



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



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)

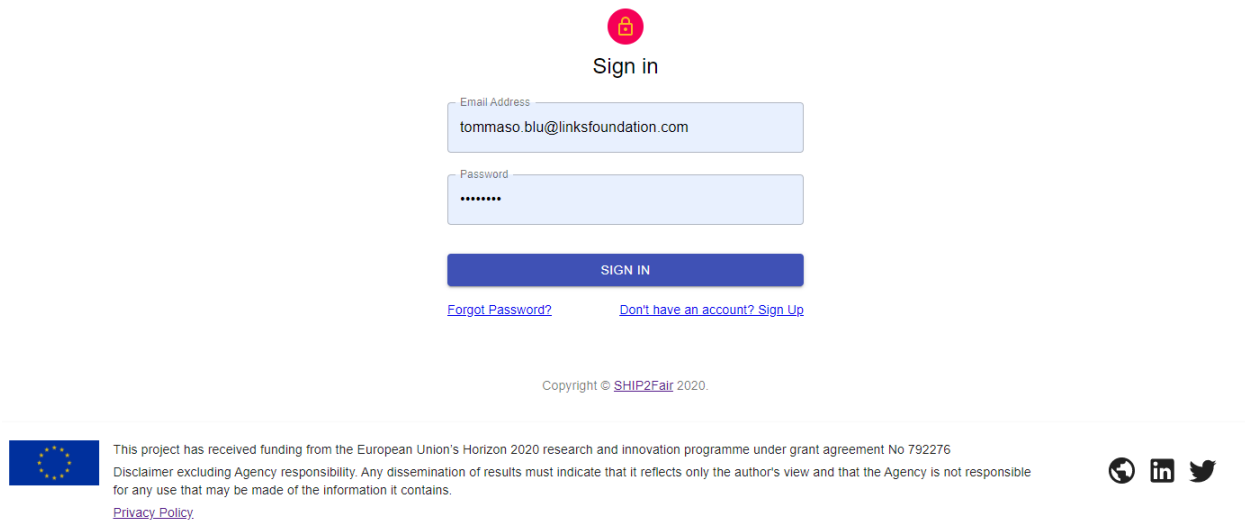
Where to find the replication tool? Create an account here: <https://replicationtool.ship2fair.cloud/login>



Chapter 3

Example

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



The screenshot shows a minimalist login interface. At the top center is a red circular icon with a white padlock. Below it is the text "Sign in". There are two input fields: "Email Address" containing "tommaso.blu@linksfoundation.com" and "Password" with masked characters. Below the fields is a blue "SIGN IN" button. Under the button are two links: "Forgot Password?" and "Don't have an account? Sign Up". At the bottom, there is a copyright notice "Copyright © SHIP2Fair 2020." and a footer section. The footer includes the European Union flag, a funding statement, a disclaimer, a privacy policy link, and social media icons for GitHub, LinkedIn, and Twitter.

Sign in


Email Address
tommaso.blu@linksfoundation.com




Password

SIGN IN

[Forgot Password?](#) [Don't have an account? Sign Up](#)

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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.

U

User Information

First Name

Last Name

E-mail















Tommaso

Blu

tommaso.blu@linksfoundation.com

P

Projects List

| Project Name | Status | Project ID | Actions |
|---------------|---|--------------------------------------|---|
| Test project | Updated General Information | 4ae1f242-c5f5-442c-a760-2d422c0d753f |   |
| Project 2 | Solar Mapping Outputs Updated | 6da17598-b6ae-4d7f-9733-c7fd3071fbc1 |   |
| My project 3 | Thermal Demand Inputs Completed Updated | 9b3939fe-5445-4cd2-93ef-03ad88e75477 |   |
| Sugar Project | Updated General Information | c00a04a9-67ac-43a4-b8c3-0cea2e3ce7fa |   |
| Wine Project | Project Created | c71c5cf9-8ffd-4564-b9b1-20a44489219a |   |
| My project | Solar Mapping Outputs Updated | dd68fddd-b7cc-4062-9b19-0e64863832dc |   |
| White Sugar | Integration Outputs Updated | e3ce4bb9-5c61-4b8b-ac25-00fc5b5eac19 |   |

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CREATE 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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Replication Tool
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LOGOUT

1 General Information
2 Solar Mapping Module
3 Thermal Demand Characterization
4 Simulation Module
5 Integration Module

P
Project Name: Project
Owner ID: def03c8e-2f65-4f5c-95c3-32e499fa977b

Company Information

Company Name: LINKS Foundation
City: Turin
Country: Italy

Contact Information

Contact Name: Tommaso Blu
E-mail: tommaso.blu@linksfoundation.com
Telephone: 011231231

Production Information

Production Sector: Chemicals
Year of Study: 2022
Total Production: 42500 Tons/Year
Product Name: Chemicals
Year of Production: 2020

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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**.

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Project Name: Project
Owner ID: def03c8e-2f65-4f5c-95c3-32e499fa977b

Industrial Site Location

Location of the Industrial Site

Insert the coordinates of the industrial site, writing it manually, clicking on the map, or searching for a location on the Search box.

Latitude: 45.0621642° N
Longitude: 7.6658170° E

Search position here

Solar Field Characterization

Assessment of Solar Radiation and Sun Position

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SAVE AND SHOW RESULTS
SHOW RESULTS

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



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Industrial Site Location

Solar Field Characterization

Solar Field Characterization

Input the configuration of the solar field.

Available area for the installation of the solar thermal collectors

Area

26245

m²

Type of installation

Roof/Ground

Ground

Roof Typology

Flat Roof

Corrective Factors

C1 - Inclination and Obstacles

INFO

0: Many obstacles

1: No obstacles

C2 - Shading

INFO

0: Shading

1: No shading

C3 - Maintenance Allowance

INFO

0: Need for maintenance space

1: No need for maintenance space

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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Industrial Site Location

Solar Field Characterization

Assessment of Solar Radiation and Sun Position

Assessment of Solar Radiation and Sun Position

Input the configuration of the solar plant.

Choose the dataset settings to evaluate the solar radiation and sun position.

Solar plant configuration

Panel Orientation

0

degrees

☐ Optimize Orientation

Panel Slope

degrees

☒ Optimize Slope

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SAVE AND SHOW RESULTS

SHOW RESULTS

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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)

Solar Mapping Module Results

Optimized Angles

Optimized Panel Slope: 38 °

Optimized Panel Orientation: 177 °

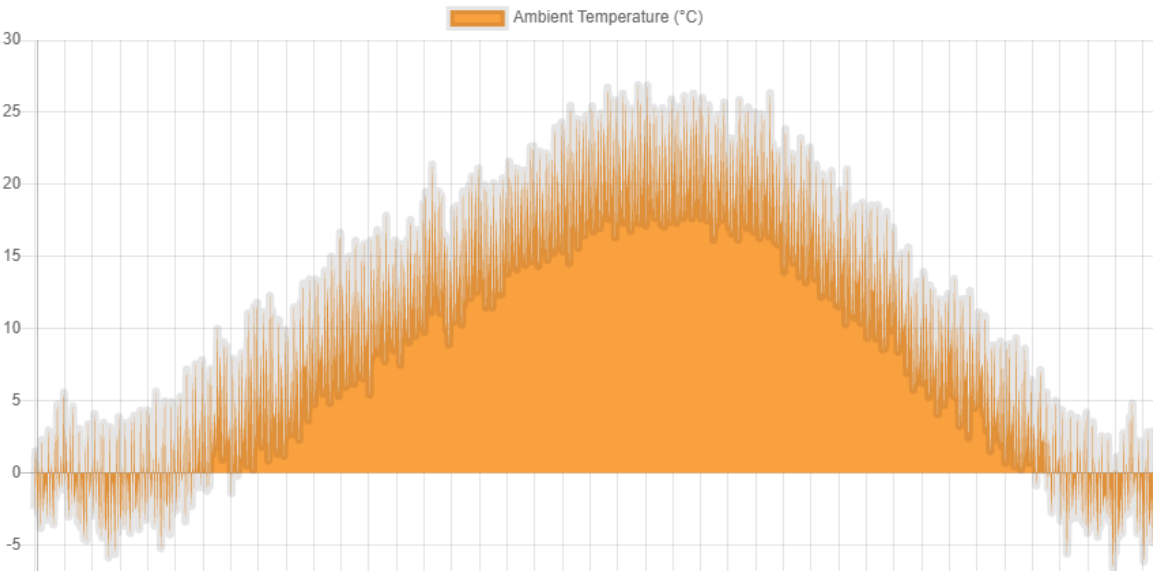
Installation Surface

net surface area available for solar field installation:
26245 m²

Total Corrective factor: 1

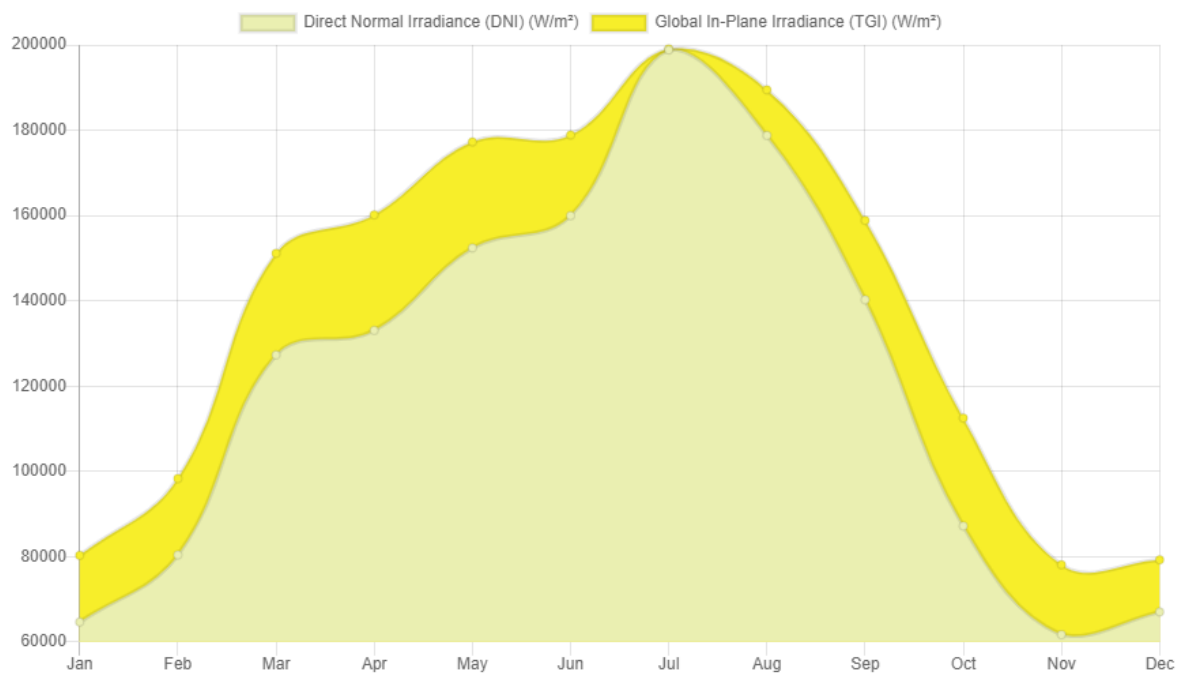
Ambient Temperature

Hourly Profile



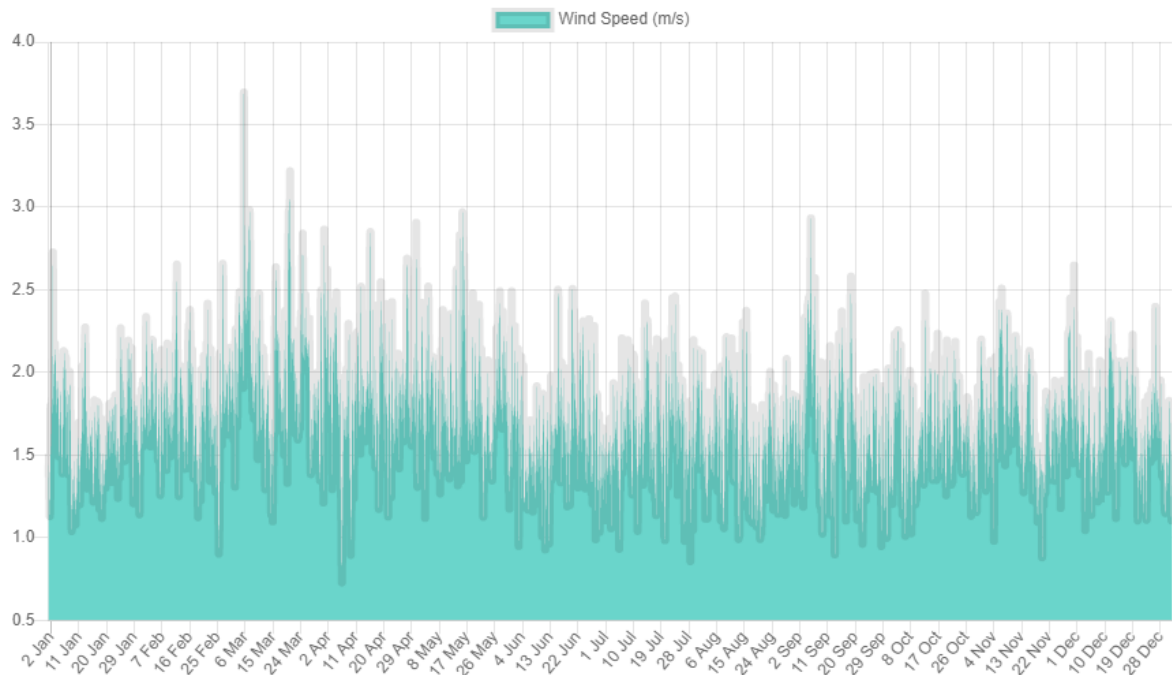
Solar Irradiance

Monthly Profiles



Wind Speed

Hourly Profile



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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✓

General Information

✓

Solar Mapping Module

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Project Name: Project

Owner ID: de103c8e-2f55-4f5c-95c3-32e499a977b

ENERGY SOURCES

EQUIPMENT INVENTORY

PROCESS DEFINITION

Energy Sources

Add at least one **energy source** and define the energy volumes consumed each month of the year.

Only consumption by **thermal equipment** must be considered.

Energy Source

Unit

+ ADD ENERGY SOURCE

Natural Gas

kWh

✎

✖

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SAVE AND SHOW RESULTS

SHOW RESULTS



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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.

| Month | Consumption (kWh) |
|-----------|-------------------|
| January | |
| February | 1398593 |
| March | 1583511 |
| April | 1547851 |
| May | 1307091 |
| June | 1425441 |
| July | 1427364 |
| August | 1302457 |
| September | 1335785 |
| October | 1452114 |
| November | 1301764 |

○ Equipment inventory

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

| Equipment ID | Type | Simultaneous Units |
|-----------------|---------------------|--------------------|
| + ADD EQUIPMENT | | |
| Equipment1 | Boiler - Condensing | 1 |

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).

- **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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Owner ID: def03c8e-2f65-4f5c-95c3-32e499a977b

ENERGY SOURCES


EQUIPMENT INVENTORY

PROCESS DEFINITION

Process Definition

Select the equipments of your plant and associate them to energy sources and industrial processes.

[Reset Processes](#)


| Industrial Process | Equipment ID |
|--------------------|--|
| Heating Process 1 | Equipment1  |

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SAVE AND SHOW RESULTS

SHOW RESULTS



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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.

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).



Thermal Demand Module Results

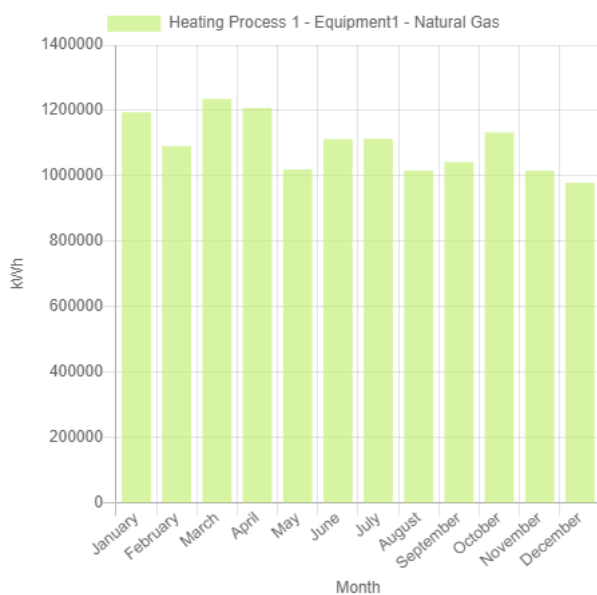
| | |
|-----------------|-----------------|
| Total Demand: | 13156787.28 kWh |
| Heating Demand: | 13156787.28 kWh |
| Cooling Demand: | 0 kWh |

Processes

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

Monthly Heating Demand

No cooling demand



Select Process

Heating Process 1 Equipment1 Natural Gas

Month

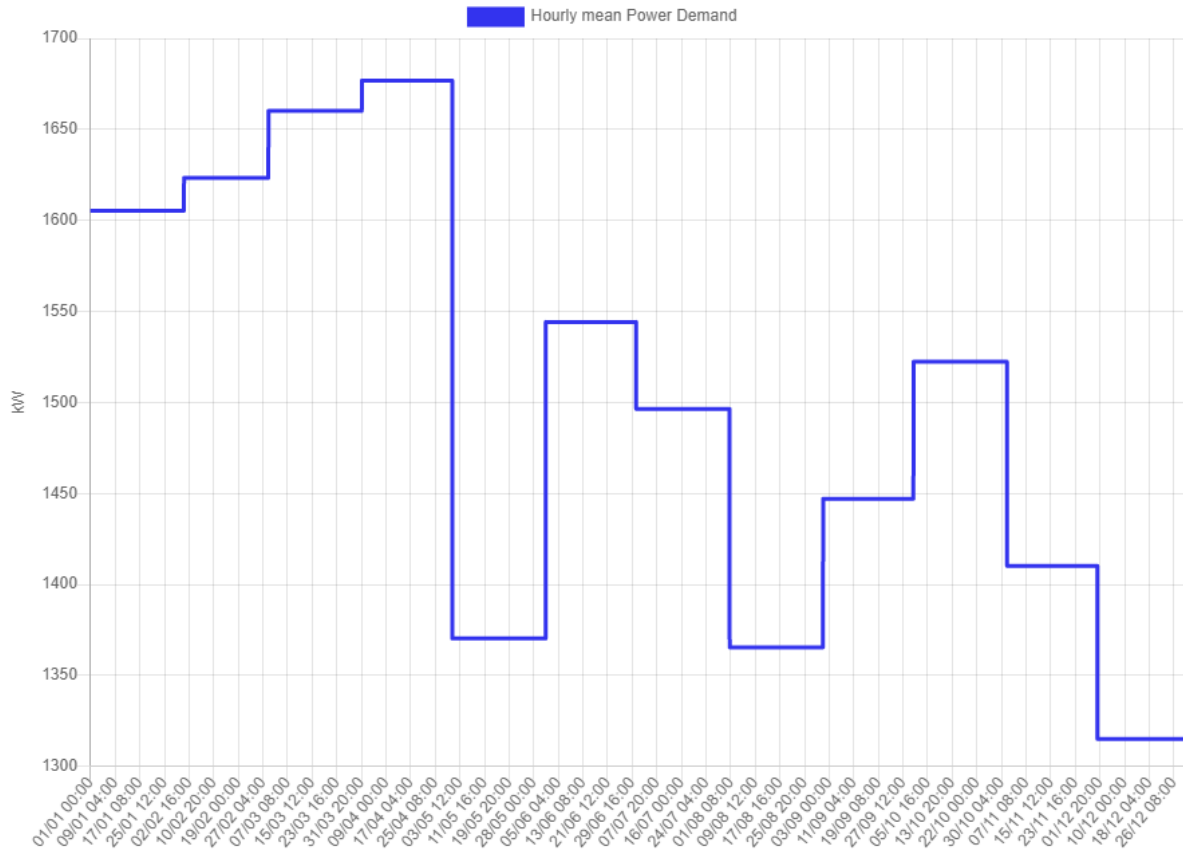
All

Week

All

Day

All



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.



SHIPFAIR Replication Tool

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General Information

Solar Mapping Module

Thermal Demand Characterization

Simulation Module

Integration Module

P

Project Name: Project
Owner ID: def03c8e-2f65-4f5c-95c3-32e499fa977b

Number of cases to analyze

-

2

+

Min: 2, Max: 16

LRF

PTC

EDIT COMMON PARAMETERS

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SHIPFAIR Replication Tool

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General Information

Integration Module

LRF

Case Name
LRF

Solar field layout

Fiat Solar Collectors (FPC)

Evacuated Tubes Collectors (ETC)

Linear Fresnel Collector (LFR)

Linear Compound Parabolic Collectors (LCPC)

Parabolic Troughs Collectors (PTC)

Evacuated Tubes Collectors (ETC) – Viessmann Vitosol type

High Vacuum Flat Panels (HVFPs)

Ground/roof slope angle (defined from 0° to 90°)

0

Angle between the north and the collector axis projected onto the horizontal plane

Ground/roof orientation angle (0° to 360°, clockwise from North)

180

Angle between the north and the direction of the ground/roof normal vector projected onto the horizontal plane

Land occupation factor – relative to the solar field

0.75

Ratio collector entire surface / net ground (or roof) surface available

Solar Collector Performance Coefficients

η_0 Optical efficiency

0.688

Relative to the gross collector area, except for fresnel: relative to mirror area


c_1 Zero heat loss coefficient




0

Relative to the gross collector area, except for fresnel: relative to mirror area

CANCEL

OK

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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 Relative to the gross collector area, except for fresnel: relative to mirror area W . m ⁻² . K ⁻¹ |
| c_2 : Temperature effect on c_1 coefficient 0,0002664 Relative to the gross collector area, except for fresnel: relative to mirror area W . m ⁻² . K ⁻² | c_3 : Wind effect on c_1 coefficient (this input is optional) 0 Relative to the gross collector area, except for fresnel: relative to mirror area J . m ⁻³ . K |
| c_4 : Sky temperature effect on c_1 coefficient 0 Relative to the gross collector area, except for fresnel: relative to mirror area | c_5 Wind effect on η_0 coefficient 0 Relative to the gross collector area, except for fresnel: relative to mirror area s . m ⁻¹ |

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 Relative to the gross collector area, except for fresnel: relative to mirror area €/m ² | OPEX 4,21 Relative to the gross collector area, except for fresnel: relative to mirror area €/m ² /year |
| Capex Land 0 Relative to the ground/roof surface available €/m ² | |

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.



Common Parameters

Process complementaries information

| | | | | | |
|---|----|----|---|----|----|
| Temperature Difference At Process Level | 20 | °C | Temperature Difference Mean Process/Solar Field | 10 | °C |
| | | | Temperature difference between the mean process temperature and the mean temperature of the solar field | | |

Storage definition

| | | | | |
|----------------------------------|------------------------------|----------------------|------|-----|
| Number of storage capacity cases | 10 | Storage Capacity Max | 1000 | kWh |
| Storage Type | Case 1 : constant efficiency | Storage Efficiency | 70 | % |

Fluid properties

| | | |
|------------------------------------|------|--|
| Collector Fluid Mass Heat Capacity | 4180 | J . kg ⁻¹ . K ⁻¹ |
|------------------------------------|------|--|

Heat and Electricity production efficiencies

| | | | | | |
|-------------------|-----|---|---------------------------|----|---|
| Boiler Efficiency | 100 | % | Net Electrical Efficiency | 36 | % |
|-------------------|-----|---|---------------------------|----|---|

Cost data

| | | | | | |
|-------------------------|-------|-------|--|-------|------------|
| CAPEX_TES | 6,5 | €/kWh | OPEX_TES | 0,078 | €/kWh/year |
| Traditional Energy Cost | 0,065 | €/kWh | Annual Traditional Energy Cost Increase Rate | 2,2 | %/year |
| Inflation Rate | 5 | % | Weighted Average Cost of Capital | 4 | % |

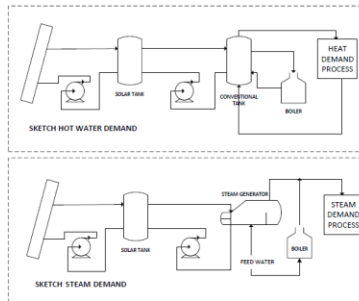
Environmental data

| | | | | | |
|---|-----|-------|--|-----|-------|
| CO ₂ Emissions From Light Fuel Oil | 300 | g/kWh | CO ₂ Emissions From Light Heavy Oil | 320 | g/kWh |
| CO ₂ Emissions From Liquefied Petrol Gas | 274 | g/kWh | CO ₂ Emissions From Natural Gas | 234 | g/kWh |
| CO ₂ Emissions From Coal | 384 | g/kWh | | | |

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.



Project Name: Tests_2
Owner ID: def03c8e-2f65-4f5c-95c3-32e499fa977b



Assumptions

| Component | Variable | Value | Type of Optimization |
|-------------------|-----------------|--|----------------------|
| | | | Energy |
| | | | Working Fluid |
| Solar Tank | Temperature max | 95 °C (Water Case) | Hot water (<100 °C) |
| Solar Tank | Temperature max | 260 °C (Steam Case) | |
| Conventional Tank | Temperature max | Defined by the heat demand (only for Water Case) | |

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.

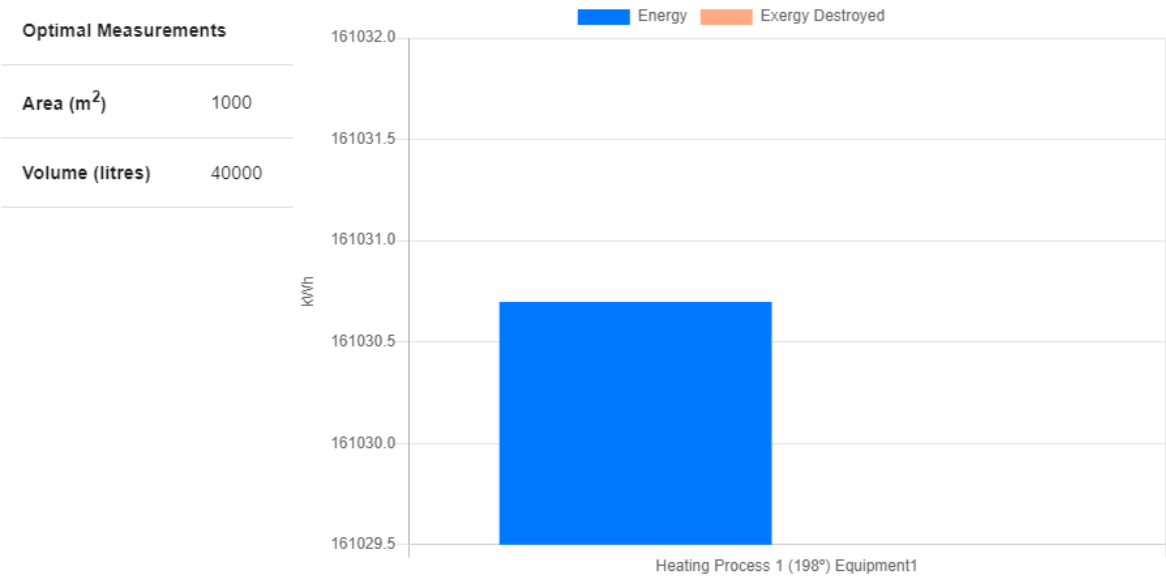
These results show:

- 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.

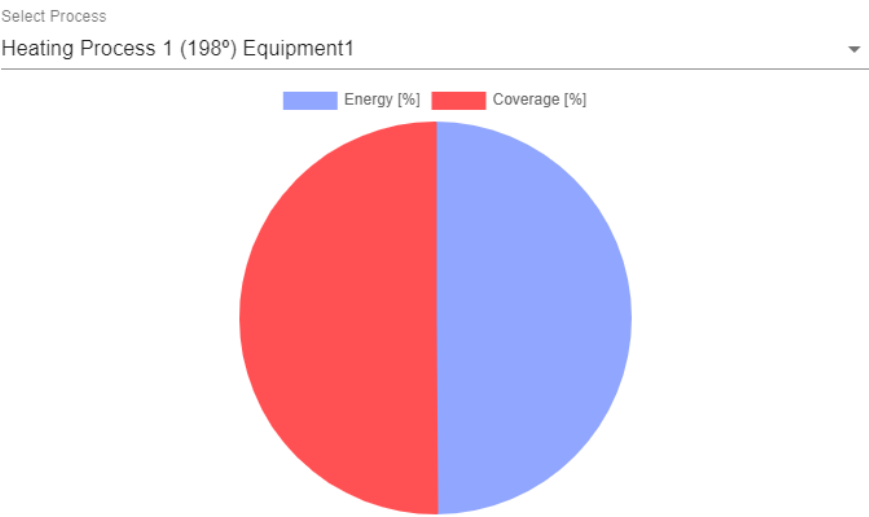


Integration Module Results

Yearly Results



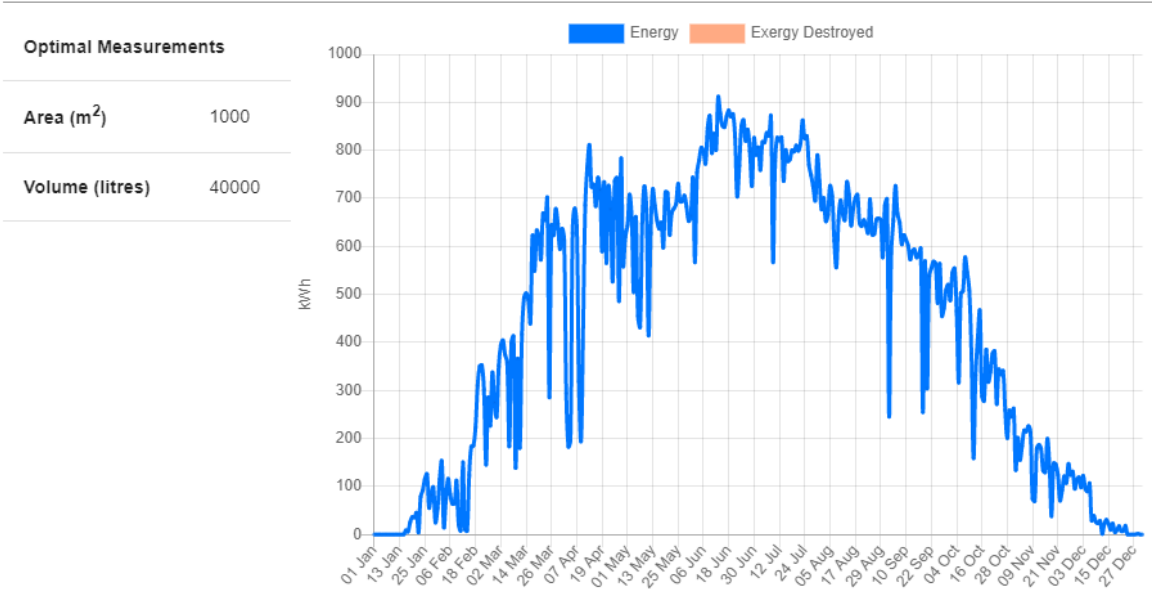
Energy percentage respect the global thermal demand covered by solar



Monthly Results

Select Process

Heating Process 1 (198°) Equipment1



Monthly Results - Optimal Schedule

