Improving Water-Energy-Climate Nexus Modeling at the Metropolitan Scale

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I. Background and Research Question

- Future plans of electricity capacity expansion often **does not consider climate and water constraints**.

- **Recent studies** analyzed the effect of these constraints **over large regions** such as the US (Miara et al., 2022).

- However, such modeling efforts: (1) **disregard** the effects of **various water users**; and (2) **consider a large study domain** that **does not** directly inform **the power utility** in charge of planning the capacity expansion.

Research question:
How do **surface water availability** and **climate change** affect **power expansion** at the metropolitan scale?

II. Study Area

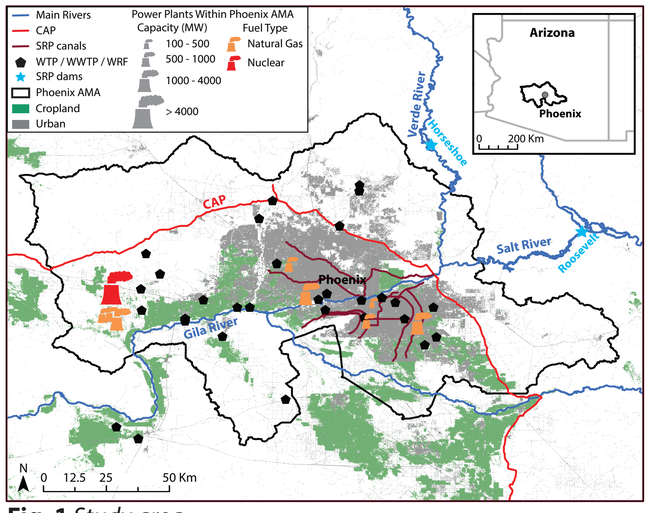


Fig. 1 *Study area.*

- The **Phoenix Active Management Area (AMA)**: hybrid hydrogeological-political unit that includes Phoenix Metro Area.

- **Water sources**: (1) surface water managed by the Salt River Project (**SRP**); (2) surface water through the **Central Arizona Project** canal; (3) **groundwater**; (4) **reclaimed water**.

- **Energy provided by SRP** and **Arizona Public Service utilities**, operating 9 power plants within the region boundary, along with 22 large power plants outside this area.

III. Proposed Framework

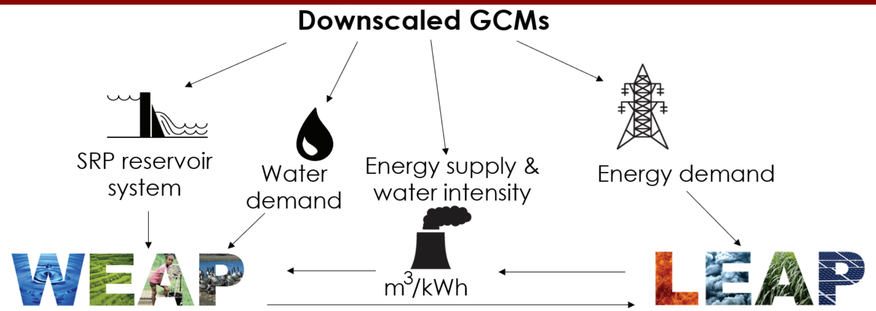
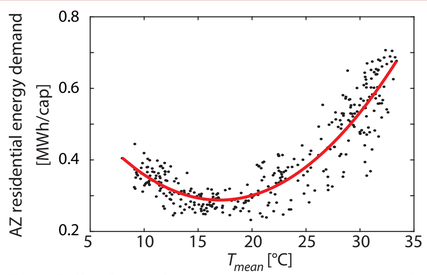


Fig. 2 *Integrated modeling of water, energy, and climate.*

- Water Evaluation and Planning (**WEAP**) and Long-range Energy Alternatives Planning (**LEAP**) **are coupled** to simulate interactions of water-energy systems.

- **Statistical regression models** generate monthly time series of **water demand and supply** and of **energy demand** that depend on climate.

IV. Climate Effect on Energy Demand



Residential energy demand is **nonlinearly** related to monthly mean temperature, T_{mean}.

Fig. 3 *Residential energy demand as a function of monthly mean temperature.*

- Simulations of residential energy demand rely on a multiple regression model using as predictors **cooling/heating degree days** and the **antecedent demand**.

$$y_t = a_0 + a_1 \cdot CDD_t + a_2 \cdot HDD_t + a_3 \cdot HDD_t^2 + a_4 \cdot y_{t-1}$$

Energy demand in a given month | Cooling degree days | Heating degree days

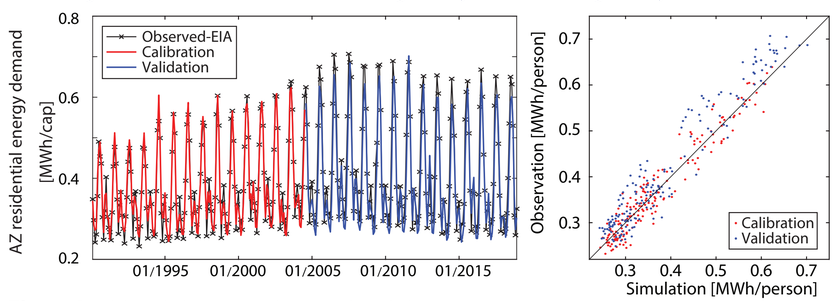


Fig. 4 *Residential energy demand in Arizona.*

V. Climate Effect on Power Plant Water Use

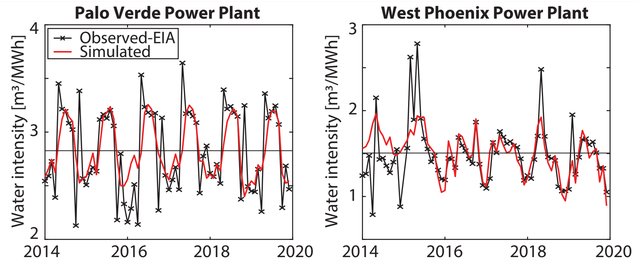


Fig. 5 *Power plant water intensity.*

- Simulations of power plants **water intensities depend on** T_{mean} (Rutberg et al., 2011).

VI. Climate Effect on Water Supply

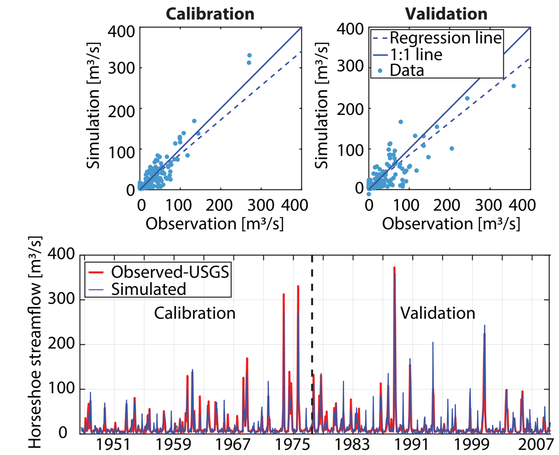


Fig. 6 Streamflow simulations for the Horseshoe reservoir.

- **Streamflow** simulations for the SRP system are based on a multiple regression with **precipitation, temperature, snowfall,** and the **antecedent streamflow** as predictors.

VII. References

- Miara, A. et al. 2019. Climate-Water Adaptation for Future US Electricity Infrastructure. Environ. Sci. Technol. 53, 14029–14040.
- Rutberg M. et al. 2011. A system-level generic model of water use at power plants and its application to regional water use estimation. Proceedings of the American Society of Mechanical Engineers.

VIII. Acknowledgments

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