IESR
Institute for Essential Services Reform

Enabling High Share of Renewable Energy in Indonesia's Power System by 2030

Alternative electricity development plan compatible with 1.5°C Paris Agreement

Thursday, 24 November 2022

Current status of Indonesia's energy system

Energy sector emission has to be curbed now to realign the temperature increase projection with the 1.5 C pathway

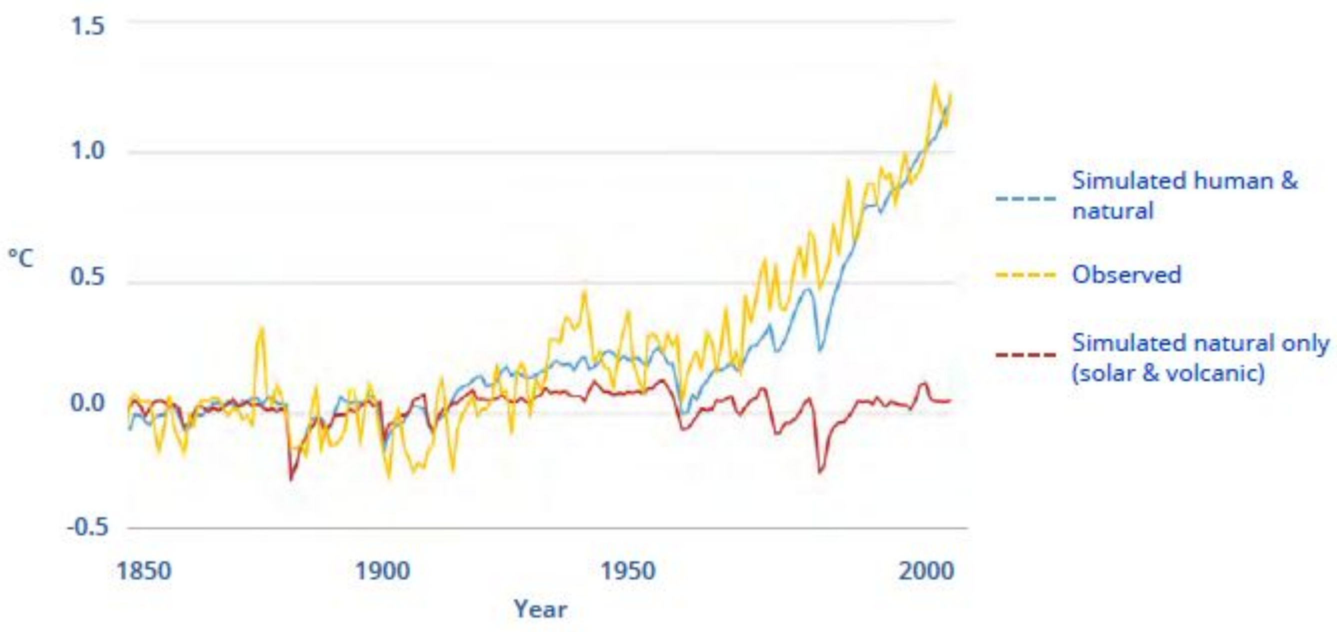


Figure 1. Comparison between observed and simulated global surface temperatures changes

- Energy sector is responsible for around three-quarters of today's global greenhouse gas emissions (IEA, 2021)
- As the seventh largest economy in the world, Indonesia becomes the twelfth largest energy consumer and the ninth largest emitter of CO2 from fuel combustion
- With the expected economic growth over the next decades, energy consumption and emissions are predicted to rise
- In the Indonesia's enhanced NDC document, the pledge of emission reduction by 31.2% (without international aid) and by 43.2% (with international aid) compared to the business-as-usual (BAU)

Current power system planning seek an increase in renewables generation, but not looking for accelerated growth in the mid-to-long term

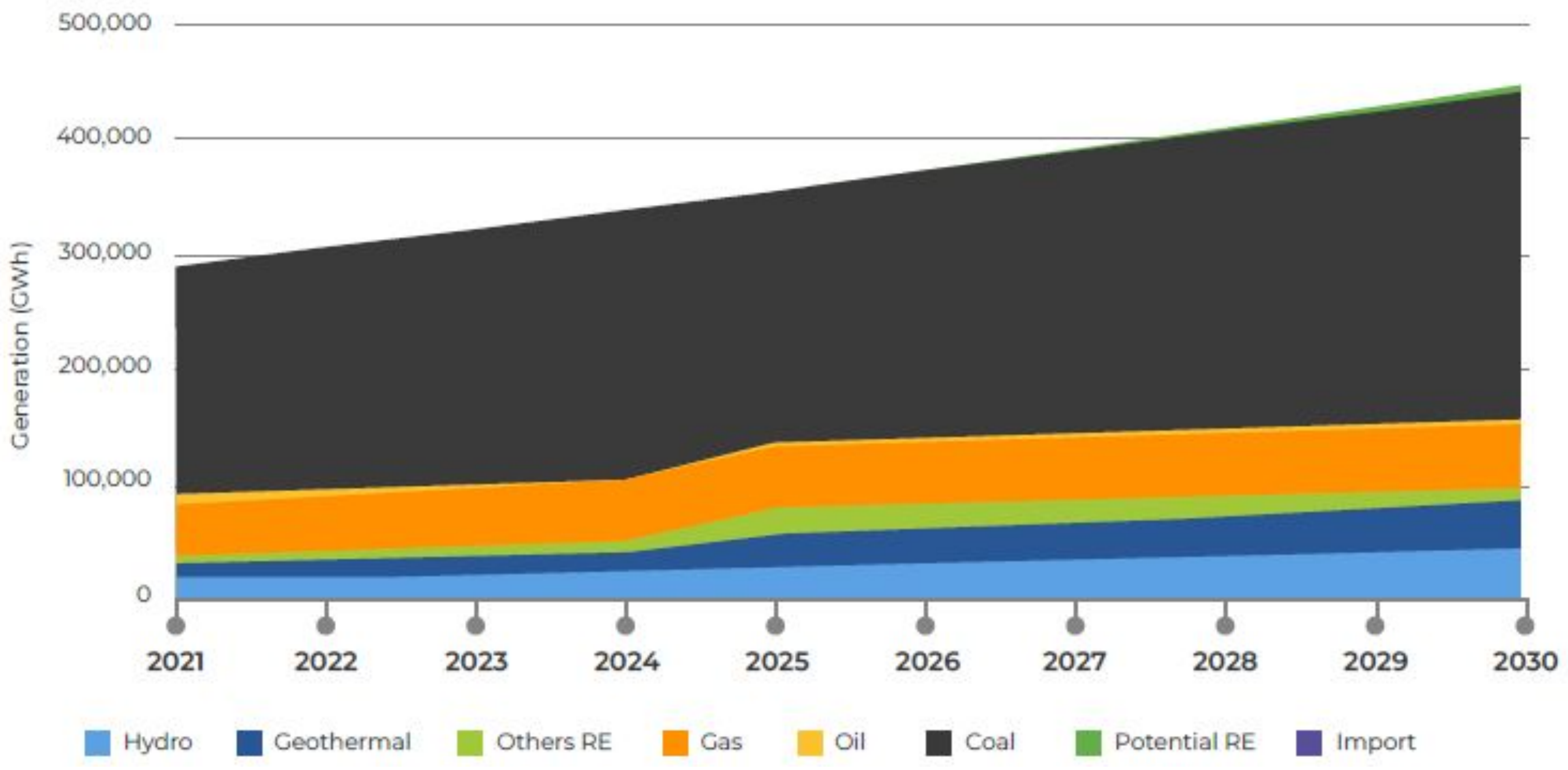
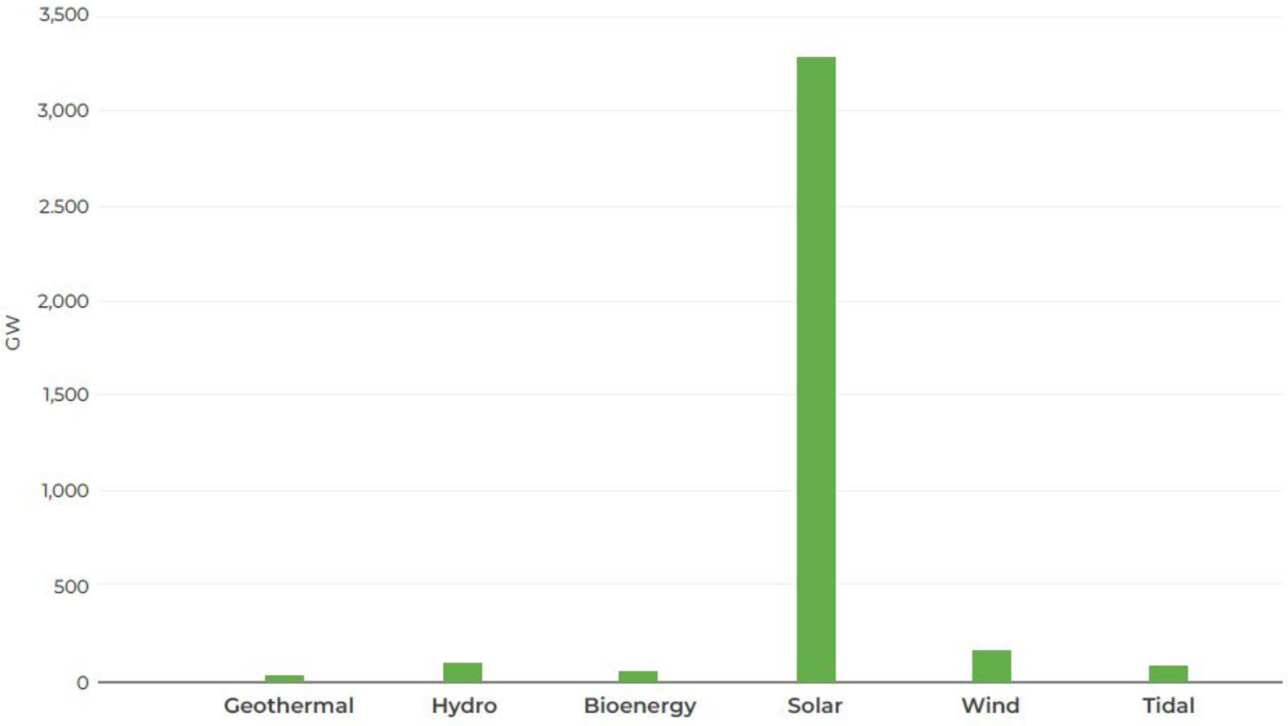


Figure 2. Projected energy mix in power generation using optimal scenario in RUPTL 2021-2030

77% Non-renewable energy

23% Renewable energy

Enormous renewable energy potential is left untapped



	Geothermal	Hydro	Bioenergy	Solar	Wind	Tidal
Potential (GW)	23.7	94.6	56.9	3,294	154.9	59.9
Installed	9.22%	6.80%	3.38%	0.01%	0.10%	0.00%

Figure 3. Installed capacity in 2021 compared to the estimated potential renewable energy capacity

- Total installed capacity of renewable energy is 10.8 GW
- Renewable energy's growth between 2021 and 2030 would be 60-61 TWh, with biomass taking a large share of growth.
- The massive growth only happens between 2021 and 2025 (122%) due to the government's target of 23% share of renewables in the electricity mix by 2025.
- In the following year until 2030, the growth will only account for 19%.

The possible alternatives to reach Paris Agreement’s target

IESR deep decarbonisation study shows possible pathway for energy system emission to align with 1.5 C emission pathway

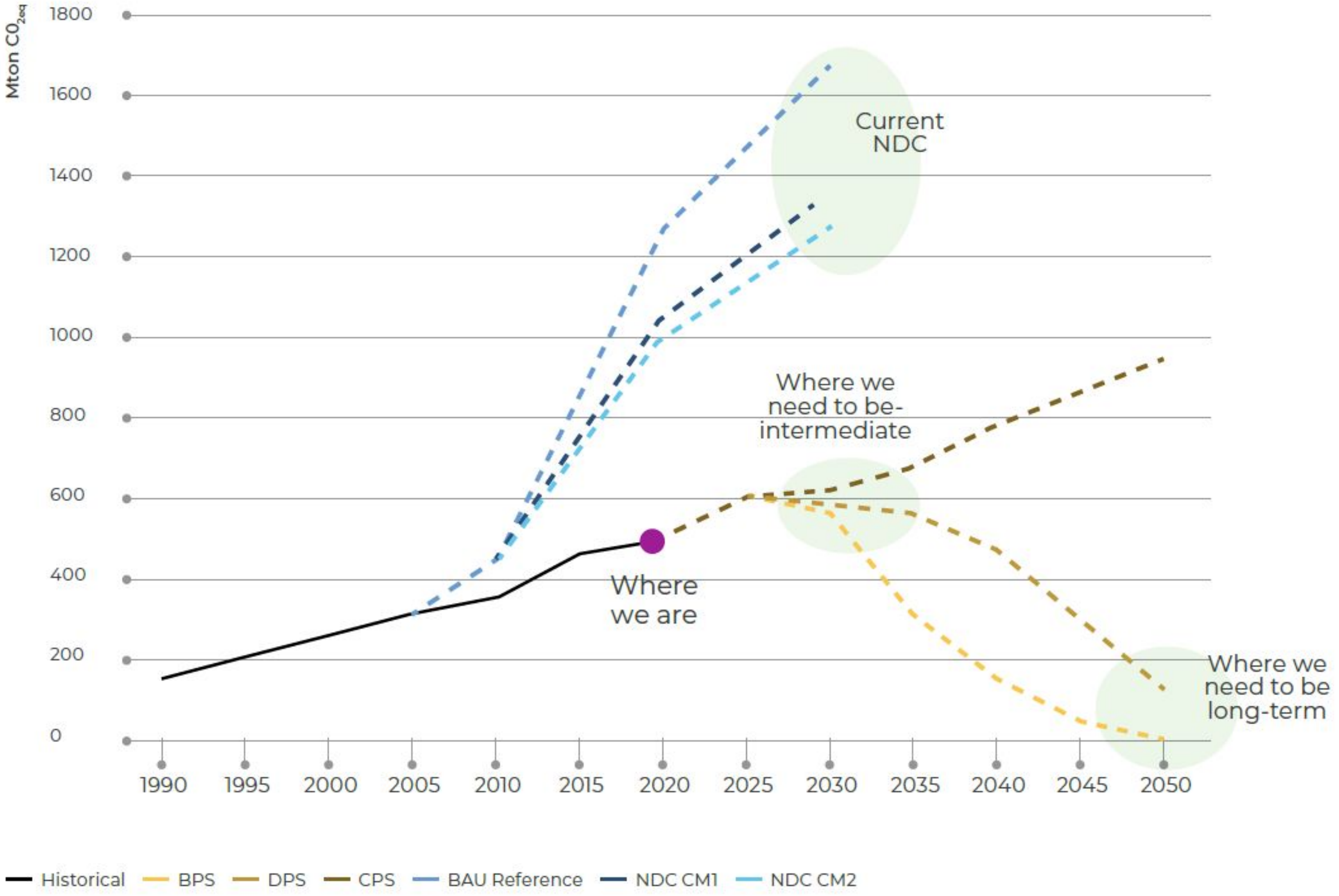


Figure 4. Historical emissions in the energy sector and emission reduction pathways in Indonesian NDC and this study

In previous study, electrification of all sectors and integration of renewables are key strategy.

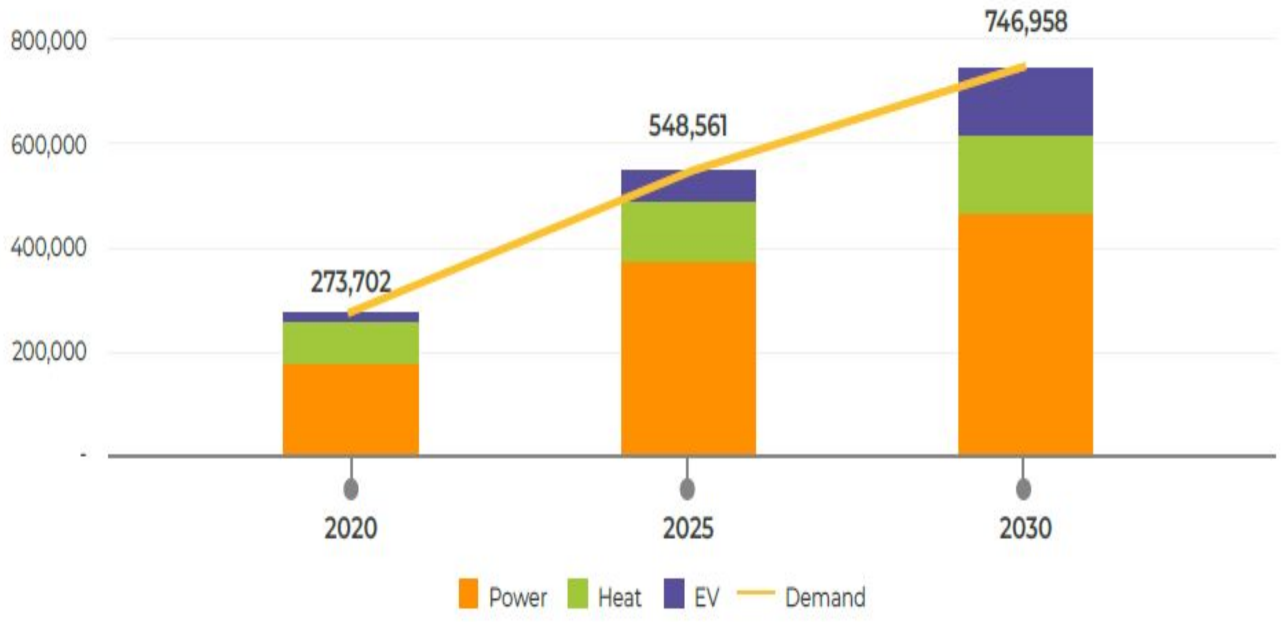


Figure 5. Projected energy demand to be in line with the Paris Agreement based on IESR's study

- Electrification of all sectors
- High utilisation of renewable energy

Continuing previous study, we look into the technical, economic, and reliability of the power sector in adopting the Paris Compatible emission pathway

- Capacity expansion study
  - Optimise the additional capacity investments to adequately supply future loads
  - Minimise the investment and operation costs
  - Satisfy the reliability constraints
  - Identify the least-cost mix of power system resources
- Grid impact study
  - Load flow analysis
  - Stability analysis

Load demand projection is adjusted to consider current condition and stable demand growth while reaching high electrification of transport and heating sector

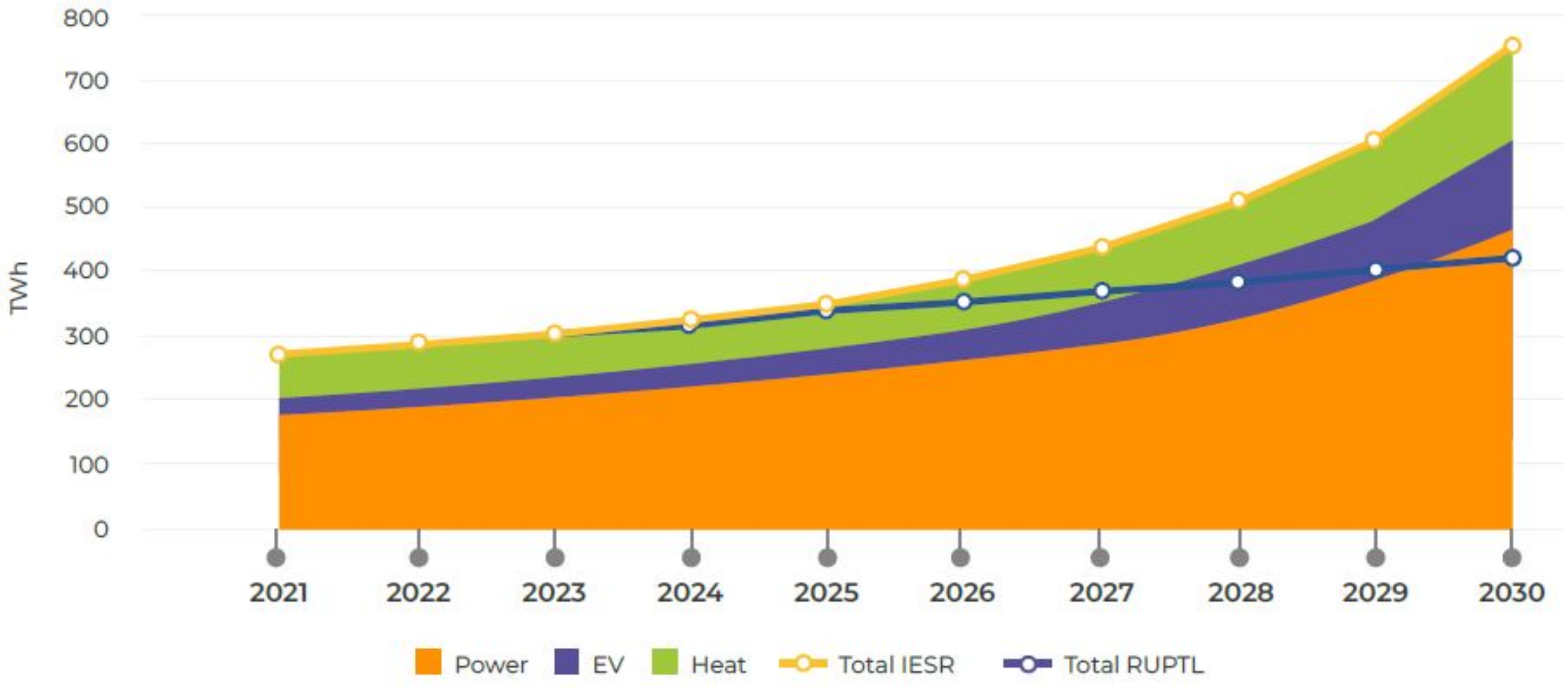


Figure 6. Projected electricity demand 2021–2030 based on IESR Deep Decarbonisation study and adjusted according to the annual growth stated in RUPTL 2021-2030

Development plan: An alternative power system planning

All the power plants that are planned in RUPTL 2021-2030 are constructed on time

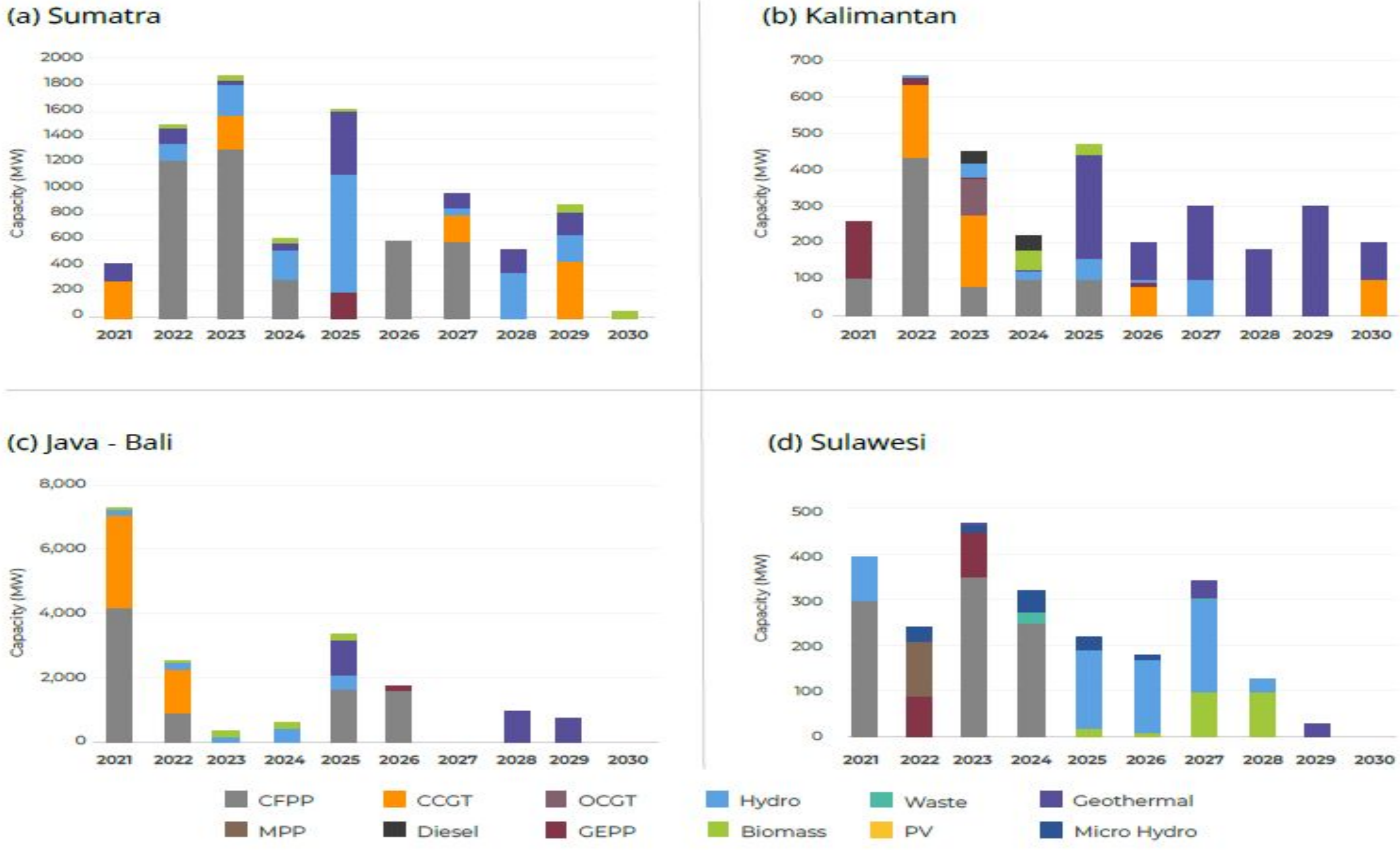


Figure 7. Committed power plant to be added in the systems based on the RUPTL 2021–2030

All power plants are put as candidates to allow for low-cost capacity expansion while CFPP is refurbished to give more flexibility into the grid

- Coal - fired power plants
  - Existing coal-fired power plants will be refurbished through a retrofit programme to make them more flexible
- Gas - fired power plants
  - The only thermal power plant candidates considered in this study
- Geothermal, hydropower, and pumped hydro energy storage
  - Due to the technical, economic, financial, and socio-environmental viability, this study has only adopted geothermal and hydropower projects that have been indicated by PLN in the RUPTL.
- Solar PV, wind power, biomass
  - As the capacity expansion priority due to their shorter duration to come online and lower investment needed compared to other technologies
  - The potential is based on *Beyond 443 GW Indonesia's Infinite Renewable Energy Potentials*
- Battery

Results of capacity expansion study shows a high capacity addition mixed from all candidates power plants after 2027

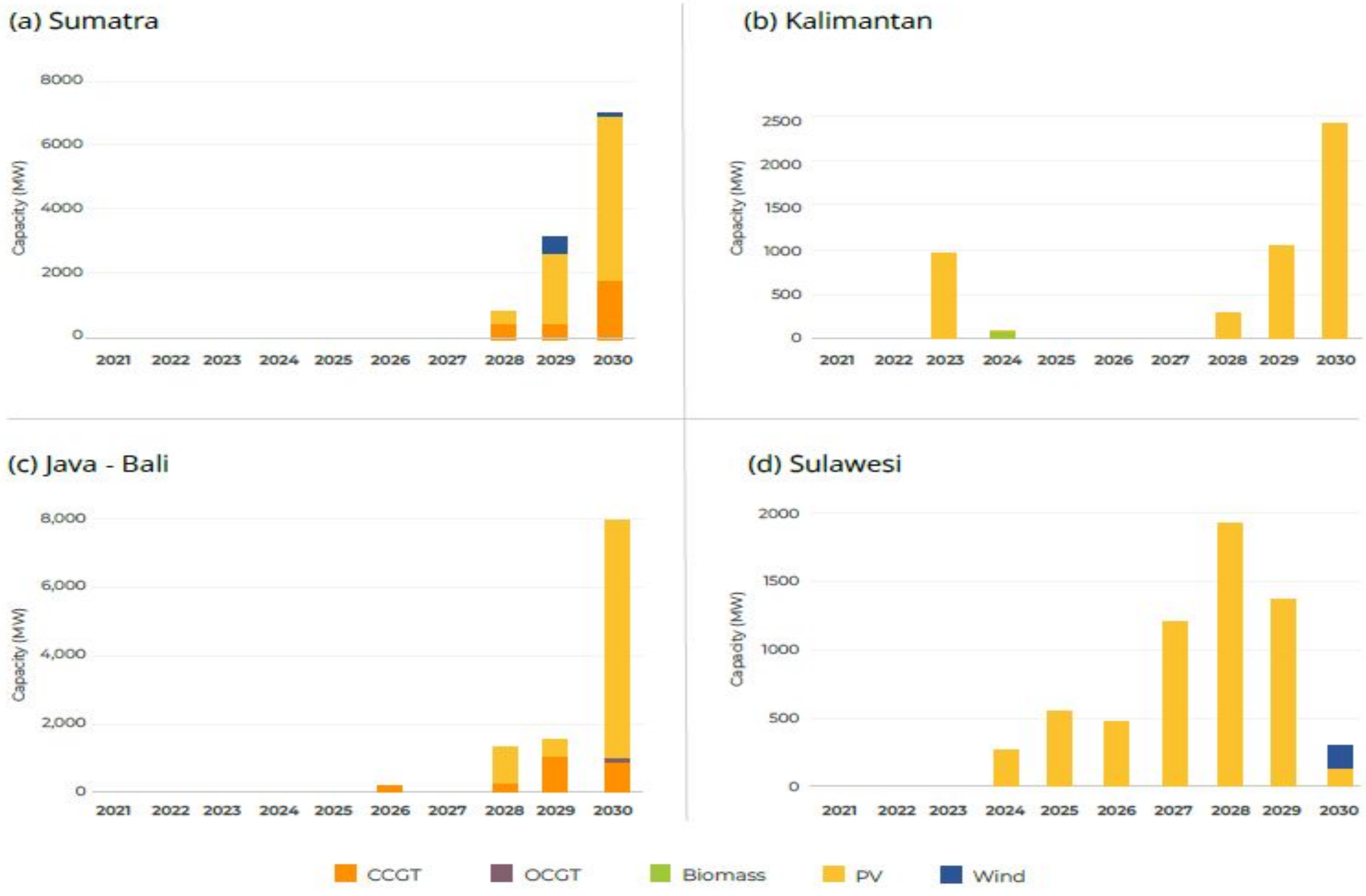


Figure 9. Capacity expansion study results

The reserve margin is maintained above 30%, ensuring a reliable supply of electricity

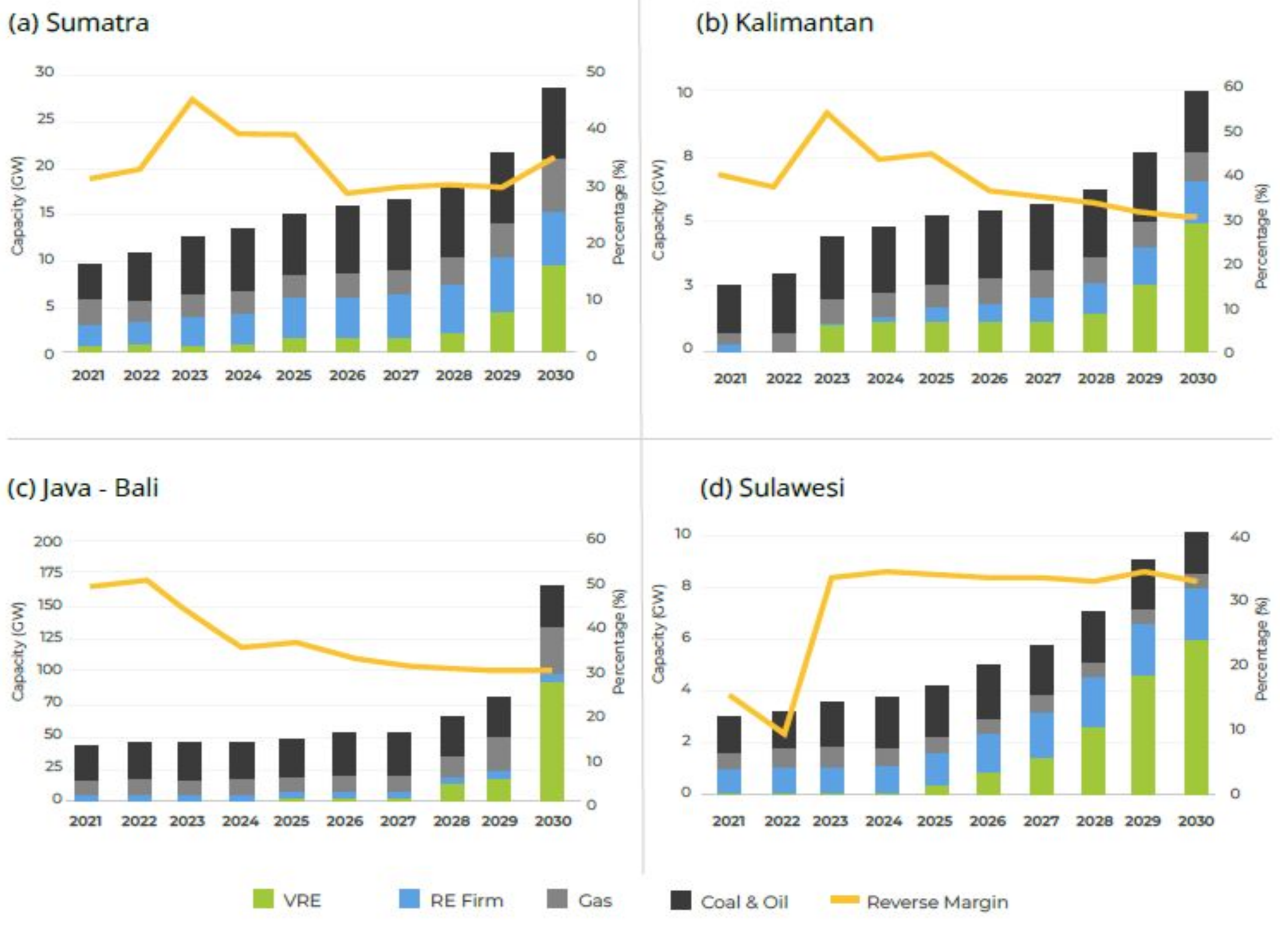


Figure 10. Installed capacity and reserve margin

Various penetration of renewable energy ranging between 31%-51%, with VRE reaching as high as 31% in Sulawesi system. Gas and battery is optimized to maintain reliability.

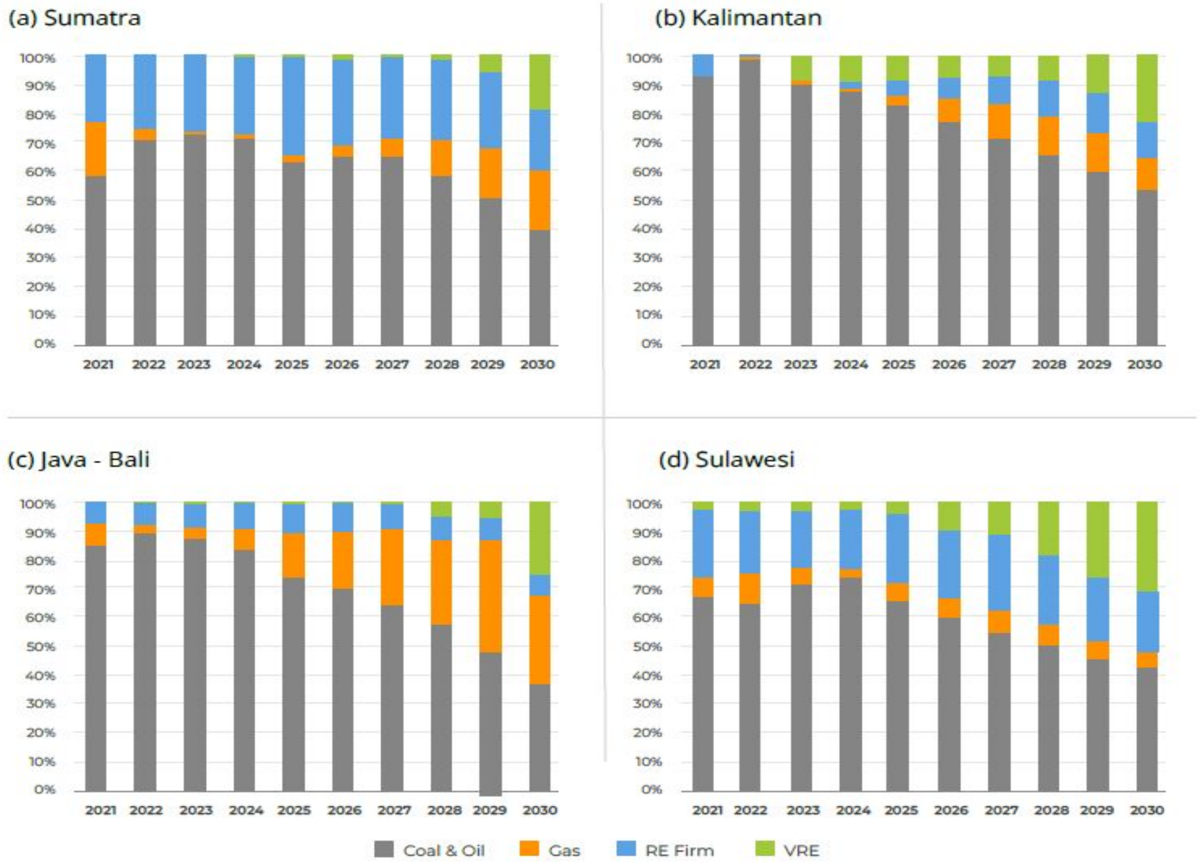


Figure 11. Power generation mix

Environmental, economic, and technical impacts

Emission intensity in all system drop significantly to the level of 400 kgCO2/MWh

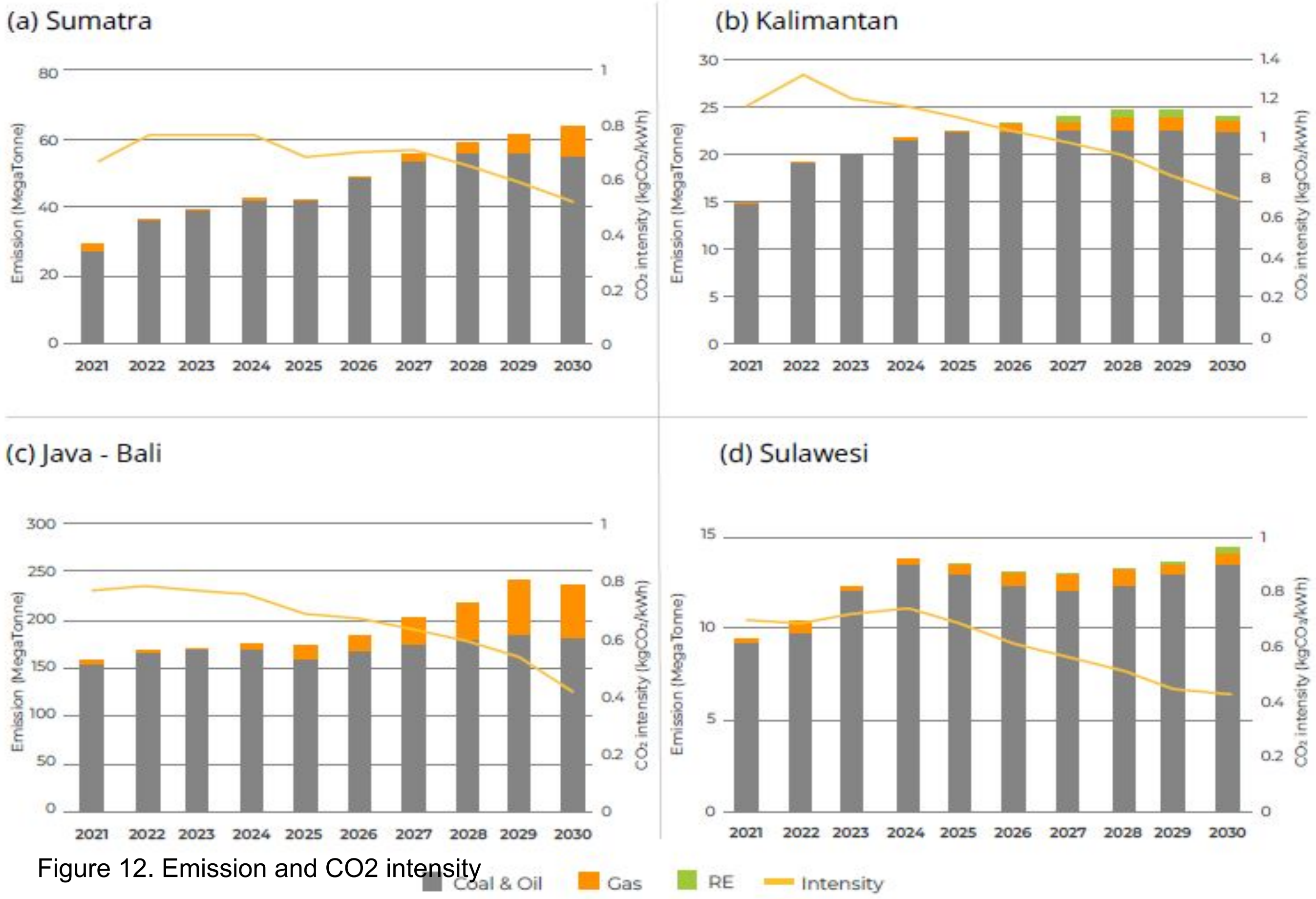


Figure 12. Emission and CO2 intensity

Eventhough total system cost experience a slight increase, the generation cost is reduced with high renewable integration

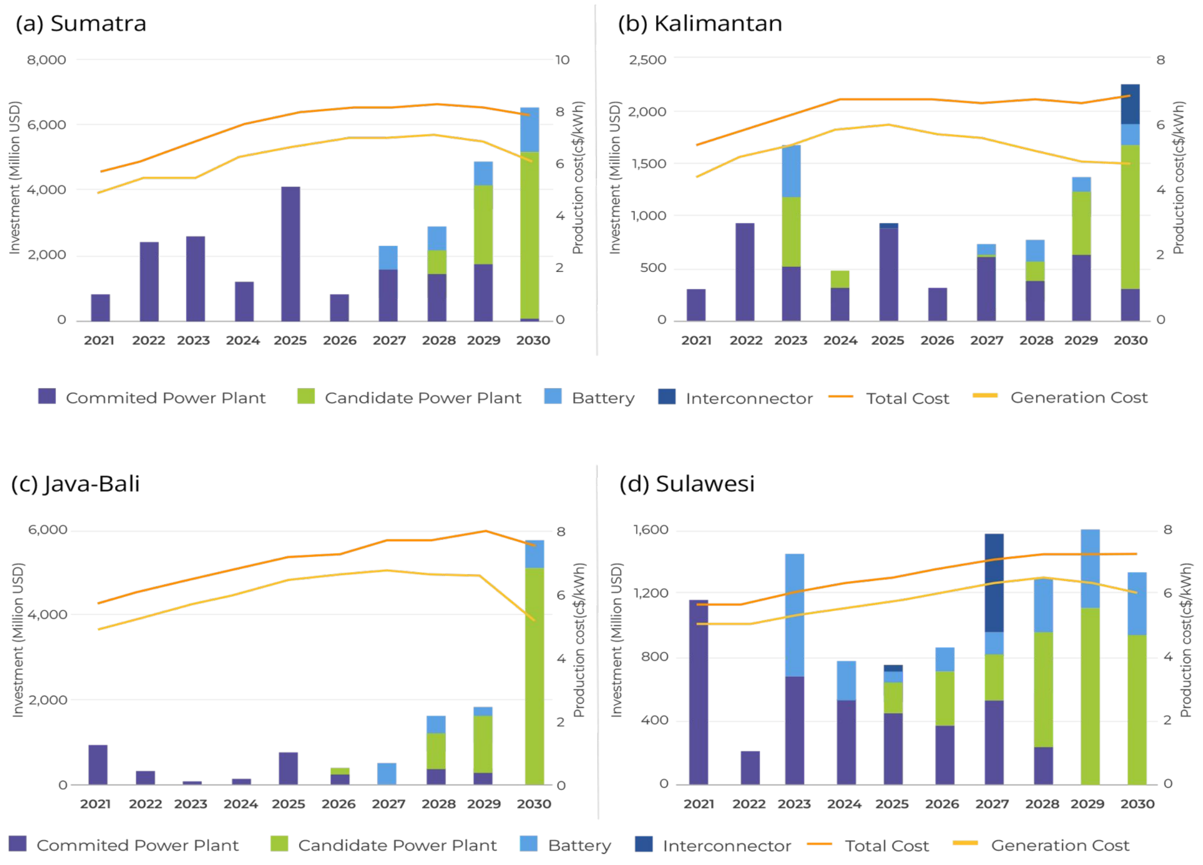


Figure 13. Production cost & investment needed

A load flow analysis and frequency stability are conducted to test the system reliability in 2030

- Simulation is conducted in Sulawesi system by 2030
- Peak load adjusted to 3.03 GW based on forecasted demand stated before
- For load flow analysis there are two simulation scenarios
    - Day peak load
    - Night peak load
- For frequency stability analysis there are two simulation scenarios
    - Solar PV intermittency due to cloud movement
    - Single solar PV plant contingency

Upgrade of substation are needed in some area, but could be minimized with better distribution of power plants candidate

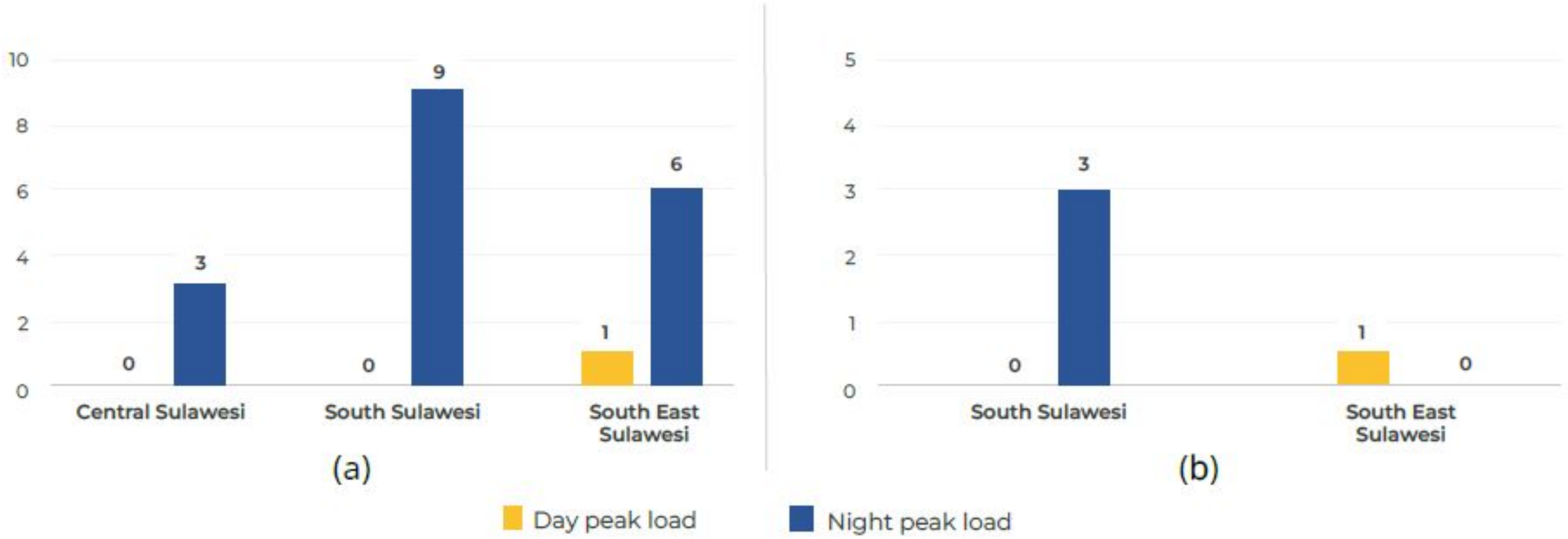


Figure 14. Number of overloaded distribution transformers (a), Inter-Bus Transformer (b)

Through testing several cases of intermittency from VRE plants still shows that system frequency could still be kept within grid code recommended range

Table 5. Sulawesi 2030 frequency stability simulation result

Area	Scenario	Nadir frequency (Hz)
North Sulawesi	Intermittency	49.71
	Contingency	49.82
Gorontalo	Intermittency	49.71
	Contingency	49.83
Central Sulawesi	Intermittency	49.61
	Contingency	49.81
South Sulawesi	Intermittency	49.63
	Contingency	49.79
South East Sulawesi	Intermittency	49.52
	Contingency	49.73

Conclusion and recommendations

Conclusion

- Measures that could be taken to achieve the Paris Agreement targets include transforming the power sector through increasing the share of renewables and reducing the use of fossil fuels in the electricity generation
- The total capacities of renewable energy in the grid can be enhanced to 112.1 GW of solar PV, 9.2 GW of hydro power, 5.2 GW of geothermal, 1.5 GW of wind turbine, and 1 GW of biomass in the combined systems of Java-Bali, Sumatra, Kalimantan, and Sulawesi
- In terms of power generation mix, the renewable energy accounted for 32%, 35%, 35%, and 51% in Java-Bali, Sumatra, Kalimantan, and Sulawesi systems respectively.
- The increased penetration of solar PV in both systems causes the reduction of system frequency. However, the value of nadir frequency is safe and still within the grid code limit. Based on the load flow analysis, several equipment need to be uprated, such as transformers and transmission lines

Recommendations

- Utility/Regulator
  - Evolving the grid operation into a more flexible one
  - Early retirement of CFPP
  - Increasing VRE project’s in the project pipeline
  - Enhanced planning and operation procedures to support the power system transformation
- Policymaker
  - Regulations that fully support renewable energy development are needed
  - Electrification in most other sectors, besides power, must be accelerated
  - Regulation to support flexible operation of CFPP, including the new contractual structures
  - Preparing regulation and roadmap to support the improvement of the local solar PV industry
- Other parties
  - Customer participation through load demand response and becoming prosumer
  - Building a mechanism to accommodate and provide incentives for ancillary services in the current regulated market structure

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Thank You

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