Optimal allocation of willingness to pay for renewable electricity generation and grid transmission in transition to a low-carbon society in Japan

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1. Introduction

- Japan decided a net zero GHG reduction target by 2050.
- To achieve this target, electricity production by renewable energy resources expect to play a key role
- Another challenge is transmitting electricity generated in remote areas.
- Although the higher capital cost for renewable energy and transmitting, 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 and transmitting?

3. Future Scenario

- ✓ **Ref** : WTP = 0
- ✓ **Scenario 1** : WTP only used for RE
- ✓ **Scenario 2:** WTP only used for transmitting
- ✓ **Scenario 3** : WTP used for RE and transmitting (50% WTP for each item)

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)

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

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.

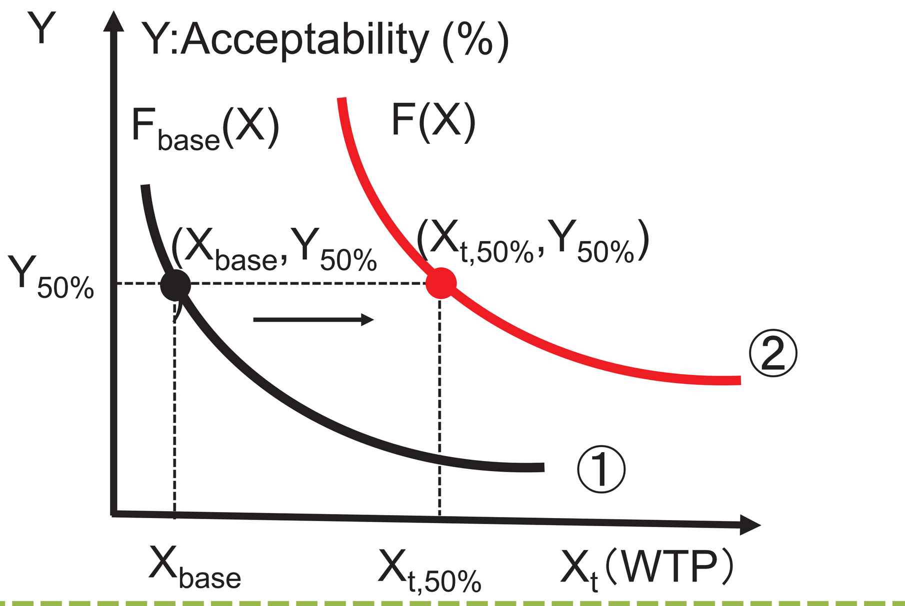
② Shift in acceptability curve

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

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

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

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 $\Upsilon(t)$

$\Upsilon(t) + TL(t) < TWTP$

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

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

$\Upsilon(t)$: Renewable energy cost
TL: cost for transmission lines
$\Omega(t)$: 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

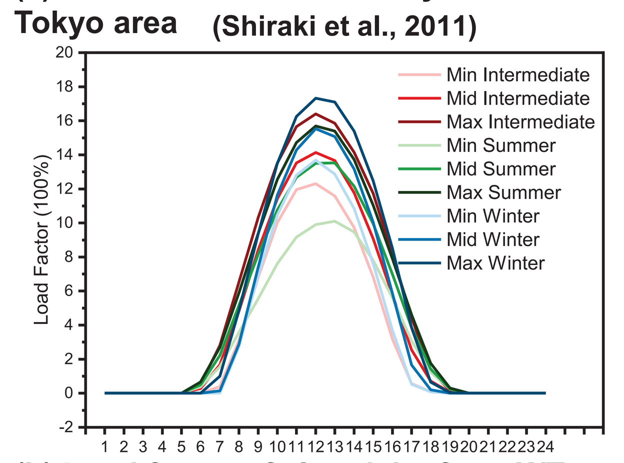
RE capacity $\Omega(t)$

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

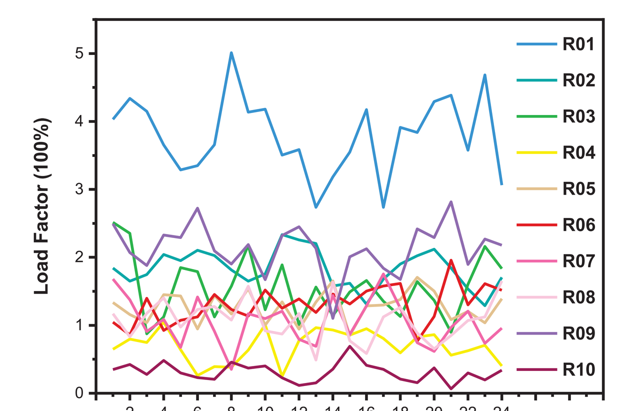
DMND: Electricity demand
O: Electricity generation
STR: PumpHydro & Second battery
FIX: Nuclear & hydro
TR_{in}: Energy supply quantity from other prefecture
TR_{out}: Energy supply quantity to other prefecture

2. Data

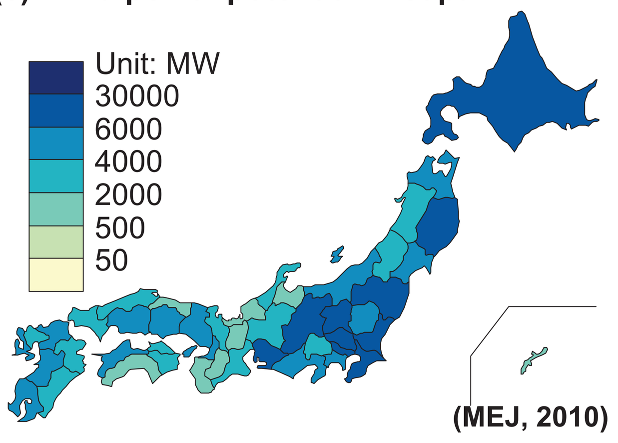
(a) Load factor of electricity from PV in Tokyo area (Shiraki et al., 2011)



(b) Load factor of electricity from WT

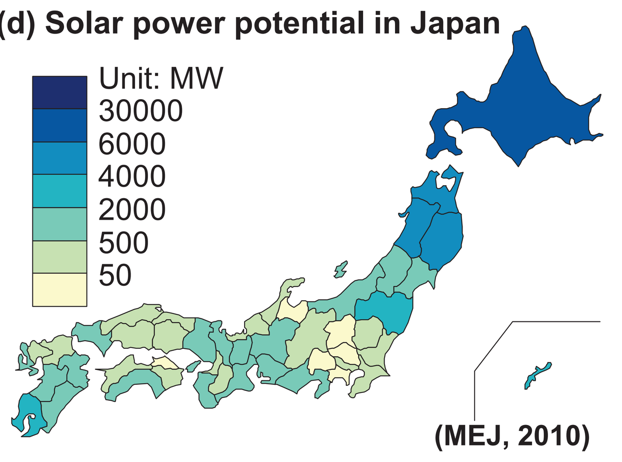


(c) Wind power potential in Japan



(MEJ, 2010)

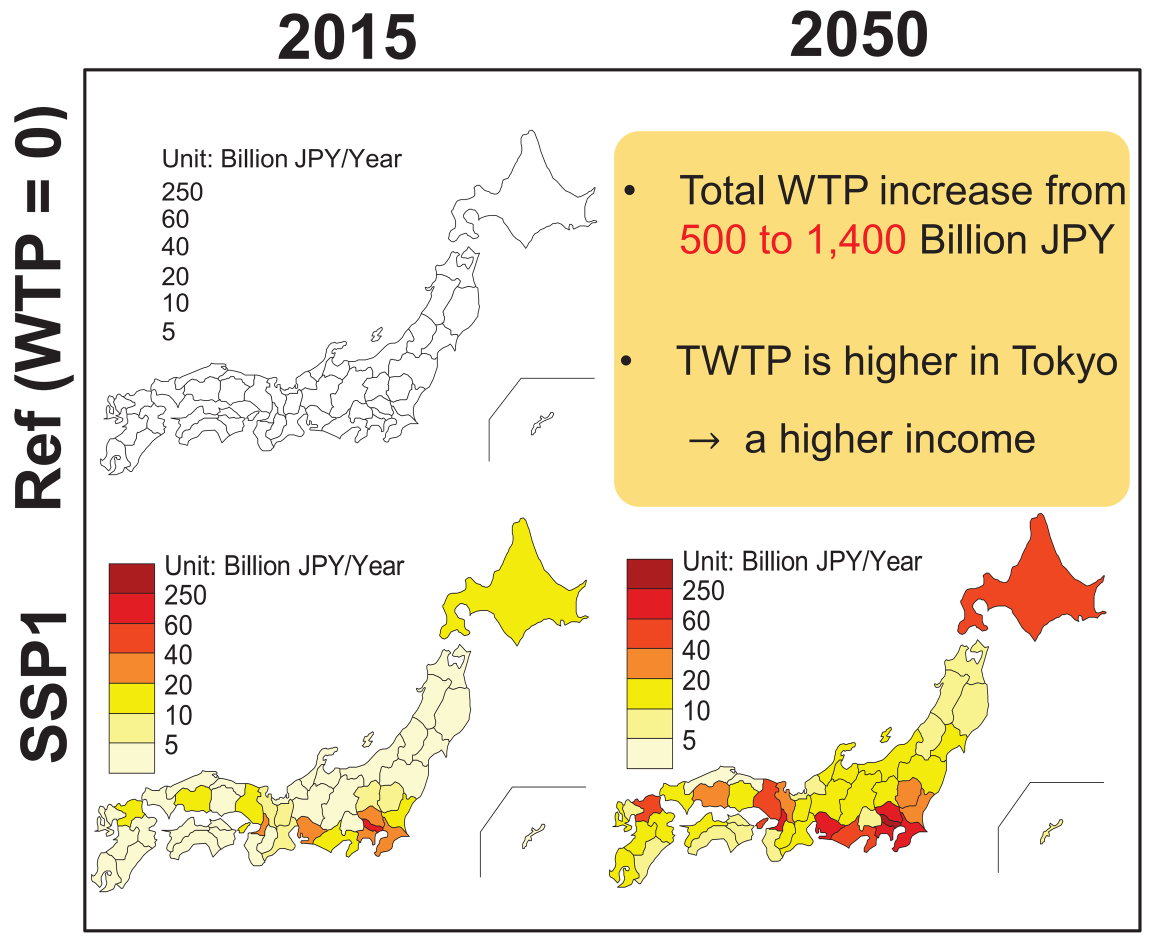
(d) Solar power potential in Japan



(MEJ, 2010)

5. Result and Discussion

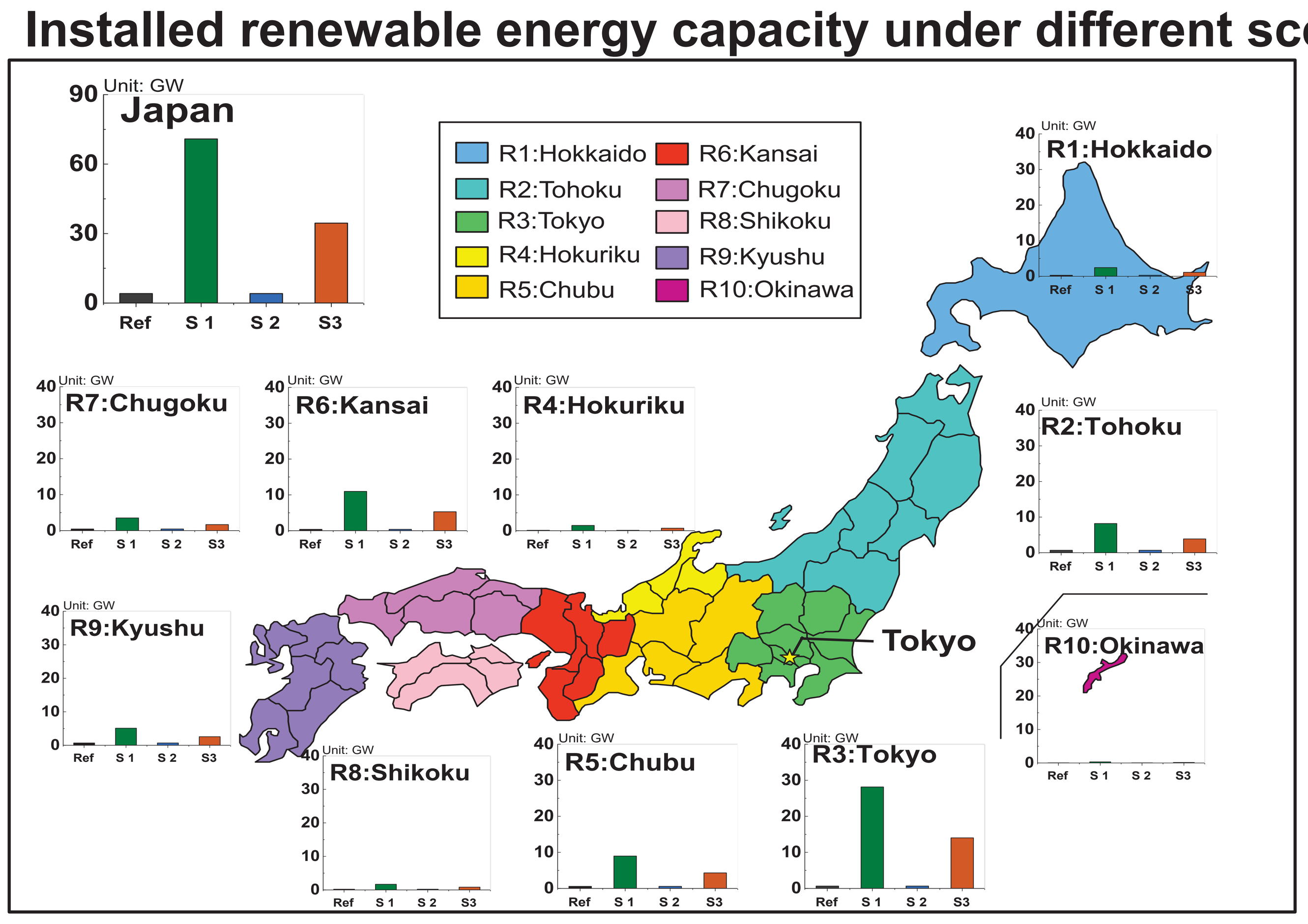
5.1 Prediction of the Total WTP



- Total WTP increase from 500 to 1,400 Billion JPY
- TWTP is higher in Tokyo
  → a higher income

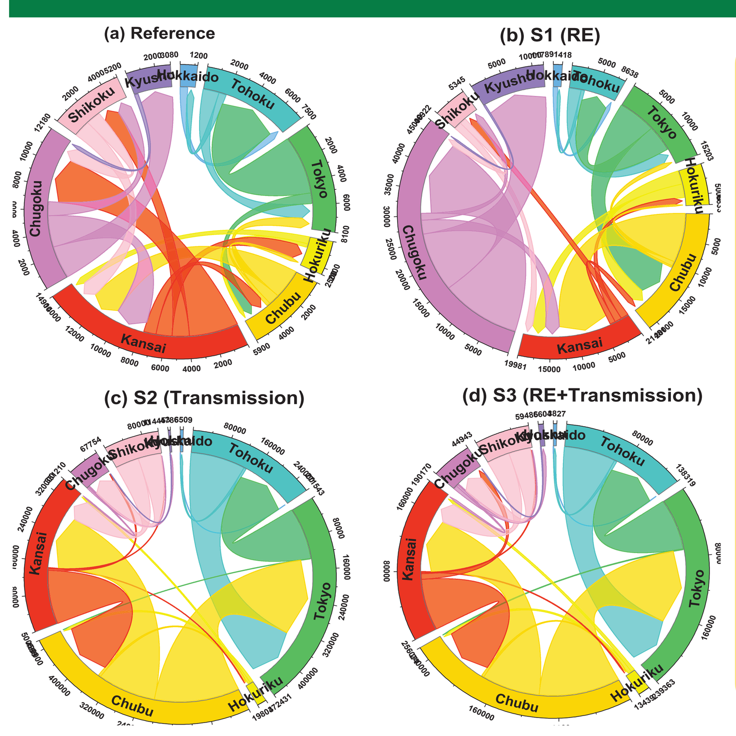
5.2 Influence of WTP on diffusion of RE

Installed renewable energy capacity under different scenario in 2050



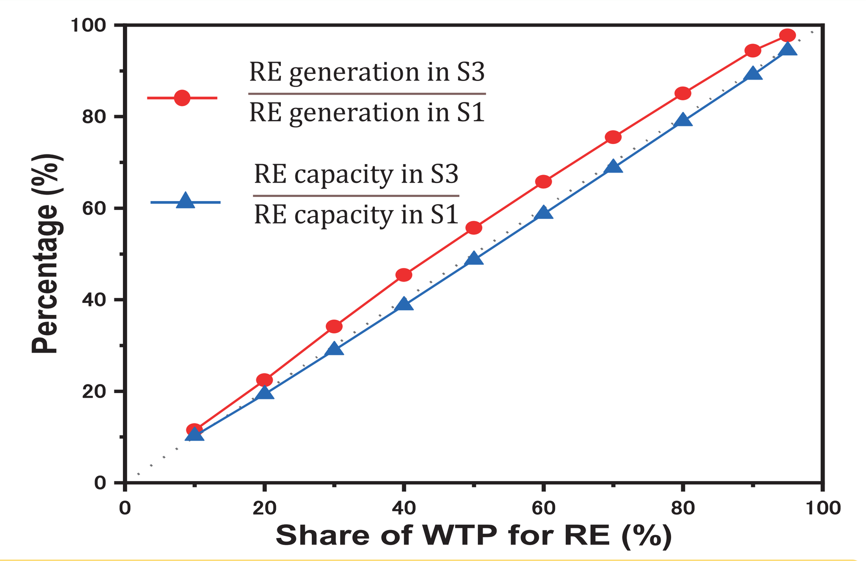
- In S1, the electricity generation is expected to be 17-fold than Ref
- R3 is higher than other area, which is contributed by the higher income

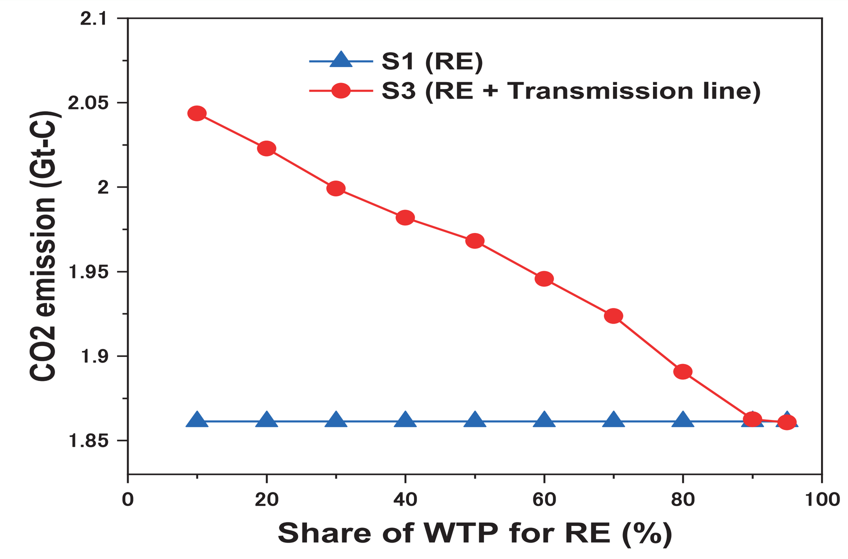
5.3 Power transmission capacity



- Transmission capacity in S2 and S3
  → increase 9-18-fold than Ref
- Specific from Tohoku to Tokyo, and Chubu to Tokyo
  → great protentional increase transmission capacity

5.4 Sensitive Analysis





- Transmission → improve RE generation under similarly capacity
- Transmission + RE
  → future increase the CO2 emission ↓

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 500 to 1400 Billion JPY
- Electricity generation from renewable energy and transmission line
  → consider the WTP is expected to be 17-fold and 18-fold than Ref
- Carbon emission
  → Both consider the RE and transmission line can future increase the carbon emission reduction

☐ Future work

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

} Zero GHG ↓