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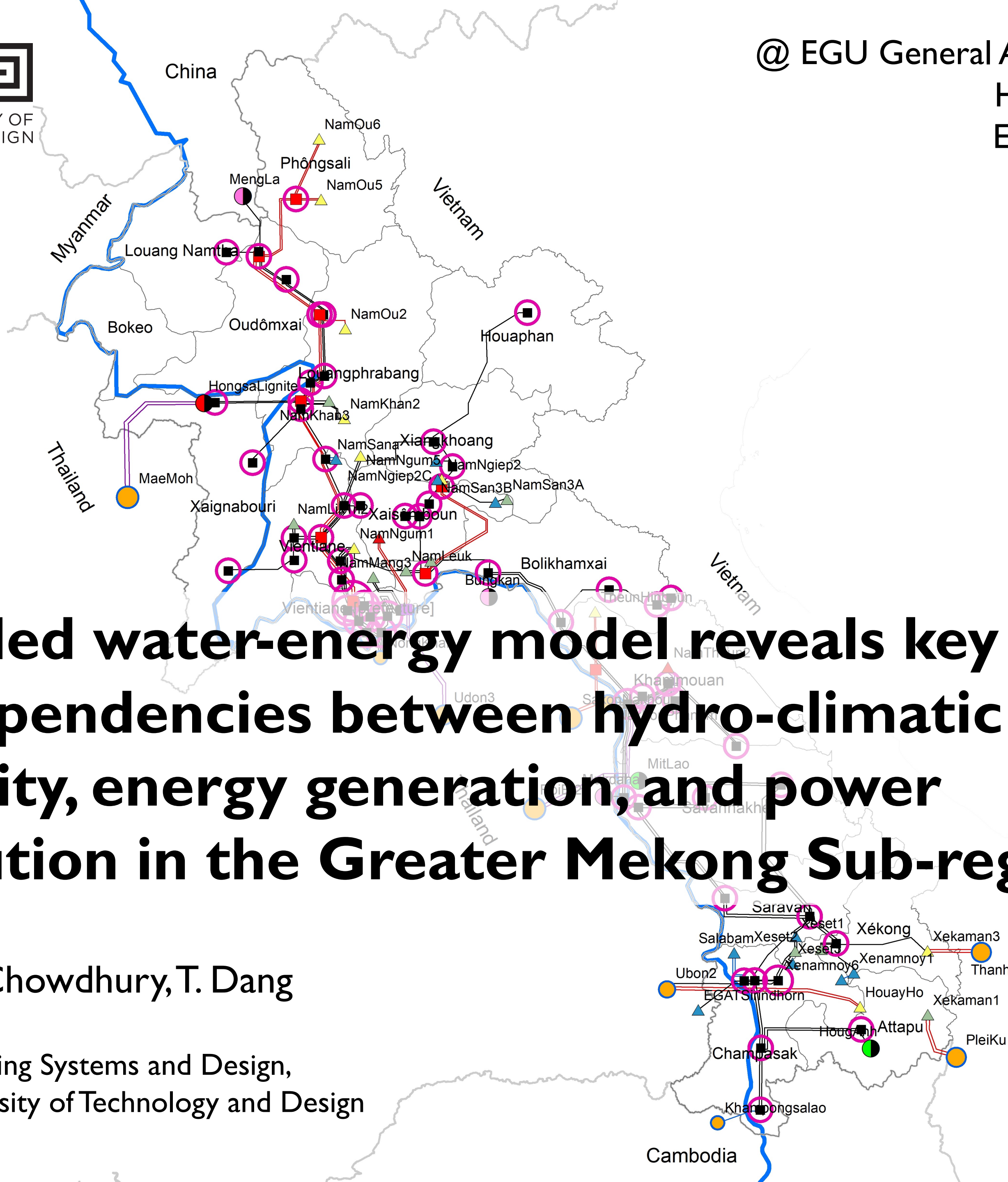

A coupled water-energy model reveals key interdependencies between hydro-climatic variability, energy generation, and power distribution in the Greater Mekong Sub-region

S. Galelli, K. Chowdhury, T. Dang

Pillar of Engineering Systems and Design,
Singapore University of Technology and Design

Introduction

Mekong hydropower development

RESEARCH

RESEARCH ARTICLE SUMMARY

SUSTAINABILITY

Designing river flows to improve food security futures in the Lower Mekong Basin

J. L. Sabo,* A. Ruhi, G. W. Holtgrieve, V. Elliott, M. E. Arias, Peng Bun Ngor, T. A. Räsänen, So Nam

INTRODUCTION: The Mekong River provides renewable energy and food security for a population of more than 60 million people in six countries: China, Myanmar, Lao PDR, Thailand, Vietnam, and Cambodia. Seasonal rains flood the river's floodplain and delta. This flood pulse fuels what is likely the world's largest freshwater fishery in Cambodia's Tonle Sap Lake, with >2 million tonnes of annual harvest valued at ~$2 billion. Hydropower development is crucial to the region's economic prosperity and is simultaneously a threat to fisheries and agriculture that thrived in the natural-flow regime. The Mekong is testament to the food, energy, and water challenges facing tropical rivers globally.

RATIONALE: We hypothesized that high fisheries yields are driven by measurable attributes of hydrologic variability, and that these relationships can be used to design and implement future flow regimes that improve fisheries yield through control of impending hydropower operations. Hydrologic attributes that drive strong fisheries yields were identified using a data-driven approach that combined 17 years of discharge and standardized harvest data with several time-series methods in the frequency and time domains. We then analyzed century-scale time series of discharge data on the Mekong and associated hydrodimate data sets to understand how current dams, independent of climate, have changed key drivers of the fishery since the early 1960s. Finally, we used estimated hydrologic drivers of the historical bag net, or "Dai," fishery on the Tonle Sap River—the largest commercial fishery in the Mekong—to design better fisheries futures by comparing designed flows to current and pre-dam (natural-flow) regimes.

in ecosystems subject to flood pulses, such as the Mekong. NAA is the annual sum of daily residual flows standardized to the long-term average hydrograph. Hence, NAA is a compact measure of hydrologic variance and can be further decomposed into nine shape "components."

Subsistence fisher tending nets on the Tonle Sap Lake, Cambodia.

Several of these components drive high fisheries yields, including a long low-flow period followed by a short, strong flood pulse with multiple peaks. All essential drivers of the flood pulse fishery have been changing since the closure of the first Mekong tributary dam and are independent of changes associated with climate

jected to exceed that of the natural-flo by a factor of 3.7. This result was rob inclusion of density-dependent recru our time-series model.

CONCLUSION: A data-driven app veals a new perspective on hydrolog of fishery productivity in the Mekon tent of the flood pulse is paramoun vious literature but so are othe tors of hydrologic including anom flows. Varianc specifically, the and timing of w anomalous high and low flows. A foc iance shifts the conversation from "H water do we need?" to "When do we r most, and when can we spare it?" I components of variance in the l be described by a simple Fou asymmetric rectangular pulse

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Read the full article at http://dx.doi.org/10.1126/science.aao1053

titative ecological objective func cal gap in the balancing of fis with other important objectiv cluding hydropower generation, and transportation. This open of specifying and implementir to manage rivers to satisfice tra

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Review papers

Hydropower dams of the Mekong River basin: A review of their hydrological impacts

Jory S. Hecht[a,b,*], Guillaume Lacombe[c], Mauricio E. Arias[d], Thanh Duc Dang[e,f,g], Thanapon Piman[h]

[a] Department of Civil and Environmental Engineering, Tufts University, Medford, MA, USA
[b] Vermont EPSCoR, University of Vermont, Burlington, VT, USA
[c] International Water Management Institute, Vientiane, Lao People's Republic
[d] Department of Civil and Environmental Engineering, University of South Florida, Tampa, FL, USA
[e] Institute for Water and Environment Research, Thuy Loi University, Ho Chi Minh City, Viet Nam
[f] Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand
[g] Engineering Systems and Design Pillar, Singapore University of Technology and Design, Tampines, Singapore
[h] Stockholm Environment Institute, Bangkok, Thailand

ARTICLE INFO

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ABSTRACT

Hydropower production is altering the Mekong River basin's riverine ecosystems, which contain the world's largest inland fishery and provide food security and livelihoods to millions of people. The basin's hydropower reservoir storage, which may rise from ~2% of its mean annual flow in 2008 to ~20% in 2025, is attenuating

ELSEVIER

Science of The Total Environment

Volume 625, 1 June 2018, Pages 114-134

Changing sediment budget of the Mekong: Cumulative threats and management strategies for a large river basin

G. Mathias Kondolf [a, b], Rafael J.P. Schmitt [a, c], Paul Carling [d], Steve Darby [d], Mauricio Arias [e], Simone Bizzi [c], Andrea Castelletti [c], Thomas A. Cochrane [f], Stanford Gibson [g], Matti Kummu [h], Chantha Oeurng [a, i], Zan Rubin [a], Thomas Wild [j]

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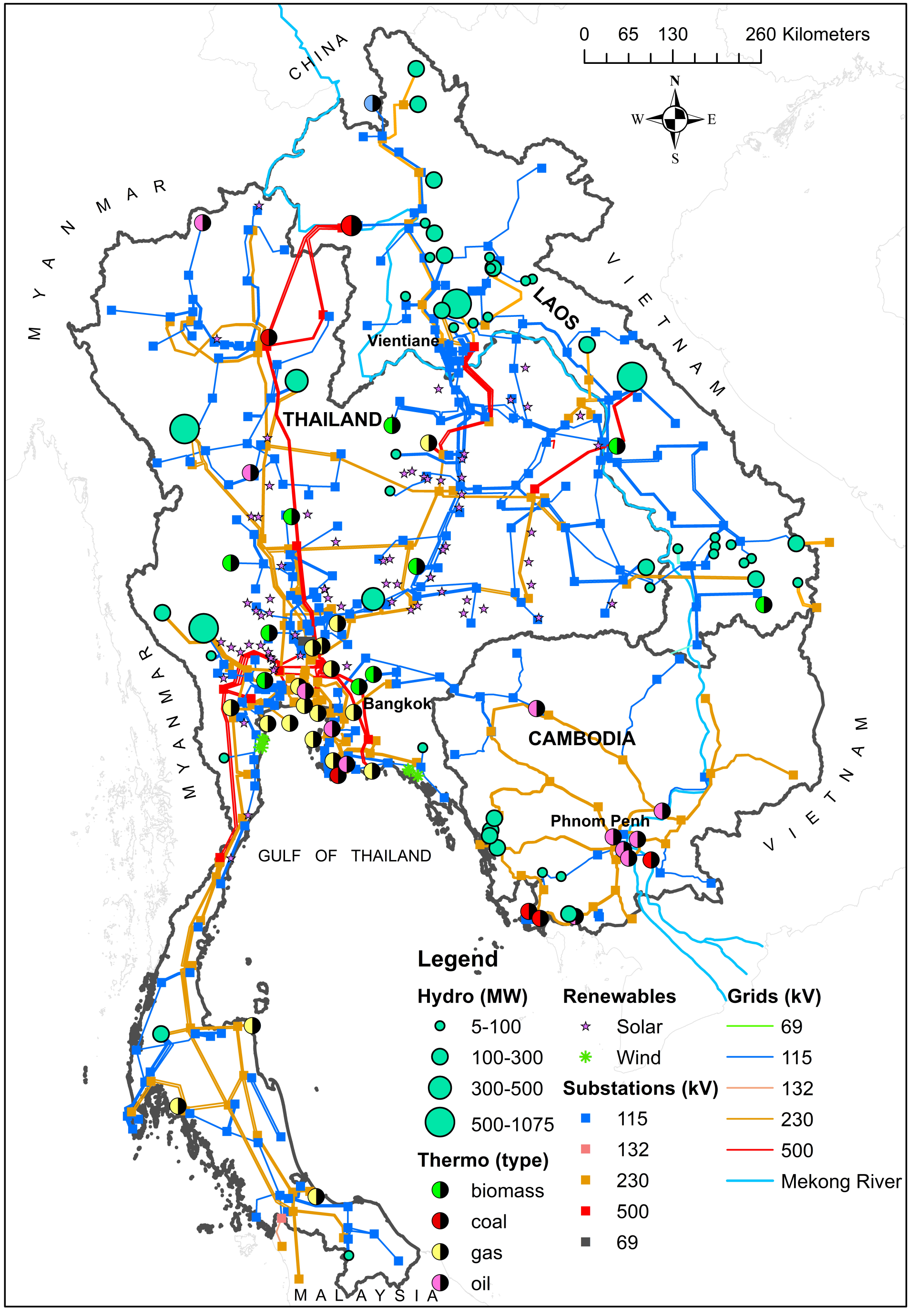
https://doi.org/10.1016/j.scitotenv.2017.11.361

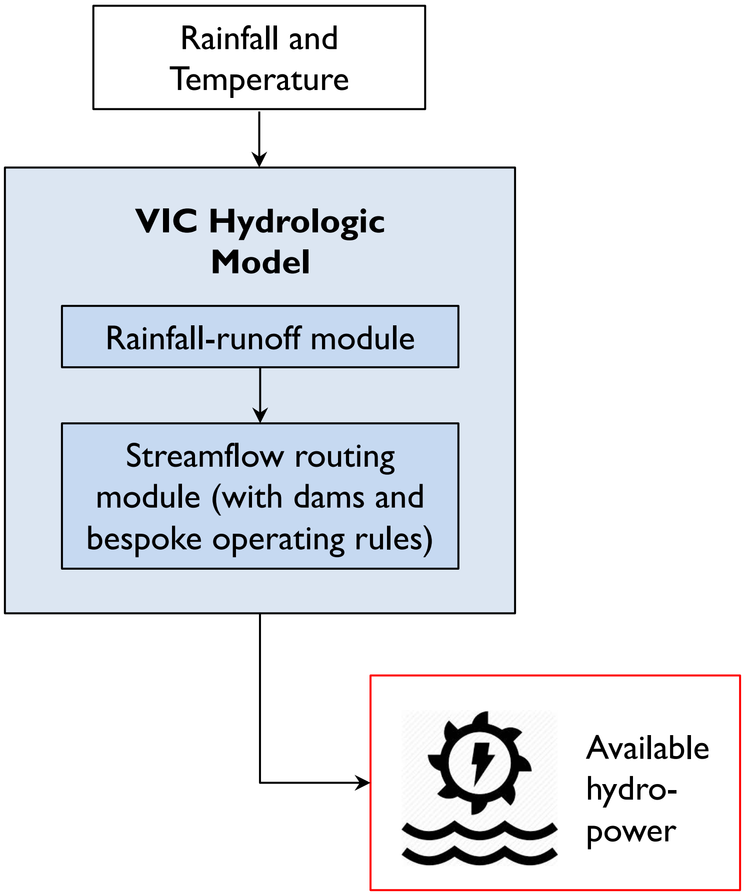
Introduction

Some open issues

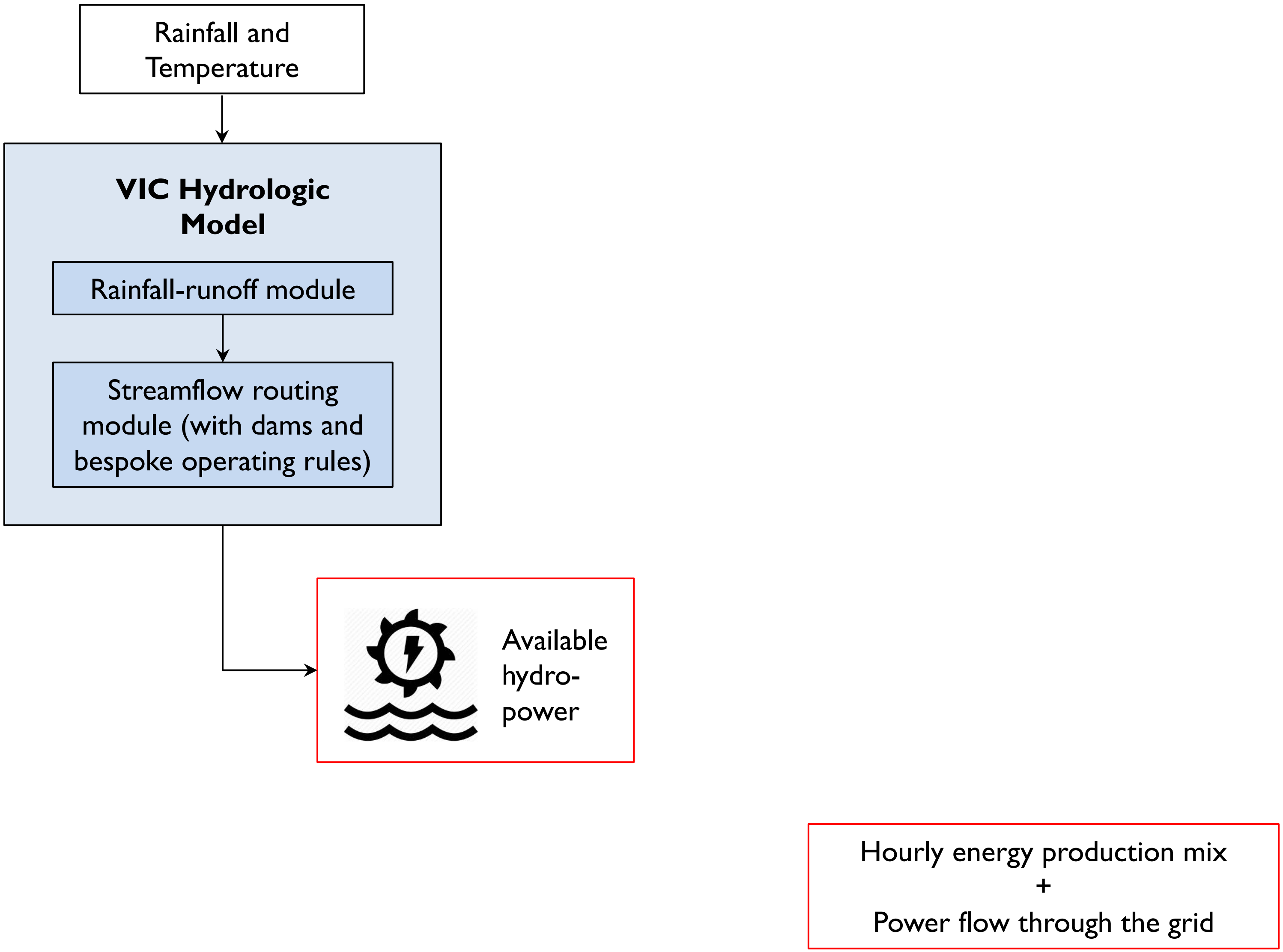
- Effect of hydro-power generation on power supply and distribution
- Vulnerability of the coupled water-energy system to hydro-climatic variability



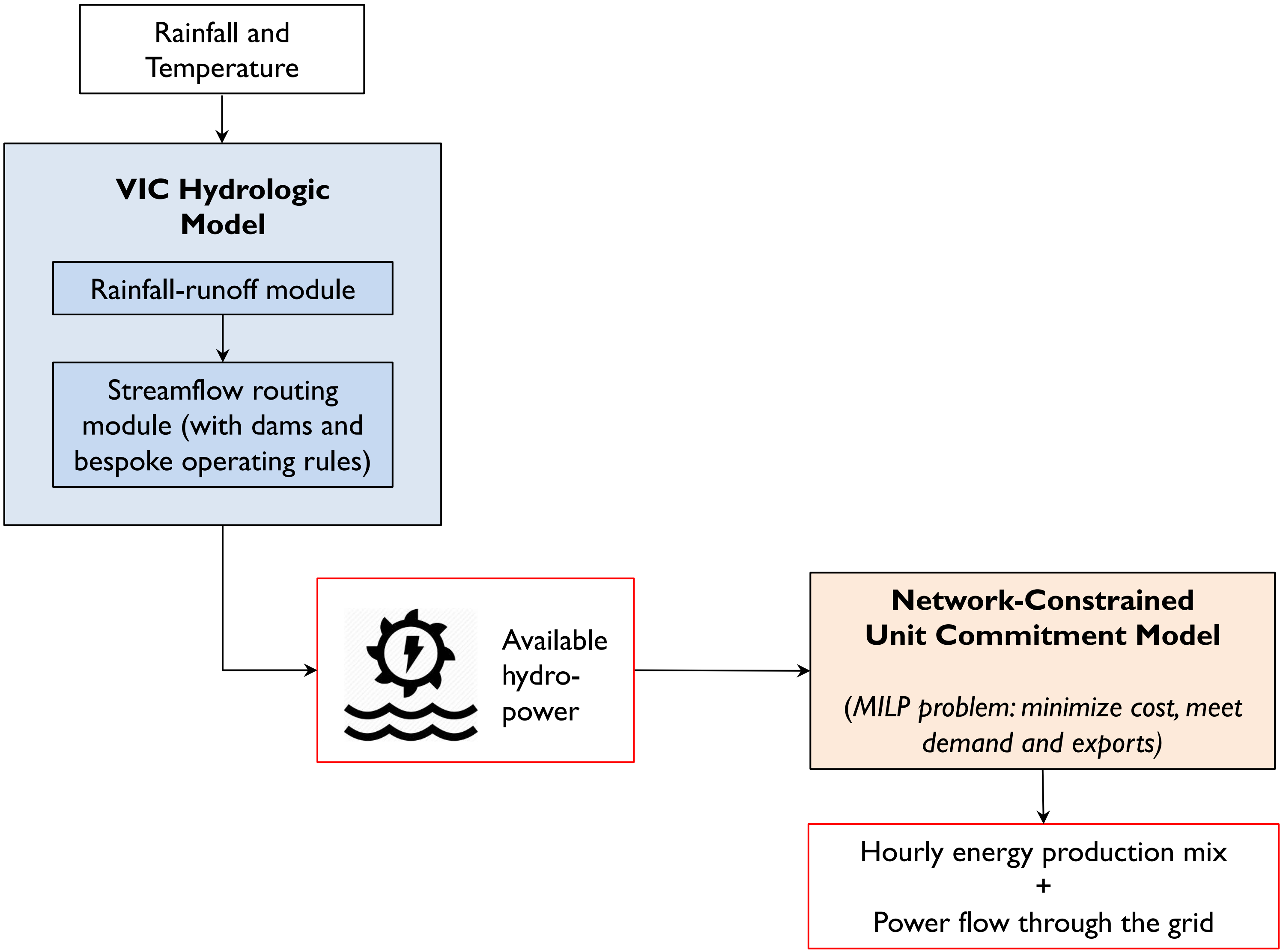
Water-Energy model



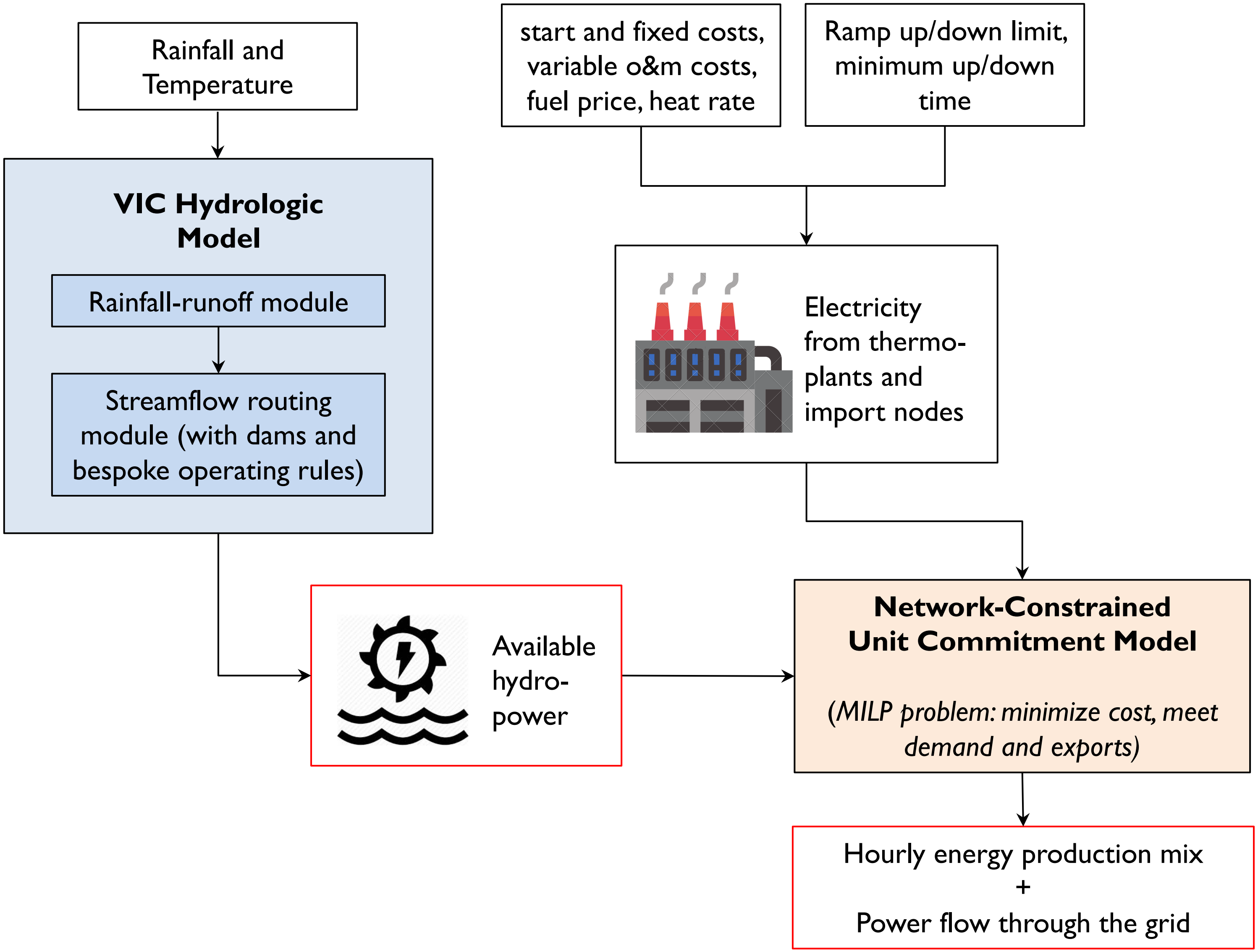
Water-Energy model



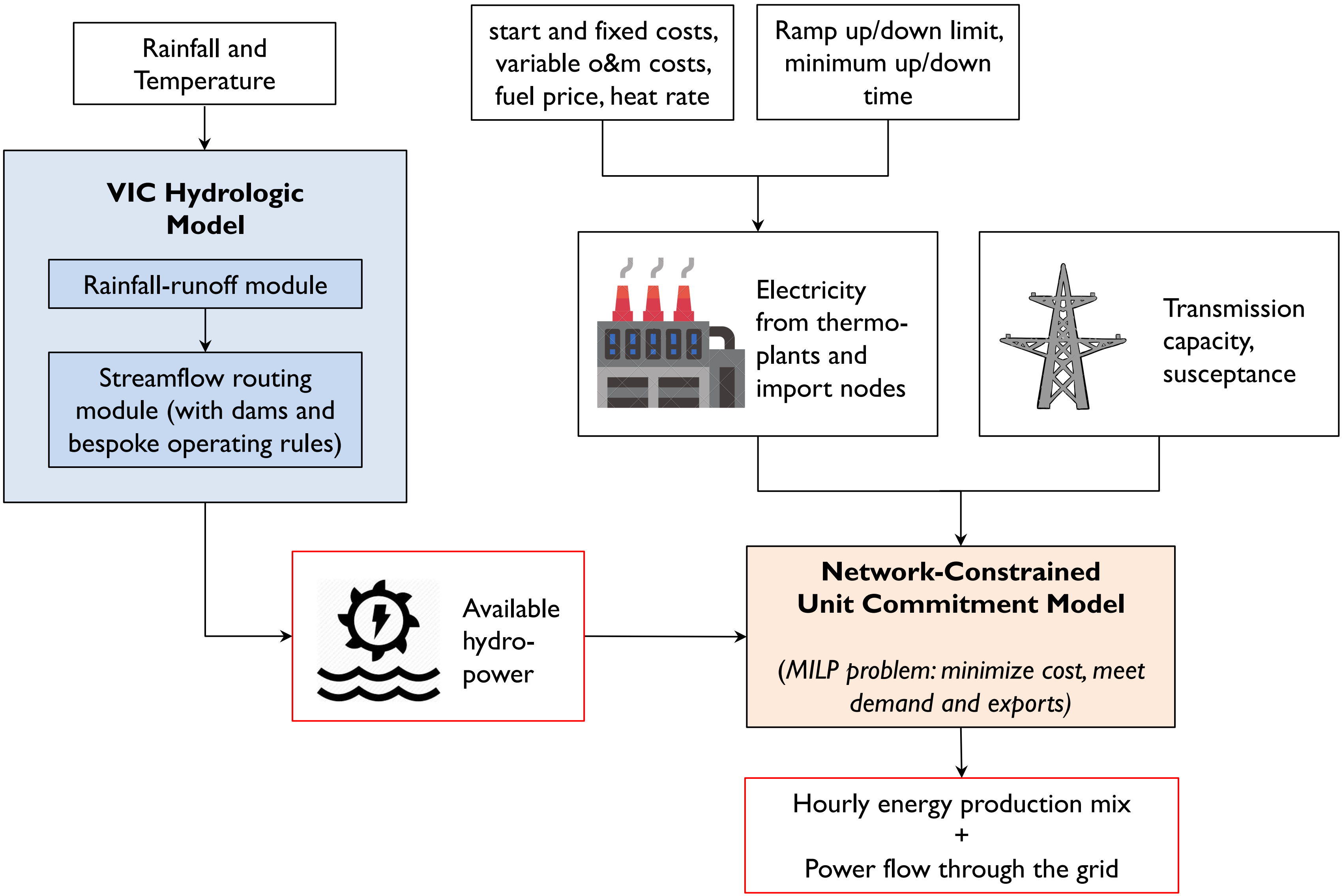
Water-Energy model



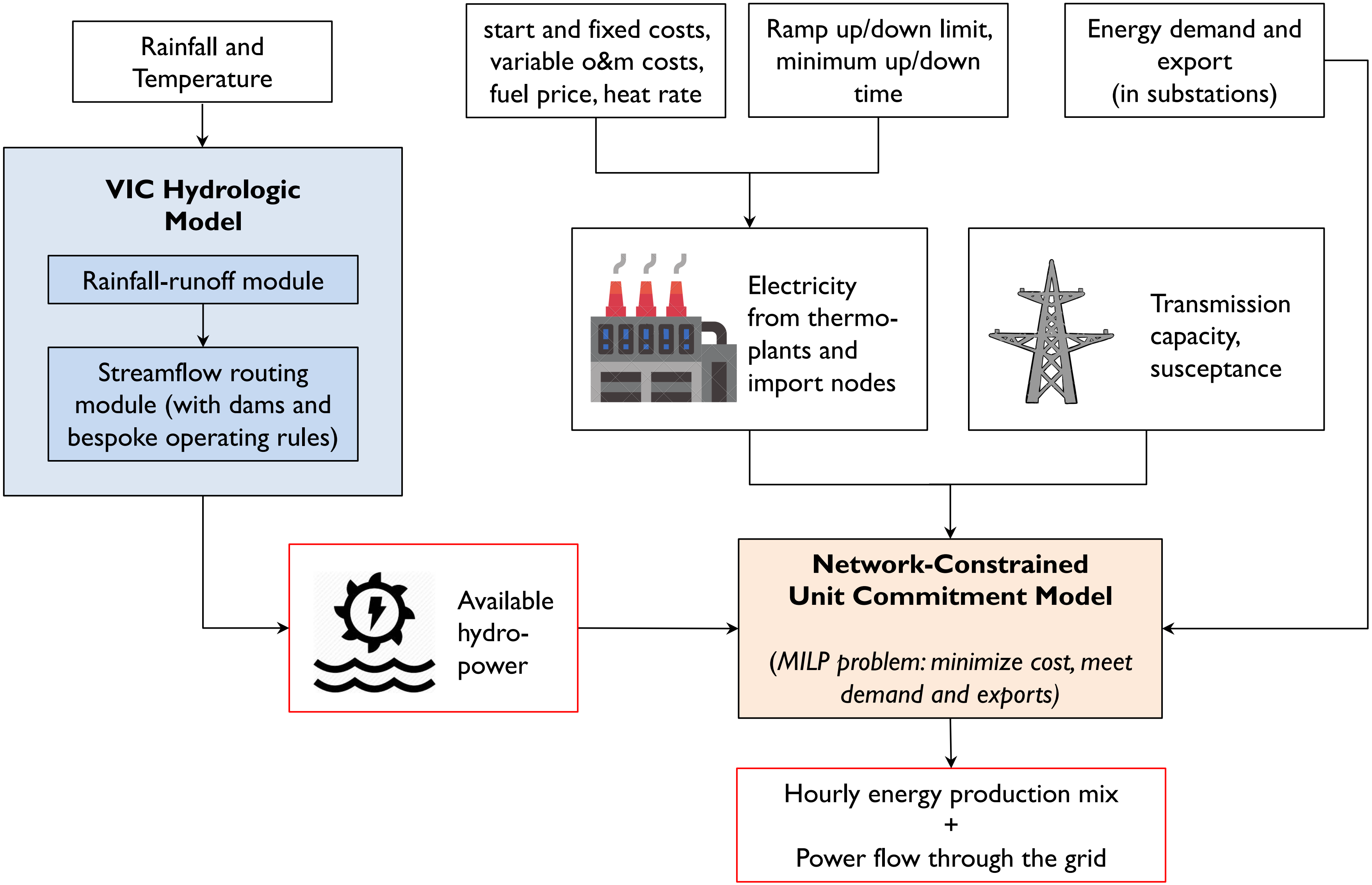
Water-Energy model



Water-Energy model



Water-Energy model

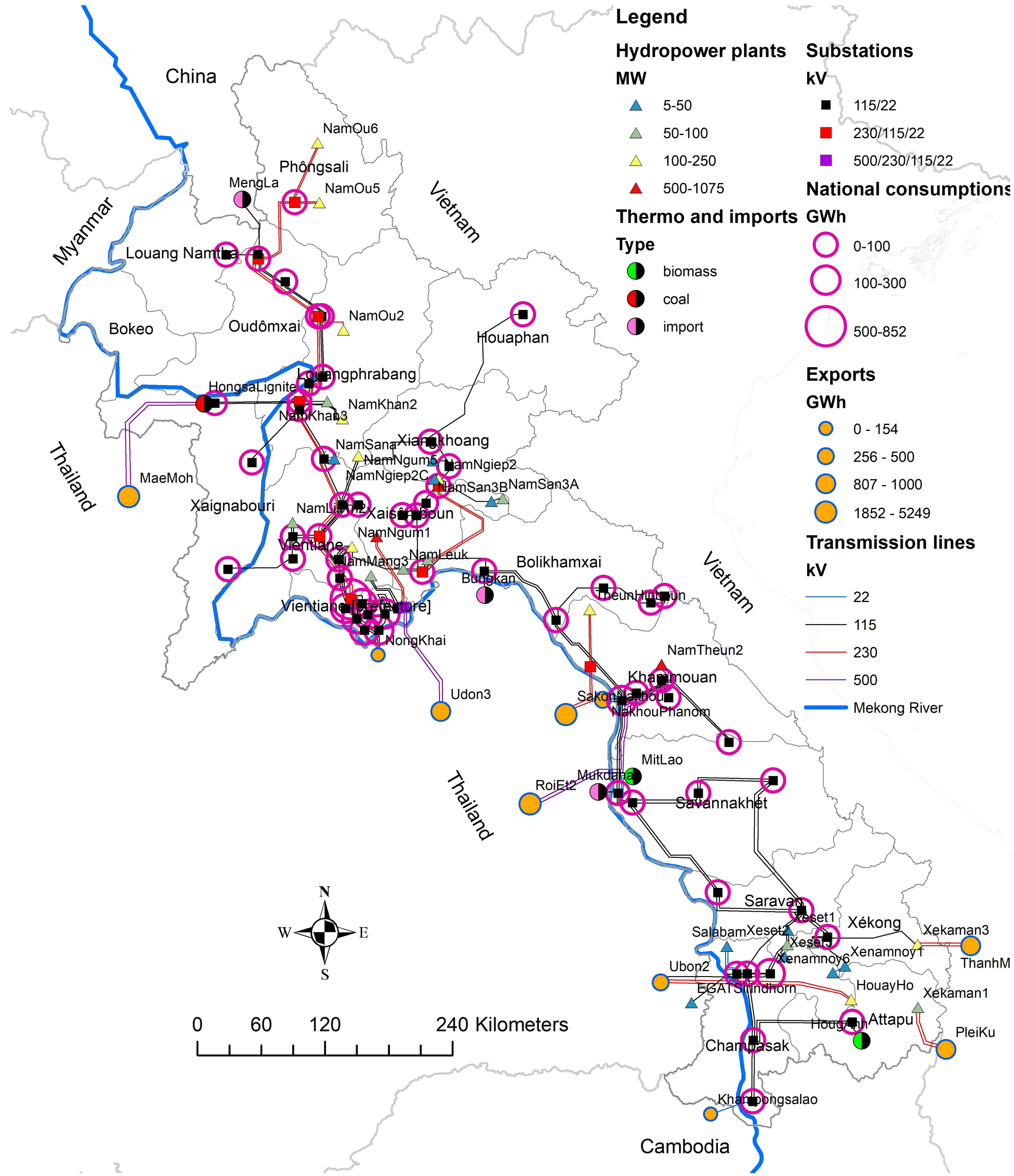


Model setup

110 nodes (2016 data):

- **Generators:** 30 hydro (4,734 MW), 1 coal (1,878 MW), 2 biomass (40 MW)
- **Import nodes:** 3 from Thailand, 1 from China
- **Substations:** 64 transformers
- **Export nodes:** 7 to Thailand, 2 to Vietnam, 1 to Cambodia

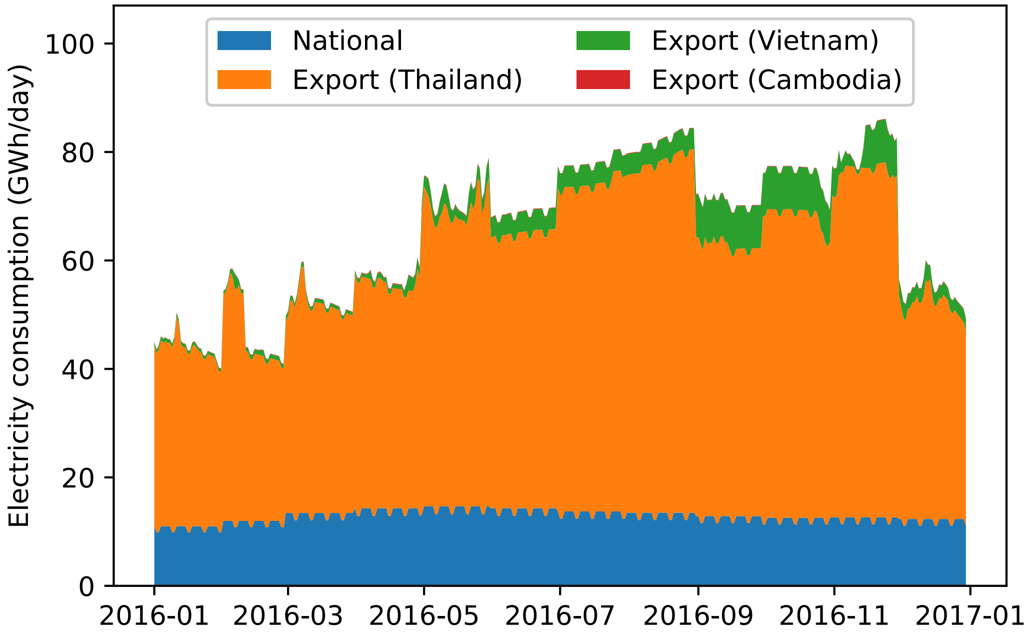
- Hourly resolution
- 4,753 continuous + 931 binary decision variables (for 24 hours)
- Implementation in Pyomo and Gurobi



Model setup

Electricity consumption (2016 data):

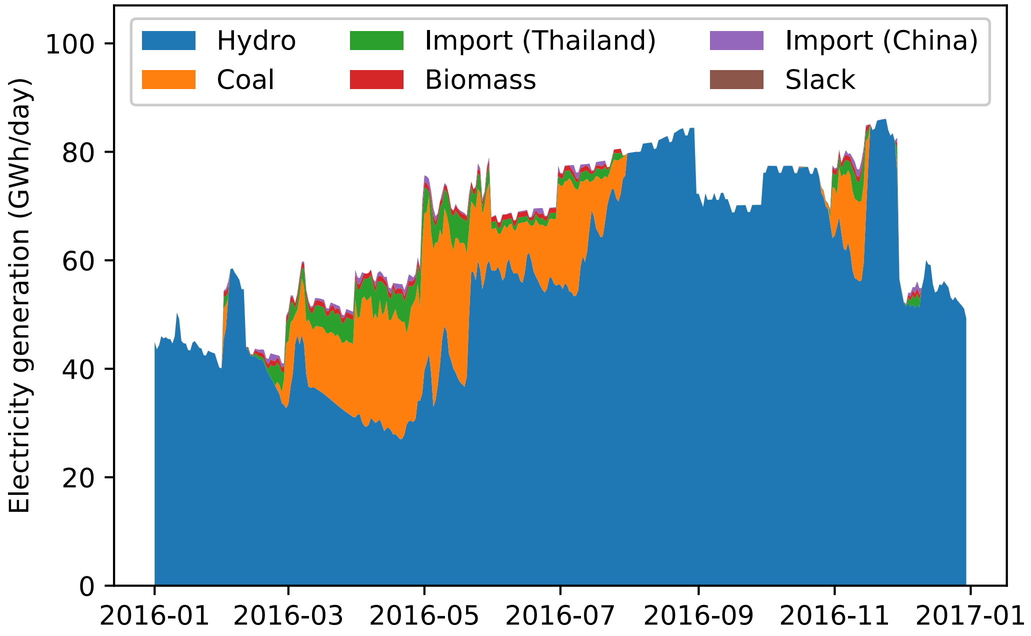
- **Total national:** 4,647 GWh
- **Export to Thailand:** 18,099 GWh
- **Export to Vietnam + Cambodia:** 1,287 GWh



Results

Impact of seasonal hydro-climatic variability – energy mix

- High hydro-electricity production at the peak of the monsoon season
- Strong dependence on other energy sources during the pre-monsoon months



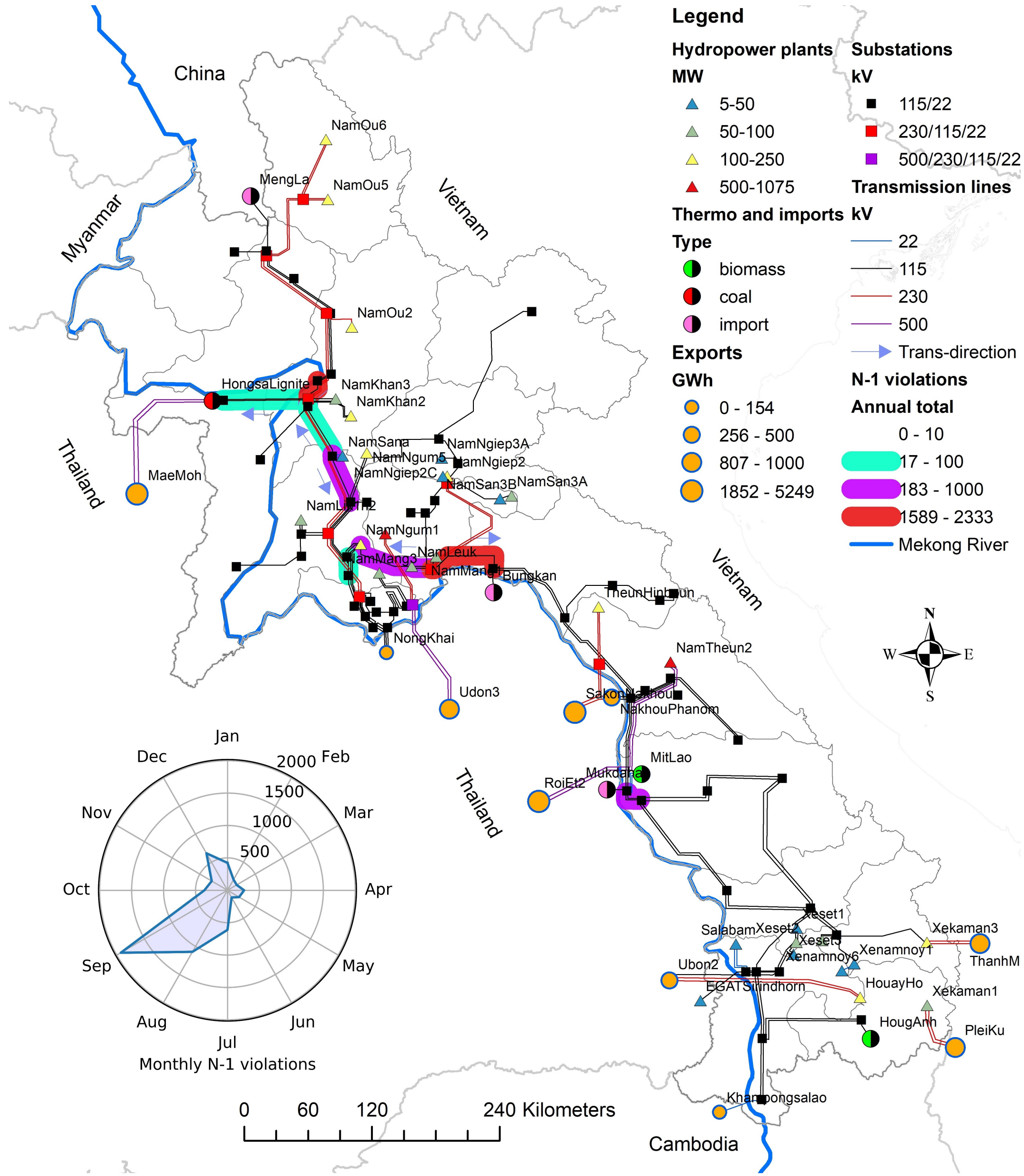
Results

Impact of seasonal hydro-climatic variability – energy transmission

- ~70% of the N-1 violations* occurring during the monsoon season

→ <u>The dispatch of hydro-electricity is constrained by the capacity of the transmission lines</u>

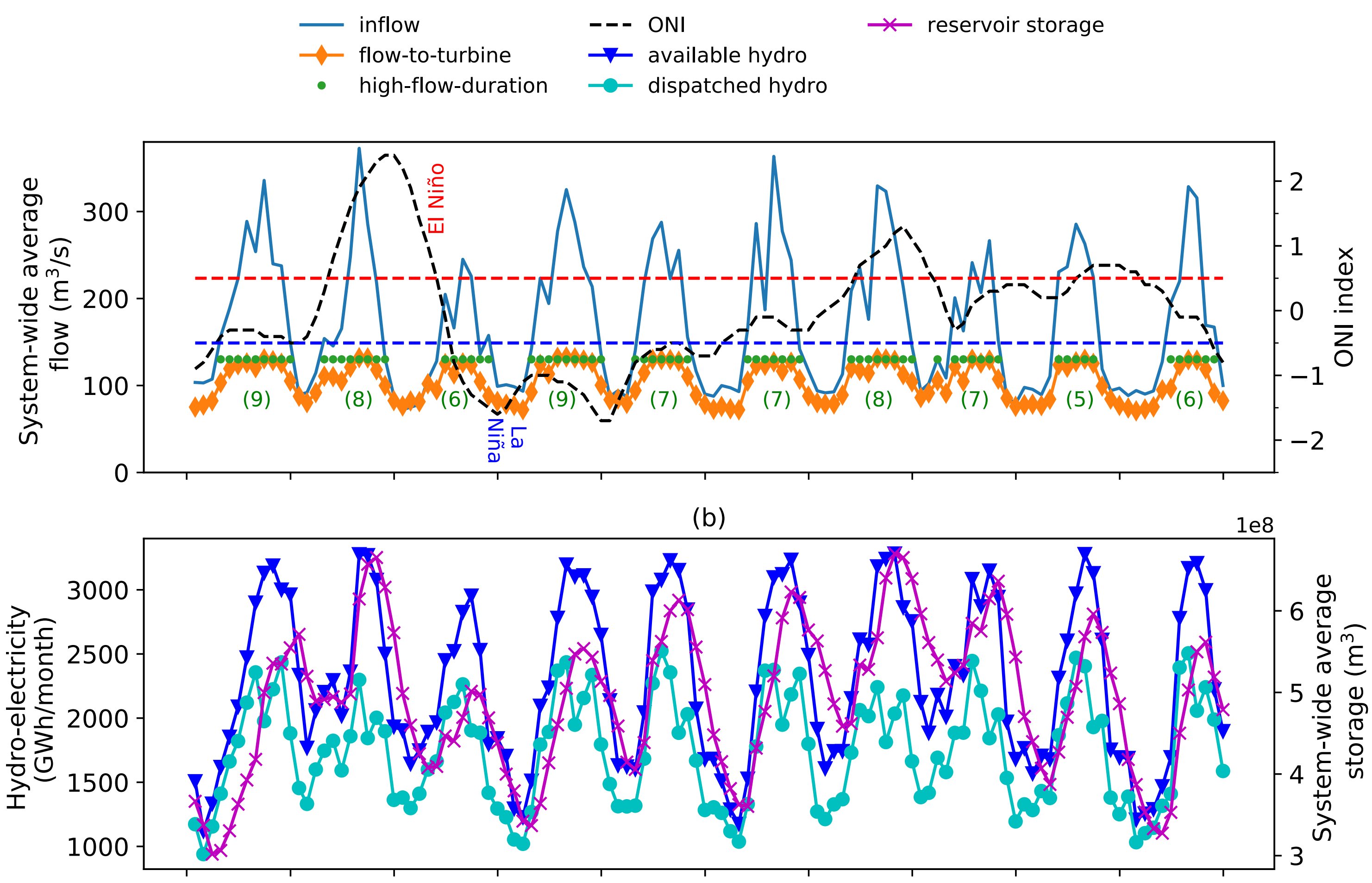
- ~20% of the available hydro-electricity remains unused (mostly during the monsoon season)



* N-1 violation: line usage is at least 75% of the line capacity (at any hour)

Results

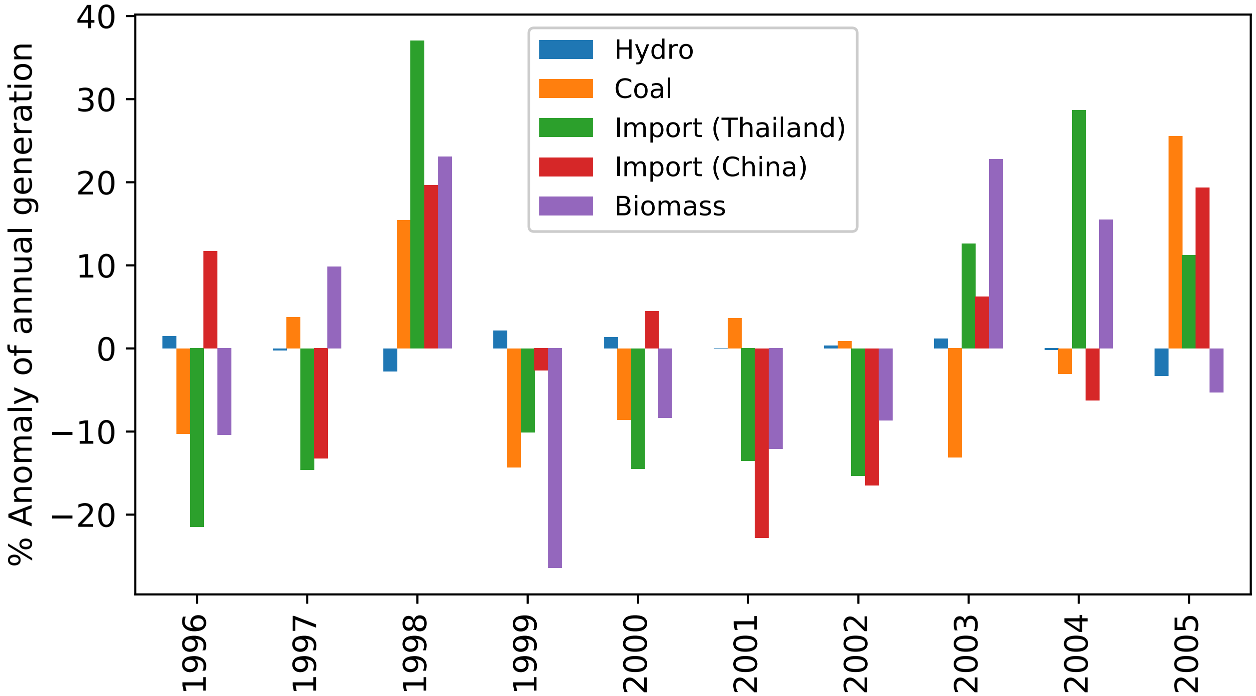
Impact of inter-annual hydro-climatic variability (1996-2005) – relation with climate drivers



Results

Impact of inter-annual hydro-climatic variability (1996-2005) – energy mix

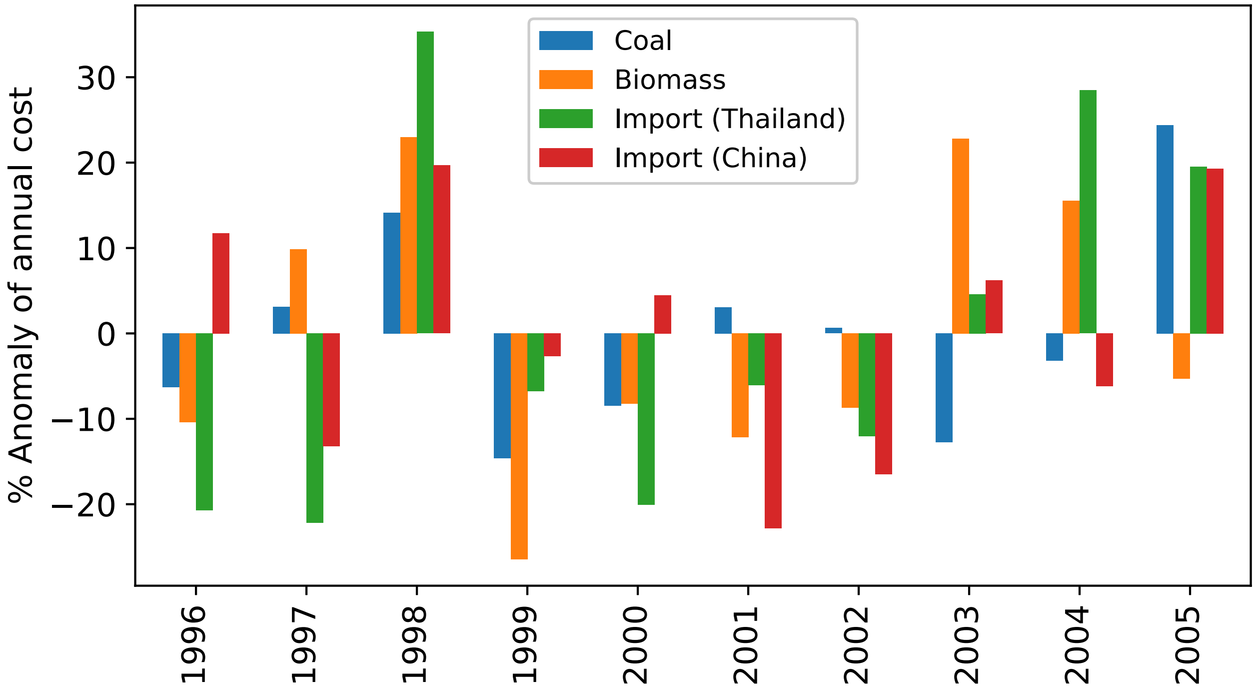
- The anomaly of dispatched hydro-electricity is at most 3%
- Yet, this largely influences imports and power production from coal



Results

Impact of inter-annual hydro-climatic variability (1996-2005) – energy mix

- Production cost increases by ~20-30% during dry years
- Negative effect of droughts on CO_2 emissions (increase by ~25% during dry years)



Conclusions

Impact of seasonal hydro-climatic variability

- Strong effect of seasonal water availability on the energy mix
- Dispatch constrained by the transmission capacity
- Part of the available hydro-power remains unused

Conclusions

Impact of seasonal hydro-climatic variability

- Strong effect of seasonal water availability on the energy mix
- Dispatch constrained by the transmission capacity
- Part of the available hydro-power remains unused

Impact of inter-annual hydro-climatic variability

- Strong effect of ENSO-driven water availability on the energy mix, production costs, and CO_2 emissions

Conclusions

Potential interventions

- Further expansion of the transmission lines
- More water storage (?)
- Forecast-informed management of the water-energy system
- …

Thanks!

Stefano Galelli
stefano_galelli@sutd.edu.sg

Resilient Water Systems Group
http://people.sutd.edu.sg/~stefano_galelli/

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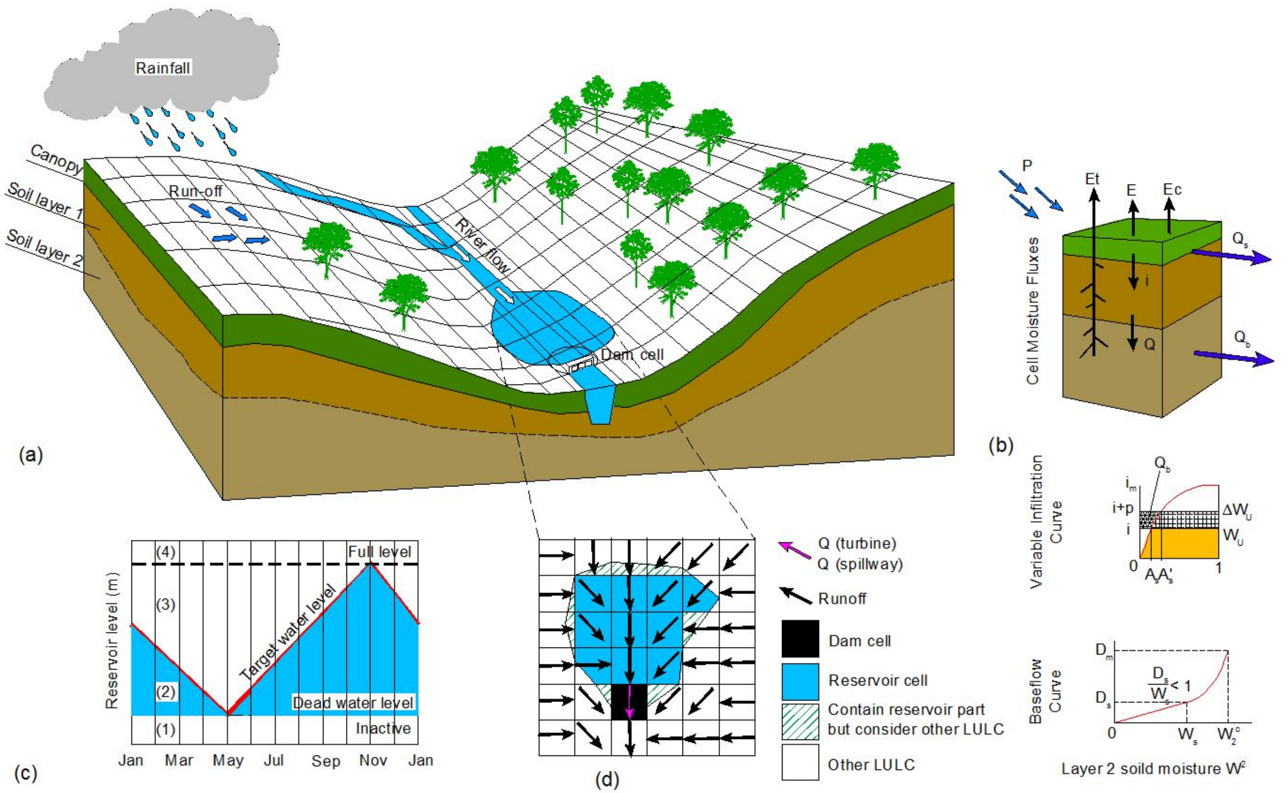
Appendix

Model setup

Variable Infiltration Capacity (VIC):

- **Spatial resolution:** 0.0625 degrees (~6.9 km)
- **Rainfall and Temperature:** APHRODITE + CFSR
- **Soil and Land use:** HWSD + GLCC
- **Bespoke operating rules** for each reservoir



Model setup

Energy model – validation

	Hydro	Coal	Biomass	Import (Thailand)	Import (China)
Observed	20883	2246	163	521	115
Simulated	20656	2453	174	541	103
% Deviance	-1%	9%	7%	4%	-10%