MANCHESTER 1824
The University of Manchester

New approaches and tools to identify high-value infrastructure solutions in Nile region

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Nile Basin Development Forum
Tuesday, 03 October 2023

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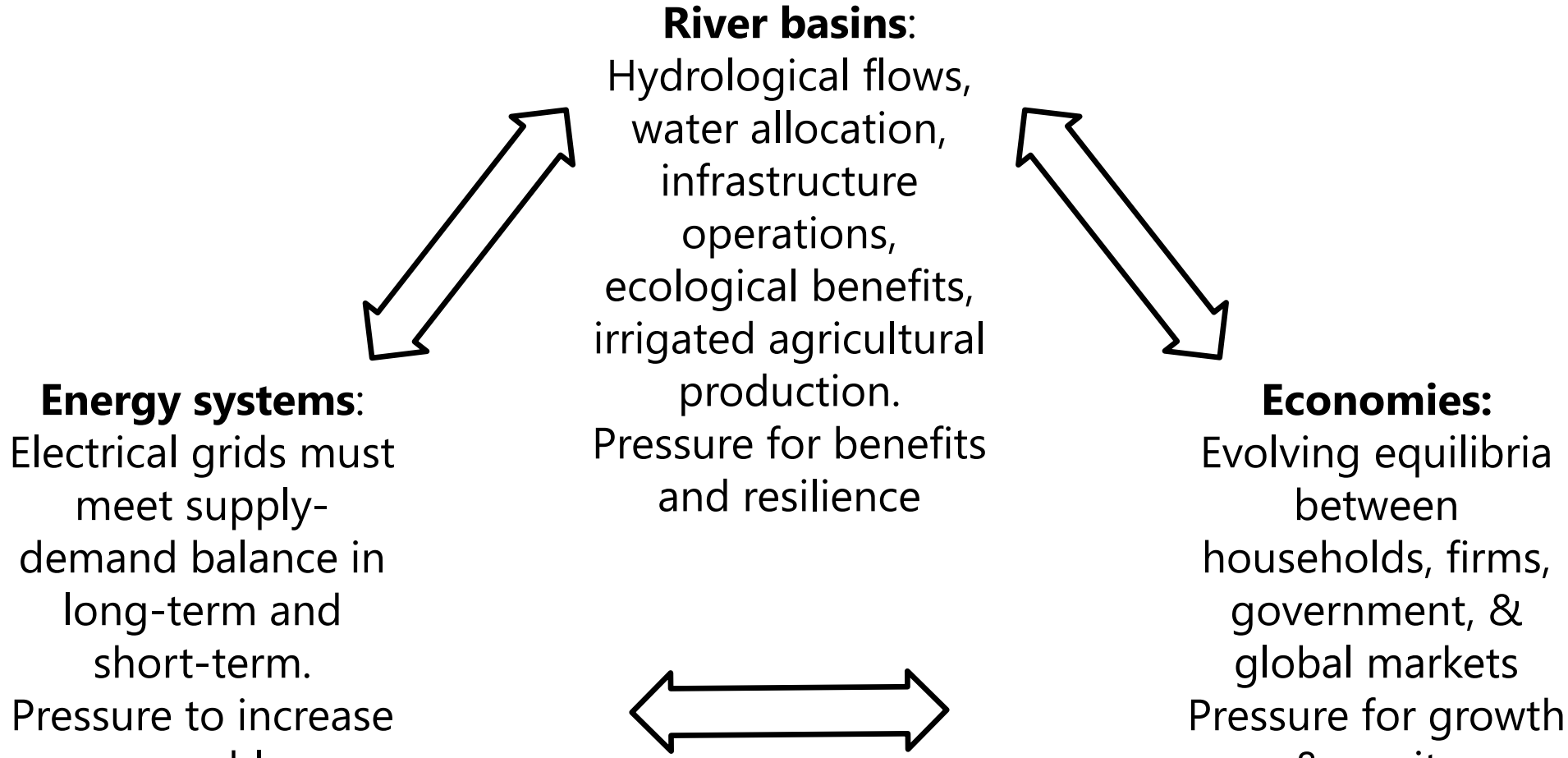
Integrated assessment of water-economy-energy systems



Requirements

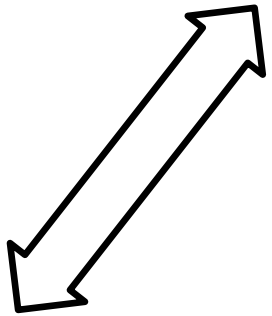
- ❑ Reliable credible single system simulation
- ❑ Connections with feedbacks (reach equilibrium)
- ❑ Consider uncertainty (scenarios)
- ❑ Consider multiple dimensions
- ❑ Simulate & optimise

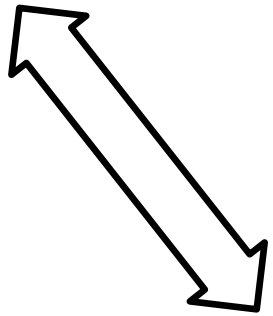
Multi-sector simulation tools

Multi-sector simulation

River basins:

Pywr





Energy systems:

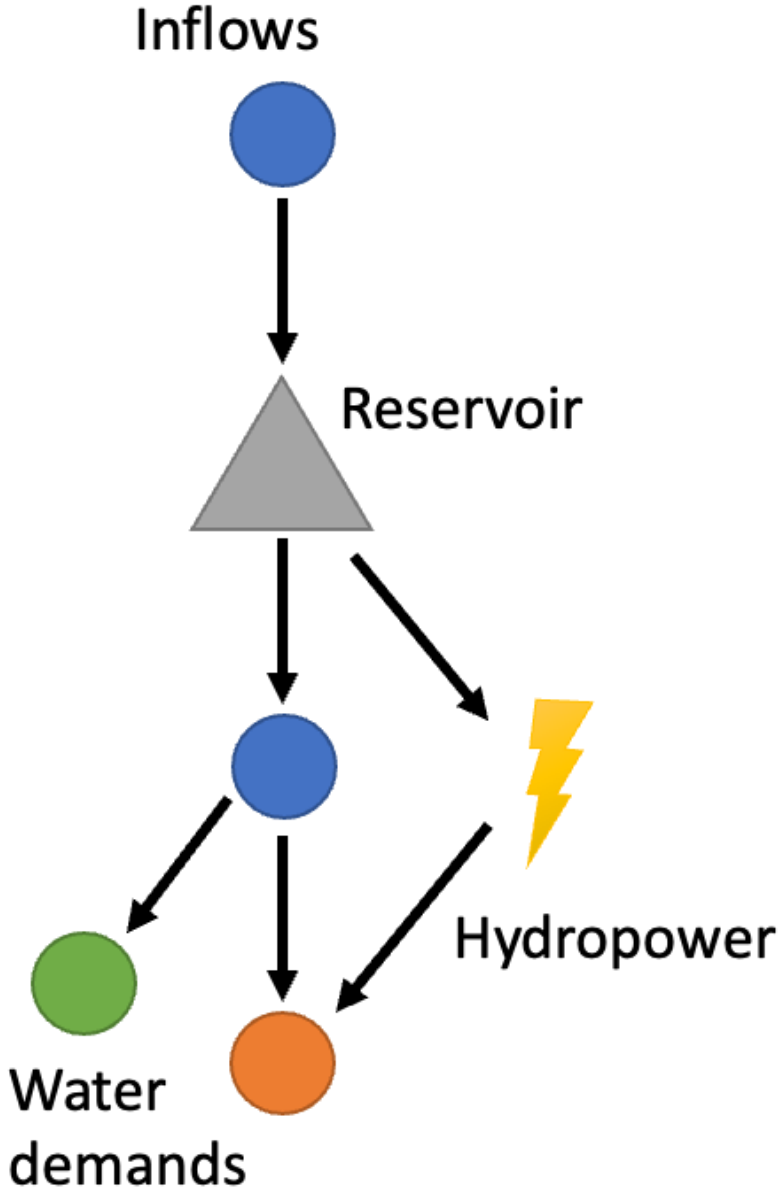
Pyenr

Economies:

IFPRI CGE

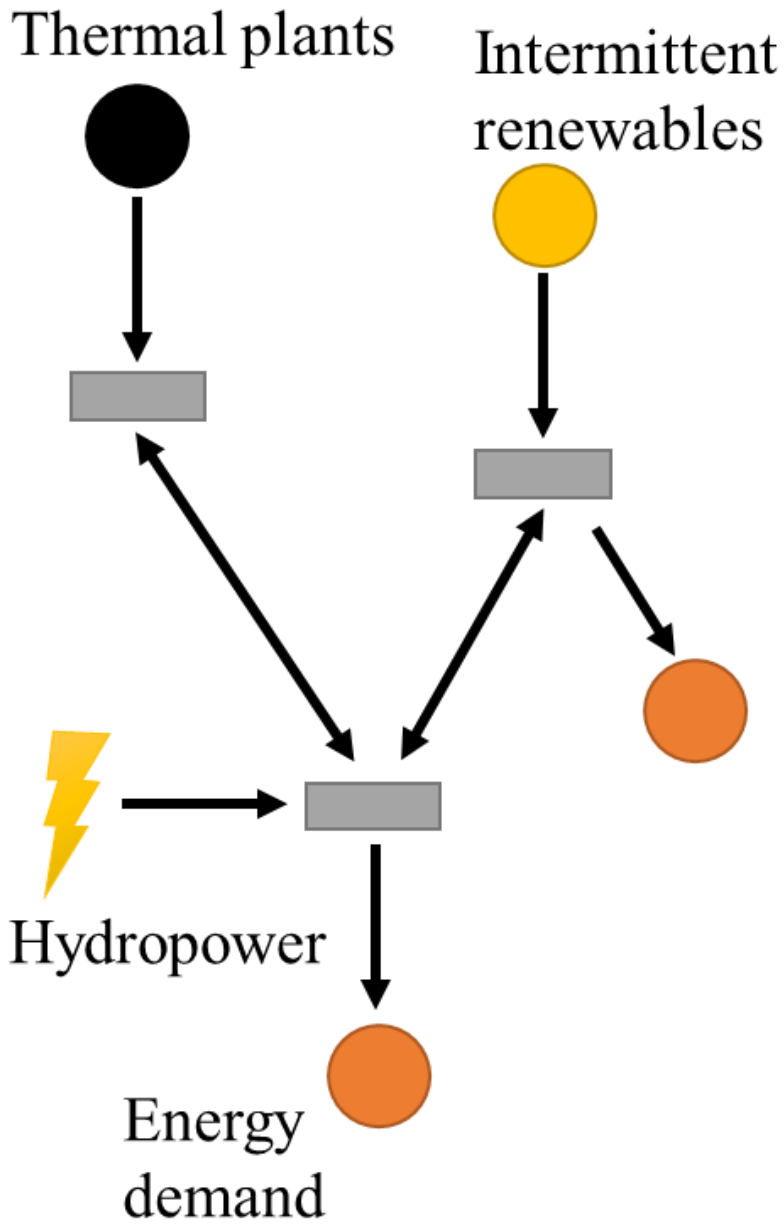
Water resource system simulator (Pywr)

- Open-source generalized managed water system simulator
- Represent complex realistic water allocation and operations
- Fast multi-scenario simulation for decision-making under deep uncertainty
- Link to multi-objective optimisation

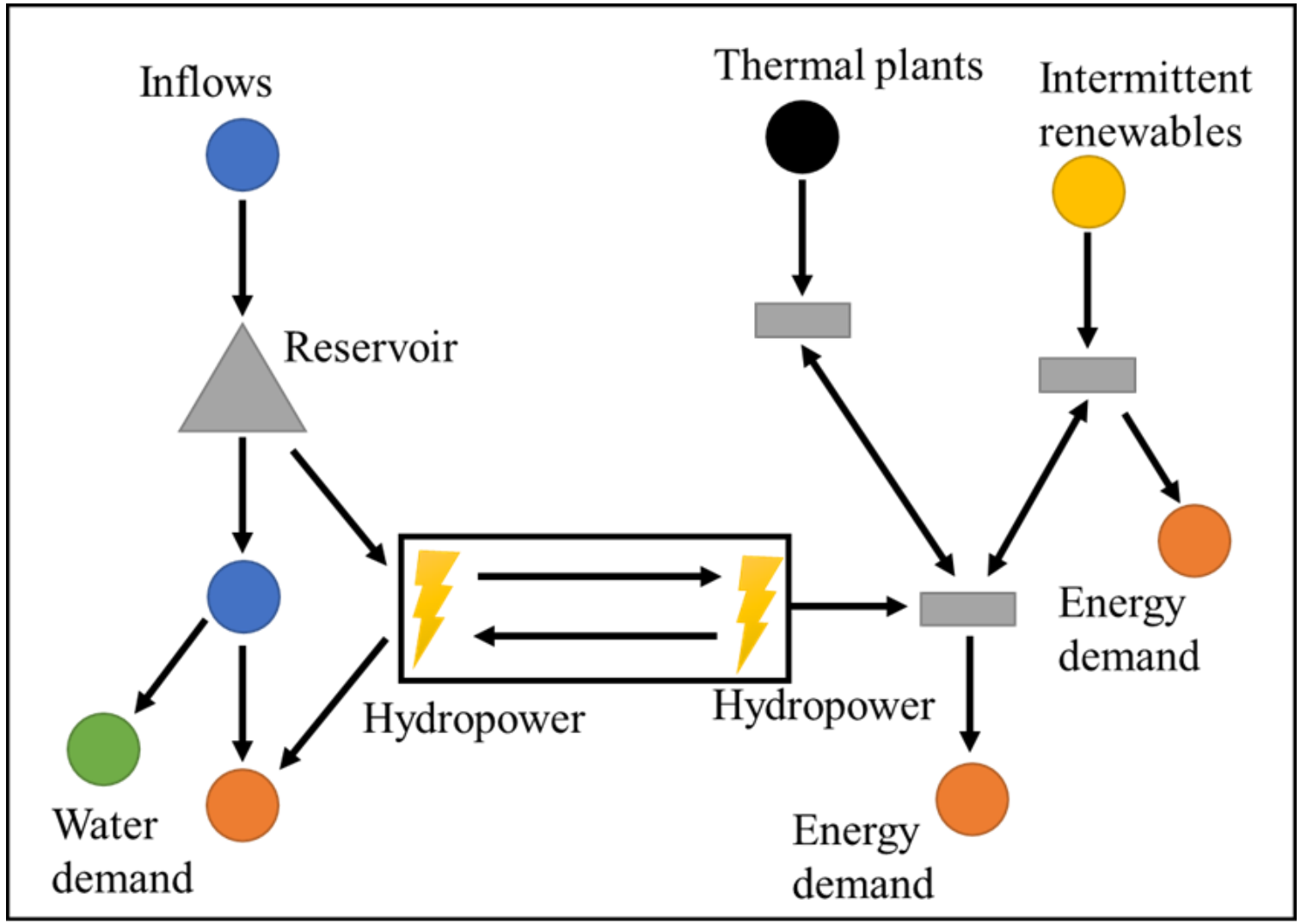


Energy system simulator (Pyenr)

- A fast open-source generalized energy system simulator (DC optimal power flow)
- Multi-scenario simulation
- Link to multi-objective optimisation

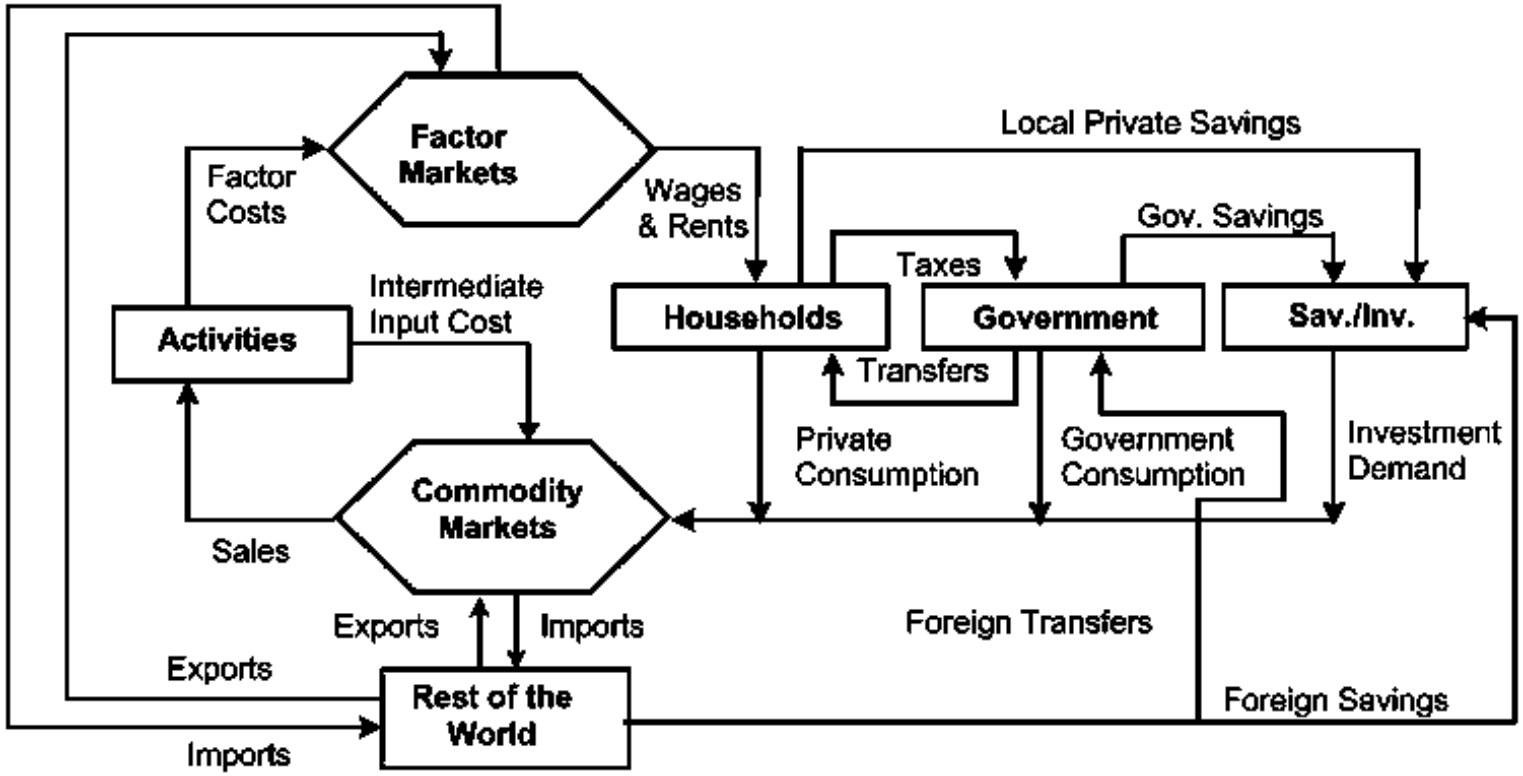


Integration (Pynsim)



Whole economy model (IFPRI CGE)

- Dynamic computable general equilibrium (CGE) models for Sudan, Ethiopia, and Egypt
- Based on the standard CGE model of IFPRI



User-interface

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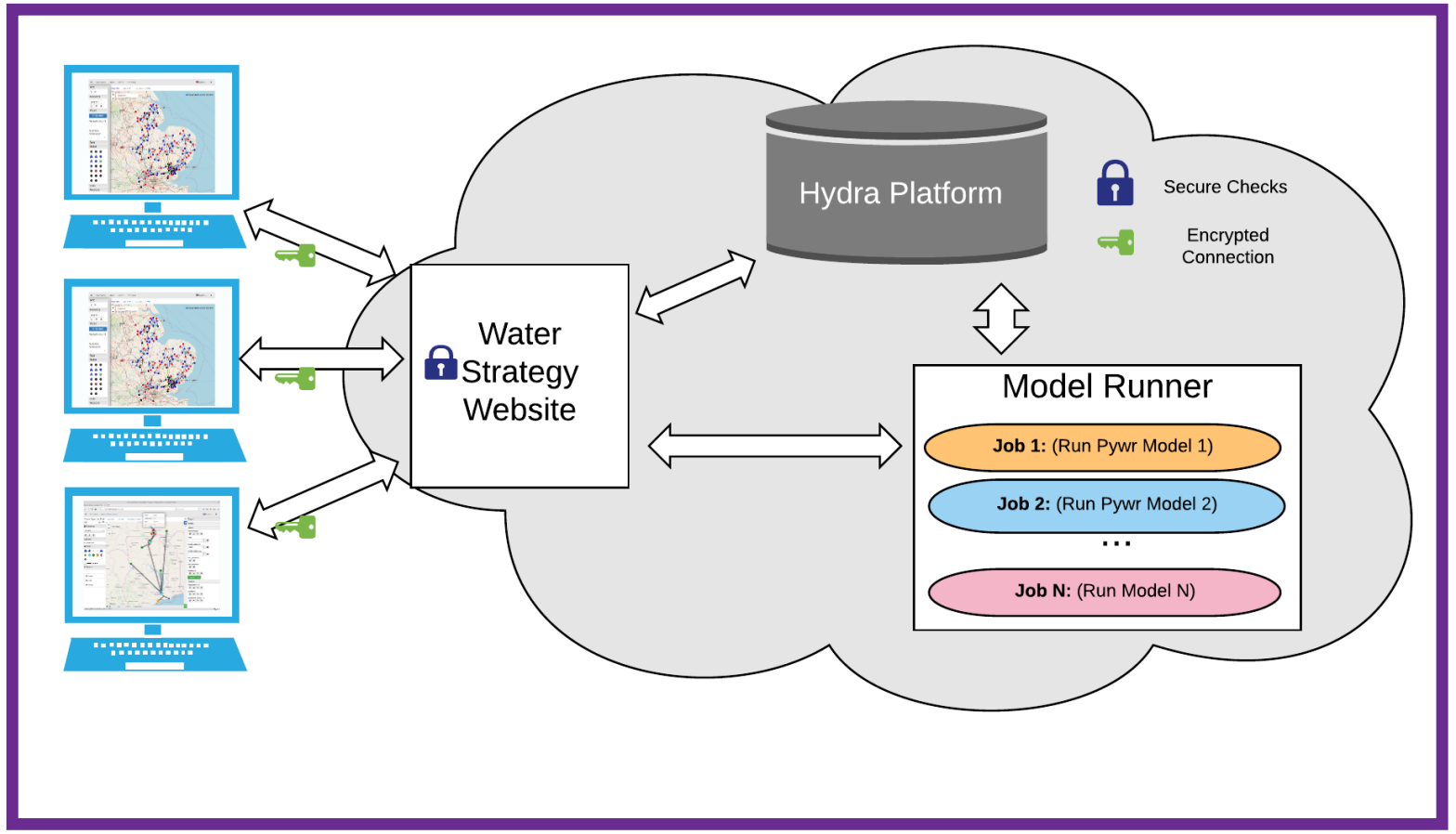
Web platforms to securely host river basin and water-energy simulators

- 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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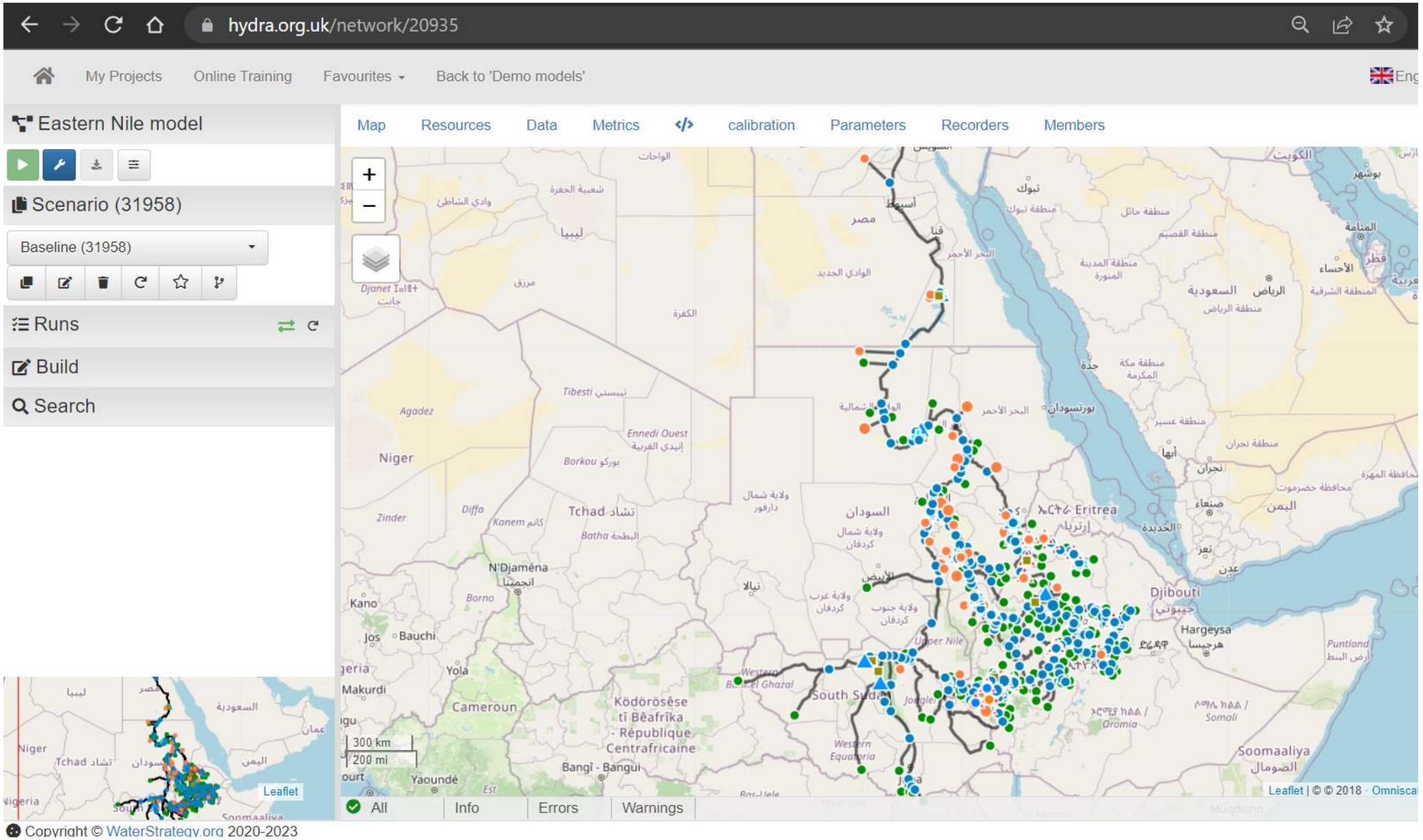
River basin simulation



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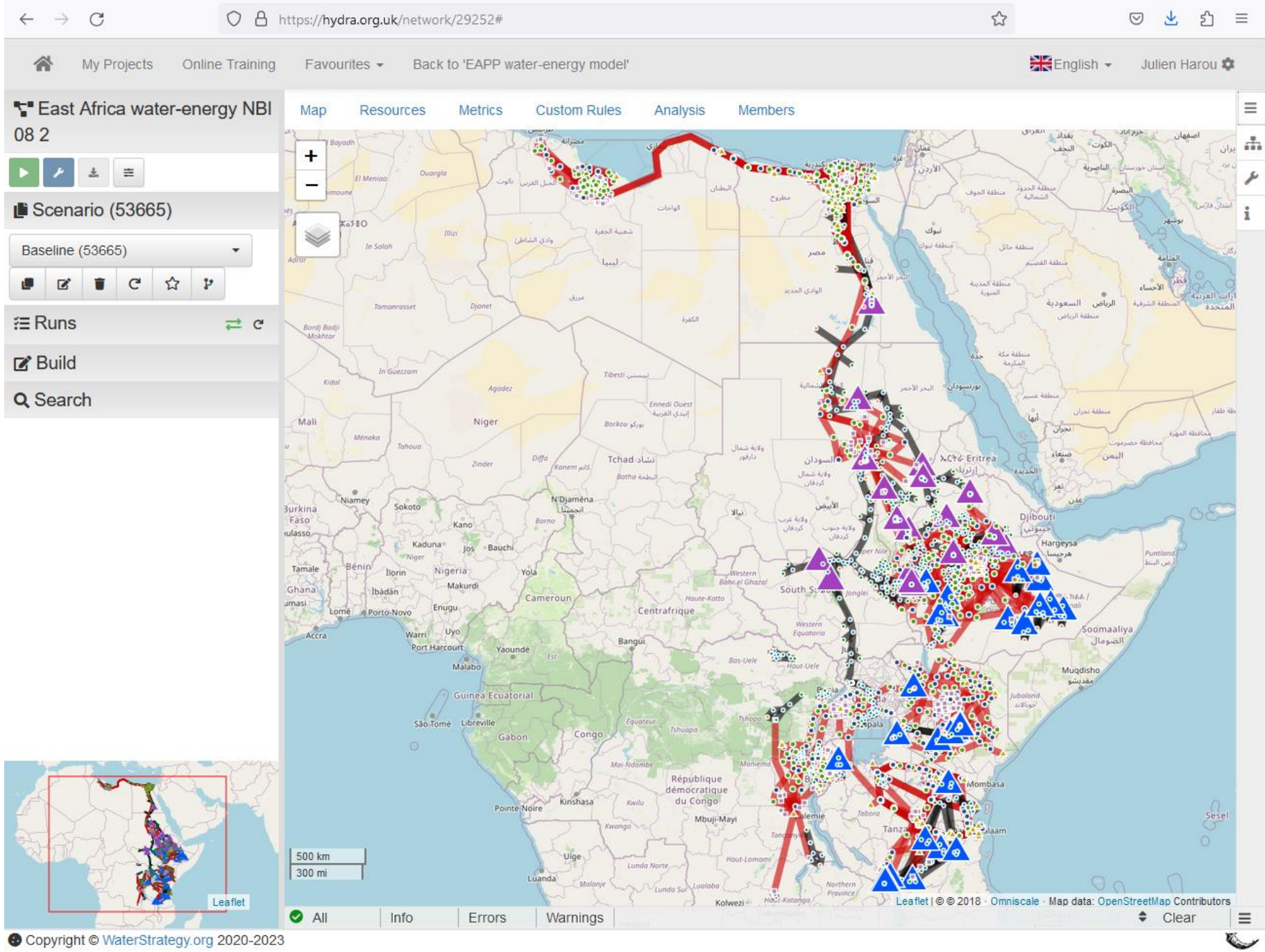
Water-energy simulation



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Approach

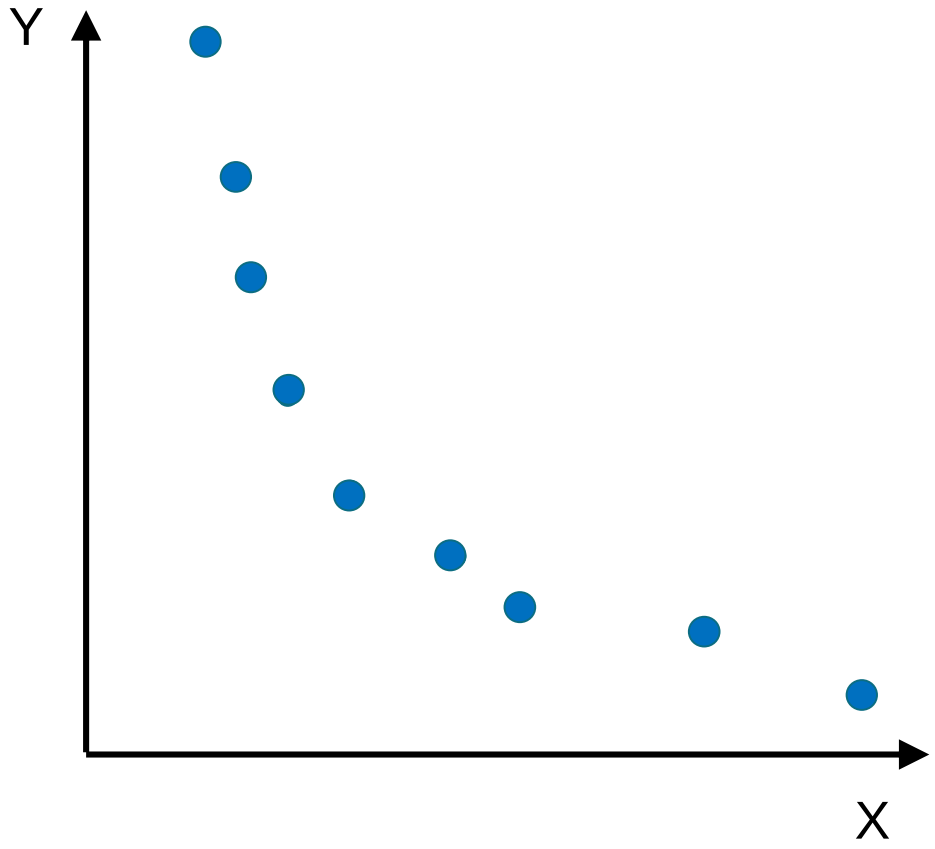
Approach

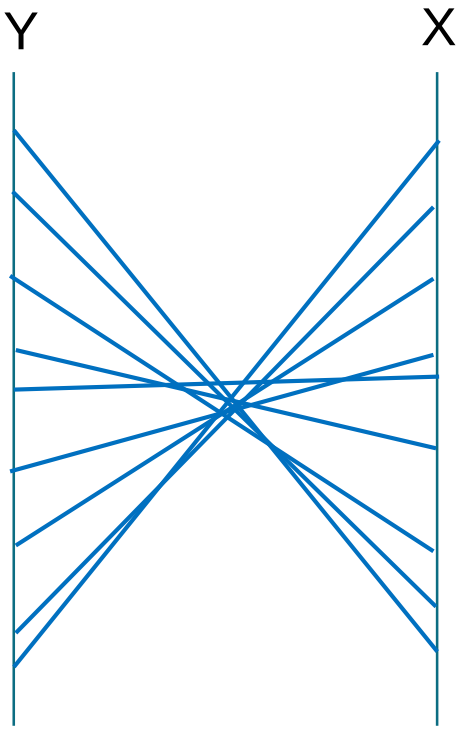
1. **Simulate**: engineering, environmental, & economic performance

2. **Search**: to find the most efficient portfolios or pathways of interventions and their trade-offs

3. **Deliberate**: Collaborative interactive stakeholder assessment & negotiation

(2) Trade-offs implied by the best possible solutions





(3) Stakeholder co-production

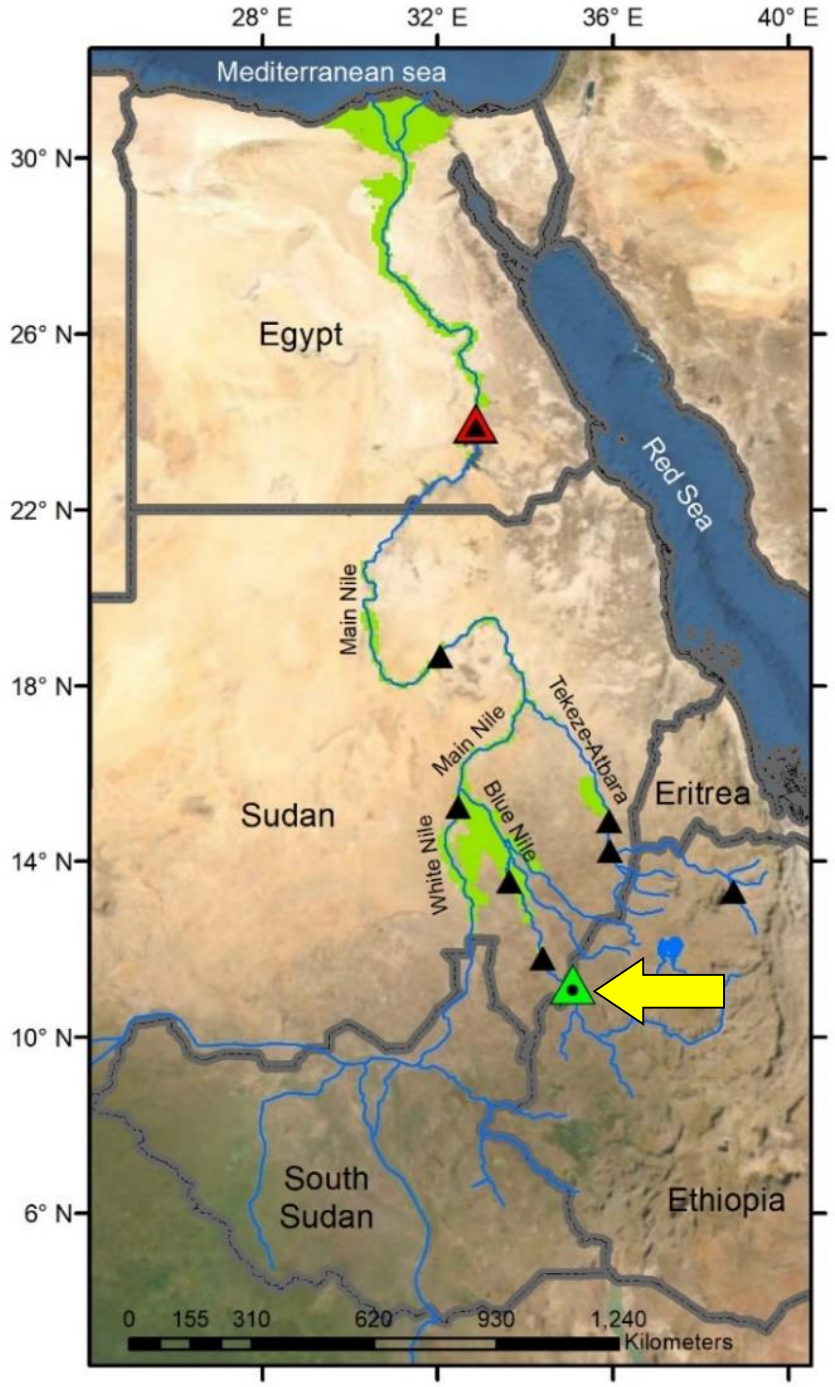
- Review simulators, design formulation
- Train, build trust
- Deliberate trade-offs, select compromise solution(s)

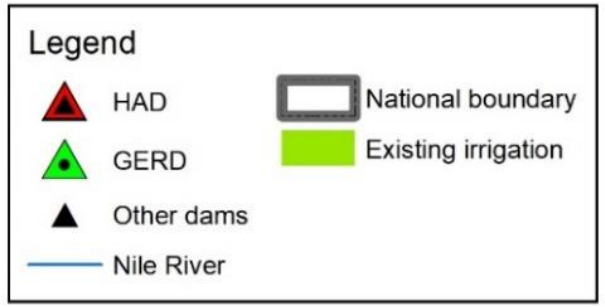
Case-studies:

Case-study 1: Grand Ethiopian Renaissance Dam (GERD)

- There are downstream concerns about GERD's impact on water availability

How to fill and operate the dam adaptively?

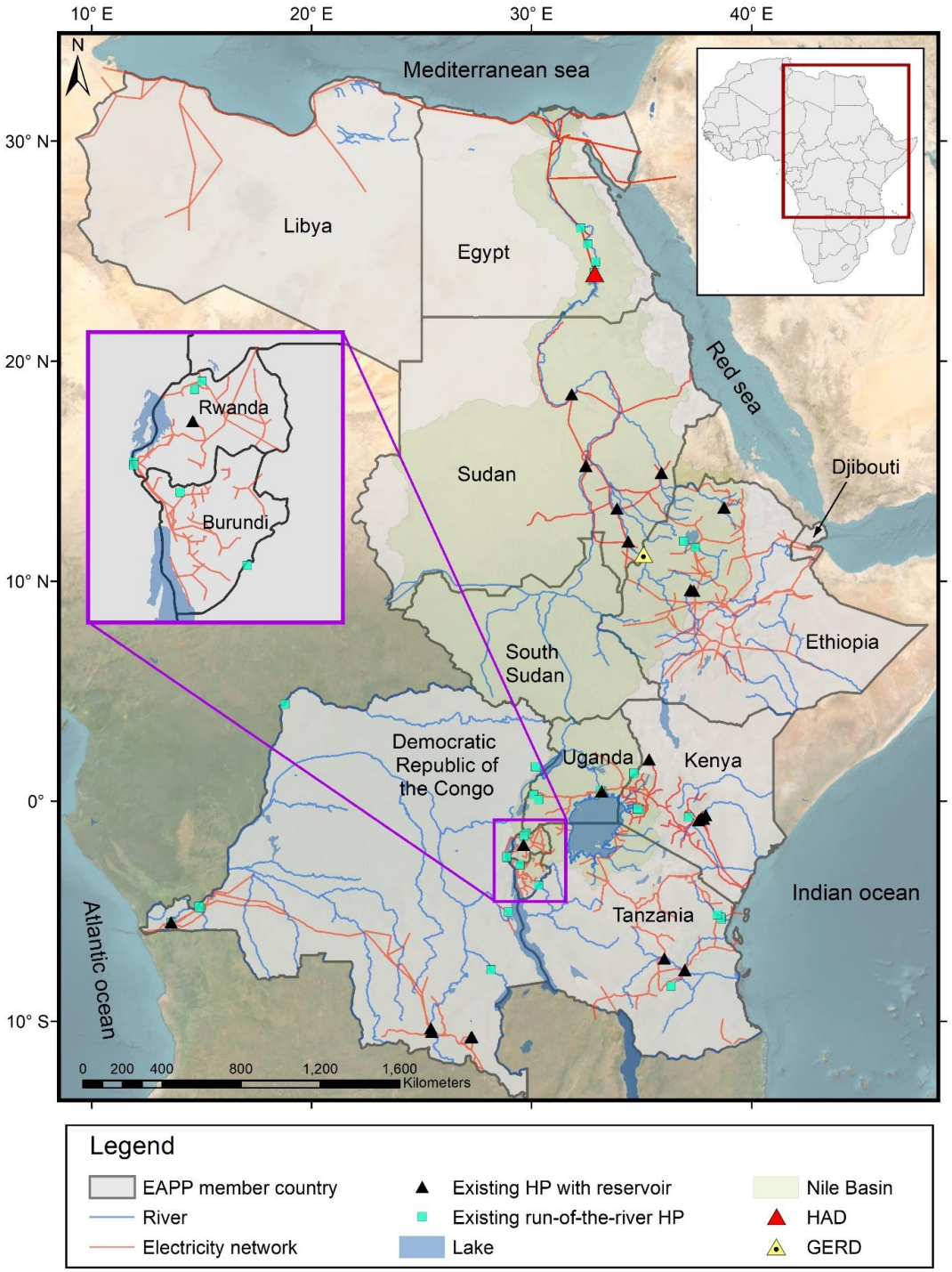




Case-study 2:
East Africa's water-energy system

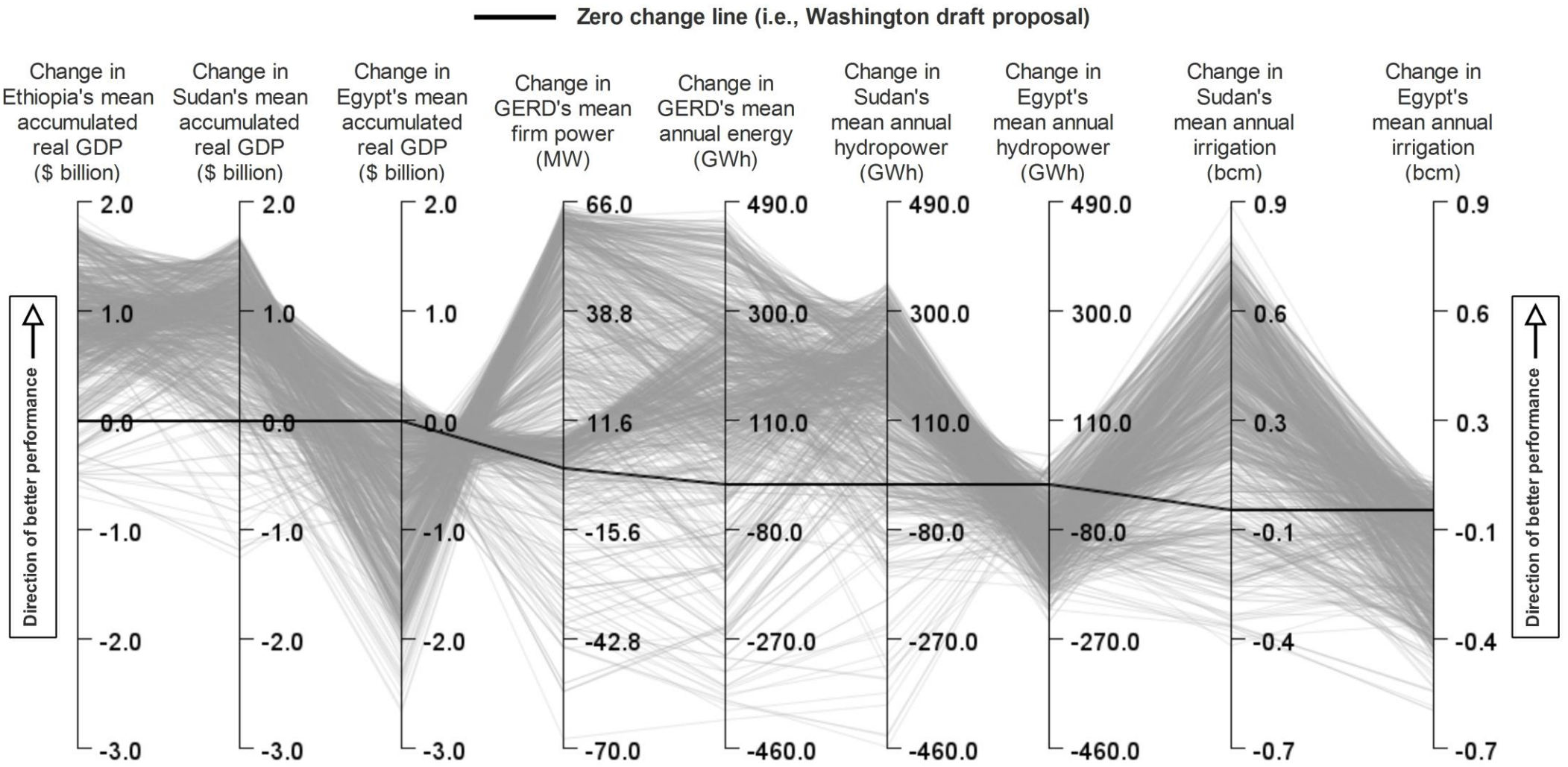
- East African Energy system: increasing cooperation and interconnectivity

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

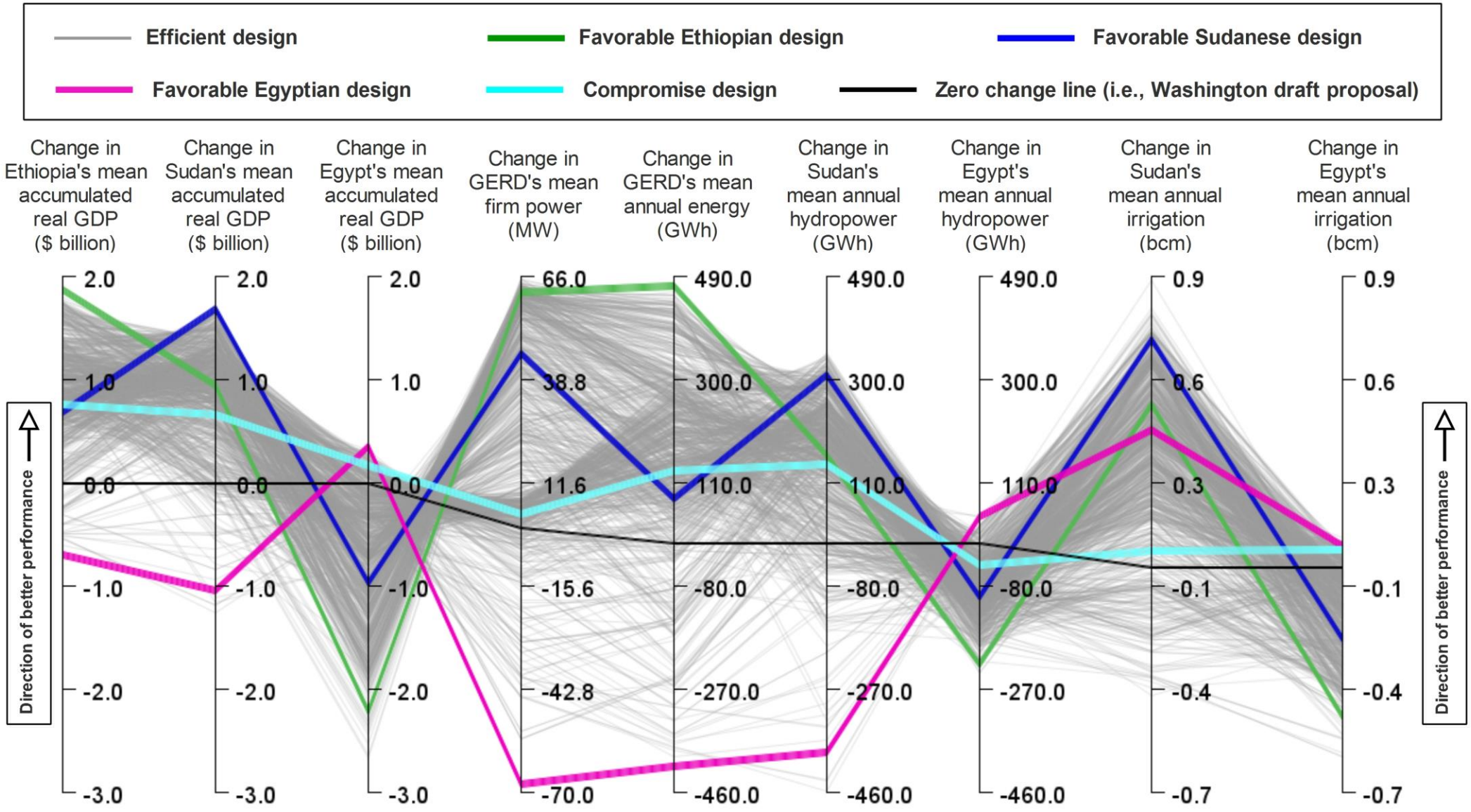


Results

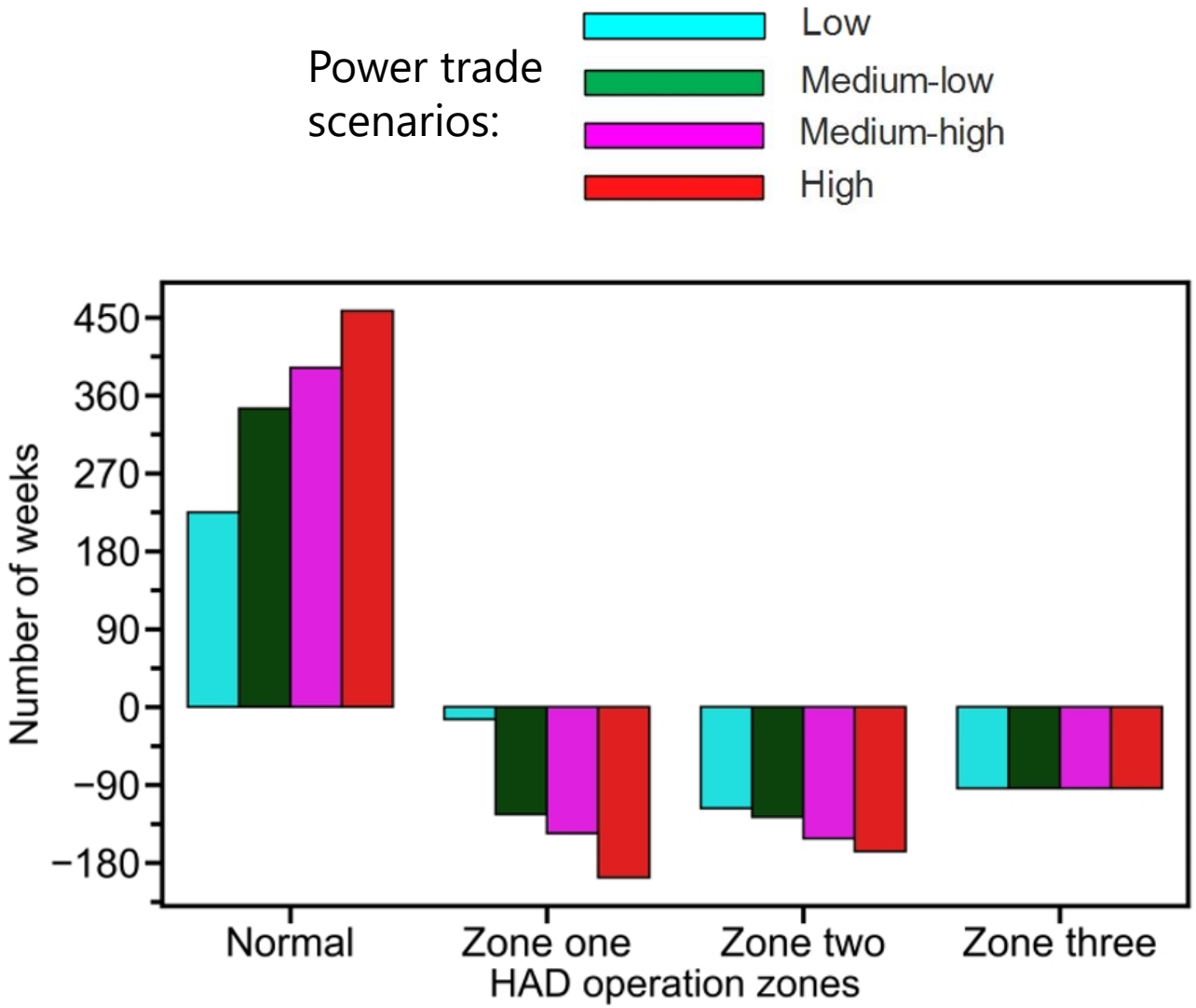
Case-study 1: Optimized GERD adaptive rule results



Case-study 1: Selected high performing rules



Case-study 2: Energy trade between countries increases water resilience



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

Case-studies – further information

www.nature.com/articles/s41558-022-01556-6

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

Concluding

Last thoughts

- Simulating river – energy – economy connections helps identify new solutions
- Goal: use infrastructure to increase synergies between countries and sectors
- AI-assisted design allows considering synergies & trade-offs between benefits; intervening in an efficient & balanced way