Energy Planning Under Deep Uncertainty in South Sudan

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Introduction and Motivation

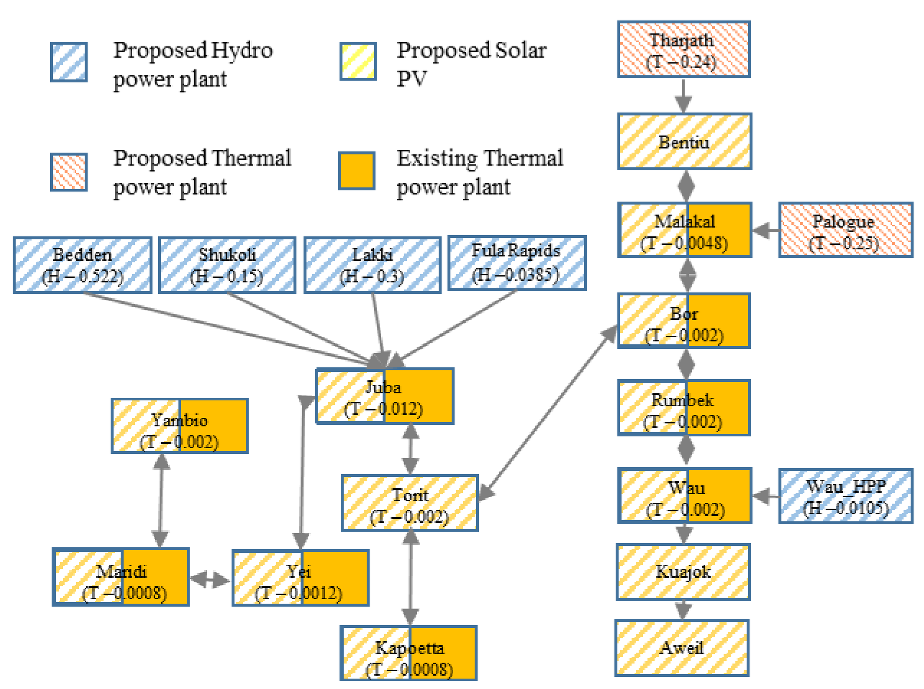
- South Sudan (founded in 2011) has been suffering through **civil war**.
- The total installed capacity is approximately **30 MW** which can only serve 1% of the population
- Prone to economic collapse despite having **rich natural resources, such as oil and perennial rivers**
- Various studies have proposed building **large scale hydro power** plants (HPP) due to the presence of perennial rivers
- Large plants such as hydro are **vulnerable to damage** during conflict
- A **decentralized system** might be less expensive when the risk of conflict is explicitly considered

Objectives

- Develop a **multistage stochastic programming** model which focuses on how conflict can affect electricity related investment decisions
- Generate actionable model-based insights that can inform planning
- Develop methods to estimate **damage costs** to electricity infrastructure
- Develop a method to measure the monetary **effects of implementing naïve least cost solution**

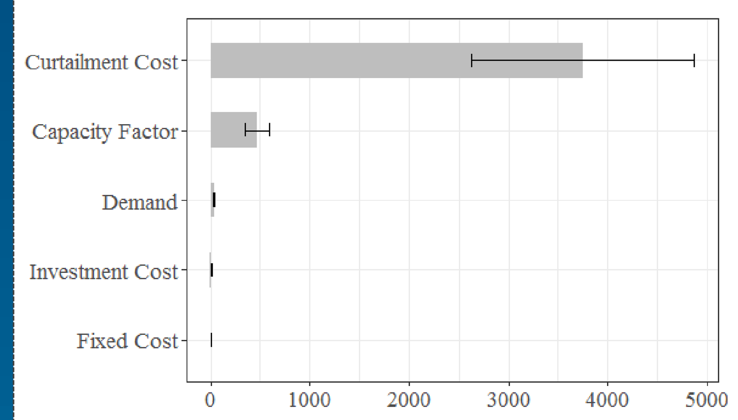
Methods for damage value estimation

Regional Effects – (RE)	$FOM \times (1 + DR \times RCR \times Pr(C))$
Intensified Regional Effects – (IRE)	$FOM \times (1 + \alpha \times DR \times RCR \times Pr(C))$
Without Regional Effects – (WRE)	$FOM \times DR$



One of the proposed grid design. Labels represent the type of a power plant and limit on capacity built (GW) over the entire time horizon.

Methodology



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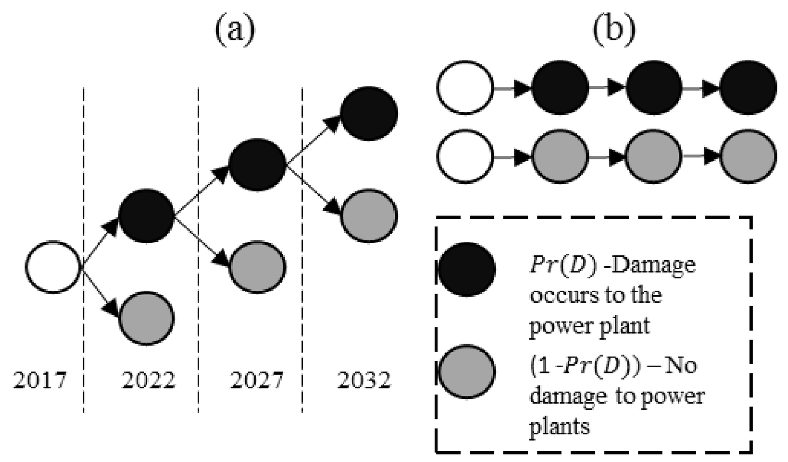

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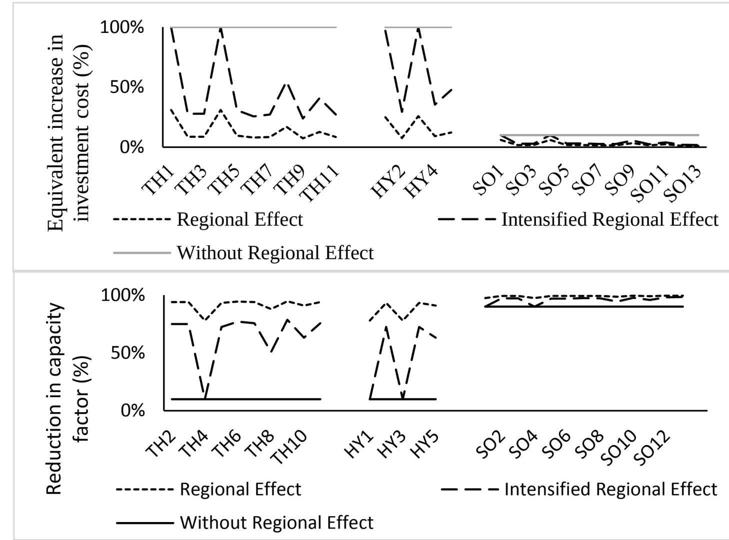
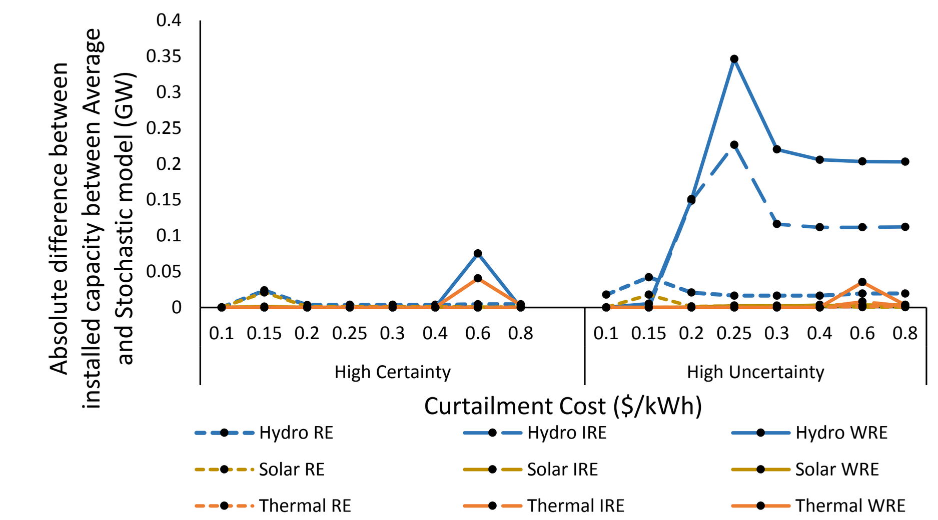
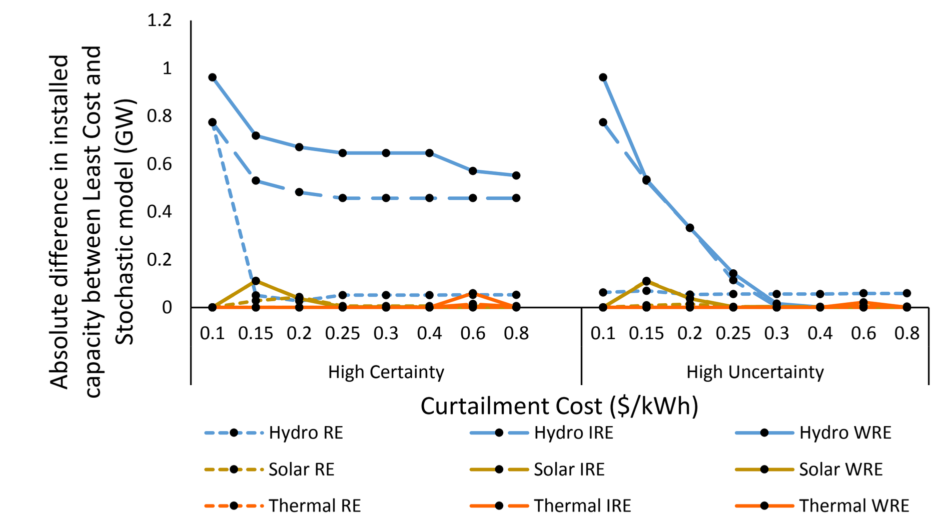
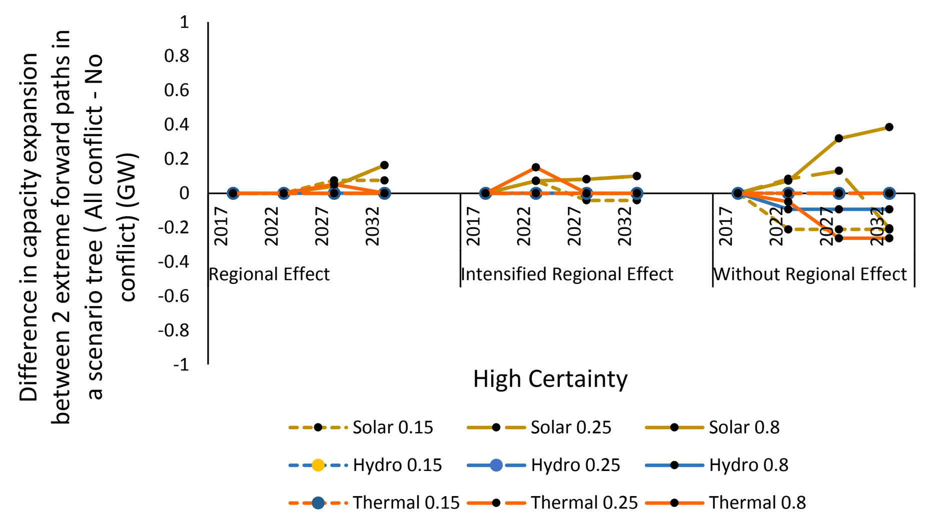


Stochastic Solution

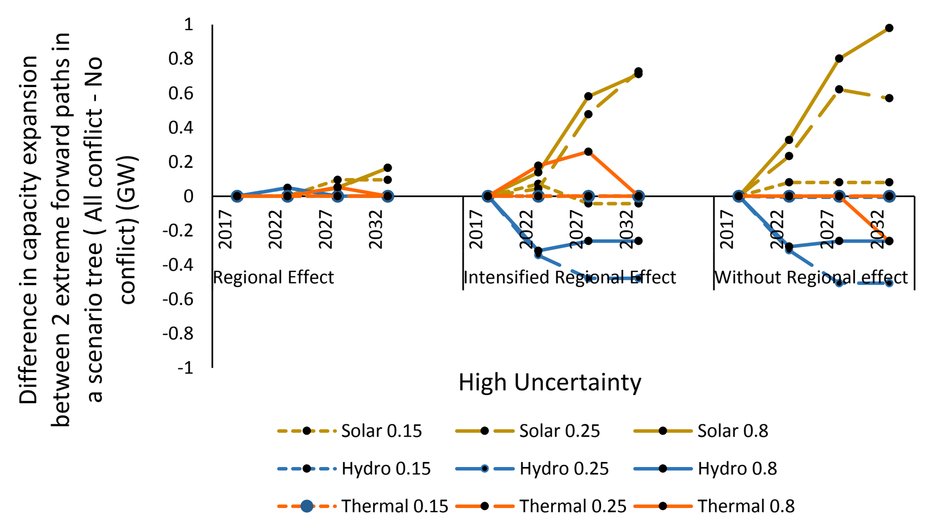


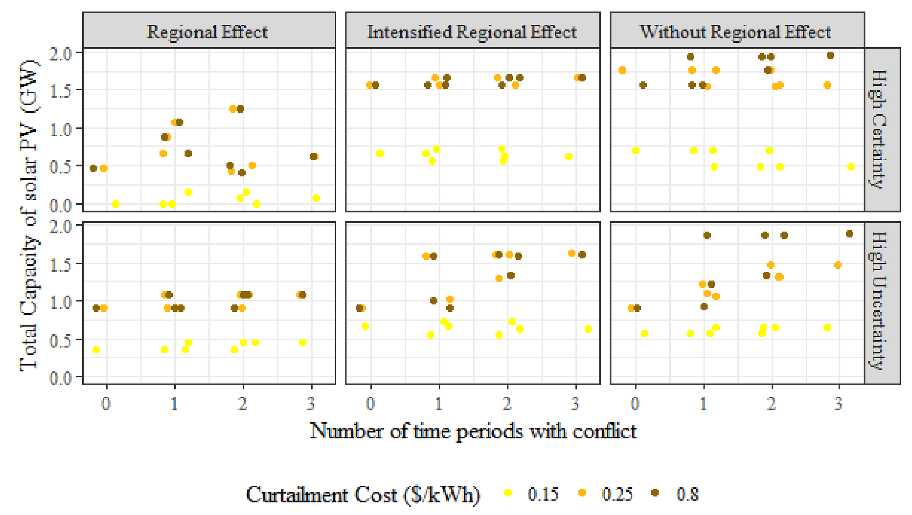
How much is the average or least cost solution different than the stochastic solution?



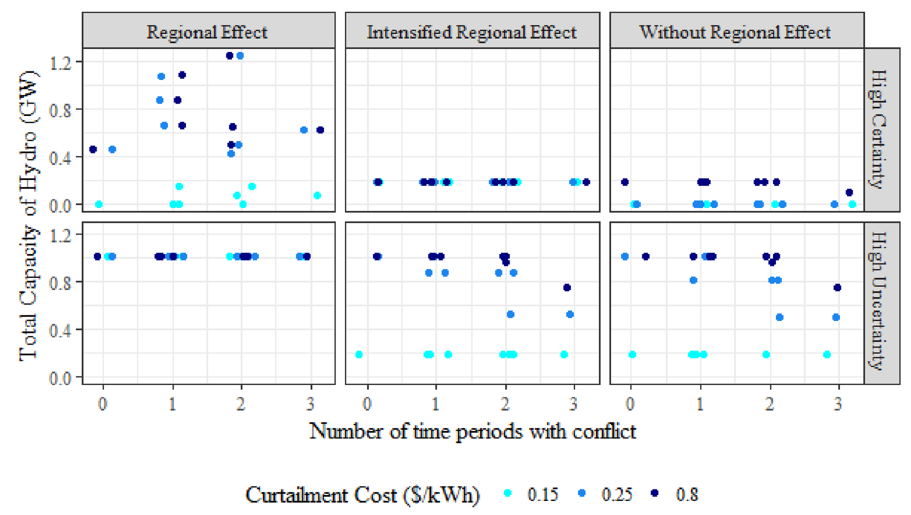


How does the probability of damage to power plants affect future capacity expansion?

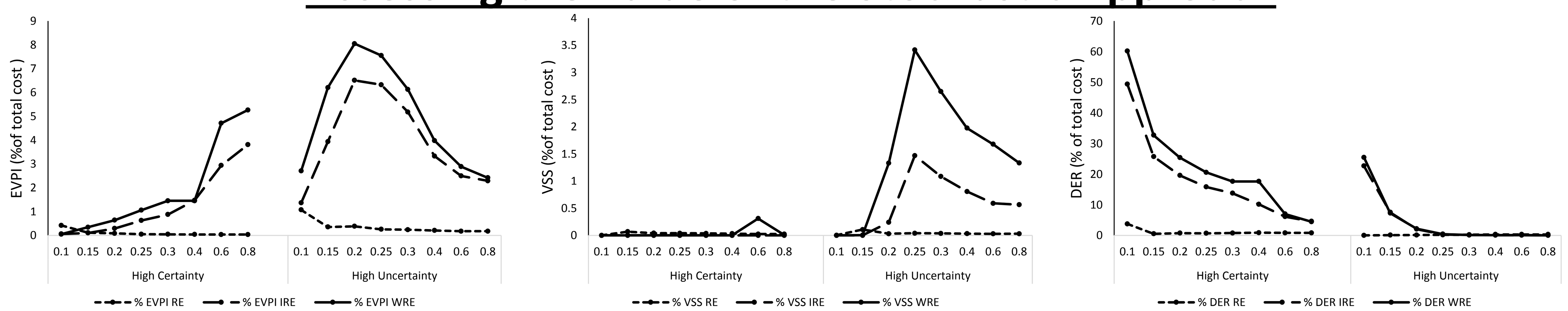




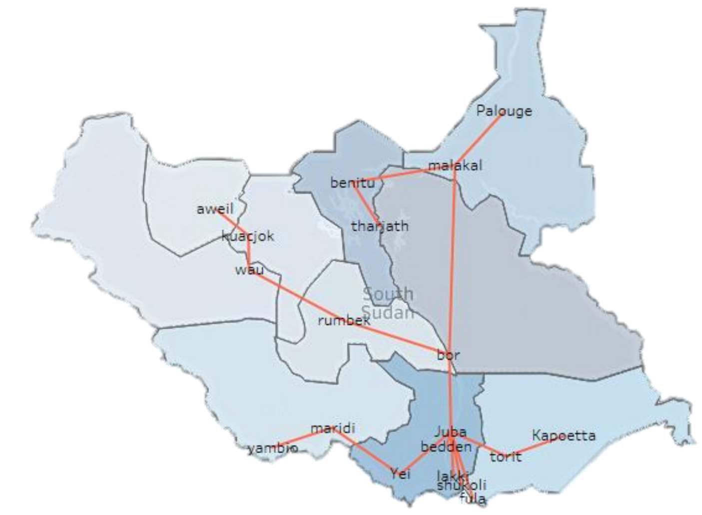
How does the number of conflict periods affect capacity expansion?



Assessing the Value of the Stochastic Approach



Discussion and Conclusions



Model Parameter	High Uncertainty EVPI	VSS	DER
Curtailment cost ($/kWh)	Follows a bell curve for method 2 and 3. Decreases monotonically for method 1	Proportional to absolute difference between stochastic and average solutions	Proportional to absolute difference between stochastic and naïve deterministic solutions
Damage cost (Calculated by RE, IRE and WRE)	Increases when conflict intensity increases	Increases when conflict intensity increases	Increases when conflict intensity increases

- Applying a multistage stochastic programming model can yield more **robust and adaptive power system expansion** plans for South Sudan.
- Ignoring conflict risk can have **significant economic consequences** (EVPI ~10%; $400 million, VSS ~5%; $200 million, DER ~ 60%, 2.3 billion)
- The model is much more sensitive to the **penalty for unsatisfied demand** and capacity factor of generators than demand, investment cost and fixed cost.

Future Work

- Develop or identify better data to improve the system representation.
- Examine different grid topologies and their performance under conflict.
- Incorporate elastic demands rather than relying on curtailment cost.
- Consider the possibility that conflict damages transmission infrastructure

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