



# Estimation of photovoltaic power generation potential over 2020-2060: An empirical study from China

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## 1. Introduction

- ▶ Chinese government had announced the goal of achieving carbon neutrality before 2060
- ▶ 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 power generation potential?**

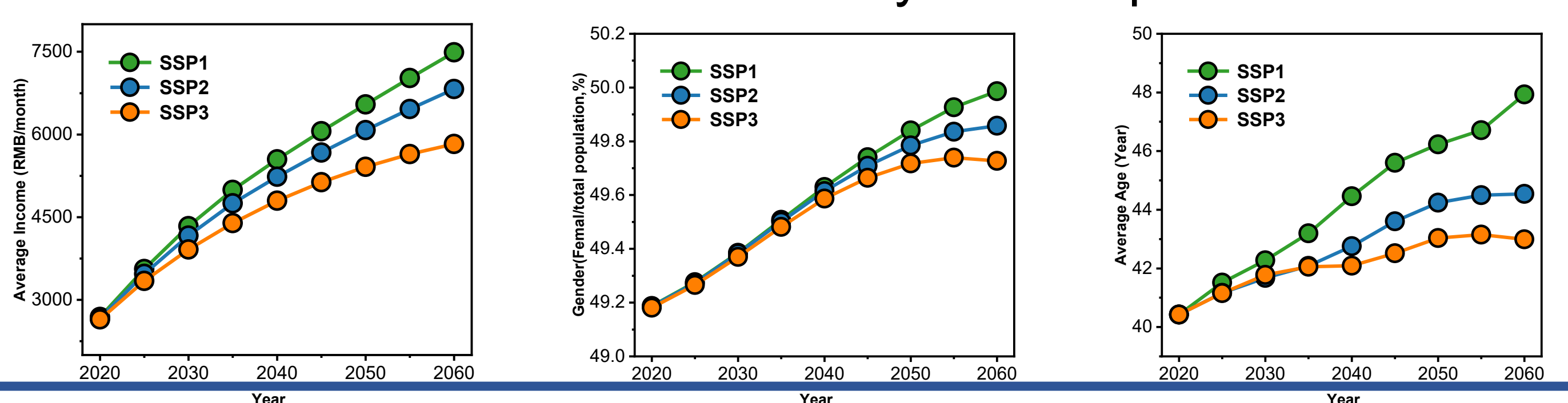
## 2. Description of Scope Areas

- ▶ Key word: WTP, China, CVM + renewable, green, electricity, power, wind, solar, photovoltaic and hydro

Author	Survey Year	Survey Area	WTP	Object analyzed
Guo et al., 2014	2010	Beijing	35.82	WTP for promoting renewable
Xie et al., 2018	2016	Tianjin	19.44	WTP for promoting green electricity
Zhang et al 2012	2010	Jiangsu	6.70	WTP for promoting green electricity
Duan et al., 2013	2010	Shanghai	14.10	WTP for CO <sub>2</sub> emission reduction
Duan et al., 2014	2010	Beijing	18.80	WTP for CO <sub>2</sub> emission reduction
Duan et al., 2015	2010	Shandong	17.90	WTP for CO <sub>2</sub> emission reduction
Jin et al., 2019	2017	Beijing	47.96	WTP for photovoltaic power
Wu et al., 2021	2018	Henan	64.57	WTP for promoting renewable
Gon et al., 2020	2018	Henan	51.65	WTP for promoting renewable
Liu et al., 2011	2010	Beijing	35.16	WTP for promoting green electricity
Zhao et al., 2018	2015	China	23.20	WTP for promoting renewable
Xie et al., 2019	2016	Tianjin	46.22	WTP for promoting green electricity
Li et al., 2022	2012	Ningxia	45.09	WTP for photovoltaic power
Bai et al., 2023	2021	Qinghai	22.51	WTP for promoting renewable

## 3. Future Scenario Setting

- ✓ **Scenario 1** : WTP and Electricity consumption under SSP1
- ✓ **Scenario 2** : WTP and Electricity consumption under SSP2
- ✓ **Scenario 3** : WTP and Electricity consumption under SSP3



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## 4. Methodology

### 4.1 Estimation of WTP

□ Meta-regression was used to forecast the WTP

$$WTP_{med} = f(\text{Age, Gender, Income, Education, Electricity, YEAR})$$

Where *Age* is the average for target area, *Gender* is the percentage of female share within total population (%), *Income* is the annual average household income (JPY), *Education* is the percentage of the adult population held a university degree (%), *Electricity* is the electricity consumption(kWh) and *YEAR* is the survey year

### 4.2 Estimation of 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 JPY/(household-month).  $a$  and  $b$  are assumed to 6.505 and 1.065.

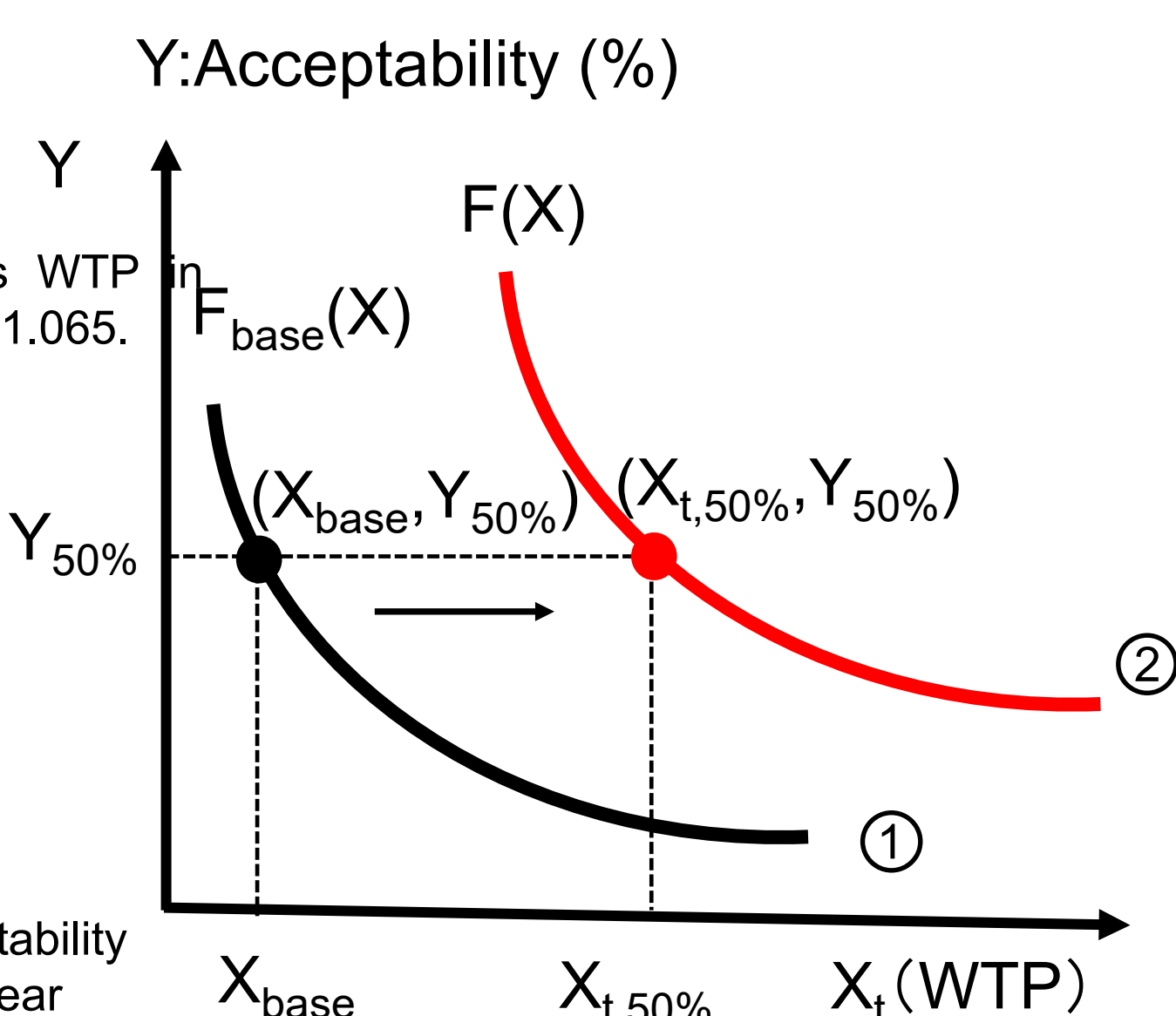
② Shift in acceptability curve

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

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

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

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 The provincial PV generation potential

#### Calculation Process

Solar radiation intercepted by PV panels ( $ssrd_{panel}$ )

Minimal footprint of individual solar panels ( $A$ )

Maximum solar panels area under different grids ( $A_a$ )

PV power generation of a grid ( $E_i$ )

Provincial power generation in the suitable area ( $E$ )

$$ssrd_{panel} = \epsilon_{direct} \cdot ssrd_{direct} + \epsilon_{diffuse} \cdot ssrd_{diffuse} + \epsilon_{reflect} \cdot ssrd$$

$$\epsilon_{direct} = \frac{\cos \Sigma + |\tan \beta| \cdot \cos \varphi}{1 + \cos \Sigma}$$

$$\epsilon_{diffuse} = \frac{1 - \cos \Sigma}{2} \cdot \beta$$

$$\epsilon_{reflect} = \frac{1 - \cos \Sigma}{2} \cdot \beta$$

$$ssrd_{direct} = ssrd \cdot \frac{\sin \beta}{\sin \beta + C}$$

$$ssrd_{diffuse} = ssrd \cdot \frac{\sin \beta + C}{\sin \beta + C}$$

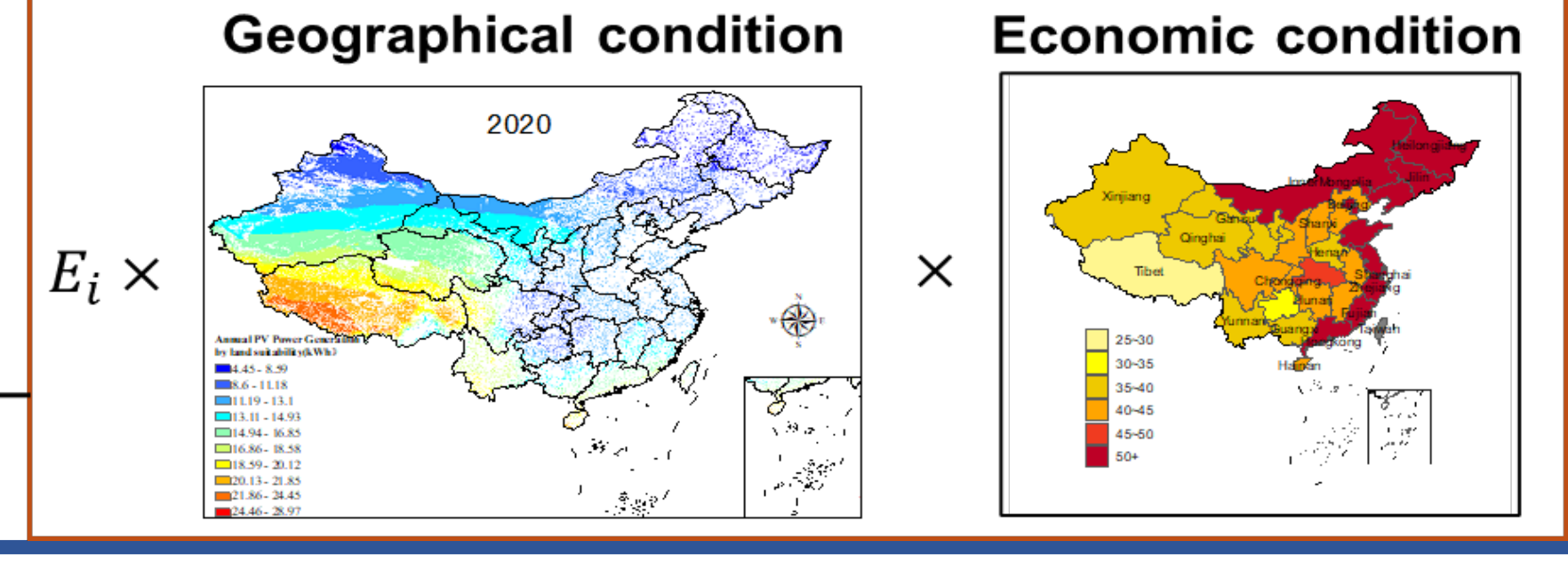
$$\Sigma = 1.4 + \theta(1.2 + \theta(-0.01 + \theta \cdot 0.00008))$$

$$A = 2 \times d \quad A_r = (111 \times 0.1)^2 \times \cos \theta$$

$$d = l \times \cos \Sigma + \frac{l \times \sin \Sigma}{\tan \beta} \cdot \cos \varphi \quad A_a = A_r \times \frac{1}{A} \times 2$$

$$E_i = \eta \times A_a \times ssrd_{panel} \times PR$$

$\eta$ : PV module efficiency  
 $PR$ : ratio of the final system yield to the reference yield

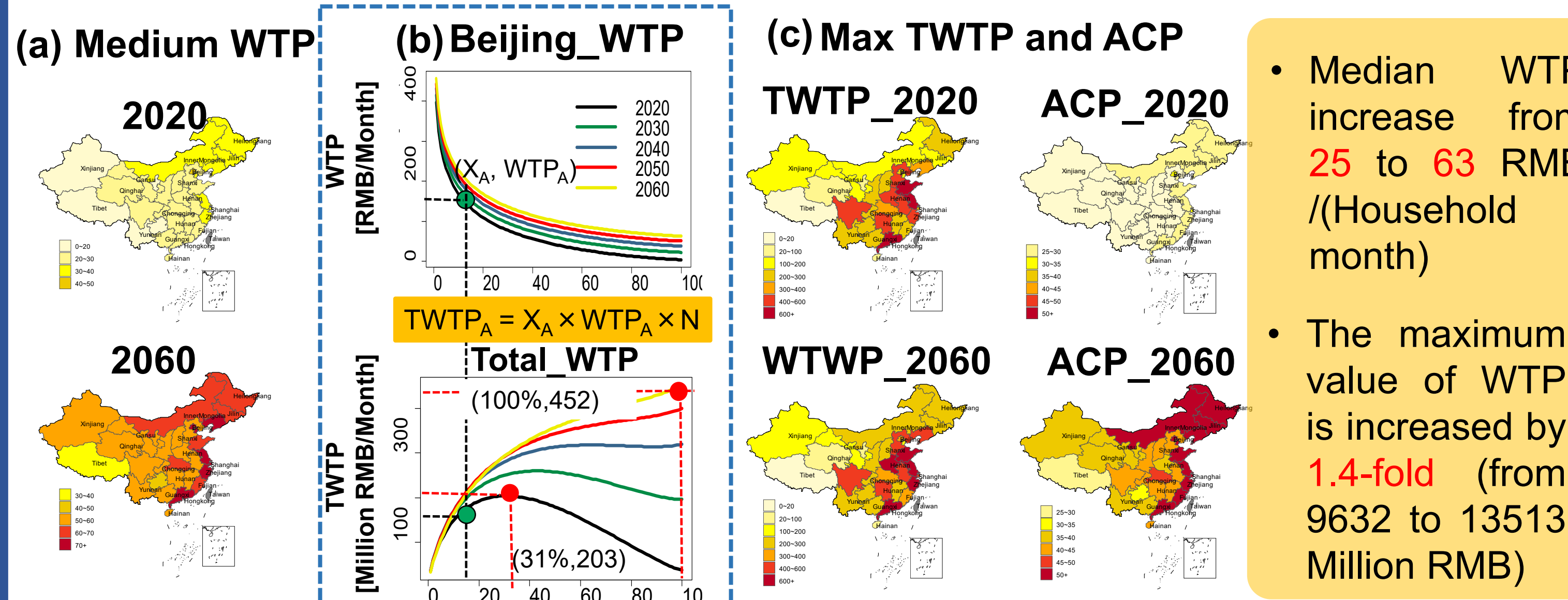


## 6. Conclusion and future work

- From 2020-2060
  - Maximum value of WTP → increase from  $9.6 \times 10^9$  to  $1.3 \times 10^{10}$  RMB
  - PV power generation → increase from  $1.2 \times 10^5$  to  $2.1 \times 10^5$  TWh
  - Investment subsidy → increase from  $2.1 \times 10^{12}$  to  $1.7 \times 10^{12}$  RMB
- Future work
  - ✓ Consider the impact of production cost reduce
  - ✓ Evaluation the impact of WTP on energy use by models

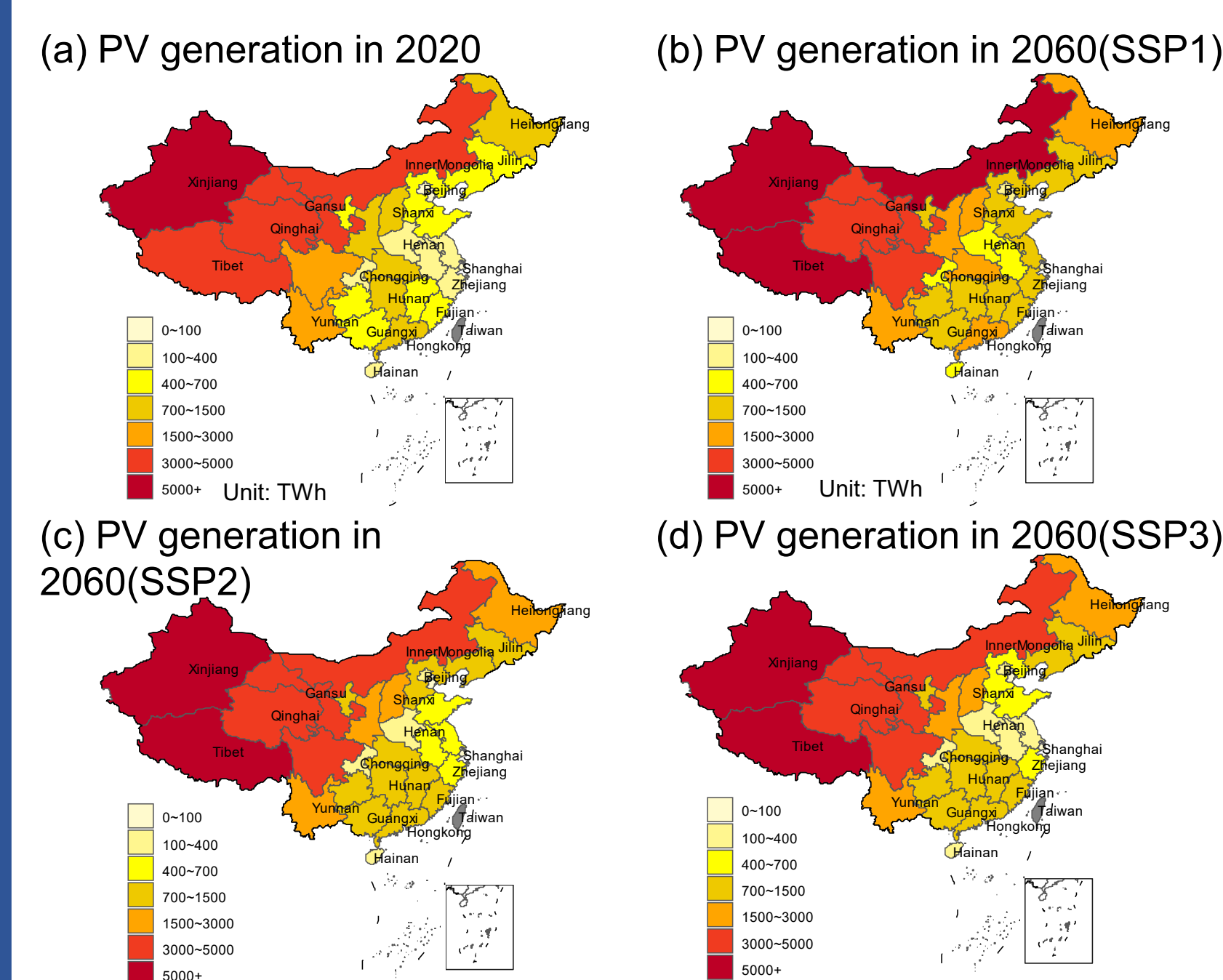
## 5. Result and Discussion

### 5.1 Prediction of medium and total WTP in SSP1



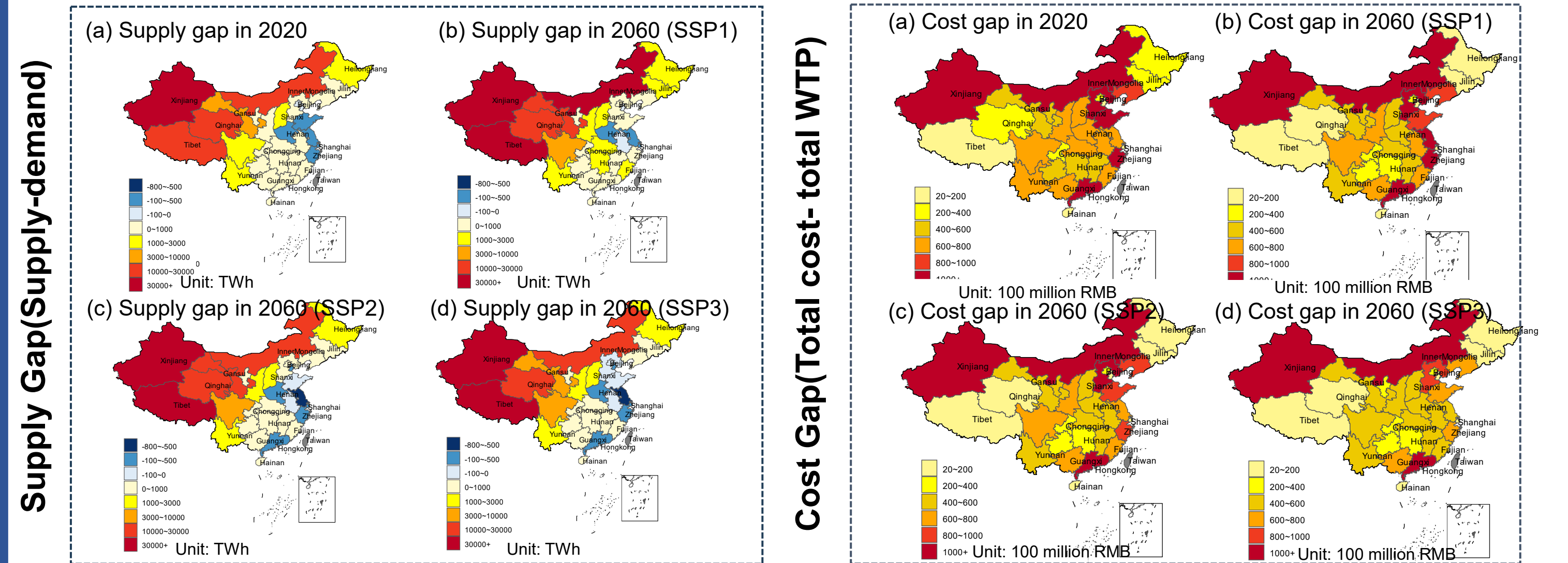
- Median WTP increase from 25 to 63 RMB/(Household-month)
- The maximum value of WTP is increased by 1.4-fold (from 9632 to 13513 Million RMB)

### 5.2 PV power generation potential in 2060



- The total PV power generation of China exhibits a significant increase, ranging from  $1.2 \times 10^5$  TWh in 2020 to  $2.1 \times 10^5$ ,  $1.7 \times 10^5$  TWh and  $1.5 \times 10^5$  TWh in 2060 under SSP1-SSP2, respectively
- In SSP1, PV power generation is more than  $1 \times 10^5$  TWh in Inner Mongolia, Tibet, Qinghai, and Xinjiang

### 5.3 Prediction of CO<sub>2</sub> reduction potential



- Number of the coastal areas, such as Tianjin, Shanghai, Jiangsu, Anhui and Henan, the PV power generation no longer meet the larger power demand of the province.
- Annual cost for increasing the PV power generation are expected to be within  $2.3 \times 10^{12} \sim 1.8 \times 10^{12}$  RMB
- These costs will decrease to  $2.1 \times 10^{12} \sim 1.7 \times 10^{12}$  RMB, (the request investment subsidy), attributing by the WTP.

