VRA Hydro resource optimisation model

AIWW

Project related

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Outline

- *Background*
- *Challenges*
- *The model*
- *Interface*
- *Conclusions*

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Hydro resource optimisation model

- A hydro Resource Optimisation model (HRO-model) has been developed for the Volta River Authority (VRA)
- Executed between October 2021 and November 2022
- Final product has been delivered
- Used for general operations of the planning department

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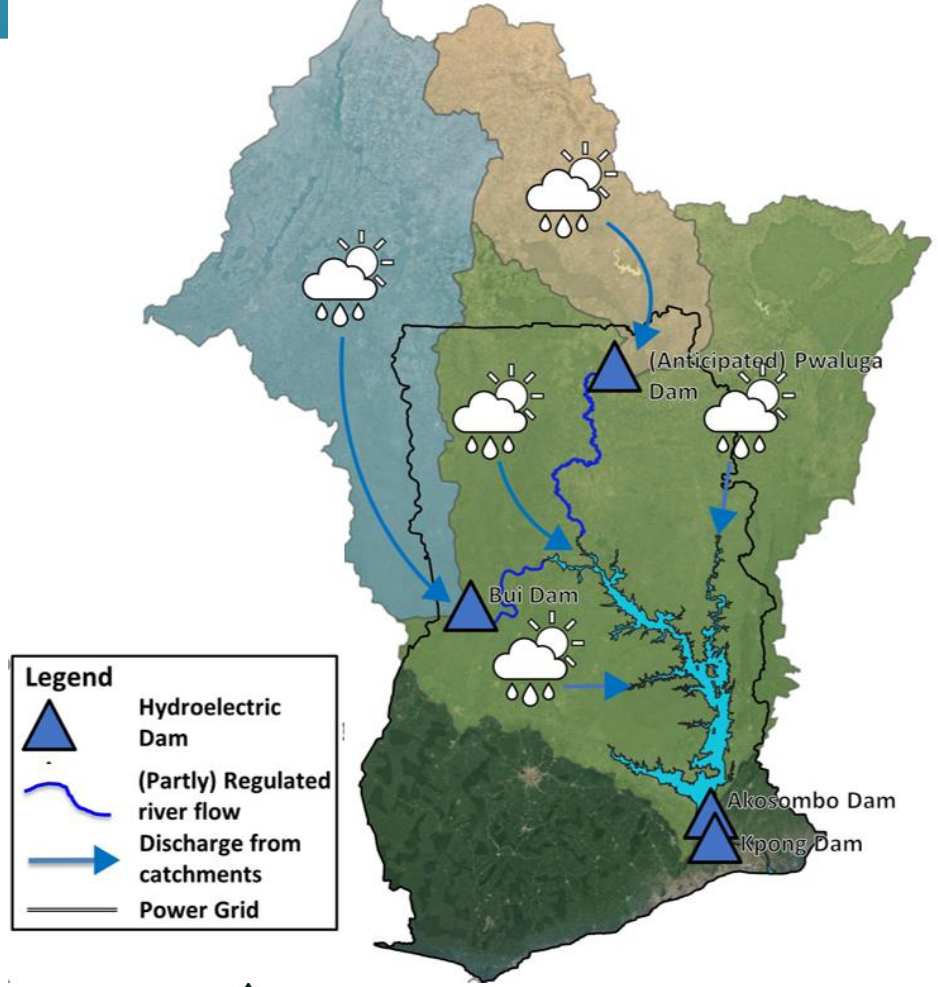
Background

- Volta river basin is the main river basin in Ghana (also covers Burkina Faso, Ivory Coast and Togo)
- Akosombo Dam (Lake Volta)
  - 1020 MW installed capacity
  - 70 km^3 of active storage
  - 30 km^3 of yearly average inflow
- Kpong reservoir
  - Run of the river downstream of Akosombo
  - 160 MW installed capacity
- Bui reservoir
  - In black volta tributary
  - 400 MW installed capacity
  - Operations not managed by VRA
- High growth in power demand
- Risks of multi-year draughts and wet periods
- Spilling is a rare occurrence and in the current setting holds significant risk of downstream flood issues
- Main takeaway: very long planning horizon



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Objectives of this Assignment

- **Develop a simulation and optimization model for the Volta basin reservoir system**
- **Develop an interface that supports the planning department in planning hydropower operations with a time horizon of 3 years**
- **The developed system should provide risks associated to the planned operational strategy**
- Develop a scheduling tool to integrate planned hydropower production into the broader supply of power by the VRA to the Ghana electricity network.
- Develop a tool to get insights in the costs associated to the planned operations and give advice on the tariff structure

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Challenges

- Developing an intuitive and easy to use interface for the user group that fits with their level of expertise.
- Trade-off between system complexity and maintenance requirements.
- Translate current operational procedures and requirements into formalised operating rules such that relevant operational advice can be provided by the system.

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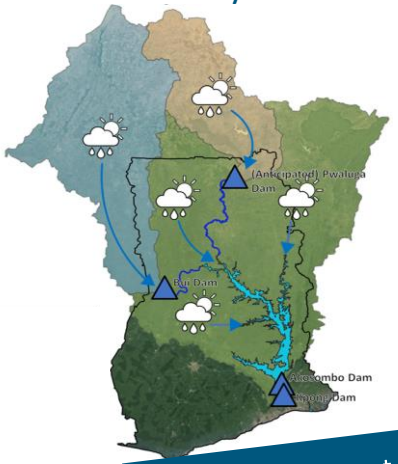
Reservoir system



SIMULATION PARAMETERS

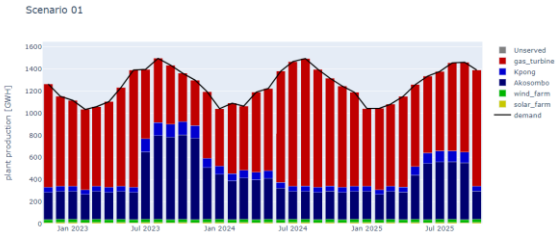
Start date simulation (first day of the month):	01-01-2023	Info
Forecast horizon [years]:	2	Info
Level of safety against exceeding 240 ft. level [year]:	25	Info
Level of safety against exceeding 276 ft. level [year]:	25	Info
Number of scenarios:	4	Info

Yearly net inflow Akosombo in MAF per scenario (including evaporation losses)

	scenario_001	scenario_002	scenario_003	scenario_004
2023	24.6	24.6	24.6	24.6
2024	24.6	24.6	24.6	24.6

AKOSOMBO RESERVOIR

Initial level Akosombo at start of the month [ft+MSL]:	262	Info
Other water demand [CFS]:	3,9729375	Info
Spill capacity [CFS]:	706300	Info
Range turbine Power [MW]:	340 – 1020	Info

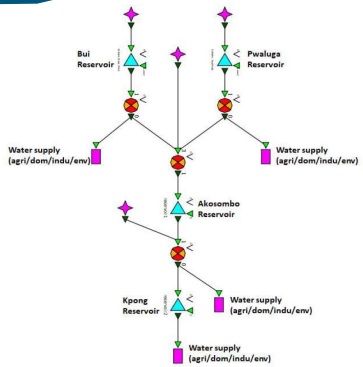


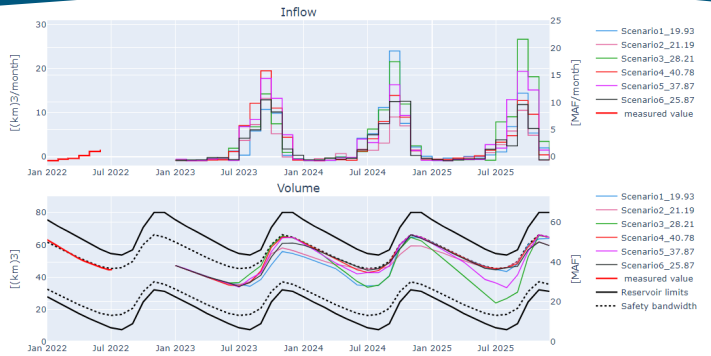
Model development

User interface

Result visualisation

Resource allocation





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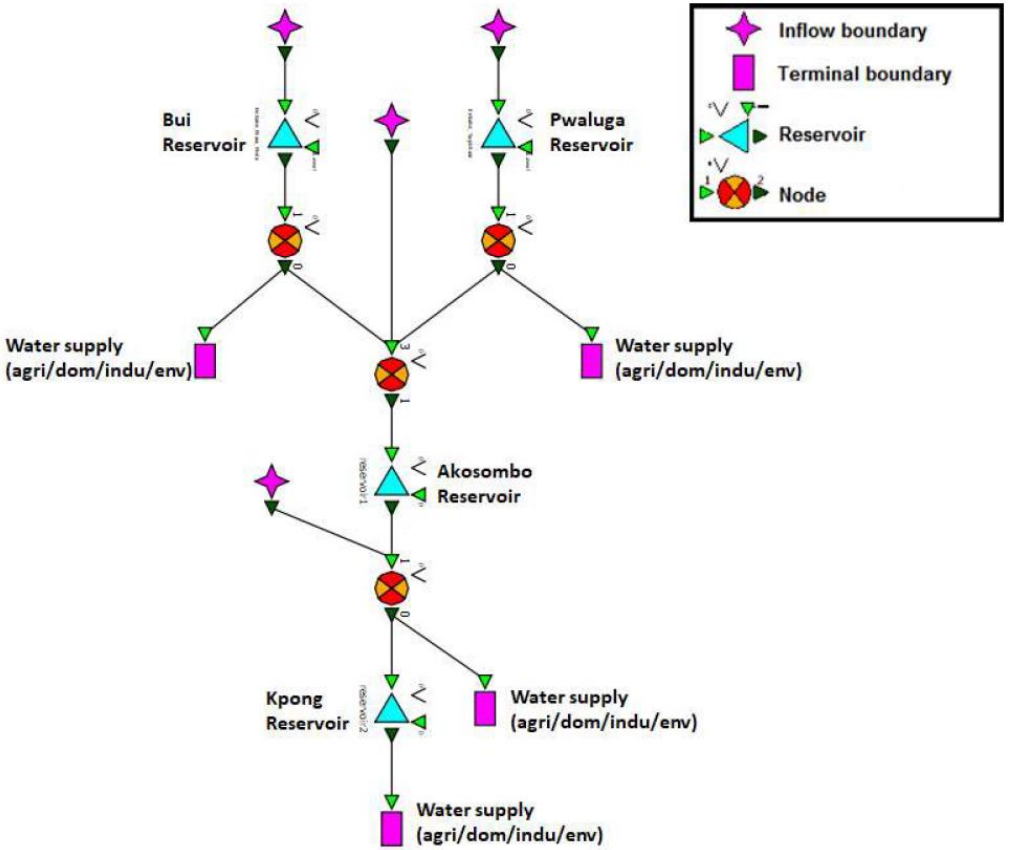
The model

Based on RTC-tools (Real-Time control and optimisation package developed by Deltares)

- Open modellica model structure
- Developed in Python

- Basic box models of reservoirs with:
  - Storage curve
  - Inflow from the catchments
  - Interactions between reservoirs
  - Release structures

- Defined objective function
  - Keep water level within required range
  - Minimise spilling
  - Avoid an empty reservoir
  - Trade-off between maximising current use and s water for future production



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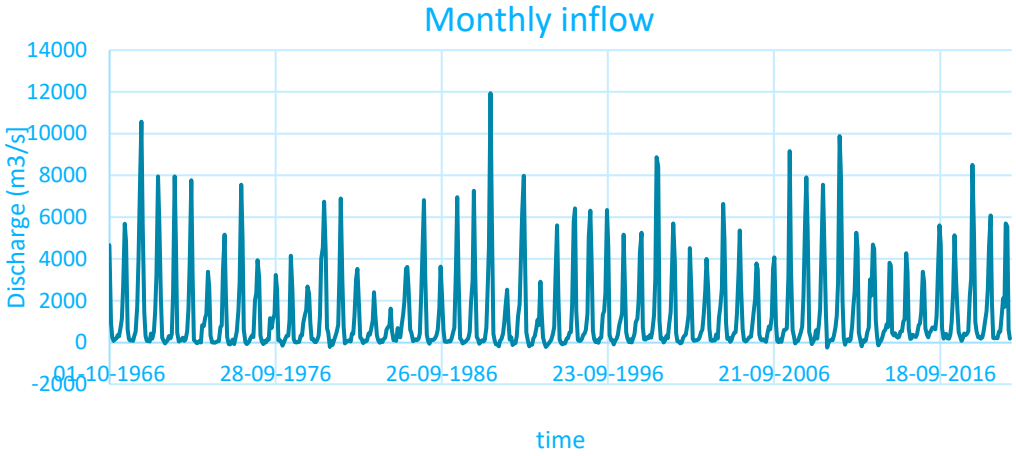
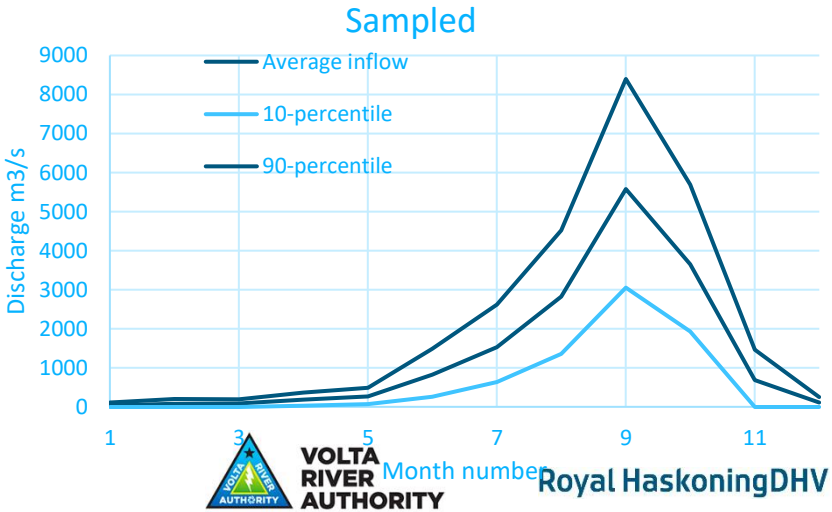
Data analysis

- Release data and reservoir levels are available from 1966-2021
- Monthly inflow can be determined
- Statistical characteristics determined
- Operationalised to:
  - Generate random inflow ensembles
  - Calculate return period of known or chosen inflow scenario
  - Associate a risk level to a particular reservoir level at a given point in time





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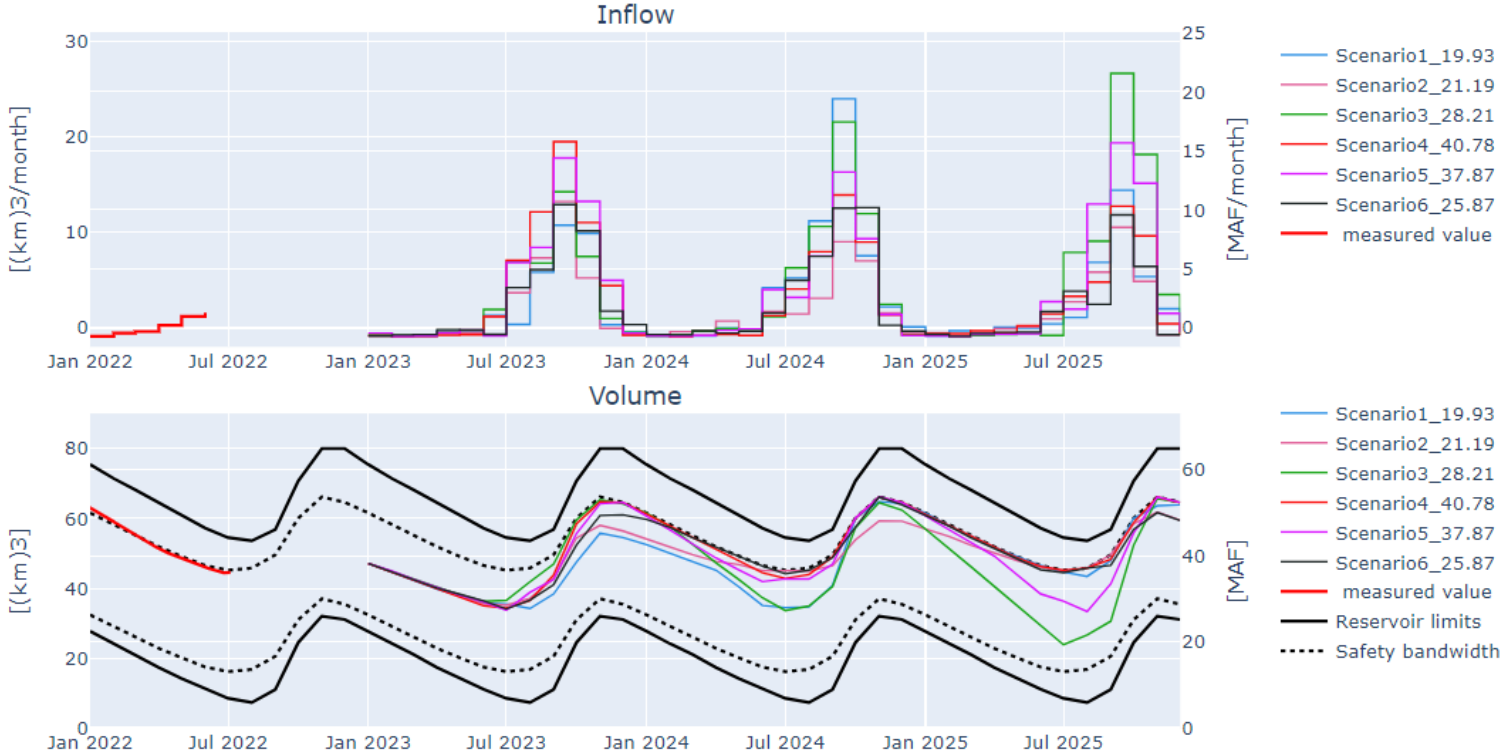
Ensemble simulations



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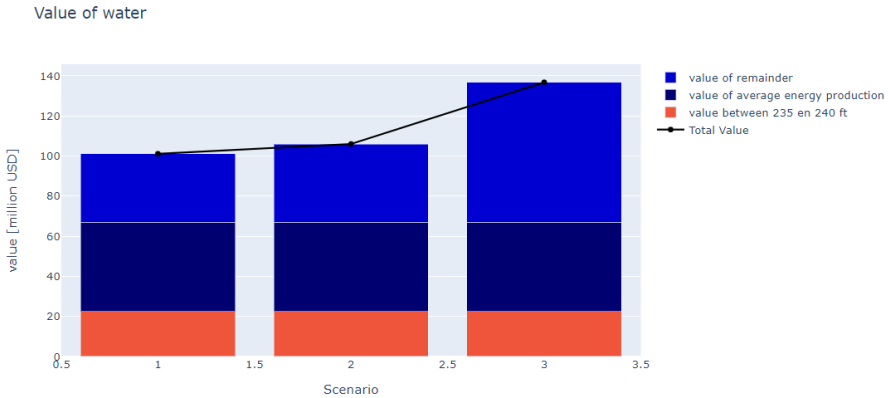
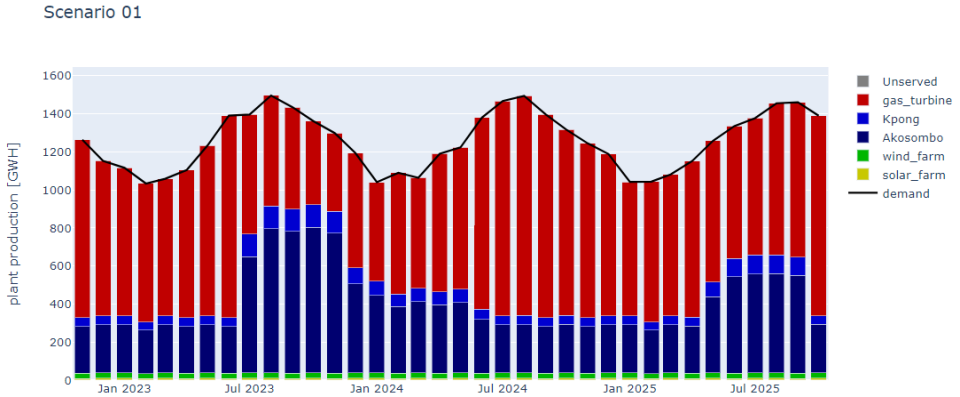
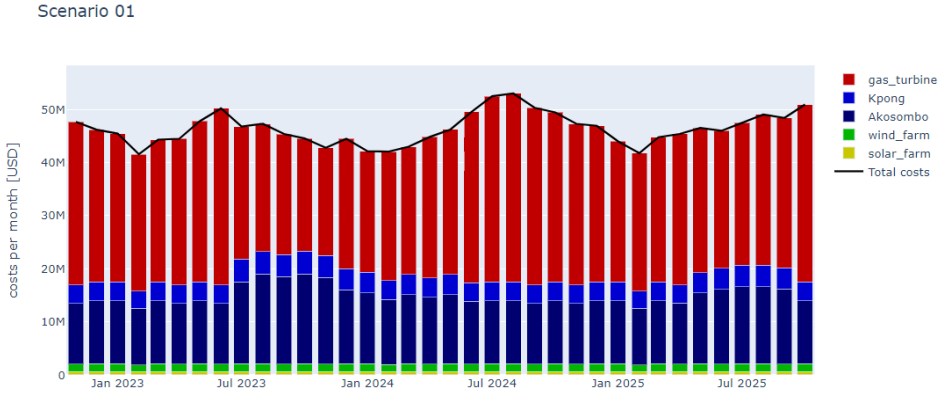
Further data processing

- Resource allocation tool for all VRA operated power production plants
  - Based on cheapest production unit first
- Cost calculation module based on allocation outcome
- Tariff calculation based on allocation outcome
- Calculation of potential revenue based on current reservoir storage (value of water)







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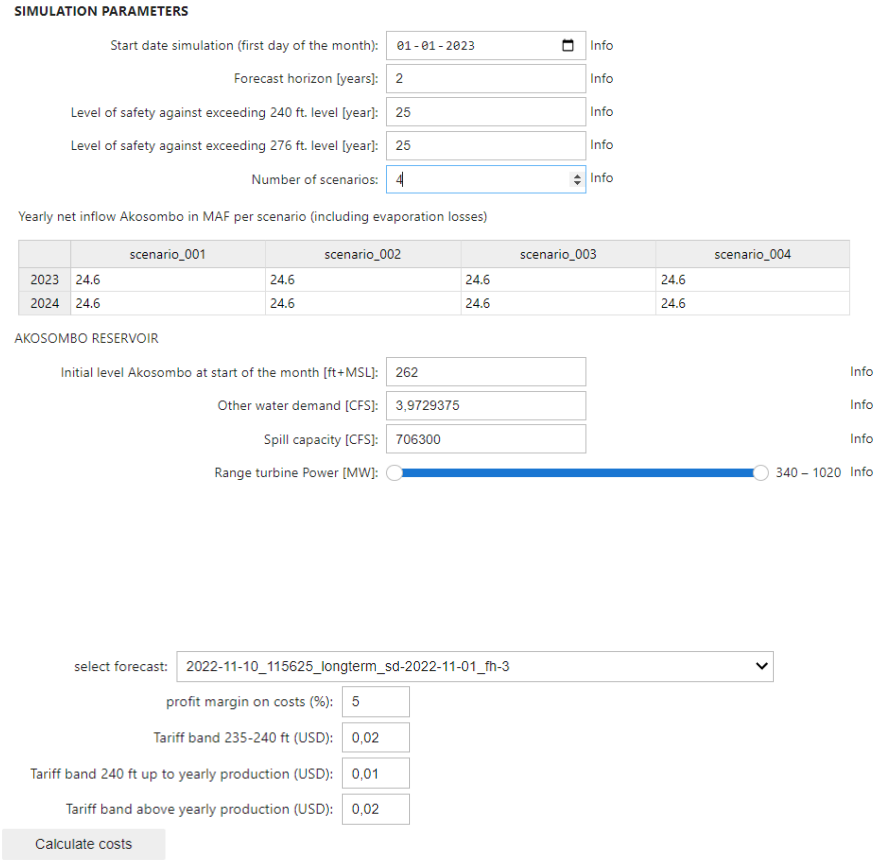
Jupyter notebooks

- All functioning code is in python code
- User interface based on Jupyter notebooks
  - notebooks for data import/input
  - Several notebooks for running the optimisation model in different modes (e.g. random inflow ensembles, target production rate, fixed inflow scenario's)
  - Notebooks for further data processing
  - Notebooks to produce automated reports and standardised visualisations

- User configure settings and operate the workflows via Ipywidgets
- All output is available in csv file format for further (offline) processing
- IT-setup:
  - File based data base
  - Code deployed as wheel
  - Python environment setup in miniconda



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Conclusions

- An easy to use interface was developed based on client specifications while csv files are made accessible for advanced processing
- Easy to deploy software package, updates simply require setup of a new wheel
- Excellent working relation with the client resulted in a tailor-made system according to their requirements with little compromise

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Thank you for your attention