The Impact of Electricity Price Policy on the Economic Performance of Distributed Building Photovoltaic Systems across China

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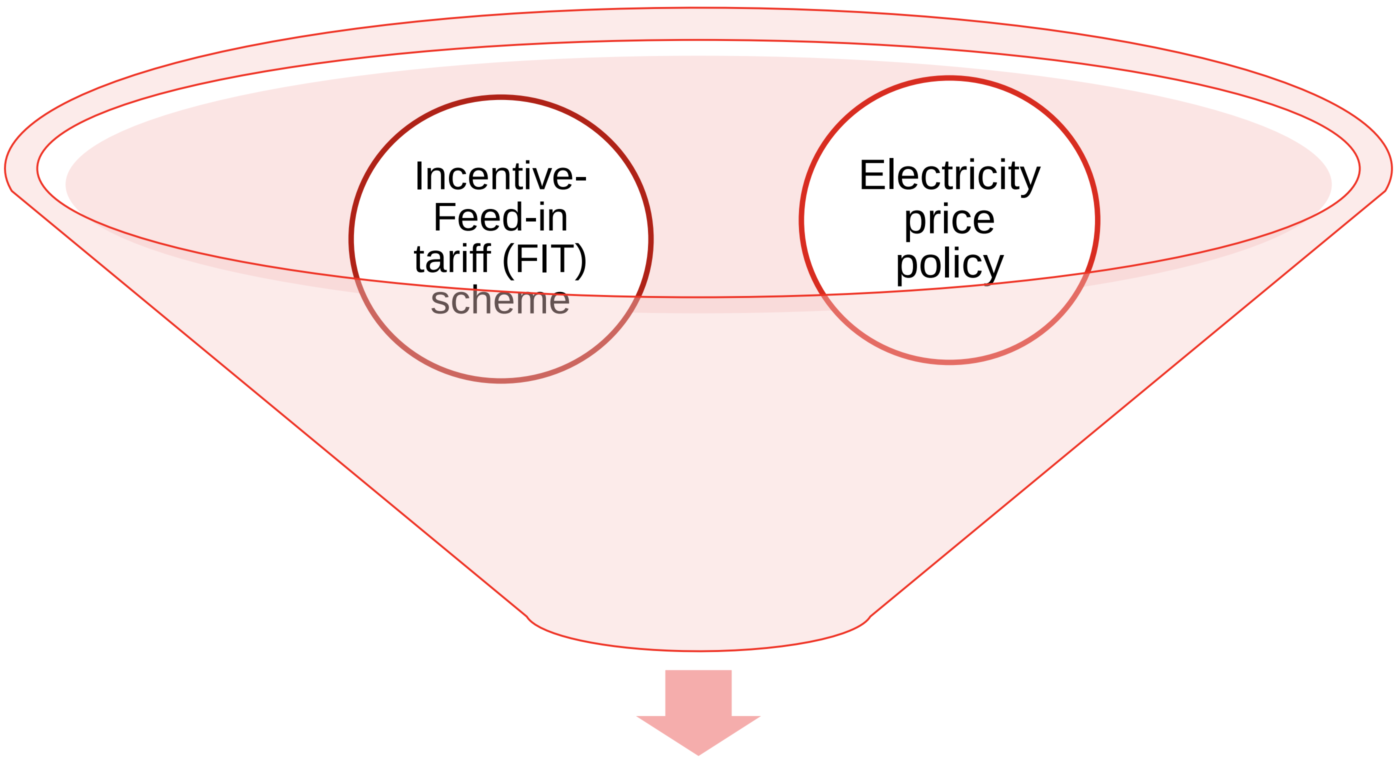
Introduction

- Buildings PV applications in the urban environment can be considered as one promising solution to improving sustainability of a city thanks to cost reduction and efficiency improvement, abundant product supply and government support (Yuan et al., 2014, Zhang et al., 2015, Zhao et al., 2015, Nemet et al., 2017).

- As a decentralized power source, building PV systems can also help relieve the heavy electricity load of the urban area and improve the grid security (Alazraki and Haselip, 2007, Liu et al., 2010, Gautam et al., 2015).

- Drawbacks of the large-scale PV systems exposed over time and then distributed PV systems in the urban areas has been increasingly emphasized by the Chinese government since 2013 (Zhang et al., 2015a).

The impacts of policies on financial value outcomes of distributed PV applications



Need to understand impacts of changing policy conditions in China

Background of FIT in China

- Feed-in tariff (FIT) scheme for distributed PV

Mode	Benefit of the generation
1. Self-consumption	Self-consumption energy price = electricity price for end user/local retail rate of electricity + national subsidy + other subsidy Surplus energy price = local electricity price generated by desulfurized coal + national subsidy + other subsidy National subsidy before June 2018: RMB 0.37/kWh Other subsidy depending on the local/provincial policy
2. Selling all to the grid	Energy price = local feed-in tariff

Electricity price policy

- This study focuses on the distributed PV systems with high self-consumption ratio using the “self-generated and self-consumed” mode. As a result, the saved electricity bill makes up the main economic benefit for the PV systems.
- Many factors can cause the fluctuation of the retail electricity price and it is hard to forecast the change of electricity price.
- Many studies have considered the electricity price change by involving a single price evolution rate (e.g. Lacchini and Rüther, 2015, Vilaça Gomes et al., 2018 and Rodrigues et al., 2016).
- Limited research has taken into consideration the difference of the electricity price change between different geographic location in a nation.
- There is a few research investigating the influence of the electricity price change on the economic performance of distributed building PV projects.

Research gaps

- In the context of China, the electricity tariff for retail is still under the strict control of the central government, which varies between provinces and municipalities (Zhang et al., 2018).
- China is large in territory with diverse climatic and policy conditions. Cities in different provinces have their own electricity price policy and growth rate (Wang and Zhang, 2016).
- There is a lack of research investigating the influence of the electricity price change on the economic performance of distributed building PV projects across China.
- There is limited research comparing the economic performance of different building PV applications (i.e. BAPV and BIPV) across China.

Research aim

- This study aims to understand the economic value of various kinds of distributed building PV systems (both BAPV and BIPV) across China by considering the impacts of electricity price change.

Research process

1

- 12 city selection and analysis
- Case building collection and scenario establishment

2

- Energy generation vs Energy consumption
- Determining benefit mode

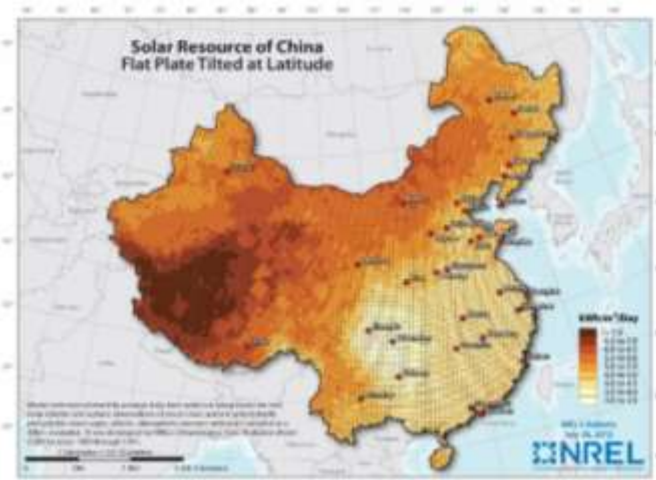
3

- Economic evaluation using MATLAB
  - Net Present Value (NPV) per kW

City selection and analysis

- 12 representative cities
  - One city for each zone
  - highly urbanized and population-concentrated
  - high GDP and high energy consumption

Climate Solar kWh/m2/ day	I Severe Cold	II Cold	III Hot Summer & Cold Winter	IV Hot Summer & Warm Winter	V Temperat e	VI & VII Severe Cold & Cold
IV	Hohhot					Urumqi
V	Harbin	Taiyuan				
VI		Tianjin		Shenzhen	Kunming	
VII			Shanghai	Guangzhou		
VIII			Chengdu		Guiyang	
IX			Chongqing			



12 City selection and analysis

City	Local Electricity Policy	Local Electricity Price for Commercial Building RMB/kWh	Local Electricity Price Growth Rate	Local Subsidy Policy	National Subsidy Policy
Urumqi	Fixed price	0.5850	0.59%		For self-consumed Part 20-year subsidy: RMB 0.37/kWh (in 2018)
Kunming	Fixed price	0.6550	2.08%		
Guiyang	Fixed price	0.7224	2.60%		
Hohhot	Fixed price	0.7440	-0.08%		
Chengdu	Fixed price	0.7799	-0.37%		
Chongqing	Fixed price	0.7925	0.07%		
Shenzhen	Fixed price	0.8616	2.04%		
Harbin	Fixed price	0.8665	1.12%		
Guangzhou	Fixed price	0.8983	2.04%	One-off subsidy: RMB 0.2 /w (max 2,000,000)	
Taiyuan	Time-of-use price	0.6963 (11-18;7-8) 1.0076 (8-11;18-23) 0.4068 (23-7)	4.72%		
Tianjin	Time-of-use price	0.8367 (7-8 11-18) 1.2035 (8-11;18-23) 0.5522 (23-7)	3.17%		
Shanghai	2-season Time-of-use price	Summer (July, August, September) 1.095(6-22) 0.541(22-6) Other Seasons 1.060(6-22) 0.506(22-6)	7.51%	For industrial and commercial building 5-year subsidy: RMB 0.25/kWh	

Case study – building information

- Analyzing cases

Case Building	a	b		c	
Scenario	**1**	**2**	**3**	**4**	**5**
Application	BAPV	BIPV	BIPV	BAPV	BIPV
PV Type	Roof	Roof	Roof	Roof	Façade (Window)
Cell type	Polycrystalline	Quasi-monocrystalline	Quasi-monocrystalline	Monocrystalline	Thin-film
Capacity (kW)	2,825.4	60	60	28.08	50.58
Solar cell Area (A) (m^2)	18,025.83	914.76	914.76	183.84	865.48
Array Tile	Local latitude	0	0	Local latitude	90
Efficiency (r)	16%	17%	17%	18%	10%
Construction Cost (RMB)	20,605,098	2,157,000	2,157,000	315,628	769,107
Construction cost RMB/ kW (BIPV without offsets)	7,293	35,950	35,950	11,240	15,206
Construction cost RMB/ kW (BIPV with offsets)	7,293	29,812	17,352	11,240	7,506


Case building a


Case building b



Case building c

2

- Energy generation vs Energy consumption
- Determining benefit equation

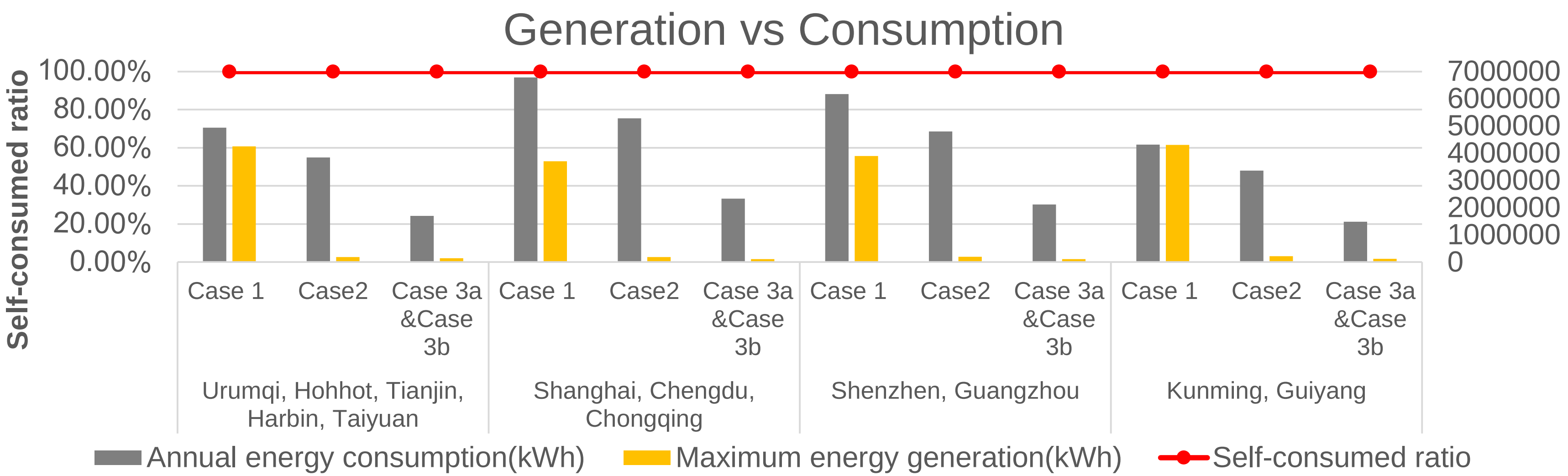
Energy Generation

$$E = A \times r \times H \times PR$$

Where:
E is the energy output in kWh;
A is the total solar cell area in m2;
r is the PV product efficiency;
H is the hourly solar radiation in W/m2 from PVWatts;
PR is the system performance ratio.

Energy consumption

Building Climate zone	Severe cold and cold zone (including I II VI VII)	Hot summer and cold winter III	Hot summer and warm winter IV	Temperate V
Commercial office building kWh/m2/year	80	110	100	70



2

- Energy generation vs Energy consumption
- Determining benefit mode

- 100% Self-consumption Benefit

$$\mathbf{B(n)} = \sum_{n=1}^{N} \sum_{h=1}^{8760} \mathbf{ep_h} \times (1 + \Delta\mathbf{ep})^{\mathbf{n}} \times \mathbf{E(h)} + \sum_{h=1}^{8760} \boldsymbol{Sb_n} \times \mathbf{E(h)} +)\mathbf{sb}_{\boldsymbol{l}}$$

where:
n is the number of the year;
ep_h is the electricity price of that hour;
$\Delta\mathrm{ep}$ is the compounded growth rate of the electricity price of the city;
E(h) is the hourly energy generation;
Sb_n is the unified national subsidy provided by the government lasting for 20 years;
Sb_l is the extra subsidy provide by the local government.

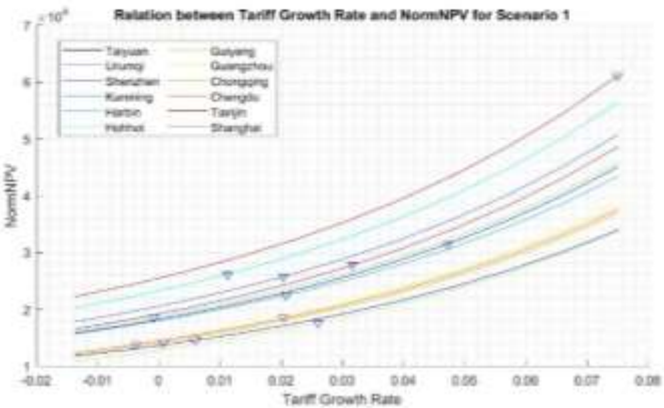
3

- Economic evaluation using MATLAB
  - Net Present Value (NPV) per kW

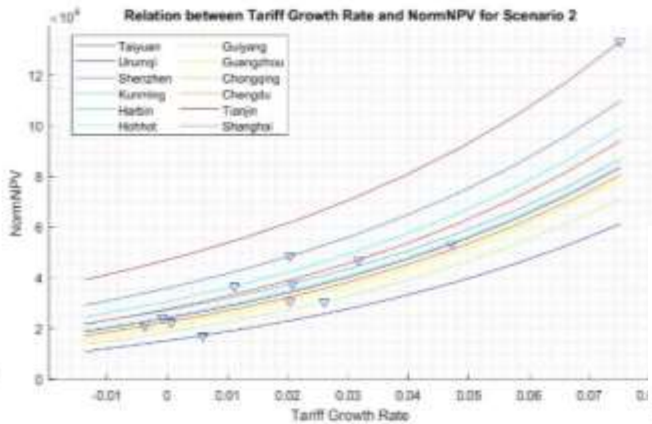
- A 25-year cost-benefit analysis is carried out to study the actual value of all 5 PV designs in 12 cities by considering the electricity growth rate.
  - Net present value (NPV) kW
  - The range of tariff growth rate is from -1.37% (i.e. the average of all negative tariff growth rates in China) to 7.52% (i.e. the highest tariff growth rate), based on the study of Wang and Zhang (2016).
- Cost: the initial investment cost of each system and the maintenance cost during the 25 years
- Benefit: based on the benefit equation

Results and discussion

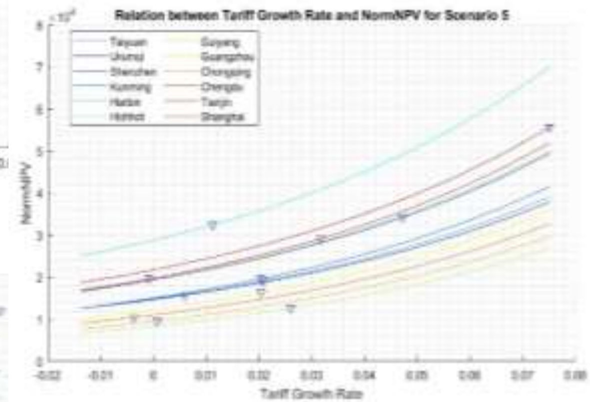
- Based on the building PV application type:



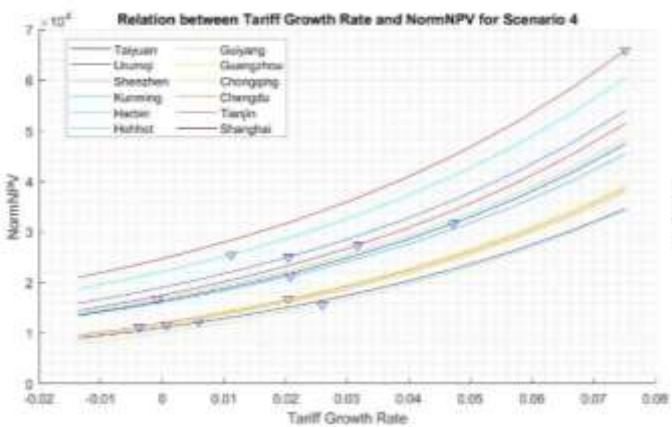
Roof BAPV

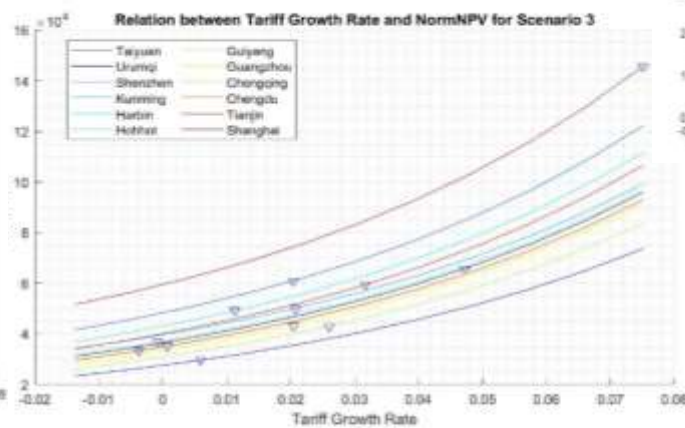


Roof BIPV



facade BIPV





Results and discussion

- The difference between cities:
  - The 25 years' energy generation in 12 cities and their ranks.
  - The electricity price policy in 12 cities.

City	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	Output	Rank	Output	Rank	Output	Rank	Output	Rank	Output	Rank
Urumqi	48092285	6	2312236	6	2312236	6	546870	6	613252	3
Hohhot	50522977	3	2352968	4	2352968	4	551163	3	617135	2
Harbin	52932524	2	2319267	5	2319267	5	555418	2	643143	1
Taiyuan	48740273	4	2274184	7	2274184	7	548014	4	612926	4
Tianjin	43664456	8	2097291	11	2097291	11	539050	8	593667	6
Shanghai	46199702	7	2369064	3	2369064	3	543529	7	582937	7
Chengdu	40990967	9	2186486	8	2186486	8	534329	9	567799	9
Chongqing	39845702	11	2155379	9	2155379	9	532306	10	559172	12
Shenzhen	48536026	5	2516981	2	2516981	2	547655	5	579325	8
Guangzhou	36774678	12	1902819	12	1902819	12	526882	12	562231	10
Kunming	53634896	1	2673963	1	2673963	1	556660	1	603163	5
Guiyang	40121265	10	2141589	10	2141589	10	532793	11	559544	11

City	Local Electricity Policy	Local Electricity Price RMB /kWh		Local Electricity Price Growth Rate		Local Subsidy Policy	National Subsidy Policy
		Value	Rank	Value	Rank		
Urumqi	Fixed price	0.5850	12	0.59%	9		For self-consumed part 20-year subsidy: RMB 0.37/kWh
Kunming	Fixed price	0.6550	11	2.08%	5		
Guiyang	Fixed price	0.7224	10	2.60%	4		
Hohhot	Fixed price	0.7440	9	-0.08%	11		
Chengdu	Fixed price	0.7799	8	-0.37%	12		
Chongqing	Fixed price	0.7925	6	0.07%	10		
Shenzhen	Fixed price	0.8616	5	2.04%	6		
Harbin	Fixed price	0.8665	4	1.12%	8		
Guangzhou	Fixed price	0.8983	3	2.04%	6	One-off subsidy: RMB 0.2 /w (max 2,000,000)	
Taiyuan	3-period price	0.6963 (11-18;7-8) 1.0076 (8-11;18-23) 0.4068 (23-7)	7	4.72%	2		
Tianjin	3-period price	0.8367 (7-8 11-18) 1.2035 (8-11;18-23) 0.5522(23-7)	2	3.17%	3		
Shanghai	2-season 2-period price	Summer (July, August, September) 1.095(6-22) 0.541(22-6) Other Seasons 1.060(6-22) 0.506(22-6)	1	7.51%	1	5-year subsidy: RMB 0.25/kWh	

Conclusion and recommendations

- This study examines that economic performance of 5 kinds of building PV system in 12 representative cities of China, taking a given range of tariff growth rate into consideration. The findings are as follows:
  - The relationship between NPV per kW and the tariff growth rate of all five scenarios in 12 cities complies with the cubic function in the given range, which indicates that the NPV per kW rises faster as the tariff growth rate increases.
  - The economic performance of different types of building PV applications differs under the change of retail electricity price growth rate. In general, Roof BAPV and Rood BIPV share similarity while façade BIPV is quite different.
  - For roof BAPV and roof BIPV, Shanghai has the greatest economic performance while the electricity price growth rate has the largest impact on the NPV per kW in Shanghai. Urumqi is the opposite.
  - For façade BIPV, Harbin is the city with the highest NPV per kW and the greatest sensitivity to the tariff growth rate while Guiyang is the opposite.

Conclusion and recommendations

- Based on the above findings, recommendations are generated for both policymakers and investors to better boost the uptake of building PV applications in China.
    - For those scenarios with high NPV per kW and high sensitivity, the PV investment would become more favourable when the electricity price is expected to experience significant rise in the future.
        - Investors should pay more attention to the outlook of electricity price.
        - The policymakers should be more cautious about the adjustment of retail electricity policy for the overall economic benefit of building PV projects will be greatly influenced.
    - Under the current electricity price growth rate, some scenarios in some cities are not suitable for the investment compared with other cities. The research reveals that the investment of PV application with high sensitivity to the electricity price change can be encouraged by the policymakers when there is high possibility that electricity price will increase greatly in the future.

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Thank you for listening!

Q&A