The technical and economic potential of renewables in Indonesia and scenarios for power system decarbonisation

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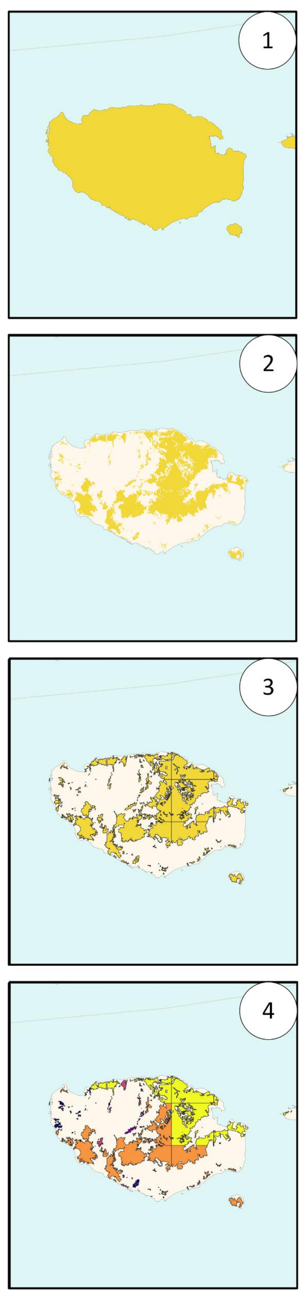
Introduction

- Indonesia is a strongly growing country in terms of population and economy
- Current electricity demand is mostly met with fossil fuels (82.6% in 2018)
- Nonetheless, Indonesia pledged to become carbon neutral by 2060, amongst others by shifting from fossil fuels to renewables
- There is already evidence that Indonesia's renewable energy resources, or *potentials,* are large in principle [1]
- However, it is unclear how these potentials are distributed across Indonesia's more than 14,000 islands and whether they suffice to meet future demand

- This research addresses these gaps by:
  1. Mapping the technical and economic potential of renewables in Indonesia
  2. Energy system optimisation modelling of options for full decarbonisation of Indonesia's power system

Methods & Materials

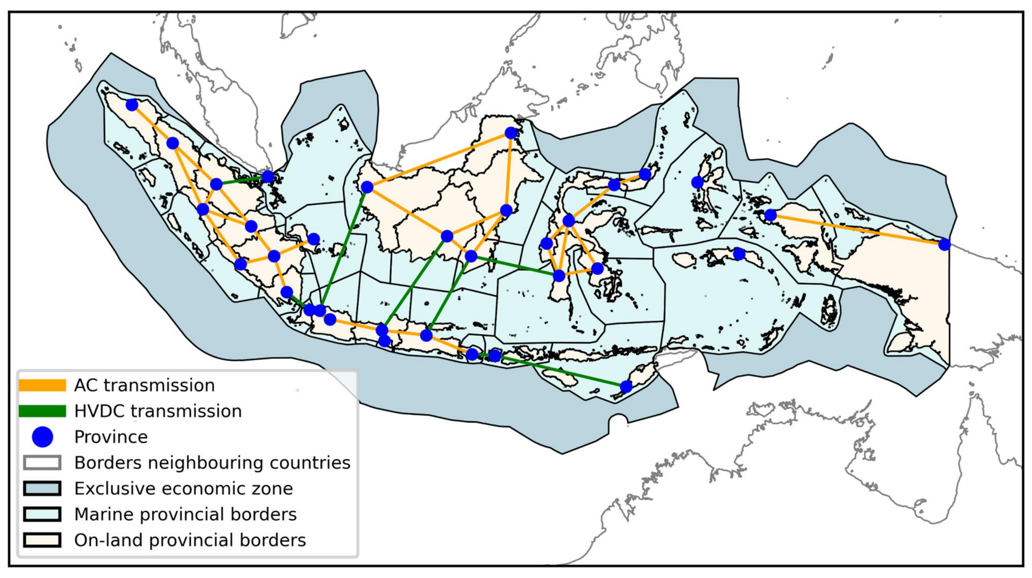


Mapping technical and economic potentials

- Studied technologies: onshore wind [2], offshore wind [3], and solar PV [4]
- Ocean Thermal Energy Conversion (OTEC) already mapped previously [5]
- ①: All available land/ marine area
- ②: Removal of areas unsuitable for renewables (e.g., conservation zones)
- ③: Subdivision of remaining areas with grid mesh
- ④: Sampling of renewable resource data (e.g., wind speed) inside subdivided areas
  - ➢ 20 years of hourly ERA5 reanalysis coupled with high-resolution resource maps, e.g., Global Wind Atlas
- PV and wind farm modelling to calculate electricity production at mapped sites
- **Technical potential**: annual electricity production at all technically feasible sites
- **Economic potential**: Technical potential with *Levelised Cost of Electricity (LCOE)* ≤ local tariff

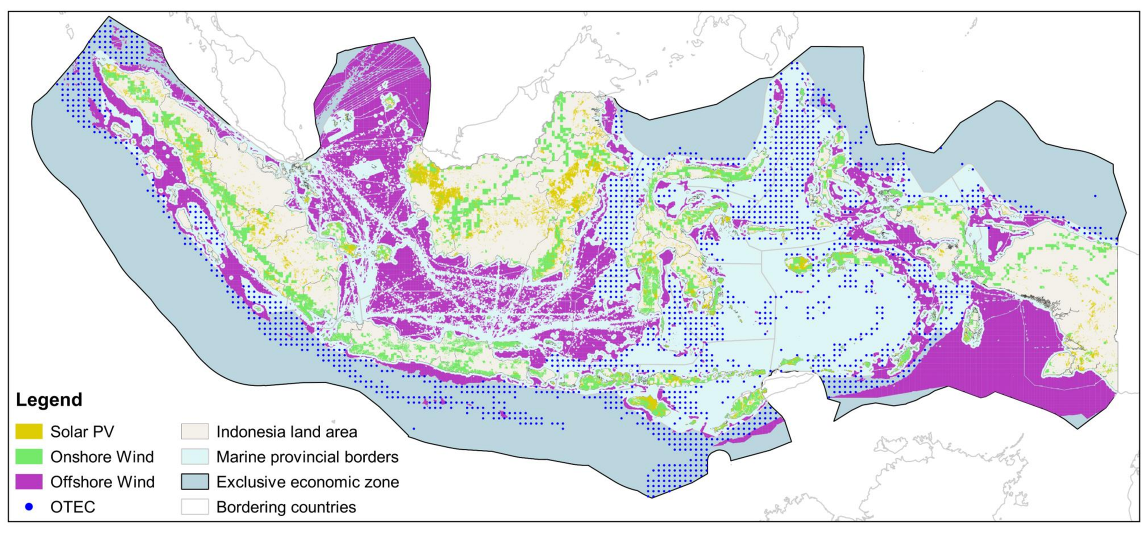
Energy system optimization modelling

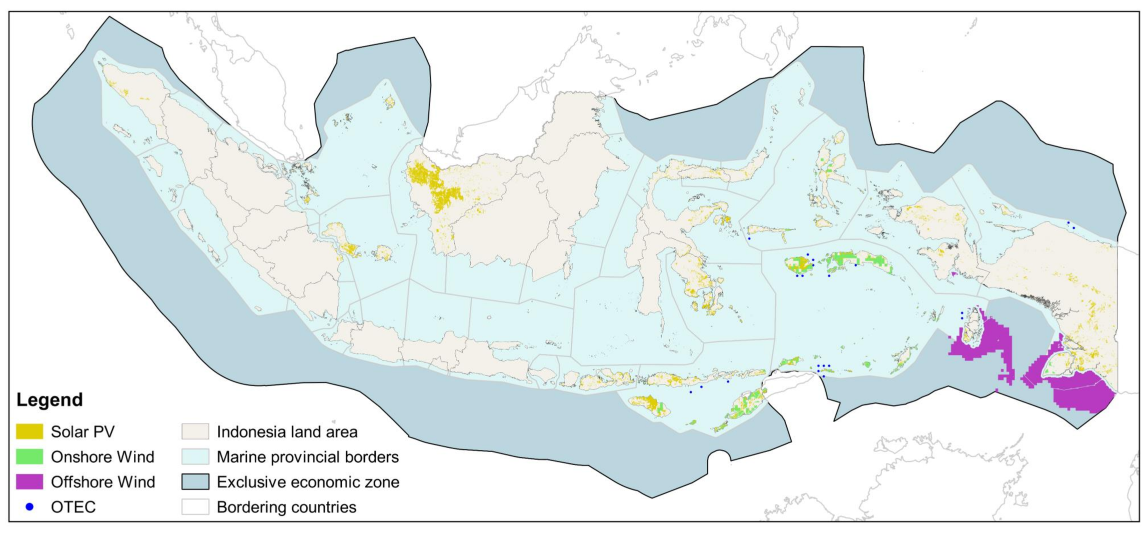
- Used model: *Calliope*
- Mapped potentials used as inputs
- For other renewables, datasets from official sources and literature
- Full power system decarbonisation by 2030, 2040, and 2050
- Two studied transmission grid topologies with and without inter-island links
- Scenario analysis to reveal differences and commonalities of obtained solutions



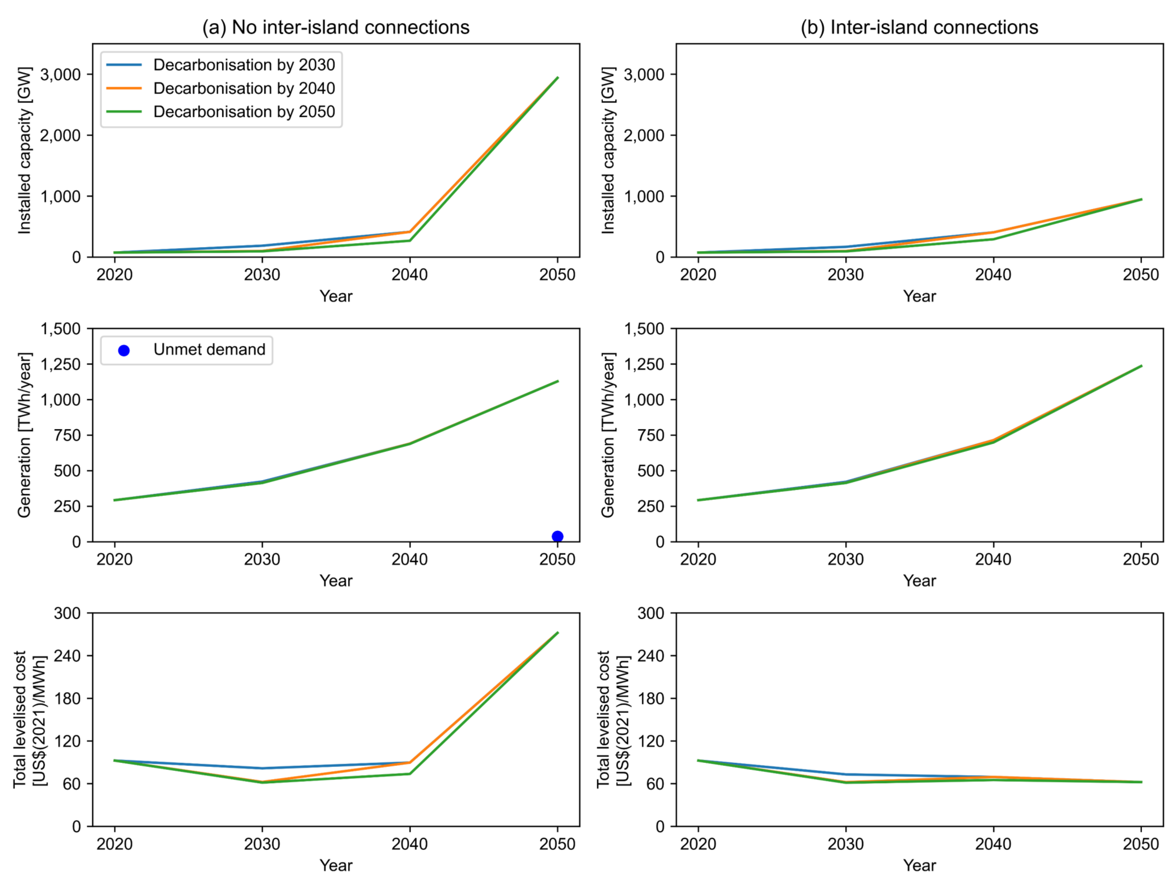
Results & Discussion

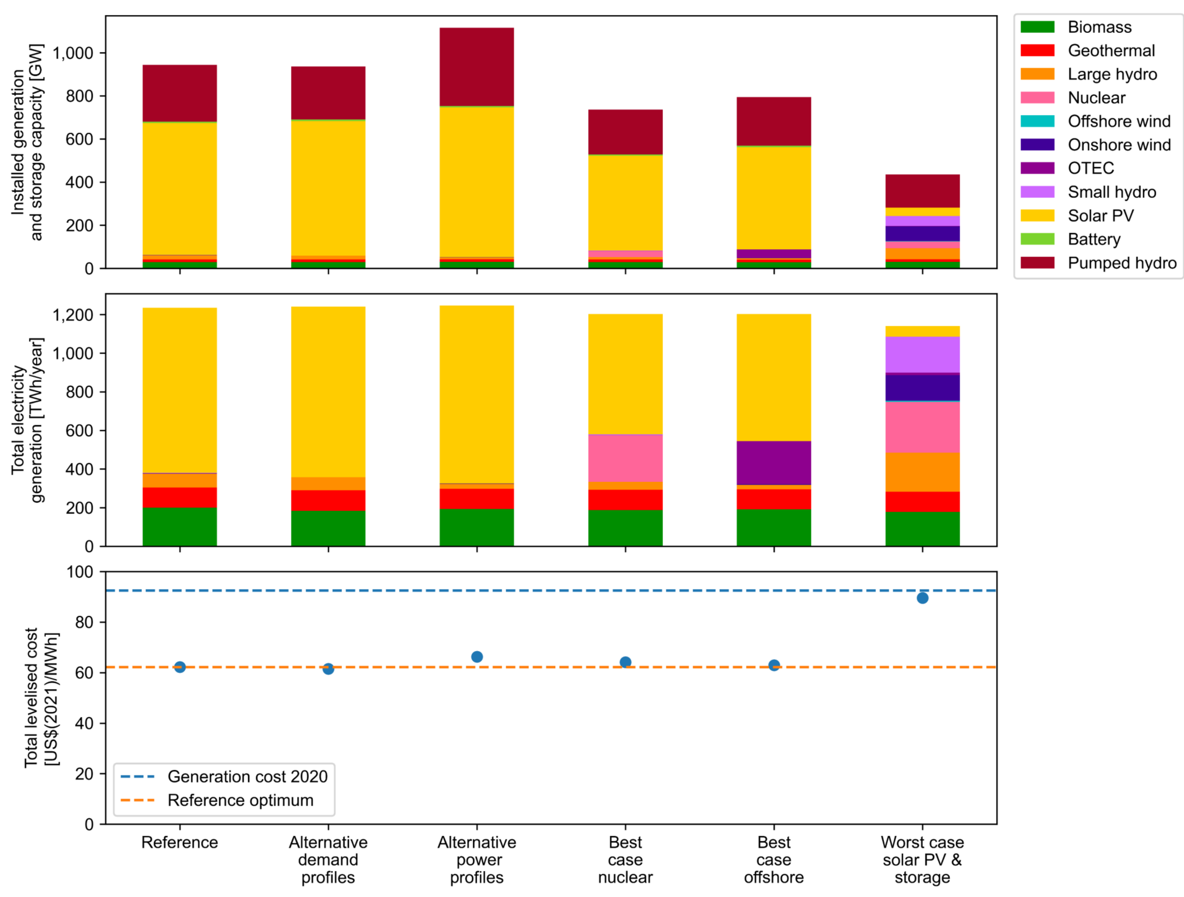
- Total tech potential (left map): 17,700 TWh/year (9–14 times the expected 2050 demand)
- Limited available land for solar PV on Java due to competition with other land uses [4]
- Total eco potential (right map): 7,000 TWh/year (3.5–6 times 2050 demand)
- Economic potential mainly in rural East where tariffs are high, but demand is low [2–5]
- A carbon tax of 50 US\$/tCO2e [2] or a feed-in tariff of 11.50 US¢/kWh [4] could boost the eco potential in high-demand regions like Java





- Solar PV and pumped hydroelectric storage key techs for full system decarbonisation
- Inter-island links to Java essential as local renewable resources are not enough to meet long-term demand (see unmet demand)
- Inter-island links help reducing total system cost
- Low-solar systems are possible with little surplus cost and distinct benefits (e.g., less installed capacity)
- Biomass, geothermal, and large hydro deployed in all scenarios as baseload generators





Conclusions

- Indonesia has abundant renewable resources, especially offshore
- Land use competition can inhibit the potential of technologies like solar PV
- Indonesia has many options for full power system decarbonisation
- These options foot on technologies that are not yet established in Indonesia, like solar PV
- Still, full power system decarbonisation could be possible earlier than 2060, e.g., with the measures proposed here

Short-term measures

- Reduce fossil (over)capacity
- Temporary lift of local content for solar PV modules
- Expand domestic solar PV manufacturing capacity (with international expertise)
- Implementation of technologies with long lead times (hydropower, PHES, nuclear, geothermal)
- Concept for nuclear waste disposal
- Land acquisition for biomass, solar PV, etc.

Medium-term measures

- Ramp up solar PV implementation (manufactured domestically)
- Cultivate power crops
- Develop storage capacity further (PHES if feasible, alternatively battery storage)
- Strengthen on-land transmission and distribution grid
- Establish first inter-island connections once nuclear power online and/or strong demand growth

Long-term measures

- GW-scale implementation of solar PV and storage
- Develop inter-island connections between Java, Kalimantan, and Sumatera
- If commercially available, develop novel technologies like OTEC for last-mile decarbonisation

Power system decarbonisation roadmap

Present → Year X (e.g. 2040)

Acknowledgements

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