



CMET

Center for Microbial Ecology and Technology



CAPTURE

Centre for Advanced Process Technology
for Urban REsource recovery



**FACULTY OF
BIOSCIENCE ENGINEERING**

High resolution assessment of water production and reuse driven by on-site electricity production

A Simulink modelling approach available as standalone application

Seppe Ongena 21/10/24



De Watergroep

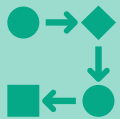
Contents (click for link)



Introduction: what is the model (not) for?



App layout: screenshots, description of app



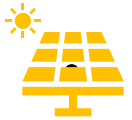
Example workflow: from data to results

What is it for?



High temporal resolution (15 min) simulation of household

- Diurnal water usage patterns
- Water balance: incoming precipitation, storage tanks, usage, and infiltration
- Simplified treatment simulation: removal efficiency, energy use, design flow, recovery
→ Adding commercial technologies based on “specsheet”



Renewable energy (PV) simulation for pumping + treatment

- Energy use: prioritized between demanding treatments
- Grid electricity: back-up
- Battery can be used
- Built-in simple PV and cloud models if data is unavailable



Rapid simulation: 30 ± 10 s for 10 years @ 15 min resolution
(depends on hardware platform)

What is it for?



High flexibility:

- Direct use of city water → from centralized to extremely decentralized
- Scalable from single household to district level (e.g. weighted rain correction factor for roads vs. roofs, increased pump energy for greater distances,...)



High modifiability: easily choose streams to reuse and for which applications



Standalone app (.exe) with user interface

- Built-in key performance indicators (KPI) for scenario analysis
- Scheme automatically adapts to user input
- Simulation results displayed in graphs
- Results, settings, and graphs savable to file

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 code, 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

Decentralized closed loop – C++ model

- 90% of model code written in C++, MATLAB for data pre-processing, output visualization, app,...
- Leveraging class/object-based programming, e.g., rainwater tank is an object of the tank class
- Main code loop based on on/off control system with hysteresis (e.g. treatment flows between tanks) which reacts to perturbations (precipitation and water use), followed by water and pollutant balances to verify model correctness

App layout

Decentralized Household Model

App Load/Save Simulation

Current scenario 8 - Extreme dec. + BW reuse

Scenario input data Scenario settings Scenario simulation and management KPI info Publications and partners

Load data

Simulate current

Add Load Simulate Delete Save

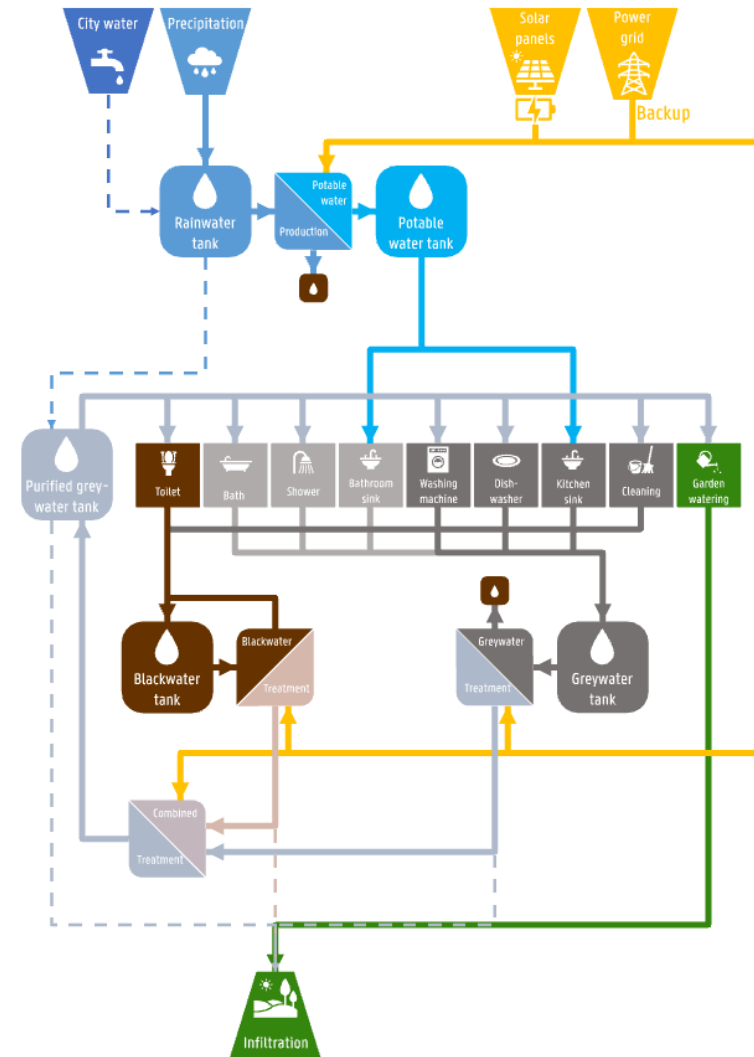
Select	Scenario	Name	Simulated
<input type="checkbox"/>	1	0 - Centralized	<input checked="" type="checkbox"/>
<input type="checkbox"/>	2	1 - Rainwater use	<input checked="" type="checkbox"/>
<input type="checkbox"/>	3	2 - GW treatment for reuse	<input checked="" type="checkbox"/>
<input type="checkbox"/>	4	3 - Dec. treatment and infil.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	5	4 - PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	6	5 - GW reuse and PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	7	6 - Dec. treatment + PW	<input checked="" type="checkbox"/>
<input type="checkbox"/>	8	7 - Extreme dec.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	9	8 - Extreme dec. + BW reuse	<input checked="" type="checkbox"/>

Log

[2024-11-05 14:13:14] Simulating... Scenario //9
[2024-11-05 14:13:41] Simulation completed in 15.5374 seconds.
[2024-11-05 14:13:41] Simulating... Scenario 8/9
[2024-11-05 14:14:12] Simulation completed in 18.0936 seconds.
[2024-11-05 14:14:12] Simulating... Scenario 9/9
[2024-11-05 14:14:45] Simulation completed in 18.2291 seconds.
[2024-11-05 14:14:45] All scenarios were successfully simulated.

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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,...)

The screenshot displays the 'Decentralized Household Model' interface, divided into two main sections: the 'User input side' (left) and the 'Graph side' (right).

User input side (Left Panel):

- Current scenario:** 8 - Extreme dec. + BW reuse
- Scenario input data:** Load data, Simulate current
- Scenario settings:** Add, Load, Simulate, Delete, Save, Up, Down
- Scenario simulation and management:** Table of scenarios with 'Simulated' status.
- Log:** Simulation progress and completion times.

Select	Scenario	Name	Simulated
<input type="checkbox"/>	1	0 - Centralized	✓
<input type="checkbox"/>	2	1 - Rainwater use	✓
<input type="checkbox"/>	3	2 - GW treatment for reuse	✓
<input type="checkbox"/>	4	3 - Dec. treatment and infil.	✓
<input type="checkbox"/>	5	4 - PW production	✓
<input type="checkbox"/>	6	5 - GW reuse and PW production	✓
<input type="checkbox"/>	7	6 - Dec. treatment + PW	✓
<input type="checkbox"/>	8	7 - Extreme dec.	✓
<input type="checkbox"/>	9	8 - Extreme dec. + BW reuse	✓

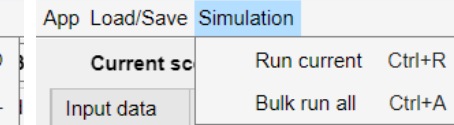
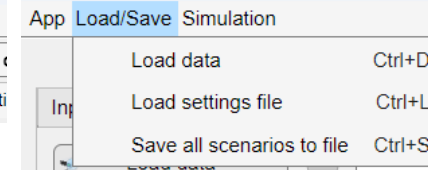
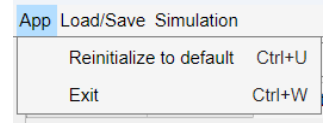
Graph side (Right Panel):

- Scheme:** Water tanks, Renewable energy, Balance checks
- Diagram:** Schematic of the household water system showing inputs (City water, Precipitation), storage (Rainwater tank, Potable water tank), distribution (Toilet, Bath, Shower, etc.), treatment (Blackwater tank, Greywater tank), and disposal (Infiltration).

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Log (simulation progress, errors, info,...)

1.0 User input side



Main menus (quickly select actions, shortcut keys possible)

Tab selector

1.1 Scenario input data

1.2 Scenario settings

1.3 Scenario simulation and management

1.4 KPI info

1.5 Publications and partners

Scenario selector

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

Select	Scenario	Name	Simulated
<input type="checkbox"/>	1	0 - Centralized	<input checked="" type="checkbox"/>
<input type="checkbox"/>	2	1 - Rainwater use	<input checked="" type="checkbox"/>
<input type="checkbox"/>	3	2 - GW treatment for reuse	<input checked="" type="checkbox"/>
<input type="checkbox"/>	4	3 - Dec. treatment and infil.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	5	4 - PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	6	5 - GW reuse and PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	7	6 - Dec. treatment + PW	<input checked="" type="checkbox"/>
<input type="checkbox"/>	8	7 - Extreme dec.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	9	8 - Extreme dec. + BW reuse	<input checked="" type="checkbox"/>

Tab contents

1.1 Scenario input data

Timezone for data reading

Scenario input data | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

Time zone: Europe | Europe/Brussels

Precipitation data

C:\Users\songena\OneDrive - UGent\PhD\Text\1. Decentralized household | Browse file

Delimiter: ; | Decimal sep.: , | Time format: yyyy-MM-dd'T'HH:mm:ss.SSSZZZZ

Data should be a .csv file obtained from [WaterInfo.be](#) or in a similar format.

Renewable energy data

☒ Use photovoltaic panel model

Model settings | Data settings

Panel slope (degrees): 40

Panel tilt angle (degrees): 0

☐ Advanced settings

File format:

- Metadata header rows
- Followed by (at least) two columns for the data:
- #Timestamp: first column, in time format
- Value: precipitation in mm
- Followed by optional footer rows

Cloud data table (days or %)

	Clear	Cloudy	Overcast
J	1.4000	22.0000	7.7000
F	1.9000	19.2000	7.1000
M	3.1000	22.4000	5.6000
A	2.6000	24.8000	2.5000
M	2.7000	24.6000	3.7000
J	2.1000	25.5000	2.4000
J	2.1000	26.4000	2.5000
A	2.7000	27.0000	1.2000
S	2.7000	25.3000	2.0000

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 Scenario input data: PV model

Scenario input data | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

Time zone: Etc | Etc

Precipitation data

Delimiter: ; | Decimal sep: , | Time format: yyyy-MM-dd'T'HH:mm:ss.SSSZZZ

Data should be a .csv file obtained from [WaterInfo.be](https://waterinfo.be) or in a similar format.

Renewable energy data

☒ Use photovoltaic panel model

Model settings | Data settings

Panel slope (degrees): 40
Panel tilt angle (degrees): 0

☒ Advanced settings

Advanced settings

T_{LK} , Linke turbidity factor: 3
 ρ , ground reflectivity: 0.2

Cloud data table (days or %)

	Clear	Cloudy	Overcast
J	3.2000	9.2000	18.5000
F	3.3000	10.9000	14.1000
M	4.4000	13.3000	13.5000
A	4.8000	15.2000	10.0000
M	5.1000	16.5000	9.4000
J	4.7000	16.8000	8.5000
J	5.8000	18.9000	6.3000
A	5.6000	19.0000	6.4000
S	5.9000	15.4000	8.7000

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 Scenario input data: renewable energy

Scenario input data | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

Time zone: Europe | Europe/Brussels

Precipitation data

C:\Users\songena\OneDrive - UGent\PhD\Text\1. Decentralized household | Browse file

Delimiter: ; | Decimal sep.: , | Time format: yyyy-MM-dd'T'HH:mm:ss.SSSZZZZ;

Data should be a .csv file obtained from [WaterInfo.be](#) or in a similar format.

Renewable energy data

☐ Use photovoltaic panel model

Model settings | Data settings

| | Browse file

Delimiter: , | Decimal sep.: . | Time format: yyyyMMdd:HHmm

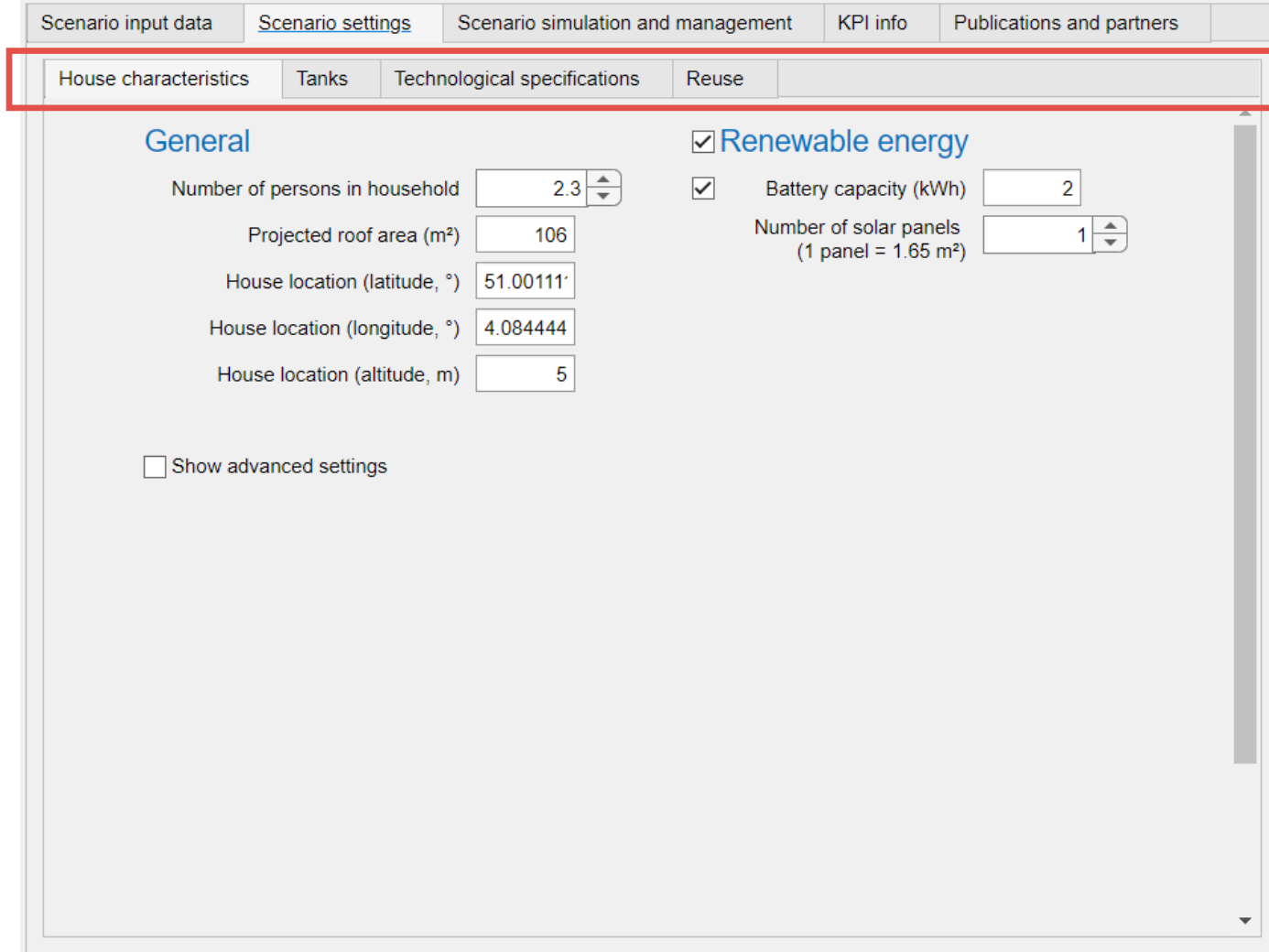
Data should be a .csv file obtained from [PVGIS](#) or in a similar format.

File format:

- Metadata header rows
- Followed by (at least) two columns for the data;
- time: first column, in time format
- G(i): Global irradiance on the inclined plane in W/m²
- Followed by optional footer rows

Similar to precipitation data

1.2 Scenario settings



The image shows a web application interface with a top navigation bar containing five tabs: 'Scenario input data', 'Scenario settings', 'Scenario simulation and management', 'KPI info', and 'Publications and partners'. The 'Scenario settings' tab is selected and highlighted with a red box. Below this, a subtab bar contains four subtabs: 'House characteristics', 'Tanks', 'Technological specifications', and 'Reuse'. The 'House characteristics' subtab is selected and highlighted with a red box. The main content area displays the 'General' settings for the selected subtab. It includes a 'Renewable energy' section with a checked checkbox and several input fields: 'Number of persons in household' (2.3), 'Projected roof area (m²)' (106), 'House location (latitude, °)' (51.00111), 'House location (longitude, °)' (4.084444), 'House location (altitude, m)' (5), 'Battery capacity (kWh)' (2), and 'Number of solar panels (1 panel = 1.65 m²)' (1). A 'Show advanced settings' checkbox is also present.

Scenario input data Scenario settings Scenario simulation and management KPI info Publications and partners

House characteristics Tanks Technological specifications Reuse

General

☒ Renewable energy

Number of persons in household

Projected roof area (m²)

House location (latitude, °)

House location (longitude, °)

House location (altitude, m)

☐ Show advanced settings

☒ Battery capacity (kWh)

Number of solar panels (1 panel = 1.65 m²)

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

Scenario input data | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

House characteristics | Tanks | Technological specifications | Reuse

General

☒ Renewable energy

Number of persons in household: 2.3

Projected roof area (m²): 106

House location (latitude, °): 51.00111

House location (longitude, °): 4.084444

House location (altitude, m): 5

☒ Battery capacity (kWh): 2

Number of solar panels (1 panel = 1.65 m²): 1

☒ Show advanced settings

Advanced settings

Flows and concentrations | Rain correction factor | Photovoltaics

Pollutant name (only affects graph legends): Chloride

Pollutant concentrations in tap- and rainwater (mg/L): C_{tap} 70, C_{rain} 7.7

Appliance daily flows (L/p/d)

Q_{TL} 21.3, Q_{BT} 5.1, Q_{SH} 23.8, Q_{WM} 16.6, Q_{BS} 9.4, Q_{DW} 2.3

Wastewater pollutant concentrations for tap water (mg/L)

C_{TL} 100, C_{BT} 166, C_{SH} 284, C_{WM} 450, C_{BS} 237, C_{DW} 716

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) Rain correction factor tables

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

Flows and concentrations | Rain correction factor | Photovoltaics

Photovoltaic panel heat efficiency: 0.9 $\eta_{heat} = (1 - \text{losses due to heat})$

Efficiency of the DC/AC inverter: 0.95 $\eta_{inverter}$

Efficiency of the battery: 0.9 $\eta_{battery}$

Panel wattpeak/m²: 300

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

Advanced settings

Flows and concentrations | Rain correction factor | Photovoltaics

Total rain correction factor: 0.81 η_{rain}

1. Correction for roof slope & tilt (in case SW = main wind direction)

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

2. Correction for roof type

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

3. Correction for coarse filter

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

Scenario input data

Scenario settings

Scenario simulation and management

KPI info

Publications and partners

House characteristics

Tanks

Technological specifications

Reuse

Tank settings

(is the tank installed?, maximum volume?, is tank initially filled with tap water?, what is the initial volume?)

		Nominal volumes (m ³)	Initial volume (m ³)
Potable water tank)	<input checked="" type="checkbox"/>	<input type="text" value="1"/>	<input checked="" type="checkbox"/> <input type="text" value="1"/>
Rainwater tank	<input checked="" type="checkbox"/>	<input type="text" value="10"/>	<input checked="" type="checkbox"/> <input type="text" value="10"/>
Purified greywater tank	<input checked="" type="checkbox"/>	<input type="text" value="1"/>	<input checked="" type="checkbox"/> <input type="text" value="1"/>
Blackwater/septic tank	<input checked="" type="checkbox"/>	<input type="text" value="1"/>	<input type="checkbox"/> <input type="text" value="0"/>
Greywater buffer tank	<input checked="" type="checkbox"/>	<input type="text" value="0.5"/>	<input type="checkbox"/> <input type="text" value="0"/>

assumes tap water

☒ Show advanced settings

Advanced settings - control parameters

$\max(c_{PGW})$

$\min(V_{RW})$

(Advanced) maximum PGW concentration

Maximum allowed pollutant concentration in the purified greywater tank. When exceeding this concentration, the tank will be purged with rainwater (see reuse settings).

(Advanced) minimum RW tank level

Minimum volume of the rainwater tank. When below this, the refilling mechanism will come into action.

1.2.3 Scenario settings: technological specifications

Scenario input data | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

House characteristics | Tanks | Technological specifications | Reuse

☒ **Greywater treatment**
Design flow (m³/d)
Energy use (kWh/m³)
Water recovery
Removal efficiency

☒ **Blackwater treatment**
Design flow (m³/d)
Energy use (kWh/m³)
Water recovery
Removal efficiency

☒ **Potable water treatment**
Design flow (m³/d)
Energy use (kWh/m³)
Water recovery
Removal efficiency

☒ **Combined grey- and blackwater treatment**
Design flow (m³/d)
Energy use (kWh/m³)
Water recovery
Removal efficiency

☒ **Water pumps**
Design flow (m³/d)
Energy use (kWh/m³)

Q_{feed} c_{feed} or $Q_{influent}$ $c_{influent}$

$Q_{retentate}$ $c_{retentate}$ or Q_{waste} c_{waste}

Water recovery (r) $r = \frac{Q_{permeate}}{Q_{feed}} = 1 - \frac{Q_{retentate}}{Q_{feed}}$

Removal efficiency (R) $R = \frac{c_{feed} - c_{permeate}}{c_{feed}} = 1 - \frac{c_{permeate}}{c_{feed}}$

☒ Show advanced settings
Advanced settings - salts removal in buffer tanks
Removal in blackwater tank
Removal in greywater tank

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

Scenario input data

Scenario settings

Scenario simulation and management

KPI info

Publications and partners

House characteristics

Tanks

Technological specifications

Reuse

☒ Reuse blackwater?

Blackwater excess

Send to sewer

Greywater excess

Empty by truck

Rainwater excess

Infiltrate

Purge water

Infiltrate

☐ Treat rainwater before purging/refilling purified greywater tank?

☒ Rainwater excess: pass through purified greywater tank (purge)?

This serves as a purge by diluting the PGW with rainwater. WARNING! Can heavily impact energy use when the rainwater is also treated first!

Source water:

Toilet flushing

Purified greywater

Bathing

Purified greywater

Showering

Purified greywater

Bathroom sink

Potable water

Washing machine

Purified greywater

Dishwasher

Purified greywater

Kitchen sink

Potable water

Cleaning

Purified greywater

Garden watering

Purified greywater

City water

Potable water

Rainwater

Purified greywater

Wastewater to:

Blackwater tank

Blackwater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Greywater tank

Blackwater tank

Blackwater tank

Infiltration

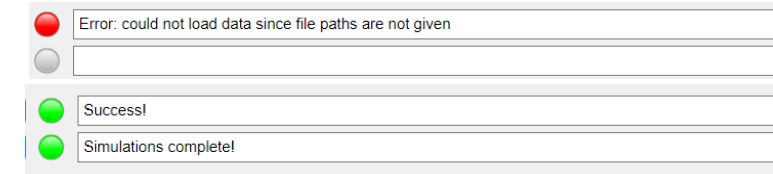
Infiltration

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



Load data for current scenario

Simulate the model for this scenario

(Save settings for current scenario, reload data if necessary)

Scenario overview/manipulation

When adding a scenario, the settings of the currently selected scenario will be copied

Load one or multiple scenario settings files

Bulk simulation of scenarios (see next slides)

Data loading progress info

Simulation progress info

Move selected scenarios up/down in list and plots

Save settings, schemes, KPI, results to file (see next slides)

Delete selected scenarios

Scenario input data

Scenario settings

Scenario simulation and management

KPI info

Publications and partners

Load data

Simulate current

Add

Load

Simulate

Delete

Save

↑

↓

Select	Scenario	Name	Simulated
<input type="checkbox"/>	1	0 - Centralized	<input checked="" type="checkbox"/>
<input type="checkbox"/>	2	1 - Rainwater use	<input checked="" type="checkbox"/>
<input type="checkbox"/>	3	2 - GW treatment for reuse	<input checked="" type="checkbox"/>
<input type="checkbox"/>	4	3 - Dec. treatment and infil.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	5	4 - PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	6	5 - GW reuse and PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	7	6 - Dec. treatment + PW	<input checked="" type="checkbox"/>
<input type="checkbox"/>	8	7 - Extreme dec.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	9	8 - Extreme dec. + BW reuse*	<input checked="" type="checkbox"/>

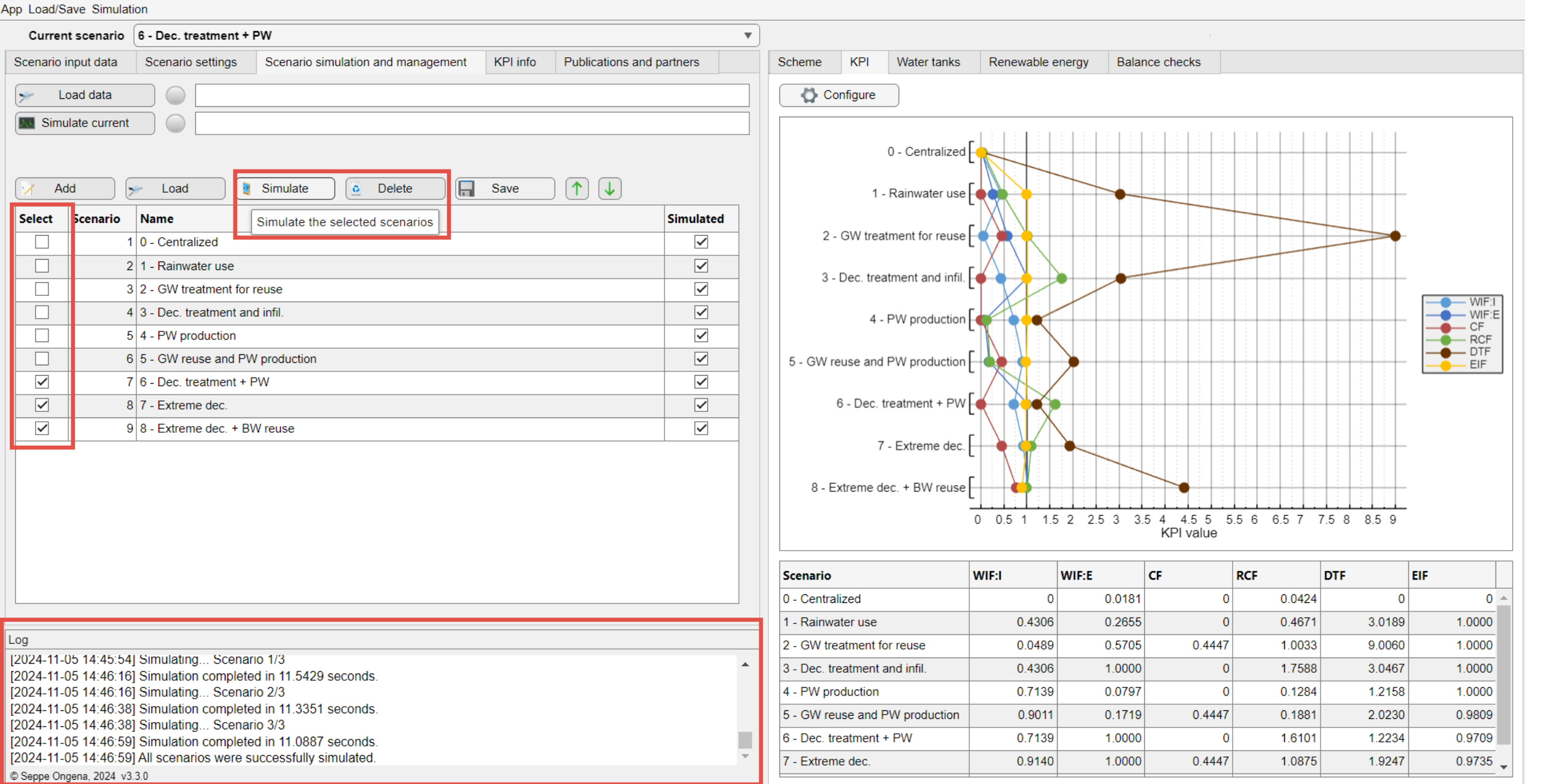
A " * " indicates settings were changed but not yet saved/simulated

Is scenario already simulated? Re-simulating will overwrite results

A " * " indicates settings were changed but not yet saved/simulated

Is scenario already simulated? Re-simulating will overwrite results

Bulk simulation



Saving files: save dialog screen

Save configuration

Select scenarios to save output for

Select output to save

Select variables in the data to save

Scenarios

Select	Name	Simulated
<input type="checkbox"/>	2 - GW treatment for reuse	<input checked="" type="checkbox"/>
<input type="checkbox"/>	3 - Dec. treatment and infil.	<input checked="" type="checkbox"/>
<input type="checkbox"/>	4 - PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	5 - GW reuse and PW production	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	6 - Dec. treatment + PW	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	7 - Extreme dec.	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	8 - Extreme dec. + BW reuse	<input checked="" type="checkbox"/>

Save output

- ☒ KPI
- ☒ Data
- ☒ Settings
- ☒ Schemes

Data variables

- ☒ Volumes
- ☒ Concentrations
- ☒ Energy
- ☐ Treatments
- ☒ Output flows
- ☒ Decentralization information
- ☐ Model diagnostics

Select folder

Saving files: output

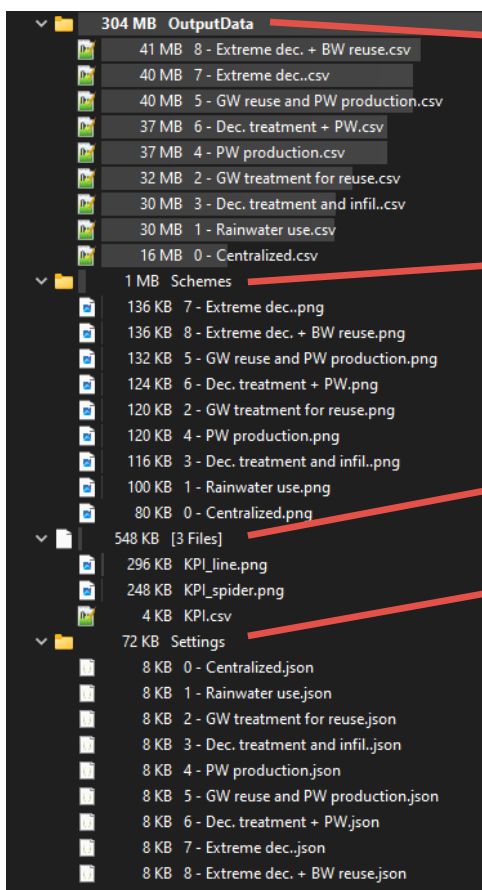
Log

```
[2024-11-05 15:18:04] Starting file saving...
[2024-11-05 15:18:05] [WARNING] Not saving KPI/Output data/Settings/Scheme simultaneously may cause mismatch between settings and results.
[2024-11-05 15:18:05] [WARNING] No scenario selected to save is visible on the KPI plot (not selected or not simulated). Skipping KPI saving
[2024-11-05 15:18:05] [WARNING] Previously saved scenarios detected in the current folder. Scenarios with the same name will be overwritten, KPI data and figure will be merged
[2024-11-05 15:18:12] [WARNING] Scenario 3/3 (Scenario 11) not simulated, no output data to save.
[2024-11-05 15:18:12] [WARNING] Unsaved (scenario already simulated but settings changed later) or unsimulated (scenario not yet simulated) scenario settings and schemes detected. Unsaved changes will be discarded. Unsimulated settings will be saved.
[2024-11-05 15:18:12] Scenario 2/3 (8 - Extreme dec. + BW reuse): reverting settings
[2024-11-05 15:18:14] Files saved successfully!
© Seppe Ongena, 2024 v3.3.0
```

All possible warnings triggered

```
"RenewableEnergySettings": {
  "RenewableEnergy": true,
  "n_panel": 2.0,
  "UseBattery": true,
  "C_battery": 2.7
},
```

(full view - example)



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

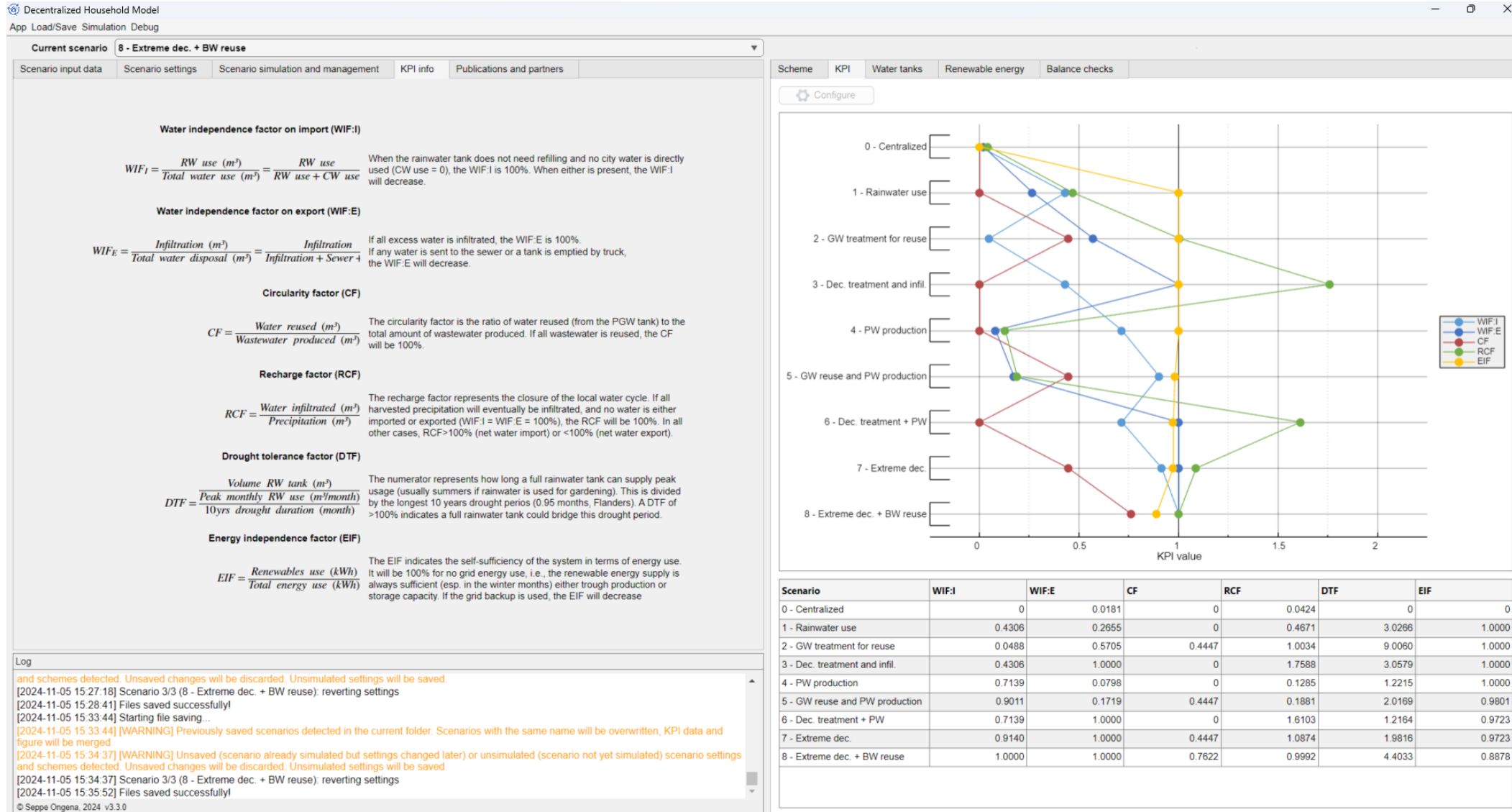
Progress is shown in log

```
[2024-11-05 15:33:44] Starting file saving...
[2024-11-05 15:33:44] Saving... Step 1/4: KPI plots
[2024-11-05 15:34:32] Saving... Step 2/4: Output data - Scenario 3/3
[2024-11-05 15:34:39] Saving... Step 3/4: Settings - Scenario 1/3
[2024-11-05 15:35:02] Saving... Step 4/4: Scheme - Scenario 2/3
[2024-11-05 15:35:52] Files saved successfully!
```

```
{
  "InputData": {
    "TimeZoneArea_DropDown": "Europe",
    "TimeZone_DropDown": "Europe/Brussels",
    "WaterOptions": {
      "RainDataPath": "C:\\Users\\songena\\OneDrive - ...",
      "Decimalsep": ".",
      "Delimiter": ";",
      "tformat": "yyyy-MM-dd'T'HH:mm:ss.SSSZZZZ"
    },
    "SolarOptions": { ...
  },
  "ModelSettings": {
    "HouseCharacteristics": {
      "IE": 2.3,
      "A_roof": 106.0,
      "RenewableEnergySettings": {
        "RenewableEnergy": true,
        "n_panel": 2.0,
        "UseBattery": true,
        "C_battery": 2.7
      },
      "Advanced": {
        "PhotoVoltaics": { ...
      },
      "eta_rain": 0.81,
      "DailyFlows": { ...
    },
    "PollutantConcentrations": { ...
  },
  "Tanks": {
    "V_RW_min": 0.5,
    "C_PGM_max": 350.0,
    "NominalVolumes": { ...
  },
  "Prefilled": { ...
  },
  "InitialVolume": { ...
  },
  "TechnologicalSpecifications": { ...
  },
  "Reuse": {
    "General": { ...
  },
  "WaterQualityUsed": { ...
  },
  "WastewaterToGW": { ...
  }
}
```

(collapsed view)

1.4 KPI info



Best used in conjunction with KPI graph tab
(gives calculation method for each KPI and a brief explanation)

1.5 Publications and partners

Scenario input data

Scenario settings

Scenario simulation and management


KPI info

Publications and partners


For more information:

[Van de Walle et. al \(2022\). In silico assessment of household level closed water cycles: Towards extreme decentralization. Environmental Science and Technology, 10, 100148](#)


Ongena et. al (s.d.). An in silico, high resolution assessment of water production and reuse at house level driven by on site electricity production. Unpublished.




De Watergroep



CAPTURE



GHENT
UNIVERSITY



CMET

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

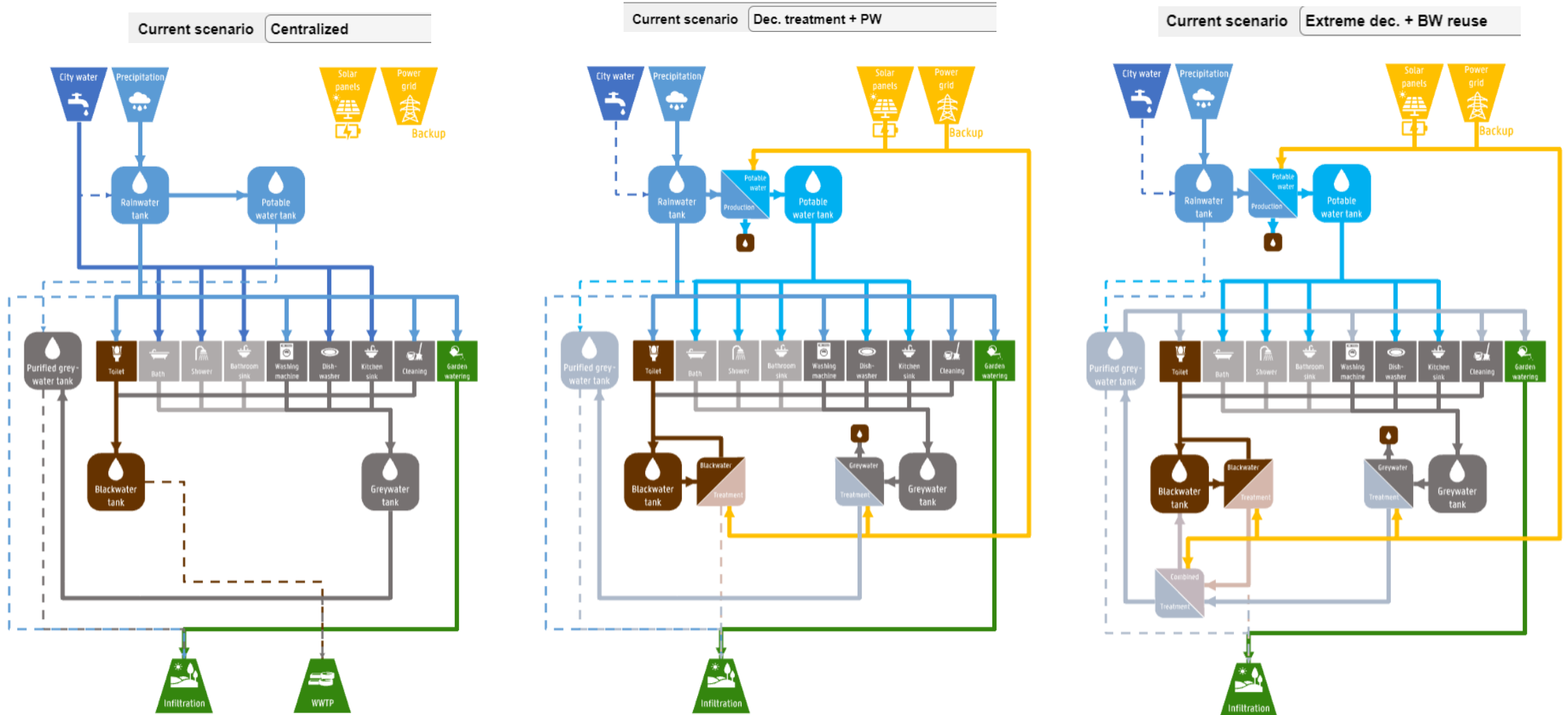
2.4 Renewable energy

2.5 Balance checks



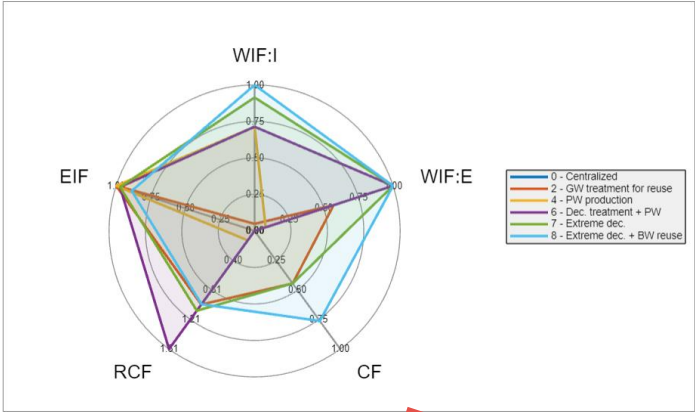
2.1 Graphs: scheme

Scheme updates based on selected settings



2.2 Graphs: KPI

Plot (line or spider), table



KPI plot configuration

Which scenario to plot in graph/show in table

Scenarios

Select	Scenario	Simulated
<input checked="" type="checkbox"/>	0 - Centralized	<input checked="" type="checkbox"/>
<input type="checkbox"/>	1 - Rainwater use	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	2 - GW treatment for reuse	<input checked="" type="checkbox"/>
<input type="checkbox"/>	3 - Dec. treatment and infil.	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	4 - PW production	<input checked="" type="checkbox"/>
<input type="checkbox"/>	5 - GW reuse and PW production	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	6 - Dec. treatment + PW	<input checked="" type="checkbox"/>

KPI

☒ WIF:I
☒ WIF:E
☒ CF
☒ RCF
☐ DTF
☒ EIF

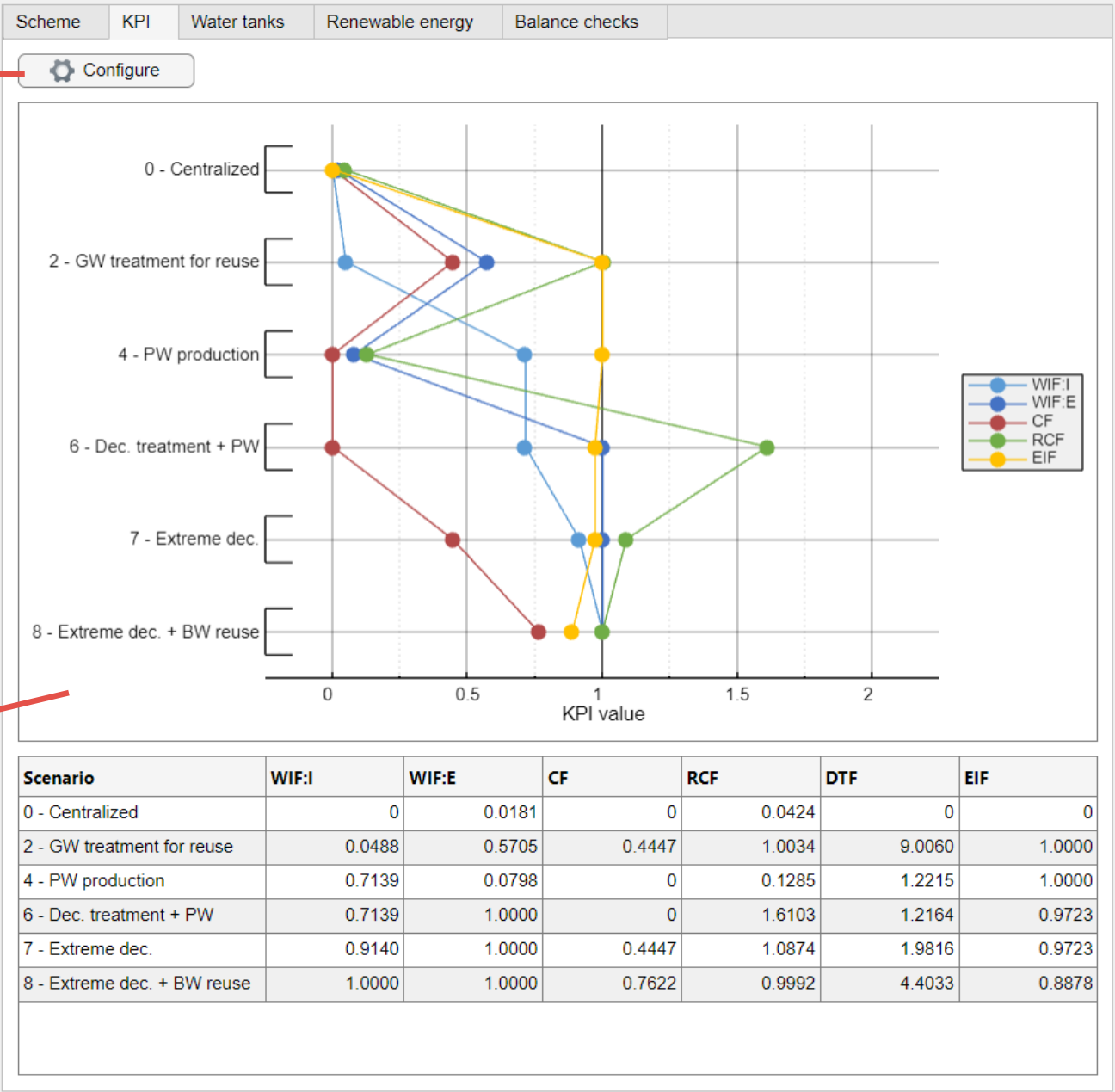
Which KPI to plot in graph

Plot type

Spider
Spider
Line

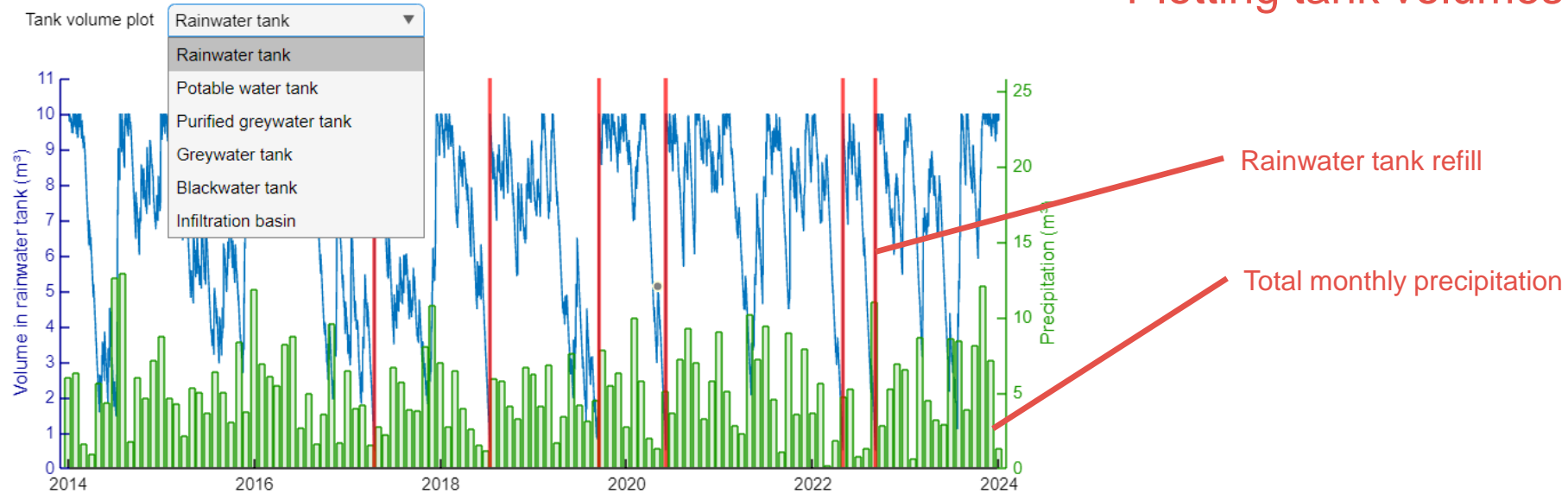
Apply

OK

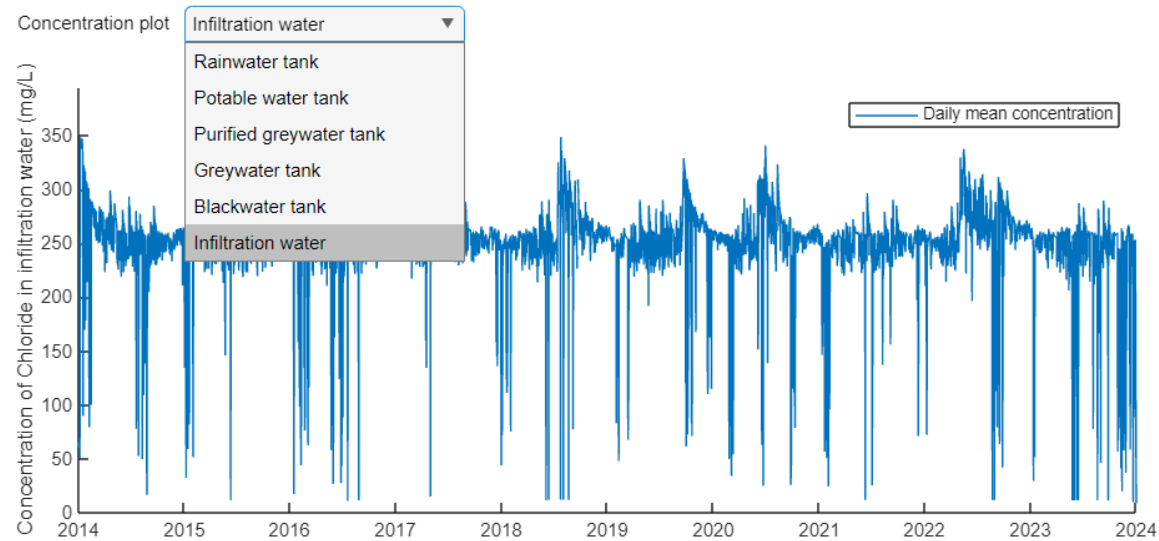


2.3 Graphs: Water tanks

Plotting tank volumes over time

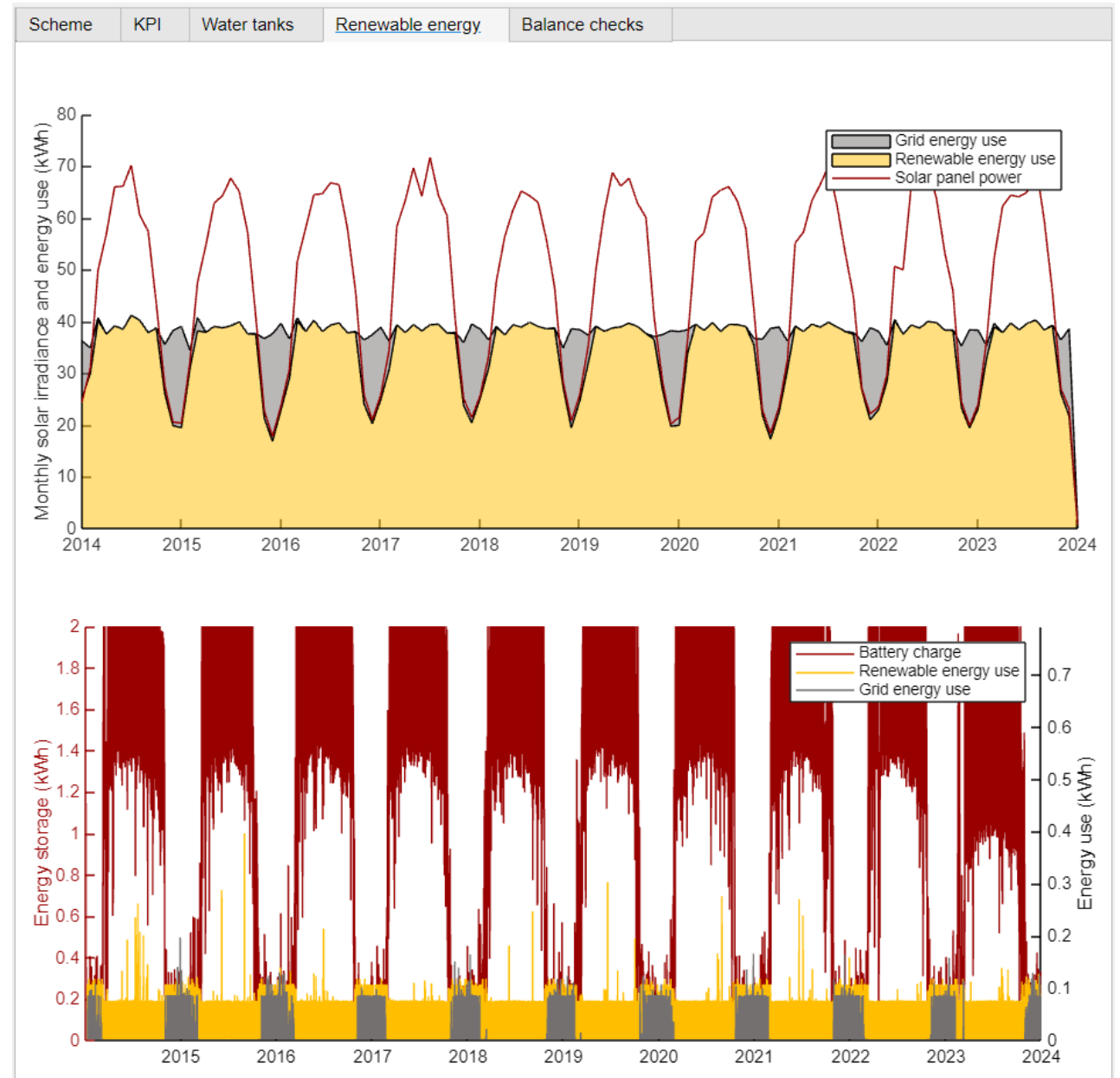


Plotting tank concentrations over time



2.4 Graphs: renewable energy

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

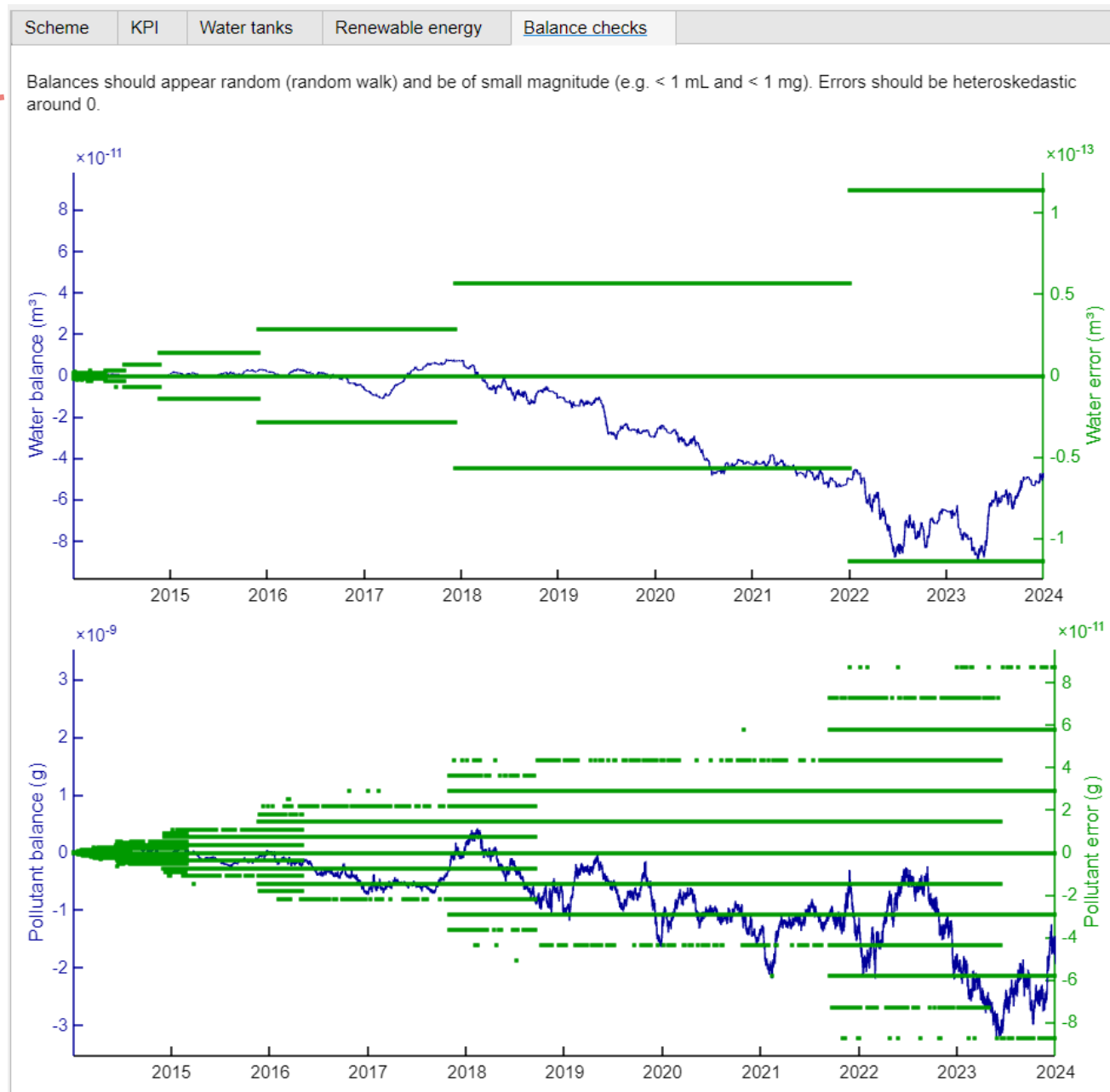


Battery charge and energy use over time

2.5 Graphs balance checks

Balance checks for model correctness

(see explanation)



Example workflow: step 0 – Initialization

Decentralized Household Model

App Load/Save Simulation

Current scenario Scenario 1*

Scenario input data Scenario settings Scenario simulation and management KPI info Publications and partners

Load data ☐

Simulate current ☐

Add Load Simulate Delete Save

Select	Scenario	Name	Simulated
<input type="checkbox"/>	1	Scenario 1*	<input type="checkbox"/>

Wait for app initialization

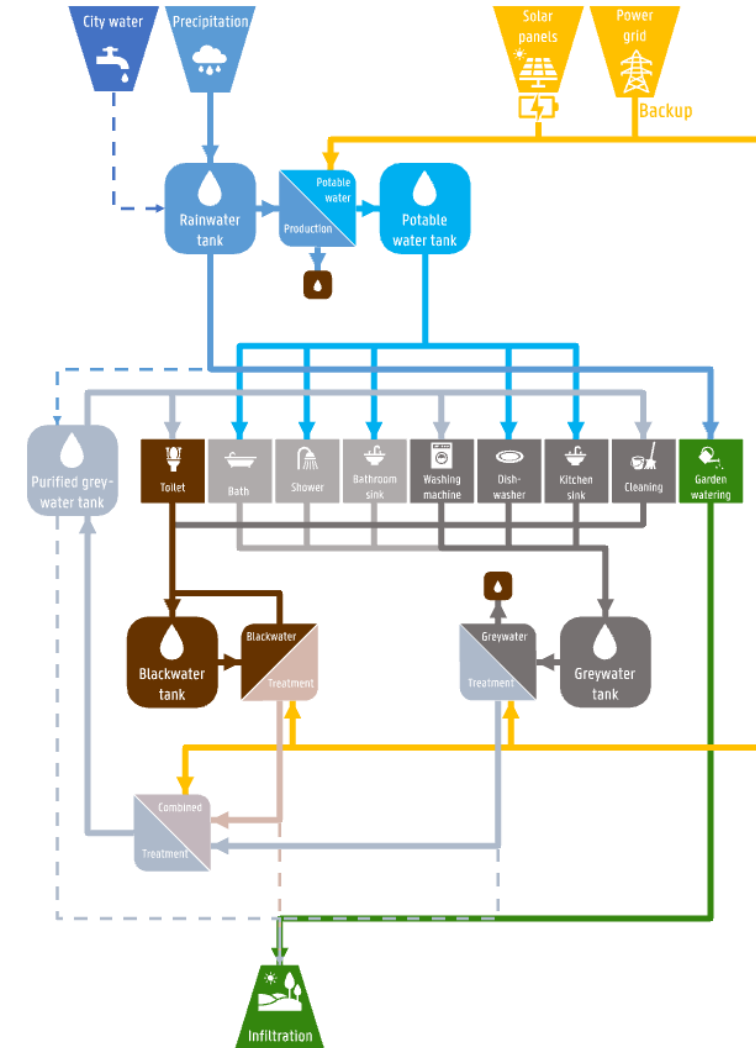
(usually 30s after window appears)

Log

[2024-11-05 15:56:01] Initializing app (1/6): Setting up...
[2024-11-05 15:56:03] Initializing app (2/6): Generating initial plots...
[2024-11-05 15:56:09] Initializing app (3/6): Generating base scheme...
[2024-11-05 15:56:17] Initializing app (4/6): Loading default scenario...
[2024-11-05 15:56:19] Initializing app (5/6): Generating figures...
[2024-11-05 15:56:21] Initializing app (6/6): Done!

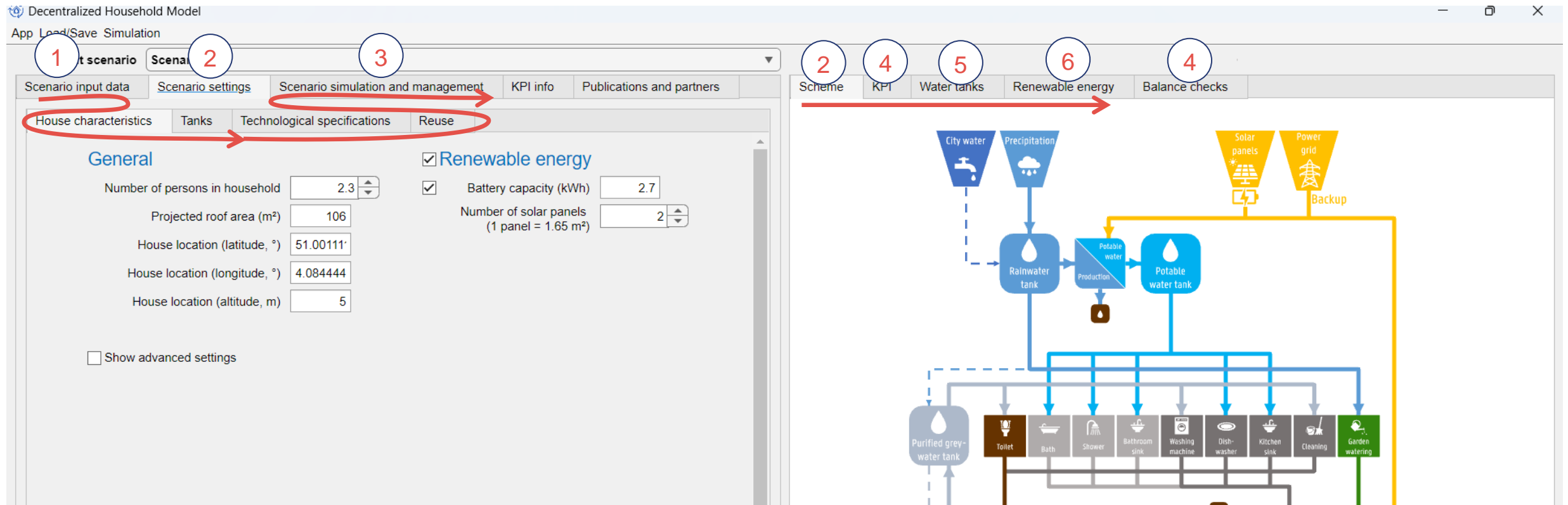
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Scheme KPI Water tanks Renewable energy Balance checks



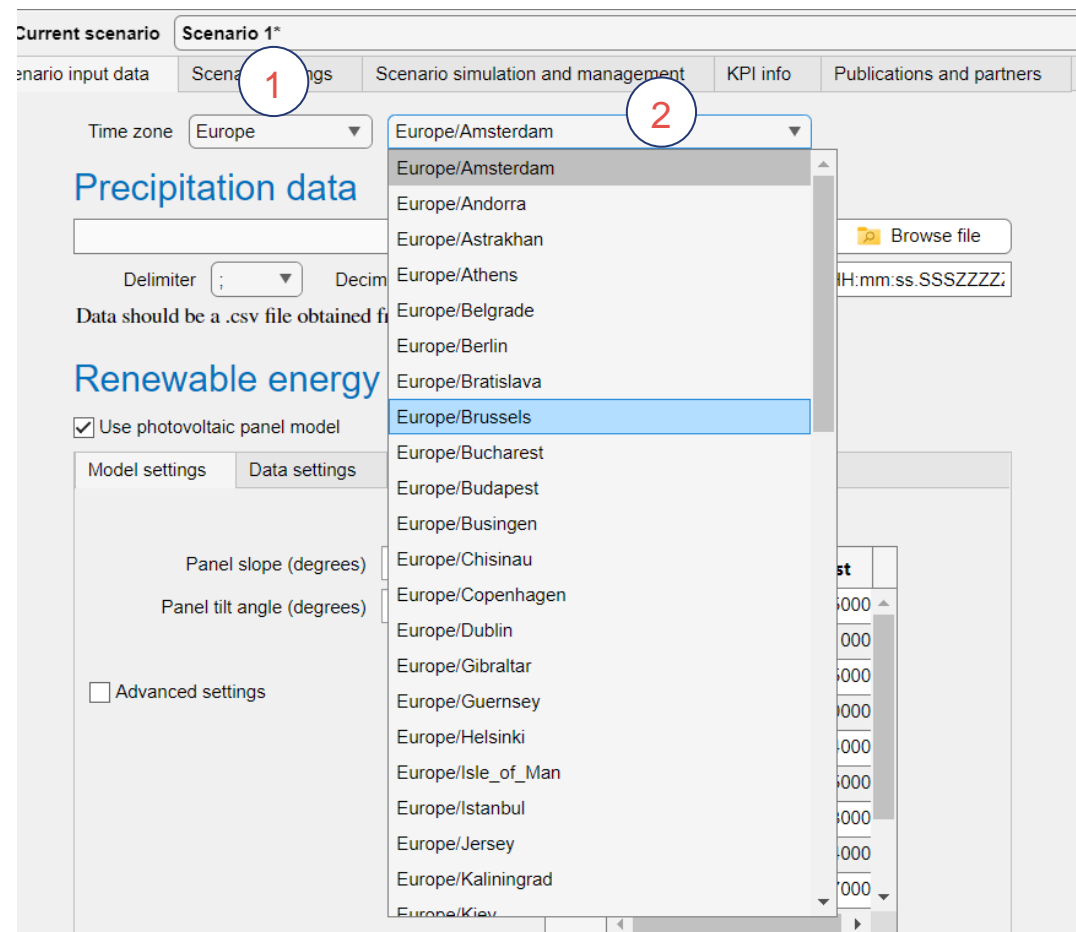
Example workflow: overview

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

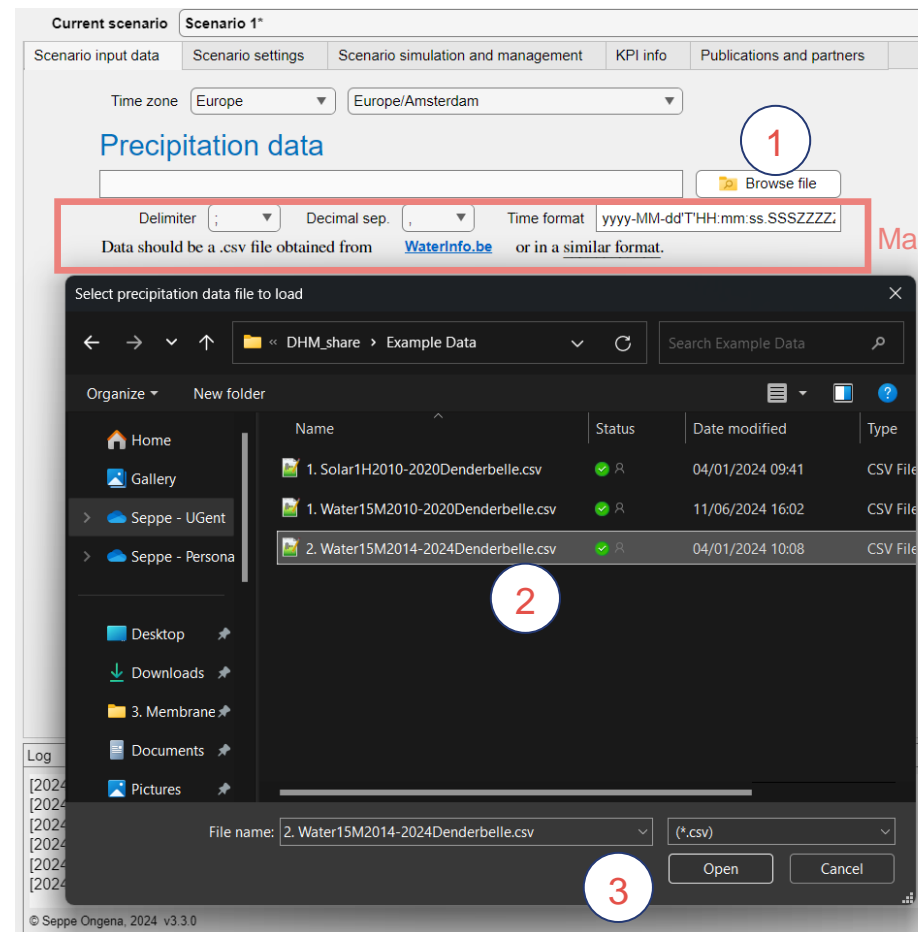


Example workflow: step 1 – Input data

Select time zone area and time zone



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)

Current scenarioScenario 1*

Scenario input dataScenario settingsScenario simulation and managementKPI infoPublications and partners

House characteristicsTanksTechnological specificationsReuse

☒ Greywater treatment

Design flow (m³/d)1.2

Energy use (kWh/m³)1.85

Water recovery0.95

Removal efficiency0

☒ Water pumps

Design flow (m³/d)1.2

Energy use (kWh/m³)0.2

☐ Blackwater treatment

Design flow (m³/d)1.2

Energy use (kWh/m³)0.5

Water recovery0.9

Removal efficiency0

☒ Potable water treatment

Design flow (m³/d)0.6

Energy use (kWh/m³)2

Water recovery0.8

Removal efficiency0.95

☐ Combined grey- and blackwater treatment

Design flow (m³/d)1.2

☐ Show advanced settings

$$Q_{\text{feed}} \quad c_{\text{feed}} \quad \text{or} \quad Q_{\text{influent}} \quad c_{\text{influent}}$$
$$Q_{\text{permeate}} \quad c_{\text{permeate}} \quad \text{or} \quad Q_{\text{effluent}} \quad c_{\text{effluent}}$$
$$Q_{\text{retentate}} \quad c_{\text{retentate}} \quad \text{or} \quad Q_{\text{waste}} \quad c_{\text{waste}}$$

$$r = \frac{Q_{\text{permeate}}}{Q_{\text{feed}}} = 1 - \frac{Q_{\text{retentate}}}{Q_{\text{feed}}}$$
$$R = \frac{c_{\text{feed}} - c_{\text{permeate}}}{c_{\text{feed}}} = 1 - \frac{c_{\text{permeate}}}{c_{\text{feed}}}$$

Log

[2024-11-05 15:56:01] Initializing app (1/6): Setting up...
[2024-11-05 15:56:03] Initializing app (2/6): Generating initial plots...
[2024-11-05 15:56:09] Initializing app (3/6): Generating base scheme...
[2024-11-05 15:56:17] Initializing app (4/6): Loading default scenario...
[2024-11-05 15:56:19] Initializing app (5/6): Generating figures...
[2024-11-05 15:56:21] Initializing app (6/6): Done!
[2024-11-05 16:01:07] Data file selected: precipitation

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SchemeKPIWater tanksRenewable energyBalance checks

Example workflow: step 3 – Simulate

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

App Load/Save Simulation

Current scenario: **My dream house**

Scenario input data | Scenario settings | Scenario simulation and management | KPI info | Publications and partners

Load data | Success! | Simulate current | Simulations complete!

Add | Load | Simulate | Delete | Save | Up | Down

Select	Scenario	Name	Simulated
<input type="checkbox"/>	1	My dream house	<input checked="" type="checkbox"/>

Log

[2024-11-05 16:02:10] Initializing simulation (2/2): Passing data...
[2024-11-05 16:02:11] Running simulations...
[2024-11-05 16:02:30] Retrieving data...
[2024-11-05 16:02:30] Calculating infiltration and peak rainwater use...
[2024-11-05 16:02:31] Calculating KPI...
[2024-11-05 16:02:31] Plotting data...
[2024-11-05 16:02:36] Simulation completed in 24.2252 seconds.

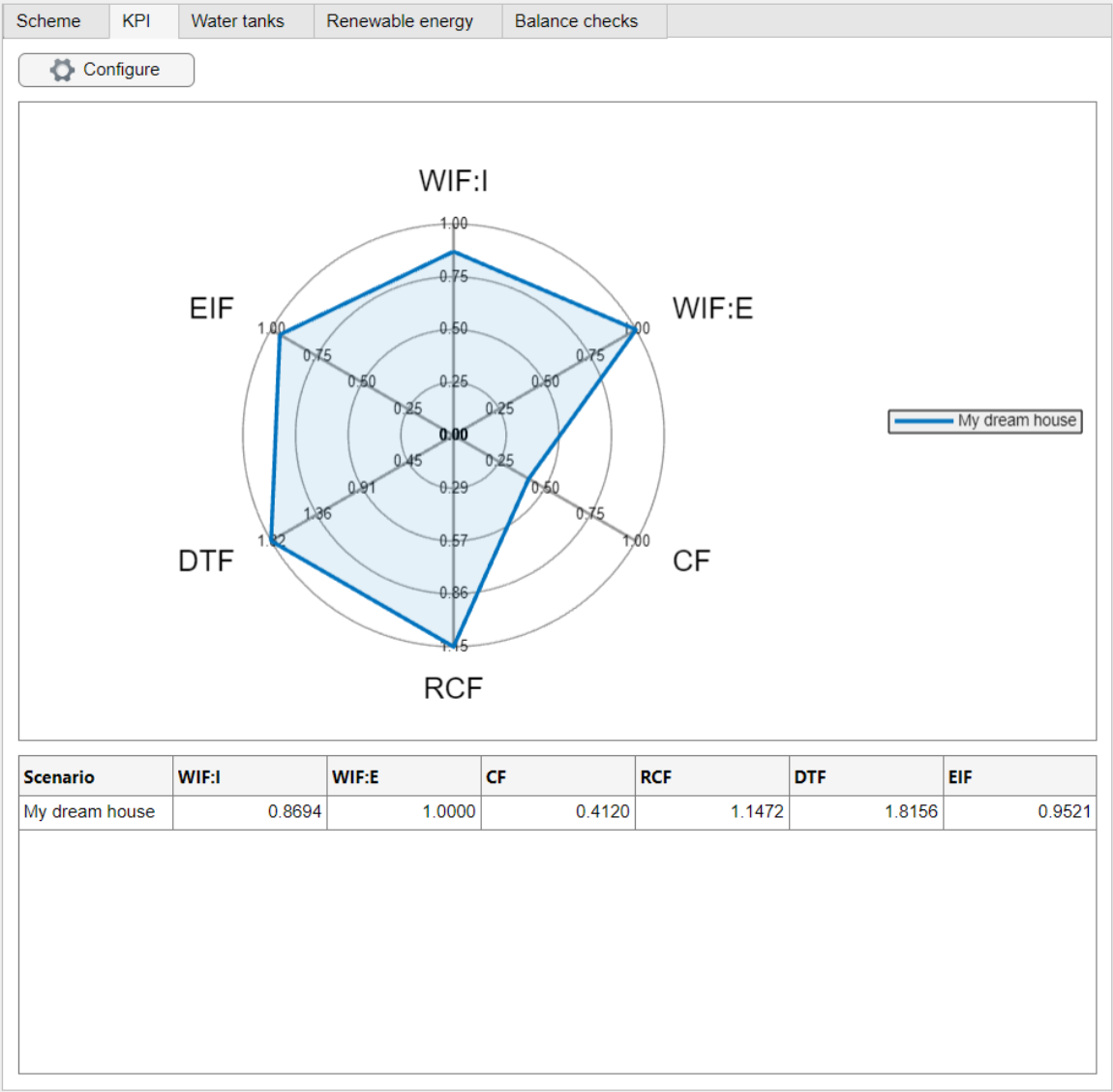
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Scheme | KPI | Water tanks | Renewable energy | Balance checks

```
graph TD
    CityWater[City water] -.-> RainwaterTank[Rainwater tank]
    Precipitation[Precipitation] --> RainwaterTank
    RainwaterTank --> Production[Production]
    Production --> PotableTank[Potable water tank]
    PotableTank --> PotableWater[Potable water]
    SolarPanels[Solar panels] --> PotableWater
    PowerGrid[Power grid] --> PotableWater
    PotableWater --> Backup[Backup]
    RainwaterTank --> Toilet[Toilet]
    RainwaterTank --> Bath[Bath]
    RainwaterTank --> Shower[Shower]
    RainwaterTank --> BathroomSink[Bathroom sink]
    RainwaterTank --> WashingMachine[Washing machine]
    RainwaterTank --> DishWasher[Dish-washer]
    RainwaterTank --> KitchenSink[Kitchen sink]
    RainwaterTank --> Cleaning[Cleaning]
    RainwaterTank --> GardenWatering[Garden watering]
    Toilet --> BlackwaterTank[Blackwater tank]
    Bath --> BlackwaterTank
    Shower --> BlackwaterTank
    BathroomSink --> BlackwaterTank
    WashingMachine --> GreywaterTank[Greywater tank]
    DishWasher --> GreywaterTank
    KitchenSink --> GreywaterTank
    Cleaning --> GreywaterTank
    GardenWatering --> Infiltration[Infiltration]
    BlackwaterTank --> BlackwaterTreatment[Blackwater treatment]
    GreywaterTank --> GreywaterTreatment[Greywater treatment]
    BlackwaterTreatment --> CombinedTreatment[Combined treatment]
    GreywaterTreatment --> CombinedTreatment
    CombinedTreatment --> PurifiedGreyWaterTank[Purified grey-water tank]
    PurifiedGreyWaterTank --> RainwaterTank
    PotableWater --> CombinedTreatment
```

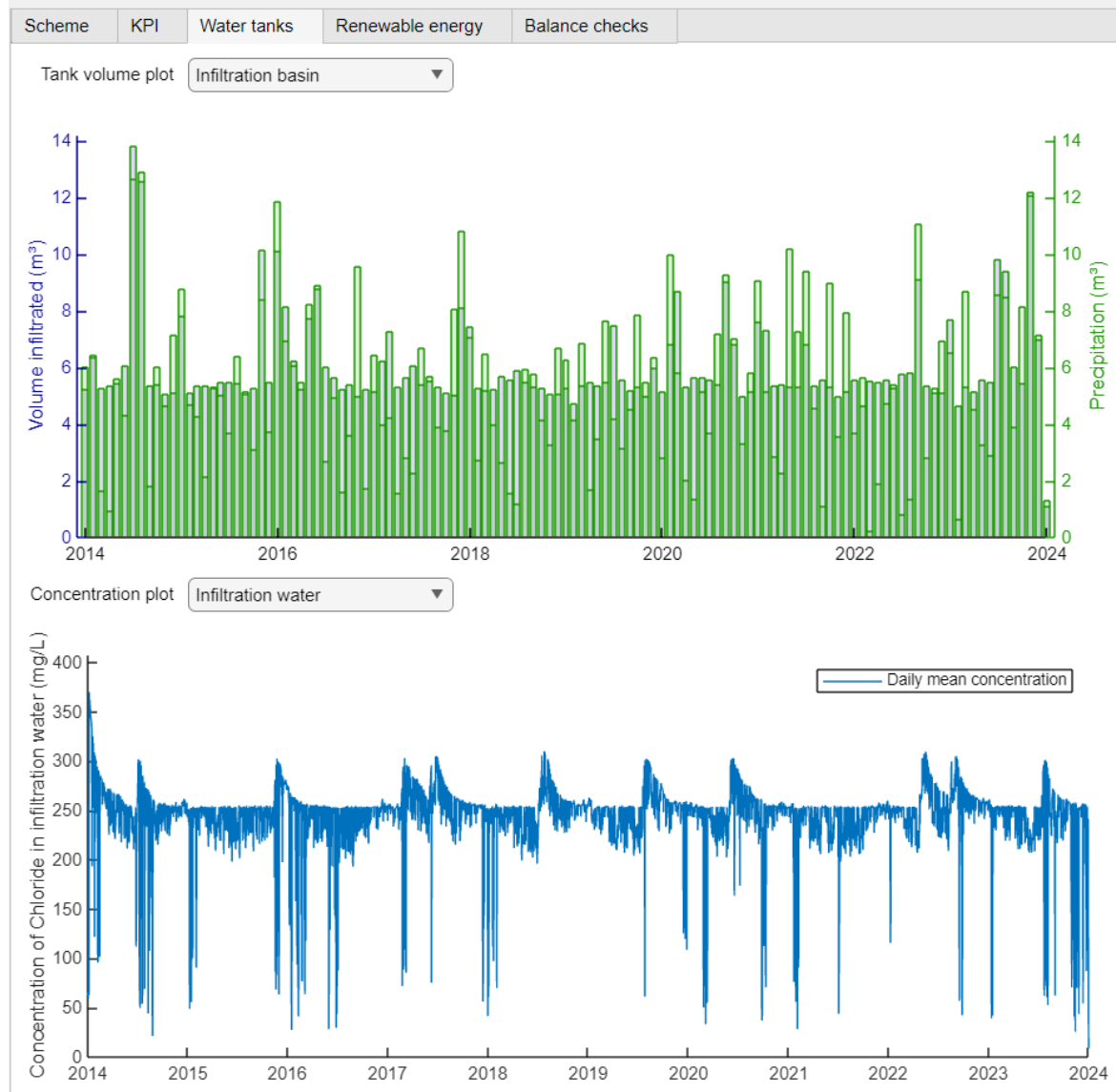
Example workflow: step 4 – Evaluate KPI

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



Example workflow: step 5 – Delve into water tanks

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

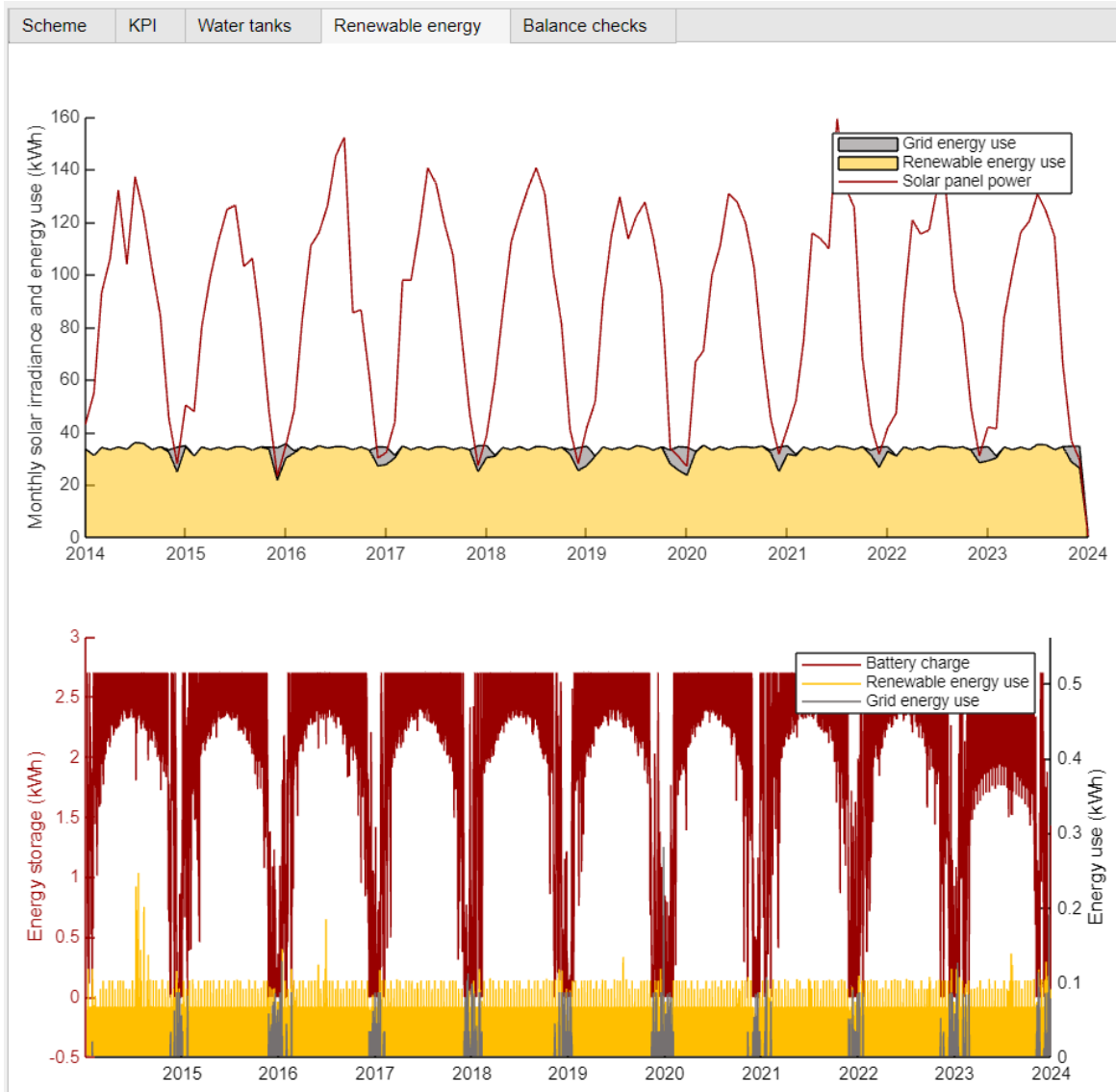


Admire the buffering effect of a decentralized household

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

The screenshot displays the 'Decentralized Household Model' software interface. The main window shows the 'Current scenario' as 'My dream house' and the 'Save' button. A 'Save configuration' dialog box is open, showing the following steps:

- Press 'Save' in the main window.
- Choose a folder to save.
- Select scenarios to save (e.g., 'My dream house').
- Select data variables to save (e.g., 'Energy').

The background shows two line graphs: 'Scheme' (top) and 'Energy' (bottom), both displaying data from 2015 to 2024. The 'Scheme' graph shows 'Grid energy use' (grey), 'Renewable energy use' (yellow), and 'Solar panel power' (red). The 'Energy' graph shows 'Battery charge' (red), 'Renewable energy use' (yellow), and 'Grid energy use' (grey).

Log:

- [2024-11-05 16:06:14] Retrieving data...
- [2024-11-05 16:06:14] Calculating infiltration and peak rainwater use...
- [2024-11-05 16:06:15] Calculating KPI...
- [2024-11-05 16:06:15] Plotting data...
- [2024-11-05 16:06:24] Simulation completed in 18.0086 seconds.
- [2024-11-05 16:06:51] Loading scenario...
- [2024-11-05 16:06:55] Scenario loaded

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Ir. Seppe Ongena

E: Seppe.Ongena@ugent.be

T: +32 9/264 59 76



Seppe Ongena

www.cmet.ugent.be

www.capture-resources.be

