CMET
Center for Microbial Ecology and Technology

CAPTURE
Centre for Advanced Process Technology for Urban REsource recovery

FACULTY OF BIOSCIENCE ENGINEERING

Linking on site water recovery options to key resilience drivers using the OSiRIS tool

A C++ modelling approach available as standalone application

Seppe Ongena 21/10/24

De Watergroep

Image credit: WRF

Contents (click for link)

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OSiRIS: what is it?

OSiRIS Model and current OSiRIS App

- High flexibility with building blocks, configurable in .json file:
  - Water tanks: volume, pre-filled or not, is tracked over time with pollutant concentration
  - Treatments and pumps: simplified, based on “specsheet”
  - Applications (e.g. toilet):
    - Water use: any tank or external source
    - Wastewater production: any tank or external sink, adds pollutant to source water
    - Different IE per application → multiple applications = household and/or community
    - Actor (pump, treatment, gravity, tap pressure) provides flow
  - Sources: 2 types
    - Catchment: catchment area with pollutant concentration and collection efficiency
    - Tap: tap water source with pollutant concentration
  - Sinks: e.g., sewer system, infiltration, collection trucks
  - PV system: installed panel capacity (kWp), battery, efficiencies

OSiRIS: what is it?

OSiRIS Model and current OSiRIS App

- High flexibility with building blocks (contd.):
  - Controls:
    - Hysteresis or full control, for filling/emptying tank, increasing/decreasing tank concentrations
    - Separate limits for locally produced and grid energy, e.g. grid as back-up
    - Any number of steps (e.g. first treatment, then pumping to other tank, then infiltration)

- Highly efficient C++ model
  - Rapid simulation
  - 12 seconds for 10 years @ 15 min resolution (350 000 time points, 114 000 000 datapoints on Intel i5-1145G7)
  - Water and pollutant balances for error checks
  - Streaming in & out of data: low RAM memory use, potential for online data streaming

OSiRIS: what is it?

OSiRIS Model and **current OSiRIS App**

Standalone app (.exe, Windows)

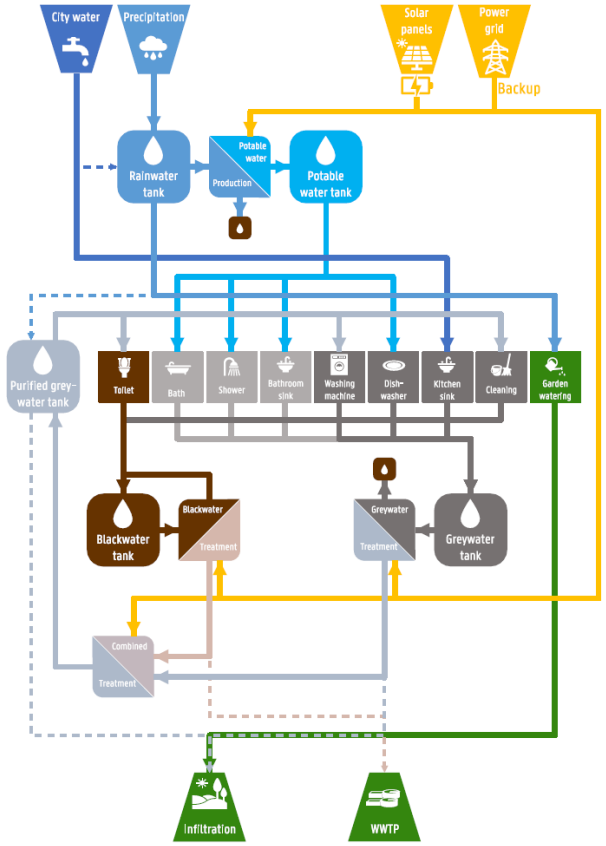
- User interface for scenario management and comparison based on KPI
- Scheme automatically adapts to user input
- Simulation results displayed in graphs
- Results, settings, and graphs saved to file

Pre-configured household from building blocks

- Most model parameters configurable
- Default pollutant = chloride
- Modifiable from centralized to extremely decentralized

Sub-models built-in:

- Diurnal water usage patterns: enables use of high-resolution precipitation data(15 min)
- Garden watering based on insolation (~plant transpiration)
- Insolation and cloud models if insolation data is unavailable



What is it ***not*** for?

Complex modeling of wastewater treatment

- e.g. distinction between recalcitrant and degradable organics not *currently* possible
- Degradation is implemented in model (can be used separately), but not released in app

Design tool for dimensioning volumes/treatments/photovoltaics

- Not straightforward *currently*
- Main focus = scenario comparison
- Possible through trial-and-error
- Future “design mode” potential

Smart control of rainwater tank refilling/emptying (e.g. RainPlus project)

- Full refill when empty
- Implementation of more dynamic control possible in future

OPEX/CAPEX estimation

App layout

OSiRIS

App Load/Save Simulation

Current scenario 8 - Extreme dec. + BW reuse

Datasets | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

Load data — Success!

Simulate current — Simulations complete!

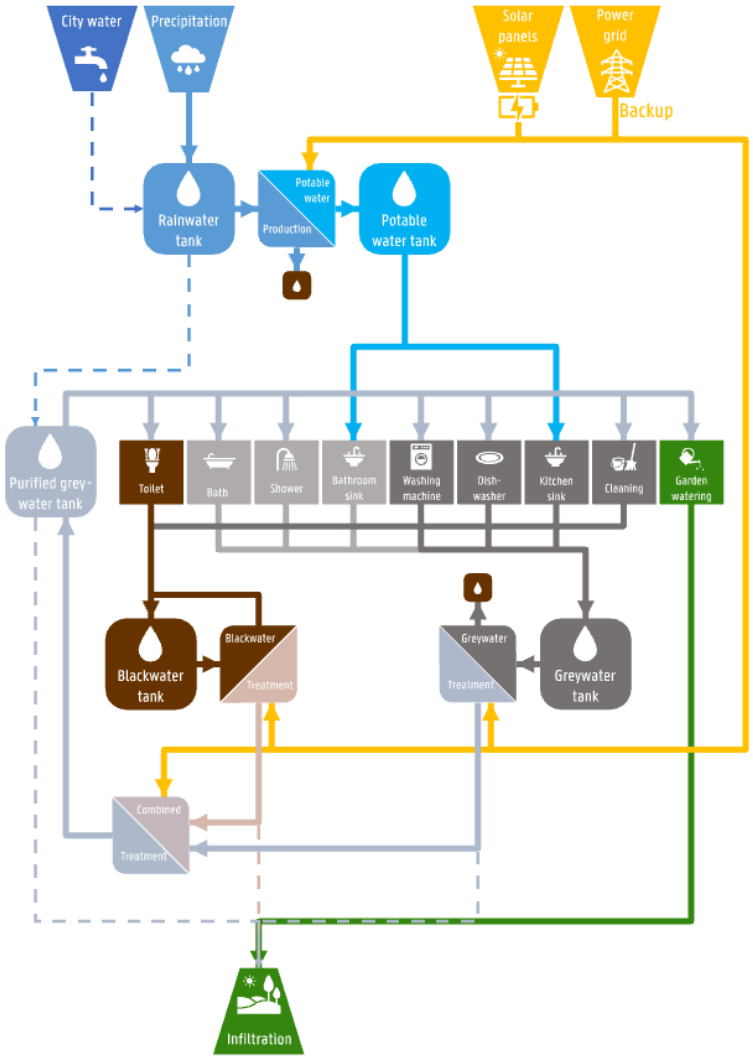
Add | Load | Simulate | Delete | Save

Select	Scenario	Name	Simulated
☐	1	0 - Centralized	☑
☐	2	1 - Rainwater use	☑
☐	3	2 - GW treatment for reuse	☑
☐	4	3 - Dec. treatment and infil.	☑
☐	5	4 - PW production	☑
☐	6	5 - GW reuse and PW production	☑
☐	7	6 - Dec. treatment + PW	☑
☐	8	7 - Extreme dec.	☑
☐	9	8 - Extreme dec. + BW reuse	☑

Log

[2025-07-10 10:34:24] Scenario 4/9 completed in 25.1659 seconds
[2025-07-10 10:34:45] Scenario 5/9 completed in 20.6135 seconds
[2025-07-10 10:35:17] Scenario 6/9 completed in 32.3333 seconds
[2025-07-10 10:35:41] Scenario 7/9 completed in 23.7611 seconds
[2025-07-10 10:36:07] Scenario 8/9 completed in 25.7667 seconds
[2025-07-10 10:36:33] Scenario 9/9 completed in 25.9487 seconds
[2025-07-10 10:36:33] All scenarios were successfully simulated.

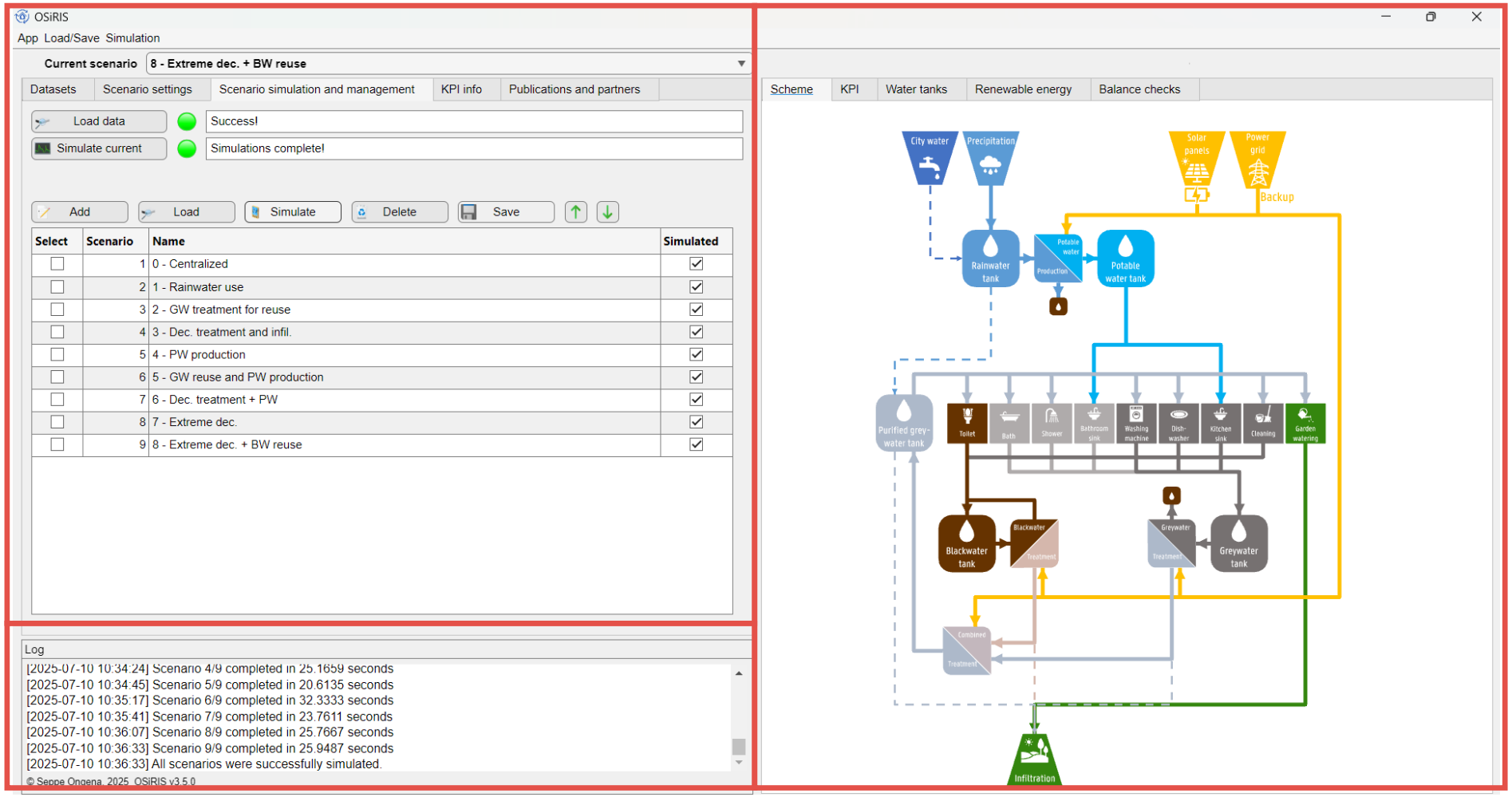
Scheme | KPI | Water tanks | Renewable energy | Balance checks



Main Interface

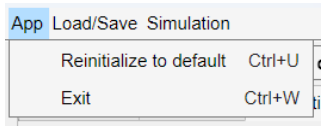
1.0 User input side (changing settings, scenario's,…)

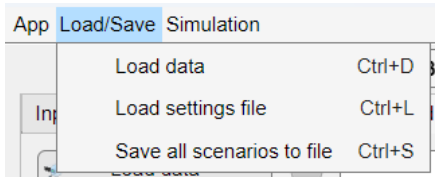
2.0 Graph side (display results, current scheme,…)

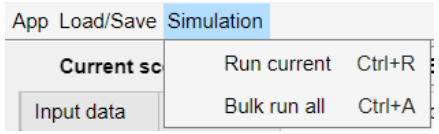


Log (simulation progress, errors, info,…)

1.0 User input side







Main menus (quickly select actions, shortcut keys possible)

Tab selector

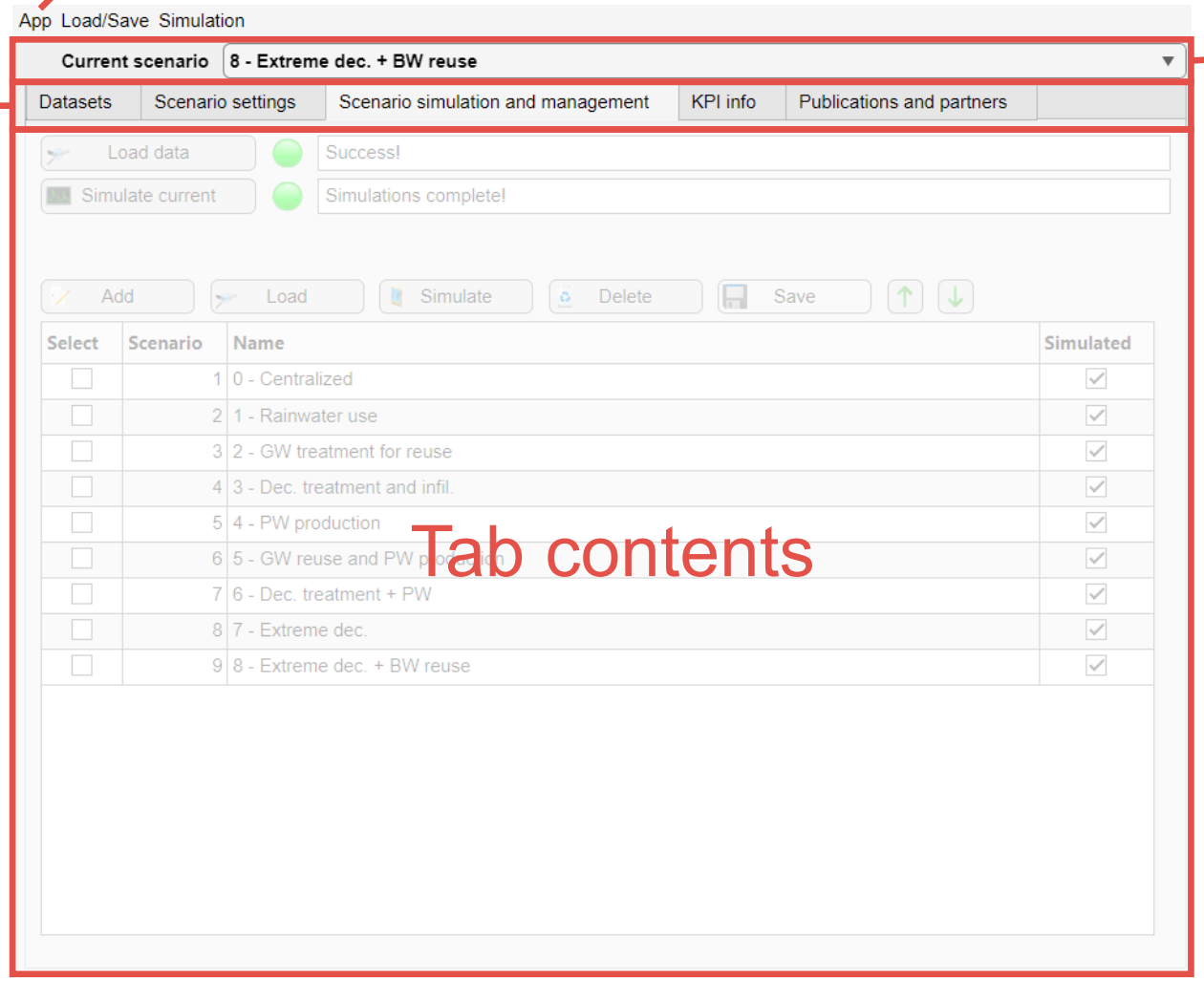
1.1 Datasets

1.2 Scenario settings

1.3 Scenario simulation and management

1.4 KPI info

1.5 Publications and partners

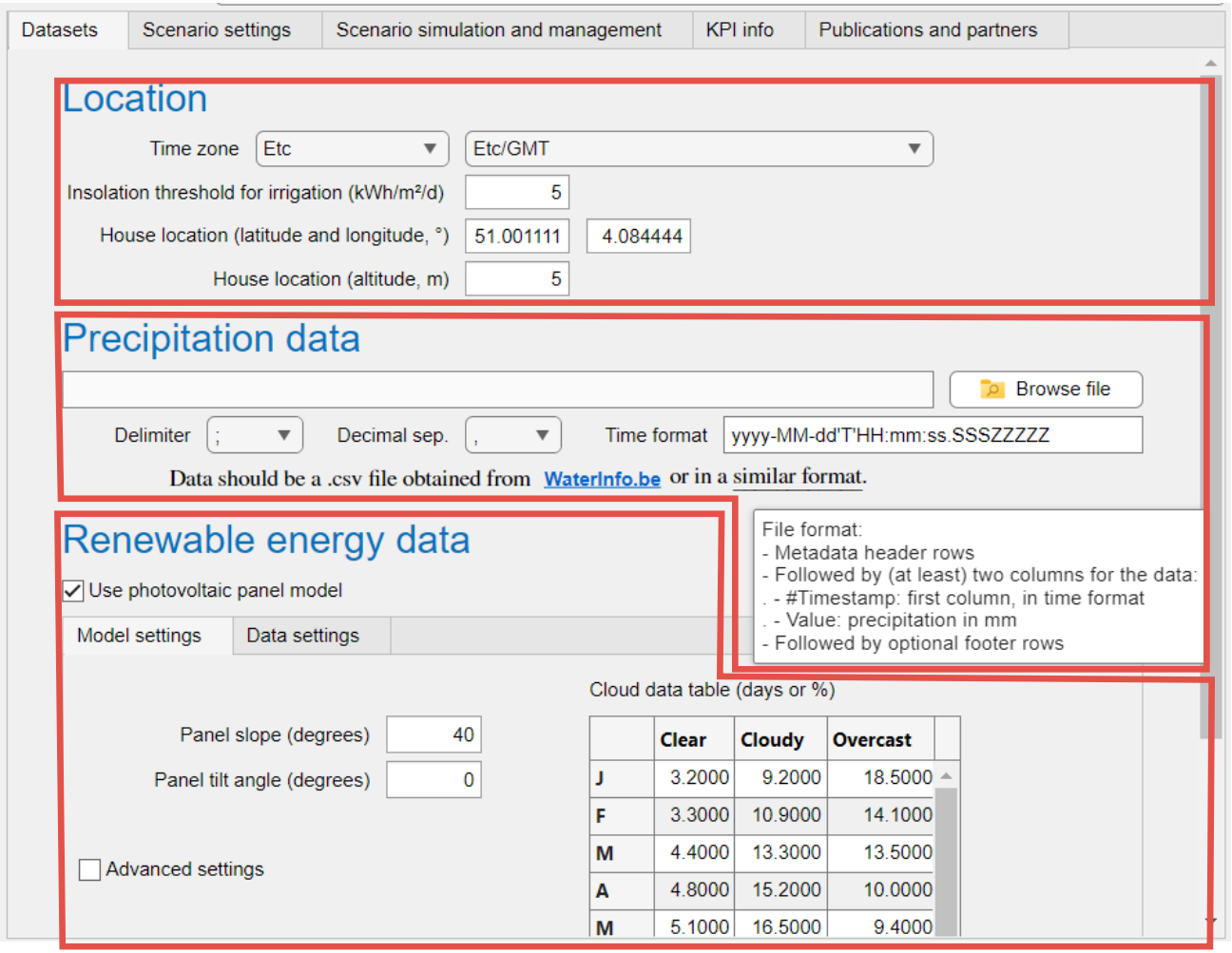


Tab contents

Scenario selector

select scenario for editing, copying settings to new scenario, displaying plots,…

1.1 Datasets



Location

Timezone for data reading
Irrigation threshold for garden watering
House location for solar model

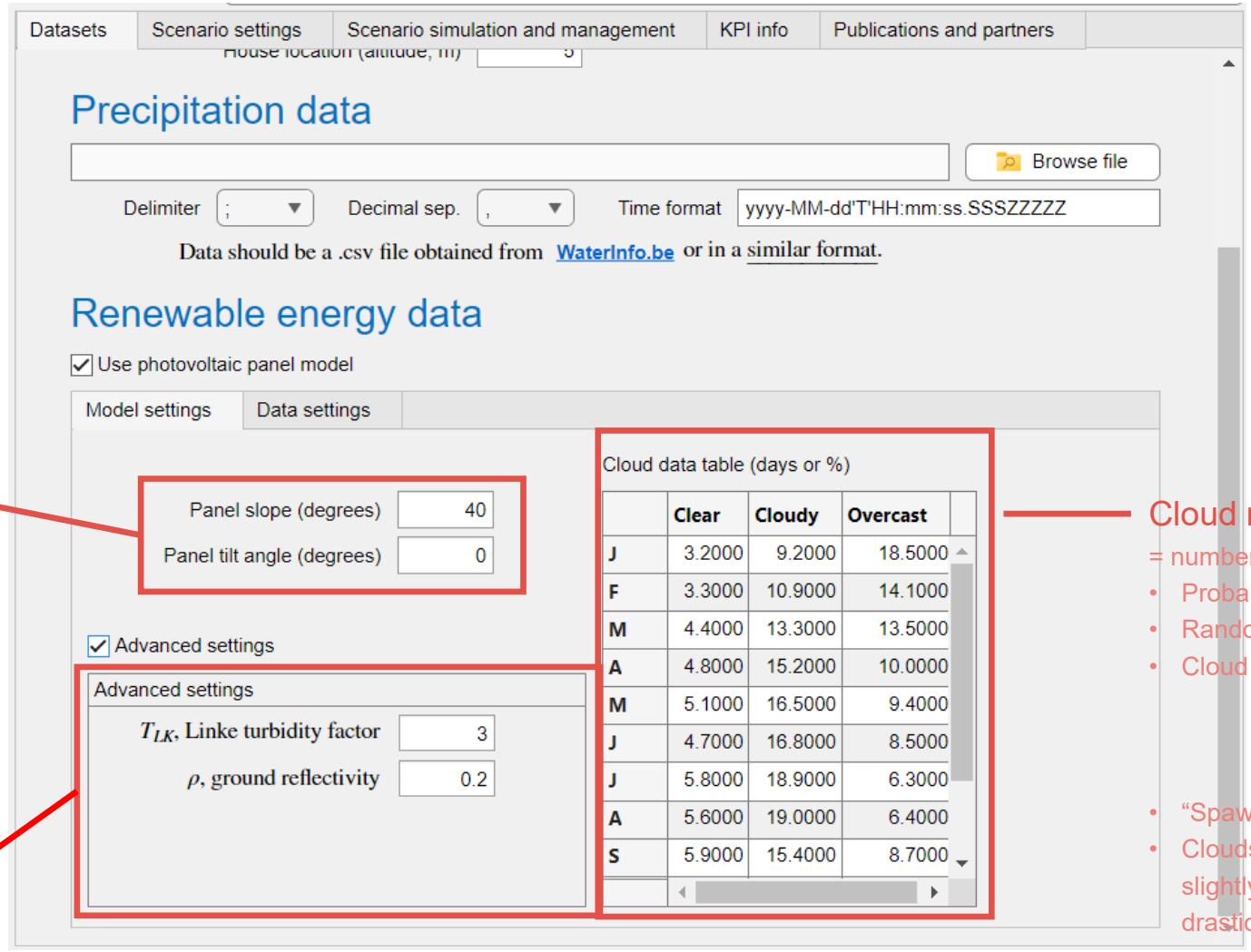
Precipitation file selection

including browse button, file options, required format tooltip

Renewable energy data

option between PV model (1.1.1) and datafile (1.1.2)

1.1.1 Datasets: PV model



Solar panel orientation

(Solar panel technological settings in House characteristics (1.2.1))

Cloud model parameters

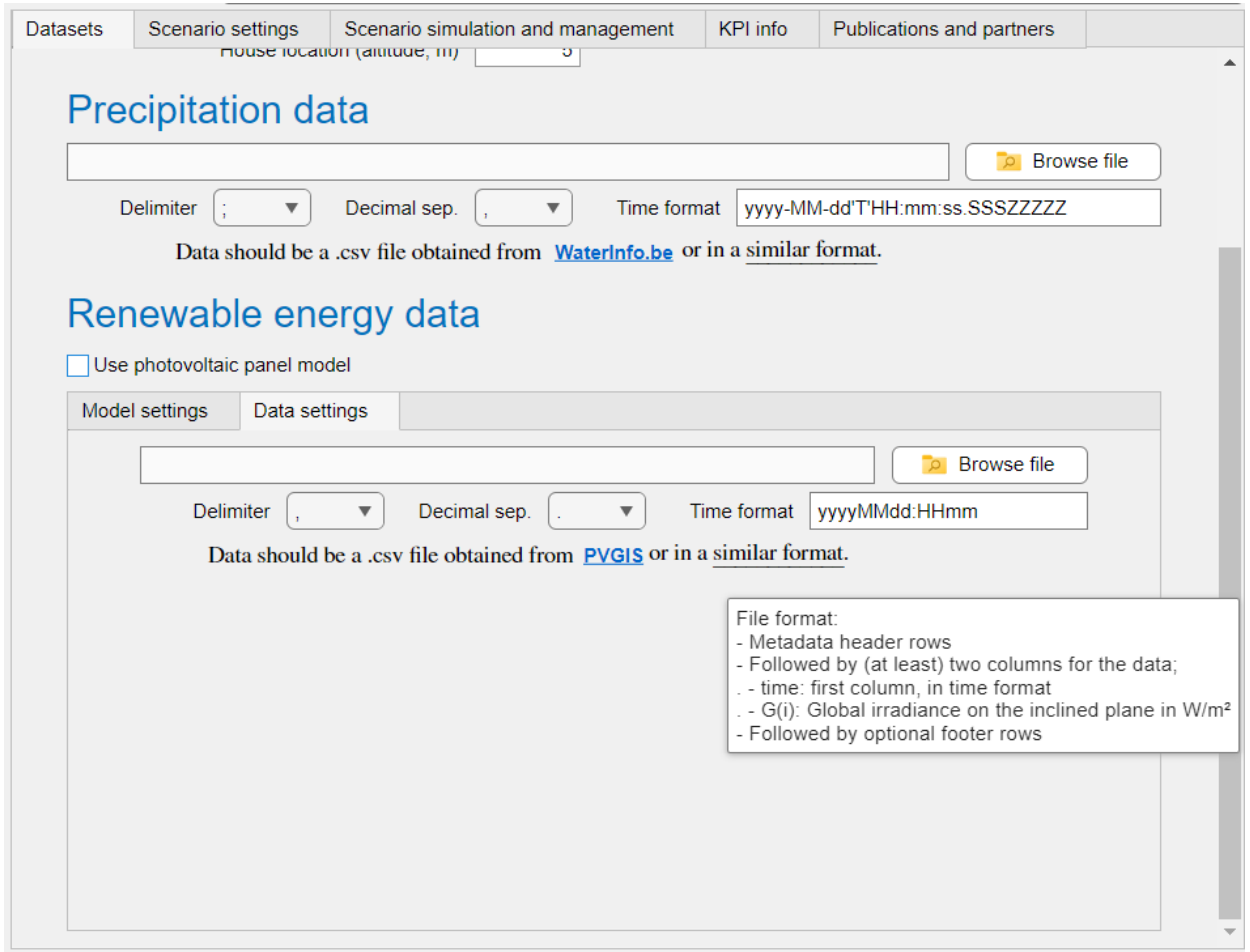
= number or % of clear, cloudy, and overcast days

- Probabilistic model
- Random number to determine type of day
- Cloud probability:
  - 0-20% on a clear day
  - 20-80% on a cloudy day
  - 80-100% on overcast day
- "Spawn" in cloud: value 0 or 1
- Clouds eliminate beam insolation, slightly increase diffuse insolation, drastically reduce reflections

(Advanced) Atmospheric model parameters

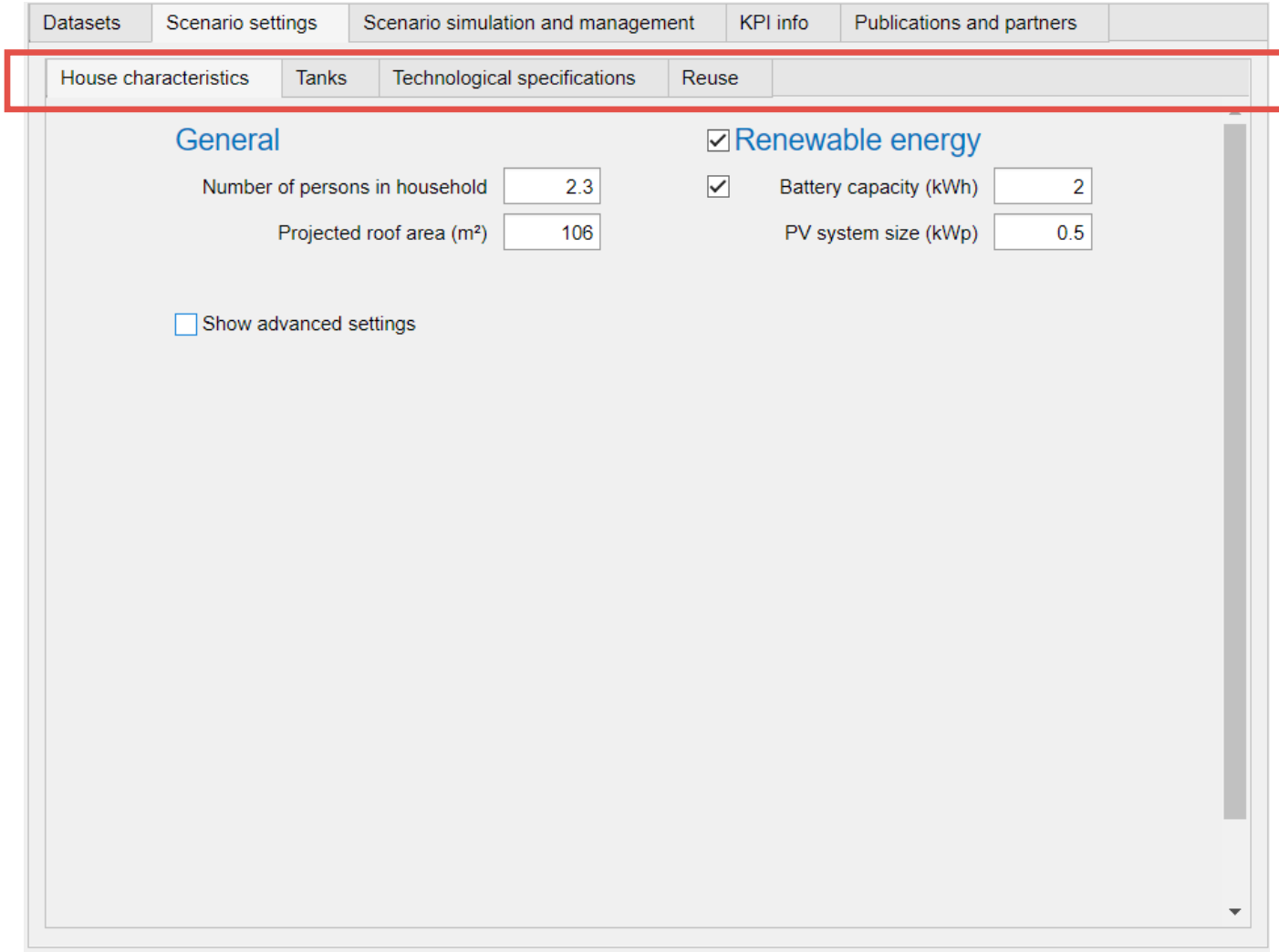
- For calculation of total panel irradiation
  = beam, diffuse and reflected irradiance
- Based on trigonometric model

1.1.2 Datasets: renewable energy



Similar to precipitation data

1.2 Scenario settings



Subtab selection

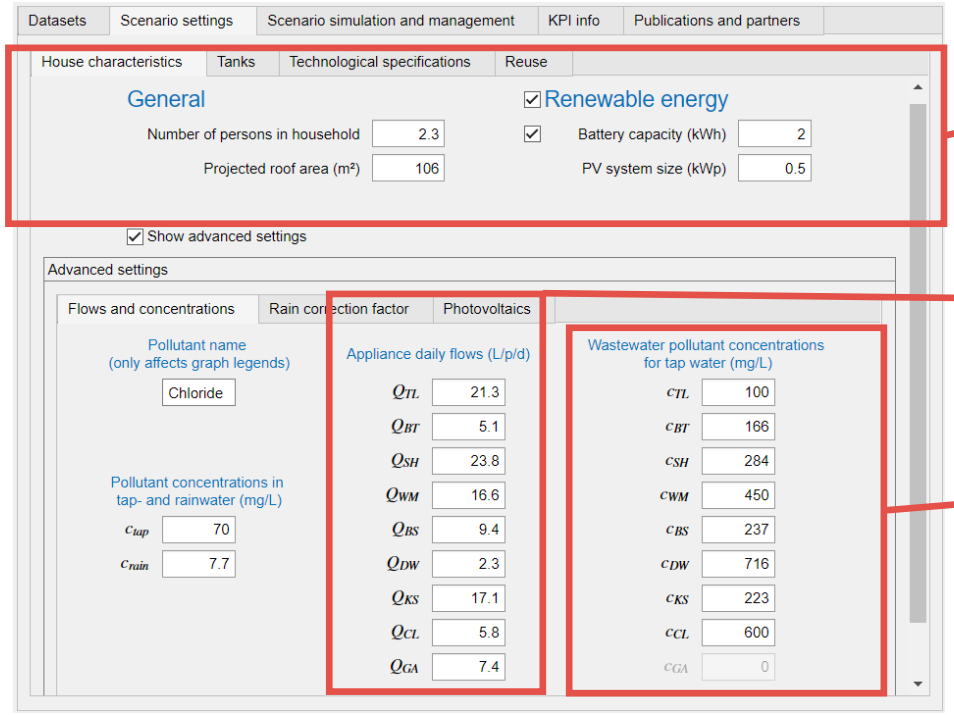
1.2.1 House characteristics

1.2.2 Tanks

1.2.3 Technological specifications

1.2.4 Reuse

1.2.1 Scenario settings: house characteristics



General settings and renewable energy settings

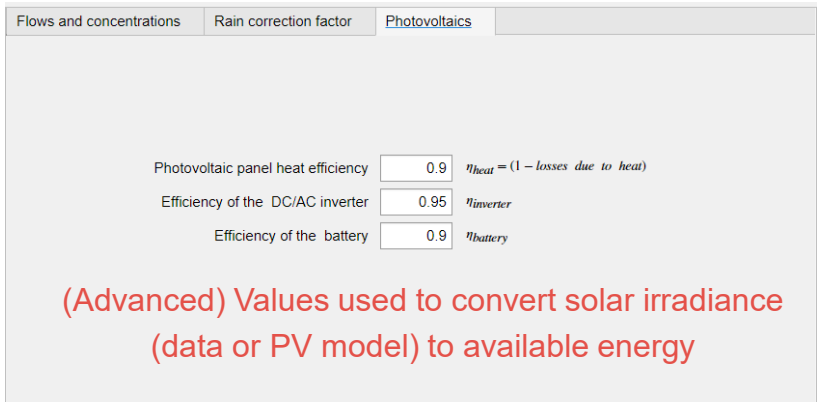
(i.a. checkbox whether to use renewable energy and whether to use a battery)

(Advanced) Total daily flows

(used to calculate diurnal flow values based on literature patterns)

(Advanced) Pollutant concentrations for tap water

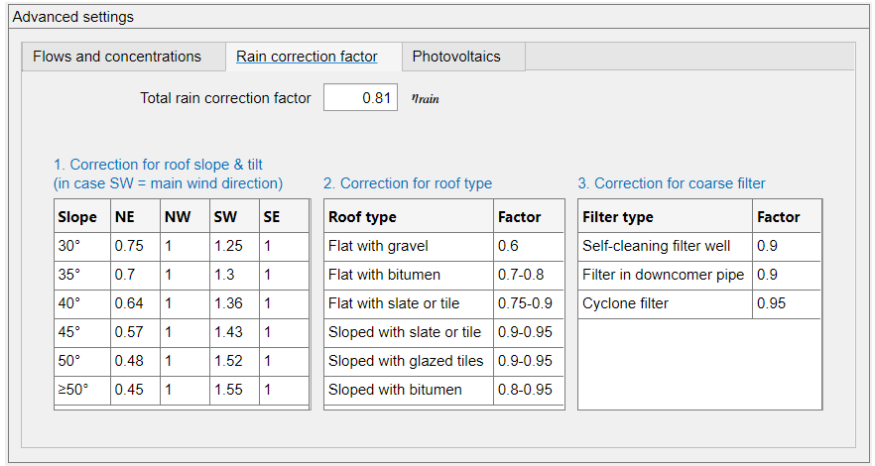
(the model will subtract the tap water concentration from these values and add the background concentration from the used source water streams)



(Advanced) Values used to convert solar irradiance (data or PV model) to available energy

(Advanced) Rain correction factor tables

(for main wind/rain direction, evaporation, filter efficiencies,…)

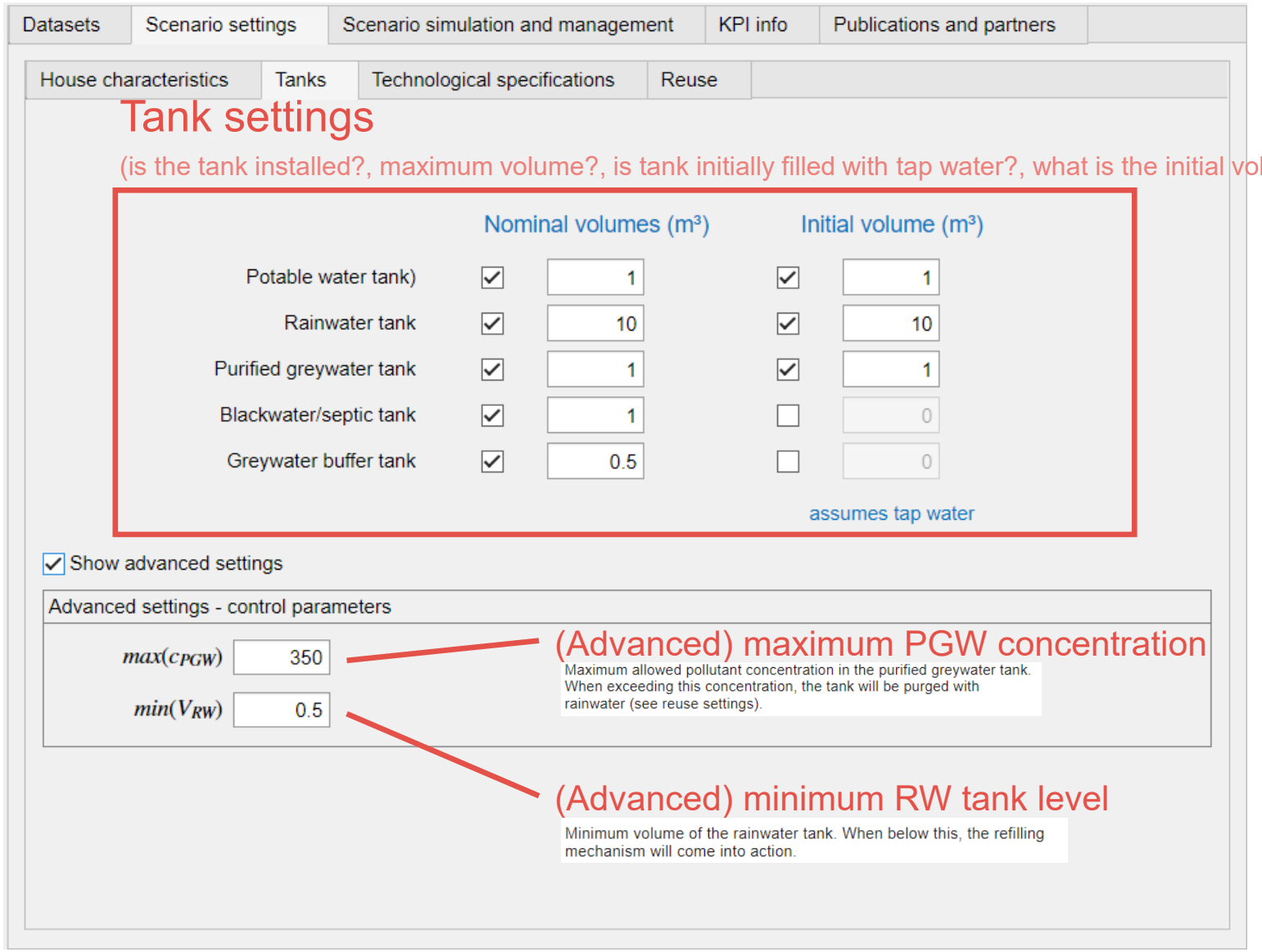


Slope	NE	NW	SW	SE
30°	0.75	1	1.25	1
35°	0.7	1	1.3	1
40°	0.64	1	1.36	1
45°	0.57	1	1.43	1
50°	0.48	1	1.52	1
≥50°	0.45	1	1.55	1

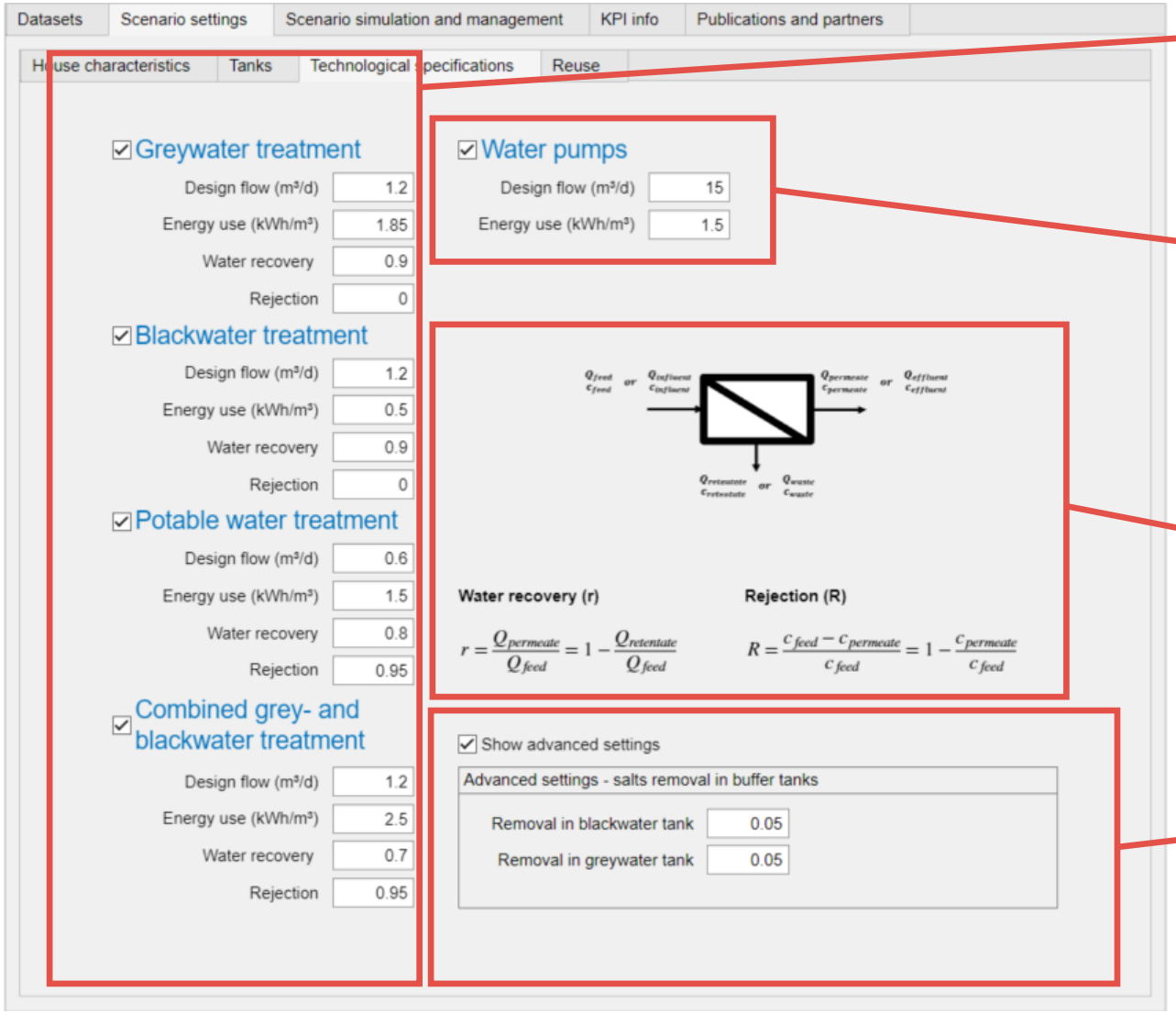
Roof type	Factor
Flat with gravel	0.6
Flat with bitumen	0.7-0.8
Flat with slate or tile	0.75-0.9
Sloped with slate or tile	0.9-0.95
Sloped with glazed tiles	0.9-0.95
Sloped with bitumen	0.8-0.95

Filter type	Factor
Self-cleaning filter well	0.9
Filter in downcomer pipe	0.9
Cyclone filter	0.95

1.2.2 Scenario settings: tanks



1.2.3 Scenario settings: technological specifications



Technology selection

(select whether a technology is present and fill its primary specifications)

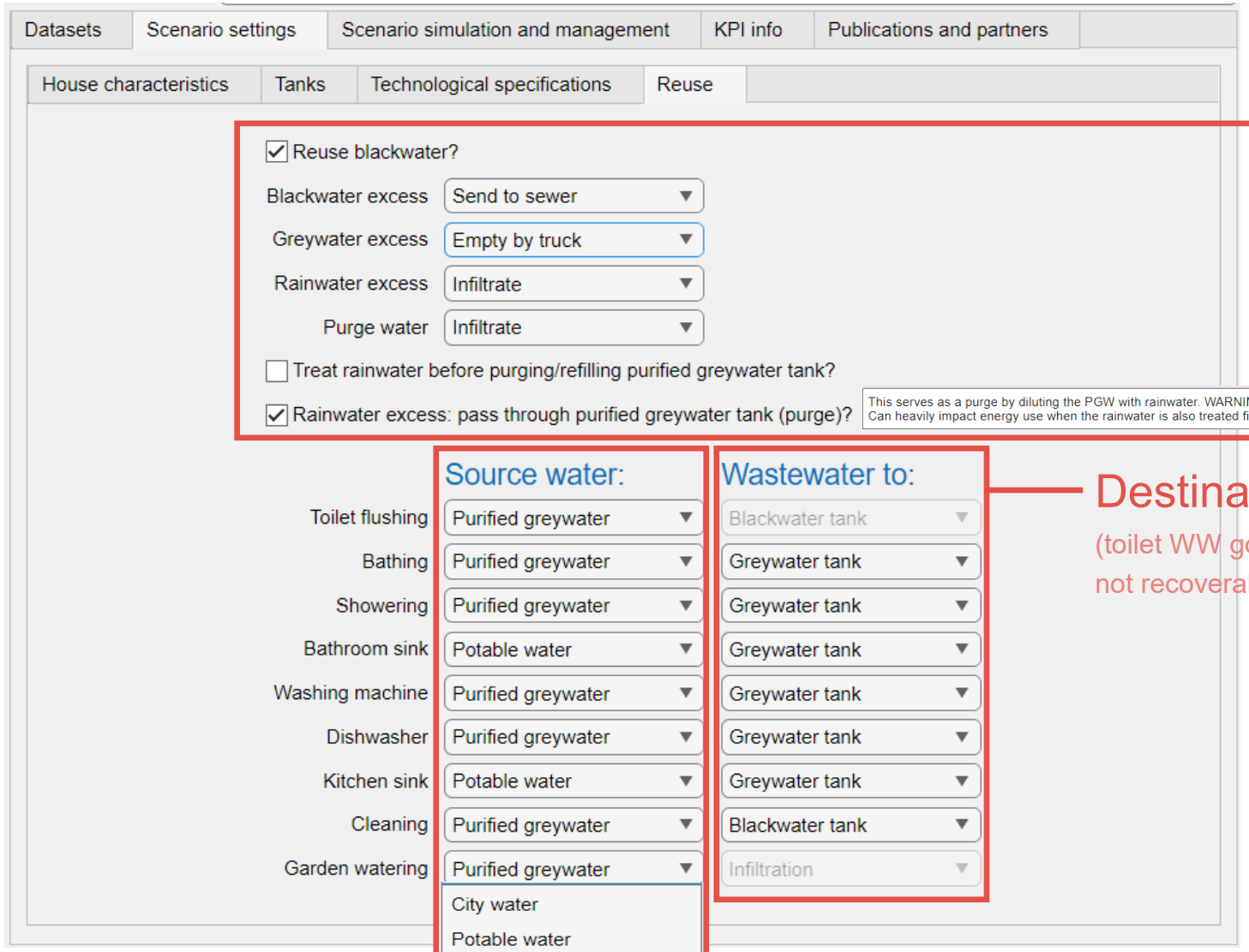
Water pumps

(whether to consider pump energy for i.a. rainwater pumping to applications or when a treatment is not installed)

Theoretical explanation and visualisation of the primary specifications recovery and removal

(Advanced) Salts removal due to sedimentation

1.2.4 Scenario settings: reuse



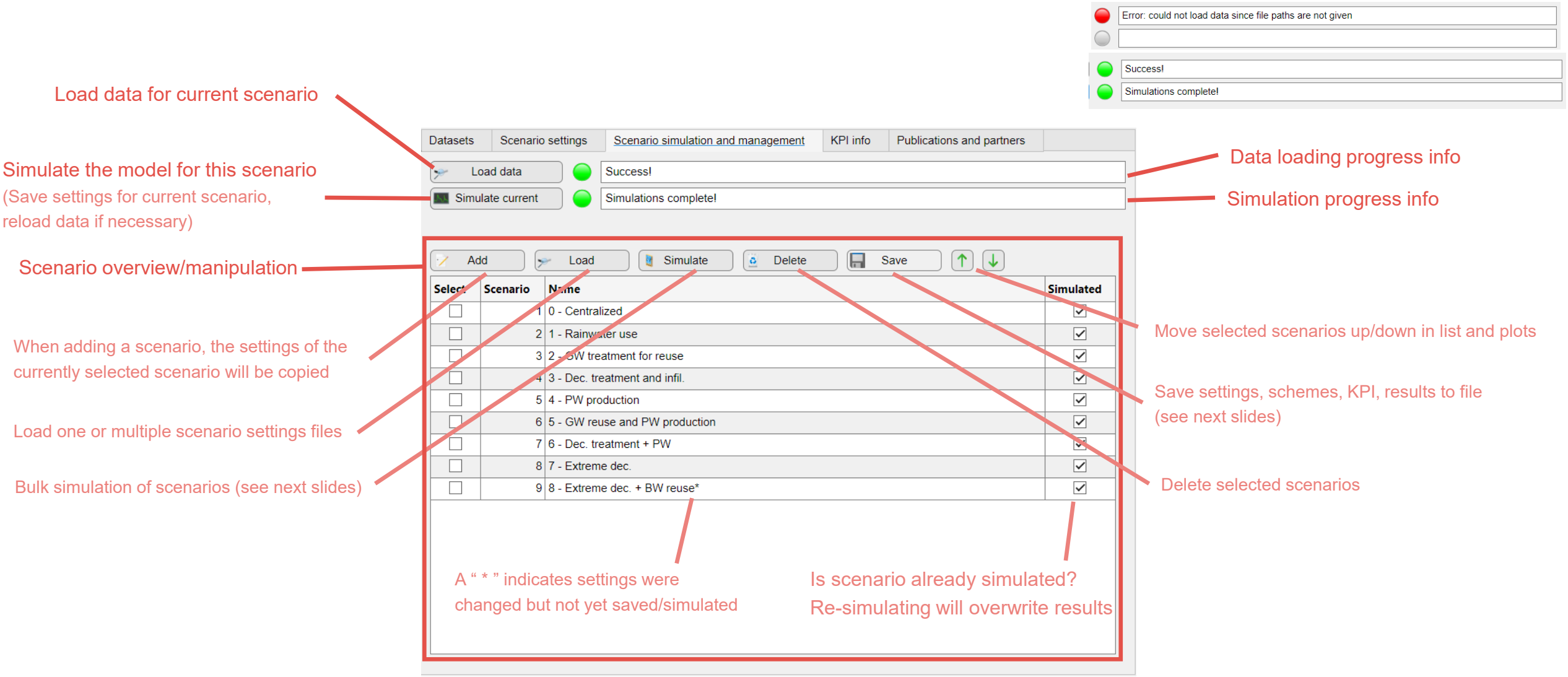
General reuse settings

Destination tank of wastewater after use

(toilet WW goes to blackwater tank per definition, gardening water is not recoverable)

Selection of water source per application

1.3 Scenario simulation and management



Bulk simulation

App Load/Save Simulation

Current scenario 8 - Extreme dec. + BW reuse

Datasets | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

Load data — Success!

Simulate current — Simulations complete!

Add | Load | Simulate | Delete | Save

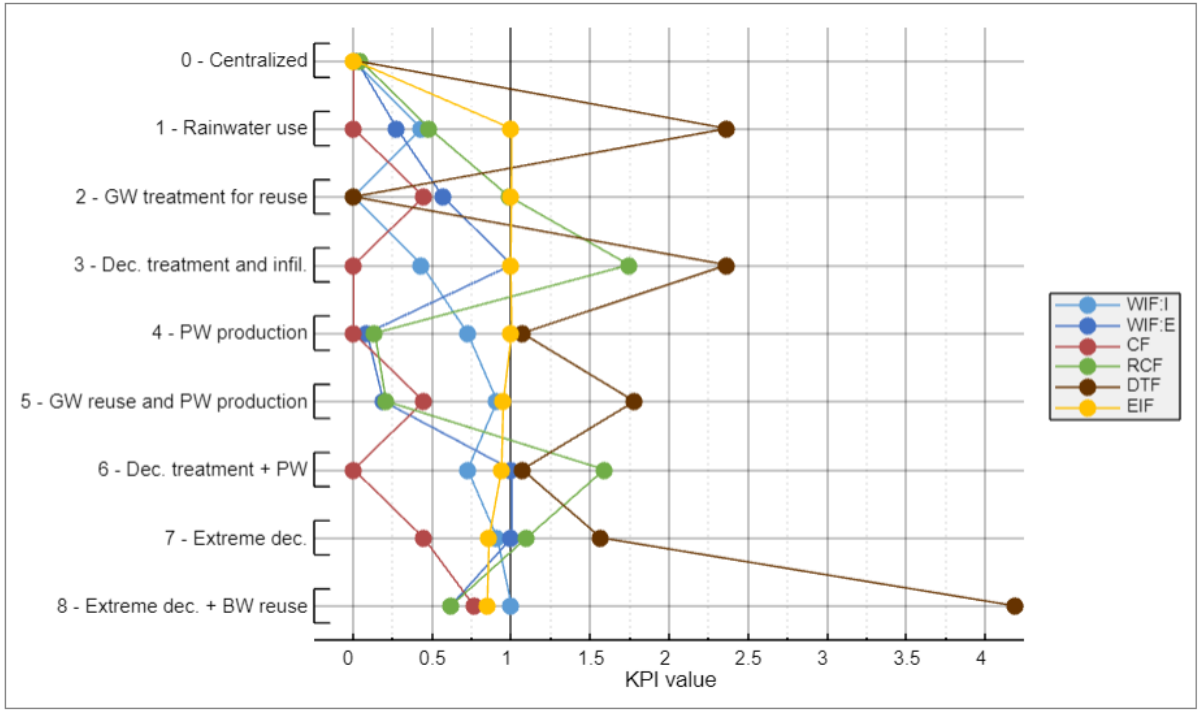
Select	Scenario	Name	Simulated
☐	1	0 - Centralized	☑
☐	2	1 - Rainwater use	☑
☐	3	2 - GW treatment for reuse	☑
☐	4	3 - Dec. treatment and infil.	☑
☐	5	4 - PW production	☑
☐	6	5 - GW reuse and PW production	☑
☑	7	6 - Dec. treatment + PW	☑
☑	8	7 - Extreme dec.	☑
☑	9	8 - Extreme dec. + BW reuse	☑

Log

```
[2025-07-10 11:16:39] Data file selected: precipitation
[2025-07-10 11:16:55] Data file selected: precipitation
[2025-07-10 11:16:59] Starting simulations...
[2025-07-10 11:16:59] Scenario 7 already simulated
[2025-07-10 11:16:59] Scenario 8 already simulated
[2025-07-10 11:17:43] Scenario 3/3 completed in 43.2828 seconds
[2025-07-10 11:17:43] All scenarios were successfully simulated.
```

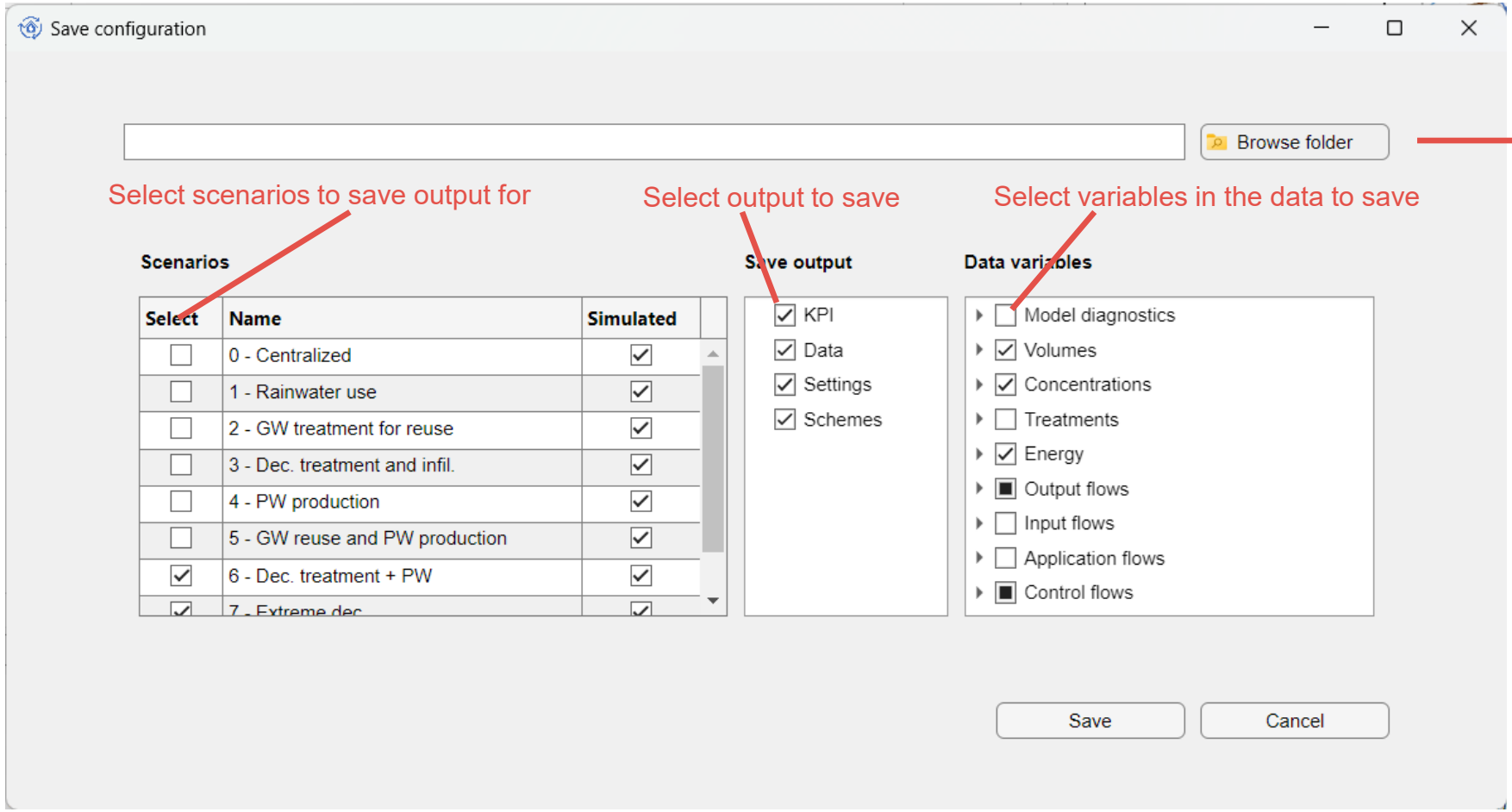

Scheme | KPI | Water tanks | Renewable energy | Balance checks

Configure



Scenario	WIF:I	WIF:E	CF	RCF	DTF	EIF
0 - Centralized	0	0.0180	0	0.0416	0	0
1 - Rainwater use	0.4306	0.2746	0	0.4791	2.3634	1.0000
2 - GW treatment for reuse	0	0.5654	0.4447	0.9857	0	0.9986
3 - Dec. treatment and infil.	0.4306	1.0000	0	1.7444	2.3634	0.9943
4 - PW production	0.7212	0.0847	0	0.1344	1.0668	1.0000
5 - GW reuse and PW production	0.9084	0.1885	0.4447	0.2062	1.7775	0.9473
6 - Dec. treatment + PW	0.7209	1.0000	0	1.5867	1.0668	0.9360
7 - Extreme dec.	0.9085	1.0000	0.4425	1.0945	1.5643	0.8573

Saving files: save dialog screen



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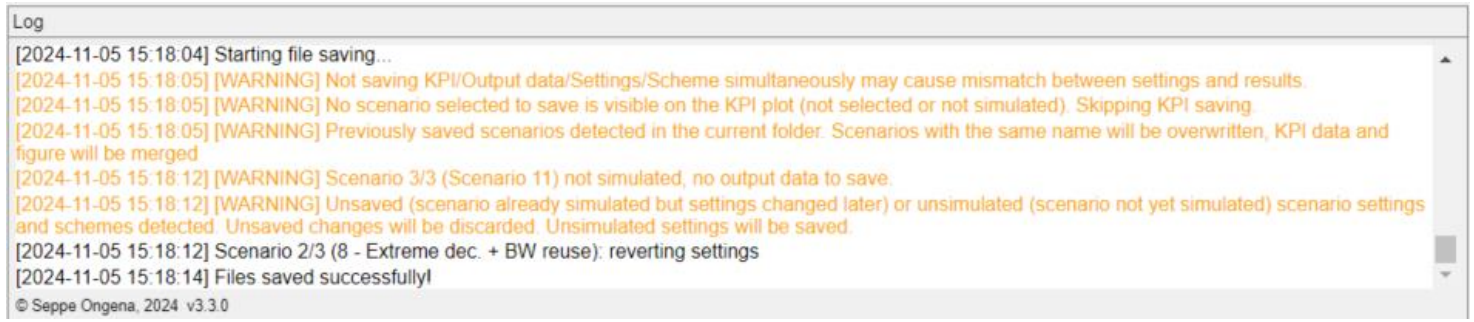
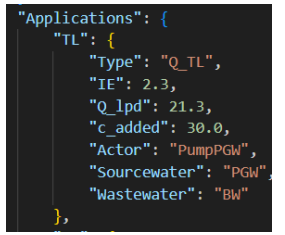
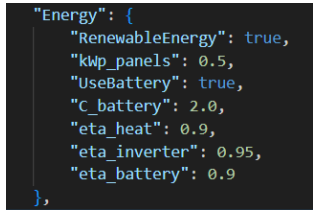
Saving files: output

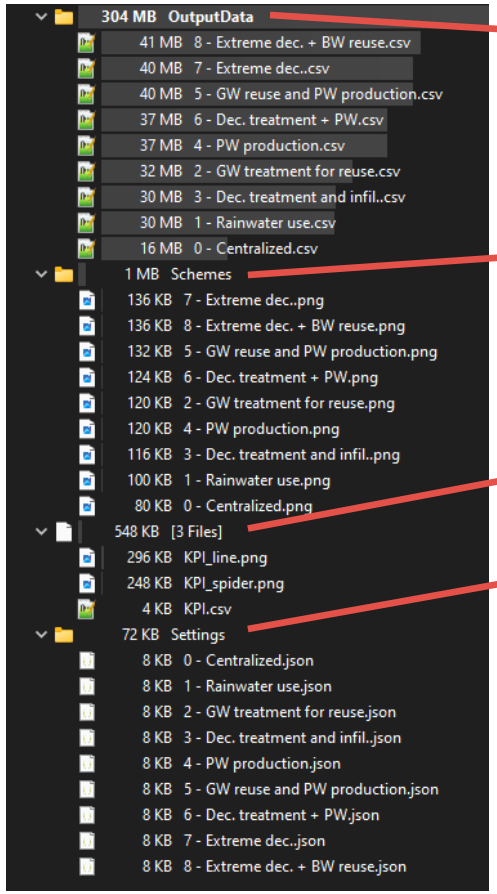


All possible warnings triggered





(full view - examples)



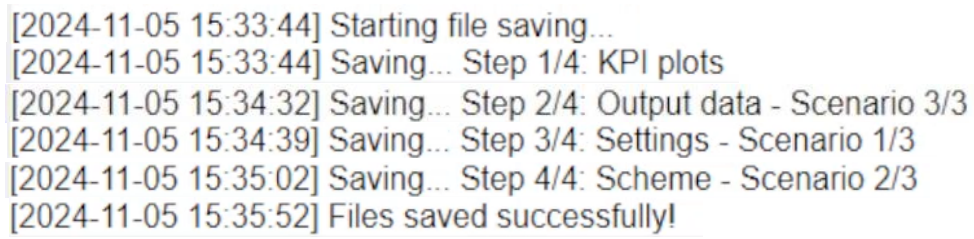
Datafiles: per scenario as .csv files, each variable = column

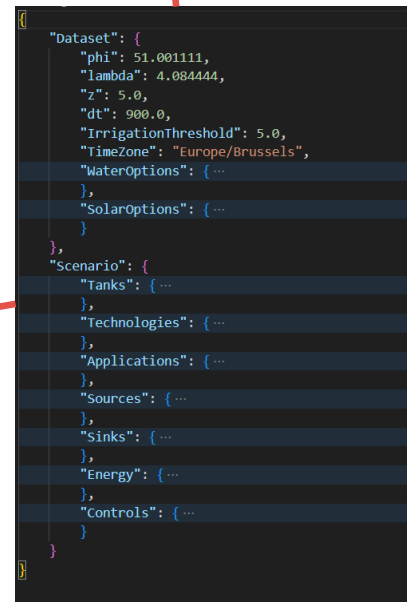
.png of schemes per scenario

KPI spider and line plot (.png) and KPI table (.csv)

Scenario settings as “human readable” .json files

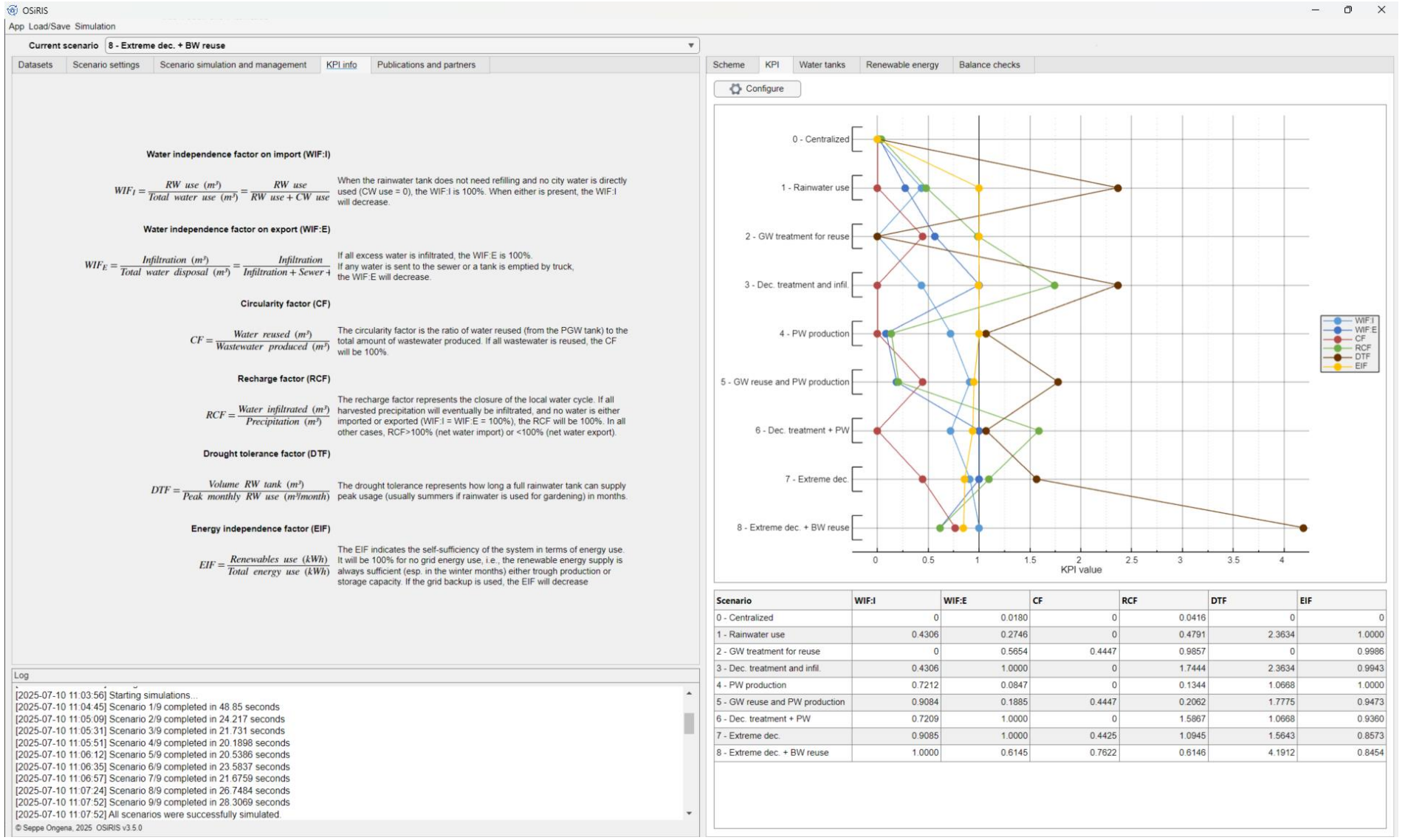
Progress is shown in log





(collapsed view)

1.4 KPI info

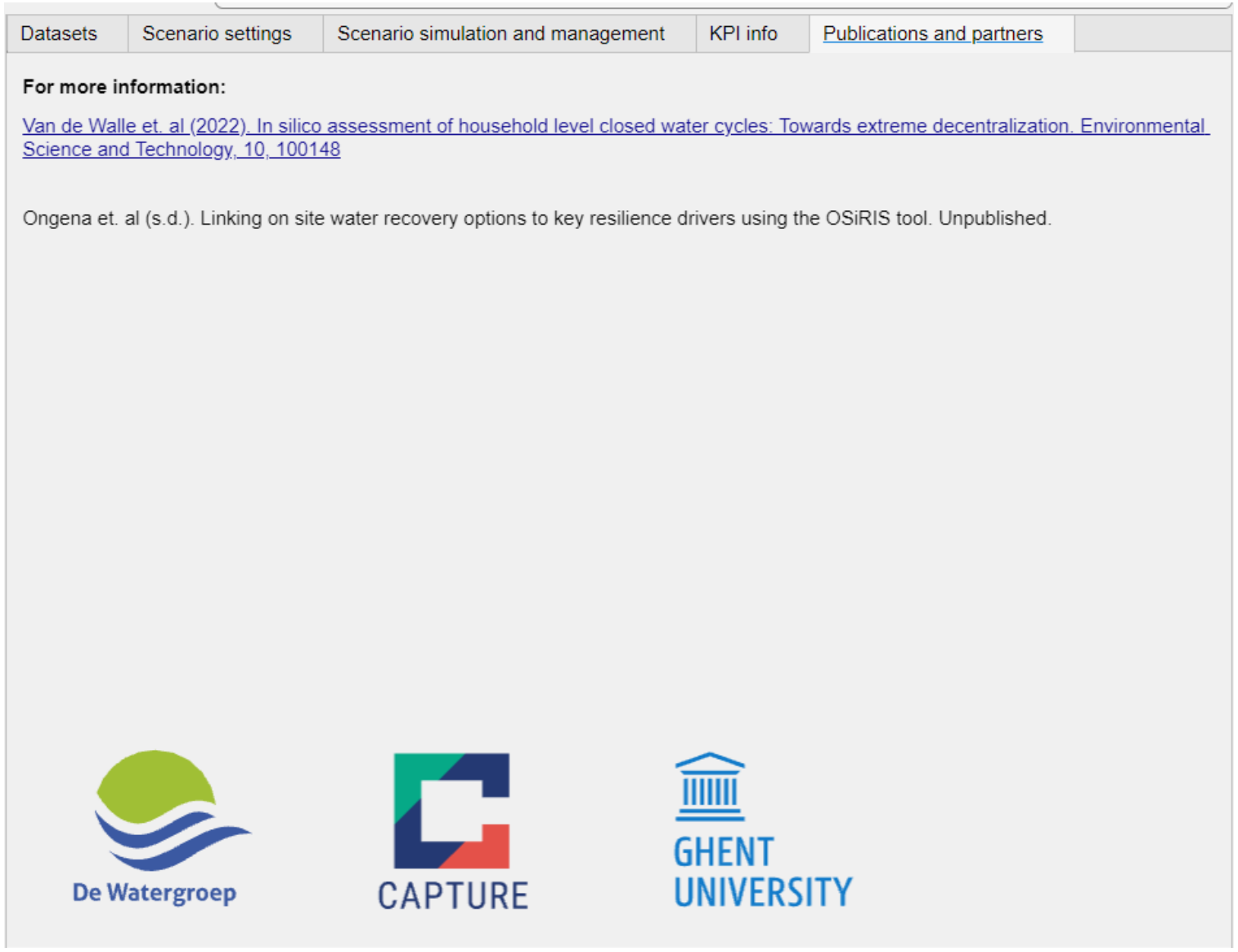


Scenario	WIF:I	WIF:E	CF	RCF	DTF	EIF
0 - Centralized	0	0.0180	0	0.0416	0	0
1 - Rainwater use	0.4306	0.2746	0	0.4791	2.3634	1.0000
2 - GW treatment for reuse	0	0.5654	0.4447	0.9857	0	0.9986
3 - Dec. treatment and infil.	0.4306	1.0000	0	1.7444	2.3634	0.9943
4 - PW production	0.7212	0.0847	0	0.1344	1.0668	1.0000
5 - GW reuse and PW production	0.9084	0.1885	0.4447	0.2062	1.7775	0.9473
6 - Dec. treatment + PW	0.7209	1.0000	0	1.5867	1.0668	0.9360
7 - Extreme dec.	0.9085	1.0000	0.4425	1.0945	1.5643	0.8573
8 - Extreme dec. + BW reuse	1.0000	0.6145	0.7622	0.6146	4.1912	0.8454

Best used in conjunction with KPI graph tab

(gives calculation method for each KPI and a brief explanation)

1.5 Publications and partners



List of publications with more in-depth information on model and used default values

List of contributing partners

2.0 Graph side

Tab selector

2.1 Scheme

2.2 KPI

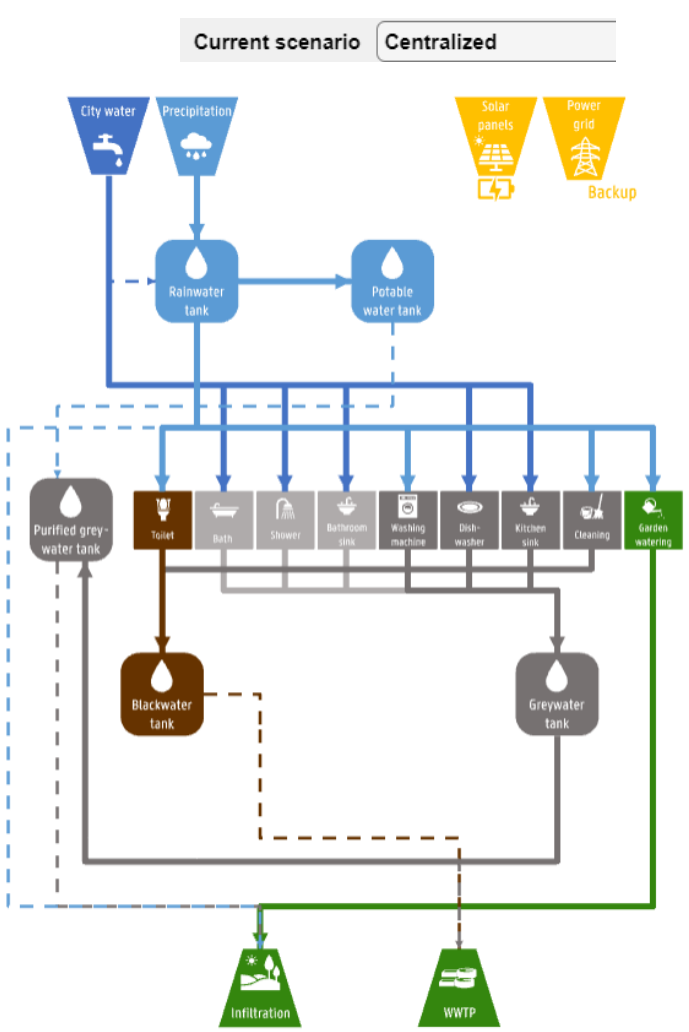
2.3 Water tanks

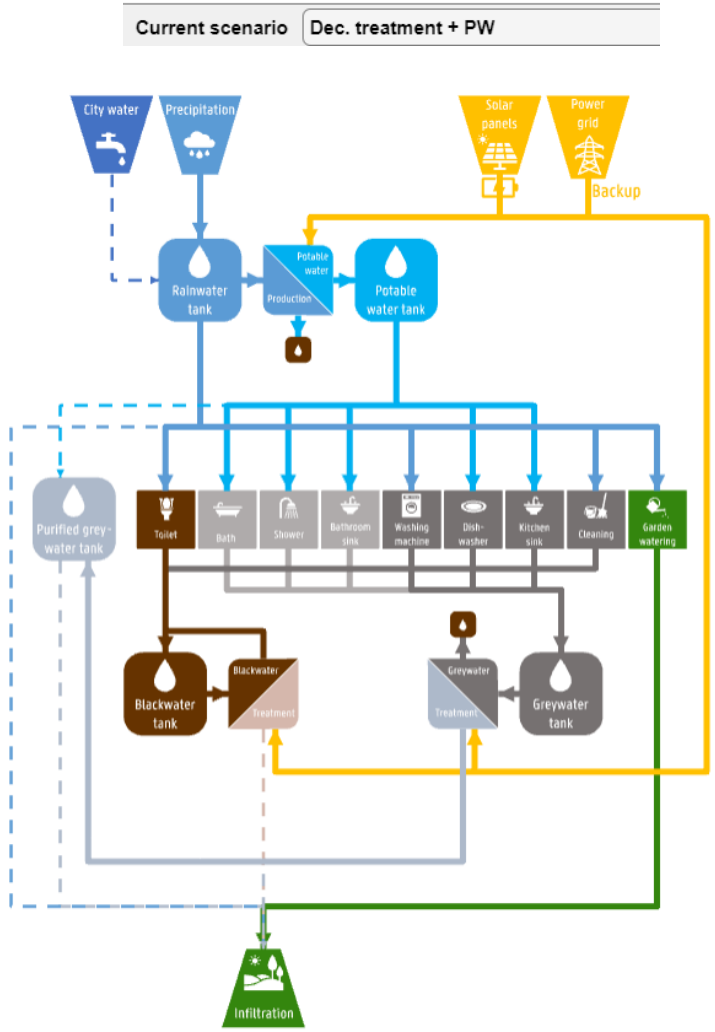
2.4 Renewable energy

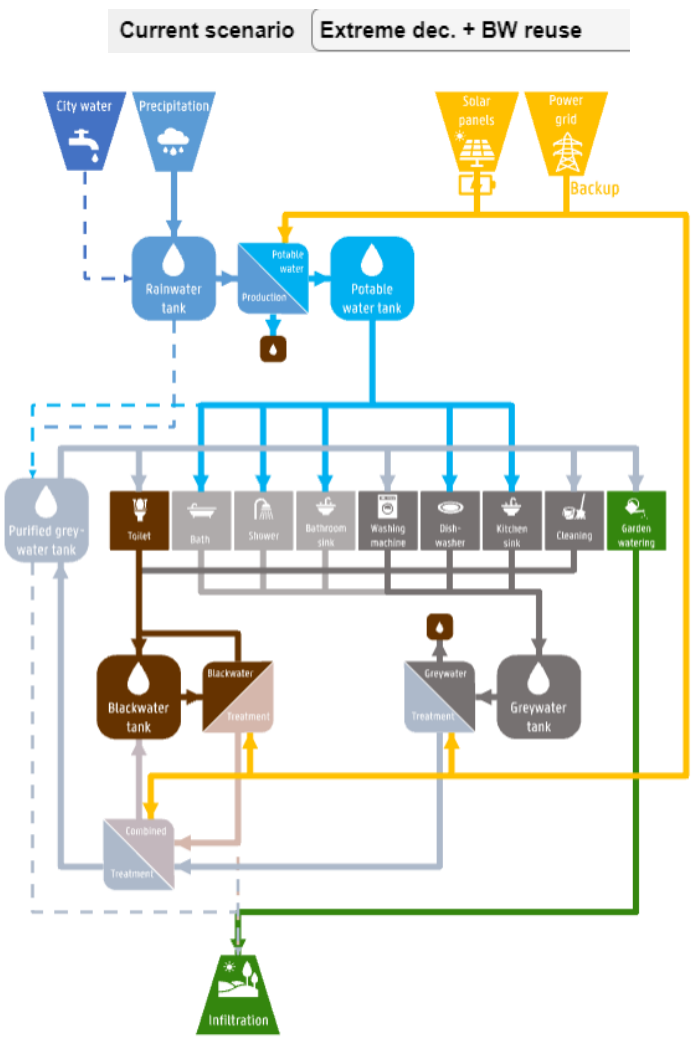
2.5 Balance checks

2.1 Graphs: scheme

Scheme updates based on selected settings

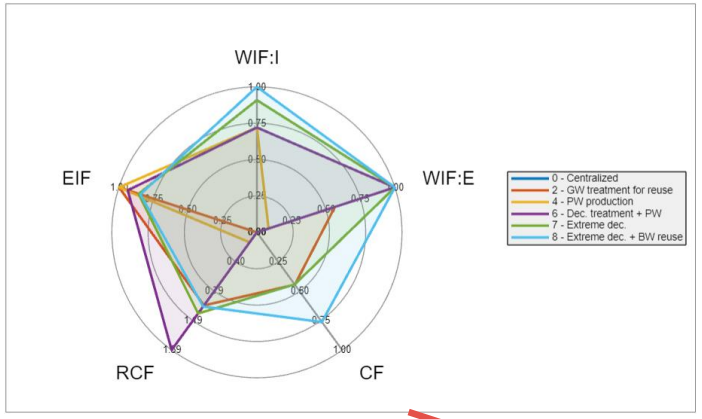




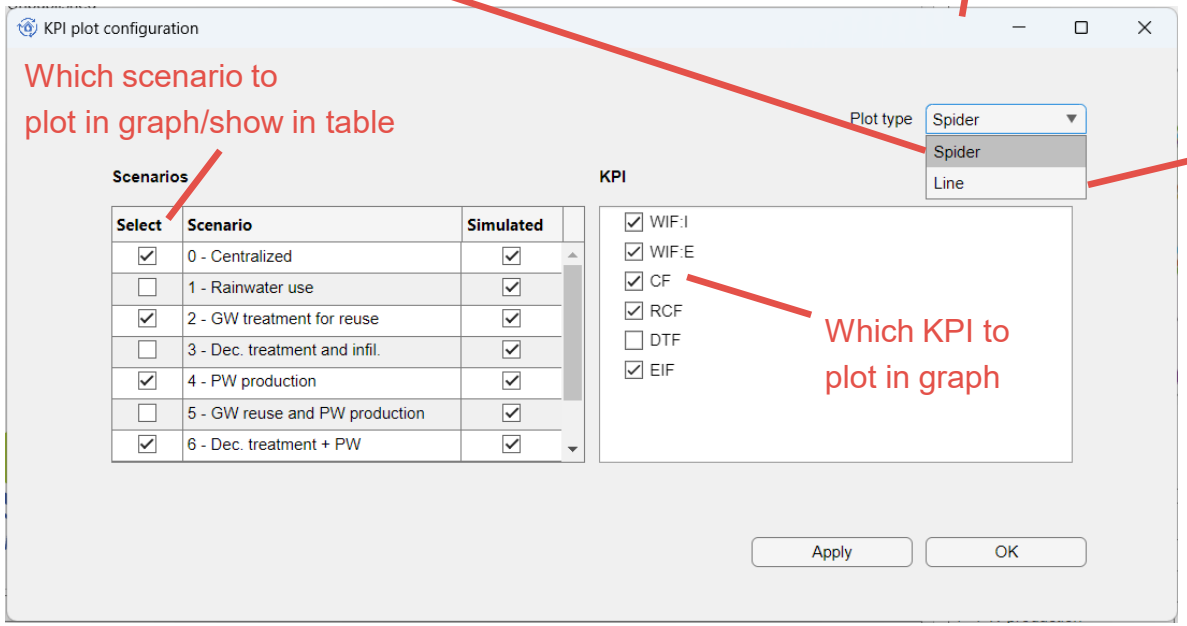


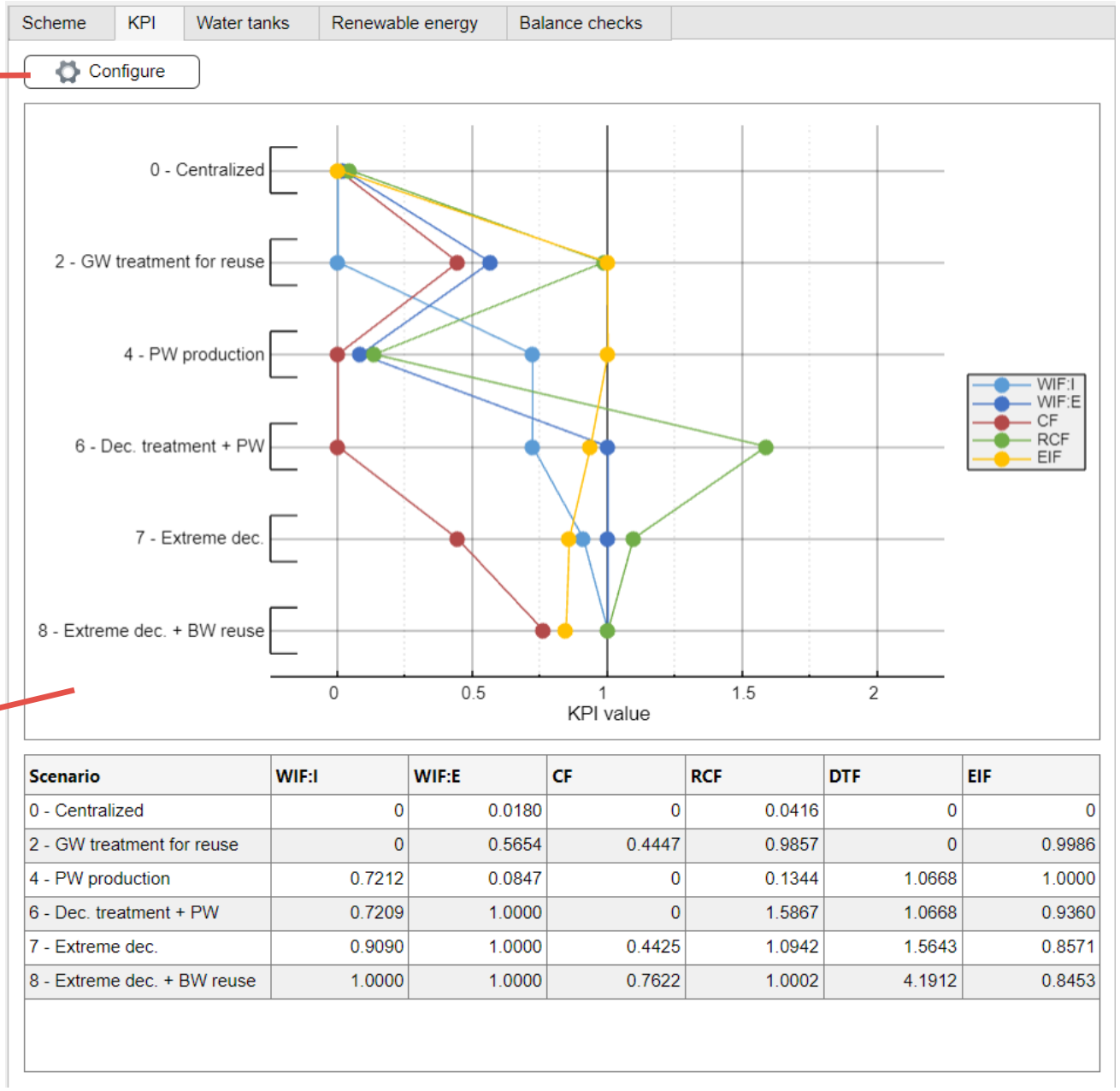
2.2 Graphs: KPI

Plot (line or spider), table



Configuration dialog





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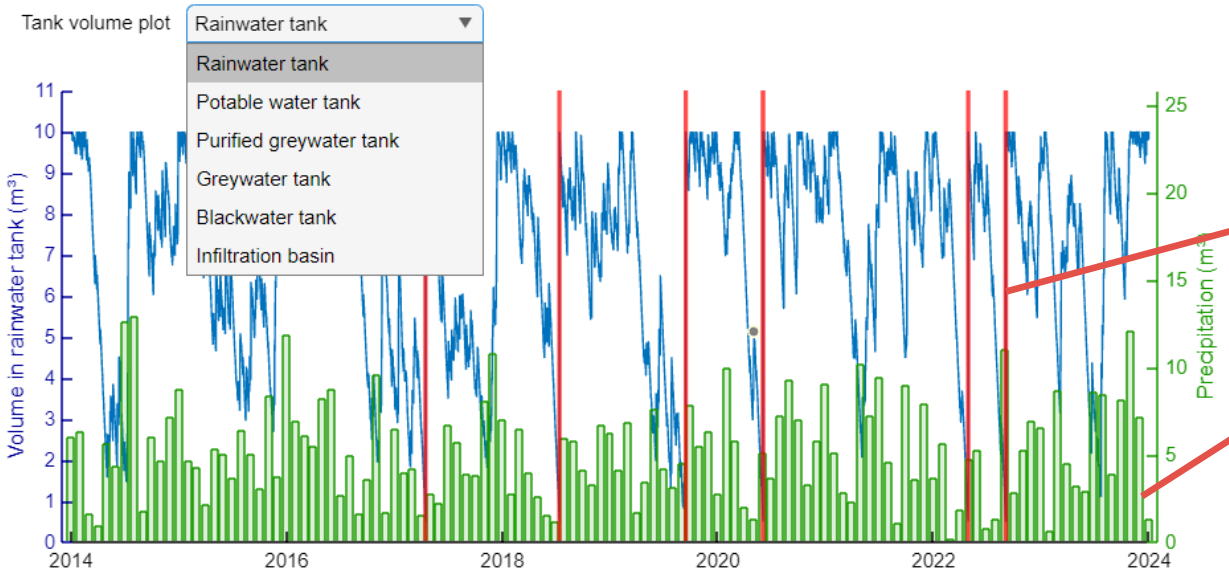
2 - GW treatment for reuse	0	0.5654	0.4447	0.9857	0	0.9986
4 - PW production	0.7212	0.0847	0	0.1344	1.0668	1.0000
6 - Dec. treatment + PW	0.7209	1.0000	0	1.5867	1.0668	0.9360
7 - Extreme dec.	0.9090	1.0000	0.4425	1.0942	1.5643	0.8571
8 - Extreme dec. + BW reuse	1.0000	1.0000	0.7622	1.0002	4.1912	0.8453

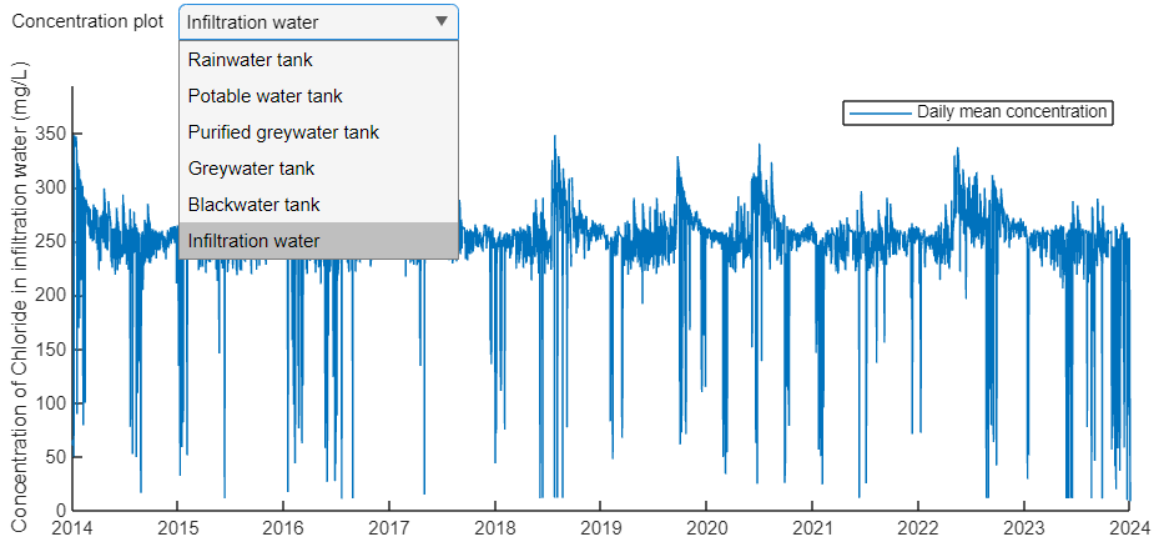
2.3 Graphs: Water tanks



Plotting tank volumes over time

Rainwater tank refill

Total monthly precipitation

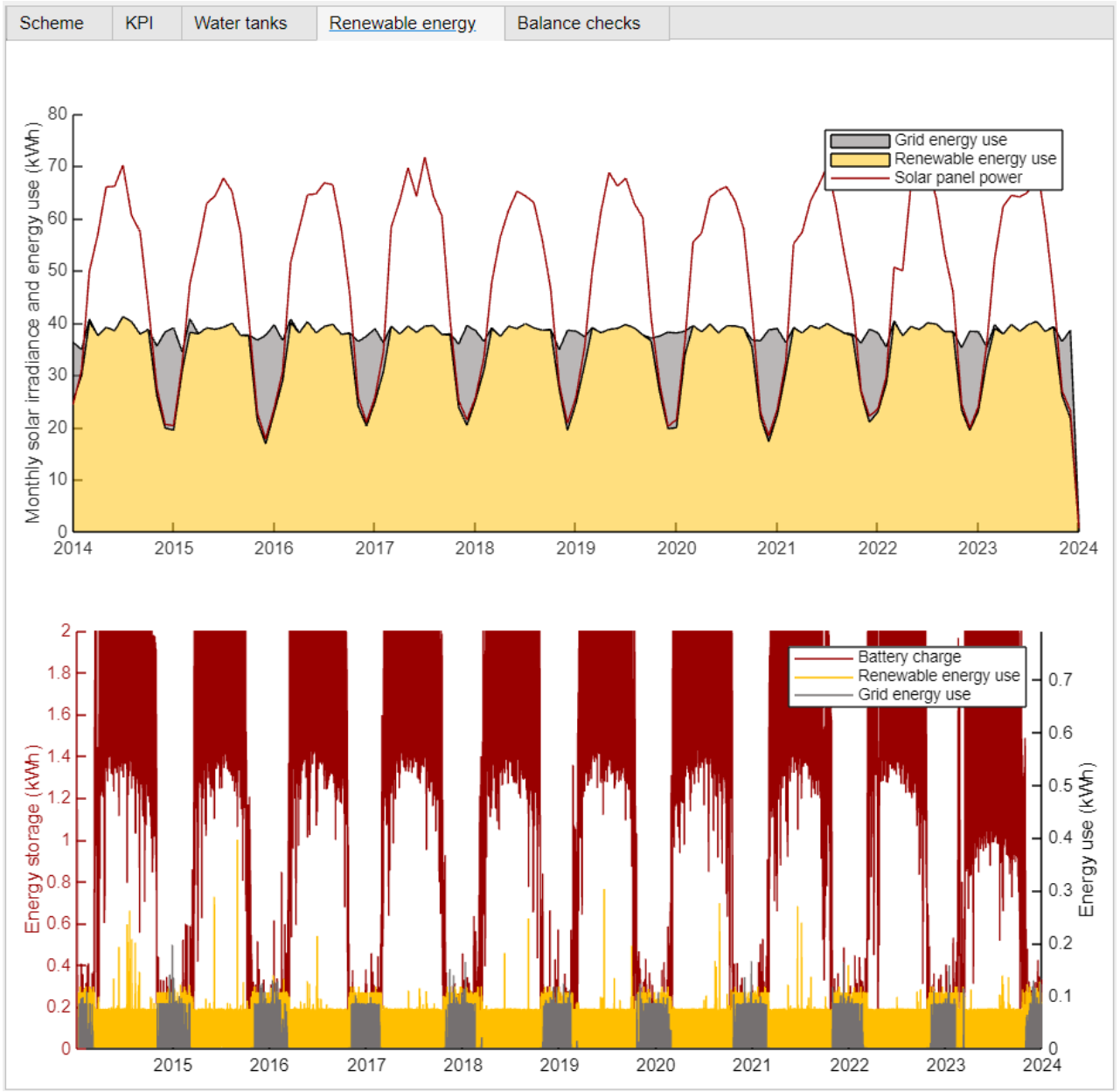


Plotting tank concentrations over time

2.4 Graphs: renewable energy

Total monthly solar irradiance (line), and stacked area renewables and grid use

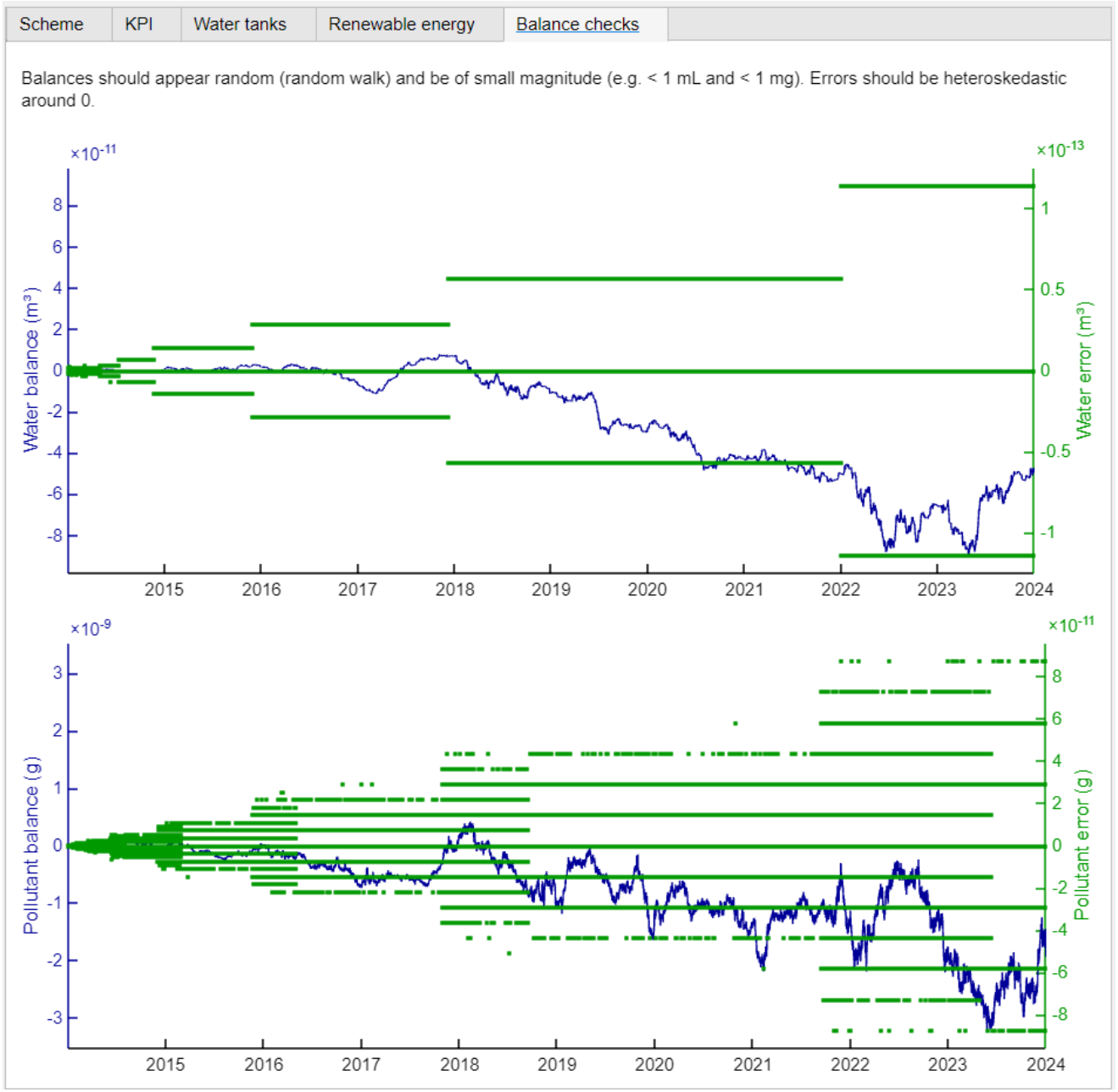
Battery charge and energy use over time



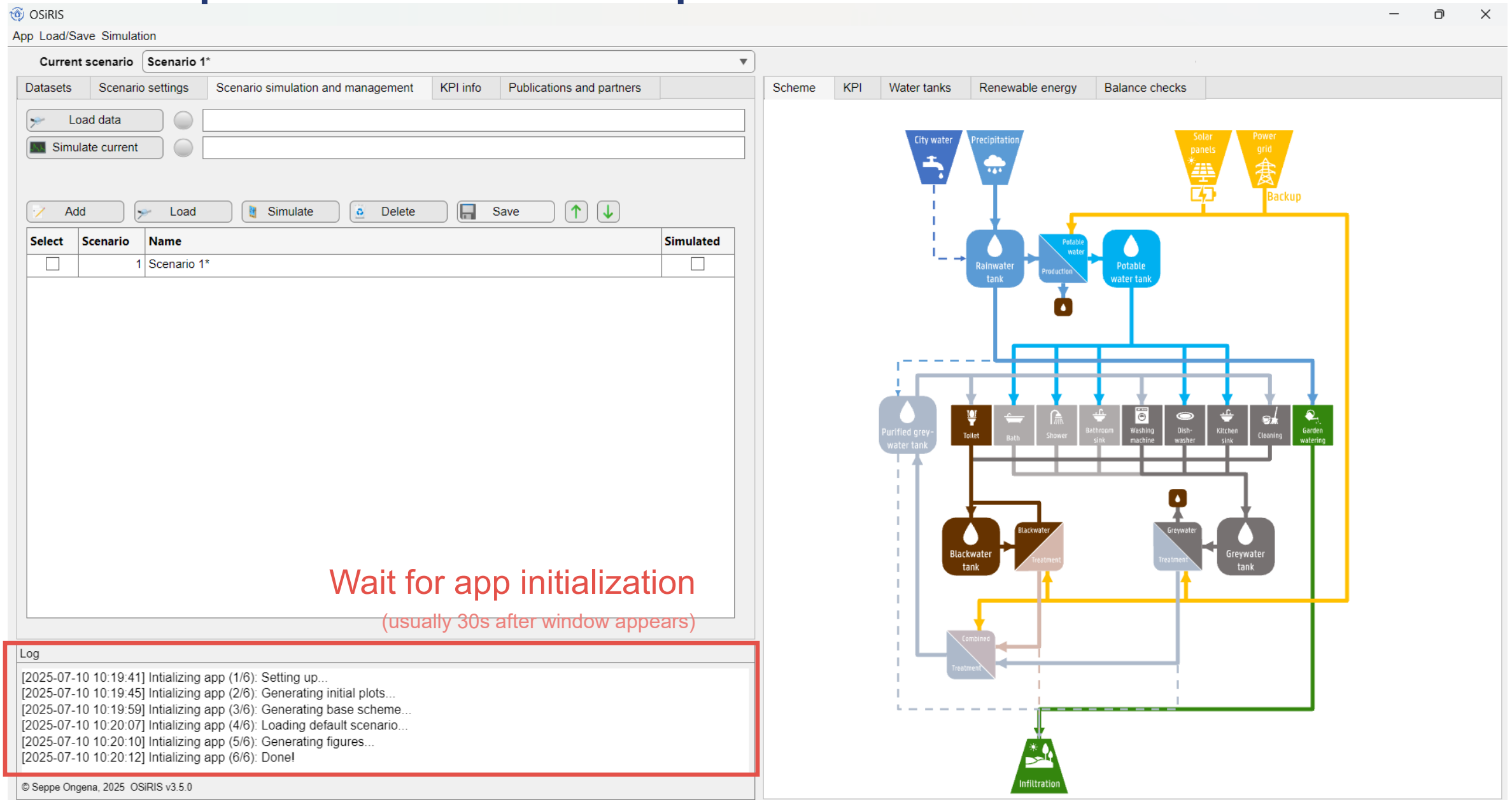
2.5 Graphs balance checks

Balance checks for model correctness

(see explanation)

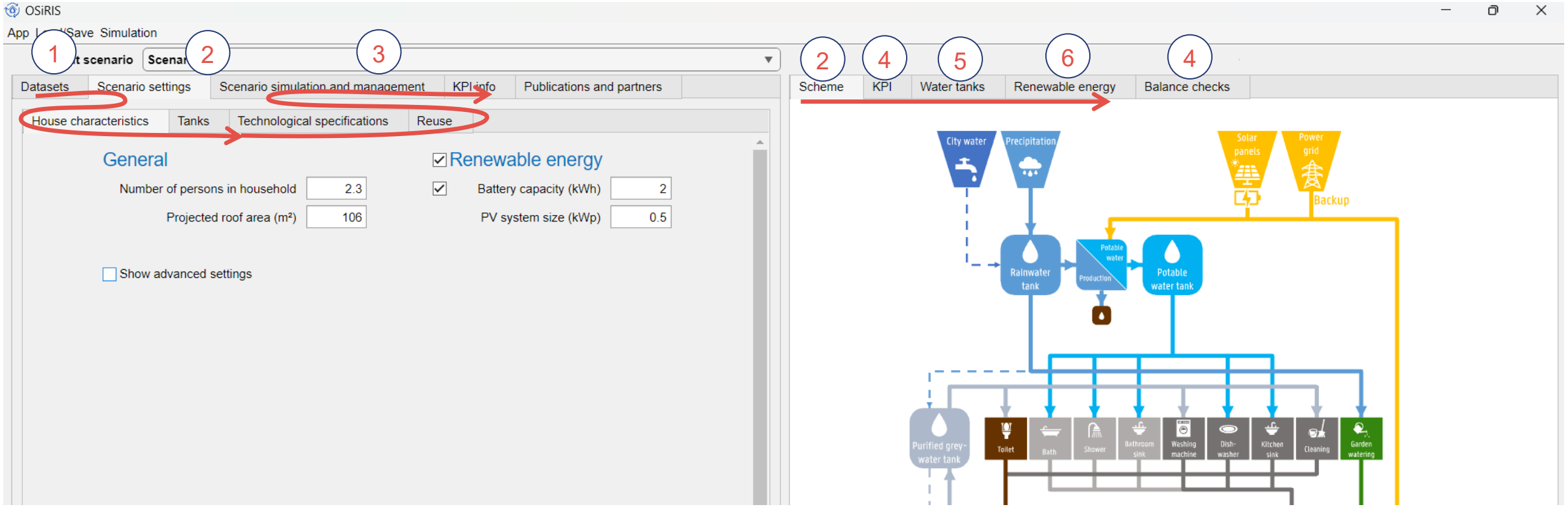


Example workflow: step 0 – Initialization



Example workflow: overview

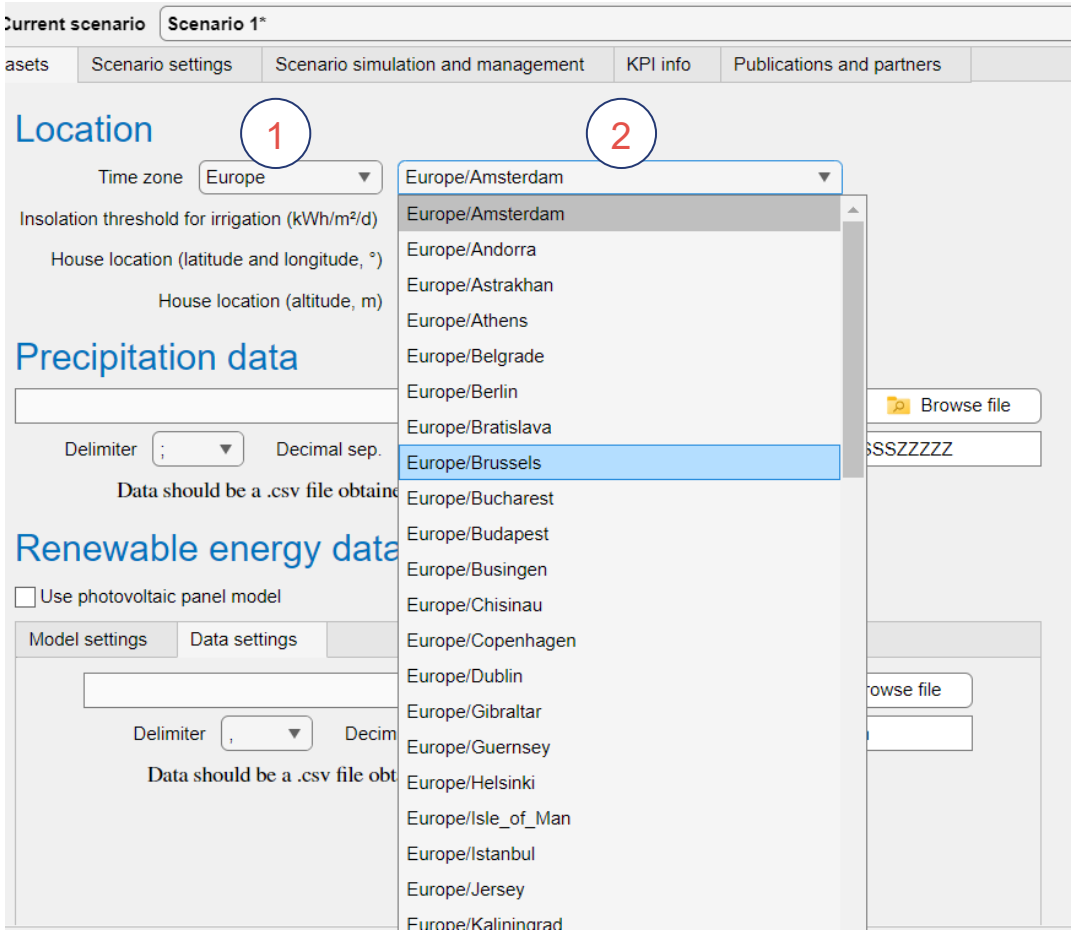
Within a scenario, go through tabs from left to right, changing settings where needed (see next slides)



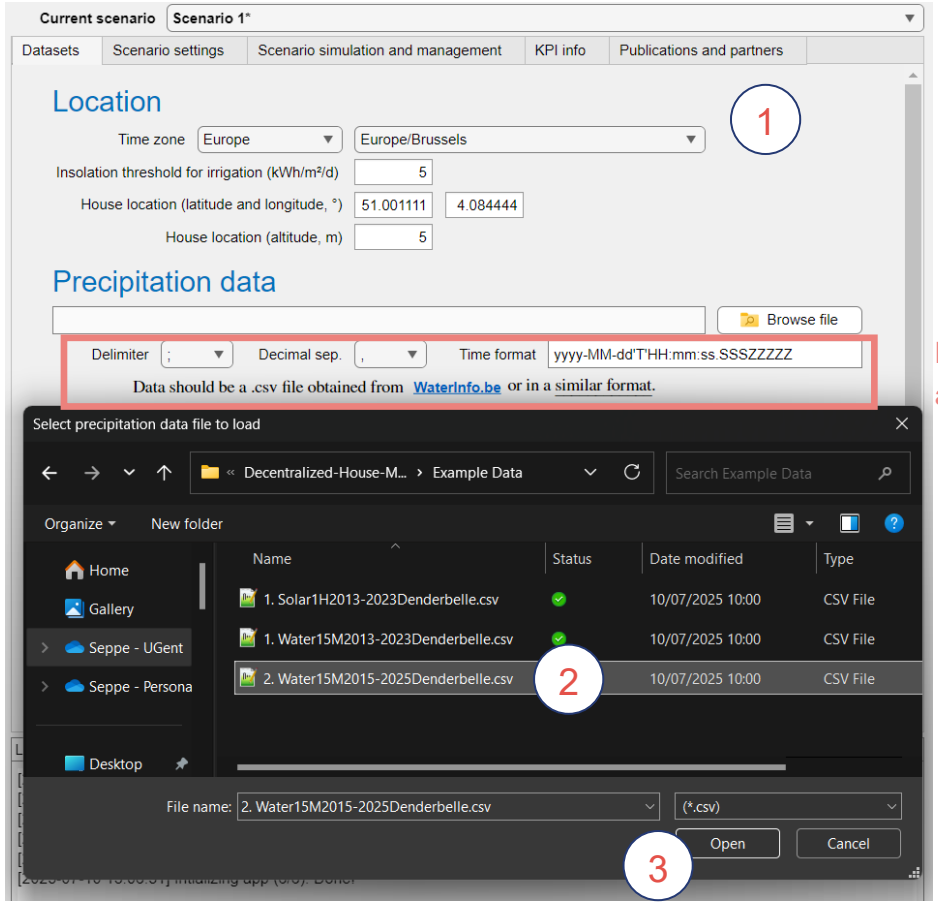
Example workflow: step 1 – Input data

Select time zone area and time zone,

Fill in house location



Select precipitation file from example data

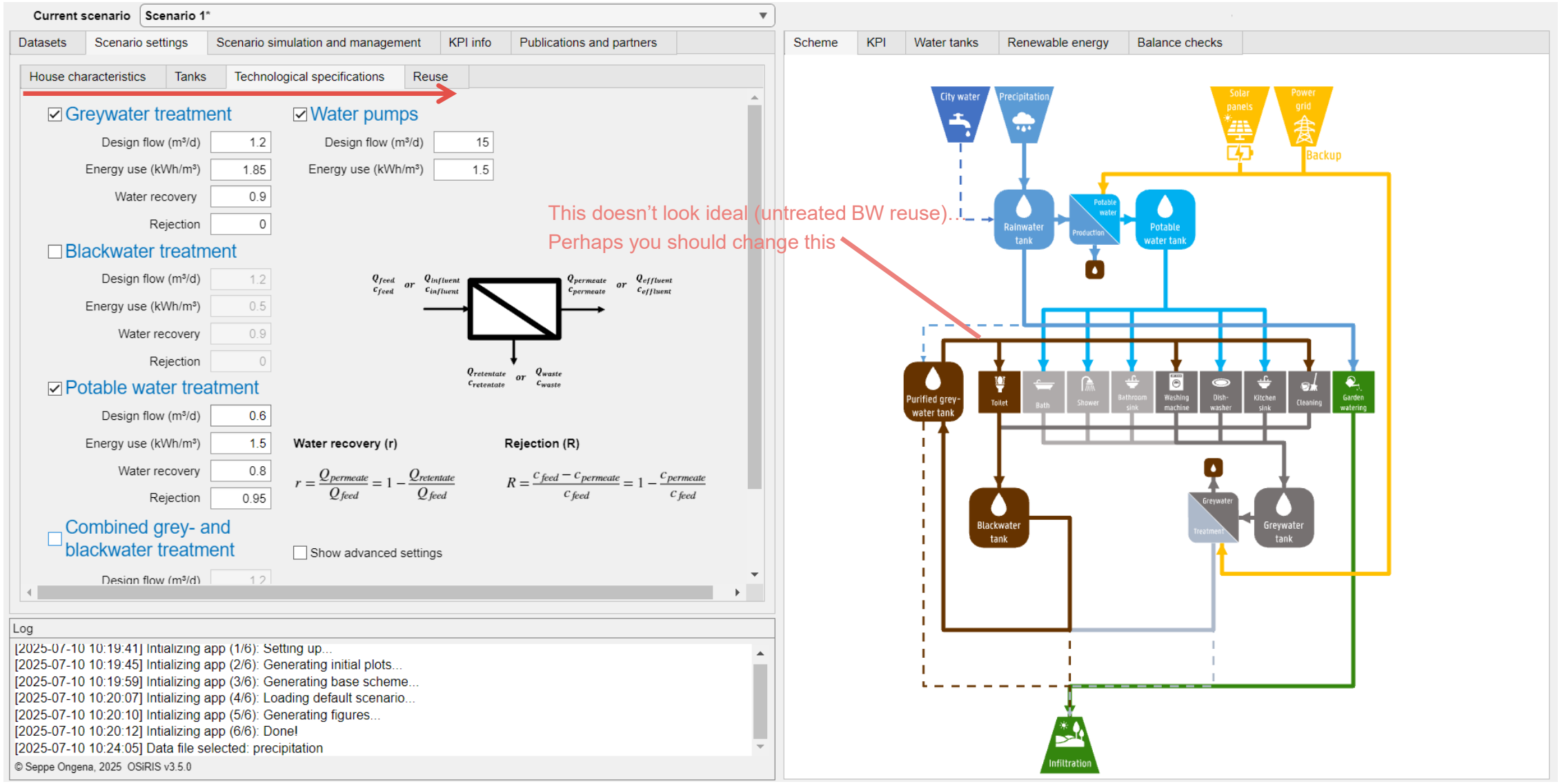


Make sure the formats are correct

Solar data can be loaded or left to the photovoltaic panel model to generate. **If using photovoltaic data, the temporal coverage should be equal or greater than the precipitation data!**

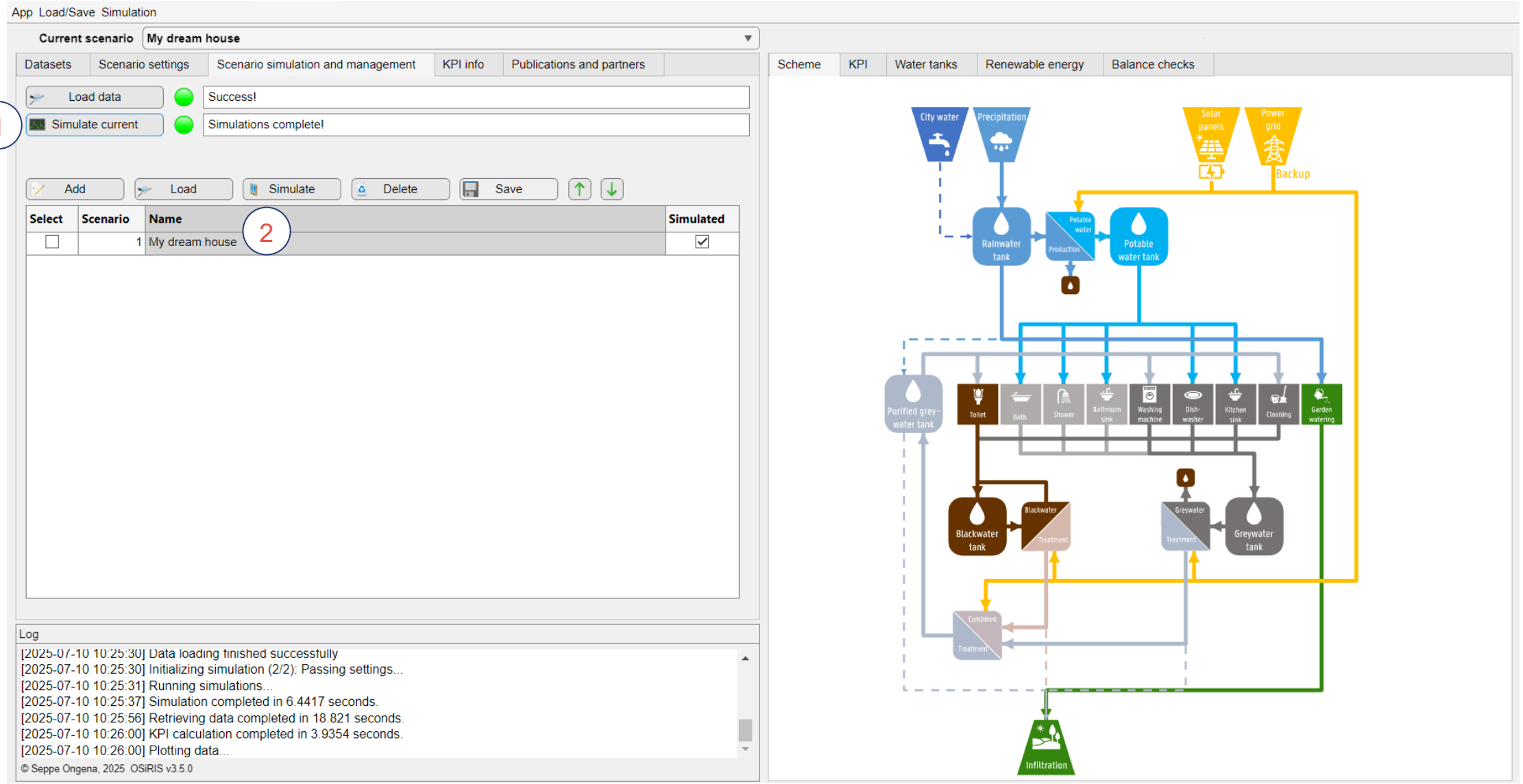
Example workflow: step 2 – Settings

Go over each tab and change settings where wanted (open the scheme tab for visual feedback)



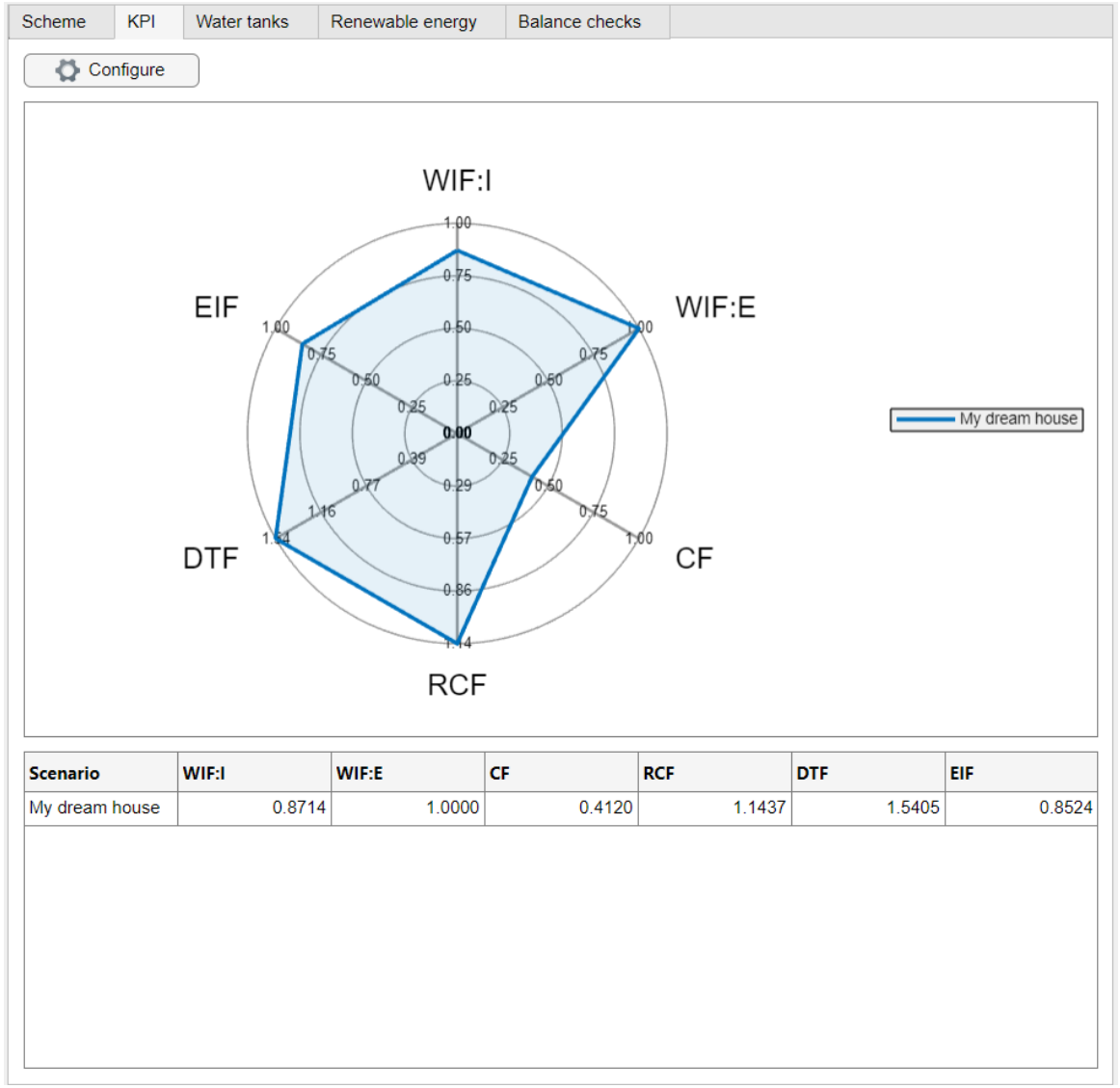
Example workflow: step 3 – Simulate

Press the “simulate current” button and change the scenario name by double clicking it in the table



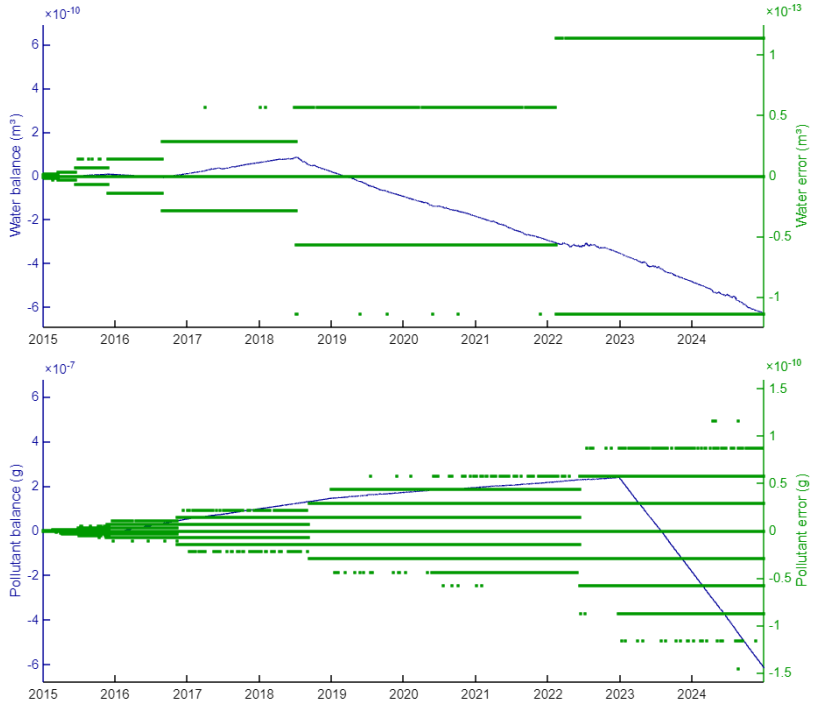
Example workflow: step 4 – Evaluate KPI

Evaluate the KPI graph (right side of app) and table. Are these results what you expected?



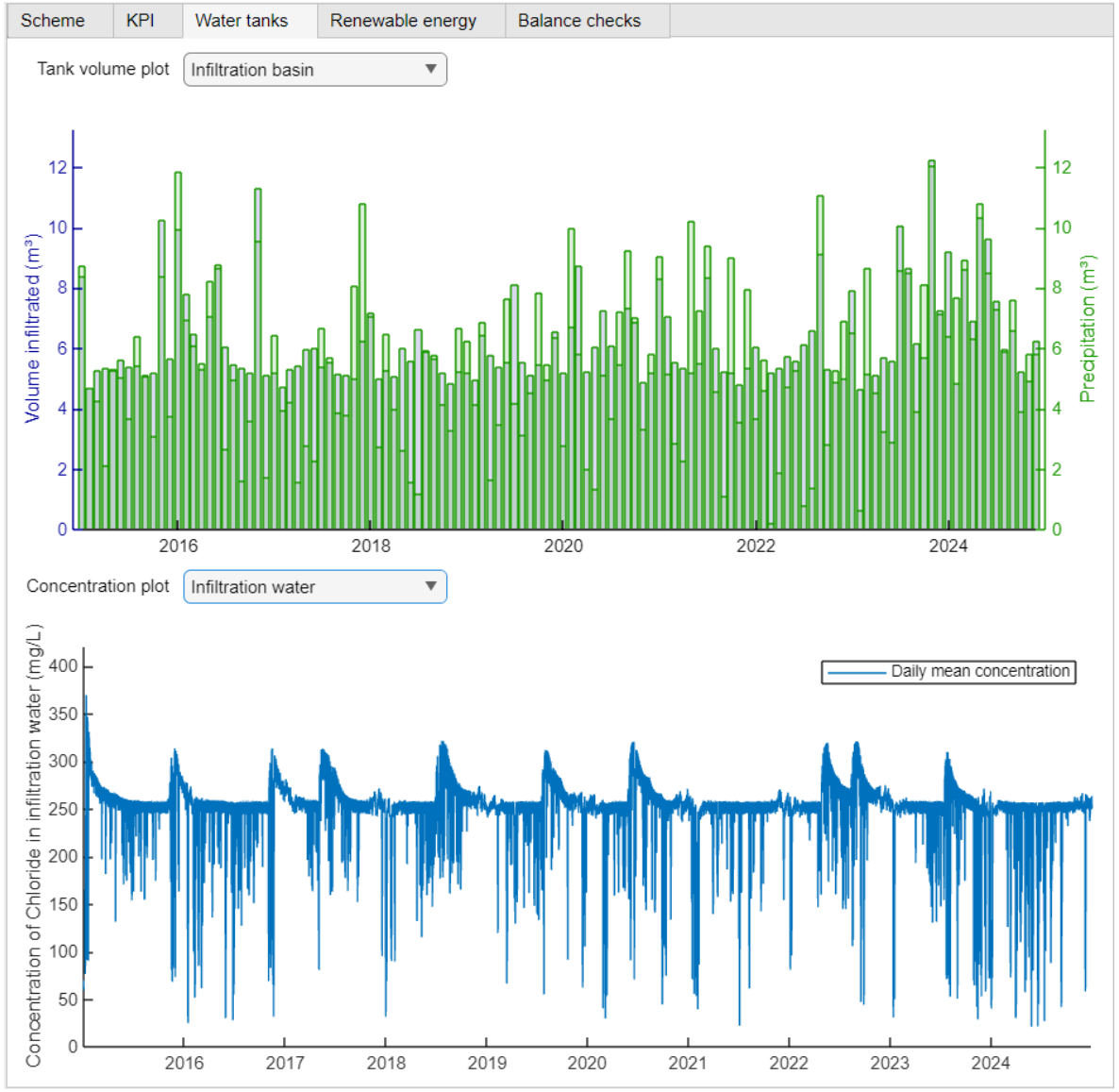
Scenario	WIF:I	WIF:E	CF	RCF	DTF	EIF
My dream house	0.8714	1.0000	0.4120	1.1437	1.5405	0.8524

If the results seem weird to you, you can always check the balance to see if I forgot to account for something in the model.



Example workflow: step 5 – Delve into water tanks

Take a closer look at the levels and concentrations of each tank – and the infiltration basin

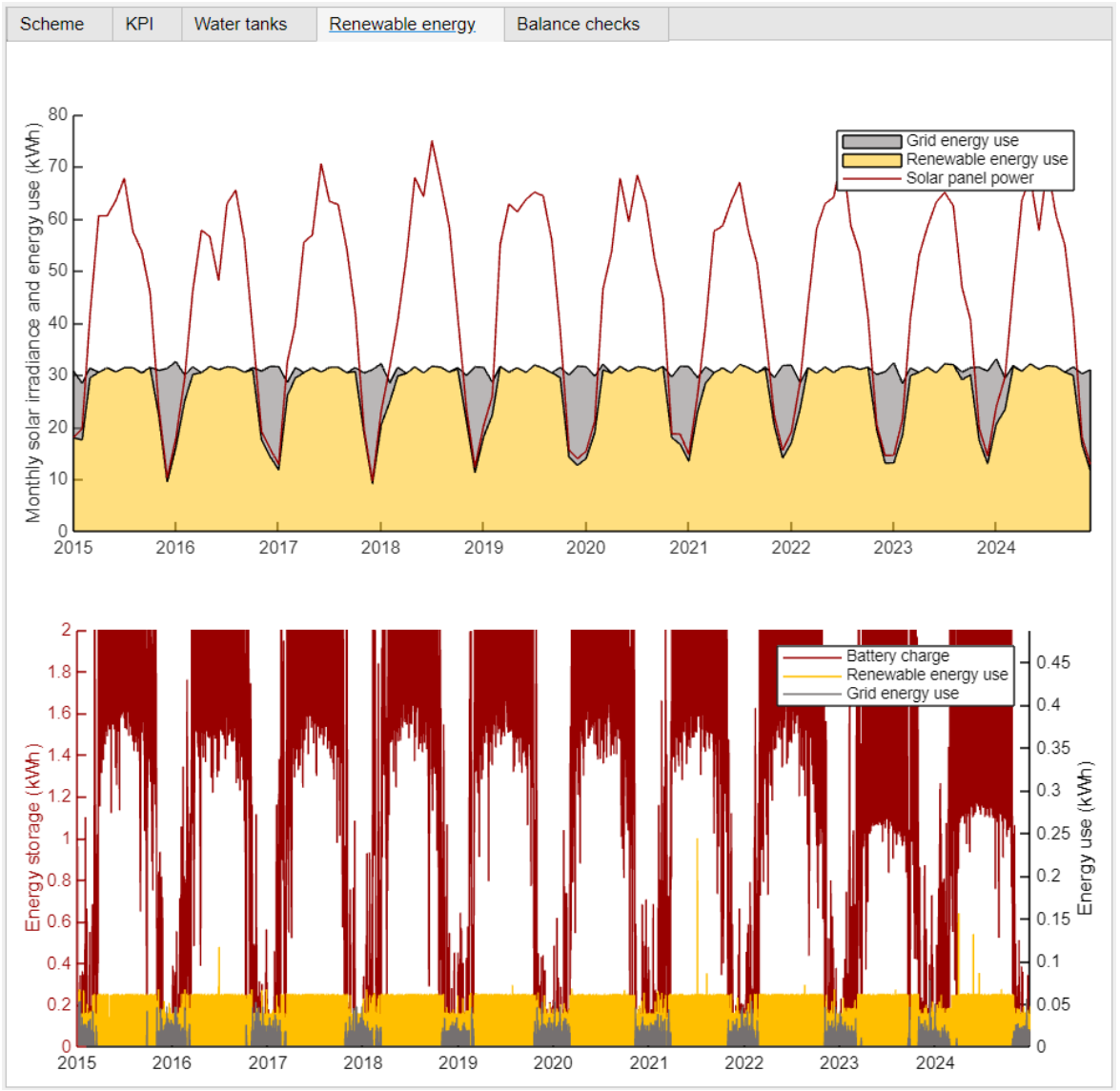


Admire the buffering effect of a decentralized household

Local regulations may apply here!

Example workflow: step 6 – Feeling energetic

Examine the energy usage

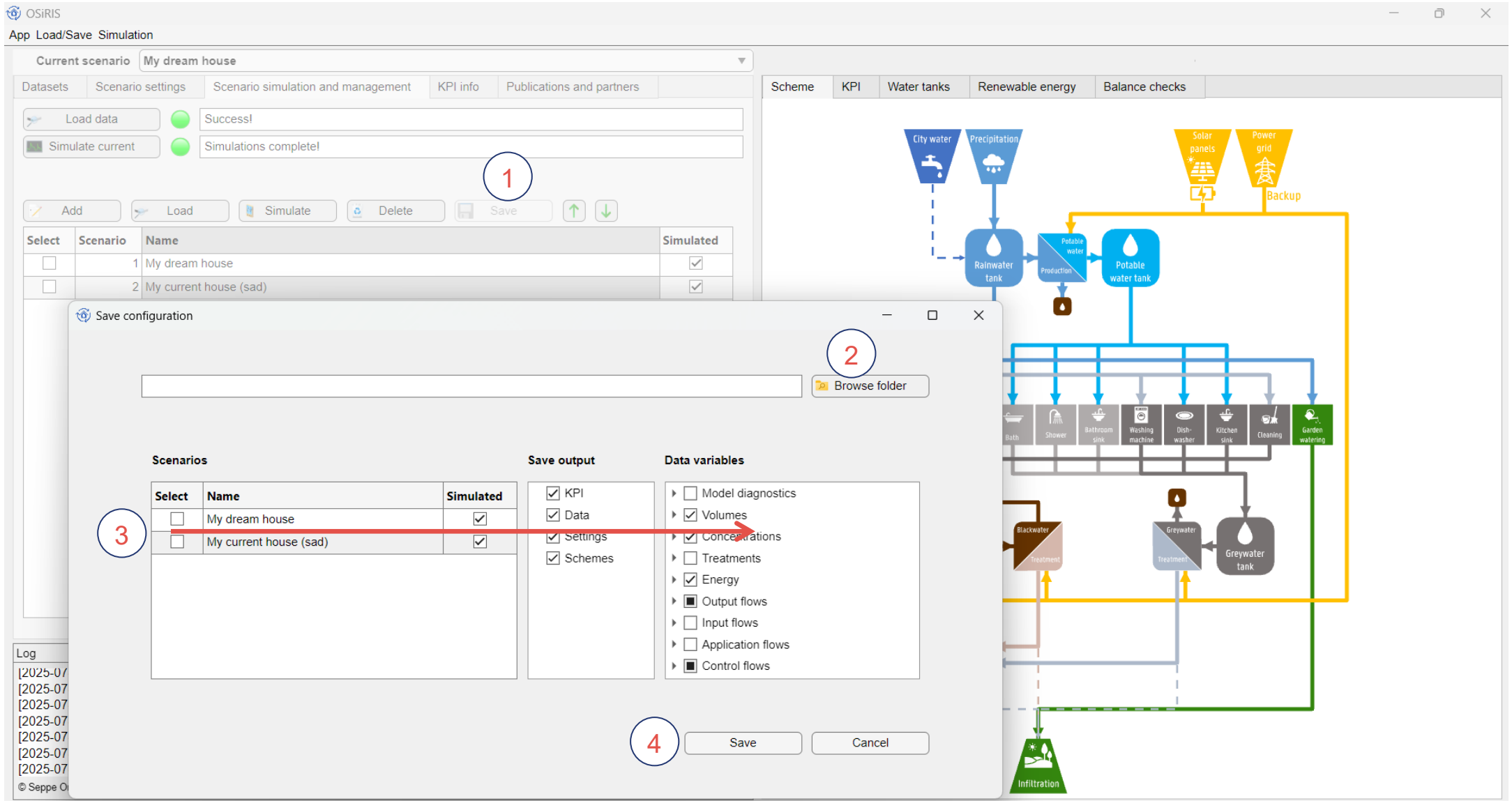


Grid energy used in winter. Notice the intersection of solar panel power and total energy requirement (use) and the disparity between renewable energy use and available solar power.

Battery is discharged most in winter, plenty full in summer.

Example workflow: step 7 – Save results

Press save, choose folder, select scenarios to save, which outputs, and which variables to save



CMET
Center for Microbial Ecology and Technology

CAPTURE
Centre for Advanced Process Technology
for Urban REsource recovery

Ir. Seppe Ongena

E: Seppe.Ongena@ugent.be

T: +32 9/264 59 76

Seppe Ongena

De Watergroep

www.cmet.ugent.be

www.capture-resources.be

GHENT UNIVERSITY

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