Toward a low carbon society in Japan: analysis of the effects of the willingness to pay on renewable energy penetration in power sector

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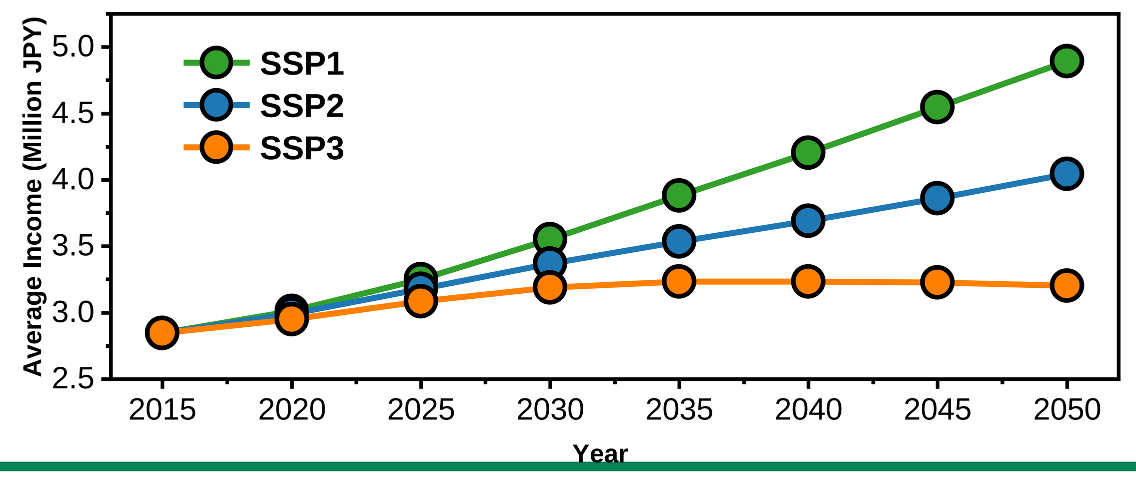
1. Introduction

- Japan decided a GHG reduction target of 80% by 2050.
- To achieve this target, electricity production by renewable energy resources expect to play a key role
- Although the higher capital cost for renewable energy, there is a movement to defray the additional cost, impacting their further diffusion
- We have developed series of models to simulate, How well the WTP will impact on the renewable energy?

3. Future Scenario

- ✓ **Ref** : WTP = 0
- ✓ **Scenario 1** : WTP under SSP1
- ✓ **Scenario 2** : WTP under SSP2
- ✓ **Scenario 3** : WTP under SSP3



4. Methodology

4.1 Estimation of WTP

☐ Regression was used to forecast

$$WTP_{med} = f\,(\text{Gender, Income})$$

Where *Gender* is the percentage of female share within total population (%), *Income* is the annual average household income (JPY),

4.2 Acceptability rate

① Baseline (Weibull distribution)

$$F_{\text{base}}(X) = \exp\left(-\exp\left(\frac{\ln X - a}{b}\right)\right)$$

Where F_{base} (X) is the base acceptability function, X is WTP in JPY/(household·month). a and b are assumed to 6.505 and 1.065.

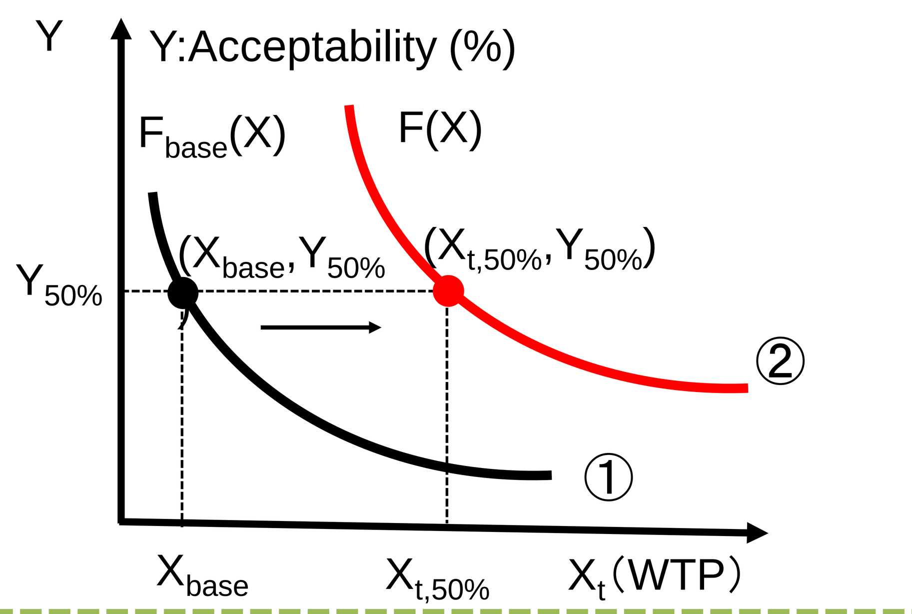
② Shift in acceptability curve

$$F(X) = \exp\left(-\exp\left(\frac{\ln(X_t - \alpha) - a}{b}\right)\right)$$

$$\alpha = X_{t,50\%} - X_{\text{base}} \qquad X_{50\%} = WTP_{med}$$

$$X_{\text{base}} = \exp(a + b\ln(-\ln(Y_{50\%})))$$

Where, *F(X)* is the acceptability function, $Y_{50\%}$ is acceptability rates in 50%, *X* is WTP in JPY/(household·month), t is the year



4.3 Energy using model

Total cost Minimization

$$Min \sum (C_c + C_O + C_f + C_t + C_{CO2}) \times \frac{i \times (1+i)^n}{(1+i)^n - 1} + MAX(RE\ cost)$$

C_c: capital cost, C_o: O&M cost, C_f: fuel cost, C_t: transport cost, C_{CO2} : carbon cost, *RE* cost: cost for RE

(Ashina et al., 2007)

Subject to

Demand = **Supply O(t)**

Exogenous

$$O(t) = \text{Efficiency} \times \Omega(t)$$

O: Electricity demand

Efficiency: Energy conversion efficiency

Nuclear Oil Hydro Coal Gas NGCC

$$\Lambda(t) \geq \Omega(t)$$

RE cost $\Upsilon(t)$

$\Upsilon(t) < TWTP$

$\Upsilon(t) = (C_c + C_o) \times \Omega(t)$

$TWTP = F(X) \times X_t \times HH$

$\Upsilon(t)$: Renewable energy cost

$\Omega(t)$: Installed capacity

Cc, Co: Capital cost , operation and maintenance cost

TWTP: Total WTP; X:WTP

F(X):Acceptability function

HH: number of household

RE Potential $\Lambda(t)$

$\Lambda(t) = F(X) \times \Lambda_{Pot}(t)$

Economic condition

Natural condition

Λ : RE potential

Λ_{Pot} : RE potential under natural condition, estimated by Shiraki et al., 2011

F(X): Acceptability function

RE capacity $\Omega(t)$

$\Omega_{WT}(t) \times 0.9 \leq (DMND + O_{STR} - O_{Fix}) + TR_{in} - TR_{out}$

DMND: Electricity demand

O: Electricity generation

STR: PumpHydro & Second battery

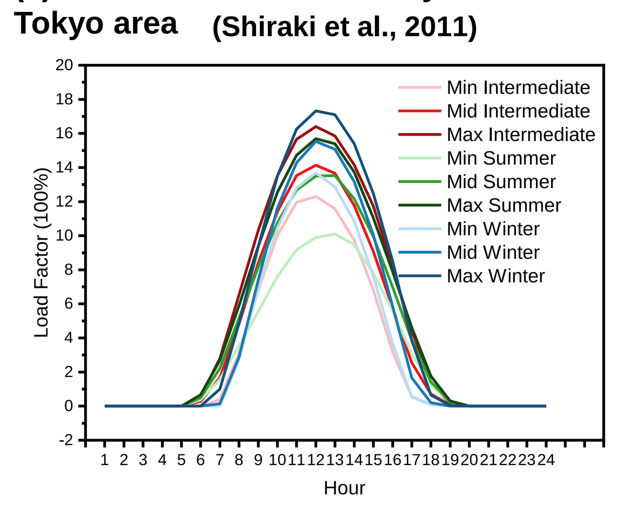
FIX: Nuclear & hydro

TR_{in}: Energy supply quantity from other prefecture

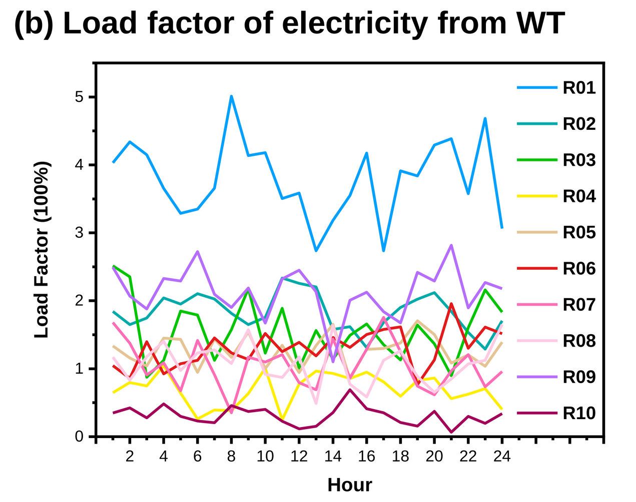
TR_{out}: Energy supply quantity to other prefecture

2. Data

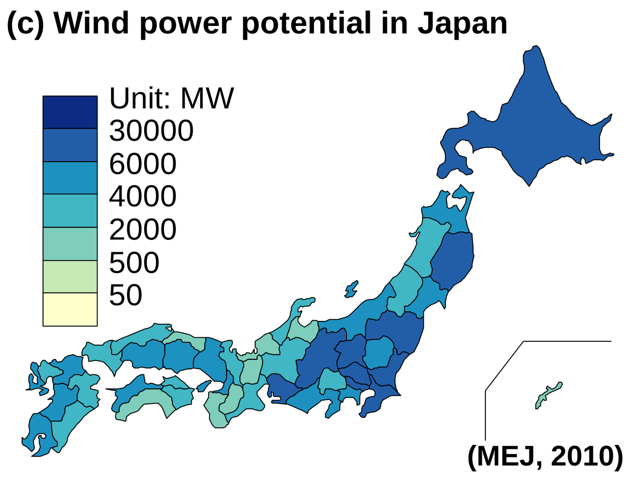
(a) Load factor of electricity from PV in Tokyo area (Shiraki et al., 2011)



(b) Load factor of electricity from WT

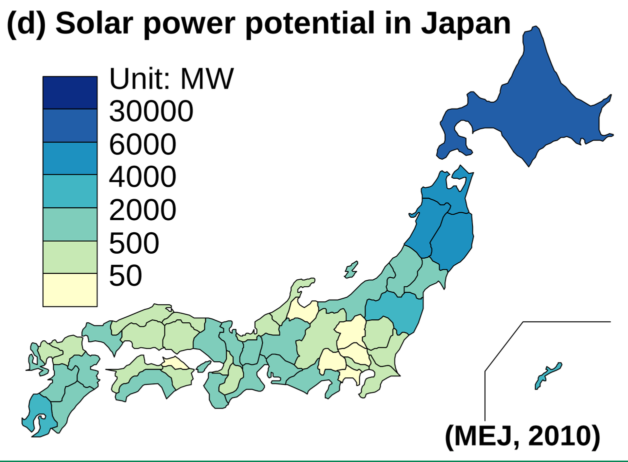


(c) Wind power potential in Japan



(MEJ, 2010)

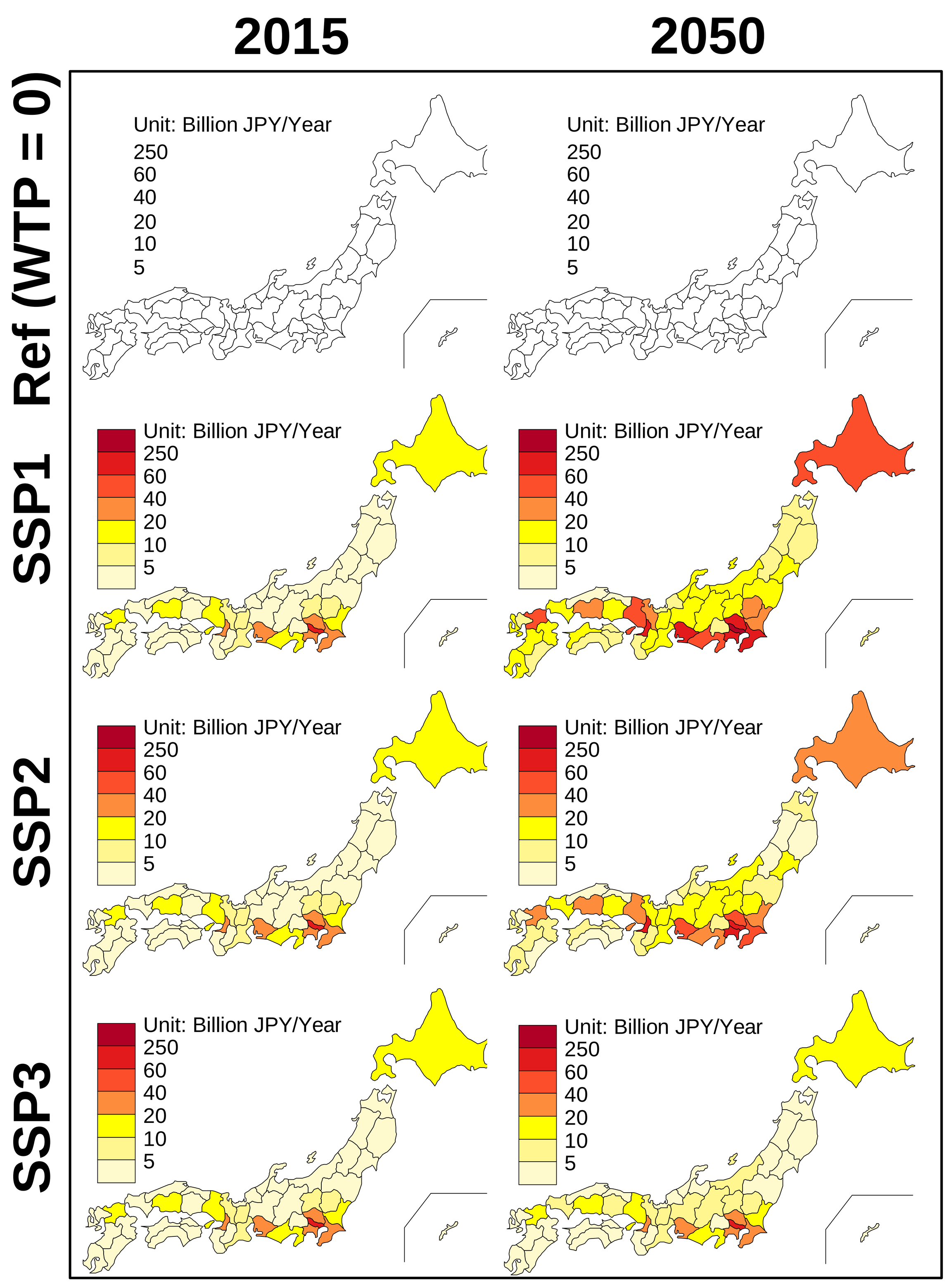
(d) Solar power potential in Japan



(MEJ, 2010)

5. Result and Discussion

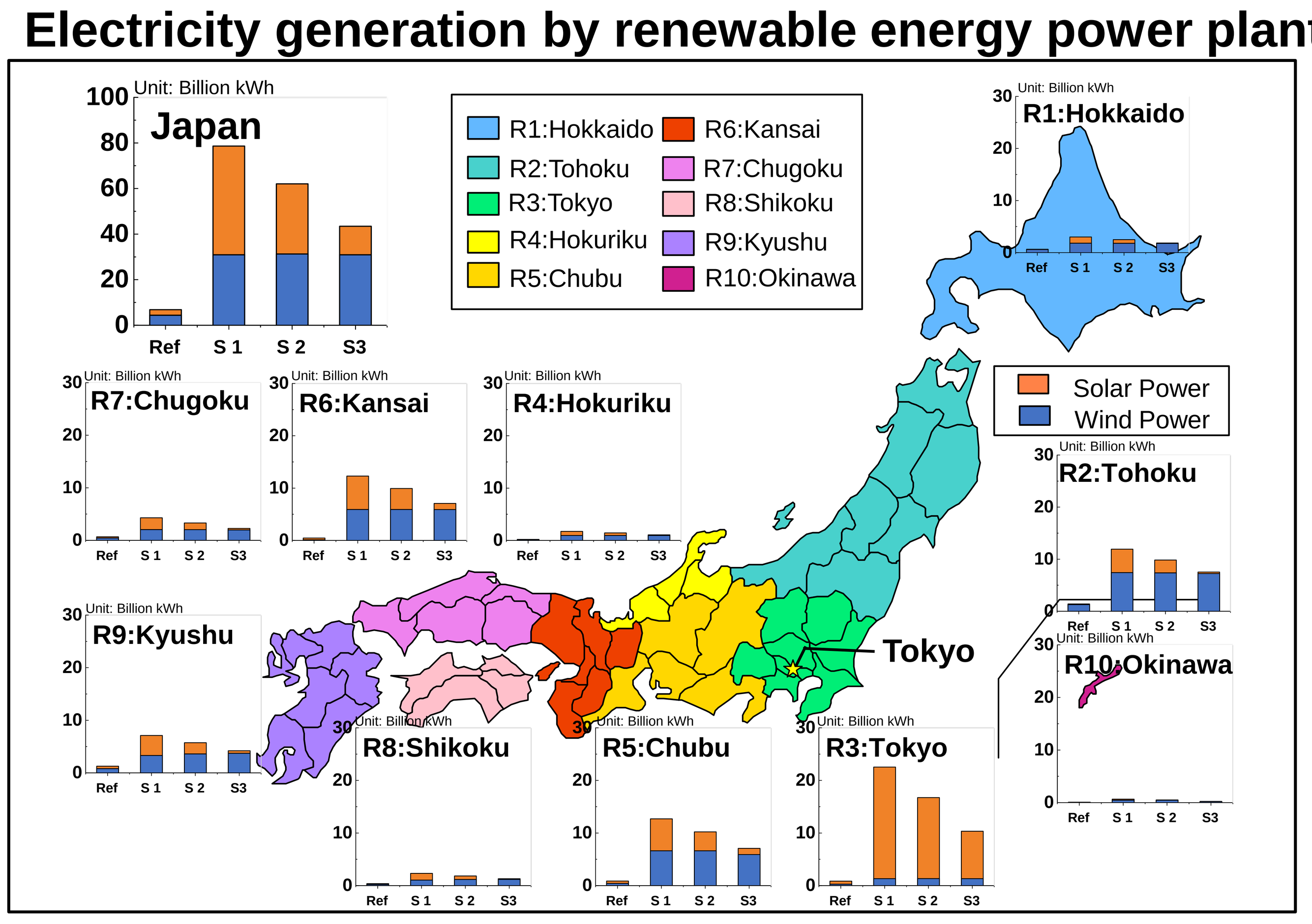
5.1 Prediction of the Total WTP



- Total WTP increase from 500 to 1,400 Billion JPY
- TWTP is higher in Tokyo → a higher income
- TWTP in SSP3 is less than in SSP1 & SSP2

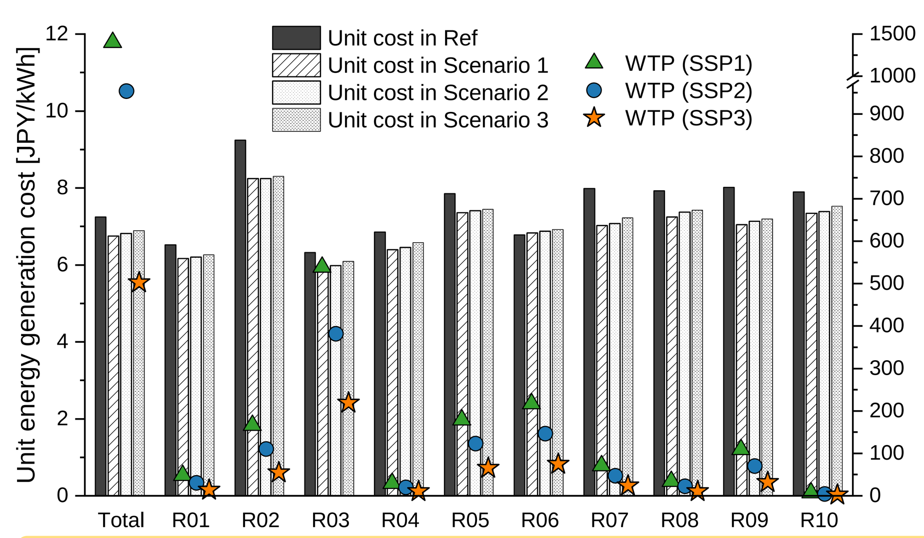
5.2 Influence of WTP on diffusion of RE

Electricity generation by renewable energy power plants in 2050



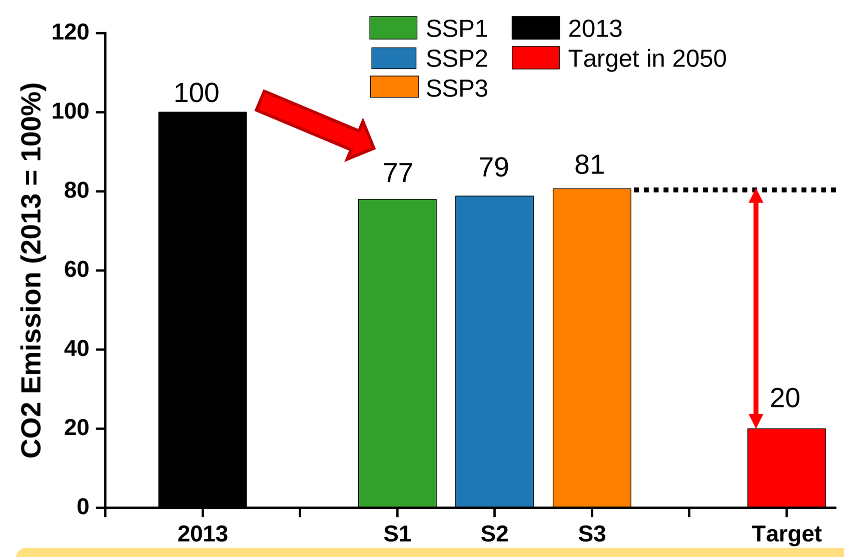
- In S1 and S2, the electricity generation is expected to be 10-fold than Ref
- R3 is higher than other area, which is contributed by the higher income

5.3 Unit Generation Cost



- Unit generation cost: S1 < S2 <S3
- TWTP : S1 > S2 > S3→ Unit cost similar

5.4 Carbon emission



- Carbon emission: S1 < S2 <S3
- Only RE → Difficult to achieve target

Reference

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2. MEJ, 2010. Study of Potential for the introduction of Renewable Energy. Ministry of the Environment.
3. Shiraki, H., Ashina, S., Kameyama, Y., Moriguchi, Y., Hashimoto, S., 2011. Simulation analysis ofrenewable energy installationscenariosin Japan's electricitysectorin 2020usingamulti-regional optimalgeneration planning model. Journal of Japan Society of Energy and Resources 33, 1-10.

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6. Conclusion and future work

- From 2015 – 2050, total WTP
  → increase from 489 to 1,388 Billion JPY
- Electricity generation from renewable energy
  → consider the WTP is expected to be 10-fold than ref scenario
- Carbon emission target in 2050
  → by only RE, it is still difficult to achieve

☐ Future work

- ✓ Increasing grid capacity + RE by WTP
- ✓ Increasing second battery + RE by WTP
- ✓ Demand management (Peak shifting)

80% CO_2 ↓