Tutorial:

Micro Grid Tool

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RLI

Features of Micro Grid Tool

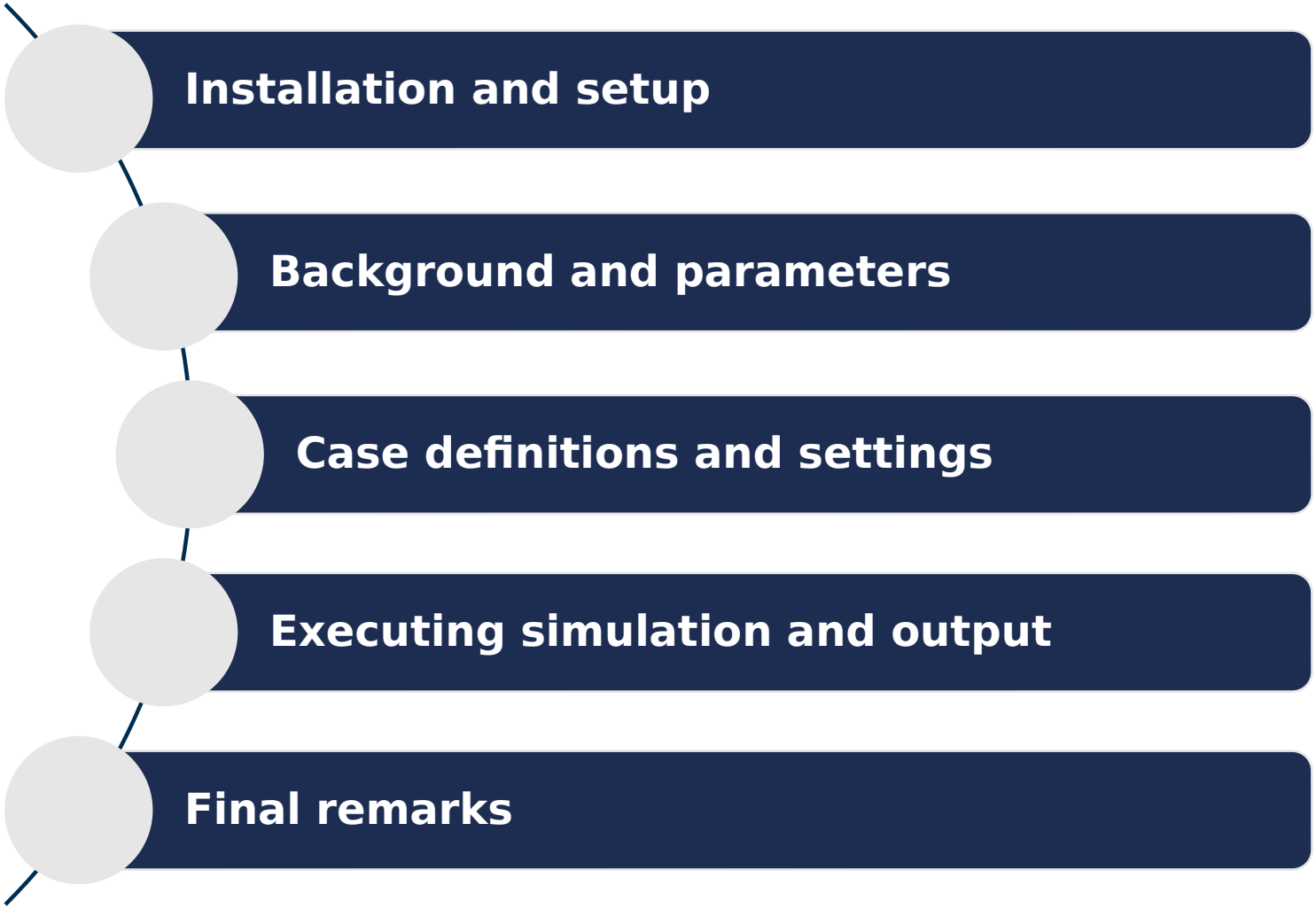
Capacity and dispatch optimization

Components	GenSet, PV, wind, storage, feed-in to / consumption from weak grid
Adaptability	Definition of all parameters and cases in excel file, multiple locations
Sensitivity	Possible for each input parameter
Technical verification	Sensitivity constraint, plausability tests

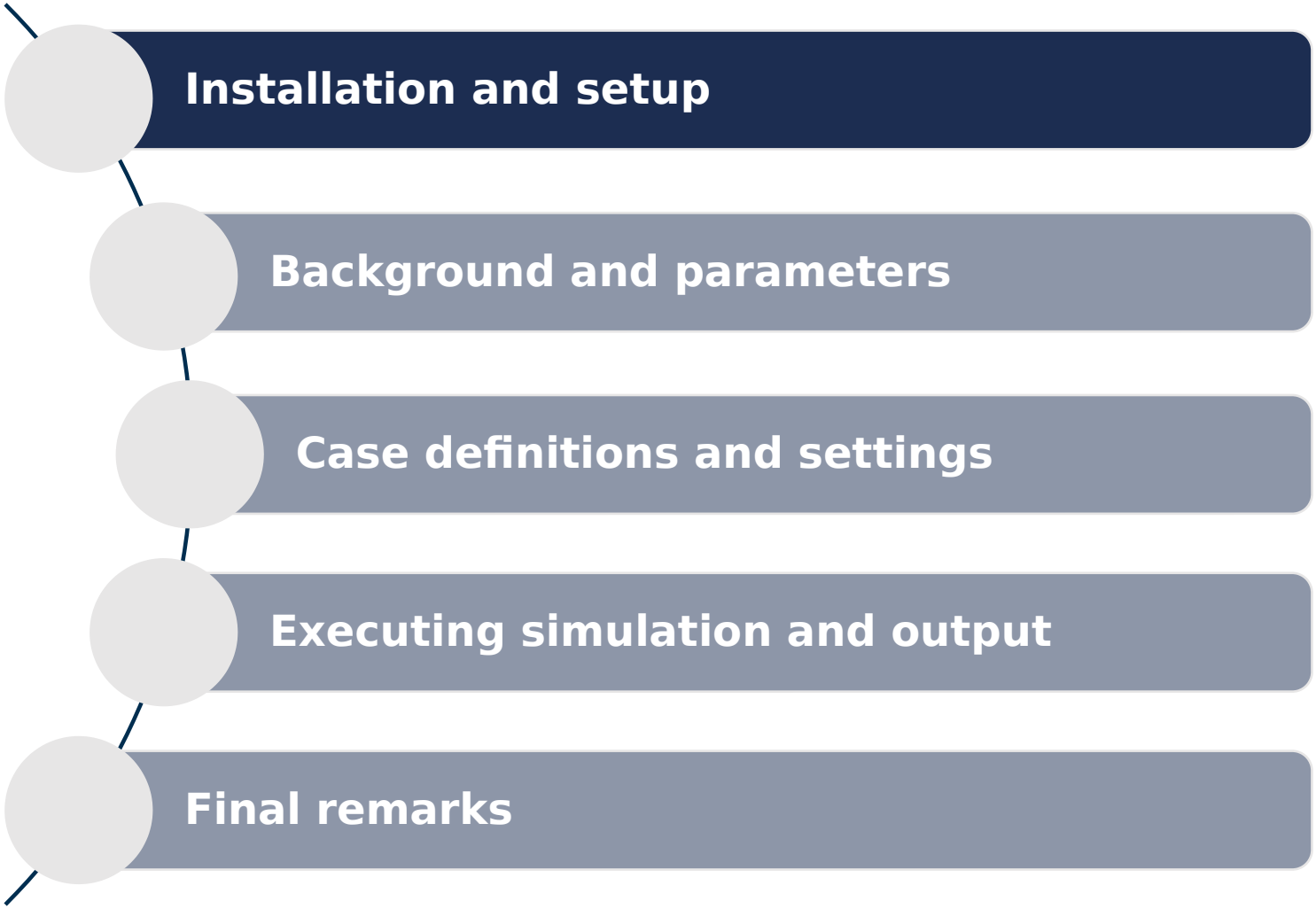
Using the MGT: Workflow

1) Installation and setup as earlier presented
2) Create timeseries file of demand + resources (**.csv**)
3) Edit **Input_template_excel.xlsx**
   → save in folder „inputs“
4) Run **A_main_script.py** in terminal or python GUI
5) **Move folder** with results to your project folder
6) Explore results

Agenda


Installation and setup
Background and parameters
Case definitions and settings
Executing simulation and output
Final remarks

Agenda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Installation Guide on Windows

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Install python using Anaconda (Miniconda):

https://docs.conda.io/en/latest/miniconda.html

You now have a terminal named “Anaconda Prompt” in your “Start” menu

Create a new virtual environment

1) open Anaconda Prompt
2) type *conda create -n [env_name] python=X.X*
3) specifc to Micro Grid Tool:

conda create -n [your_env_name] python=3.5

Activate your environment:

1) type activate *[your env_name]*

List environments:

1) type *conda env list*

Install required packages from requirements.txt file using pip:

1) activate your envrionment, type: activate [your_env_name]
2) pip install -r [path_to_requirements.txt]
3) check if installation was sucessful, type: pip list

Installation Guide on Windows

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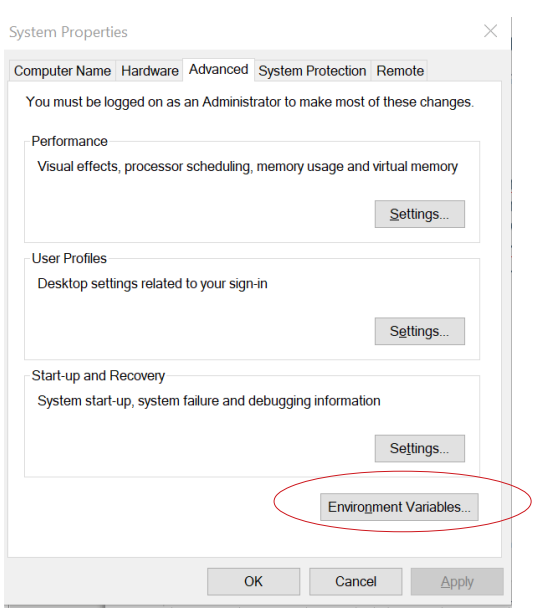
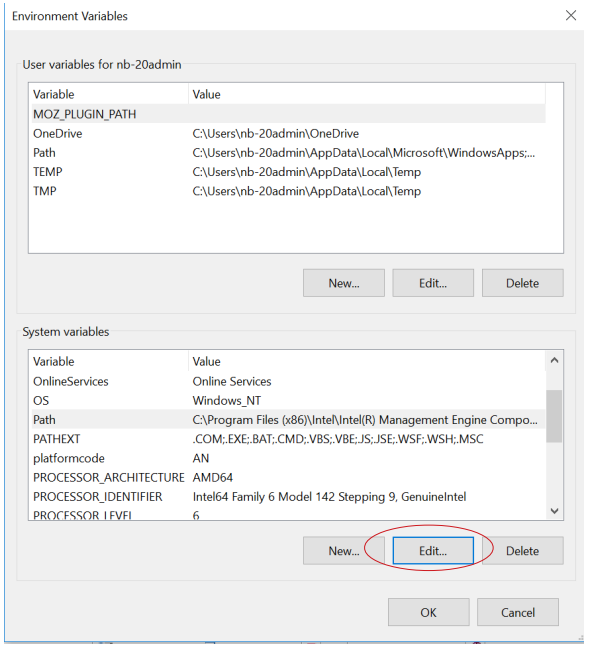
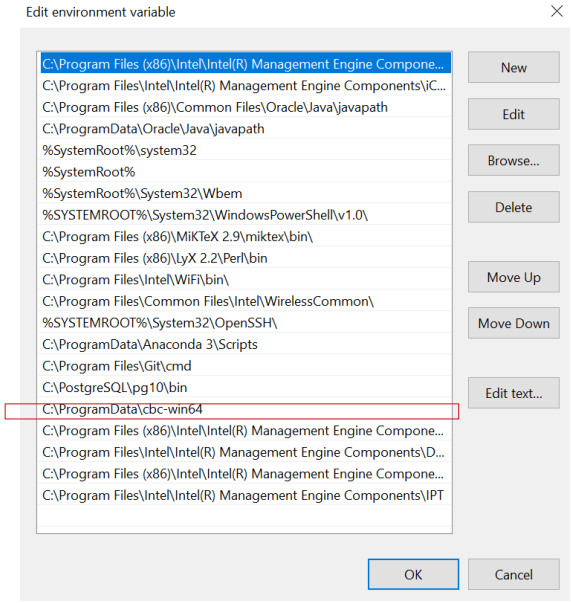
Install CBC solver on your machine

1) download CBC-solver .exe here:
   64bit: http://ampl.com/dl/open/cbc/cbc-win64.zip
   32bit: http://ampl.com/dl/open/cbc/cbc-win32.zip
2) unzip into a chosen path (maybe where you store other programs)
3) add solver path to your system envrionment variables
   (local admin rights required):
   open “System Propoerties” -->”Advanced”--> “Environment Variables”







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Oemof

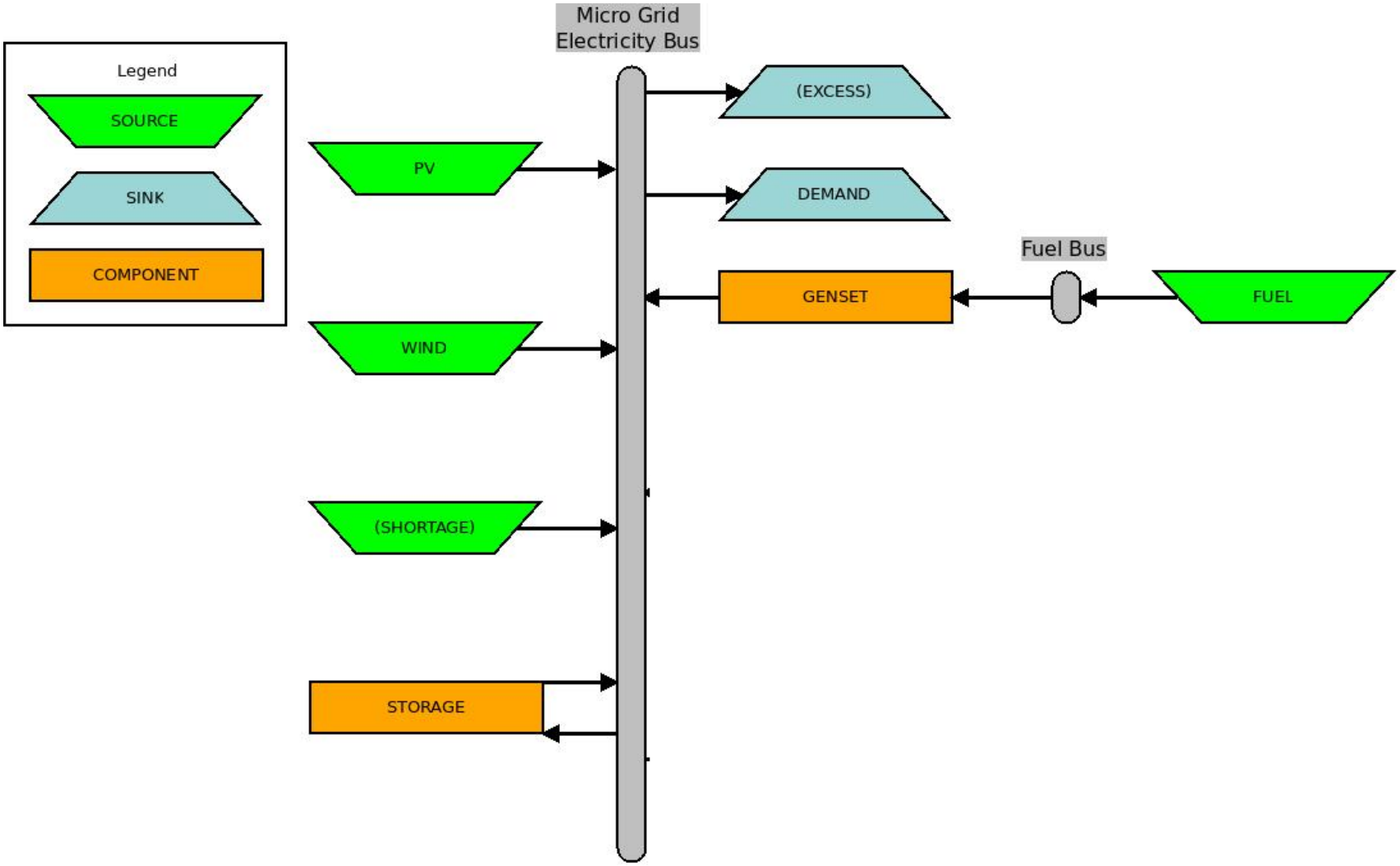
- Based on busses, sinks, sources and transformers

  → Busses are balanced out → Excess sink necessary

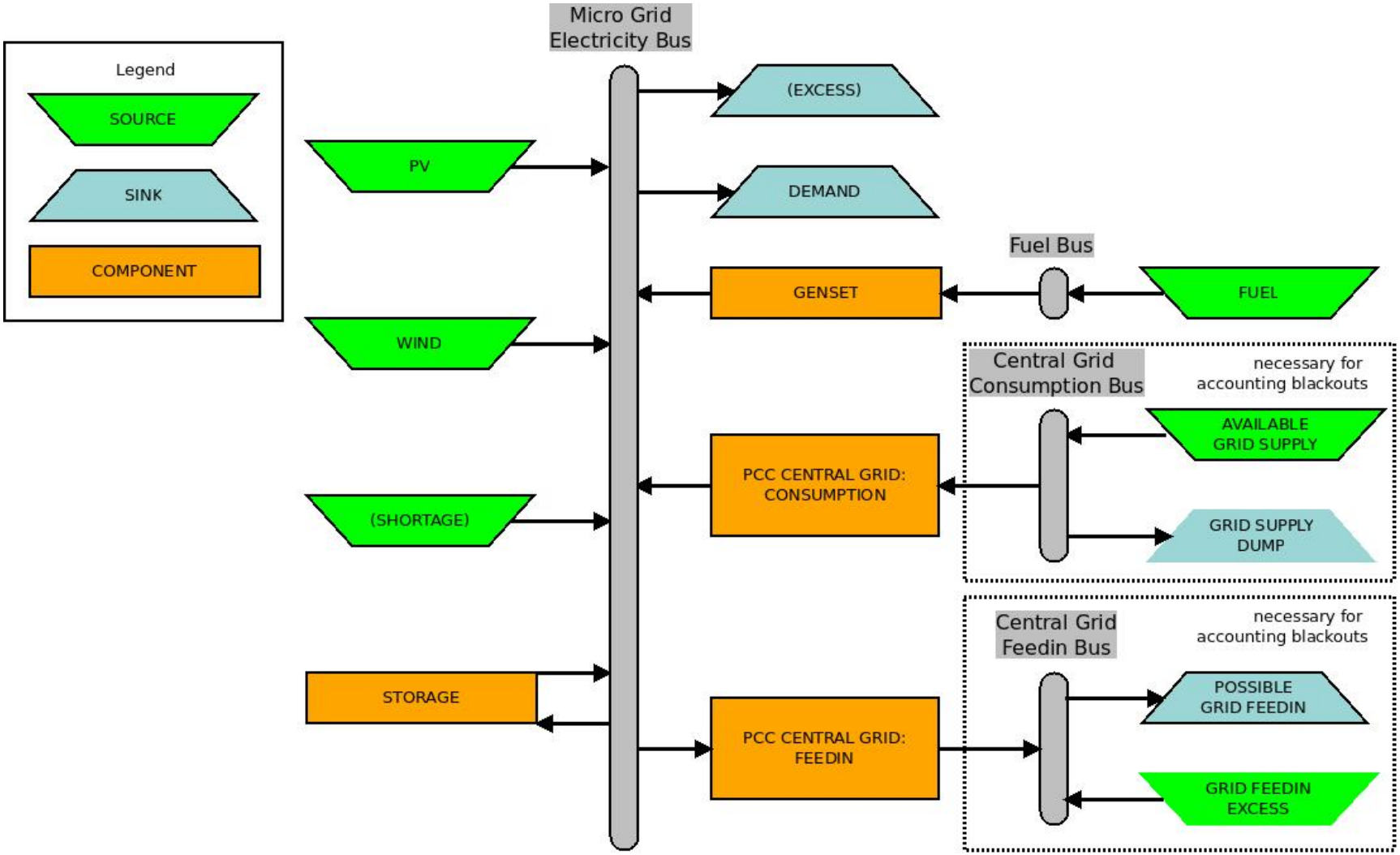
- Solves linear and mixed-integer linear problems

  → Requires certain level of simplification
  - Charge efficiency curve not possible
  - No if-then-clauses for constraints
  - No sizing of generators with minimal loading

Generalized oemof model



Generalized oemof model

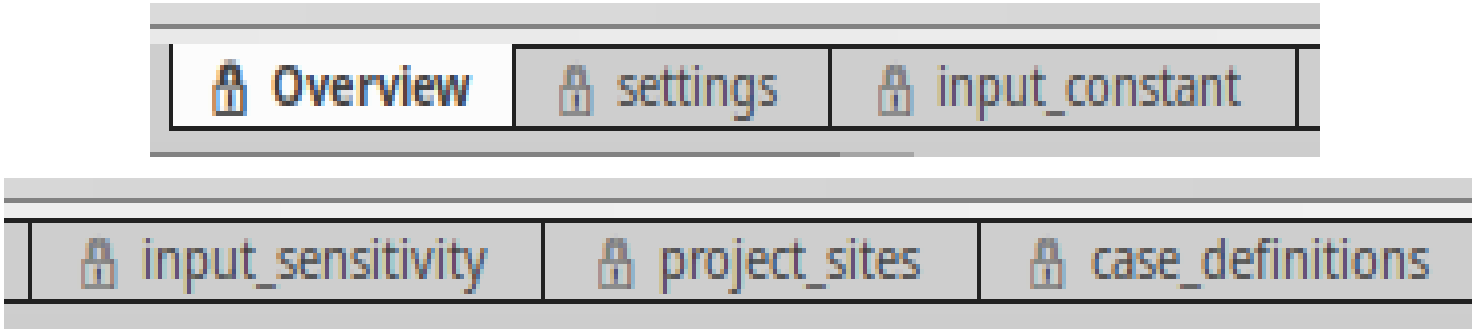


Input template

Please open

input_template_excel.xlsx in ‘./MGT_code/input**‘**

Excel sheet with multiple tabs:



→ Defines **all** simulation parameters

→ File name and location **can not be changed**!

Input parameters: Constants

Please open tab → **input_constant**

→ Defines all input parameters for simulation

→ Sensitivity analysis for each parameter possible

→ Costs should be based on today‘s values!

Definition of constant input parameters	
Doubled values	Make sure that the sensitivity setting fits the experiments you want to simulate – either sensitivity or project site values may be preffered
Missing values	Tab “data_sufficiency_check” helps to identify missing /doubled data, but is by no means a thourough check. Python error messages will occur if values are left undefined

Input data: Parameters

Parameter	Value	Unit
blackout_duration	0	hrs
blackout_duration_std_deviation	0	factor
blackout_frequency	0	/mth
blackout_frequency_std_deviation	0	factor
combustion_value_fuel	8.8	kWh/l
demand_scaling_factor	1	factor
distribution_grid_cost_investment	0	currency
distribution_grid_cost_opex	0	/a
distribution_grid_lifetime	20	a
genset_batch	0.5	kW
genset_cost_investment	650	/kW

Input data groups

- Technical and economical data on components:

  PV, storage, genset, point of common coupling (PCC)

- Prices and costs connected to grid extension

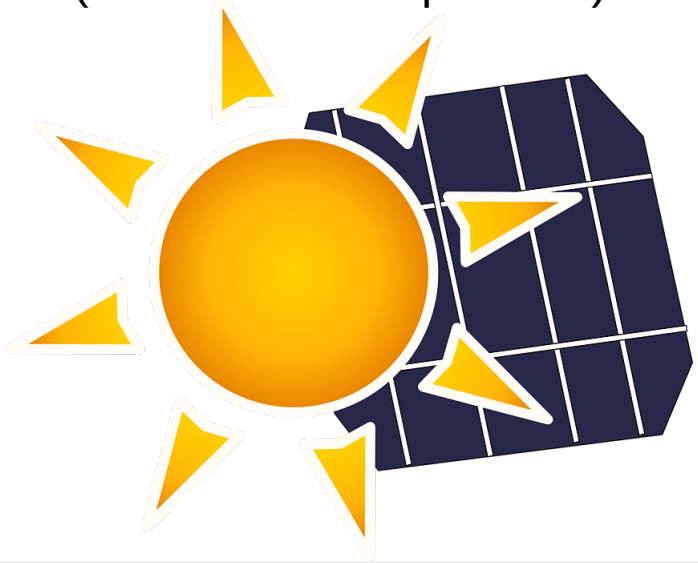
- Project costs and financial data

- Further parameters

Component models: PV panel

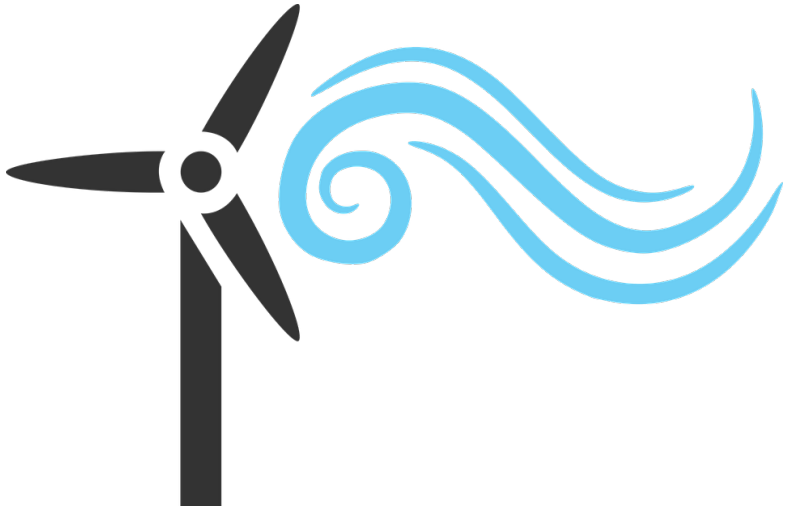
- Efficiency, temperature effects etc. already included in timeseries
- **Optimized**: Installed **kWp**
- List of input parameters:
  - pv_batch
  - pv_cost_investment
  - pv_cost_opex
  - pv_cost_var
  - pv_lifetime

Batch size, only used for optimizations based on previously evaluated case (valid for all components)



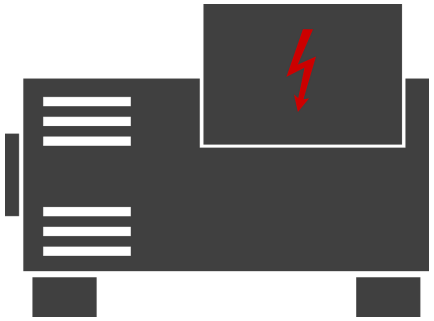
Component models: Wind plant

- Efficiency etc. already included in timeseries
- **Optimized**: Installed **kW**
- List of input parameters:
  - wind_batch
  - wind_cost_investment
  - wind_cost_opex
  - wind_cost_var
  - wind_lifetime



Component models: GenSet

- **Optimized**: Dispatch / installed **kW**
- List of input parameters:
  - genset_batch
  - genset_cost_investment
  - genset_cost_opex
  - genset_cost_var
  - genset_efficiency
  - genset_lifetime
  - genset_max_loading
  - genset_min_loading
  - genset_oversize_factor
  - price_fuel
  - combustion_value_fuel

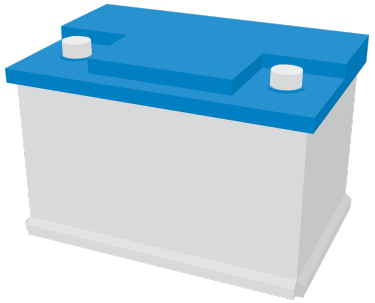


genset_efficiency → Connected to inflow

genset_max_loading, genset_min_loading → Application requires specific setting in case definition

genset_oversize_factor → Only if estimated with ‘peak_demand’, which is necessary to include Min/max loading

Component models: Storage

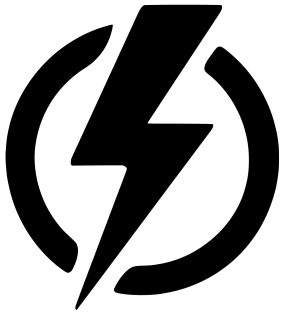


- **Optimized**: Dispatch / installed **kWh**
- List of input parameters:
  - storage_batch
  - storage_cost_investment
  - storage_cost_opex
  - storage_cost_var
  - storage_Crate_charge → Ratio, per timestep: max (dis-)charge/CAP
  - storage_Crate_discharge → Ratio, per timestep: max (dis-)charge/CAP
  - storage_efficiency_charge
  - storage_efficiency_discharge
  - storage_lifetime
  - storage_loss_timestep → Long-term storage losses
  - storage_soc_initial → Advanced setting, leave at None
  - storage_soc_max → Max. allowed charge
  - storage_soc_min → 1-DOD

Component models: PCC

- **Optimized**:

  Installed **kW** of point of common coupling (connection to/from central grid)



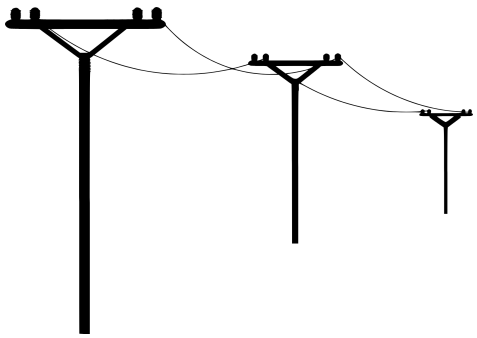
- List of input parameters:
  - pcoupling_oversize_factor → Only if capacity is estimated with ‘peak_demand’
  - pcoupling_batch
  - pcoupling_cost_investment
  - pcoupling_cost_opex
  - pcoupling_cost_var → Based on inflow
  - pcoupling_efficiency → Based on inflow
  - pcoupling_lifetime

→ For bi-directional inverter (assumption not used in oemof):

Optimized CAP=max(CAP_consumption, CAP_feedin)

Costs = 2* CAP * Cost per unit

Central grid



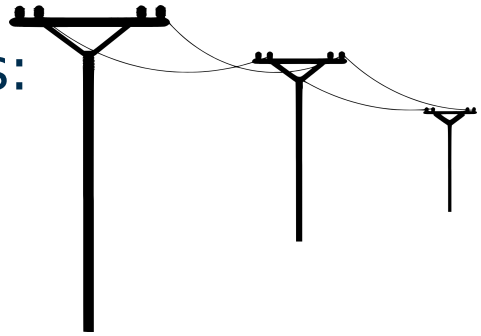
- List of financial parameters:
  - maingrid_distance
  - maingrid_electricity_price
  - maingrid_extension_cost_investment
  - maingrid_extension_cost_opex
  - maingrid_extension_lifetime
  - maingrid_feedin_tariff
  - maingrid_renewable_share → To determine renewable factor of grid-connected systems

→ Used to calculate fix central grid extension costs

→ Expenditures through central grid consumption

→ Revenues through central grid feed-in

Central grid - Blackouts



- List of parameters regarding blackouts:
  - blackout_duration
  - blackout_duration_std_deviation
  - blackout_frequency
  - blackout_frequency_std_deviation

→ Used for randomized blackout timeseries

→ For 100% reliable grid: Set all to zero

Project parameters - financial

- List of financial parameters:
  - project_cost_fix
  - project_cost_opex
  - project_life
  - distribution_grid_cost_investment
  - distribution_grid_cost_opex
  - distribution_grid_lifetime

  → Used to calculate fix costs

  - Tax → Ontop of on investment costs!
  - Wacc

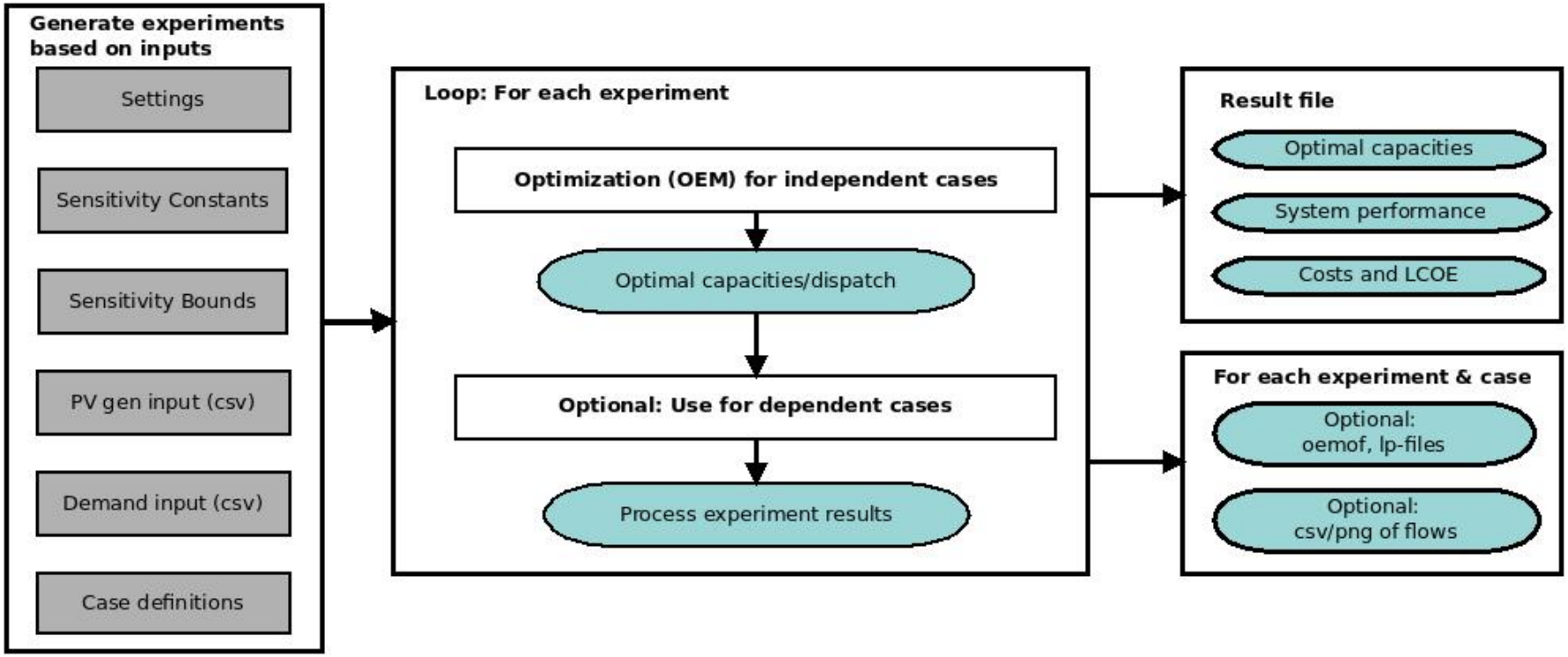
  → Used for annuity method

Project parameters - others

- demand_scaling_factor → Multiplies demand timeseries with factor, Usual setting: 1
- min_renewable_share → Currently not implemented!
- shortage_max_allowed → Relative to annual demand!
- shortage_penalty_costs → Estimation: ~LCOE
- stability_limit
- white_noise_demand
- white_noise_pv
- white_noise_wind

} Timeseries of each experiment subjected to noise
→ Limits comparability, recommentation: 0

Senstivity analysis



Terms

Project sites

Project locations with distinct demand (and PV/wind) timeseries

Experiments

Generated based on analysed project sites and based on sensitivity parameters

Complete set of input parameters

Cases

Define components modelled with oemof and optimization type (dispatch / capacity optimization)

Model definition

Scenario

Certain experiment subjected to case

Input parameters + model = Case study

Input parameters: Sensitivity analysis

Please open tab → **input_sensitivity**

→ **Defines** sensitivity analysis to be performed

Definition of sensitivity parameters	
Deleting rows	Rows can be deleted. Remember to check if the deleted value is defined in input_constant or project_sites
Doubled value	Make sure that the sensitivity setting fits the experiments you want to simulate – either sensitivity or project site values may be preffered
Parameter	Parameter from input_costant that is subject to sensitivity analysis
Min	Minimal value of parameter
Max	Maximal value of parameter
Step	Step lenght for values between min and max value of parameter

Input parameters: Sensitivity analysis

1) Copy parameter name from tab „input_constants“ into new row

2) Minimal / Maximal value of sensitivity parameter

3) Define step lenght for analysis

Parameter	Min	Max	Step
shortage_max_allowed	0	0.1	0.025
genset_lifetime	10	20	5

Value ranges here:

shortage_max_allowed in [0, 0.025, 0.05, 0.075, 0.1]

genset_lifetime in [10, 15, 20]

Input parameters: Sensitivity analysis

Sensitivity experiments defined based → „settings“:

(1) Senstitivity_all_combinations = True:

→ Experiments for all possible combinations of sensitivity parameters

→ High number of experiments

→ Analysing dependencies

(2) Sensitvitiy_all_combinations = False:

→ Only one sensitivity parameter varies at a time

→ „Base case“ defined through constant parameters OR parameters defined per project location

Project locations

Please open tab → **project_sites**

→ Defines project locations
with timeseries and specific parameters

Definition of project locations	
Number of location	An unlimited number of locations can be added below. Make sure that project site names are only used once
Necessary entries	For each project location: project_site_name, timeseries_file, title_time, title_demand, title_pv, title_wind, title_grid_availability, seperator
Additional column	Project site specific can be defined in additional columns. If one project has a specific value, the value needs to be defined here for all project sites
timeseries_file	The timeseries have to be provided in an external csv file.
title_time	Title of column with timestamp or None
title_demand	Title of column with demand in kW
title_pv	Title of column with PV generation in kW/kWp, or None
title_wind	Title of column with wind generation in kW/kW, or None
title_grid_availabil	Title of column with grid availability (boolean) or None
seperator	Seperator used in csv file

Project locations

Timeseries of grid availability at project site (boolean)

Unique project site name

Seperator of .csv file

project_site_name	timeseries_file	title_time	title_demand	title_pv	title_wind	title_grid_availability	seperator	price_fuel
17_Polo	./inputs/timeseries/17_Polo.csv	None	Demand	SolarGen	Wind	None	;	0.5
34_Araceli	./inputs/timeseries/34_Araceli.csv	None	Demand	SolarGen	Wind	None	;	0.6
107_Balut Is.	./inputs/timeseries/107_Balut Is..csv	None	Demand	SolarGen	Wind	None	;	0.7
126_Pangutaran	./inputs/timeseries/126_Pangutaran.csv	None	Demand	SolarGen	Wind	None	;	0.8

Path to timeseries file (can be anywhere, but if located in /inputs it will be copied into results folder)

Headers used in .csv
None: Not included

Optional: Parameters specific to project location, can define base case

→ Columns can be added/deleted

Timeseries file (.csv)

Demand	SolarGen	Wind	GridAvailability
0	0	0.045	1
0	0	0.052	1
0	0	0.045	1
0	0	0.052	1
0	0	0.061	1
0	0	0.079	1
0.004	0.025	0.097	1
0.004	0.147	0.075	0
0.003	0.375	0.093	1
0.003	0.585	0.097	0
0	0.65	0.063	1
0.006	0.634	0.014	1
0.006	0.5	0	1
0	0.352	0.001	1
0.003	0.324	0.005	0
0.006	0.136	0.014	0
0.003	0	0.019	1

Go to

./input/timeseries/
intermediate_Tier2.csv

For each project site:

- Demand in kW
- Solar generation in kW / kWp
- Wind generation in kW / kW
- Blackout (boolean vektor)
  1: available, 0: unavailable
- Timestamp (optional)

Timeseries file (.csv)

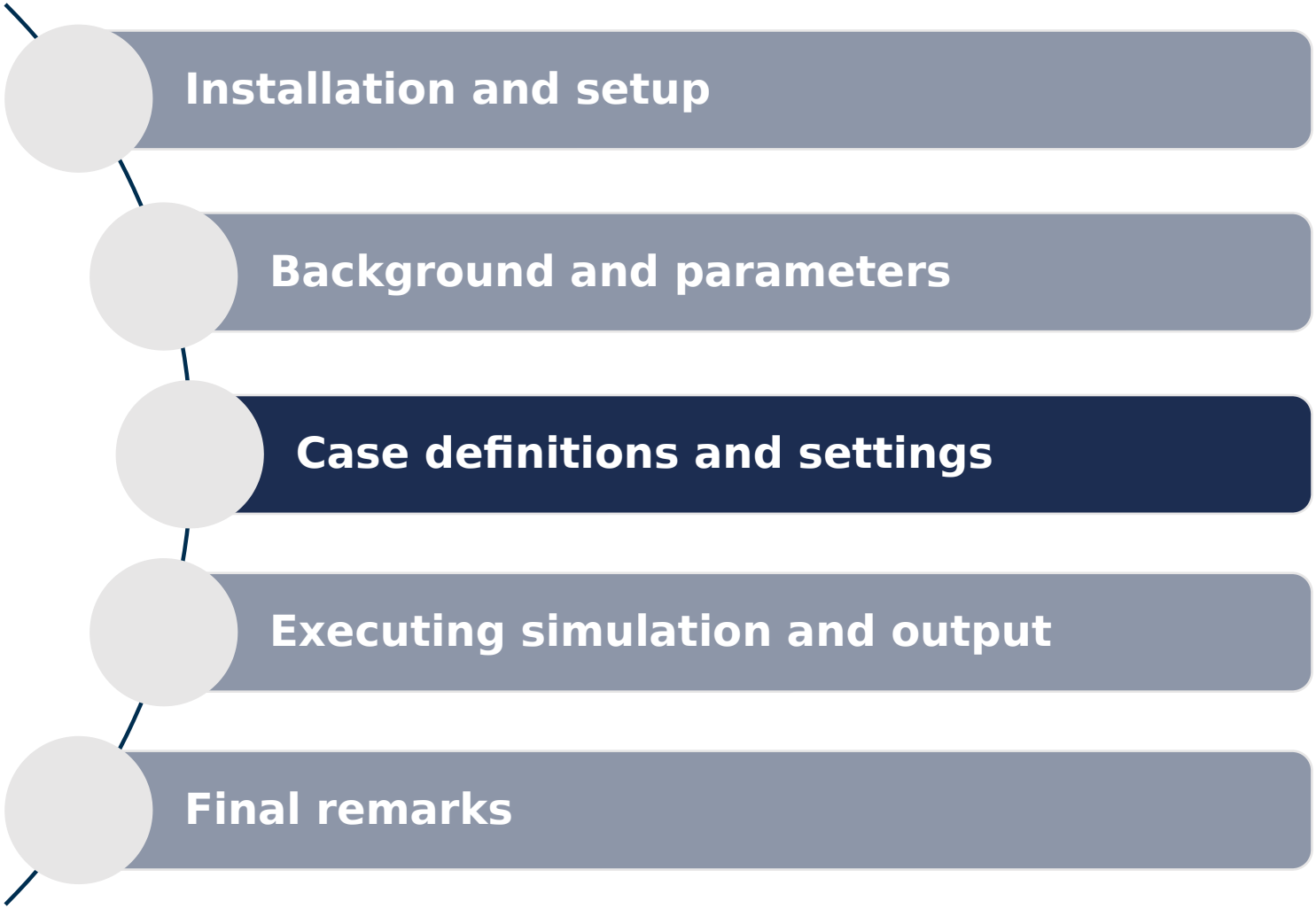
Demand	SolarGen	Wind	GridAvailability
0	0	0.045	1
0	0	0.052	1
0	0	0.045	1
0	0	0.052	1
0	0	0.061	1
0	0	0.079	1
0.004	0.025	0.097	1
0.004	0.147	0.075	0
0.003	0.375	0.093	1
0.003	0.585	0.097	0
0	0.65	0.063	1
0.006	0.634	0.014	1
0.006	0.5	0	1
0	0.352	0.001	1
0.003	0.324	0.005	0
0.006	0.136	0.014	0
0.003	0	0.019	1

- Variable file name
- Hourly timesteps, min. as many as analysed in simulation
- Column header string variable

Optional:

- Solar/Wind timeseries, but necessary if respective capacities optimized
- Blackout timeseries, otherwise randomized through input variables

Agenda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Case definitions

Please open

input_template_excel.xlsx in ‘./MGT_code/input‘

and tab **case_definitions**

→ Defines models using previous parameters

Case definitions			
Adding cases	An unlimited number of cases can be added in new columns. Make sure each has an unique name.		
case_name	string		
based_on_case	False or True		
pv_fixed_capacity	oem, string (name of base capacity case), None		
storage_fixed_capacity	oem, string (name of base capacity case), None		
genset_fixed_capacity	oem, string (name of base capacity case), None, peak_		
pcc_consumption_fixed_capacity	oem, string (name of base capacity case), None, peak_		
pcc_feedin_fixed_capacity	oem, string (name of base capacity case), None, peak_		
allow_shortage	True or False or default		
max_shortage	value or default		
stability_constraint	False / share_usage / share_backup / share_hybrid		
renewable_constraint	currently not implemented		

Case definitions

→ Easy/adaptable generation of cases in new column

→ Currently not possible to include existing capacities

case_name	mg_hybrid_no_min	mg_hybrid	solar_battery_mg	diesel_mg
perform_simulation	False	True	False	False
based_on_case	False	False	False	False
capacity_pv_kWp	oem	oem	oem	None
capacity_storage_kWh	oem	oem	oem	None
capacity_genset_kW	oem	peak_demand	None	ak_demand
genset_with_minimal_loading	False	True	False	True
number_of_equal_generators	1	2	1	2
capacity_pcc_consumption_kW	None	None	None	None
capacity_pcc_feedin_kW	None	None	None	None
capacity_wind_kW	None	None	None	None
allow_shortage	True	True	True	True
max_shortage	default	default	default	default
stability_constraint	share_hybrid	share_hybrid	share_hybrid	are_hybrid
renewable_constraint	False	False	False	False

Case definition

case_name	Off-grid MG	Unique name
perform_simulation	True	True/False
based_on_case	False	True/False
capacity_pv_kWp	oem	
capacity_storage_kWh	oem	
capacity_genset_kW	oem	
genset_with_minimal_loading	False	
number_of_equal_generators	1	
capacity_pcc_consumption_kW	None	
capacity_pcc_feedin_kW	None	
capacity_wind_kW	oem	
allow_shortage	True	True/False
max_shortage	default	value or default
stability_constraint	share_hybrid	False or ”share_hybrid”, “share_backup”, “share_usage”

Options

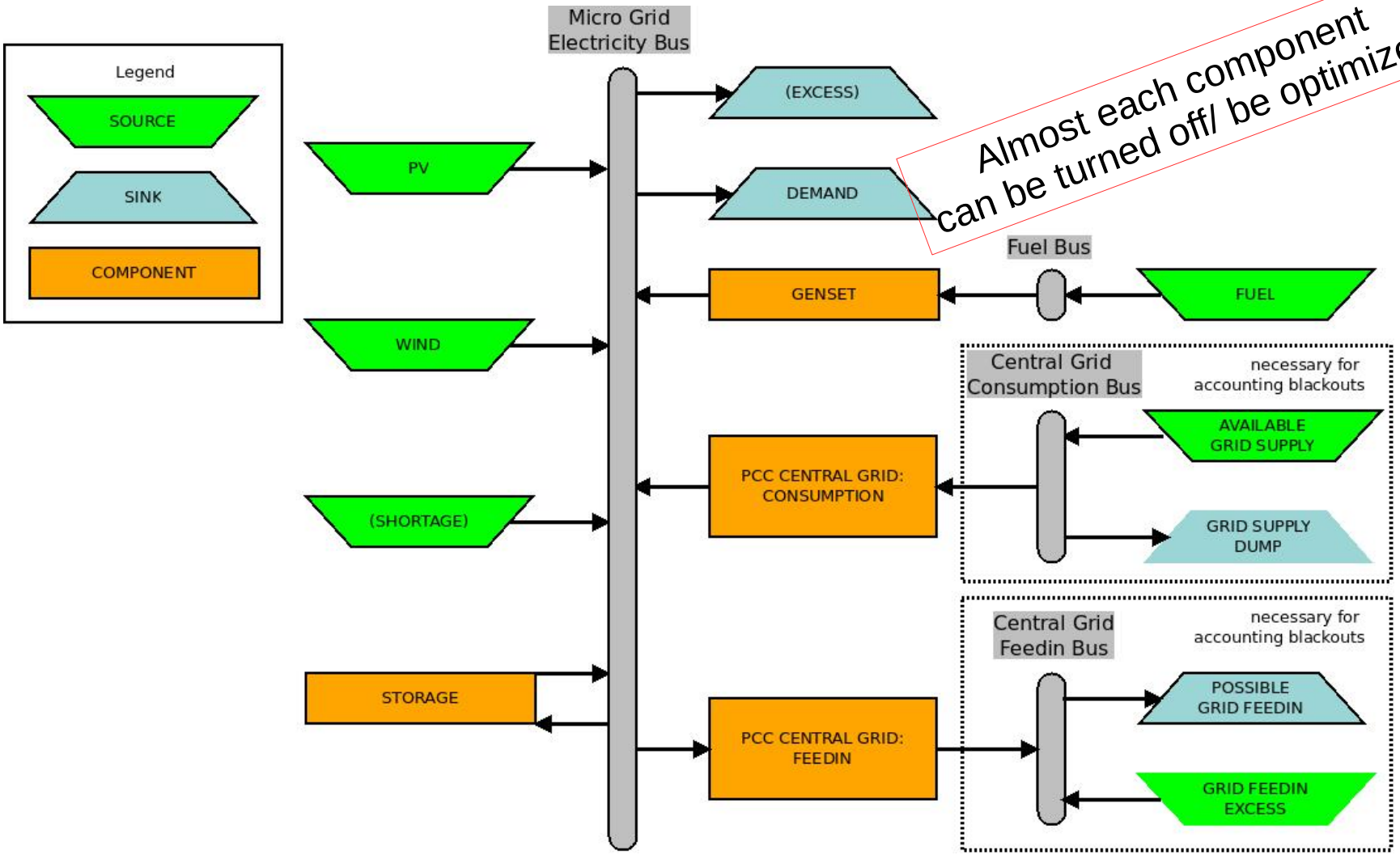
“oem”
Optimize CAP

“None”
Not included

string case_name
Use capacities of another case with based_on_case = True

For genset + pcc:
“peak_demand”

Oemof model


Legend
SOURCE
SINK
COMPONENT
Micro Grid Electricity Bus
(EXCESS)
PV
DEMAND
Almost each component can be turned off/ be optimized
Fuel Bus
GENSET
FUEL
WIND
Central Grid Consumption Bus
necessary for accounting blackouts
AVAILABLE GRID SUPPLY
PCC CENTRAL GRID: CONSUMPTION
(SHORTAGE)
GRID SUPPLY DUMP
Central Grid Feedin Bus
necessary for accounting blackouts
STORAGE
POSSIBLE GRID FEEDIN
PCC CENTRAL GRID: FEEDIN
GRID FEEDIN EXCESS

Generators with minimal loading

- Min. loading requires nonconvex equations

  → Mixed integer problems

  → Capacities of generator can not be optimized

- → Estimate capacity with „peak_load“ and adapt scaling factor „genset_oversize_factor“

- Min. load of auto-sized generator > base load

  → Error: No solution

  → Allow multiple generators, effectively lowering minimal loading

Stability criterion

Demand and (renewable) generation variability

- System response (frequency, voltage) → Stability?

  stability_limit = Share of demand that is sufficient to guarantee stable system operation

  ↔ Homer parameter „operating reserve“!

Four options:

(1) None

(2) „share_backup“

(3) „share_usage“

(4) „share_hybrid“

Stability criterion - share_backup

$$\begin{aligned}
&\text{Stability limit} \cdot \left(\text{demand} - \text{shortage}\right) \\
&\quad \leqslant \ \text{CAP}_{\text{GenSet}} \\
&\quad + \left(\text{SOC}\left(t\right) - \left(1 - \text{DOD}\right)\right) \cdot \text{CAP}_{\text{storage}} \cdot \text{Crate} \\
&\quad + \text{CAP}_{\text{PCC}} \cdot \text{grid availability}\left(t\right)
\end{aligned}$$

Stability criterion - share_backup

$$\text{Stability limit} \cdot (\text{demand} - \text{shortage})$$
$$\leqslant \text{CAP}_{\text{GenSet}} \quad \text{possible flow}$$
$$+ (\text{SOC}(t) - (1 - \text{DOD})) \cdot \text{CAP}_{\text{storage}} \cdot \text{Crate} \quad \text{possible flow}$$
$$+ \text{CAP}_{\text{PCC}} \cdot \text{grid availability}(t) \quad \text{possible flow}$$

Assumption:
Each GenSet, battery and grid consumption can stabilize micro grid instantaneously
→ Sufficient to have enough backup capacities at hand

Stability criterion - share_usage

$$\begin{aligned}\text{Stability limit} \cdot (\text{demand}(t) - \text{shortage}(t)) \\ \leqslant \ \text{Generation Genset}(t) \\ + \text{Battery discharge}(t) \\ + \text{Grid consumption}(t) \cdot \text{grid availability}(t)\end{aligned}$$

Stability criterion - share_usage

$$\text{Stability limit} \cdot \left(\text{demand}(t) - \text{shortage}(t)\right)$$
$$\leqslant \text{Generation Genset}(t)^{\text{actual flow}}$$
$$+ \text{Battery discharge}(t)^{\text{actual flow}}$$
$$+ \text{Grid consumption}(t) \cdot \text{grid availability}(t)^{\text{actual flow}}$$

Assumption:
Components have a long reaction time; to ensure stability they have to be deployed in each timestep
→ 100% renewable supply directly from its generation sources not possible

Stability criterion - share_hybrid

$$\begin{aligned}
&\text{Stability limit} \cdot \left(\text{demand}\left(t\right) - \text{shortage}\left(t\right)\right) \\
&\quad \leqslant \ \text{Generation Genset}\left(t\right) \\
&\quad + \left(\text{SOC}\left(t\right) - \left(1 - \text{DOD}\right)\right) \cdot \text{CAP}_{\text{storage}} \cdot \text{Crate} \\
&\quad + \text{CAP}_{\text{PCC}} \cdot \text{grid availability}\left(t\right)
\end{aligned}$$

Stability criterion - share_hybrid

Recommended

$$\text{Stability limit} \cdot \left(\text{demand}(t) - \text{shortage}(t)\right)$$
$$\leqslant \text{Generation Genset}(t) \quad \text{actual flow}$$
$$+\left(\text{SOC}(t) - (1 - \text{DOD})\right) \cdot \text{CAP}_{\text{storage}} \cdot \text{Crate} \quad \text{possible flow}$$
$$+\text{CAP}_{\text{PCC}} \cdot \text{grid availability} \quad \text{possible flow}$$

Assumption:
GenSet has long reaction time, while battery and PCC can react almost instantaneously

→ To provide stability to the system, the GenSet hast to actually generate electricity while battery and PCC only have to insure that a sufficient flow is possible.

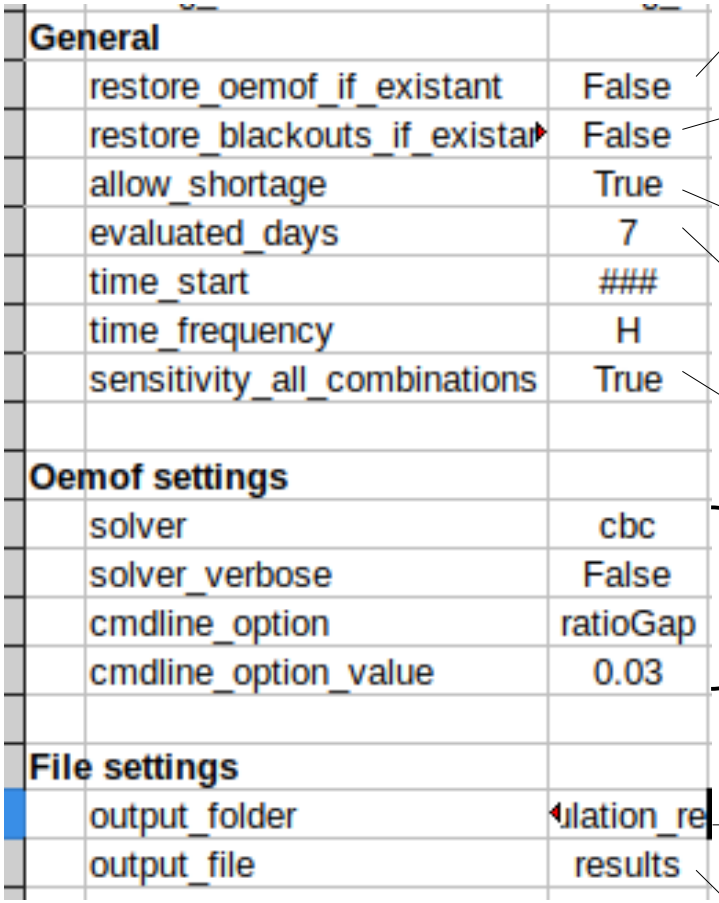
Simulation settings

Please open tab → **settings**

→ **Defines** universal simulation settings:

Defining settings	
General	Electricity solution settings
Simulated cases	Cases evaluated
Oemof settings	Oemof-internal simulation settings
File settings	File locations
Output – Files	Data saved to file
Output – Terminal display	Data is displayed in terminal
Output – Evaluated values	Simulation/evaluation values added to the result file

Simulation settings



General	
restore_oemof_if_existant	False
restore_blackouts_if_existar	False
allow_shortage	True
evaluated_days	7
time_start	###
time_frequency	H
sensitivity_all_combinations	True
Oemof settings	
solver	cbc
solver_verbose	False
cmdline_option	ratioGap
cmdline_option_value	0.03
File settings	
output_folder	ulation_re
output_file	results

Restores previous results saved as .oemof

Restores previous blackout timeseries

Overrules case definitions! Better leave at „True“

1… 365 (infuences simulation time!)

Generates sensitivity experiments (all combinations or with base case)

Advanced settings: Oemof-simulation

Defines folder name for simulation outputs – existing folder deleted!

Defines name for result file

Simulation settings

Output – files	
save_lp_file	False
lp_file_for_only_3_timesteps	False
save_oemofresults	True
save_to_csv_flows_storage	False
save_to_csv_flows_electric	True
save_to_png_flows_storage	False
save_to_png_flows_electric	True
Output – Terminal display	
display_meta	False
display_main	False
display_experiment	False
Output – Evaluated values	
results_demand_characteris	True
results_blackout_characteris	True
results_annuities	False
results_costs	False

Advanced setting:
lp-file for other solvers, checking equations for cases

Necessary to restore results

Saving flows of each experiment as csv/png

Advanced setting:
Terminal output

Sets parameters included in „result“ file

Agenda

- Installation and setup
- Background and parameters
- Case definitions and settings
- **Executing simulation and output**
- Final remarks

Execute MGT – From Terminal

Open Anaconda prompt and execute:

- Activate virtual environment

```
activate environment_name
```

- Go to MGT code folder

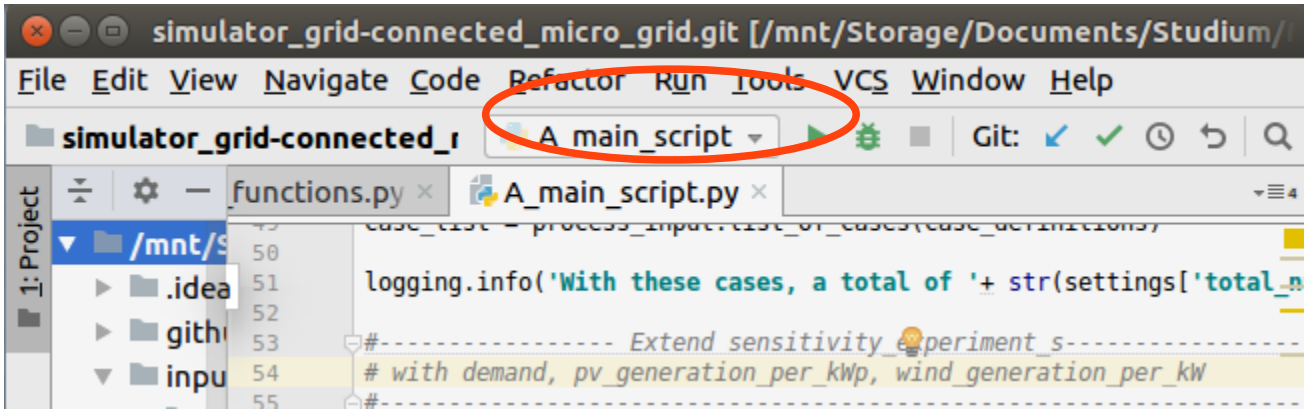
```
cd other_path/MGT_code
```

- Run script

```
python A_main_script.py
```

Execute MGT – From Pycharm

Run in graphical interface, eg. pycharm:



Terminal output

```
13:19:29-INFO-Path for logging: ./micro_grid_design_logfile.log
13:19:29-INFO-Used oemof version: 0.2.2
13:19:31-INFO-Following project locations are evaluated: 126_Pangutaran, 34_Araceli, 17_Polo, 107_Balut Is
.
13:19:35-WARNING-Attributes "shortage_max_allowed, genset_lifetime" defined in constant and sensitivity pa
rameters. Only sensitivity parameter value will be used for sensitivity_experiment_s.
13:19:35-WARNING-Attributes "price_fuel" defined in constant and project site parameters. Only project sit
e value will be used for sensitivity_experiment_s.
13:19:36-INFO-1 combinations of blackout duration and frequency will be analysed.
13:19:36-INFO-For 4 project sites with 15 scenarios each, 60 sensitivity_experiment_s will be performed fo
r each case.
13:19:36-INFO-Base capacities provided by: mg_hybrid
13:19:36-INFO-All simulated cases: mg_hybrid
13:19:36-INFO-With these cases, a total of 60 simulations will be performed.



13:19:36-INFO-Blackout experiment 1: Blackout duration 0 hrs, blackout frequency 0 per month
13:19:36-INFO-Number of blackouts in simulated timeframe: 0
13:19:36-INFO-Grid is not operational for 0 hours, with a reliability of 100.0 percent.

13:19:36-INFO-Starting simulation of case mg_hybrid, project site 126_Pangutaran, experiment no. 1/60...
13:19:37-INFO-Optimization successful...
13:19:37-INFO-Restoring attributes will overwrite existing attributes.
13:19:37-WARNING-PLAUSABILITY TEST FAILED: Charge and discharge of batteries at the same time!
13:19:39-INFO-Simulation of case "mg_hybrid" resulted in :
                33.8 EuroCt/kWh, at a renewable share of 0.0 percent with a reliability of 100.0 percent
13:19:39-INFO-    Initial simulation time (s): 0.05 / Actual evaluation time (s): 2.31

13:19:39-INFO-Starting simulation of case mg_hybrid, project site 34_Araceli, experiment no. 2/60...
13:19:39-INFO-Optimization successful...
13:19:39-INFO-Restoring attributes will overwrite existing attributes.
13:19:39-WARNING-PLAUSABILITY TEST FAILED: Charge and discharge of batteries at the same time!
13:19:40-INFO-Simulation of case "mg_hybrid" resulted in :
                23.3 EuroCt/kWh, at a renewable share of 0.0 percent with a reliability of 100.0 percent
13:19:40-INFO-    Initial simulation time (s): 0.15 / Actual evaluation time (s): 1.25
```

Terminal output

All analysed project locations

All simulated cases

```
13:19:29-INFO-Path for logging: ./micro_grid_design_logfile.log
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13:19:39-INFO-    Initial simulation time (s): 0.05 / Actual evaluation time (s): 2.31

13:19:39-INFO-Starting simulation of case mg_hybrid, project site 34_Araceli, experiment no. 2/60...
13:19:39-INFO-Optimization successful...
13:19:39-INFO-Restoring attributes will overwrite existing attributes.
13:19:39-WARNING-PLAUSABILITY TEST FAILED: Charge and discharge of batteries at the same time!
13:19:40-INFO-Simulation of case "mg_hybrid" resulted in :
                 23.3 EuroCt/kWh, at a renewable share of 0.0 percent with a reliability of 100.0 percent
13:19:40-INFO-    Initial simulation time (s): 0.15 / Actual evaluation time (s): 1.25
```

Terminal output

All analysed project locations

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13:19:39-INFO-Starting simulation of case mg_hybrid, project site 34_Araceli, experiment no. 2/60...
13:19:39-INFO-Optimization successful...
13:19:39-INFO-Restoring attributes will overwrite existing attributes.
13:19:39-WARNING-PLAUSABILITY TEST FAILED: Charge and discharge of batteries at the same time!
13:19:40-INFO-Simulation of case "mg_hybrid" resulted in :
                 23.3 EuroCt/kWh, at a renewable share of 0.0 percent with a reliability of 100.0 percent
13:19:40-INFO-    Initial simulation time (s): 0.15 / Actual evaluation time (s): 1.25
```

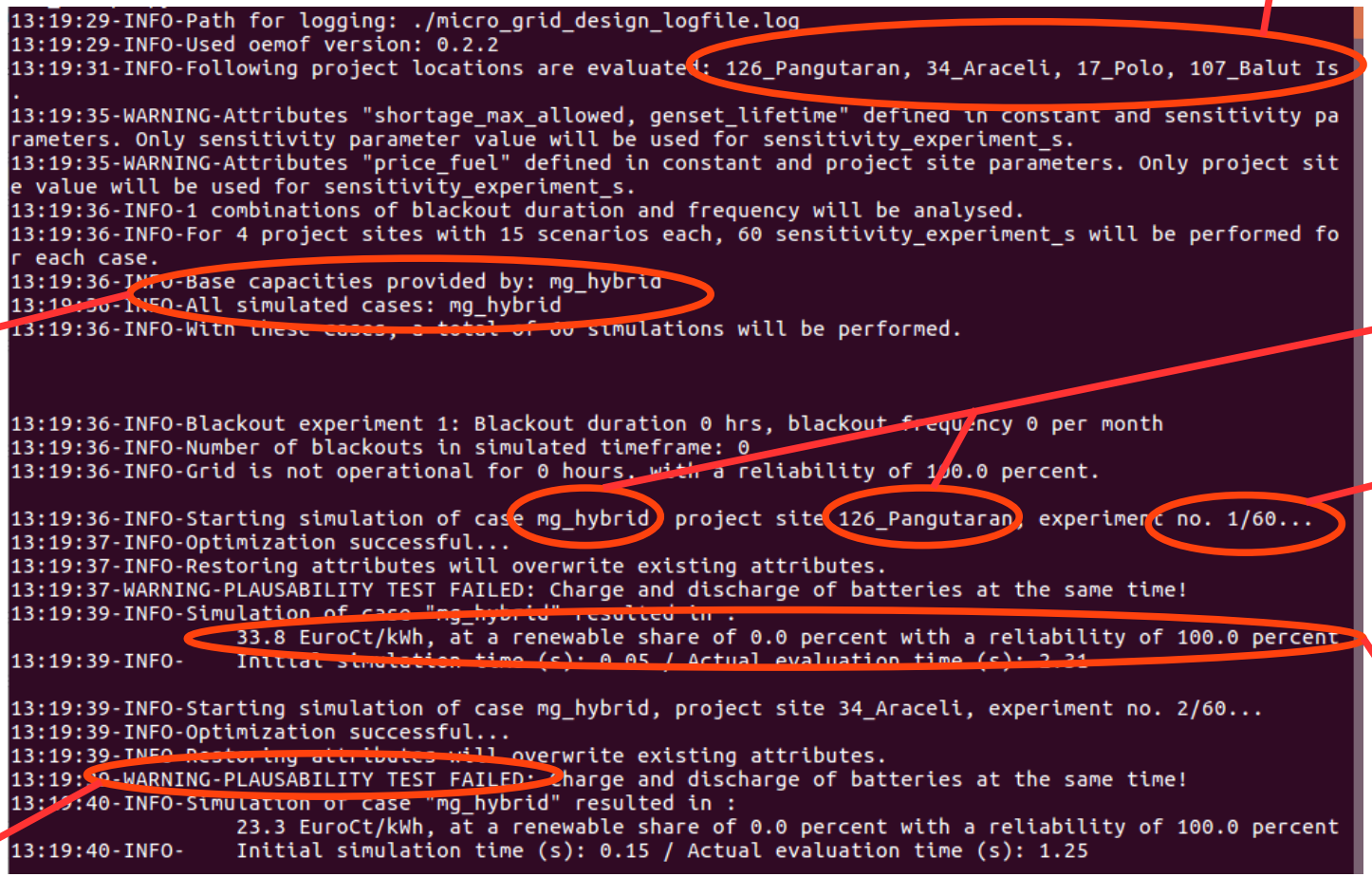
All simulated cases

Current case + location

Experiment count

Main result

Terminal output



Error messages

Don‘t worry about following warnings:

- WARNING-Attributes… defined in...
- WARNING-Stability criterion is strictly not fullfilled, but deviation is less then e6.
- WARNING-PLAUSABILITY TEST FAILED: Charge and discharge of batteries at the same time!

Plausibility tests

- Shortage mirrors unsupplied demand
- No charge at the same time of discharge

  → Warning occurring regularly, if storage_cost_var=0
- No grid consumption or feedin at the same time or during blackout
- No shortage during excess generation
- No excess if feedin possible and PCC capacity not reached

→ Automated warnings if tests violated

(„comments“-column in results file)

Output files

- Results of experiment saved in one file (.csv)
  - Optimal/used fixed capacities
  - Economic values (investment, expenditures, LCOE)
  - Summed flows (total pv generation / shortage)
  - System reliability (kWh)
  - Comments if plausibility tests failed
- Optional: Oemof- and lp-files
- Optional: Flows (.csv) and graph (1a/7d, .png)
  - Electricity flows in MG
  - Storage flows (charge, discharge, stored capacity)

Terminal output

Please go to **‘./MGT_code/your_results_folder‘**

Copy this folder before performing other analysis!

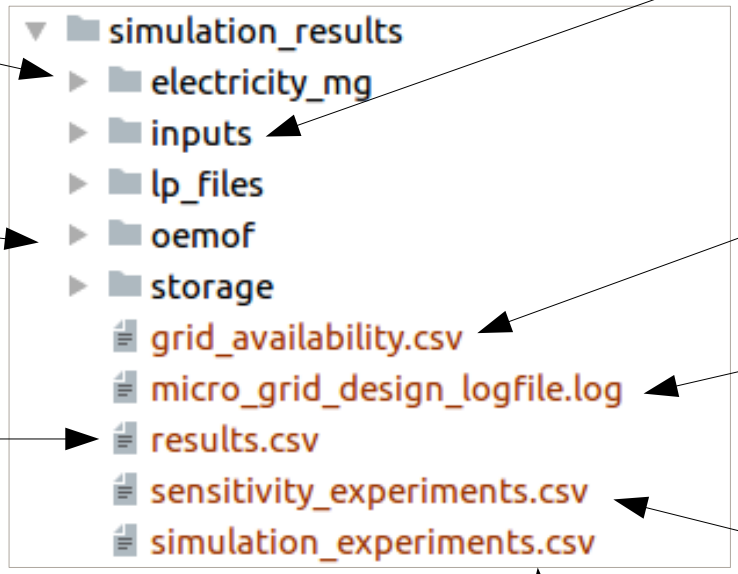
Terminal output

Copy of folder “inputs”, not including timeseries.csv from other locations!

Folder for .csv and .png files of electricity flows

.oemof result files, to enable restoring results

File with simulation results of all experiments: Performance, capacities, costs



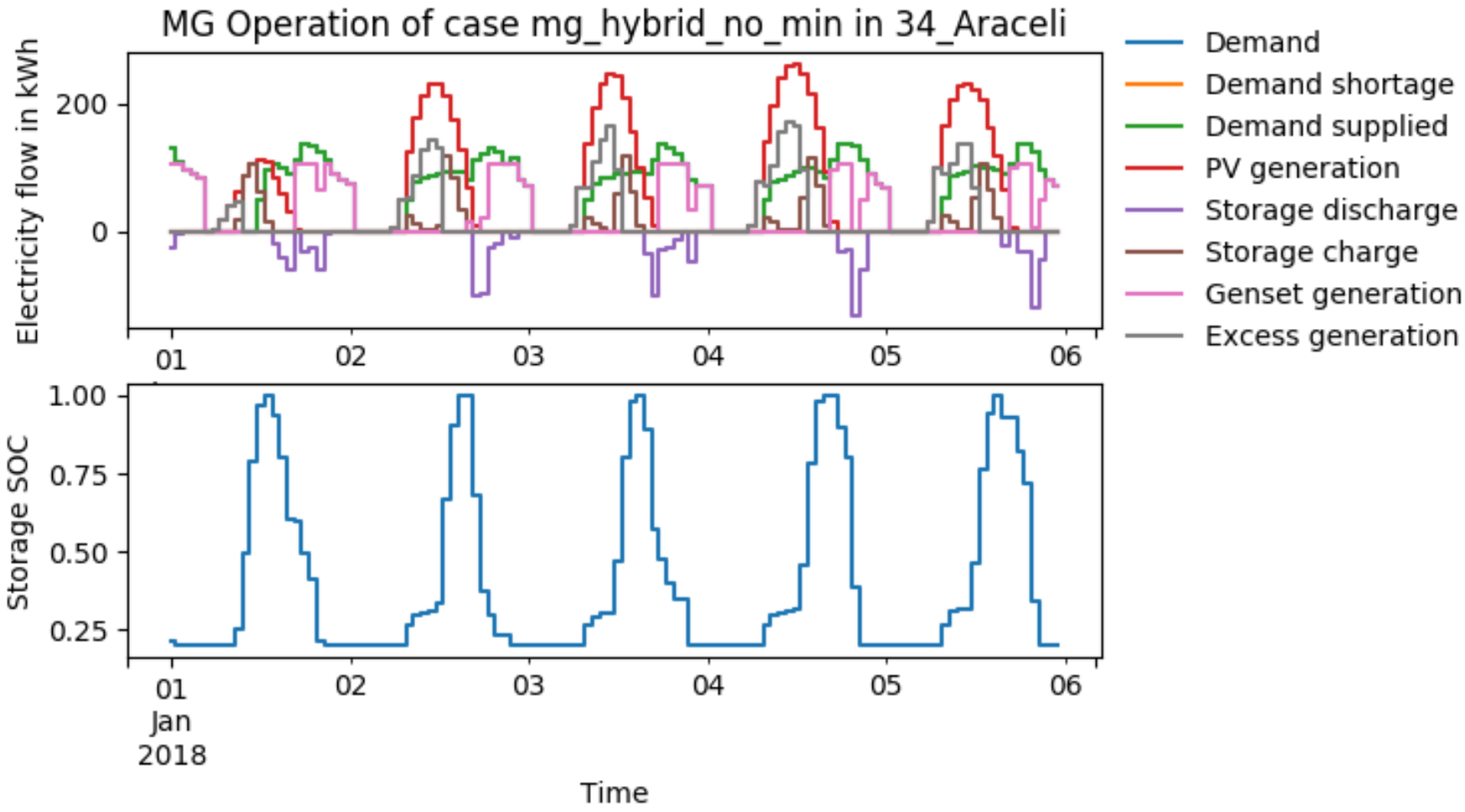
File with all randomized blackout timeseries

Logfile with Terminal and debug messages

All input values for all experiments (excluding timeseries)

Senstivity parameters of all experiements

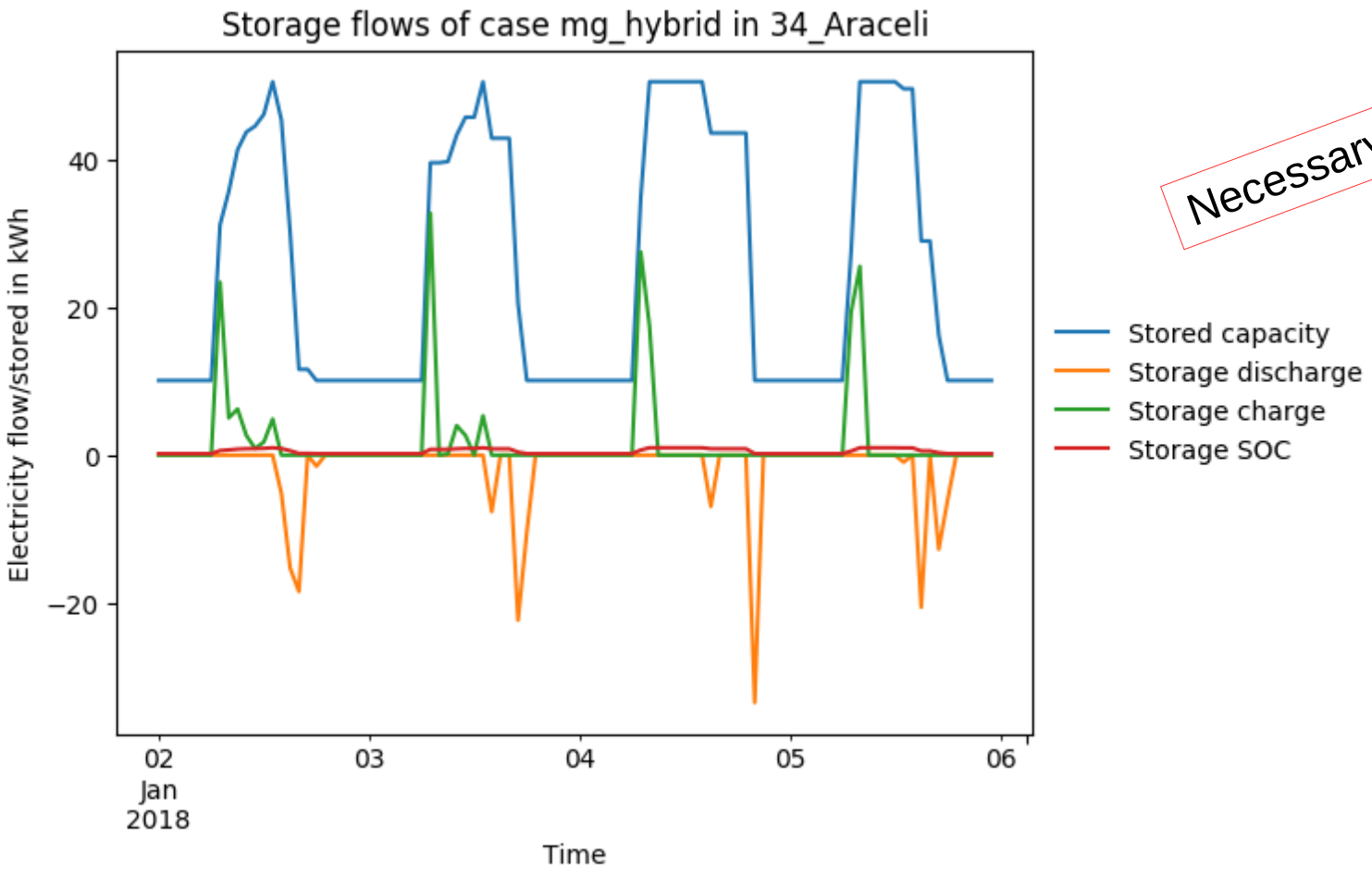
Auto-generated graphs: Energy flows



Agenda

- Installation and setup
- Background and parameters
- Case definitions and settings
- Executing simulation and output
- **Final remarks**

Auto-generated graphs: Storage



Necessary feature?

Agenda

- Installation and setup
- Background and parameters
- Case definitions and settings
- Executing simulation and output
- **Final remarks**

Shortage and penalty costs

Penalty < generation costs: Shortage preffered

= **penalty costs have to be chosen adequately!**

Ie. as high as...

- Expected LCOE/revenue
- Slightly higher as electricity price of central grid

Perfect foresight

Oemof-optimization

based on perfect foresight

of variable generation

→ Ie. storage charged right before blackout

→ Influences sizing and dispatch

Rolling time horizon optimization

currently not possible with oemof.

Accounting for shortage

Shortage can be any share of demand

→ Without demand management: **Blackout**!

Similar destabilization

through excess generation

AC/DC bus in micro grids

Currently: Electricity bus of micro grid is AC

→ No DC bus included

→ Inverter losses have to be accounted for in

- PV timeseries and
- Battery charge efficiency

Questions or remarks?

License

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