

# Off-Grid Systems Modelling with MicroGridsPy

## Hands-on 2

GitHub repository for source code:

[SESAM-Polimi/MicroGridsPy-SESAM: MicroGridsPy - SESAM-PoliMi \(github.com\)](https://github.com/SESAM-Polimi/MicroGridsPy-SESAM)

MicroGridsPy is an open-source project, currently under active development, check out the detailed online documentation for usage guidance and updates:

<https://microgridspy-documentation.readthedocs.io/en/latest/>

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## Learning outcomes

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By the end of this exercise, you will learn how to:

- 1) Interact with the MicroGridsPy User Interface
- 2) Explore the default configuration
- 3) Complete the first RUN

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### Important requirement

Ensure that MicroGridsPy is correctly installed and functioning within the dedicated conda environment. It will be also required a stable internet connection. Additionally, it is suggested (though not strictly required) to have Gurobi installed for improved performance of the model optimization. Refer to the installation procedure and guidance provided in Hands-on 1 for detailed instructions.

# Initial Configuration Page

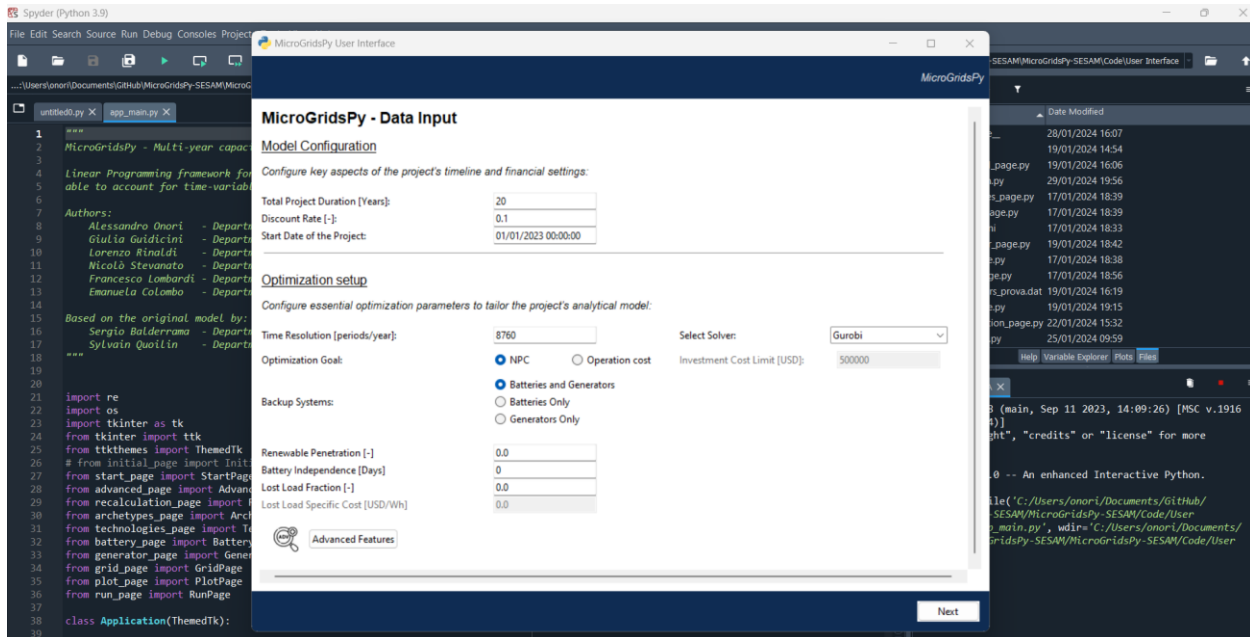
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## Launch the Application: Recap

Let's briefly recap how to launch the user interface after having correctly creating the MicroGridsPy environment using conda and downloading the MicroGridsPy folder.

- Launch Spyder Using Anaconda. To launch Spyder, an integrated development environment (IDE) for Python, users can proceed this in two ways:
  1. Using Anaconda Prompt: Open the Anaconda Prompt, activate the mgpy environment (if not already activated), type the command *spyder* and press enter to open Spyder.
  2. Using Anaconda Navigator: Launch Anaconda Navigator, activate the mgpy environment from the "Environments" tab. Then, in Anaconda Navigator's "Home" tab, find "Spyder" in the list of available applications and click "Launch" to open Spyder.
- Launch the Interface within Spyder: Once Spyder is open, follow these steps to launch the MicroGridsPy interface:
  1. Check if the default layout is suitable; if not, set it from the "View" button.
  2. Locate the MicroGridsPy working folder using the Spyder interface's "File" menu.
  3. Open the project folder by double-clicking on it.
  4. Navigate to the "Code/User Interface" folder within the project folder.
  5. Look for the `app_main.py` file and double-click on it to open it.
  6. Run `app_main.py` by pressing F5 or using the "Run" button in Spyder's toolbar.

Upon completing these steps, the MicroGridsPy interface will launch within Spyder resulting in this situation:



## Setting Configuration Parameters

Begin your data input journey by specifying fundamental parameters for your mini-grid project. This initial page serves as the central hub for configuring parameters and functionalities including duration, resolution, optimization goal, specific constraints and more. Here below a summary of the basic configuration parameters:

**Total Project Duration [years]**  
**Discount Rate [%] (0-1)**

They mainly affect the actualization of the costs and, therefore, the technology selection and sizing of the mini-grid.

**Time Resolution** ⚠

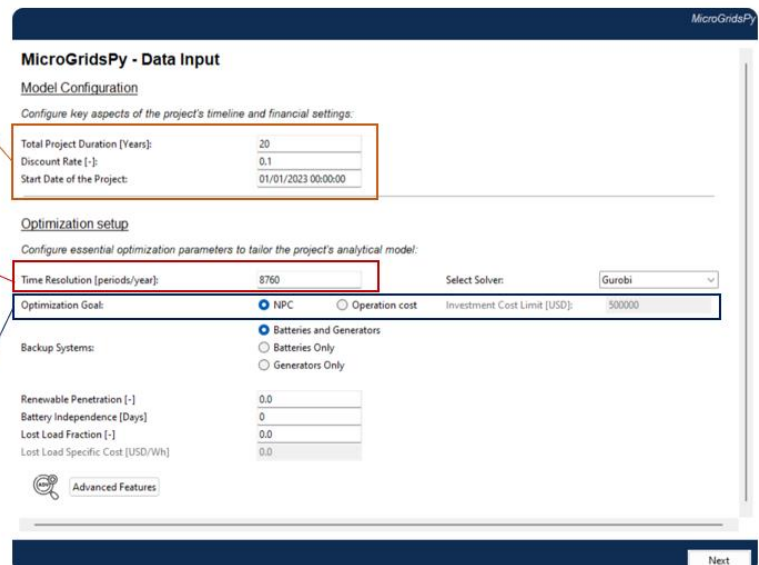
It affects result accuracy. Users can adjust it, but must ensure that any external time series data correspondingly match this resolution

**Optimization Goal**

- Net Present Cost:** focuses on optimizing both investment and operation costs
- Operation Cost:** targets minimizing only operational expenses with an option to limit capital expenditure

☒ Operation cost

Investment Cost Limit [USD]: 500000



**MicroGridsPy - Data Input**

**Model Configuration**

Configure key aspects of the project's timeline and financial settings:

Total Project Duration [Years]: 20  
Discount Rate [-]: 0.1  
Start Date of the Project: 01/01/2023 00:00:00

**Optimization setup**

Configure essential optimization parameters to tailor the project's analytical model:

Time Resolution [periods/year]: 8760  
Select Solver: Gurobi  
Investment Cost Limit [USD]: 500000

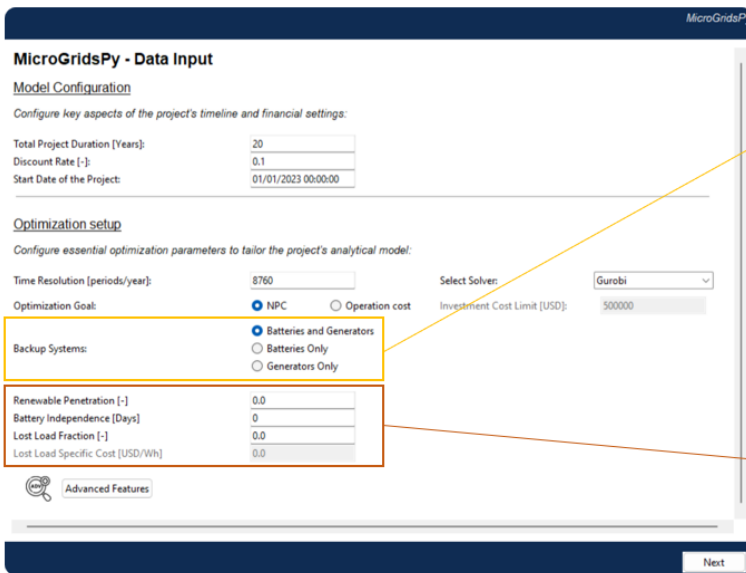
Optimization Goal: ☒ NPC ☐ Operation cost

Backup Systems: ☒ Batteries and Generators ☐ Batteries Only ☐ Generators Only

Renewable Penetration [-]: 0.0  
Battery Independence [Days]: 0  
Lost Load Fraction [-]: 0.0  
Lost Load Specific Cost [USD/Wh]: 0.0

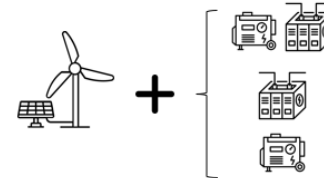
**Advanced Features**

**Next**



### Backup and Storage Systems

The user has the option to specify constraints on the types of technologies used for backup and storage within the model



### Optimization constraints

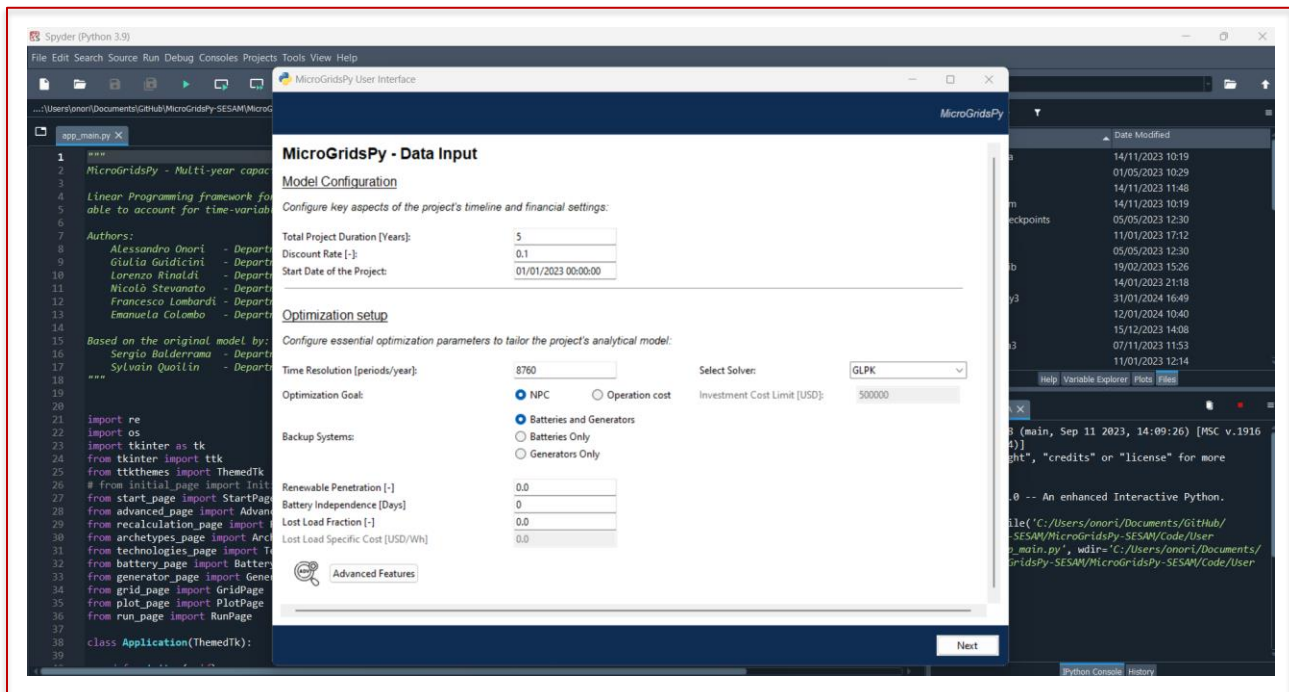
- **Renewable Penetration:** minimum percentage of total electricity from renewable sources
- **Battery Independence:** number of days the battery can power the grid without external support
- **Lost Load Fraction and Cost:** Threshold for unmet demand, with associated costs applicable only if there's a non-zero lost load

For the purpose of this hands-on exercise, our objective is to familiarize ourselves with the MicroGridsPy interface and its fundamental functionalities by testing the default configuration parameters. These default settings provide us with a comprehensive overview of the user interface and the construction of mini-grid models. The default configuration defines a project spanning a 20-year time horizon, utilizing a 10% discount rate, and operating at an hourly resolution. The primary optimization goal is to minimize net present costs (NPC). In terms of backup systems, the model will consider both batteries and a generator. Additionally, there are no additional constraints imposed, such as minimum renewable penetration or requirements for battery independence. This approach will help us gain a broad understanding of how to work with the interface and build microgrid models effectively.

### Note

If you have Gurobi installed with an activated license, you can choose to leave Gurobi as the default solver for your MicroGridsPy simulations. This solver is known for its capabilities and speed, which can significantly expedite the optimization process.

However, if you don't have a Gurobi license, you can opt to use the open-source free-to-use solver option, "GLPK," but making a specific adjustment. Please select "GLPK" from the solver dropdown menu and set the time horizon to 5 years. While this configuration may result in slight variations in the results (though not significantly), it substantially reduces the computational effort and the time required for solving. You can expect the solving time to be approximately 45-60 minutes (depending on your system computational performance), striking a favorable balance between result accuracy and computational efficiency.



As this is the default configuration, we will not delve into advanced features at this stage. Simply proceed by clicking "NEXT" and accepting the default settings. Please note that the application will display a confirmation message to ensure your intention, as it will not be possible to return and modify the model configuration at a later stage.

## RES Time Series Calculation Page

The RES (Renewable Energy Sources) estimation features within MicroGridsPy provide a convenient and comprehensive way to estimate renewable energy potential using NASA Power Project database. By simply checking the "activate" check button, all relevant parameters will be enabled, allowing users to tailor their RES estimation. The layout offers a scrollable area for a comprehensive list of parameters, including latitude, longitude, time zone, and turbine information. Custom fonts and tooltips enhance the user experience, making it a user-friendly interface for setting up required parameters. In the default configuration, the system is set to evaluate a specific location in Zambia, taking advantage of its solar-rich environment. The configuration includes a 1 kW solar PV module with standard values for parameters such as tilt angle, ground reflectivity (ro\_ground), and operating temperature. Additionally, the horizontal axis Alstom.Eco.80 wind turbine, rated at 1670 kW, is integrated into the assessment.

### Location Coordinates

Input latitude and longitude in DMS system (degrees, minutes and seconds)

### Solar PV parameters

Specifications for **solar panel module**, including **nominal power**, **tilt angle**, **azimuth**, and **efficiency-related coefficients** to calculate **solar generation potential** accurately

### Wind turbine parameters

Select the **turbine type and model**, see the associated **rated power** and input **drivetrain efficiency** to estimate **wind energy generation**

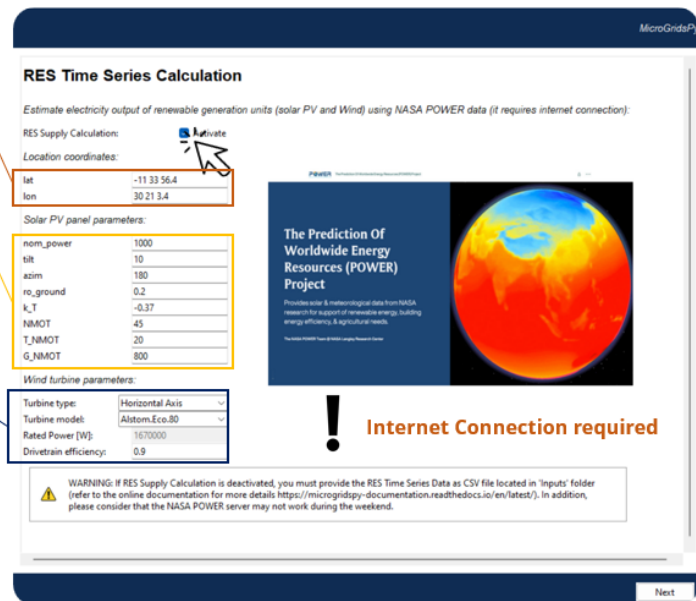


Models available:

- **Horizontal Axis:** Alstom.Eco.80 and NPS100c-21
- **Vertical Axis:** Hi-VAWT.DS1500 and Hi-VAWT.DS700



Code/Inputs/WT\_Power\_Curve.csv



Press "Next" to move forward.

## Demand Time Series Calculation Page

The Demand Time Series calculation feature offers a powerful tool for modeling load demand in a Sub-Saharan village. By activating the "activated" checkbox, users gain access to a range of parameters related to drivers, households, and public services to simulate households demand profiles by means of built-in archetypes referring to rural villages in Sub-Saharan Africa at different latitudes. Relevant parameters are composed of different types of end-users like households according to the wealth tier (i.e., from 1 to 5), hospitals with the same wealth scale and schools. The possibility for demand growth and specific cooling period are also integrated within this feature.

### Demand drivers

Estimate the demand growth as a percentage change expected annually and select the cooling period to consider seasonal variations in energy usage:

- **NC** = No Cooling
- **AY** = All Year
- **OM** = Oct-Mar
- **AS** = Apr-Sept

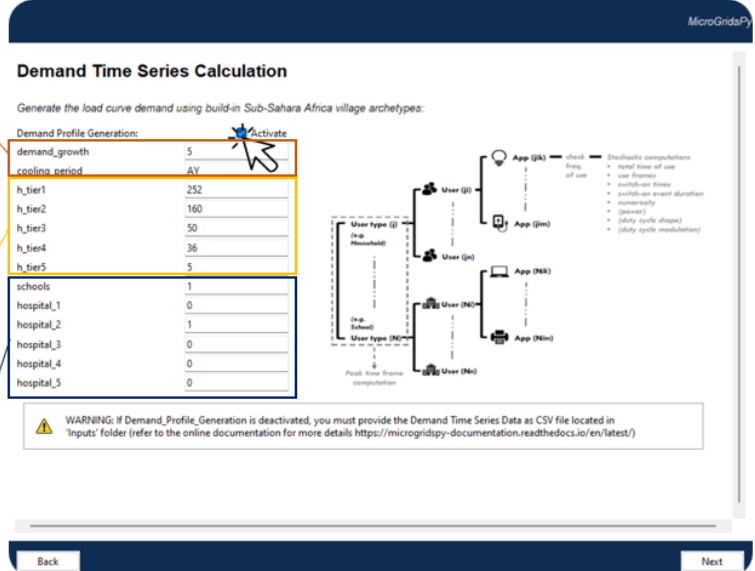
### Households

Number of households across various wealth tiers, reflecting the socioeconomic diversity of the village. The wealthier classes own more energy intensive appliances and in larger number.

### Public Services

Number of educational and healthcare facilities in the village. It includes 5 tiers of health facilities, ranging from rural dispensaries (Tier 1) to sub-county hospitals (Tier 5). Similarly, it adopts an archetypical load for a rural primary school.

 [Code/Demand\\_archetypes](#)



**Demand Time Series Calculation**

Generate the load curve demand using build-in Sub-Saharan Africa village archetypes:

Demand Profile Generation: ☒ **Activate**

demand_growth	5
cooling_period	AY
h_tier1	252
h_tier2	160
h_tier3	50
h_tier4	36
h_tier5	5
schools	1
hospital_1	0
hospital_2	1
hospital_3	0
hospital_4	0
hospital_5	0

User Type (i) (rural household) → User (i) → App (ik) → check of use → Discontinue computations

User Type (j) (rural school) → User (j) → App (jm) → check of use → Discontinue computations

User Type (k) (rural hospital) → User (k) → App (kn) → check of use → Discontinue computations

User Type (l) (rural hospital) → User (l) → App (ln) → check of use → Discontinue computations

User Type (m) (rural hospital) → User (m) → App (mn) → check of use → Discontinue computations

User Type (n) (rural hospital) → User (n) → App (nn) → check of use → Discontinue computations

Push time frame computation

WARNING: If Demand\_Profile\_Generation is deactivated, you must provide the Demand Time Series Data as CSV file located in 'Inputs' folder (refer to the online documentation for more details <https://microgridspy-documentation.readthedocs.io/en/latest/>)

Back Next

In the default configuration, the simulation focuses on a village comprising 503 households, distributed across various tiers. Additionally, the model accounts for 1 school and 1 health facility, both subject to a 5% annual growth rate. Press “Next” to move forward.

## Renewables Parameters Page

Configure the available renewable energy sources and their techno-economic properties. The page defines default parameters and their initial values for renewable energy sources (RES), manages user input for RES parameters with validation and updates, creates labels, entry fields, and tooltips for RES parameters.



### Renewables Characterization

It allows setting types, capacities, efficiencies, costs, lifespans, emissions, and expected operational output for renewable energy technologies

Parameters that would be enabled or disabled according to **specific advanced features activated** (brownfield in the example)

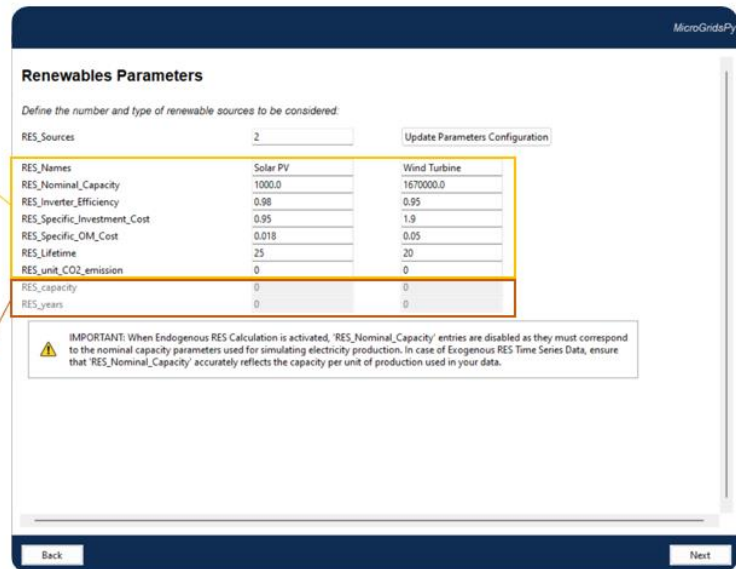
#### Advanced Features

[Advanced Modeling Options](#)

Type of Investment:

☐ Greenfield

☒ Brownfield



In MicroGridsPy renewables are considered as a general technology characterized by a set of parameters. Users have the freedom to create different "types" of renewables, and this flexibility is entirely arbitrary, allowing for customization based on project needs. Notably, within the interface, users can add an unlimited number of entries for a single parameter, and they have the liberty to define the names of these renewables as they see fit.

However, it's important to note that if users opt to utilize the built-in RES time series estimation, the model will primarily consider solar and wind as the available renewable sources. Therefore, in this scenario, users can define parameters for up to two renewable sources: one for solar and another for wind, as reflected in the interface.

In the default configuration, we simulate average data for a photovoltaic (PV) module and a wind turbine. It's essential to mention that the cost values provided in this default setting are purely exemplative and do not represent realistic cost figures. These default parameters serve as a starting point for users to explore and customize renewable technologies within the MicroGridsPy interface. Press "Next" to move forward.

## Battery Bank Parameters Page

Set up battery-related parameters. It provides robust input validation, tooltips for parameter descriptions, and conditional parameter handling, ensuring data accuracy and usability.



**Battery bank Characterization**

*It allows setting investment costs, operational costs, charge and discharge efficiencies, battery lifecycle details, and CO2 emissions*

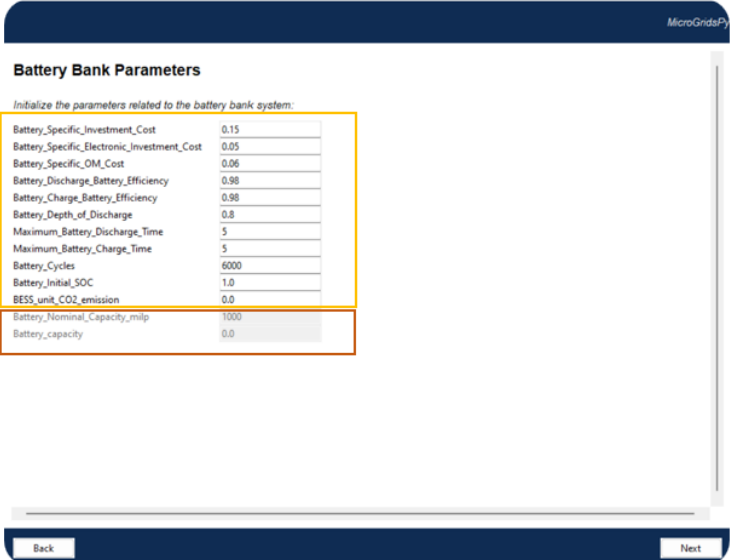
**Parameters** which would be **enabled or disabled** according to **specific advanced features activated** (MILP and brownfield in the example)

**Advanced Features**

Advanced Modeling Options

Model Formulation: ☐ LP ☒ MILP

Type of Investment: ☐ Greenfield ☒ Brownfield



Initialize the parameters related to the battery bank system:	
Battery_Specific_Investment_Cost	0.15
Battery_Specific_Electronic_Investment_Cost	0.05
Battery_Specific_OM_Cost	0.06
Battery_Discharge_Battery_Efficiency	0.98
Battery_Charge_Battery_Efficiency	0.98
Battery_Depth_of_Discharge	0.8
Maximum_Battery_Discharge_Time	5
Maximum_Battery_Charge_Time	5
Battery_Cycles	6000
Battery_Initial_SOC	1.0
BESS_unit_CO2_emission	0.0
Battery_Nominal_Capacity_milp	1000
Battery_capacity	0.0

The Battery Bank Parameters page in MicroGridsPy offers users the capability to define parameters for a single type of battery bank unlike renewables, which can have arbitrary types. In the default configuration, the provided values serve as exemplary representations, which could correspond to a lead-acid battery type.

These default parameters provide a starting point for users to work with a standard battery type within the MicroGridsPy interface. Press “Next” to move forward.

## Generators Parameters Page

Define generator types and characteristics. Similarly to renewables, the page defines default parameters and their initial values but the user can add new entries for different types of generators. It offers strong input validation, parameter description tooltips, and conditional parameter management.

### Generator Characterization

It allows setting the names, efficiencies, costs, lifespans, emissions, and capacity parameters for generators, as well as configuring fuel types, energy content, and cost parameters

### Advanced Features

#### Advanced Modeling Options

Fuel Specific Cost Calculation:



Fuel\_Specific\_Start\_Cost: 1.17  
 Fuel\_Specific\_Cost\_Rate: 0.0  
 Fuel\_Specific\_Cost\_Import: ☐ Activate

### Generator Parameters

Generator Types:	1
Generator_Names	Diesel Genset 1
Generator_Efficiency	0.3
Generator_Specific_Investment_Cost	0.4
Generator_Specific_OM_Cost	0.08
Generator_Lifetime	20
GEN_unit_CO2_emission	0.0
Generator_capacity	0.0
GEN_years	0
Generator_Nominal_Capacity_milp	5000
Generator_Min_output	0.3
Generator_pgcn	0.01

Fuel parameters:	Diesel
Fuel_Names	10140.0
Fuel_LHV	2.68
FUEL_unit_CO2_emission	1.17
Fuel_Specific_Start_Cost	0.0
Fuel_Specific_Cost_Rate	<input type="checkbox"/> Activate
Fuel_Specific_Cost_Import	

Update Parameters Configuration

Parameters which would be enabled or disabled according to **specific advanced features activated** (MILP, brownfield and partial load in the example)

### Advanced Features

#### Advanced Modeling Options

Model Formulation:

☐ LP ☒ MILP

Type of Investment:

☐ Greenfield ☒ Brownfield

WARNING: If Fuel Specific Cost Import is activated, you must provide the fuel cost values in a CSV file located in 'inputs' folder (refer to the online documentation for more details <https://microgridspy-documentation.readthedocs.io/en/latest/>)

Back

Next

Users can create distinct generator types, specifying different fuels, capacities, and other relevant parameters to accurately simulate their scenarios. This flexibility allows users to model a wide range of generator configurations to suit their specific project requirements. In the default configuration, exemplative values are provided, which can be seen as representative of a classic diesel generator. Press "Next" to move forward.

## Plot Colors Page

Visualize the color codes for data visualization by means of a dynamic color legend. These parameters are used for the aesthetic aspects of model outputs, assigning colors to different energy sources, storage options, and other model components for visual representation in plots and charts.

MicroGridsP

## Plot Colors

Select the plot colors from the drop-down menu:

RES_Colors	<div>Orange</div>	<div>Teal</div>
Generator_Colors	<div>Blue</div>	
Battery_Color	<div>Turquoise</div>	
Lost_Load_Color	<div>Red</div>	
Curtailment_Color	<div>Yellow</div>	
Energy_To_Grid_Color	<div>Green</div>	
Energy_From_Grid_Color	<div>Purple</div>	

Users can **select colors** from a **dropdown menu** to represent different components such as renewable energy sources (RES), generators, batteries, lost load, curtailment, and energy exchanged with the grid, enhancing the **clarity and distinction of various data sets** in graphical representations

**Plot Colors**

Select the plot colors from the drop-down menu:

RES_Colors	Orange	Teal
Generator_Colors	Blue	Red
Battery_Color	Turquoise	Yellow
Lost_Load_Color	Red	Green
Curtailment_Color	Yellow	Purple
Energy_To_Grid_Color	Green	Pink
Energy_From_Grid_Color	Purple	Cyan
		Magenta
		Lime
		Sapphire
		Amber

## Running the model

Finally, save your input data and initiate the optimization process. It includes the following functionalities: updating and displaying output messages in a text widget, showing dispatch, size, and cash flow plots in separate windows, generating plots based on user inputs and running a model in a separate thread, displaying progress messages and results.

MicroGridsP

Run the Model: ▶

Run

⏸

Stop

Output panel to visualize model operation, solver log and key results:

3	7.24808597e+07	-0.31160701e+08	1.466e-11	1.87e-02	3.20e+02	6s
4	1.21716508e+07	-6.83947325e+07	4.18e-11	4.00e-03	6.77e+01	7s
5	4.60624692e+06	-2.06643859e+07	4.73e-11	1.19e-03	2.08e+01	8s
6	1.88890462e+06	-8.21351014e+06	6.91e-11	4.52e-04	8.26e+00	9s
7	6.59352041e+05	-2.13170363e+06	1.03e-10	1.21e-04	2.24e+00	10s
8	4.23764434e+05	-9.87305592e+05	1.11e-10	6.16e-05	1.14e+00	10s
9	3.09756868e+05	-1.83612110e+05	9.28e-11	1.70e-05	3.68e-01	11s
10	2.41376707e+05	5.08096725e+03	1.63e-10	6.37e-06	1.67e-01	12s
11	2.05363112e+05	3.41015142e+04	4.03e-10	4.98e-06	1.26e-01	13s
12	1.86211605e+05	5.57477328e+04	5.57e-10	3.95e-06	9.81e-02	14s
13	1.73203705e+05	7.11370186e+04	7.31e-10	3.23e-06	7.91e-02	15s
14	1.63797347e+05	7.99969999e+04	8.33e-10	2.81e-06	6.97e-02	16s
15	1.61331182e+05	1.00491854e+05	9.95e-10	1.78e-06	6.74e-02	17s
16	1.55440859e+05	1.12034229e+05	1.91e-09	1.16e-06	6.33e-02	18s
17	1.52375433e+05	1.12598232e+05	5.66e-09	1.12e-06	6.13e-02	19s
18	1.51813960e+05	1.13349275e+05	5.56e-09	1.07e-06	6.02e-02	20s
19	1.50646828e+05	1.14857705e+05	7.30e-09	1.00e-06	2.84e-02	21s
20	1.49535683e+05	1.18074710e+05	2.33e-08	8.04e-07	2.43e-02	23s
21	1.45921631e+05	1.20627829e+05	5.54e-07	6.81e-07	2.01e-02	24s
22	1.40000919e+05	1.23373742e+05	2.18e-07	5.36e-07	1.43e-02	25s
23	1.37650056e+05	1.25757414e+05	7.42e-07	4.04e-07	1.05e-02	27s

Plot the Results:

Start Date for Plot:

01/01/2023 00:00:00

Number of days to plot:

3

Generate Plots:

Show Dispatch Plot

Show Size Plot

Cash Flow Plot

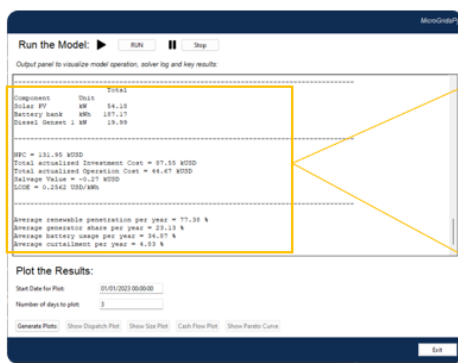
Show Pareto Curve

New Run

Upon initiating the model with the 'Run' button, users can **monitor the solver's log** and the **system's operational actions in real-time**. This output panel provides a **live feed** of the **model's processing data** displaying also potential errors messages.

## Key Results

Key results include a breakdown of the system components and various performance metrics. It outlines the installation capacities of solar panels, batteries, and generators, and presents key financial indicators such as net present cost, total investment and operation costs, salvage value, and the levelized cost of energy. It also provides percentages for renewable energy usage, generator and battery contributions, and unused renewable energy.



### Sizing of the mini-grid

Optimal capacity installed each investment steps divided by technology

### NPC (Net Present Cost) [k\$]

This is the total cost of the mini-grid system over its lifetime, discounted to present value

### Total actualized Investment and Operation Cost [k\$]

The upfront investment and operation costs for the mini-grid, actualized to the present

### Salvage Value [k\$]

The estimated residual value of the system's components at the end of the project's life

### LCOE (Levelized Cost Of Energy) [\$/kWh]

The average cost per unit of electricity generated by the mini-grid, accounting for the total actualized costs over the system's lifetime

### Average renewable penetration per year [%]

The percentage of the mini-grid's energy supplied by renewable sources on an annual basis.

### Average generator and battery share per year [%]

The proportion of energy contributed by generators and battery each year.

### Average curtailment per year

The percentage of renewable energy generated that was not used or stored annually.

Explore and take note of the key results.

## Visualizing Plots

Additionally, the interface offers functionalities to visualize the data through graphs based on selected parameters.

## Displaying plots

### Plot the Results:

Start Date for Plot:

Number of days to plot:

Generate Plots:

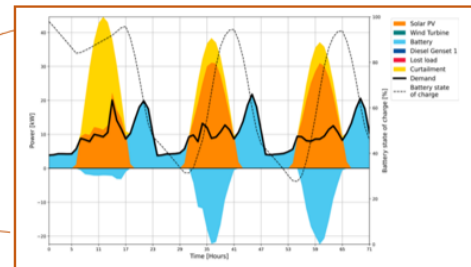
Users can create visual **plots of model outputs** by setting a date range and choosing from various plot types. The buttons **generate graphs for energy dispatch, system sizing and financial analysis**, providing a comprehensive view of the model's performance over the selected timeframe.

### Plot the Results:

Start Date for Plot:

Number of days to plot:

Generate Plots:



The model not only computes various financial and operational metrics but also saves all results in the "Code/Results" folder for record-keeping and further analysis. For visual representations, updated plots are stored in the "Code/Results/Plots" folder, allowing for a graphical overview of the system's performance. It is important to note the date on these files, as not all graphs are newly created after each model run. Some plots might be from previous simulations with different configurations, and users should be mindful to differentiate between current and older data to ensure accurate interpretations.

Save the dispatch plot for later.

Once you have reviewed and saved the necessary data, you can close the application by clicking the 'X' at the right top corner.

Well done on completing the hands-on 2!