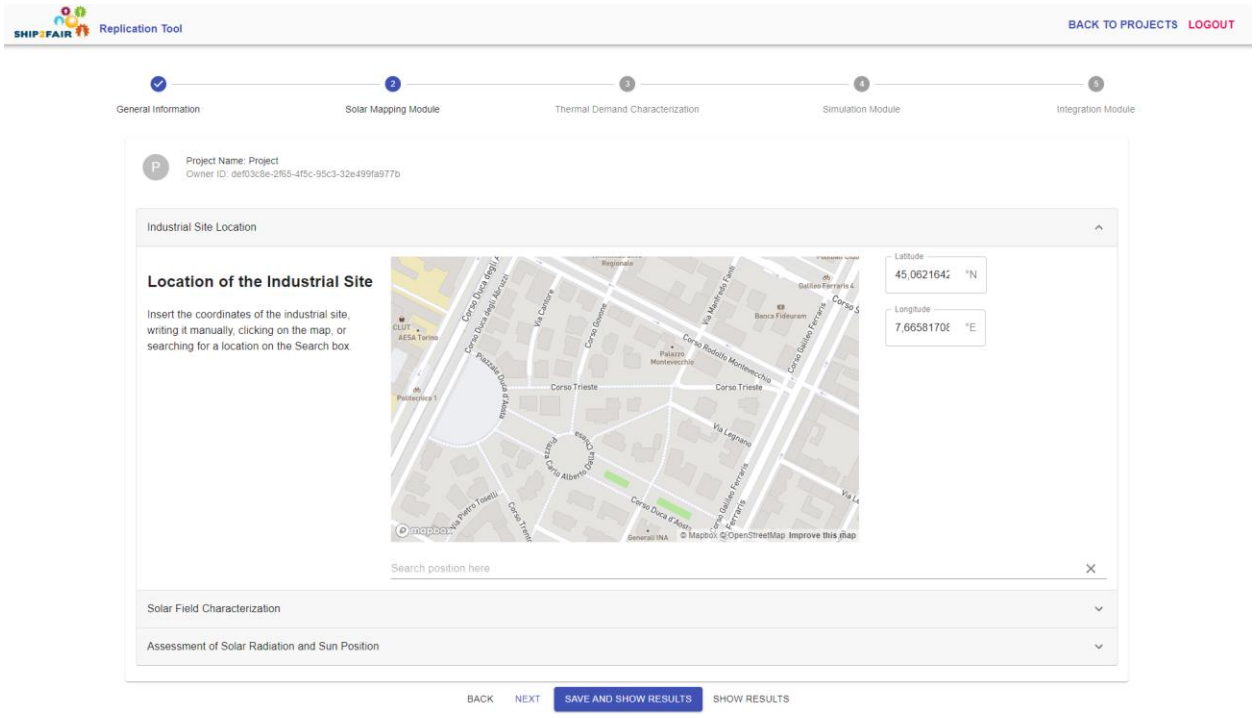


In the Solar Mapping Module section, the user inserts inputs in three expandable sections:

- **Location of the Industrial Site**: it allows the user to insert the **coordinates**.



- **Solar Field Characterization**: it allows the user to insert the area of solar field, type of installation and corrective factors.

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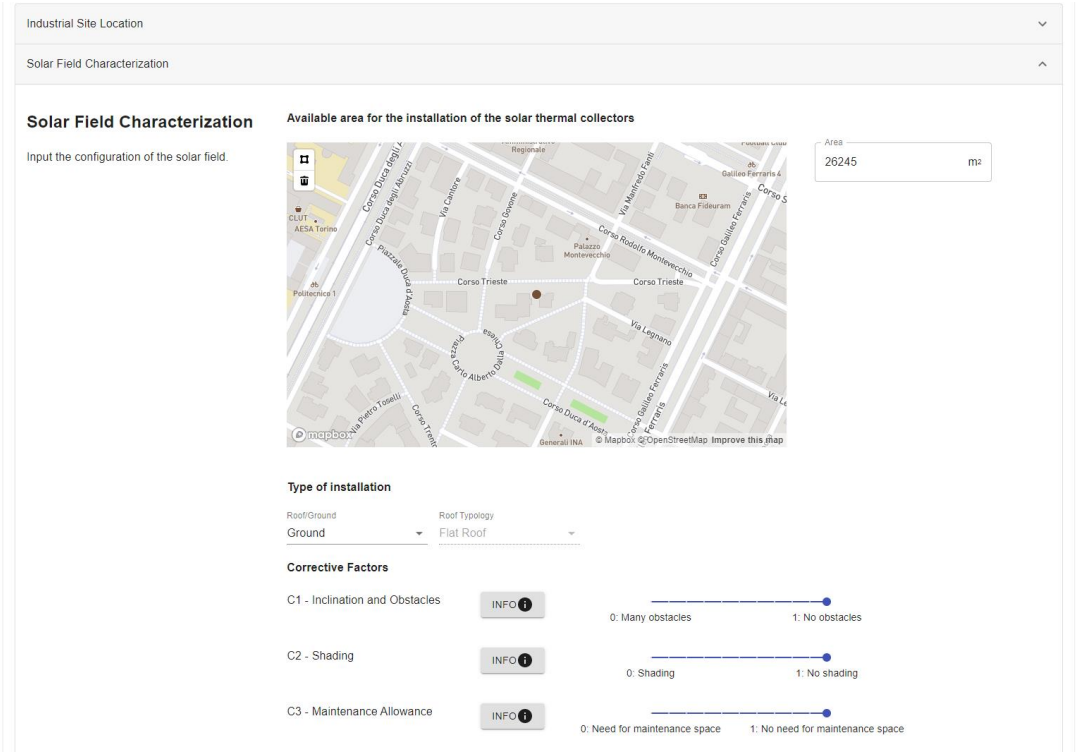

The corrective factors allow to set up three possible values:

C1 - Inclination and Obstacles

Obstacles: areas with light domes, cooling towers, ventilation devices or any other structures reducing total roof area. Estimated considering the ratio between the in-plane surface of the obstacles and the roof gross floor area.

C2 - Shading

Shading: by other buildings, vegetation, chimneys, storage tanks, etc. Estimated as a percentage of daylight time when the surface receives solar radiation due to shadowing from other buildings or the surrounding environment.

C3 - Maintenance allowance

Maintenance space: corridors or safety railings, etc. Estimated considering the ratio between the spaces required to allow maintenance activities and the roof gross area.

- **Assessment of Solar Radiation and Sun Position**: it allows the user to insert the panel's Azimuth and the panel's Slope or let the Solar Mapping Module to optimize these angles.

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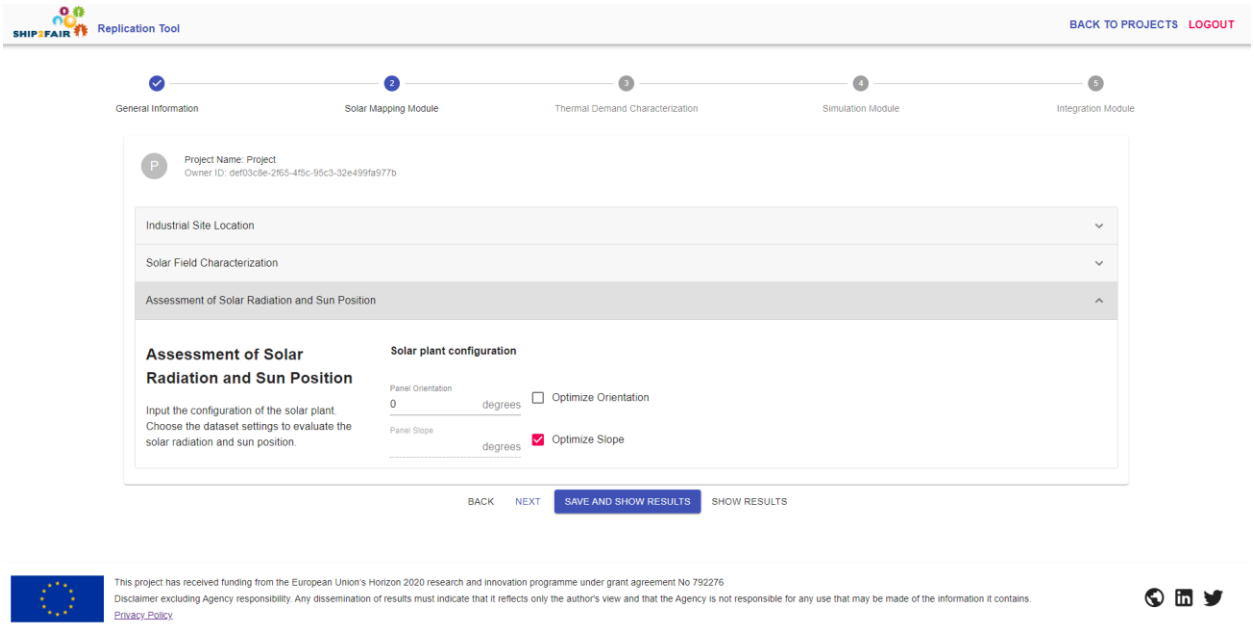

After the user has clicked on the "Save and show results" button, the results will be calculated and shown.

When the results are ready, the previous panel will be closed and another pop-up panel containing the following outputs will be displayed:

- Optimized angles (slope and azimuth)
- Net surface area
- Total corrective factor
- Ambient temperature (hourly profile)
- Solar irradiance (hourly profile)
- Wind speed (hourly profile)

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Solar Mapping Module Results

Optimized Angles

Optimized Panel Slope: 38 °

Optimized Panel Orientation: 177 °

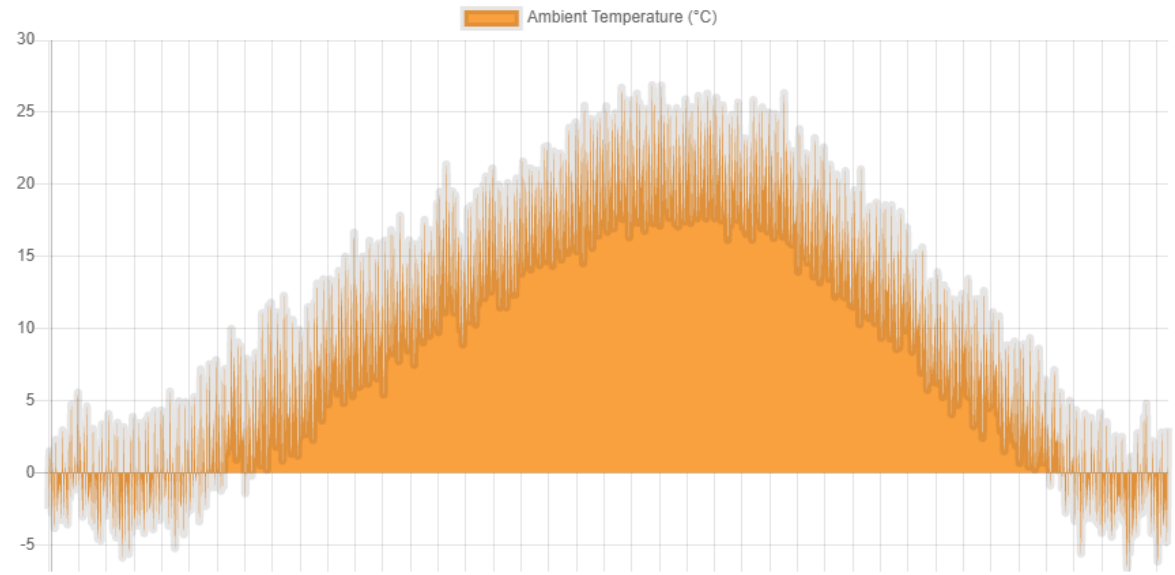
Installation Surface

net surface area available for solar field installation: 26245 m^2

Total Corrective factor: 1

Ambient Temperature

Hourly Profile



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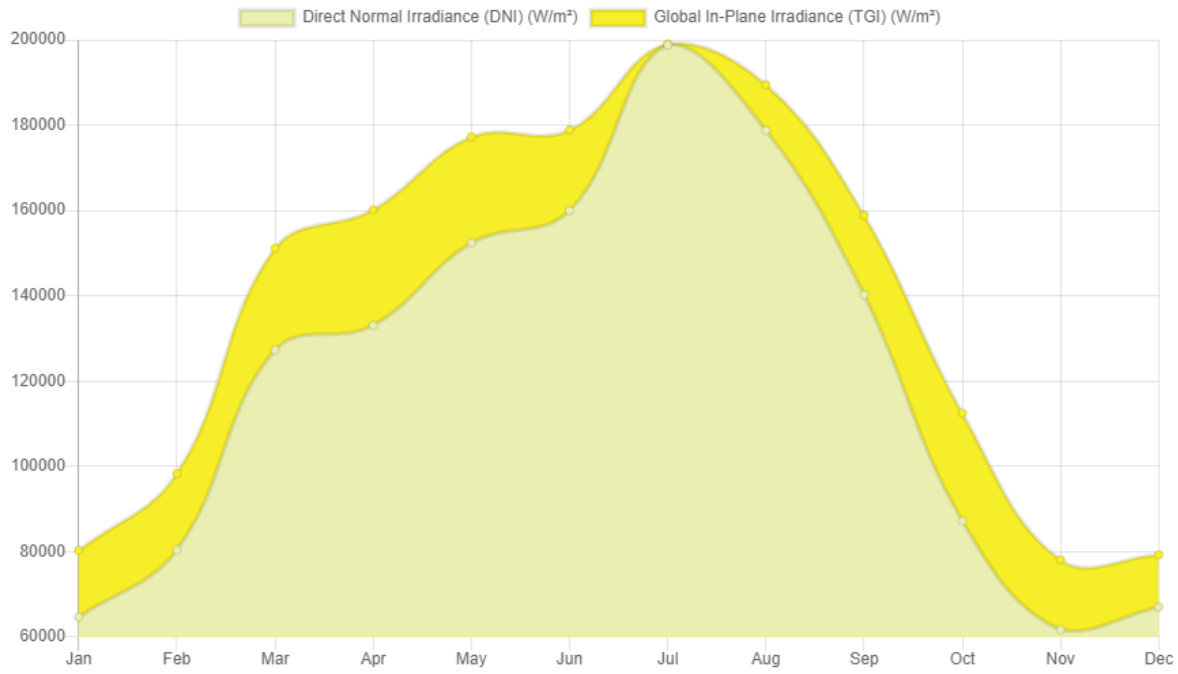
Solar Irradiance

Monthly Profiles



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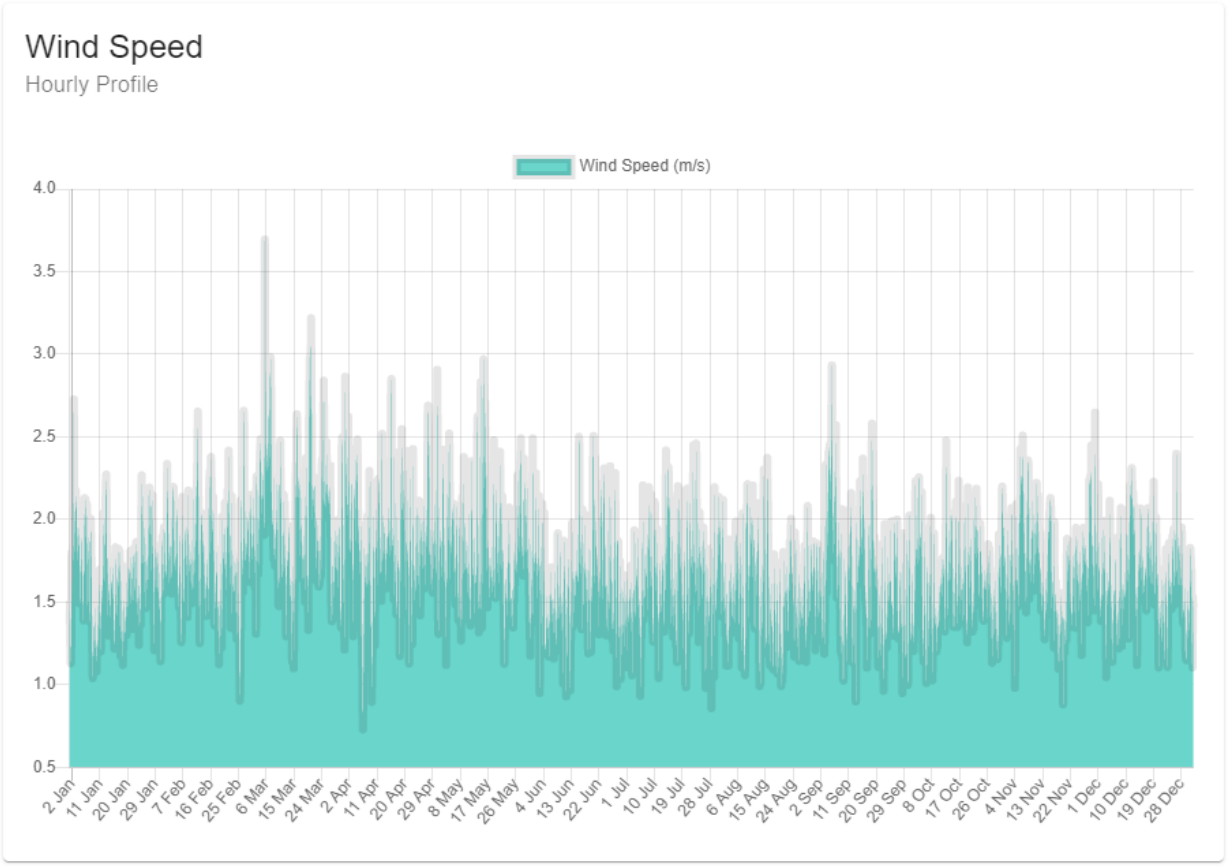
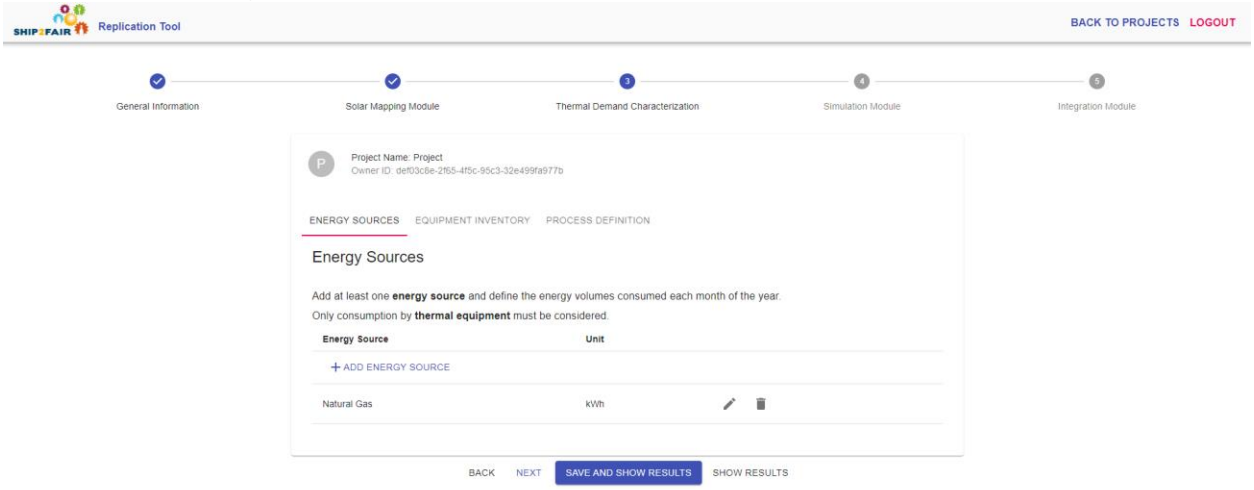


The second section shows the Thermal Demand Characterization which is divided in three sub-sections:

- **Energy sources** ((Electricity, Natural Gas, Propane, Butane, Diesel, Heavy Fuel Oil, Biomass High HV, Biomass Low HV)



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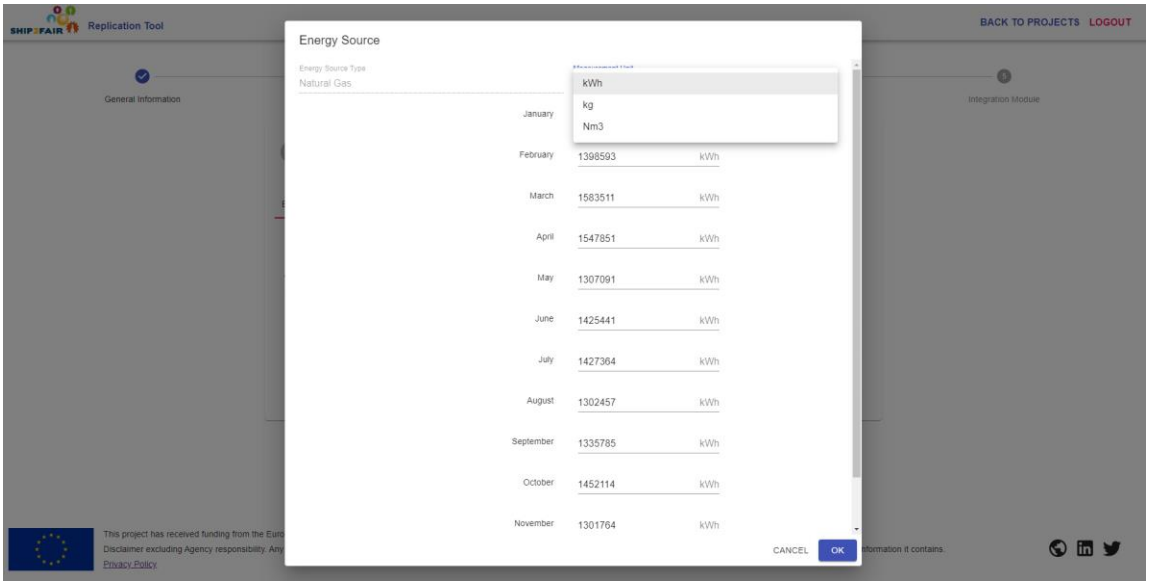
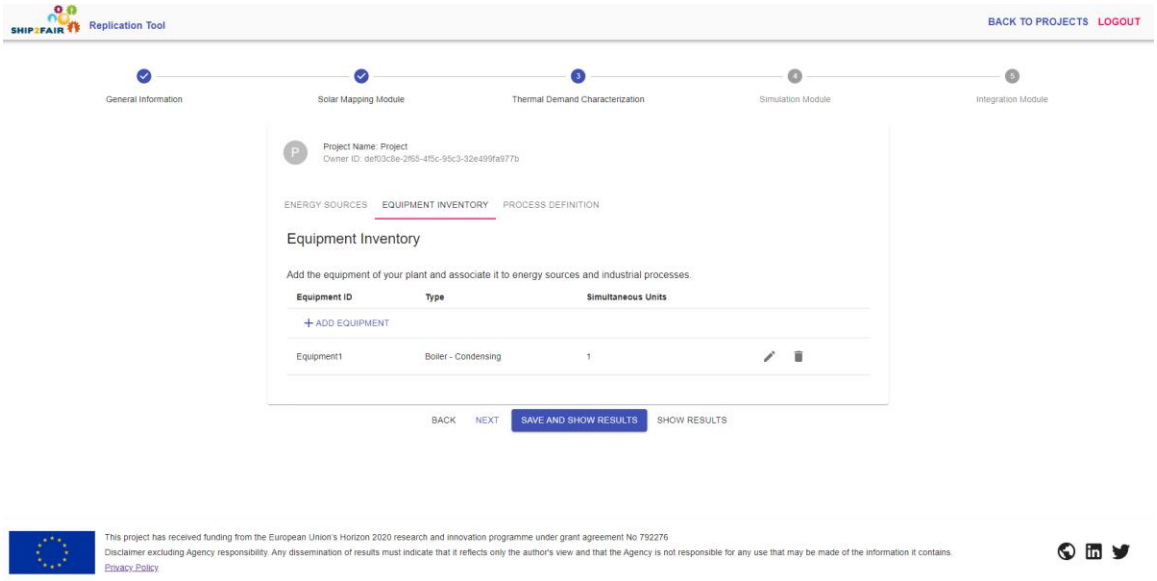
After choosing the energy source, a new dialog will appear, and you can choose the measurement unit and then insert the monthly consumptions.



- **Equipment inventory**
  User must provide the data related to the equipment by clicking on button “Add equipment”.



The following data must be provided:

- **Equipment id**
  Identification name for the equipment, given by the user.
- **Equipment type**
  A predefined list of equipment (Boiler - Condensing, Boiler - Low Temp., Boiler - Conventional, Chiller - Compression, Chiller - High Eff., CHP - TG, CHP - TV, CHP - Motor).

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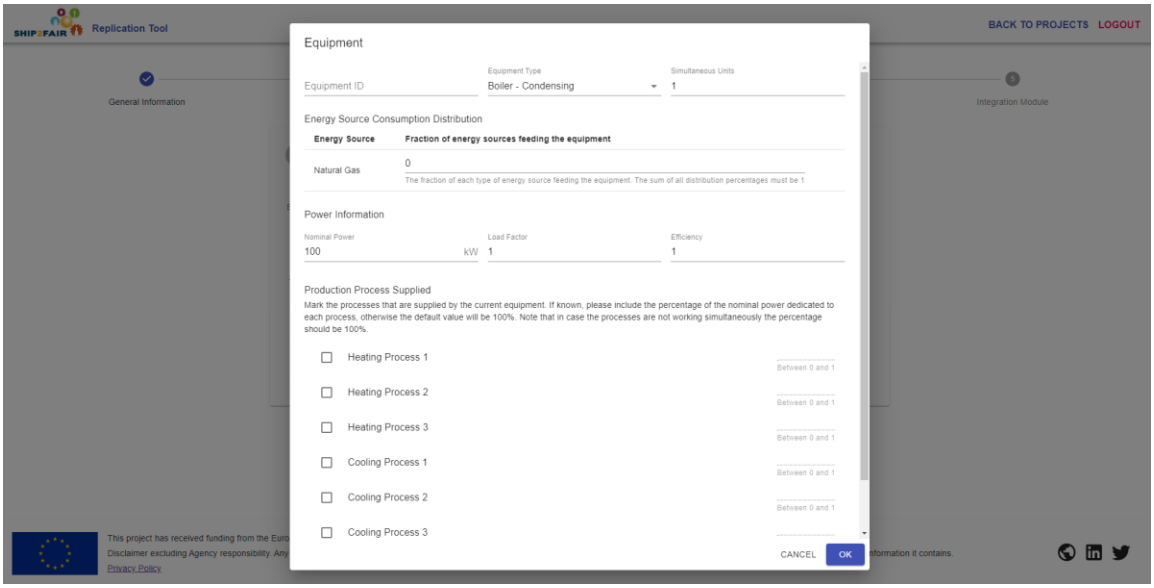
- **Simultaneous Units**
  The installation may have more than one operating unit working in parallel. In this case the user can define the total number in operation.
- **Energy source consumption distribution**
  Usage distribution percentage.
- **Nominal power**
  Equipment Rated Power.
- **Load factor**
  When in operation, the energy devices work seldom at their nominal power, they are working with a certain loading factor. If known, the user can fill the gap, otherwise the value by default will be 1.
- **Efficiency**
  Identification name for the equipment, given by the user.
- **Production processes supplied**
  The user must mark the processes that are supplied by the current equipment. If known, the user must also include the percentage of the nominal power dedicated to each process. In case the processes are not working simultaneously, the percentage should be 100%.



- **Process definition**
  The user must provide the data for the process definition. As shown in the next figure, the user will see the list of processes selected in the previous step and the associated equipment.

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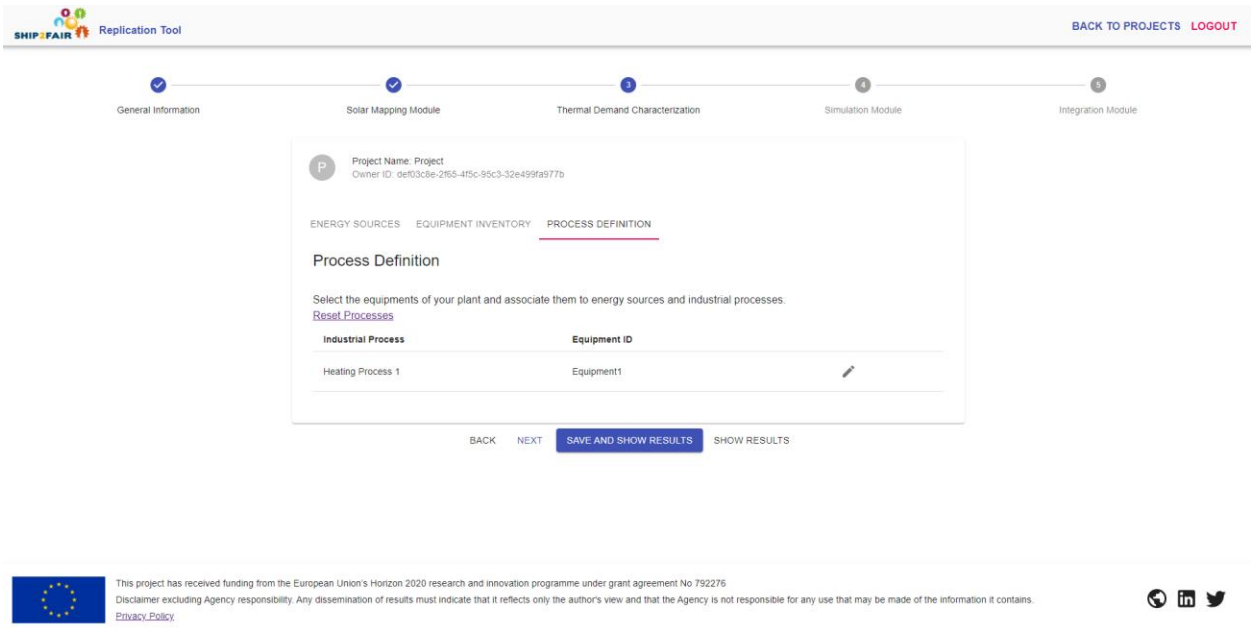

- **Thermal use**
  This field is intended to identify the thermal use required by the process. There are two available options: heating or cooling.
- **Working fluid**
  This field is intended to identify the fluid used directly in the process to provide the heating or cooling demand. There are two available options: water or steam. In case the user selects "Steam" another field will be displayed to insert the **Pressure.**
- **Thermal dependence**
  Depending on the thermal process (particularly in air conditioning), the inlet temperature of the air or water affects the equipment final consumption. In this sense, when computing the demand/consumption per process, it is recommended to include the temperature influence. Three options are available to the user:
    - No dependence: in this case the temperature algorithm is not considered to calculate the working power of individual process.
    - Water Dependence.
    - Air Dependence.
- **Operating temperature**
  Required process operating temperature that shall be kept or maintained using the thermal equipment.
- **Consumption profiles**
  In order to determine the process schedule, loading and working hours in an hourly basis for the reference year of study, it is required to insert:
    - A typical **daily profile.** User can select among five predefined profiles (Constant load, Morning Load, Afternoon Load, Full day Load, Batch Load).
    - A typical **weekly** profile. User can set a value for each day of the week.
    - A typical **yearly** profile. User can set a value for each week of the year.

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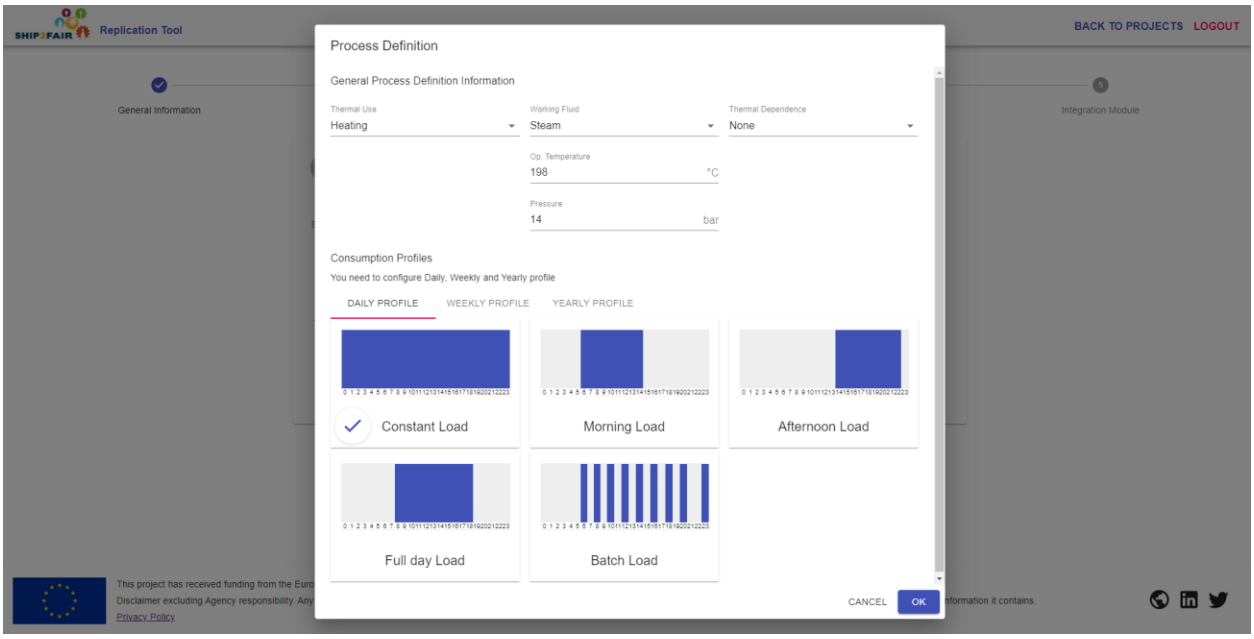

After the user has inserted the required inputs and has clicked on button “Save and show results”, a message panel is shown, informing the user to wait for the outputs to be displayed.

When the results are ready, the previous panel will be closed and another pop-up panel containing the following outputs will be displayed:

- Total thermal demand
- Heating demand
- Cooling demand
- Monthly demand distribution
- Process operating temperature
- Thermal process fluid
- Details of the thermal demand for a single process (with the specified equipment and the specified energy source). Details can be filtered by:
    - All months or a single month.
    - All weeks or a specified week (available if a single month has been selected).
    - All days of the week or a specified day (available if a single week has been selected).

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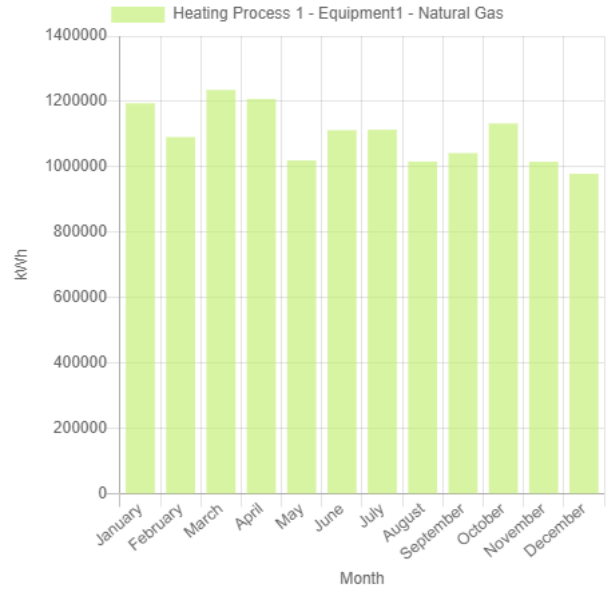
Thermal Demand Module Results

Total Demand:	13156787.28 kWh
Heating Demand:	13156787.28 kWh
Cooling Demand:	0 kWh

Processes

Heating Process 1 - Equipment1 - Natural Gas	T: 198 °C	P: 14 bar	steam

Monthly Heating Demand



No cooling demand

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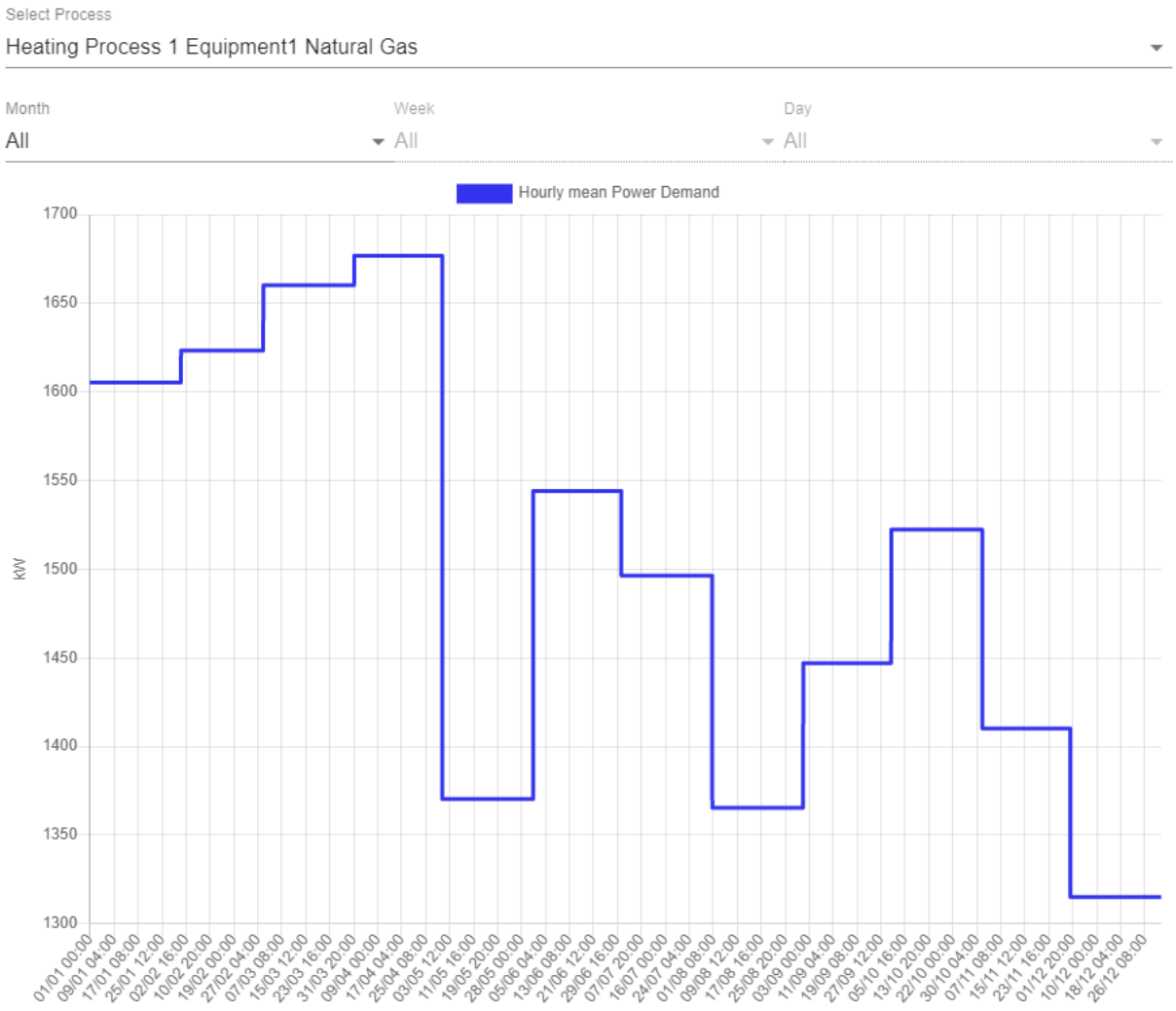

In the Simulation Module, the user inserts inputs in 2 different sections:

- A section specific for **each case study** (i.e. a defined solar plant) the user wants to compare.
  The user can compare from a minimum of 2 cases to a maximum of 10 cases. The maximum threshold is necessary due to the computational time required to perform the calculations in the Simulation Module.
  The user can set the number of cases just by clicking on the “Plus” and “Minus” buttons.

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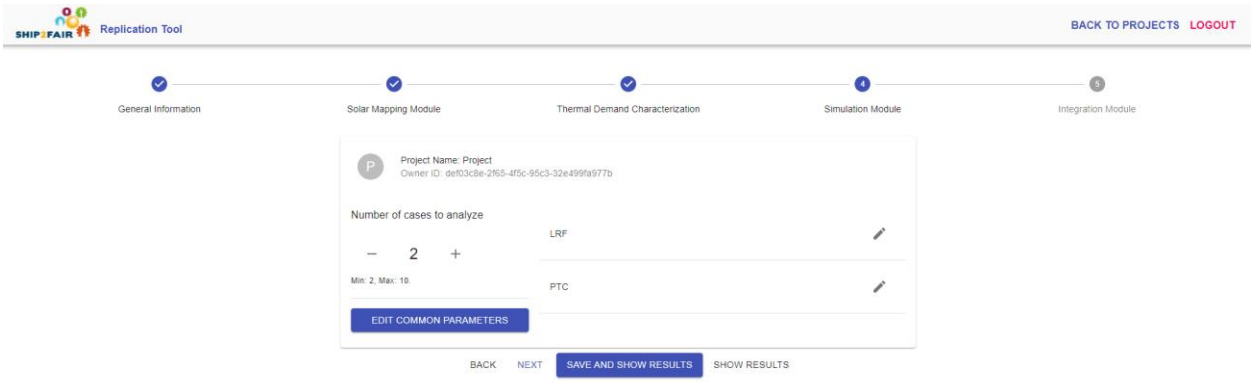

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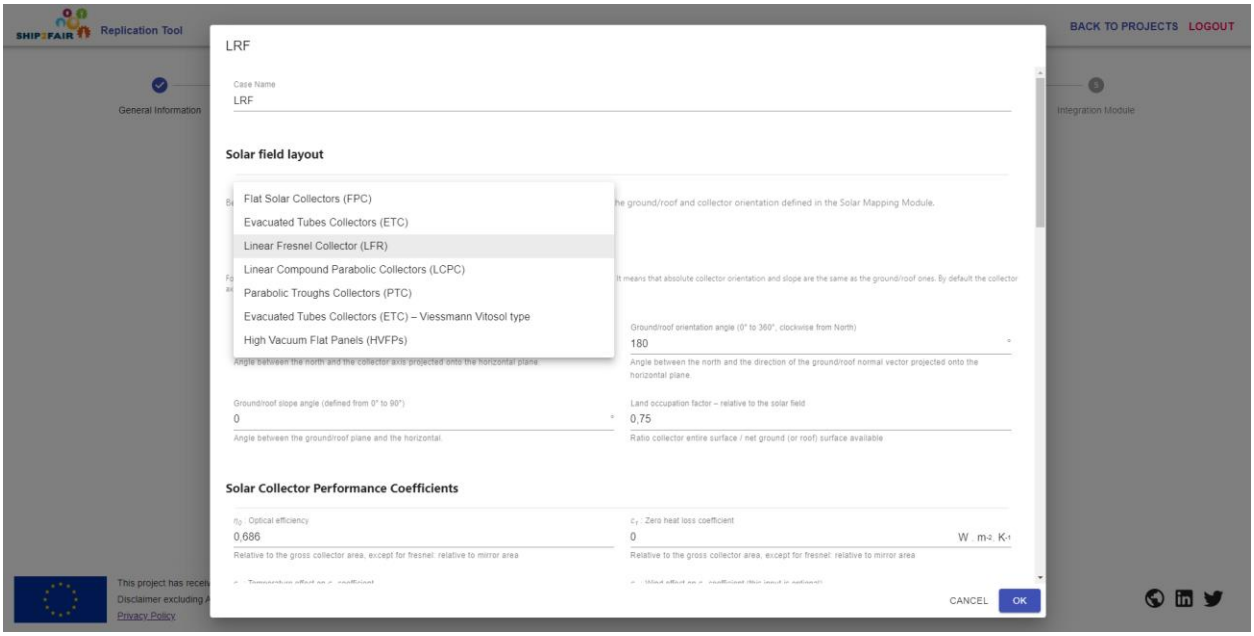

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Solar Collector Performance Coefficients

η_0 : Optical efficiency
0,686
Relative to the gross collector area, except for fresnel: relative to mirror area

c_1 : Zero heat loss coefficient
0 W . m-2. K-1
Relative to the gross collector area, except for fresnel: relative to mirror area

c_2 : Temperature effect on c_1 coefficient
0,0002664 W . m-2. K-2
Relative to the gross collector area, except for fresnel: relative to mirror area

c_3 : Wind effect on c_1 coefficient (this input is optional)
0 J . m-3. K
Relative to the gross collector area, except for fresnel: relative to mirror area

c_4 : Sky temperature effect on c_1 coefficient
0
Relative to the gross collector area, except for fresnel: relative to mirror area

c_6 Wind effect on η_0 coefficient
0 s . m-1
Relative to the gross collector area, except for fresnel: relative to mirror area

Incident angle

- ○ Default Value
- ◉ Custom Value

CONFIRM CUSTOM VALUES

⚠ After inputting new custom values or editing existing ones, you **must** confirm them or they will not be saved once the modal is closed.

Incident Angle	Transversal Incident Angle Modifier	Longitudinal Incident Angle Modifier
0	1	1
0	1	1

Solar Collector cost data

CAPEX
480,8 €/m2
Relative to the gross collector area, except for fresnel: relative to mirror area

OPEX
4,21 €/m2/year
Relative to the gross collector area, except for fresnel: relative to mirror area

Capex Land
0 €/m2
Relative to the ground/roof surface available

Complementaries informations

Lifetime
20 years

Annual Solar Collector Performance Degradation Rate
0,5 %/year

Solar plant electricity consumption
1,5 %
Ratio electricity needed to run the solar plant on thermal production

- A section **shared** for all the cases, where the user can insert the common parameters. If this section is not filled, a warning is displayed to the user.

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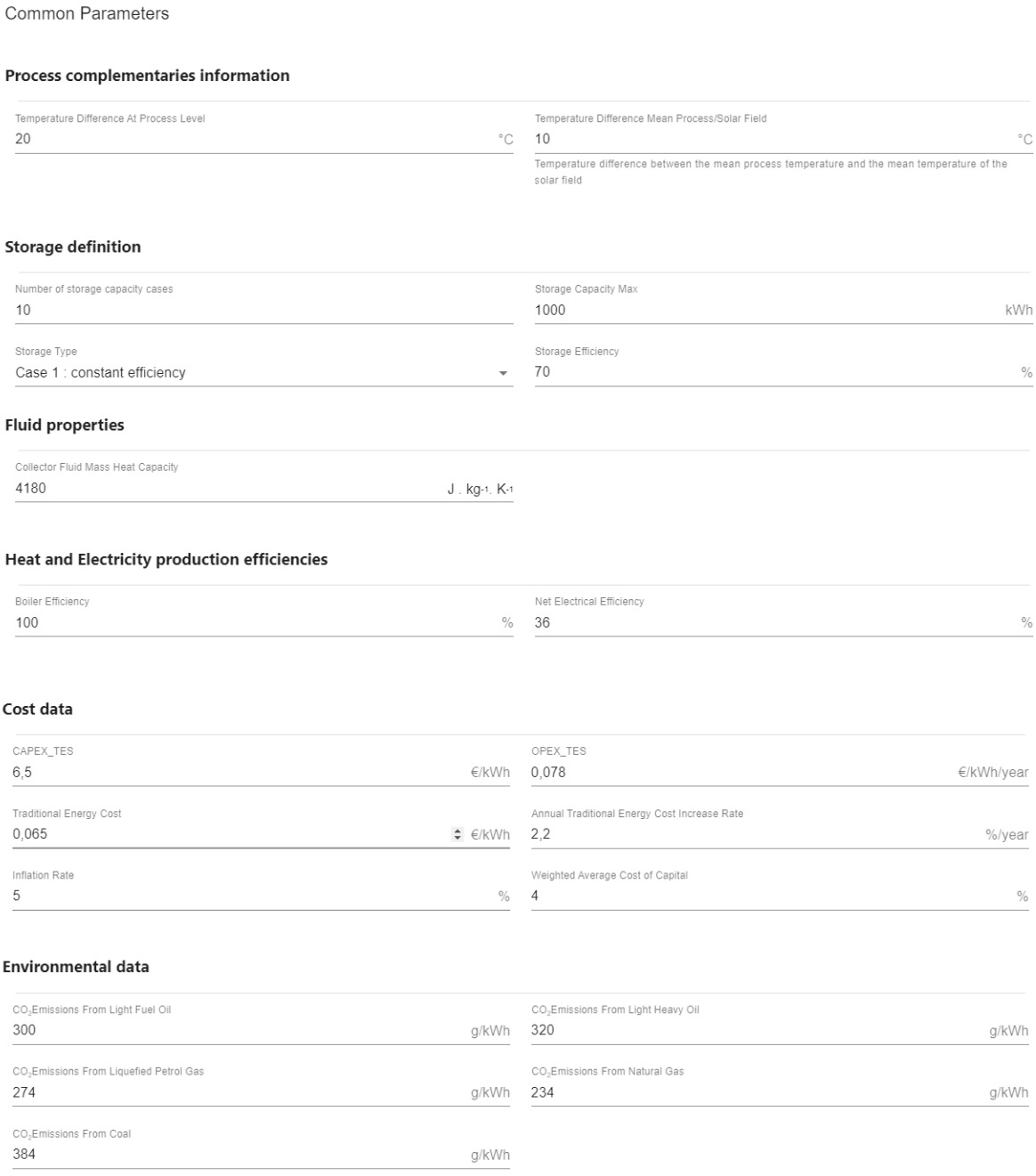

After having defined the solar and energy demand profiles, in the last module “Integration Module”, the user is advised to select the most optimal integration point for the solar energy source. In this sense, a multi-optimization algorithm approach based on minimize the energy loss (in terms of exergy), maximize the use of solar energy or maximize the ration energy/losses (in terms of energy/exergy) is applied according to the user preferences.

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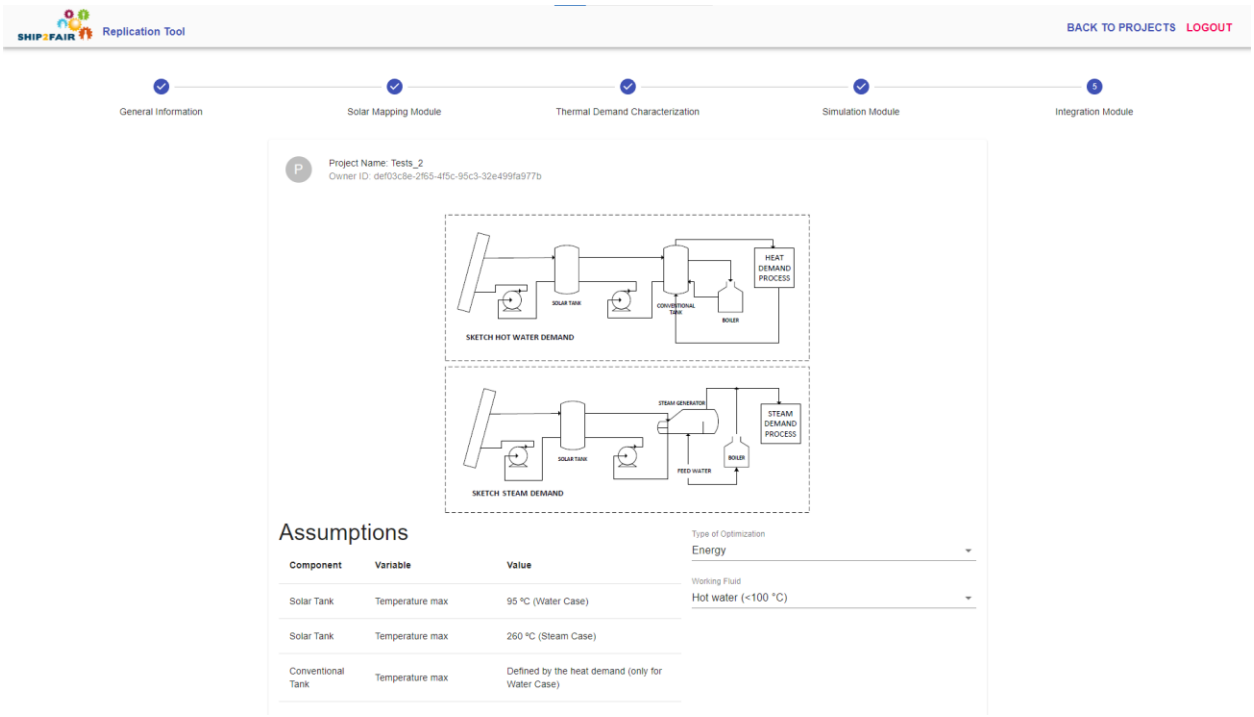

As a result, in a yearly and monthly basis, the best combination of processes to be fed by the solar energy is presented, with the optimal area and volume for the solar design.

These results show:

- The yearly results and the optimal area and volume for the solar design.
- The monthly results. The user can select by a dropdown the process to consider, and the corresponding outputs are displayed.
- In a monthly basis, the best combination of processes to be fed by the solar energy.

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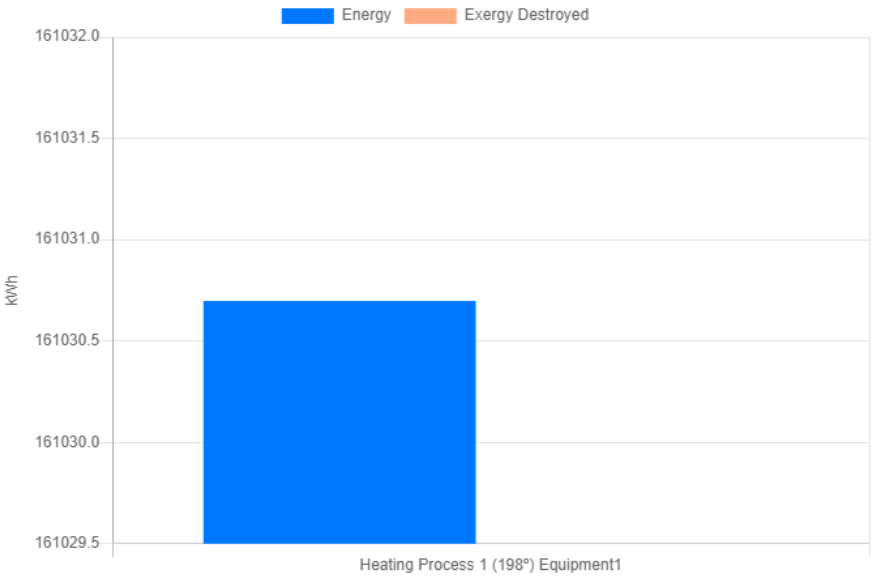
Integration Module Results

Yearly Results

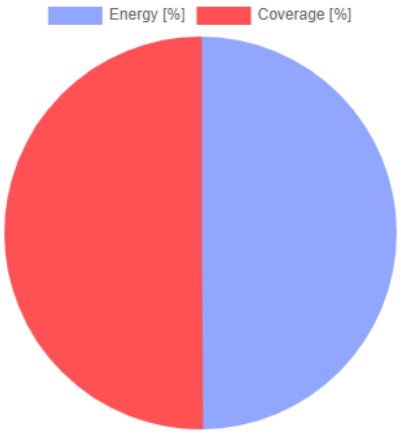
Optimal Measurements	
Area (m^2)	1000
Volume (litres)	40000



Energy percentage respect the global thermal demand covered by solar

Select Process

Heating Process 1 (198°) Equipment1



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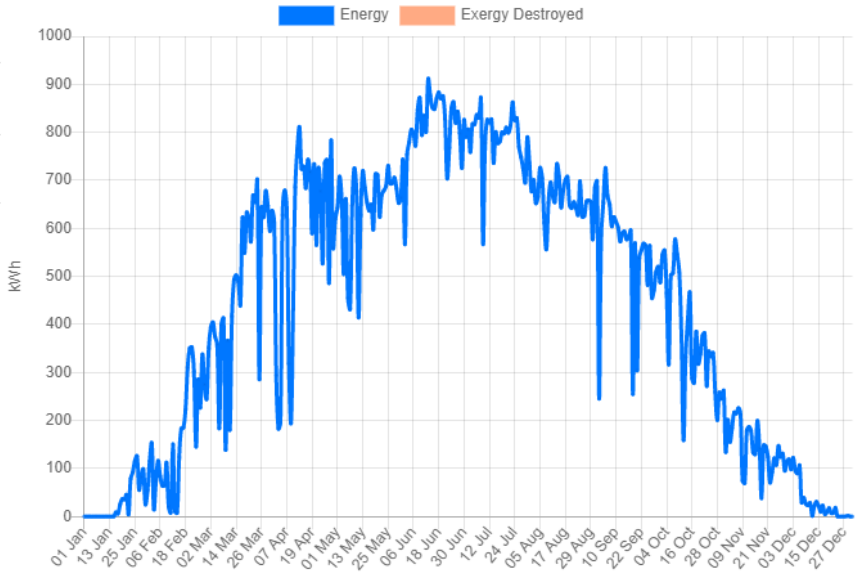
Monthly Results

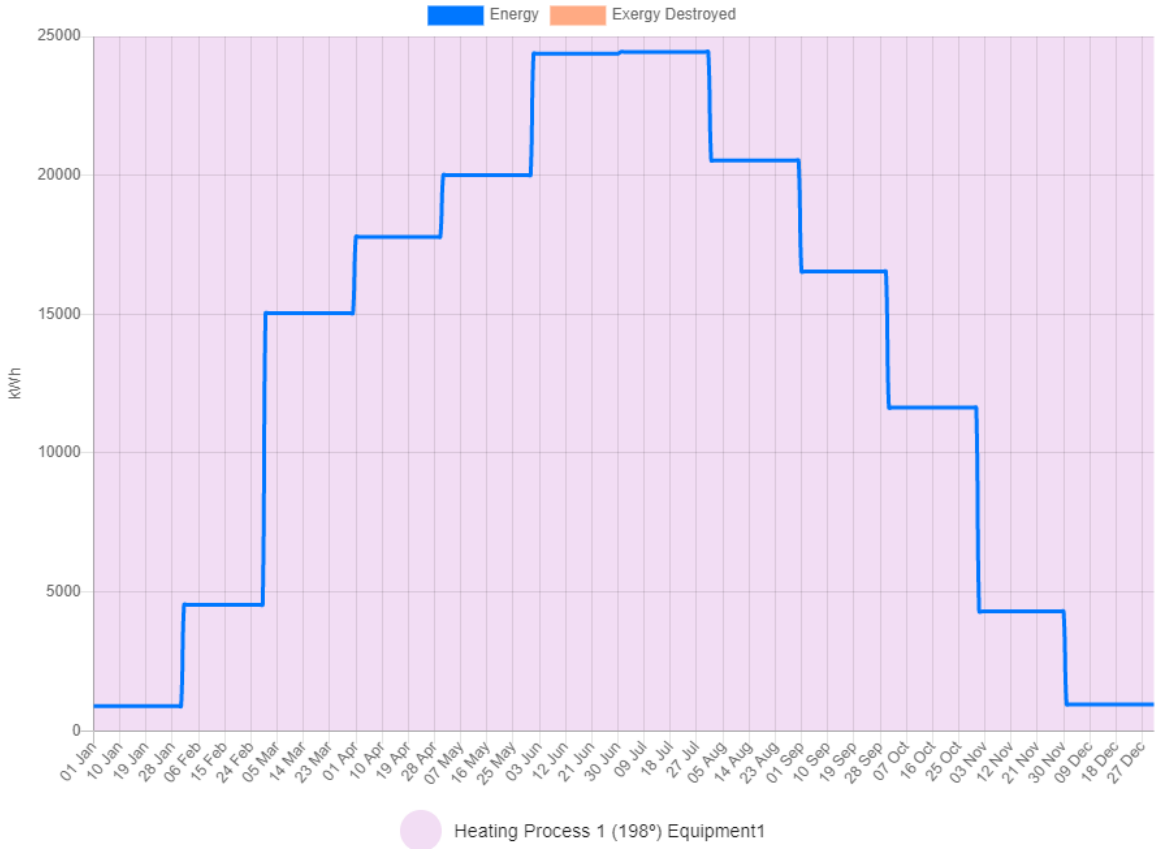
Select Process

Heating Process 1 (198º) Equipment1

Optimal Measurements	
Area (m^2)	1000
Volume (litres)	40000



Monthly Results - Optimal Schedule



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