Preliminary assessment of generation mix in 2050 using power dispatch model with long-term chronological data

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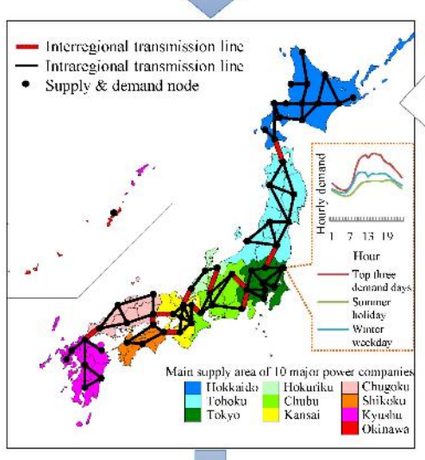
Introduction

- The large-scale development of renewable energies (REs) is indispensable to achieve the low carbon power system.
- Output fluctuation and spatial heterogeneity of REs should be modeled.
- Existing model does not fully capture the seasonal fluctuation, such as dark doldrums.
- Analysis by using long-term chronological data can provide the storage requirement for seasonal fluctuation.
- In addition, detailed spatial resolution model can help to assess the impact on the intra-reginal transmission.
- **Objectives:** develop power dispatch model with high temporal resolution/high spatial resolution

Methods

- Multiregional optimal-generation planning model[1)]

Input: Electricity demand, fuel prices, capital costs, CO_2 targets…



Output: Generation mix, generation costs, carbon price…

Spatial resolution: 60 prefectures (to be developed)
Time resolution: 8760 hours
Year: 2050
Optimization: Recursive dynamic
Generators: Coal (boiler, IGCC, - w/CCS), Oil (boiler), Gas (boiler, NGCC, -w/CCS), Hydro (Conventional, pumped), Nuclear, Solar PV, Wind (Onshore, offshore), Biomass, ~~Imported hydrogen~~
Power system stabilization measures: Economic load dispatching control (EDC), Load frequency control (LFC), Interregional transmission, Pumped hydro, Battery for long-term fluctuation (LFSB), Battery for short-term fluctuation (SFSB), Curtailment, ~~Domestic hydrogen~~

- Data collection

Hourly electricity demand and hourly capacity factors for REs
Actual data were taken from website of former general electric utilities
Resource potentials of REs by prefectures
Data were taken from the REPOS by MOEJ[2)]
Intraregional transmission lines (to be completed)
Actual data were taken from the website of former general electric utilities

- Preliminary analysis of input parameters

Correlation analysis by 10 regions:
Ratio of hourly demand to annual demand vs. hourly capacity factor of REs
Assessment of demand and supply balance by prefectures:
Annual output from potential capacity of variable REs vs. annual demand in 2050

- Preliminary analysis by a single prefecture model

Target region: Okinawa (single prefecture analysis for preliminary analysis)
CO_2 targets: X% emission reduction from 2010 level (X=50, 60, 70, 80, 90, 100)
Technological assumptions: no nuclear, no biomass, and no hydrogen

Preliminary results and discussion

Preliminary analysis of input parameters

- **REs that have a positive correlation with hourly demand vary by region.**
  - Onshore wind in the Northern Japan
  - Solar PV in the Eastern and Western Japan
- **Demand and supply balances vary by prefectures.**
  - Inter- and intra-regional transmissions are key to achieve 100% RE power system. (Figure 1)
- → *Confirmed that detailed model is necessary.*

Table 1. Correlation coefficients between hourly output from REs and hourly demand by region

	Hokkaido	Tohoku	Tokyo	Chubu	Hokuriku	Kansai	Chugoku	Shikoku	Kyushu	Okinawa
Hydro	-0.40	0.07	0.23	0.33	0.10	0.37	0.10	-0.02	0.02	
Solar PV	-0.12	0.15	0.28	0.34	0.13	0.30	0.29	0.31	0.27	0.42
Onshore wind	0.25	0.26	0.02	0.14	0.19	0.05	0.04	0.05	-0.02	-0.19
Geothermal	0.31	0.17							0.22	

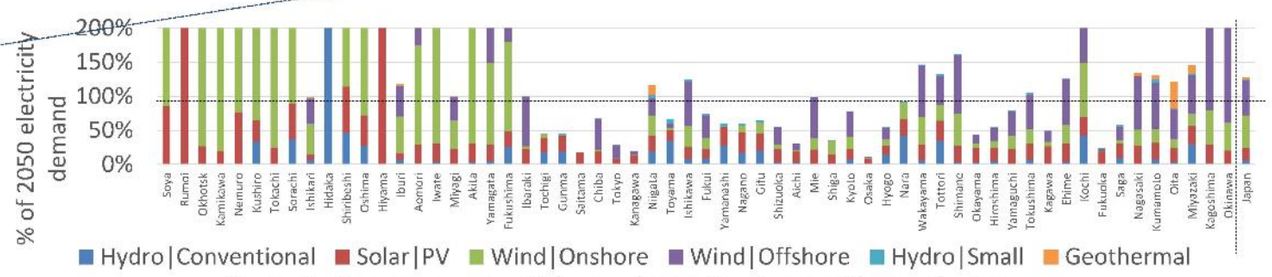


Figure 1. Resource potentials vs. electricity demand by prefecture

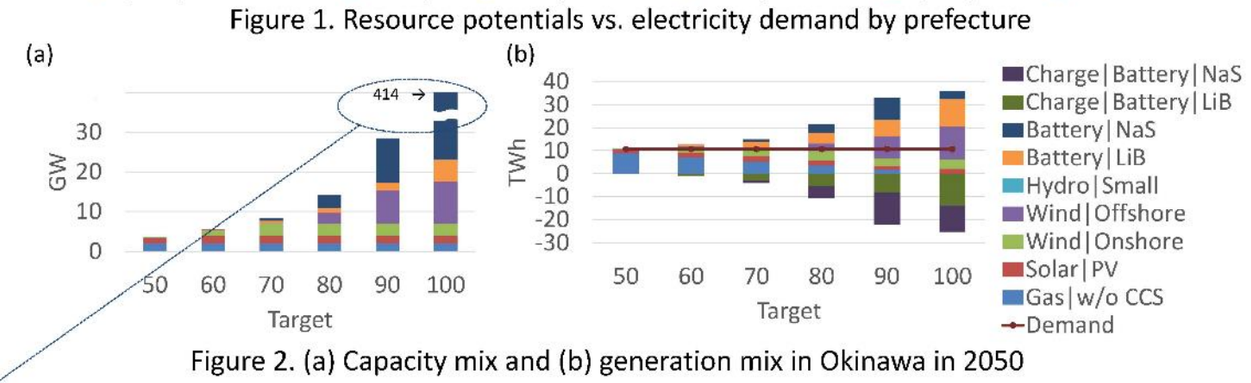


Figure 2. (a) Capacity mix and (b) generation mix in Okinawa in 2050

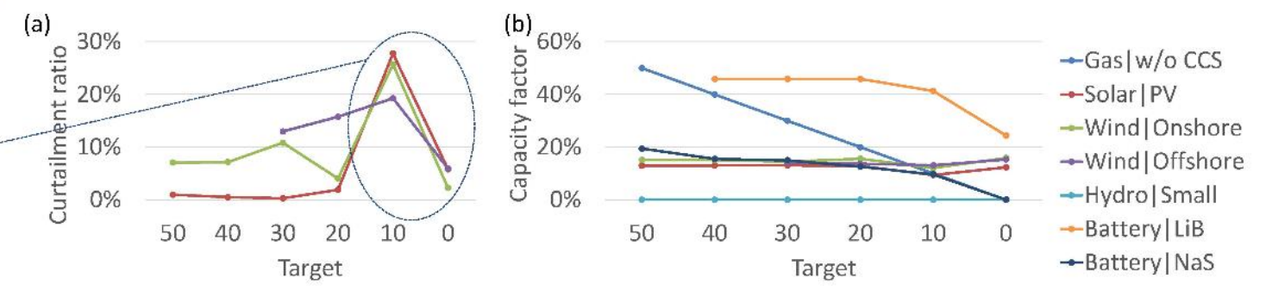


Figure 3. (a) Curtailment ratio and (b) capacity factor in Okinawa in 2050

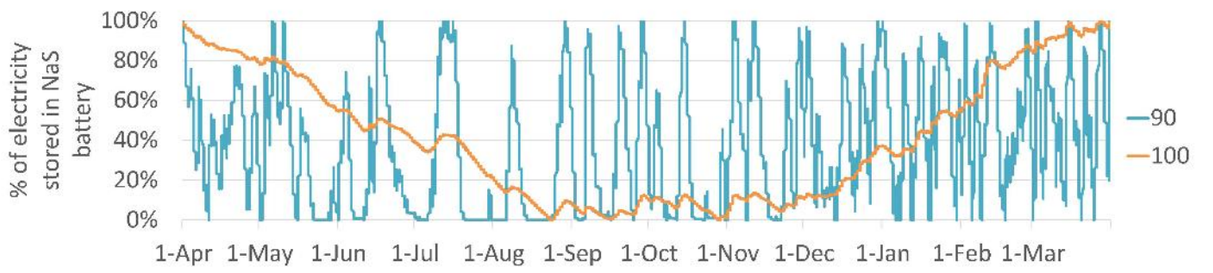


Figure 4. Hourly profile of electricity stored in NaS Battery in 90% and 100% reduction scenario

- Cases less than 80% reduction gave similar results compare to the existing model, but **the results changed drastically in 90% or more reduction cases.**
  - 100% reduction needs about 400 GW of NaS battery (Figure 2 (a)) to balance seasonal fluctuation (Figure 4).
  - Although 90% reduction case prefers curtailment to balance output fluctuations of REs, 100% reduction case uses REs output as much as possible with batteries. (Figure 3 (a))
- → *Confirmed that seasonal fluctuations are captured by the developing model.*

Future tasks

- Expand to 60 prefectures model
- Include import & domestic hydrogen module

Asia-Pacific Integrated Model
http://www-iam.nies.go.jp/aim

1) Shiraki, H. *et al., J. Clean. Prod.* **114**, 81–94 (2016), 2) MOEJ, Renewable Energy Potential System (REPOS) http://www.renewable-energy-potential.env.go.jp/RenewableEnergy/index.html (2020)