Interreg North Sea

Co-funded by the European Union

WaterWarmth

WORKPACKAGE 4

Smart integration of AE in the local energy system

4.3 Modelling tool for decentralized energy systems including AE aspects with and without energy storage

District heating optimizer modeling tool

User guide

ACCELERATING THE TRANSITION TOWARDS SUSTAINABLE HEATING AND COOLING BASED ON COLLECTIVE SURFACE WATER HEAT PUMP SYSTEM

1 Project framework and tool purpose

With the emergence of more and more energy communities and the increase of interest in energy sharing, it becomes imperative to start planning which production assets would your community need. When we talk about energy communities (ECs), engineers and developers usually refer to "decentralized electricity production and sharing" type of energy communities. This trend is also seen within the funding opportunities of new research projects. An aspect that is unfortunately commonly overlooked is heat sharing. District Heating and Cooling (DHC) sharing is as important as electricity sharing when it comes to indoor comfort, sustainability, and emissions offsetting.

The project WaterWarmth, co-financed by Interreg North Sea Region (NSR), takes the socially just and inclusive energy transition a step further. The consortium of the project works on facilitating ECs, acting as replicable examples of cooperative heating and cooling solutions, integrated into the local context, with citizens from across the NSR. A major focus of the project is the minimization of carbon emissions, pollution, reliance on energy imports, and to increase the efficiency of energy and material usage when it comes to cooperative heating and cooling. One way to do so is to investigate the potential of Aquathermal energy (AE).

AE uses thermal energy from water to provide sustainable Heating and Cooling for buildings. Surface waters act as a huge solar collector and store heat in quantities that exceed by far the energy requirements for heating and cooling. At present, the vast majority of people and energy communities are unaware of this omnipresent and readily available energy source.

As part of the project this ***District heating optimizer*** tool has been developed in collaboration with with TrikThom BV. The optimizer is a useful tool at the early stages of the planning process when a heating and cooling cooperative or a DHC system is being considered. It is designed to give a preliminary idea of the needed production assets and their capacities, which would be enough to meet the demand of the consumers while minimizing the operational costs. It can be used by designers, engineers, city planners, researchers, students, and anyone else with basic knowledge about supply and demand of heat.

It is a Mixed Quadratically Constrained Quadratic Programming (MQCQP) model, which optimizes the production of various technologies within the DHC network. The primary objective is to minimize the overall system cost while meeting the energy demand. For more information contact Howest at energiemanagement@howest.be.

It is also important to outline what the tool is NOT.

The tool is not meant for precise calculation, developing a hydraulic design, and performing detailed business plans. It is meant to be used at the initial stages of district planning as opposed to close-to-completion stages.

Attention: The tool is still a beta-version and under development

2 Creating a simulation

Step 1: Log in

The first step in using the tool is to obtain a username and password. We opted for a behind-login tool as opposed to fully open tool since this feature allows for easier maintenance and troubleshooting. Furthermore, a log-in allows to save and load existing models. This means that once a user has set up a hypothetical heat net structure, they can save it and it can be loaded again later to re-run the scenario or tweak it without having to start from zero.

The "***Save model***" function only saves the configuration of the heat net, but not the consumption profiles of the nodes. The use of the model does not require any personal information. Therefore, there is no sensitive data stored while using the tool.

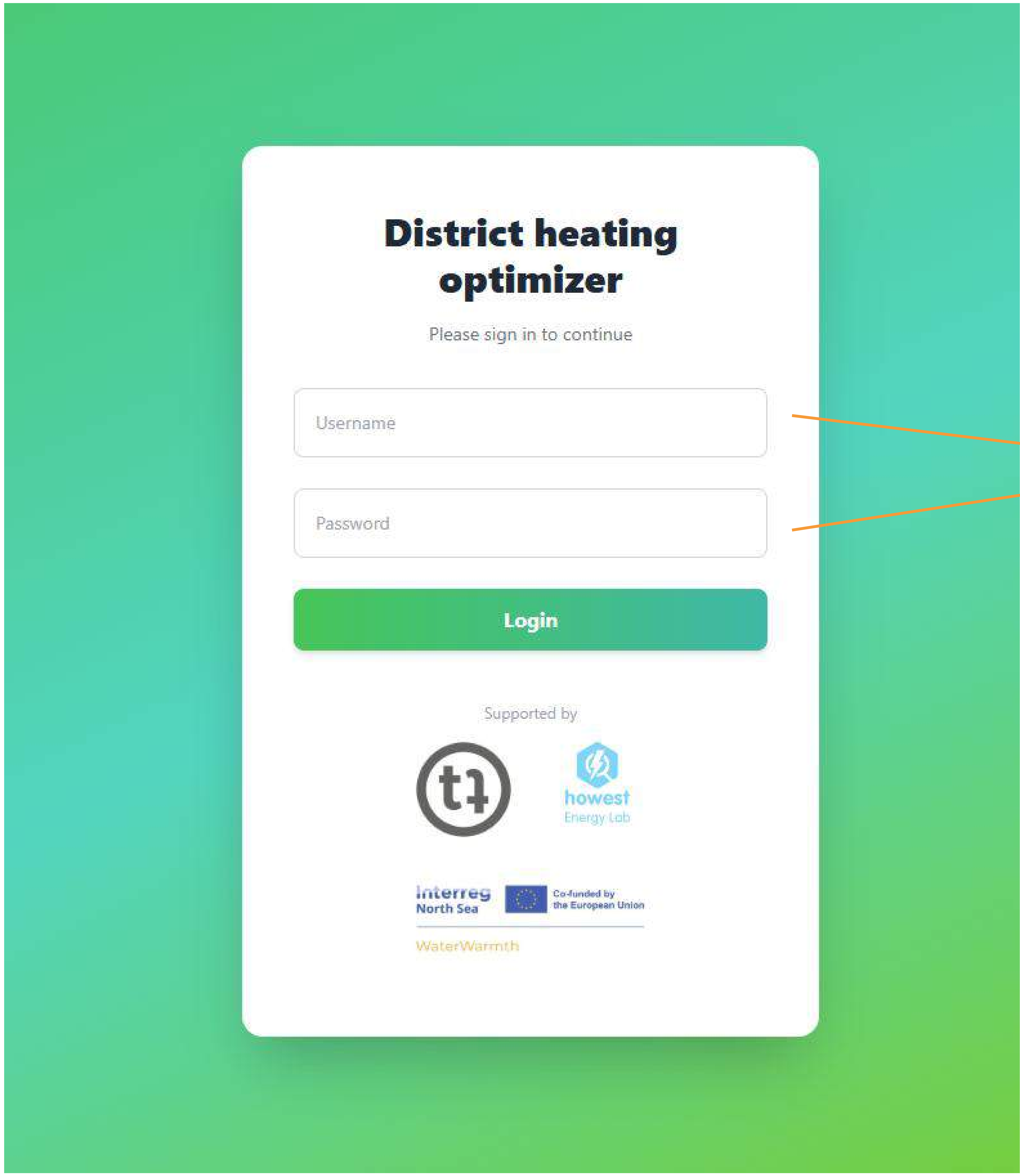
To obtain a username send a request to energiemanagement@howest.be

Step 2a: Creating a model

The next step is to create the heat net model. Here the set up of a hypothetical heat net is made. Via the "***Add Node***" button the user can add the desired amount of prosumers. The number of prosumers is not limited but it is highly advised to keep it realistic. The more Nodes are added the slower the simulation will be is the more likely it would be for an Error to occur (for Errors, see Step 3: Solve the model).

A field "***Global Solar Production CSV***", where the total solar production is uploaded, is also available. The CSV should contain data about the solar production of the whole site, not per node. It is assumed that the electricity is shared by the members of the heat net. Therefore it does not matter at which node it is produced, as it can be utilized by any of the users. The solar production is used to run heat pumps (HP) or to be stored in a battery energy storage system (Battery).

Step 1: Log in



Request a username and password

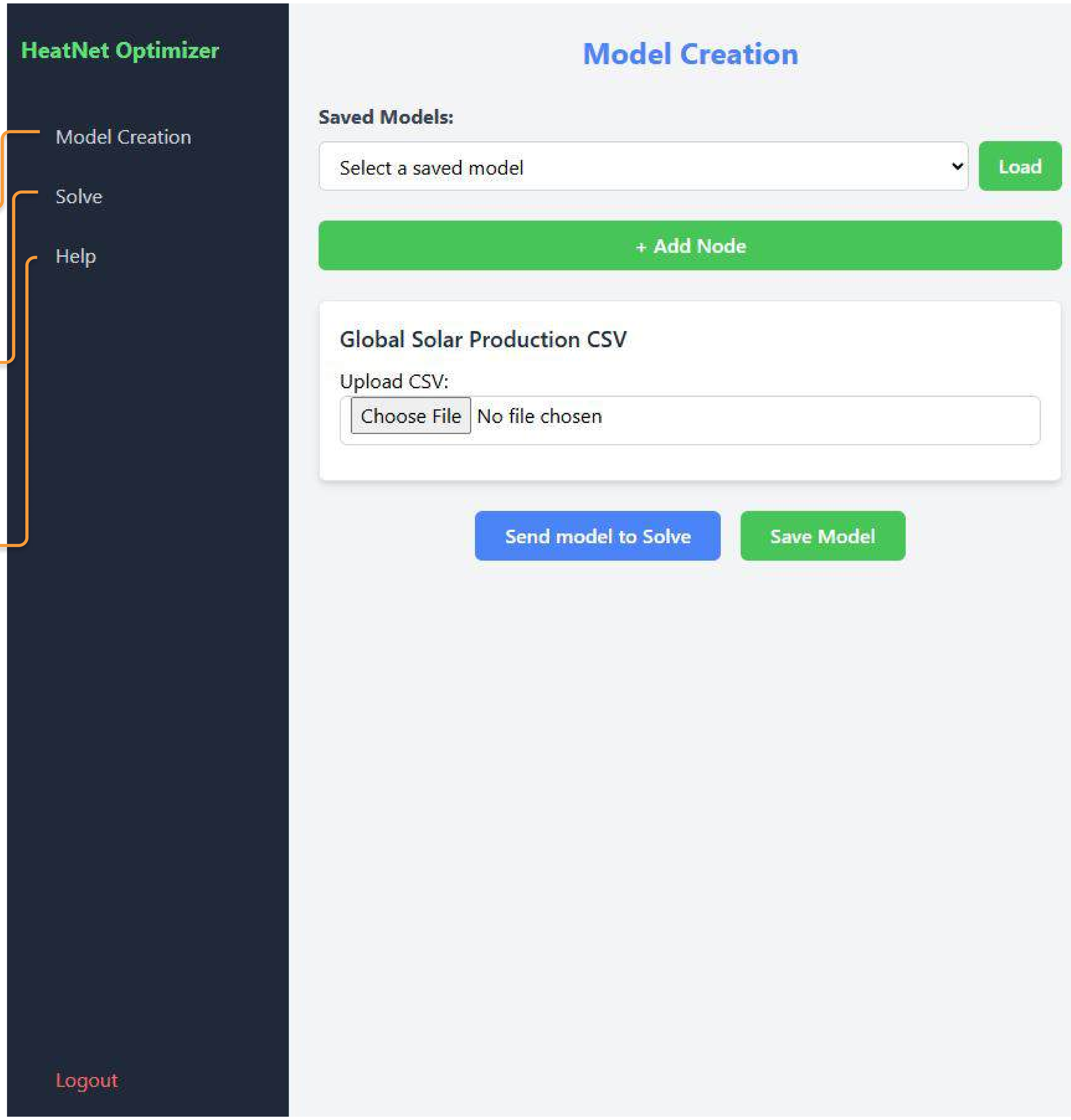
Step 2a: Creating a model

Navigation panel

Configure the model - define assets, consumption, etc.

Send the model to the solver to find the optimal solution

Help section with information about the model, Task status definitions, Error messages, etc.



Once a model is built, it can be saved via the "***Save Model***" button below and load it later to re-use the configuration via the "***Load***" button

The prosumers are denoted by *Nodes*. There is no limit as to how many you can add

Attention:
The more prosumers there are, the longer it takes to run a simulation

Here you load a CSV file, which contains the total solar production of the site, not per prosumer. This is used to run HP units optimally

Tip:
The prosumers will already use part of the total production for self-consumption, therefore the injection into the grid, which is excess solar energy, is a good estimate of "Global solar production

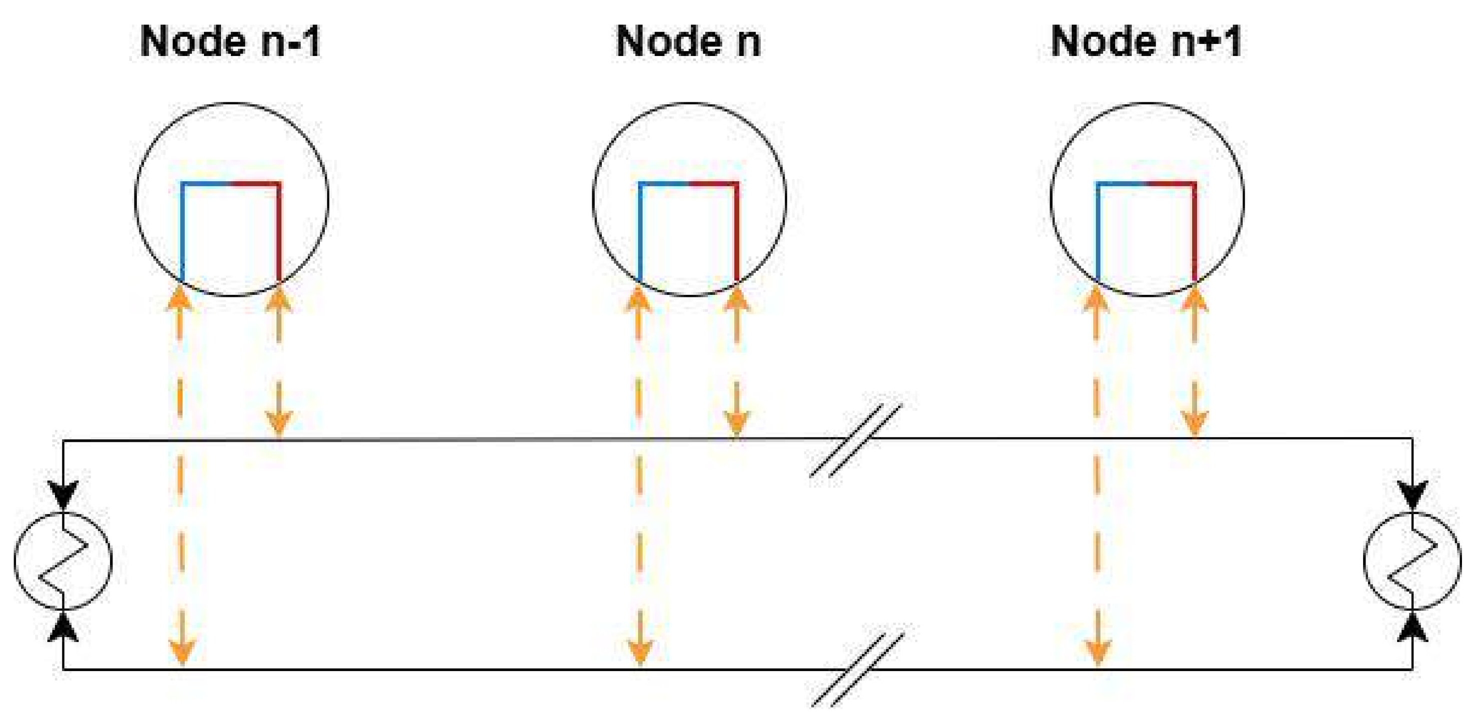
Step 2b: Adding Nodes

After the prosumers (Nodes) are added, for each of them a number of characteristics can be defined. The production units and the respective capacities in kW are set up. Each node can have minimum 0 (only consumes, but does not produce) production assets. There is no maximum limit to the number of productions assets. However, the more assets the slower the simulation will be.

The consumption profiles of each prosumer are loaded via CSV files. These are crucial features for creating the model as its main objective is to minimize the cost of operating the heat net by optimizing the thermal production at each node while meeting the demand of all consumers.

Lastly on this page, the distances between the prosumers are defined. The model assumes a circular topology, therefore the distances are measured from Node *n-1* to Node *n* to Node *n+1* and so forth.

By default the network is a closed one. This means there is no external import of heat. The net production must cover the total demand and losses. Nodes can import from and export to one another, but imports at one or more nodes should be balanced by exports at other nodes. The heat flow and the Nodes' characteristics are bidirectional. This allows for changes in the direction of heat flow at the nodes, namely - to import or export energy. This circular topology also means that it is possible for Forward or Backwards flow but not both simultaneously. The scheme below depicts the considered DHC topology. Results are calculated and made available for both cases of Forward and Backwards flow.



The **CSV files** uploaded for solar production and nodes' consumption should all contain the same number of data points and a header row "Value". For example if the simulation period is 1 year of hourly data, all CSV files should contain 8760 data entries and a header "Value". The decimal delimiter is a comma ",". The model approximates each month as 30 days.

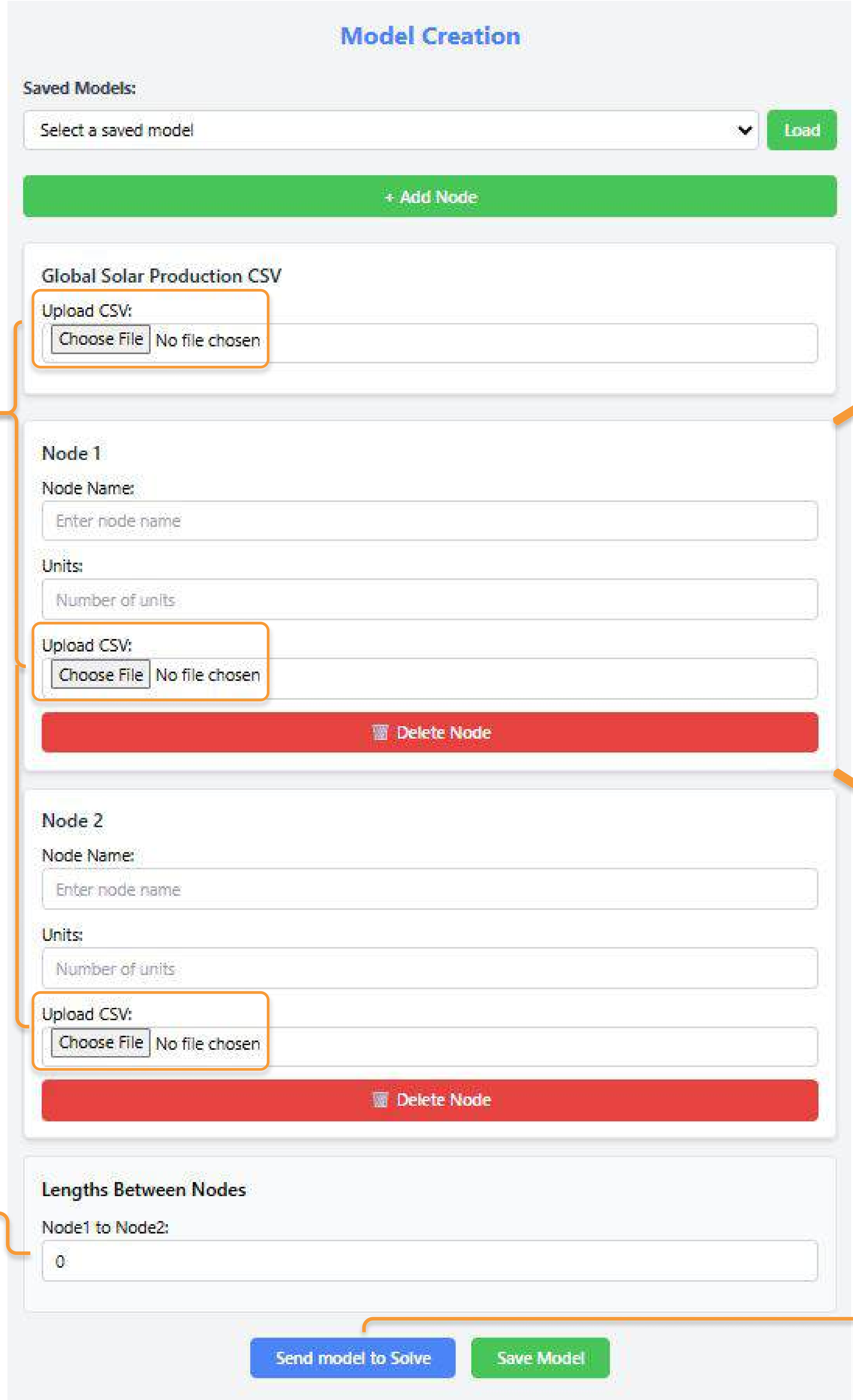
When this configuration is complete, the model can be sent to the last preparation stage through the "*Send model to Solve*" button at the bottom of the page.

Step 2b: Adding Nodes

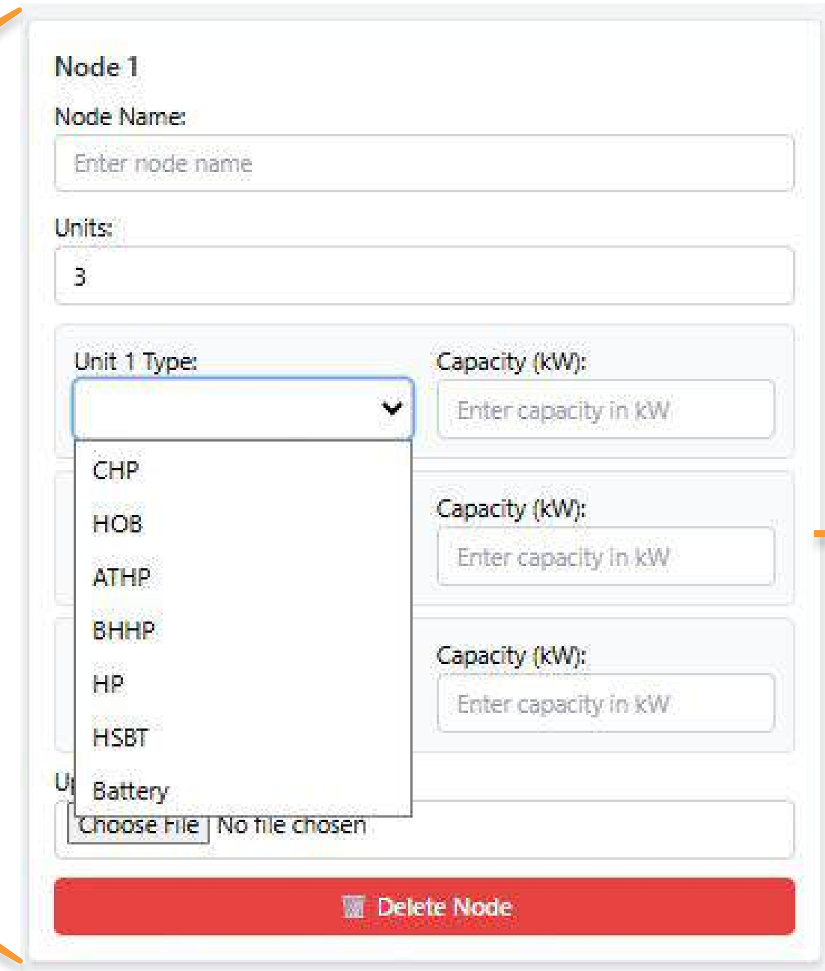
All the CSV files should have a header named "*Value*". The decimal delimiter is comma ",". Each row represents one data point (e.g 15-min, 1h, 1day)

```
Value
6,8
74
0
0
11
46,8
0
```

Recommendation:
For longer periods, use hourly data



Here the distances between the prosumers are defined. If there are more than 2 nodes, they all appear here



Here the number of production units that are present at each prosumer, which ones, and what their production capacity is are defined

Note:

Available Technologies
- *CHP* - Combined Heat and Power
- *HOB* - Heat-Only Boiler
- *ATHP* - Aquathermal Heat Pump
- *BHHP* - Borehole Heat Pump
- *HP* - Air Source Heat Pump
- *HSBT* - Heat Storage Boiler Tank
- *Battery* - Electric battery

Technology-Specific Notes
- *Battery* - Always operates with a C-rate of 0.5.
- *ATHP* - Uses a static river temperature (Leie, Belgium, 2023).

Once the heat net configuration is ready, the user can "*Send model to Solve*"

Step 3: Solve the model

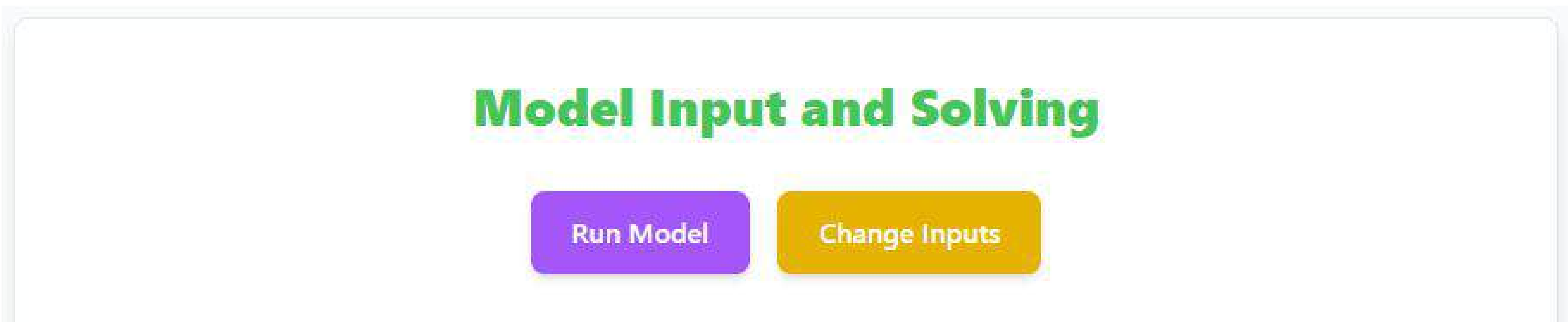
Behind the "*Solve*" page in the navigation panel the configuration of the model can be finished before solving it. In this page the temperature regime of the heat net is defined. There are some constraints that are obligatory. Supply temperature should be minimum 10C. The return temperature must be between 10C and the supply temperature. The model is designed to operate at low-medium-high temperature regimes, but not at very high (<100C).

Tip: It is highly advised to use temperatures in the range between 30 and 80C.

The temperature difference ΔT and specific heat capacity of water cp are constant.

Then the electricity and gas prices are defined by the user. Currently the model only considers fixed prices for both. At this stage of the development of the model dynamic prices will not be implemented.

Once these final adjustments are ready they can be submitted via the "*Submit and Update inputs*" button. After this, the "*Run model*" and "*Change inputs*" buttons become available.



Clicking "*Run model*" will initiate executing the simulation by sending the input information to the solver.

The tool utilizes Gurobi. Gurobi is a special kind of software called a "solver". The solver identifies the best set of decisions based on the provided inputs and the final goal. It can find optimal solution but also indicate if the defined variables and parameters are contradicting or insufficient. In this case it would return an error message.

The termination conditions of the execution process are presented in an error message in the "*Task Status*" bar. A list of the definition of the possible Error messages is available on the following page and in the "*Help*" section via the "*Navigation panel*" in the tool. If the task is executed correctly and an optimal solution is obtained, a "*SUCCESS*" message and an Easter egg become available.

Step 3: Solve the model

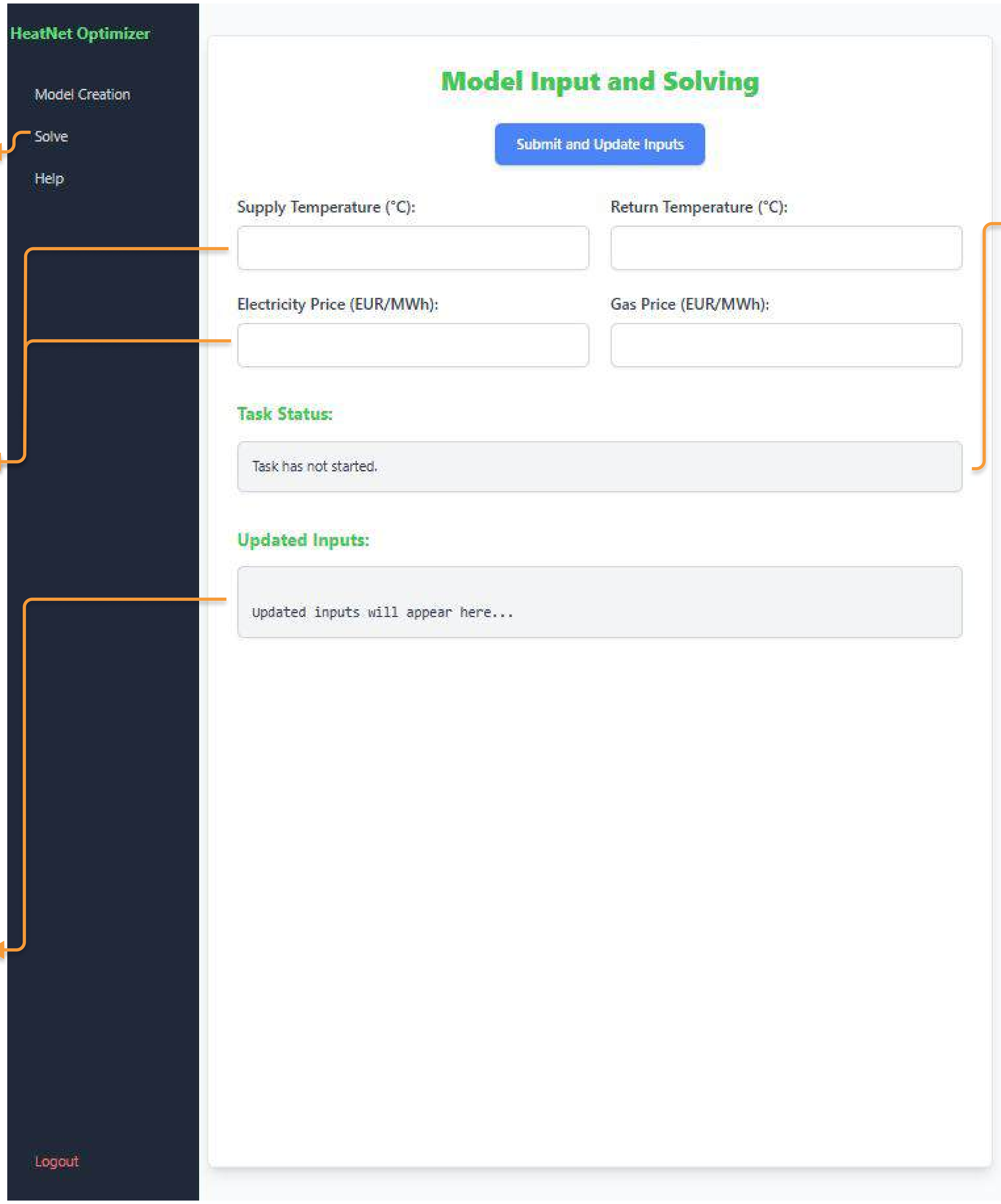
The next step is to go to the "*Solve*" page from the Navigation panel

Here you define the final characteristics of the heat net community. The electricity and gas prices, and supply and return temperatures.

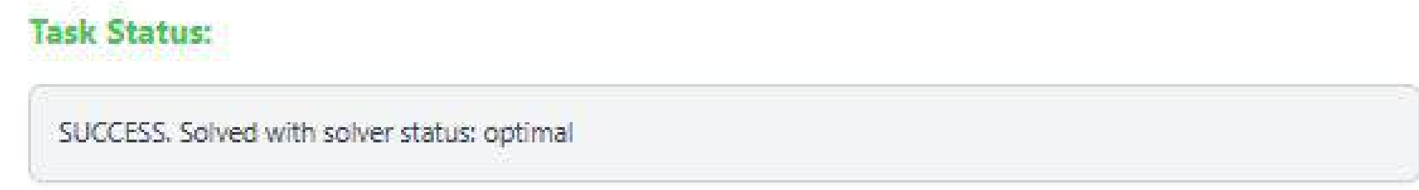
Tip:
It is recommended to provide temperatures between 30C and 80C

Attention:
Currently the model does not support dynamic prices for gas or electricity but only fixed

This field is a check-up for the user to control if the inputs being sent to the solver are correct



The "*Task Status*" bar shows the outcome of executing the simulation. If everything is correct a "*SUCCESS*" message displays, otherwise below is a list of possible Error messages



Attention:

If the model encounters an issue during execution, one of the following termination conditions may be returned:

- ***maxTimeLimit***: Exceeded maximum time limit allowed.
- ***maxIterations***: Exceeded maximum number of iterations allowed.
- ***minFunctionValue***: Found solution smaller than specified function value.
- ***minStepLength***: Step length is smaller than specified limit.
- ***globallyOptimal***: Found a globally optimal solution.
- ***locallyOptimal***: Found a locally optimal solution.
- ***optimal***: Found an optimal solution.
- ***maxEvaluations***: Exceeded maximum number of problem evaluations (e.g., branch and bound nodes).
- ***other***: Other, uncategorized normal termination.
- ***unbounded***: Demonstrated that problem is unbounded.
- ***infeasible***: Demonstrated that problem is infeasible.
- ***invalidProblem***: The problem setup or characteristics are not valid for the solver.
- ***solverFailure***: Solver failed to terminate correctly.
- ***internalSolverError***: Internal solver error.
- error: Other error.
- ***userInterrupt***: Interrupt signal generated by user.
- ***resourceInterrupt***: Interrupt signal in resources used by the solver.
- ***licensingProblem***: Problem accessing solver license.

These messages can help diagnose what went wrong during the model execution.

Note: If the status returns ***FAILED***, it indicates that the inputs are incorrect and the issue occurred before loading into the solver.

Step 4: Results and results interpretation

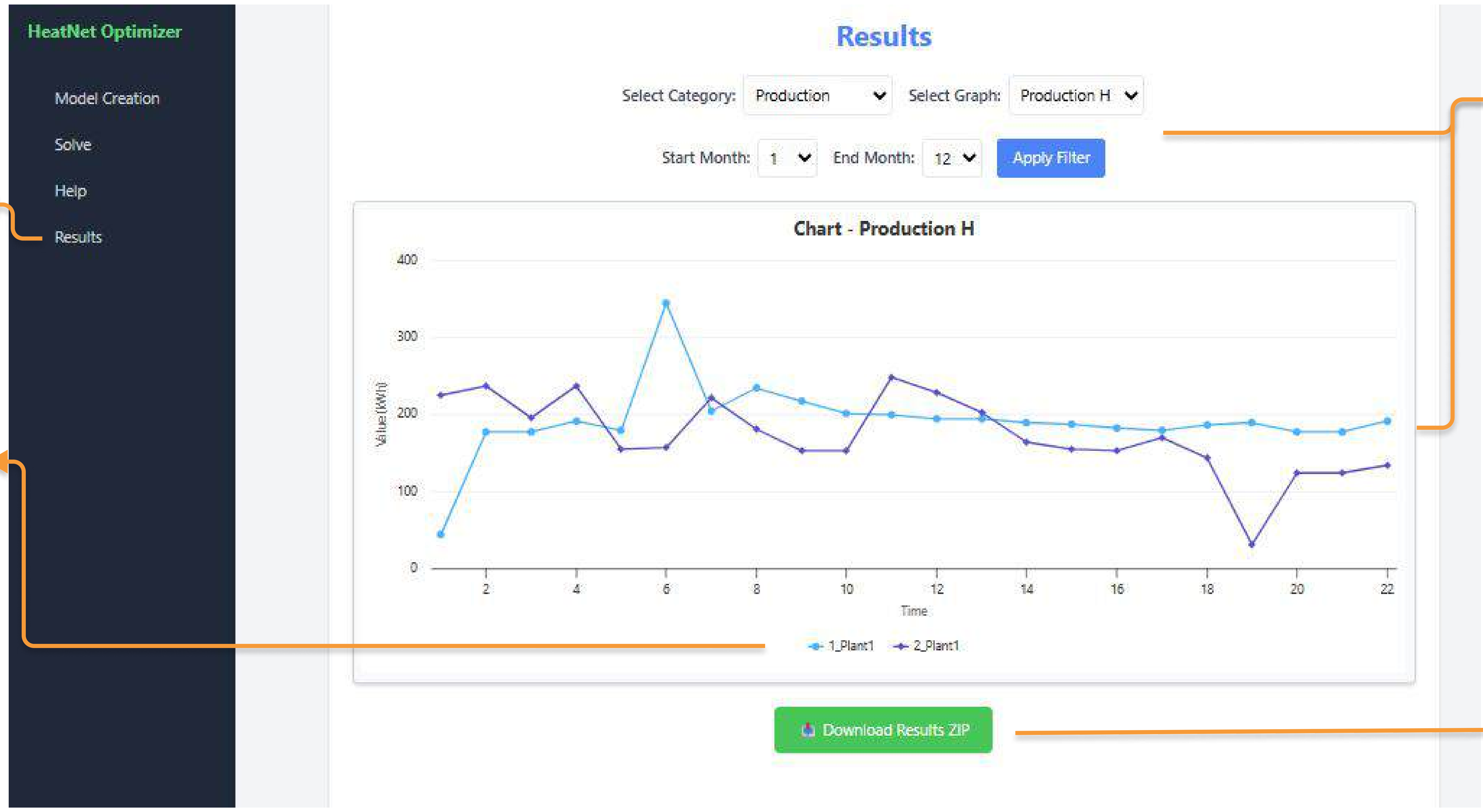
Once the model is successfully solved, a "***Results***" section becomes available in the "***Navigation panel***". In this section the results of the simulation are available. The results are presented in interactive graphs. Via the drop-down menus above the graphs, the user can select which results and for which time period are presented. The full set of results is available to download as a set of zipped CSV files. These can be used for further analysis.

Step 4: Results

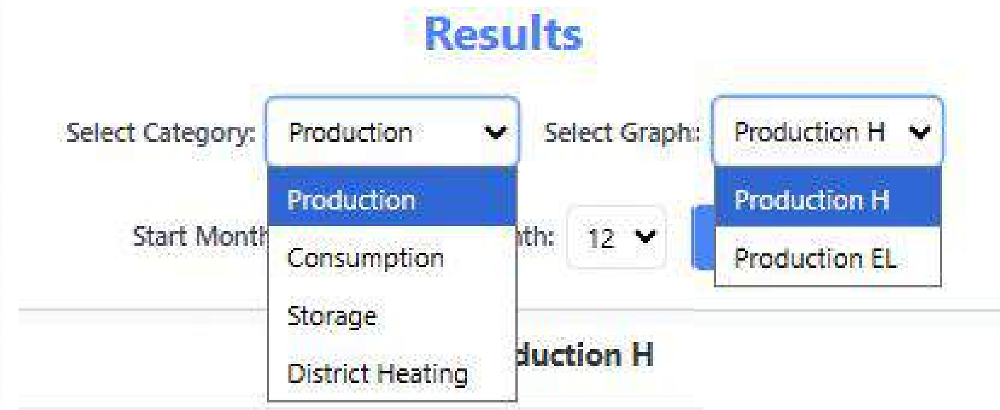
Once the simulation is solved, a section "***Results***" becomes available in the Navigation panel

The results are presented in an interactive graph.
The naming convention refers to first the prosumer, then the production asset

Example:
3_Plant2 would be your 3rd prosumer and its 2nd production unit that you defined in the "*Model Creation*" section.



On the graph you can visualize different KPIs via the drop-down menus



It is also possible to extract all the results in CSV files for further analysis