AESC Review Note 7

Singapore and Solar Energy Transition

Thomas Hin-Shun Lam [1, 2]

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[1] Department of Geography, Hong Kong Baptist University

[2] Asian Energy Studies Centre, Hong Kong Baptist University

Introduction:

In Singapore, the SolarNova Programme was established in 2014, which motivate the citizens' interests on developing solar panel. The solar target of 350 (MWp) was achieved by 2020 and working for at least 2 (GWp) by 2030. This review highlighted the solar development, electricity market liberalization and green electricity retailers in Singapore. It thus provides good references for other cities implementing the solar energy transition.

1. Solar developments in Singapore

1.1 Increase in Solar Installed Capacity

In Singapore, the cumulative solar installed capacity has been increased from 3.8 (MWp) to 300.3 (MWp) from 2009 to 2019. According to figure 1, the slope has been increased significantly after the adoption of the SolarNova Scheme. It shows that this innovative approach can motivate the citizens' interests on adopting the solar panel, as well as coordinate the works done by different department (HDB, 2020). Moreover, the Singapore government has developed its target on solar energy transition. The solar target of 350 (MWp) was achieved by 2020 and working for at least 2 (GWp) by 2030. It thus helps Singapore accomplishing the carbon-neutral goal by 2050, to fulfil the Paris agreement (EDB, 2020).

To facilitate solar development, the Housing and Development Bureau (HDB) would progressively roll out 220 (MWp) of solar panels across 5,500 residential building before 2025. It aims to generate an estimated 420 (GWh) of solar energy annually, which is approximately 5% of total electricity consumption (Chikkodi, 2021). Meanwhile, the Solar Energy Research Institute of Singapore (SERIS) has updated the Solar Photovoltaic Roadmap for Singapore, which further filters the technical potential for the actual usability of rooftop spaces. It provides a good implication for the Singapore government in formulating the solar development program (Reindl et al., 2020).

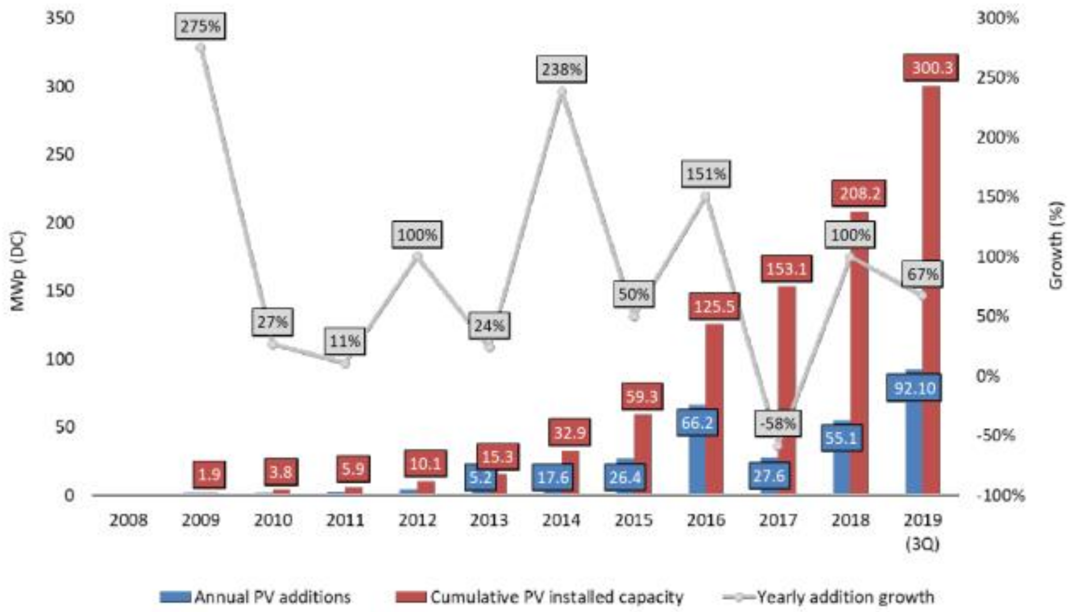

Figure 1. Solar PV Installed Capacities in Singapore, Source: (Reindl et al., 2020)

1.2 Implementation of SolarNova Scheme

In 2014, Singapore started the SolarNova Programme, which aims to promote and aggregate demand for solar PV across the government agency and housing estates. According to Figure 2, there are several responsible parties under the scheme. The Housing and Development Bureau (HDB) coordinate the “solar leasing tender” which hand-in by green electricity retailers, whereas, the Economic Development Bureau (EDB) help driving the solar ambition among the government agency. On the other hand, the Solar Energy Research Institute of Singapore (SERIS), which is the appointed technical consultant, help conducting the feasibility studies and site selection of solar PV panels (HDB, 2020).

In 2021, the Housing and Development Bureau (HDB) has launched the Sixth SolarNova tender. To optimise the energy usage, vendors are mandated to install the smart electrical sub-meter in each HDB blocks. These smart meters would help HDB analyses the energy consumption pattern, detect the equipment failure and optimise the maintenance cycles. Consequently, Singapore’s carbon footprint can be reduced and long-term sustainability can be attained. Including this tender, HDB has committed a total installed capacity of 330 (MWp) for 6,901 residential blocks, which is equivalent to powering more than 80,000 4-room flats with solar energy (Chikkodi, 2021).

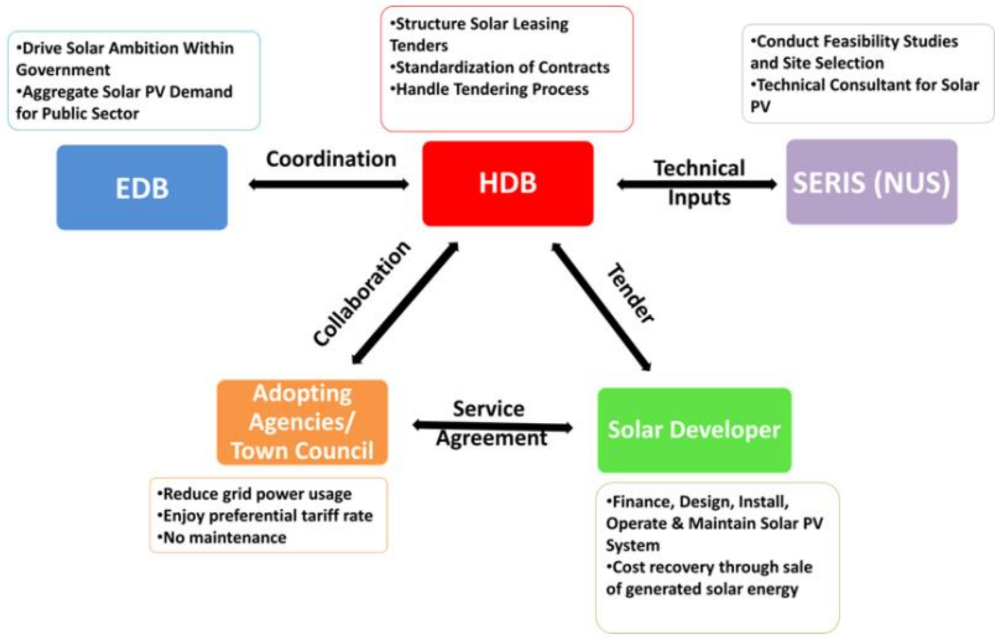

Figure 2. Responsible Parties of SolarNova Scheme, Source: (HDB, 2020)

2. Electricity Market in Singapore

2.1 Timeline of Market Reform

In the past 20 years, Singapore has gradually deregulated its electricity market to a fully divested generation with competition in the wholesale and retail electricity sectors. (Chang & Li, 2013). The literature finds that the supply competition has led to a combinatorial decrease in wholesale electricity price up to 10% (Loi & Jindal, 2019). The full retail contestability (FRC) would enable customers to choose from a variety of electricity providers and pricing arrangements. However, the customers may find it challenging to understand the differences among the various option. (Loi, Owen, & Choo, 2017).

Table 1. Timeline of Electricity Market Reform in Singapore

Timeline	Electricity Market Reform in Singapore
1995	The Singapore government corporatized the state-owned Public Utilities Board (PUB), which had been monopolized the electricity supply for more than 30 years
2001	Singapore's retail markets for industrial consumers were liberalised; Users with a maximum power requirement of 2 MW or above became contestable
2003	The Gencos were allowed to sell electricity to the National Electricity Market of Singapore (NEMS)
2015	The Electricity Futures Trading was initiated; Users with monthly consumption of 2,000 kWh or above became contestable
2018	The Open Electricity Market was expanded progressively to all users. It allows household and business users to select electricity retailers freely.

Source: (Energy Market Authority, 2011, 2019)

2.2 Positive Impacts of Market Reform

Singapore' market liberalization has created benefits towards the market structure, electricity price and system reliability. For market structure, the entry of small power producers has reduced the three MPPs. The generation capacity of three MMPs has been decreased from nearly 90% in 2005 to less than 60% in 2018 (LegCo, 2019). For electricity price, the adoption of cheaper fuel type has exerted downward pressure on wholesale electricity prices. It has led to a combinatorial decrease in wholesale electricity price up to 10% (Loi & Jindal, 2019). For system reliability, Singapore has imposed a strict performance target on interruption time. This certified the quality of services and helped Singapore's electricity grid maintain its status as one of the most reliable in the world (Energy Market Authority, 2011, 2019).

3. Green Electricity Retailers in Singapore

3.1 Green Electricity Plans in Singapore

In Singapore, 6 electricity retailers are delivering eco-friendly electricity plans to customers. According to Table 2, most of the green electricity retailers e.g. the Pacific Light, iSwitch and OHM energy offer carbon-neutral electricity. Customers may offset their carbon emission footprint by purchasing UN Certified Carbon Credits. The green electricity plan is between $0.17-$0.20 per kWh. On the other hand, Geneco and Sunseap deliver the 100% solar electricity option for clients. This truly green plan is between $0.20-$0.23 per kWh, which are slightly expensive (PropertyGuru, 2020).

Table 2. Comparison of Green Electricity Plan in Singapore

Retailer	Type of plan	Green electricity plan
Pacific Light	Carbon neutral electricity	Sunny-Side Up, $0.1739 per kWh
Geneco	Solar and carbon-neutral electricity	Get It Green, $0.1745 per kWh Get It Sunny, $0.2015 per kWh
iSwitch	Carbon neutral electricity only	Chope the Rate, $0.1760 per kWh
OHM Energy	Carbon neutral electricity only	Simply Ohm, from $0.1788 per kWh including CO2 offset add-on
Sembcorp Power	Carbon neutral electricity only	Sunshine Plan, from $0.1865 per kWh
Sunseap	Solar electricity only	Sunseap-50, $0.2161 per kWh Sunseap-100, $0.2301 per kWh

Source: (PropertyGuru, 2020)

3.1 Positive Impacts of New Market Actors

To meet the aggregated electricity demand, Singapore plans to introduce the new market actors and import green energy from Malaysia. To explain, Sunseap and Tenaga Nasional Berhad (TNB), which is the leading solar energy provider in both countries, have formed a joint venture to import renewable energy from Malaysia to Singapore. The TNB, which has a total RE portfolio of 2,732 (MW), is the leading provider of renewable energy solutions in Malaysia. The Sunseap would invest the solar generation assets in Malaysia. It aims to import 100 (MW) electricity, which accounts for 1.5% of Singapore peak electricity demand before 2025. The collaboration between these two company may solve the space limitation in Singapore, which facilitates the solar energy transition (Sunseap, 2021).

Table 3. Highlights of the Key Findings of the Literature on Singapore and Solar Energy Transition

Author	Title	Keywords	Main Findings
(Chang & Li, 2013)	The Singapore electricity market: From partial to full competition	Electricity market liberalisation; Pricing deregulation; Contestable consumer; Competition; Singapore	• This paper examines the (1) electricity market reform and (2) pricing deregulation in Singapore • In the past 20 years, Singapore has developed into a fully divested generation with competition in the wholesale and retail electricity sectors • The Singapore government is studying the feasibility of (1) importing electricity from neighbouring countries to meet the fast-growing demand • They also plan to (2) eliminate the vesting contract and (3) diversify the electricity fuel mix in future
(Lau, Kosorić, Bieri, & Nobre, 2021)	Identification of factors influencing development of photovoltaic (PV) implementation in Singapore	Built environment; Building-integrated photovoltaics (BIPV); Photovoltaics (PV); Drivers; Obstacles; Sustainability	• This article examines the (1) obstacles, (2) potentials and (3) drivers that could encourage wider photovoltaic implementation in Singapore • The web survey and qualitative interviews were conducted among local professionals • Results indicate that the costs are not the only obstacle and the problem of PV integration in Singapore is more complex
(Loi & Jindal, 2019)	Electricity market deregulation in Singapore – Initial assessment of wholesale prices	Electricity market liberalization; Singapore Wholesale Prices; Retail competition;	• This paper analyses how competitiveness in both the wholesale and retail market led to price decreases • The result finds that supply competition and retail liberalisation has led to a combinatorial

			decrease in wholesale electricity price up to 9.11% • It thus brings some insights on what to expect from full retail contestability after the latter half of 2018
(Lu, Chang, Shabunko, & Lay Yee, 2019)	The implementation of building-integrated photovoltaics in Singapore: Drivers versus barriers	Building-integrated photovoltaics (BIPV); Solar power; Drivers; Barriers	• This study aims to interpret the drivers and barriers that affect the utilization of BIPV systems • Results indicate that (1) economic benefits, (2) green mark certification and (3) CO2 reduction are the most influential drivers • By contrasts, (1) the long-term payback period, (2) high upfront cost and (3) low energy conversion efficiency are the most substantial barriers
(Luther et al., 2013)	Solar photovoltaic (PV) roadmap for Singapore (A summary)	Solar Photovoltaic (PV); Baseline scenario (BAS); Accelerated scenario (ACC)	• This study interprets the solar development scenario in Singapore, which includes the (1) baseline scenario and (2) accelerated scenario • The assessment of the future energy supply system in 2050 have been conducted
(Reindl et al., 2020)	Update of the solar photovoltaic (PV) roadmap for Singapore	Solar Photovoltaic (PV); Research and development (R&D); Energy Policy; Roadmap; Singapore	• The Singapore government has promoted the “solar leasing programme” and “renewable energy certificates (REC)” in recent years. • It has achieved its 2020 solar target of 350 (MWp) and working for at least 2 (GWp) by 2030.

Chang, Y., & Li, Y. (2013). The Singapore electricity market: From partial to full competition. Boston: Academic Press.

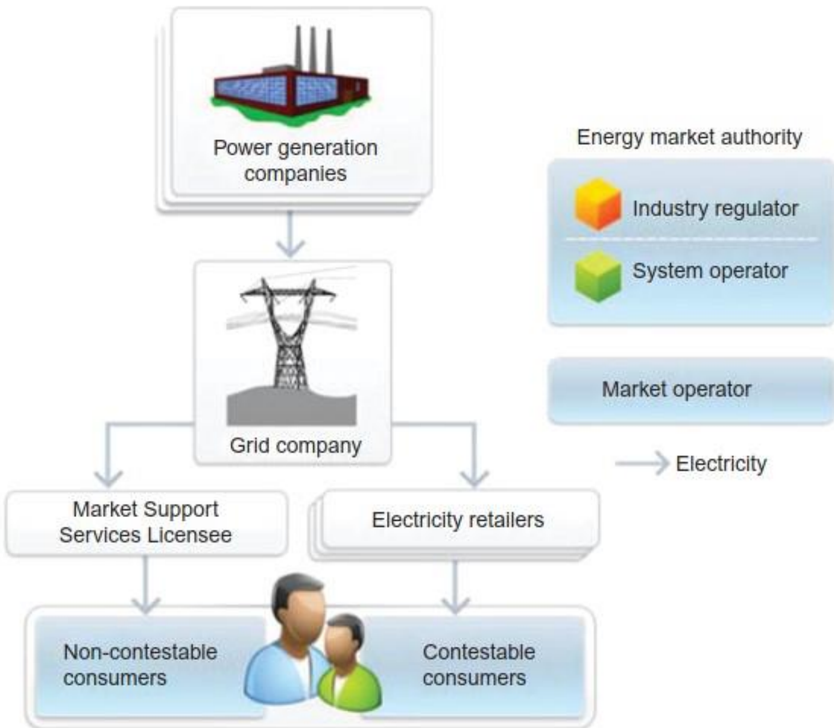

FIGURE 24.5 Electricity industry structure in Singapore. *Source: Energy Market Authority, Singapore.*

FIGURE 24.8 A schematic diagram of competitive wholesale electricity market. *Source: Energy Market Authority, Singapore.*

Lau, S.-K., Kosorić, V., Bieri, M., & Nobre, A. M. (2021). Identification of factors influencing development of photovoltaic (PV) implementation in Singapore. *Sustainability*, *13*(5). doi:10.3390/su13052630

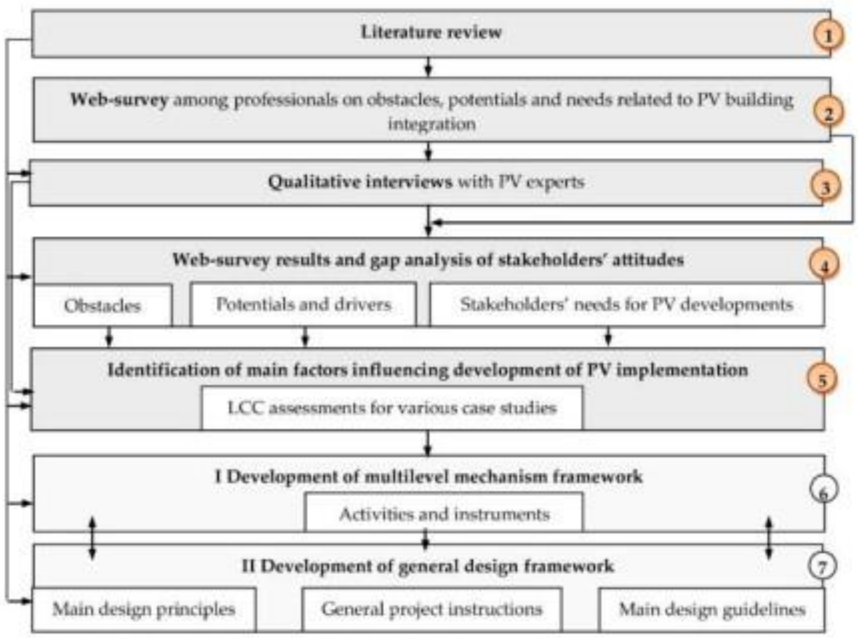

Figure 1. A methodology related to the development of a long-term holistic strategy for successful PV (photovoltaics) implementation into Singapore's built environment (the phases 1–5 (in orange) are performed in the first part of the study related to this paper).

Lu, Y., Chang, R., Shabunko, V., & Lay Yee, A. T. (2019). The implementation of building-integrated photovoltaics in Singapore: Drivers versus barriers. *Energy, 168*, 400-408. doi:10.1016/j.energy.2018.11.099

Table 1
Drivers for BIPV.

Code	List of Drivers	Sources														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D1	Positive impact on the property value	✓	✓	✓	✓		✓									
D2	Enhance green image for better marketing	✓			✓	✓										
D3	Generation of renewable energy which brings economic benefits		✓				✓		✓			✓		✓		
D4	Improve the performance of the building envelope							✓	✓							
D5	Obtain governmental incentive									✓	✓			✓		
D6	Achieve Green Mark certification						✓					✓			✓	
D7	Reduce CO_2 emission	✓		✓			✓					✓	✓		✓	
D8	Reduce dependency on fossil fuels	✓		✓			✓						✓		✓	
D9	Demonstrate green image and sustainable development to public	✓			✓	✓										
D10	Encourage the occupants to adopt pro-environmental behaviour				✓	✓										✓
D11	To be partially independent of the grid	✓						✓						✓		
D12	Grow industrial R&D capacities for technology			✓	✓					✓	✓					

Sources: 1 – Deo Prasad [6]; 2 – Pacheco-Torgal et al. [28]; 3 – Petter Jelle et al. [29]; 4 – Heinstein et al. [11]; 5 – Cholakkal [30]; 6 – Debbarma et al. [1]; 7 – Eiffert and Kiss [31]; 8 – Scognamiglio [2]; 9 – Pagliaro et al. [13]; 10 – Song et al. [14]; 11 – Harris and Roach [32]; 12 – Casini [33]; 13 – Biyik et al. [34]; 14 – Hashim and Ho [15]; 15 – Steg and Vlek [35].

Table 2
Barriers to BIPV.

Code	List of Barriers	Sources														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B1	Difficulties in obtaining governmental approvals (e.g. from different agencies)	✓														
B2	Lack of BIPV specific design standards and codes	✓		✓									✓	✓	✓	
B3	Uncertainties in BIPV policies (e.g. the source and stability of subsidy funds)	✓	✓			✓	✓	✓	✓	✓		✓		✓	✓	
B4	Lack of R&D support covering the entire industry chain of BIPV		✓			✓			✓					✓		
B5	Projects awarded to lower price tendering															✓
B6	Few choices for BIPV products									✓	✓					
B7	High upfront capital costs of BIPV		✓		✓	✓	✓	✓			✓			✓	✓	
B8	The long-term payback period of BIPV							✓	✓		✓					
B9	Low electricity tariff from conventional sources (i.e. natural gas)					✓										
B10	The low energy conversion efficiency of BIPV systems			✓		✓			✓							
B11	Difficulty in integrating BIPV into the grid			✓						✓		✓		✓	✓	
B12	Fluctuating energy generation due to weather			✓					✓							
B13	Unclear maintenance procedures (e.g. replacement of BIPV modules)			✓								✓				
B14	Few numbers of competent contractors and installers					✓		✓	✓							
B15	Lack of successful BIPV demonstration							✓		✓						
B16	Lack of BIPV knowledge for professionals					✓		✓	✓	✓						
B17	Additional time and efforts to collaborate with stakeholders (e.g. communications between engineers and designers)			✓												
B18	Lack of public awareness of BIPV				✓	✓	✓	✓			✓					

Sources: 1 – Ferrara et al. [19]; 2 – Song et al. [14]; 3 – Shukla and Sharma [36]; 4 – Sozer and Elnimeiri [7]; 5 – Yang and Zou [37]; 6 – Rahman et al. [20]; 7 – Goh et al. [38]; 8 – Azadian and Radzi [4]; 9 – Biyik et al. [34]; 10 – Jelle [23]; 11 – Mousa [39]; 12 – IEA [40]; 13 – Huo and Zhang [41]; 14 – Shen and Luo [42]; 15 – Lim [43].

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