NEXUS Gains Seminar:

Assessing and optimizing infrastructure investments in water-energy systems

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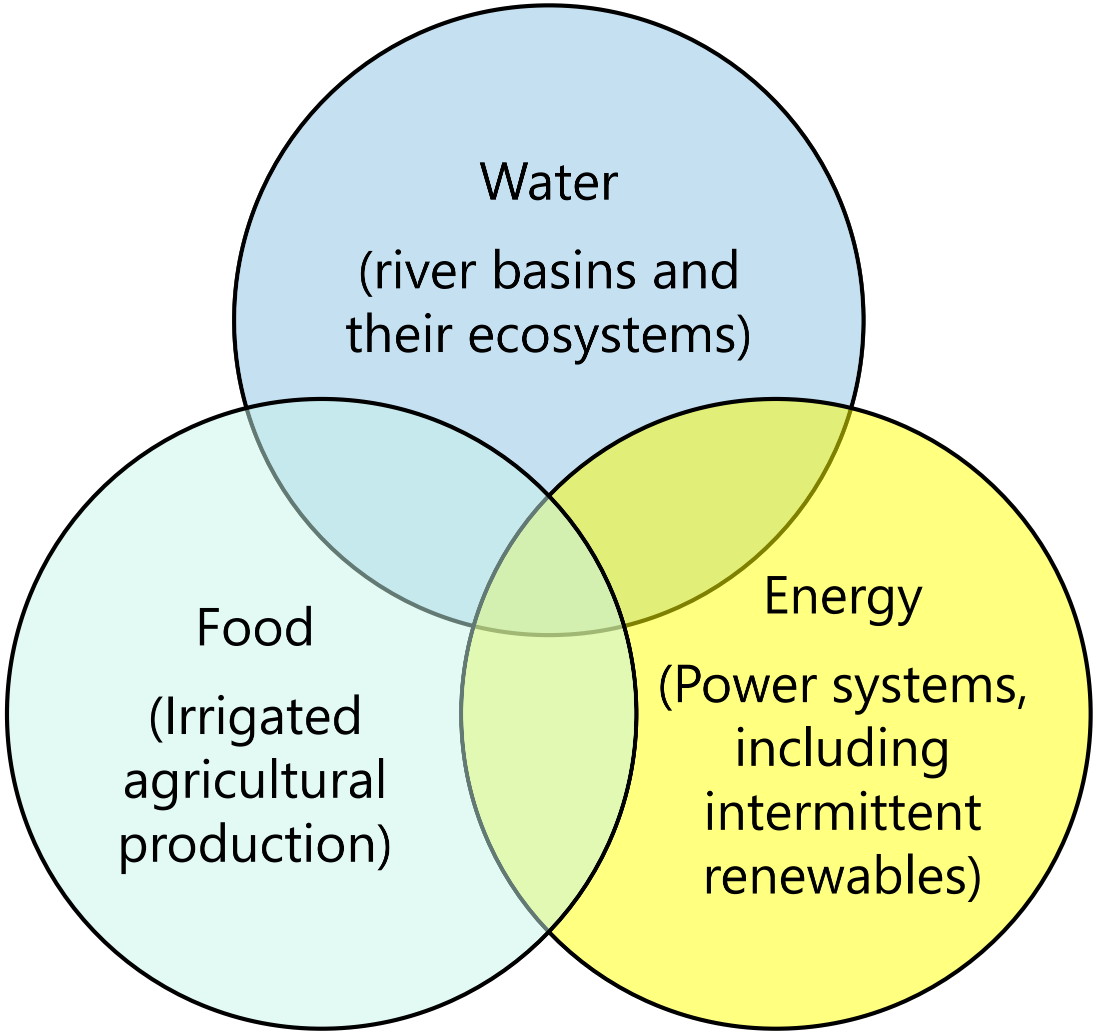
University of Manchester

Wednesday, 15 November 2023

Integrated power system and river basin and simulation & system design



Initial design framework paper:

Read more in this open-access article

https://doi.org/10.1016/j.apenergy.2020.114794

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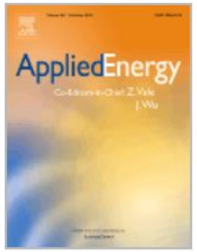
Applied Energy
Volume 269, 1 July 2020, 114794



Spatial and sectoral benefit distribution in water-energy system design

Jose M. Gonzalez [a], James E. Tomlinson [a], Julien J. Harou [a f], Eduardo A. Martínez Ceseña [b], Mathaios Panteli [b], Andrea Bottacin-Busolin [a], Anthony Hurford [a], Marcelo A. Olivares [c], Afzal Siddiqui [d e], Tohid Erfani [f], Kenneth M. Strzepek [g], Pierluigi Mancarella [b h], Joseph Mutale [b], Emmanuel Obuobie [i], Abdulkarim H. Seid [j], Aung Ze Ya [k]

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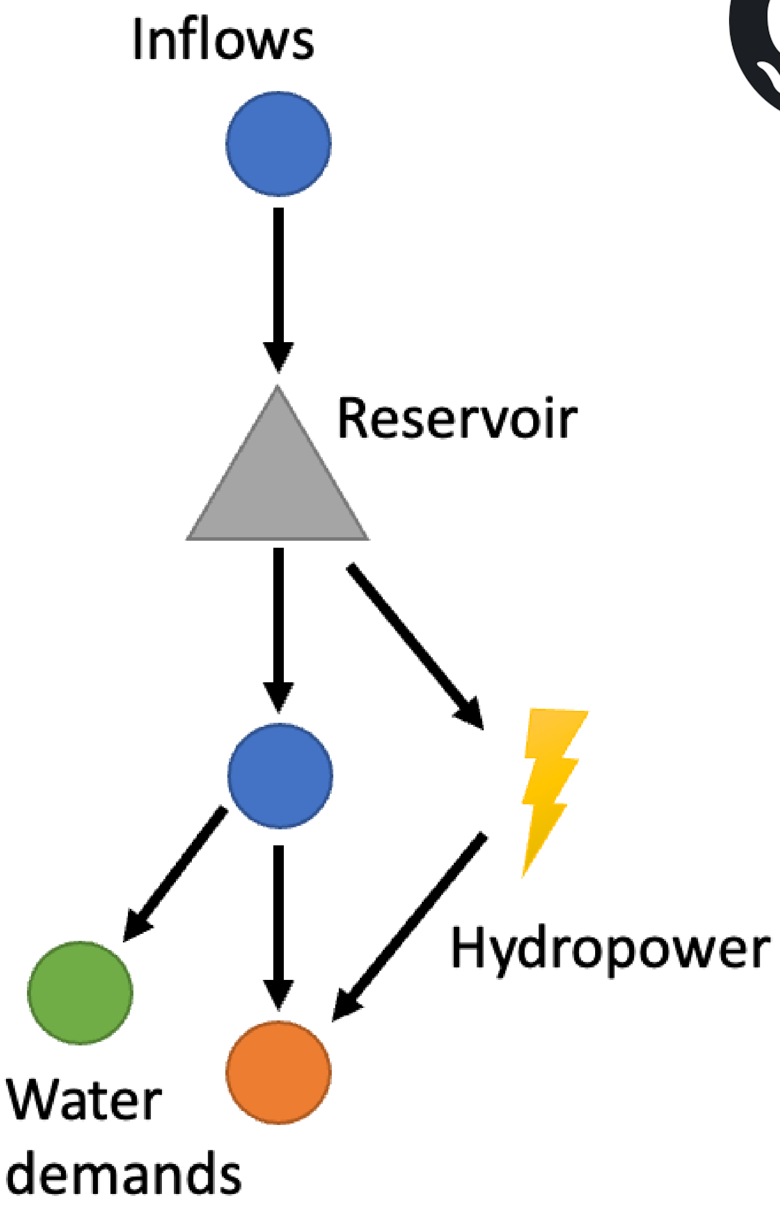
Tools: Open-source water-energy simulation models, online user-software

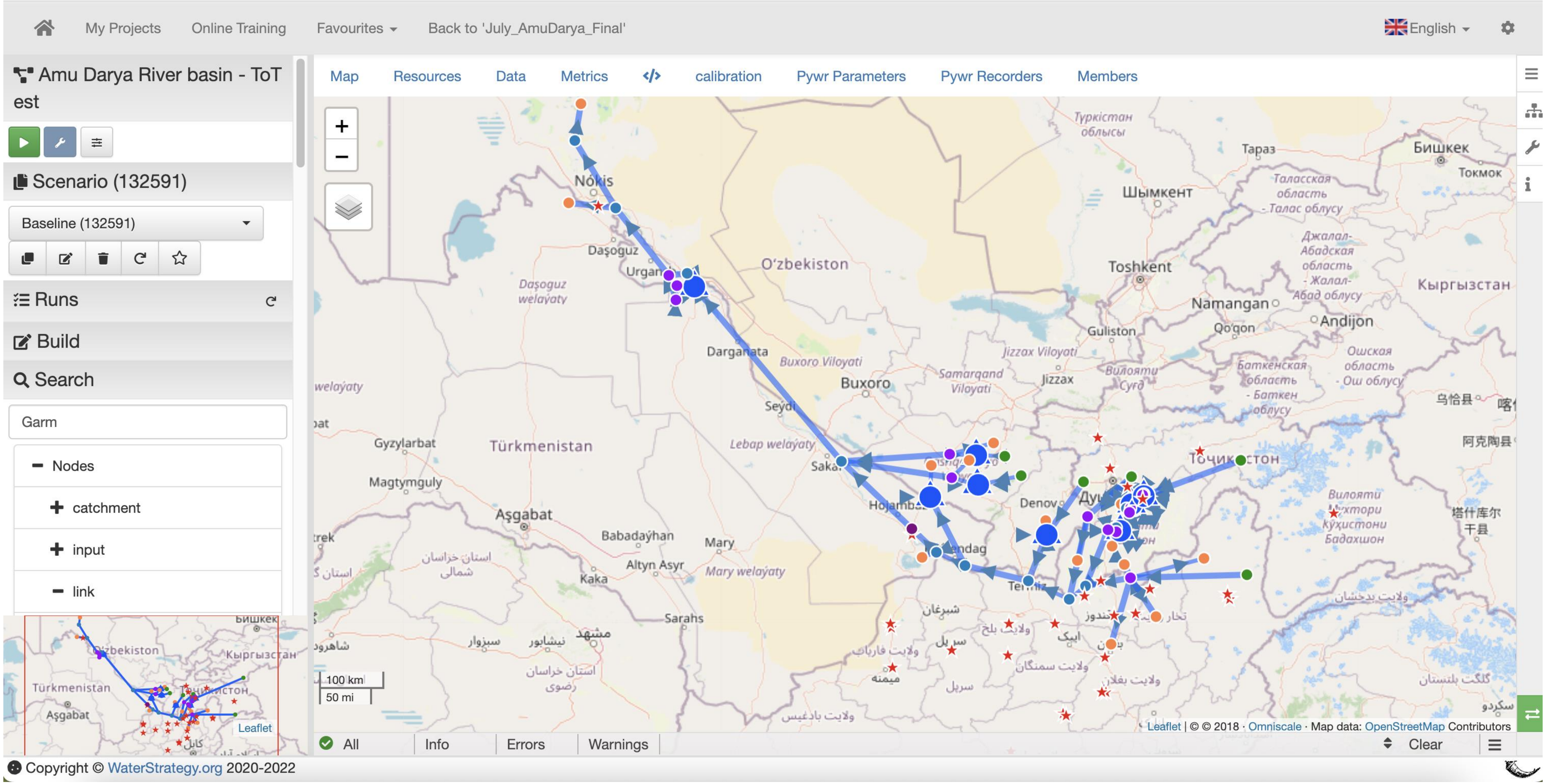
Water resource system simulator (Pywr)

- A fast open-source generalized water system simulator
- Includes multi-scenario simulation for the application of robust decision making
- Link to multi-objective optimisation
- Enables applying advanced river basin simulation of real systems



Read more in this open-access article
https://doi.org/10.1016/j.envsoft.2020.104635

Amu Darya Pywr River Basin model



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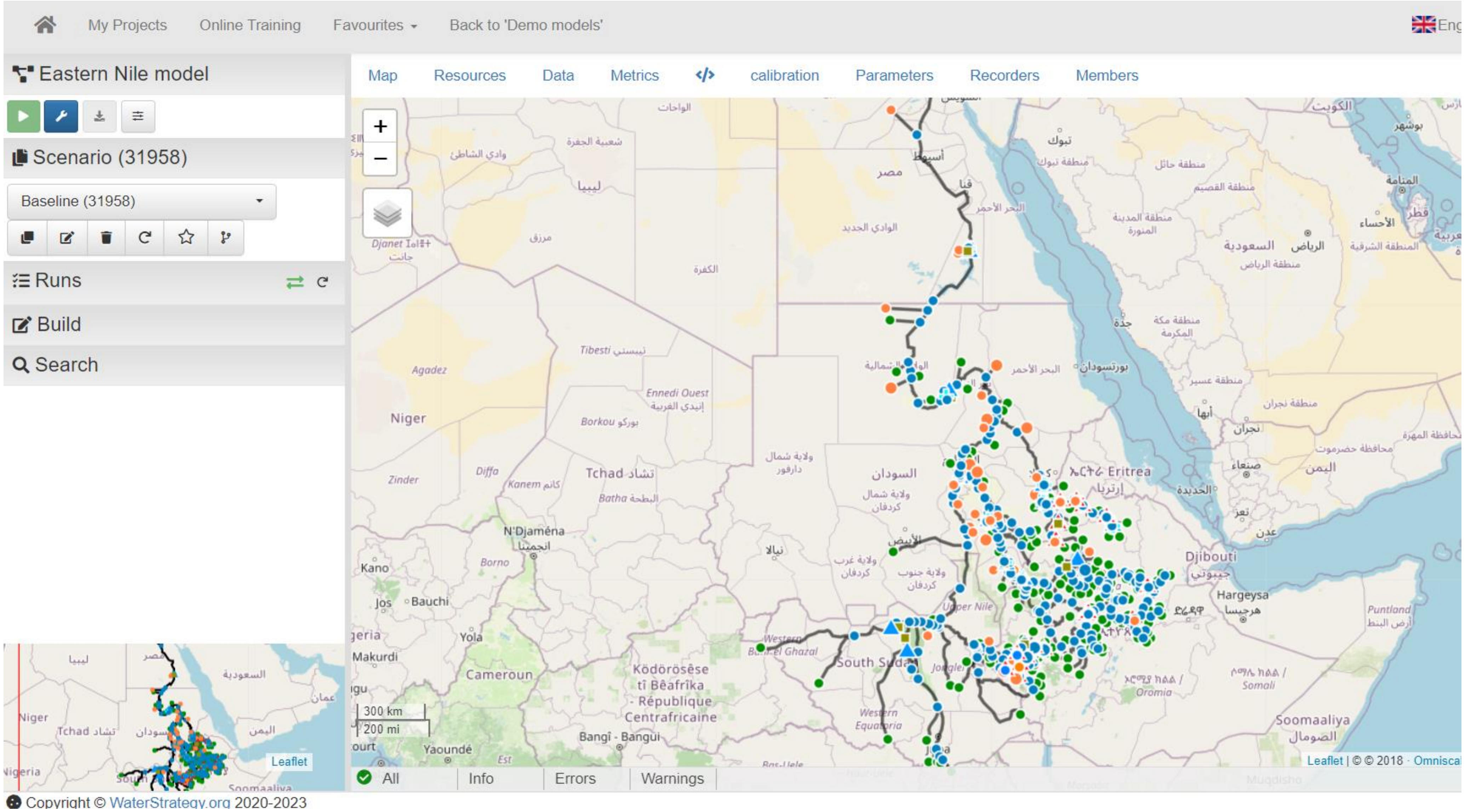
Nile basin Pywr model



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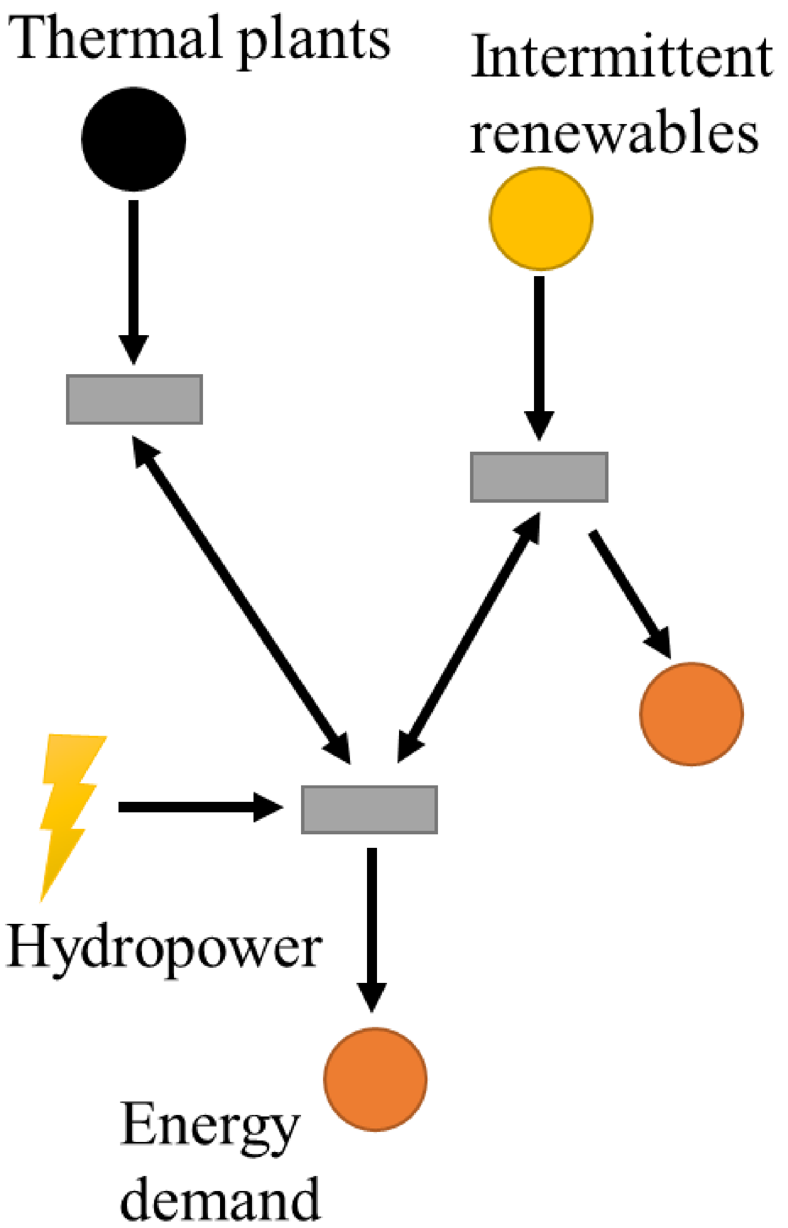
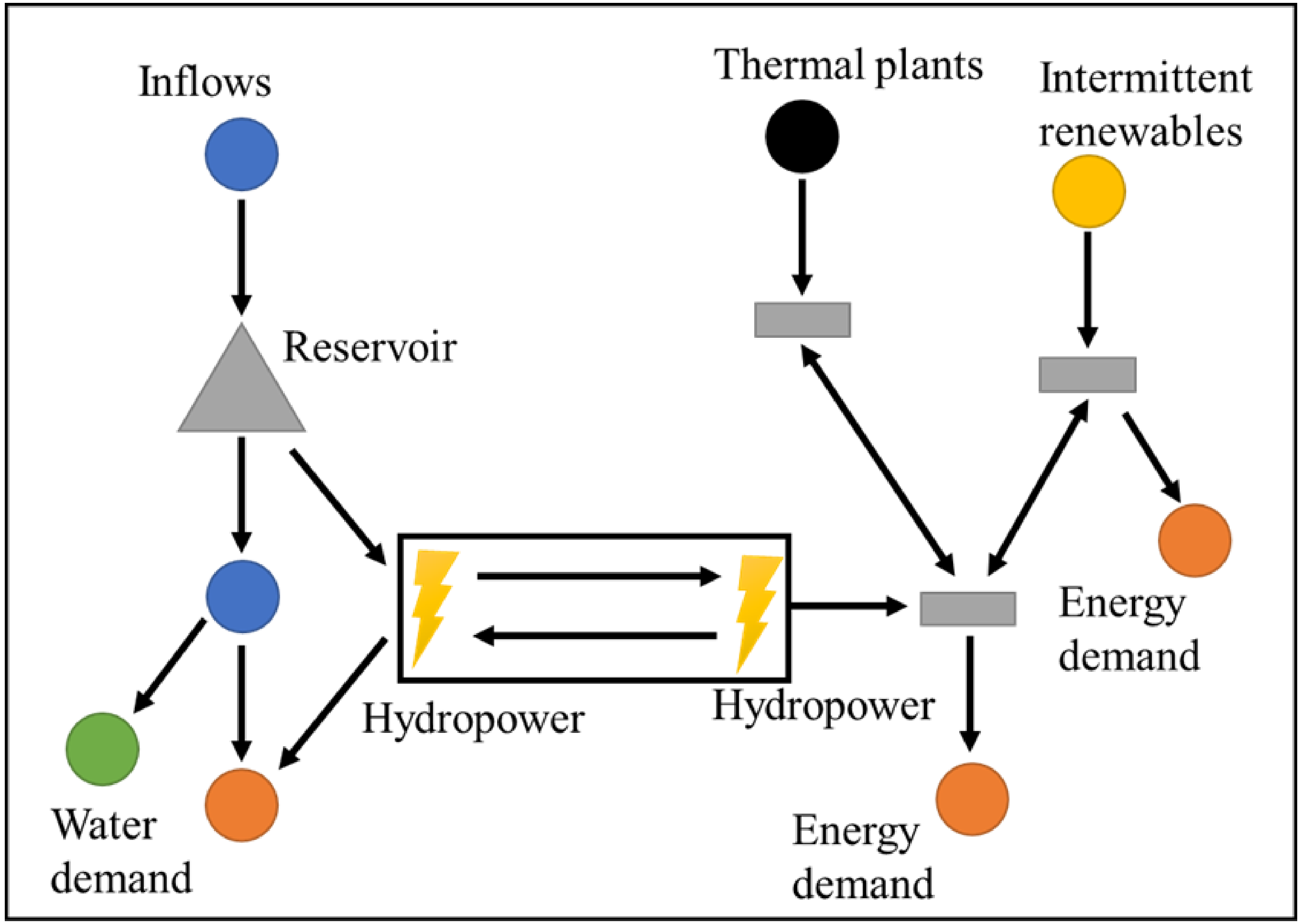
Energy system simulator (Pyenr)

- A fast open-source generalized power system simulator
- Includes multi-scenario simulation for the application of robust decision making
- Link to multi-objective optimisation
- DC optimal power flow



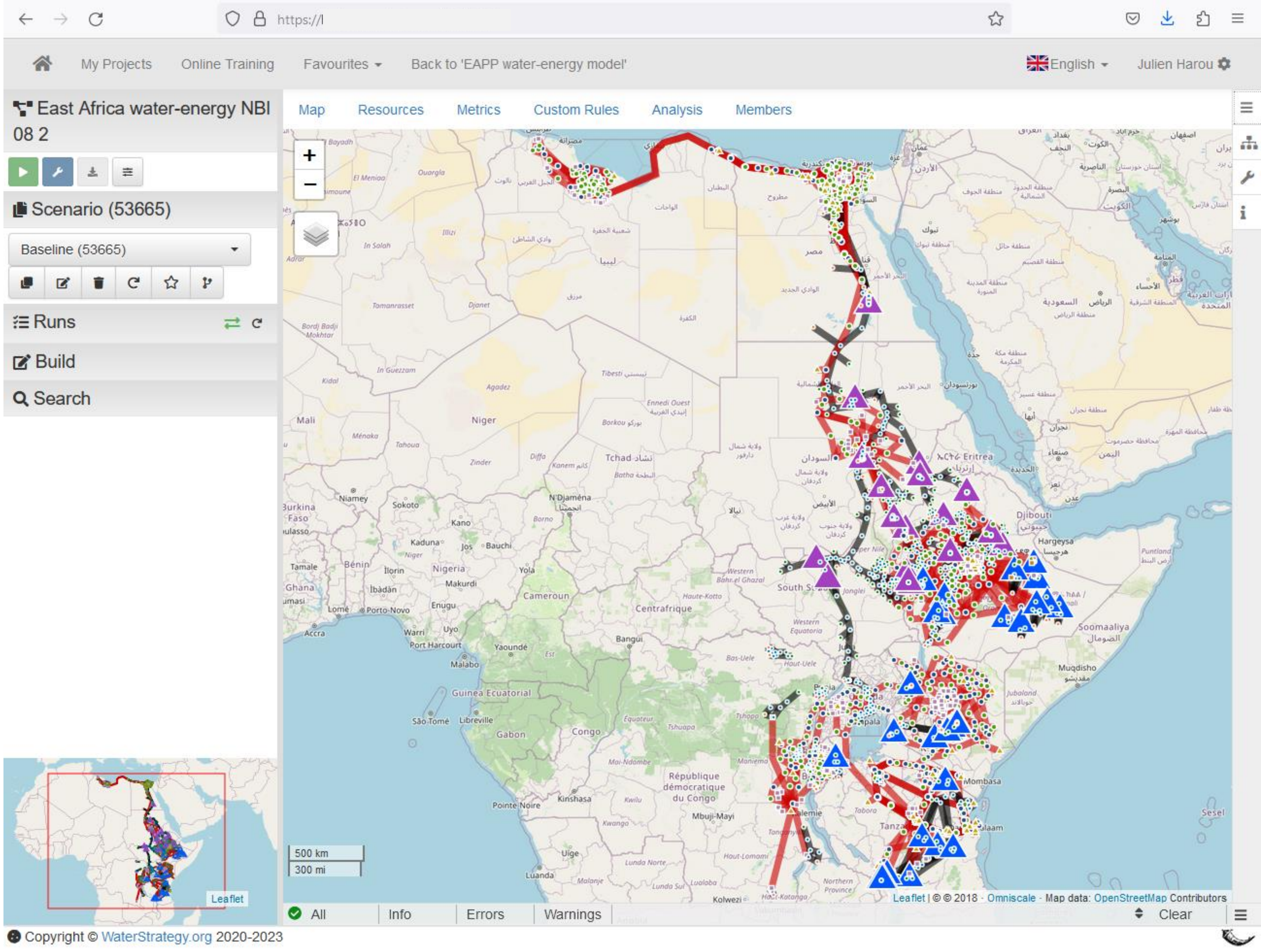
Integrated water-energy simulator (using Pynsim integrated modelling library)

- Each model stays independent
- Multi-directional interconnections
- Fast simulator
- Open access and web-based
- Multi-user and shareable
- Link to multi-objective optimisation



Read more in this open-access article
https://doi.org/10.1016/j.envsoft.2018.01.019

EAPP water-energy simulation model

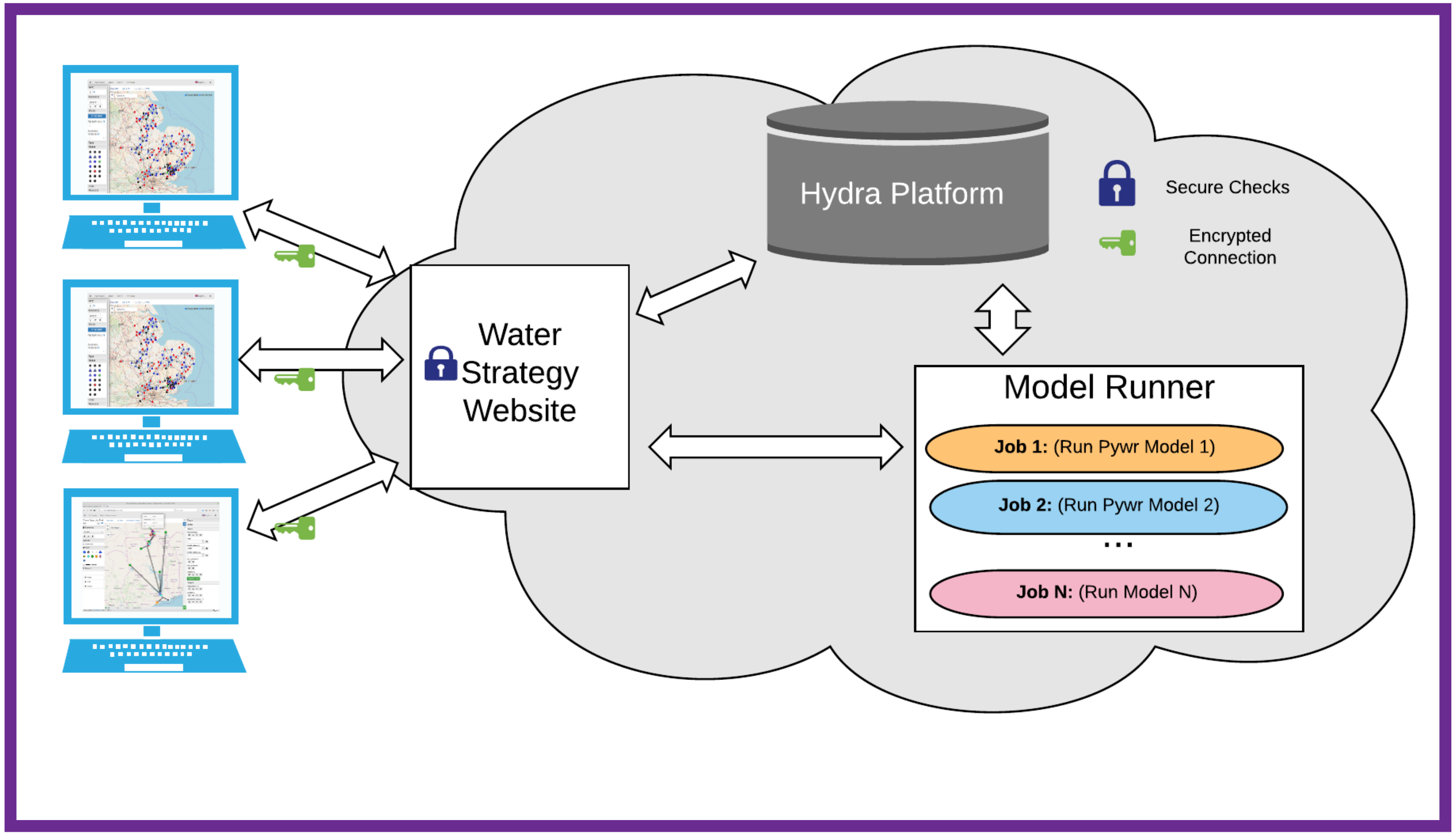


Model developed by Mikiyas Etichia, Mohammed Basheer and a wider group from NBI-ENTRO, NBI, EAPP, and UK universities.

WATERSTRATEGY.org

WaterStrategy.org securely hosts simulators

- Platforms use and open-source Python-based resource system simulators.
- Models can be run from the webpage.
- Easy-to-use graphical user interface.
- Collaborate within teams and with decision-makers and stakeholders in a controlled way.
- Multiple users can interact with the same model.



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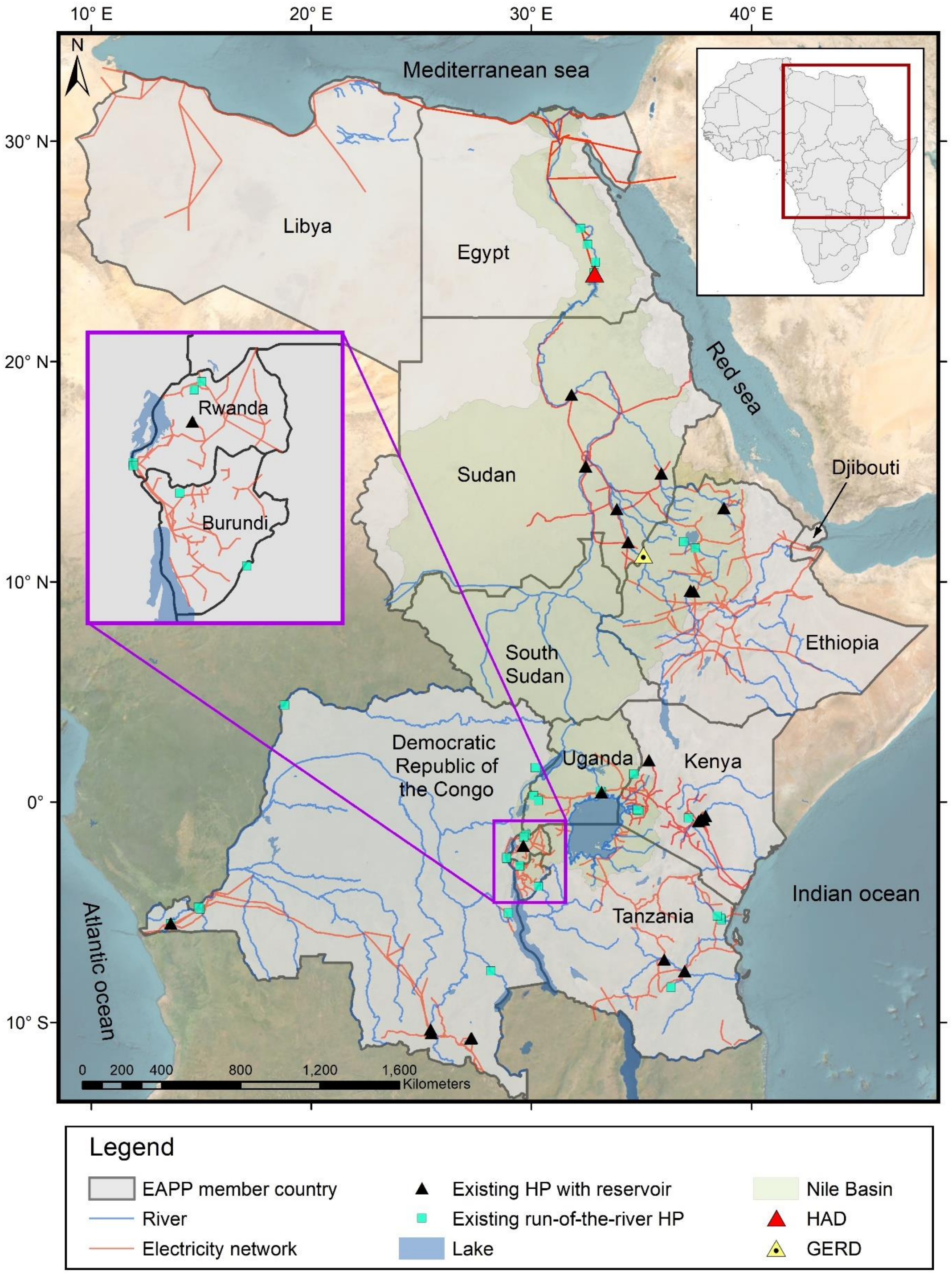
Case-studies

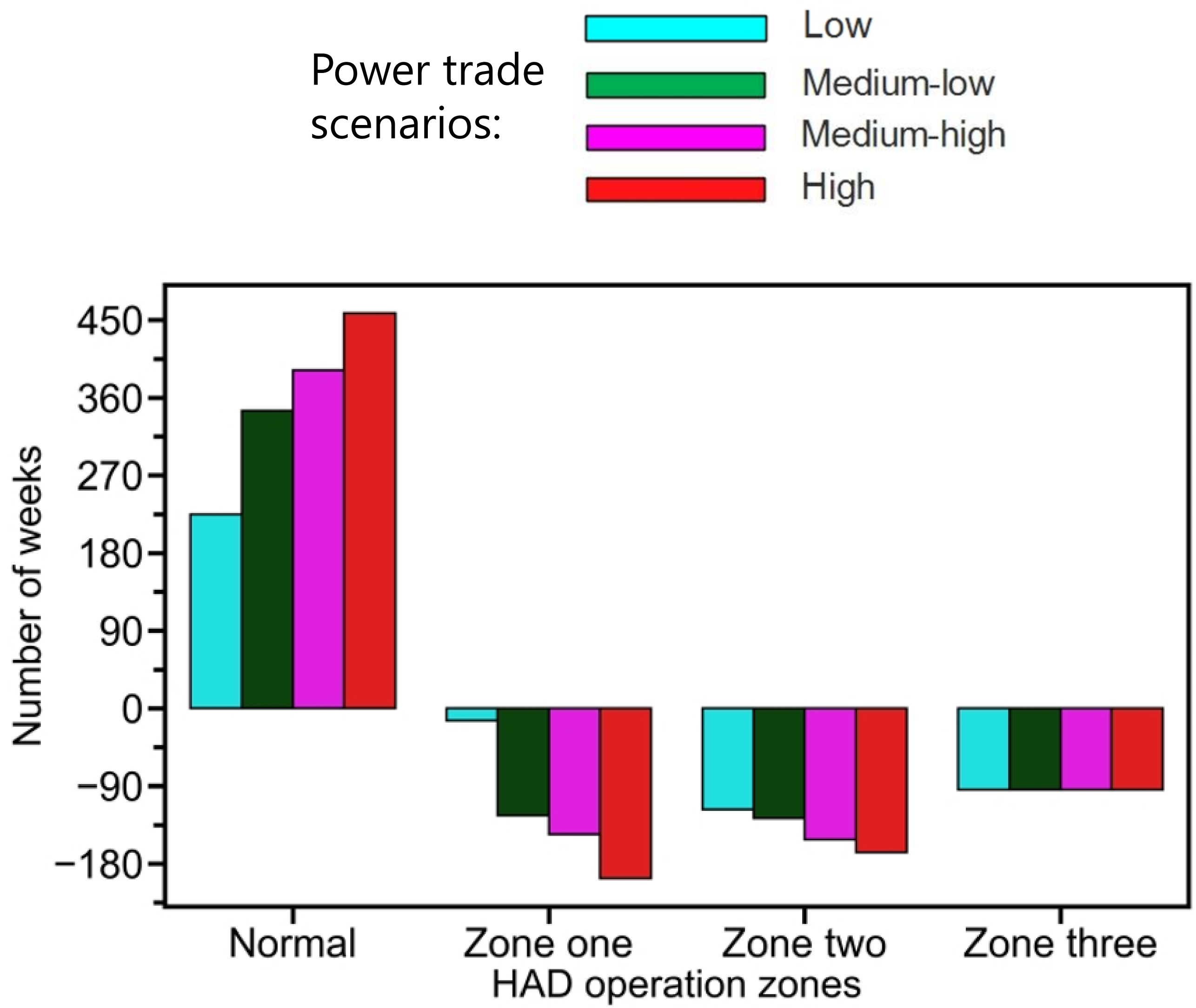
Case-study 1:
East Africa's water-energy system

- ❑ East African Energy system: increasing cooperation and interconnectivity

Could new electricity trade agreements between Ethiopia, Sudan, and Egypt help resolve GERD dispute?



Case-study 1: Energy trade between countries increases water resilience

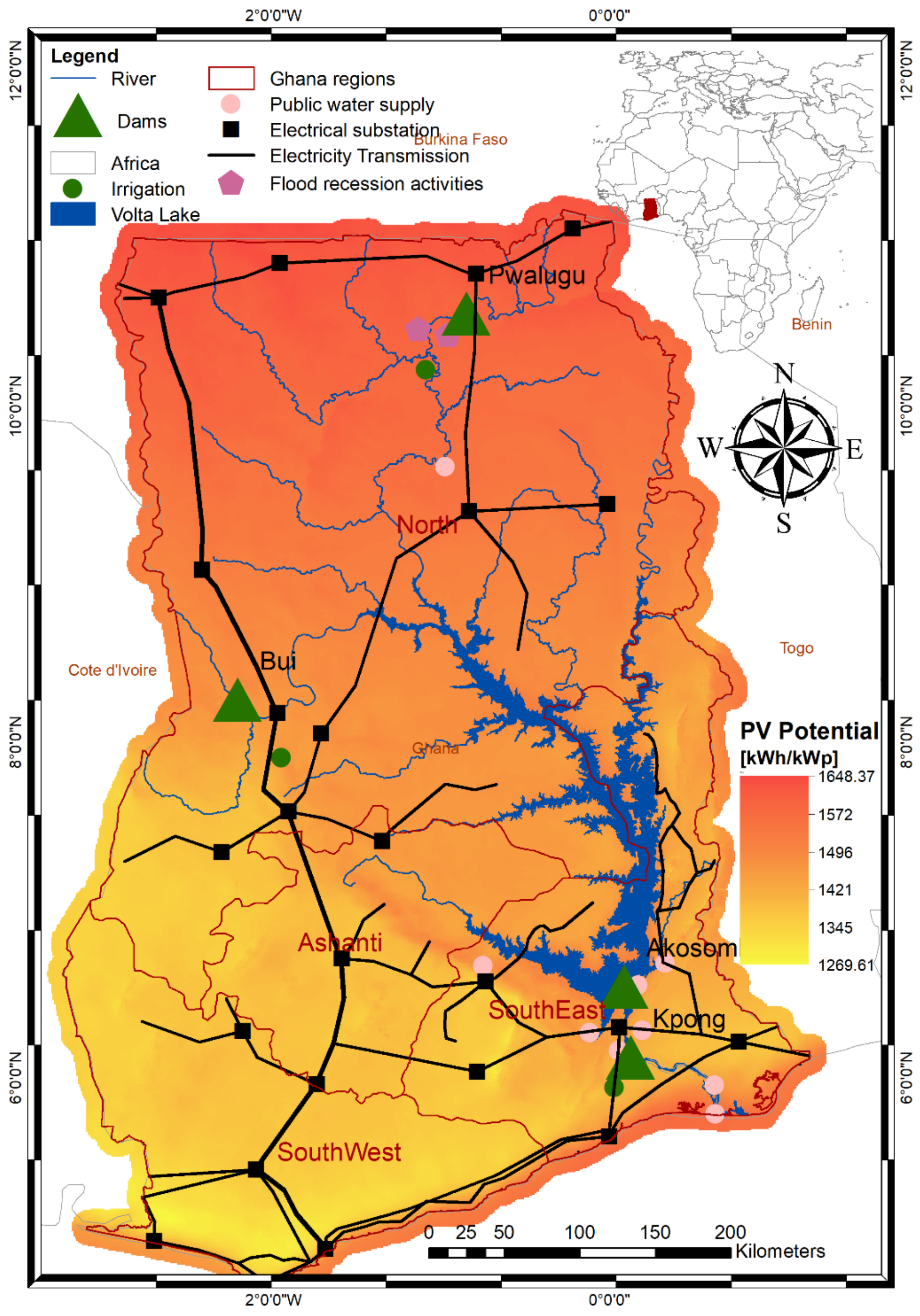


- Histogram shows change in number of weeks in which the High Aswan Dam Reservoir falls within each HAD water management zones, for each scenario compared to existing power trade.
- Results show increasing energy trade can reduce Egyptian water deficits, reduce regional greenhouse gas emissions, increase hydropower generation, reduce energy curtailment in Sudan, and increase Ethiopia's financial returns from electricity.

Case-study 2:
Ghana’s water-energy system

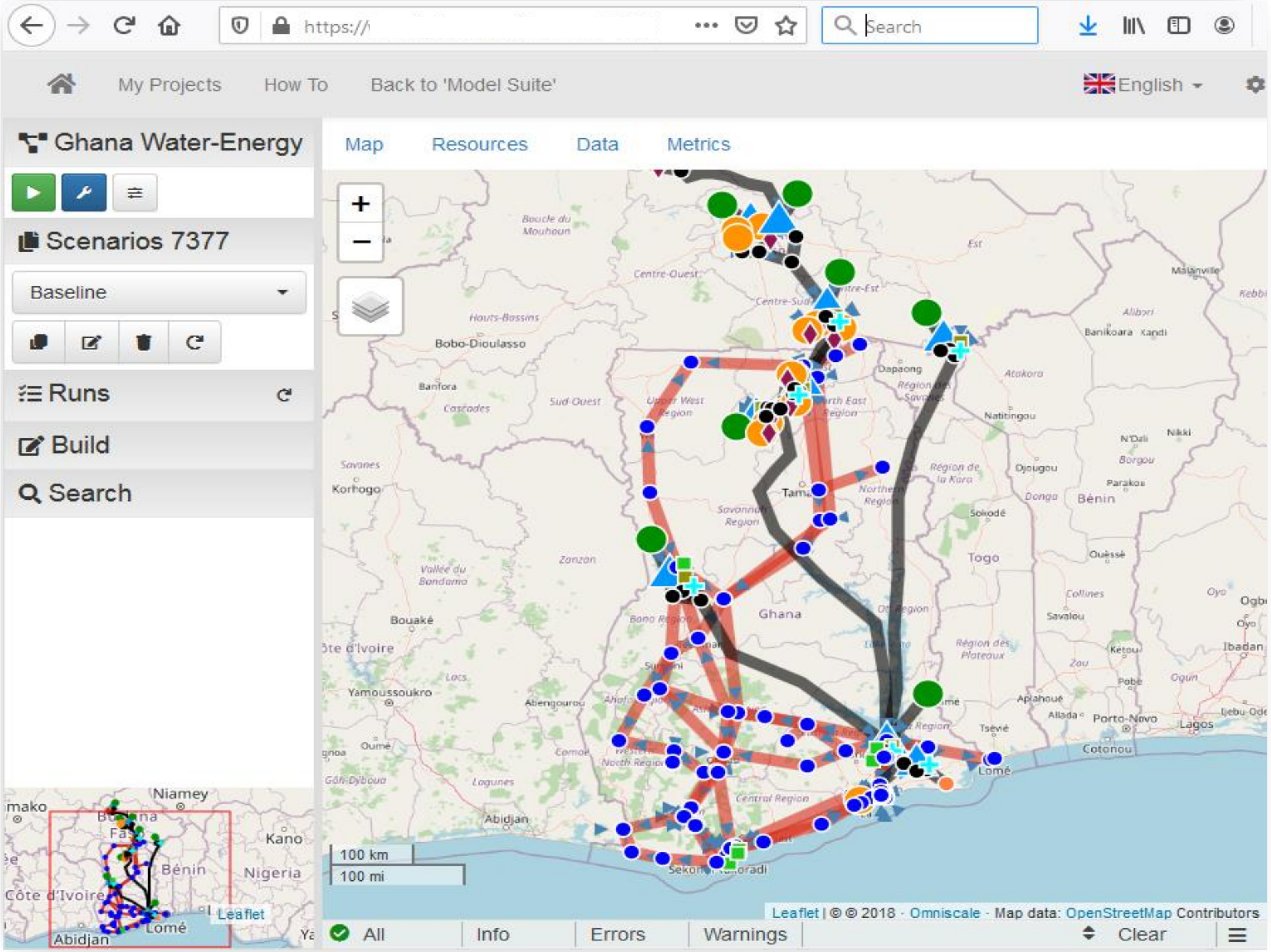
- Water, energy demands increasing
- Sun up north, demand down south

How to meet demands, reduce emissions? but also minimize ecological disruption & inter-sector conflict?



Integrated Ghanaian water-energy system simulator

- Ghana's power system model (red):
  - 23 buses
  - 4 hydropower plants
  - 2 Solar plants
  - 26 thermal plants
  - 33 high voltage transmission lines
- Ghana's water system (grey):
  - Main infrastructure in Ghana and Burkina Faso
  - Main existing and future irrigation schemes
  - Domestic water demand supply and flood recession activities



River basin – power system model for evaluating and optimising management and investment

- Hydropower release decision from reservoirs at a weekly time-step
- Hydropower generation decision at hourly time-step
- Reservoir operating rules can be optimised
- The Energy system simulator runs at an hourly time-step (captures hourly variability of intermittent renewables)

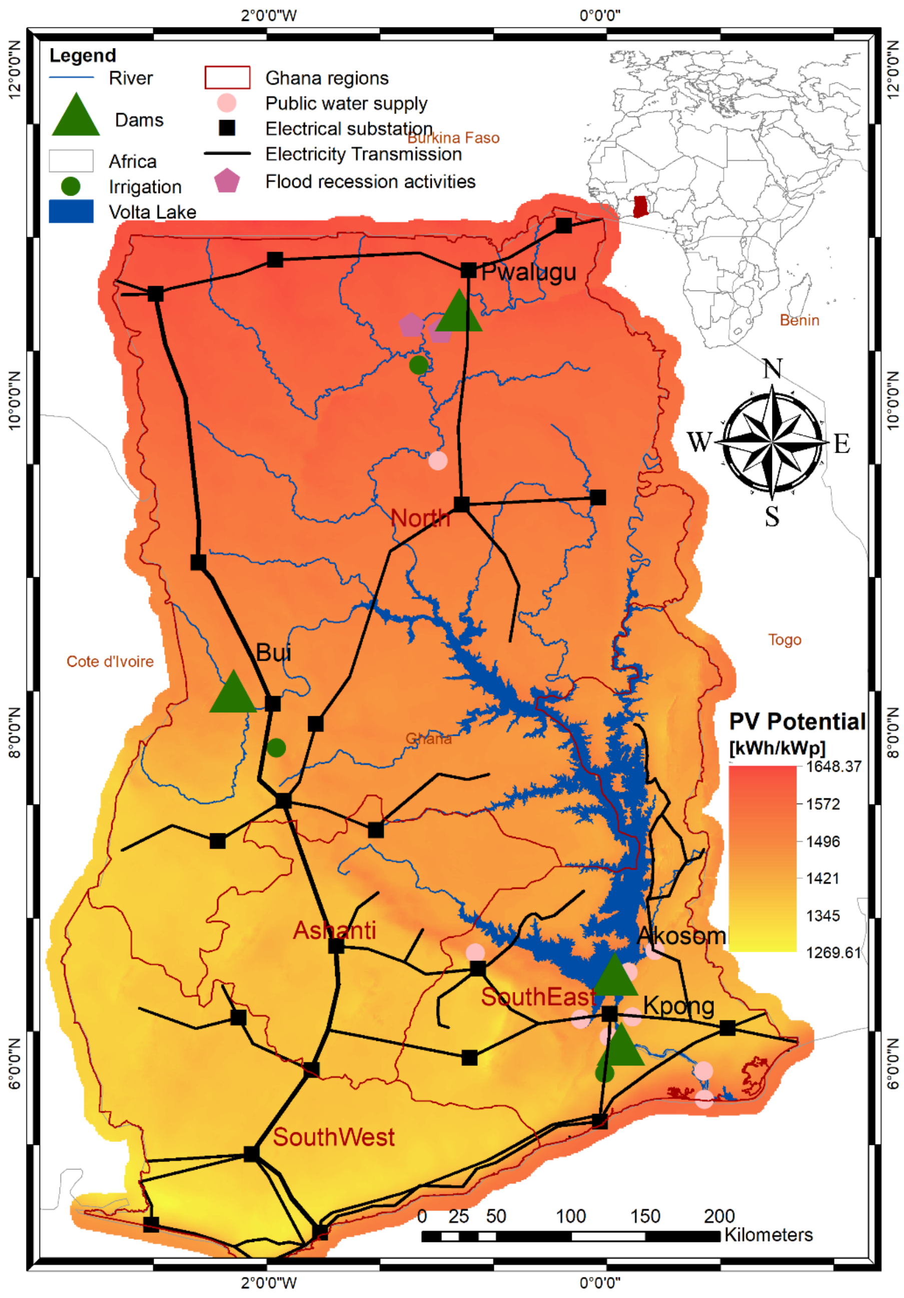
Design problem

Objectives:

- Minimise capital costs
- Minimise operation costs
- Minimise load curtailment
- Minimise CO2 emissions
- Minimise hydro-ecological alteration
- Maximise crop yields
- Maximise flood recession benefits

Decision variables:

- Reservoir operating rules
- Renewable's expansion (Solar, wind, biogas)
- Transmission line expansion



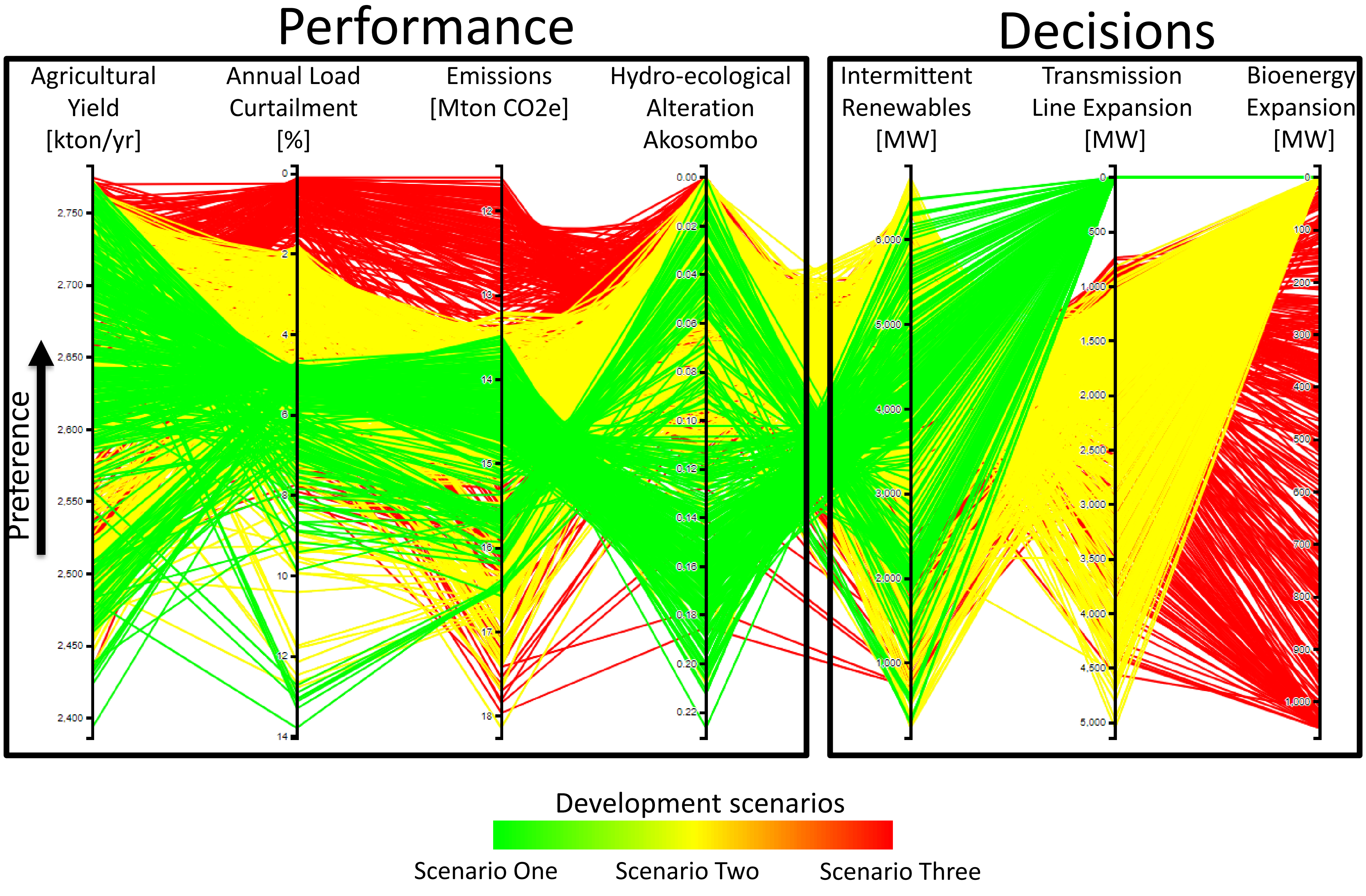
We consider 3 development scenarios, each time allowing the optimisation to trial more diverse portfolios of power generation options

1) Reservoir operating rules (+ solar, wind)

2) Reservoir operating rules plus transmission lines expansion (+ solar, wind)

3) Reservoir operating rules plus transmission lines and bioenergy expansion (+ solar, wind)

Results: Trade-offs implied by the most efficient (optimised) system designs



- Each line represents an efficient water-energy system design (package of investment options and operating rules).
- Each successive scenario achieves higher performance (better exploits the synergies between different generation technologies to stabilize the grid)

Read more in this open-access article!

https://www.nature.com/articles/s41467-021-25877-w

nature.com/articles/s41893-022-01033-0

nature sustainability

Article | Open Access | Published: 26 January 2023

Designing diversified renewable energy systems to balance multisector performance

Jose M. Gonzalez, James E. Tomlinson, Eduardo A. Martínez Ceseña, Mohammed Basheer, Emmanuel Obuobie, Philip T. Padi, Salifu Addo, Rasheed Baisie, Mikiyas Etichia, Anthony Hurford, Andrea Bottacin-Busolin, John Matthews, James Dalton, D. Mark Smith, Justin Sheffield, Mathaios Panteli & Julien J. Harou

Nature Sustainability (2023) | Cite this article

Abstract

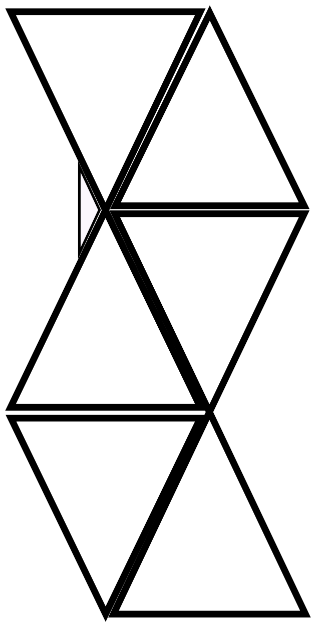
Renewable energy system development and improved operation can mitigate climate change. In many regions, hydropower is called to counterbalance the temporal variability of intermittent renewables like solar and wind. However, using hydropower to integrate these renewables can affect aquatic ecosystems and increase cross-sectoral water conflicts. We develop and apply an artificial intelligence-assisted multisector design framework in Ghana, which shows how hydropower's flexibility alone could enable expanding intermittent renewables by 38% but would increase sub-daily Volta River flow variability by up to 22 times

Concluding remarks

Overall thoughts …

- Spatially quantifying river-energy system interdependencies allows presenting decision-makers with actionable multi-sector benefit-sharing solutions.

- New AI-assisted design approaches help identify strategic interventions in power-water systems (considering multiple benefits, their synergies & trade-offs).



Water Economics and Policy | Vol. 09, No. 01, 2371003 (2023) | Policy Nook

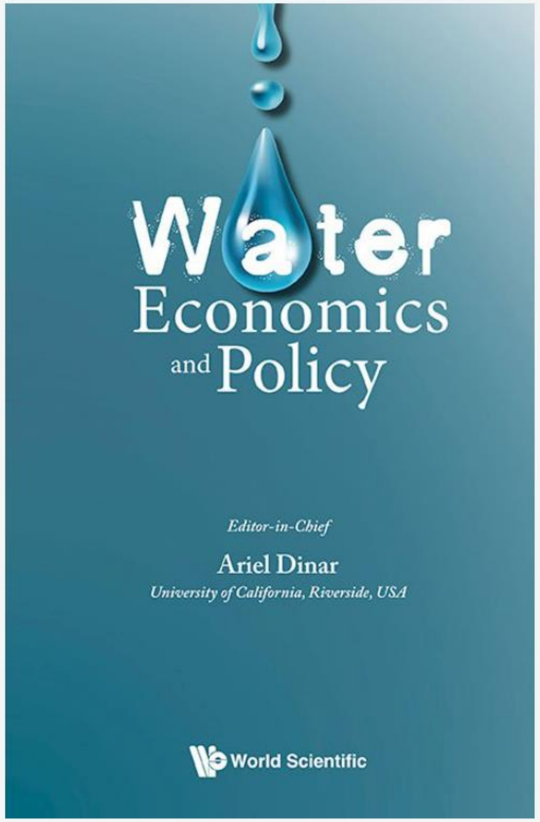
Policy Note: Artificial Intelligence Enables Multi-Dimensional Economics of Water

Julien J. Harou

Read more in this open-access article
https://doi.org/10.1142/S2382624X23710030

“Models by themselves are of limited use, even AI-enhanced ones.

Only new institutions and deliberative human planning procedures crafted to function in tough political contexts can deliver ...”



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