Smart Energy, Sustainable Future

SINGAPORE ELECTRICITY MARKET OUTLOOK

(SEMO) 2016

24 OCTOBER 2016

First Edition

ENERGY MARKET AUTHORITY
991G ALEXANDRA ROAD
#01-29
SINGAPORE 119975
www.ema.gov.sg

Disclaimer:

The information in this document is subject to change and shall not be treated as constituting any advice to any person. It does not in any way bind the Energy Market Authority to grant any approval or official permission for any matter, including but not limited to the grant of any exemption or to the terms of any exemption. The Energy Market Authority reserves the right to change its policies and/or to amend any information in this document without prior notice. Persons who may be in doubt about how the information in this document may affect them or their commercial activities are advised to seek independent legal advice or any other professional advice as they may deem appropriate. The Energy Market Authority shall not be responsible or liable for any consequences (financial or otherwise) or any damage or loss suffered, directly or indirectly, by any person resulting or arising from the use of or reliance on any information in this document.

TABLE OF CONTENT

SECTION 1 INTRODUCTION

1.1 In Singapore's liberalised market environment, power generation investments are commercially driven. Prices in the electricity market send signals to investors to make investment decisions with respect to the timing of new plantings, as well as the amount of capacity and the type of technology. For such a market-based approach to work well, it is important that there should be adequate and quality information for investors when they make their investment decisions. This is especially so for the power sector, considering the high capital cost and significant lead time required for power generation planting.

1.2 The Energy Market Authority (EMA) continually seeks to work with the industry to ensure a conducive environment for power generation investments. A public consultation paper was launched in October 2015 to seek feedback on initiatives and enhancements to prepare for future power generation investments in Singapore. This led to the publication of the EMA's Final Determination paper "Preparing for Future Power Generation Investments in Singapore" (29 July 2016) [1], wherein EMA indicated that it will henceforth be releasing an annual information package to improve visibility on the longer term outlook of the energy landscape in Singapore. This inaugural Singapore Electricity Market Outlook (SEMO) [2] seeks to provide more forward-looking information such as the projected supply and demand conditions to facilitate power generation investment decisions, and complements existing publications such as the Singapore Energy Statistics, which covers historical information.

1.3 This edition also features a special section on the solar industry, produced in partnership with the Solar Energy Research Institute of Singapore (SERIS). This is particularly timely given the growing interest to deploy solar photovoltaic (PV) systems in Singapore. This section includes the estimated electricity generation profile from solar PV systems in Singapore, to help interested parties better understand the characteristics of solar PV's output in the local environment. The EMA has also worked with SERIS to provide an indicative forecast of the pipeline of solar PV projects as part of the initiative to provide the industry with more forward-looking information.

[1] More information on the initiatives can be found in the Final Determination paper "Preparing for Future Power Generation Investments in Singapore", published on 29 July 2016 https://www.ema.gov.sg/cmsmedia/Determination_Paper_%20Preparing_for_Future_Power_Generation_Investments_Final_29_Jul.pdf

[2] The information that is put out is intended to be indicative and non-binding, and is dependent on factors such as prevailing assumptions and projections, policy considerations and the broader macroeconomic climate.

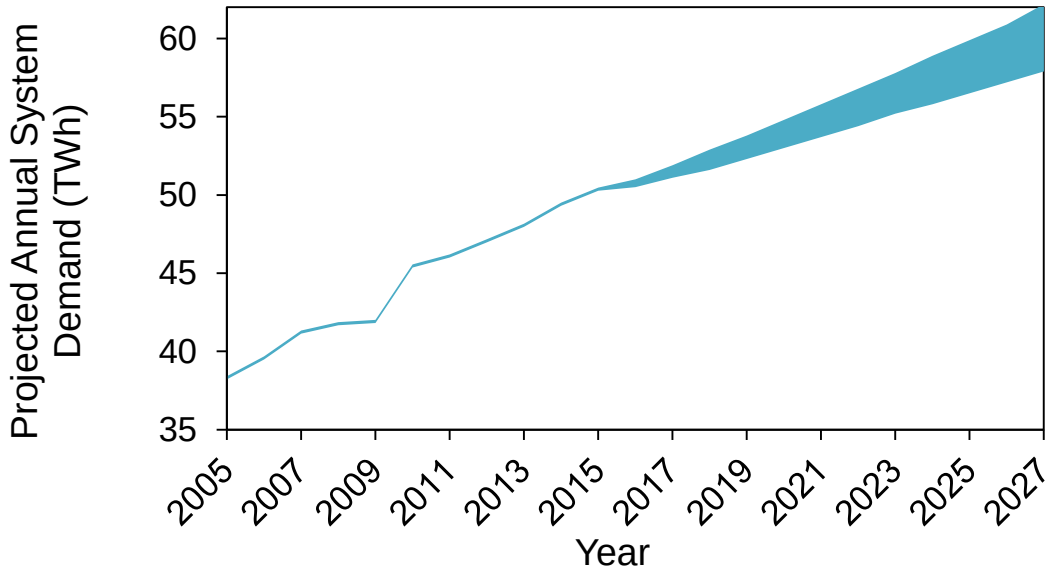
1.4 The EMA welcomes feedback on what information may be useful to include for future editions to enhance visibility on the longer term outlook of the energy landscape in Singapore, and support future power generation investments.

SECTION 2 ELECTRICITY DEMAND OUTLOOK

2.1 From 2005 to 2015, Singapore's system demand [3] has increased at a compound annual growth rate (CAGR) of 2.8%, while the system peak demand has increased at a CAGR of 2.4%.

2.2 The projected annual system demand and system peak demand are expected to grow at a CAGR of 1.3 – 1.8% from 2017 to 2027 (see Figures 1 and 2). This takes into account various factors, including changes to population and temperature, and projected Gross Domestic Product (GDP) growth rates.

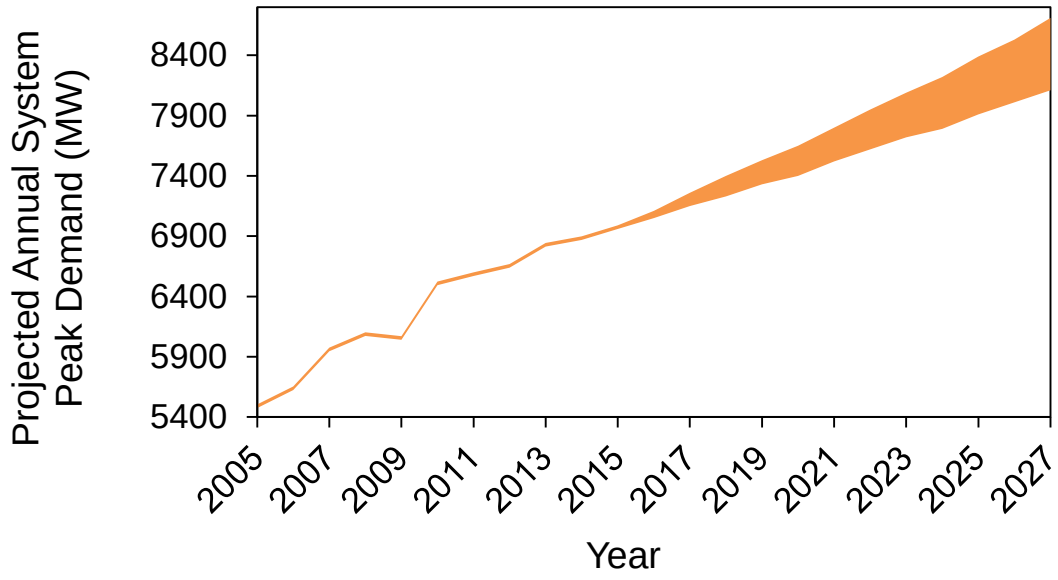
Figure 1: Projected Annual System Demand



Year	Projected Annual System Demand (GWh)
2017	51,100 – 51,900
2018	51,600 – 52,900
2019	52,300 – 53,900
2020	53,000 – 54,900
2021	53,700 – 55,900
2022	54,400 – 56,900
2023	55,200 – 58,000
2024	55,800 – 59,100
2025	56,500 – 60,200
2026	57,200 – 61,200
2027	57,900 – 62,200

[3] System demand here is defined as the electricity demand in Singapore, including demand met by generating units (including embedded generators), as well as distribution and transmission losses.

Figure 2: Projected Annual System Peak Demand



Year	Projected Annual System Peak Demand (MW)
2017	7,150 – 7,260
2018	7,230 – 7,400
2019	7,330 – 7,540
2020	7,400 – 7,660
2021	7,520 – 7,820
2022	7,620 – 7,970
2023	7,720 – 8,120
2024	7,790 – 8,250
2025	7,910 – 8,420
2026	8,010 – 8,570
2027	8,110 – 8,710

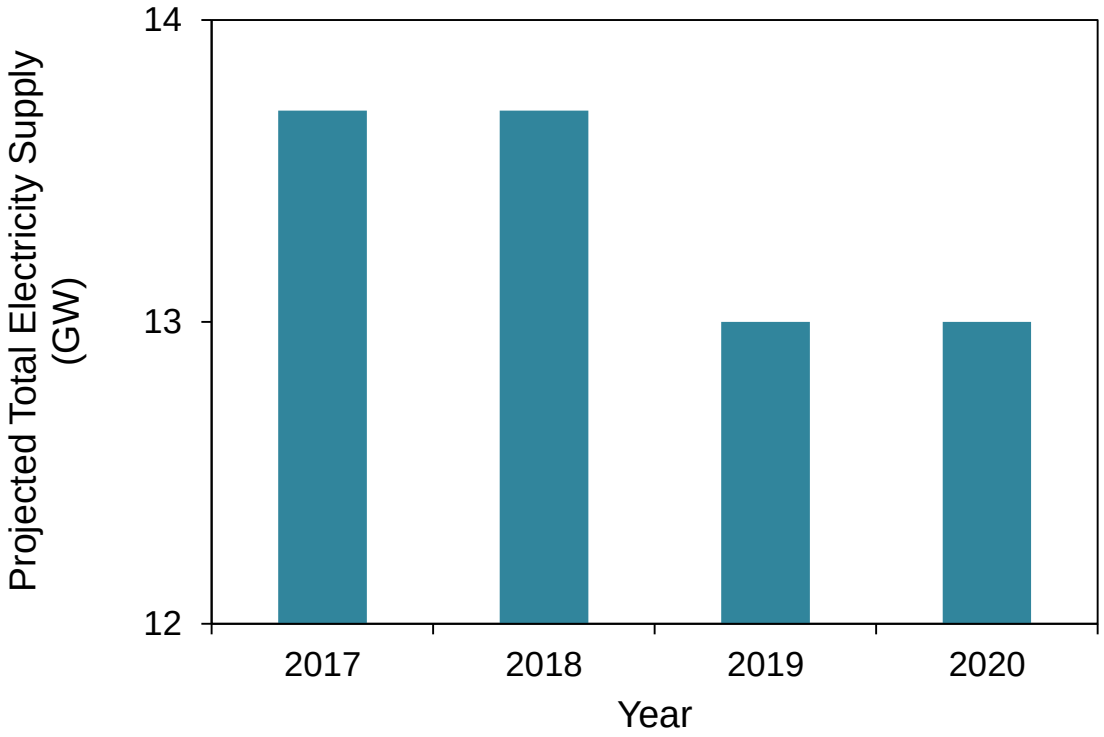
SECTION 3 ELECTRICITY SUPPLY OUTLOOK

3.1 Taking into consideration feedback received from the consultation exercise launched in October 2015, the EMA has enhanced the regulatory approval process for new and existing generation assets, so as to give better visibility of total generation capacity on a forward-looking basis.

3.2 The EMA will require generation licensees to provide its indicative generation plans (i.e. for retirement, repowering, life extension and new generation investments) with a notice period of at least 4 years[4]. Based on the feedback from the industry, the EMA will put out the electricity supply forecast on an aggregated basis to provide an indicative market supply condition outlook over the next 4 years.

3.3 The EMA has worked with the generation licensees for their indicative generation plans over the next 4 years. Based on the submissions received, the projected total electricity supply[5] over the next 4 years is indicated in Figure 3.

Figure 3: Projected Total Electricity Supply (Capacity) (2017-2020)



[4] More details can be found in the Final Determination paper "Preparing for Future Power Generation Investments in Singapore", published on 29 July 2016 https://www.ema.gov.sg/cmsmedia/Determination_Paper_%20Preparing_for_Future_Power_Generation_Investments_Final_29_Jul.pdf

[5] Based on the projected licensed capacity as of the end of the calendar year.

	Change(s) in Capacity (MW)	Projected Total Electricity Supply (Capacity) (MW)
2017	+300 (New Investments)	13,700
2018	0	13,700
2019	-700 (Retirement)	13,000
2020	0	13,000

3.4 Based on the above projected electricity demand and supply, the reserve margin over the next 4 years is expected to remain above 70%[6] (as shown in Figure 4[7]). The reserve margin is calculated (see formula in Figure 5) using the upper bound of projected annual system peak demand numbers from Figure 2 and the projected total electricity supply numbers from Figure 3.

Figure 4: Projected Reserve Margins (2017-2020)

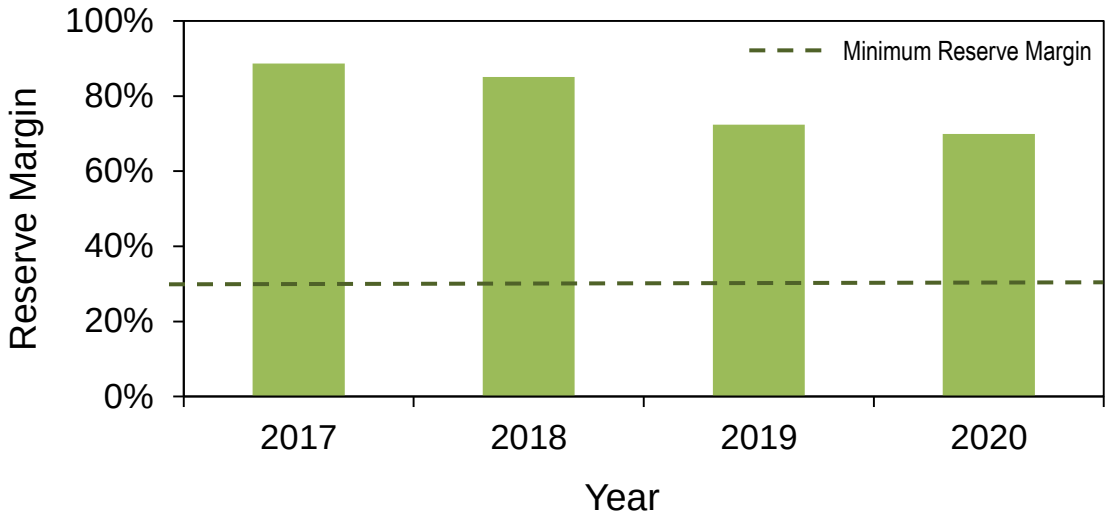


Figure 5: Reserve Margin Formula

$$\text{Reserve Margin} = \frac{\text{Total Electricity Supply (Capacity)} - \text{System Peak Demand}}{\text{System Peak Demand}} \times 100\%$$

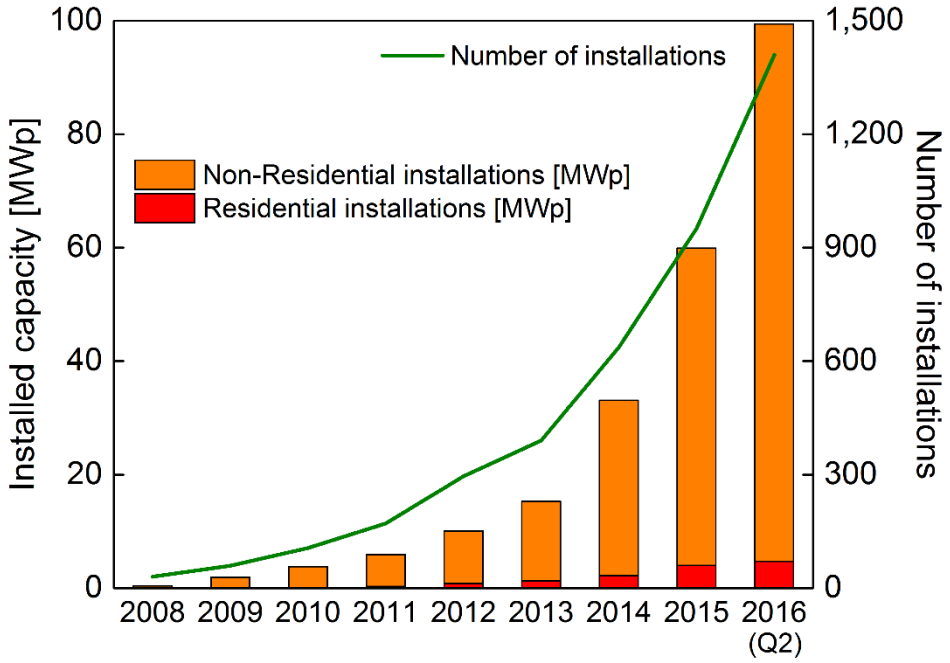
[6] In Singapore, the minimum reserve margin has been set at 30% to ensure system security is maintained.

[7] The reserve margin is a system-wide indicator. Potential investors should also consider any potential localised transmission constraints. More information on the development of Singapore's Transmission Network can be found in the Information Paper "Developments in the Singapore Electricity Transmission Network": https://www.ema.gov.sg/cmsmedia/Licensees/Electricity-Policy-Papers/Developments_in_the_Singapore_Electricity_Transmission_Network_05042011.pdf

SECTION 4 SPECIAL TOPIC: SOLAR GENERATION OUTLOOK

4.1 Advancements in electricity generation technologies will open up more options for Singapore's power sector, including the use of renewable energies such as solar PV. The EMA recognises the growing interest in solar PV deployment in Singapore; the installed PV capacity has grown from 0.4 MWp as at end 2008 to 99.4 MWp as at end-Q2 2016 (Figure 6).

Figure 6: Growth in the Number of Solar Installations and Overall Solar Capacity (2008 – 2016 Q2)



4.2 The EMA has received suggestions from the industry to put out more information related to solar PV to better understand its characteristics and potential impact on the electricity market. As such, the EMA has worked with SERIS to provide the following information to the industry:

(i) Average solar irradiance profile (W/m^2) and generation profile (kWh/kWp);

(ii) Annual average of irradiance data with exceedance probability assessment (kWh/m^2);

(iii) Typical performance ratio, specific yield and degradation; and

(iv) Indicative pipeline of solar projects up to the first half of 2017.

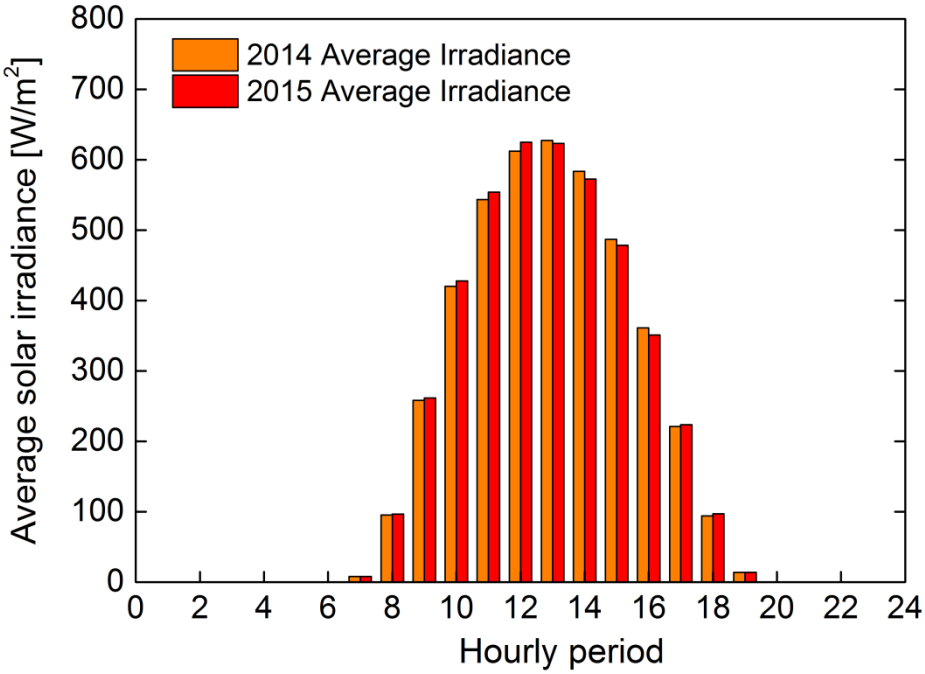
The following concepts can help investors calculate the commercial viability of solar PV projects:

- **Solar irradiance** is the average amount of solar power received per unit area. Solar irradiance differs from country to country and is dependent on the geographical location of a particular area.
- As the solar irradiance in a particular area can vary across the years, the **exceedance probability assessment** provides a measure of how likely the irradiance level would be exceeded based on the historical irradiance data measured in Singapore.
- The solar generation output will typically differ from the specifications provided by the manufacturers which are measured under "standard test conditions" (at a module temperature of 25 degrees Celsius and an irradiance of 1000 W/m^2 with an air mass of 1.5). The **performance ratio** therefore is a measure of how well a PV system converts solar irradiance into electricity, and is affected by factors such as temperature differences and irradiation that falls on the system. The performance ratio allows comparison across systems with different irradiation levels, and after factoring in efficiency losses each year (or "**degradation**" factor), enables investors to derive the **yield** which is the amount of energy (kWh) the solar PV system can generate.
- In the Singapore electricity market, wholesale prices fluctuate based on supply and demand conditions. The **solar generation profile**, which provides an estimated amount of solar generation output at different times of a typical day, is therefore another pertinent consideration when calculating the payback of investments for solar PV systems.

4.3 As the generation output of solar PV is non-dispatchable, the key factor to consider for solar PV output is the prevailing weather condition. In particular, the solar output is a function of the amount of solar irradiance received by the solar PV modules. From the 2014 and 2015 solar irradiance data provided by SERIS[8], the average hourly irradiance in Singapore reaches its peak at ~625 W/m^2 between 1200hrs to 1300hrs. The daily solar irradiance profiles in 2014 and 2015 were similar, with slightly more irradiance recorded in the mornings and less in the afternoons in 2015 compared to 2014 (see Figure 7). Another observation is that instantaneous peaks of solar irradiance can be significantly higher than the average hourly irradiance, exceeding ~1000 W/m^2 during certain times. The main reason for the relatively lower peak values compared to "Standard Test Conditions" (STC) is the high variability of the irradiance levels due to fast-moving clouds in the tropics.

[8] Based on 25 weather stations operated and maintained across Singapore, see www.solar-repository.sg for the live-irradiance map

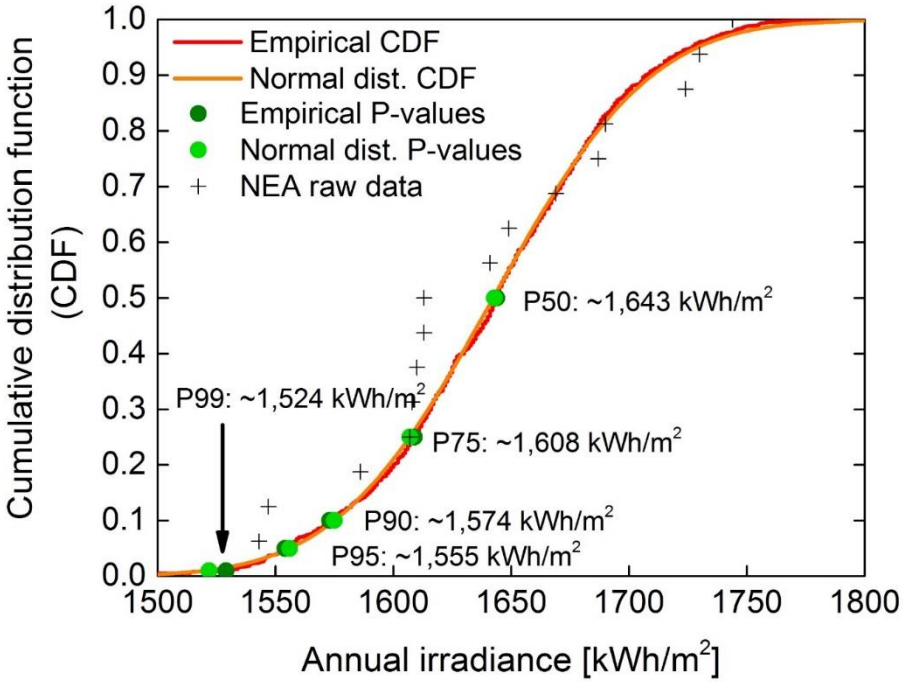
Figure 7: Solar Irradiance Data of Singapore (2014 & 2015)



4.4 Based on the 2014 and 2015 solar irradiance data (see Figure 7), the daily average is about 4.3 kWh/m^2 which translates into an annual irradiance level of ~1,580 kWh/m^2 averaged across Singapore. Year-on-year irradiance variations within 10% are not uncommon, which will affect the output of solar systems. This could explain why the annual irradiance level in recent years is lower than the ~1,630 kWh/m^2 irradiance level derived by Meteonorm[9] and the average of ~1,643 kWh/m^2 compiled from 16 years' data recorded by the Changi meteorological station of National Environment Agency (NEA). The exceedance probability assessment of the NEA data is shown in the associated cumulative distribution function (CDF) curve (see Figure 8). The P50-P99 values indicate the probabilities that the corresponding irradiance levels will be exceeded. For example, a P90 value of 1,574 kWh/m^2 for the annual irradiance level means that there is a 90% likelihood that the irradiance will be greater than 1,574 kWh/m^2. Understanding annual irradiance levels in the Singapore context would enable investors to understand the return of investments for solar PV projects, and their potential sensitivity to inter-annual irradiance variations.

[9] Meteonorm uses ground station measurements from different sources and the global radiation dataset is produced by interpolating ground measurements and satellite data.

Figure 8: Exceedance Probability Analysis of NEA Irradiance Data



4.5 The solar generation output for a given solar installation is based on its performance ratio (PR), which is the percentage of irradiance the system can convert into electricity based on (i) the amount of the solar resource reaching the plane of array (POA) of the PV installation; and (ii) the nominal system capacity at STC. The PR is affected by a number of parameters which include cable losses, soiling of the module surface, temperature effects, and reflection losses among others. A simplified formula of the PR[10] is given below:

$$\text{Performance ratio (\%)} = \frac{\text{Specific yield}}{\text{Reference yield}}$$

$$\text{Specific yield (kWh/kWp)} = \frac{\text{Net AC energy output (kWh)}}{\text{Nameplate DC power (kWp)}}$$

$$\text{Reference yield (kWh/kW)} = \frac{\text{In-plane irradiance (kWh/m}^2\text{)}}{\text{Reference irradiance (kW/m}^2\text{)}}$$

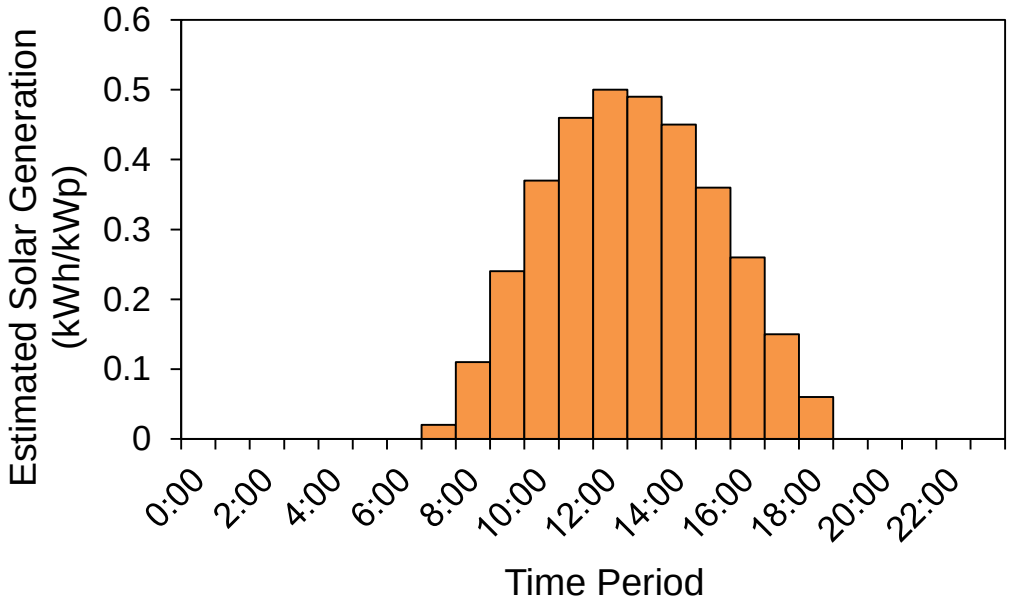
4.6 Well-designed systems in Singapore can achieve a PR of 80% or more, which results in a specific yield of ~1,260-1,300 kWh/kWp (depending on the annual irradiance resource). The specific yield can be used as a basis for the first

[10] A. Nobre, Z. Ye, H. Cheetamun, T. Reindl, J. Luther, C. Reise, High Performing PV Systems for Tropical Regions - Optimization of Systems Performance, 27th European Photovoltaic Solar Energy Conference and Exhibition

year of a system's operation, after which SERIS recommends to take into account an annual degradation rate of ~0.8% for tropical climates for the subsequent years of operation. In addition, air pollution, such as a prolonged period of haze, can impact the system's electricity generation adversely. Research by SERIS shows that a Pollutant Standard Index (PSI) of >100 can reduce the daily yield by 17% to 21%.[11]

4.7 Figure 9 shows the estimated solar generation profile per kWp of installed PV capacity during typical sun-hours (taking the average 2014 and 2015 irradiance profile from Figure 7) based on a PR of 80%.

Figure 9: Average Solar Generation Profile during Sun-Hours



Time Period	Estimated Solar Generation (kWh/kWp)
0700-0800	0.02
0800-0900	0.11
0900-1000	0.24
1000-1100	0.37
1100-1200	0.46
1200-1300	0.50
1300-1400	0.49
1400-1500	0.45
1500-1600	0.36
1600-1700	0.26

[11] André M. Nobre, Shravan Karthik, Haohui Liu, Dazhi Yang, Fernando R. Martins, Enio B. Pereira, Ricardo Rüther, Thomas Reindl, Ian Marius Peters, On the impact of haze on the yield of photovoltaic systems in Singapore, Renewable Energy, Volume 89, April 2016, Pages 389-400.

1700-1800	0.15
1800-1900	0.06

4.8 The release of data for solar irradiance and the estimated total solar generation profile in hourly periods for Singapore is intended to help investors make informed decisions on power generation investments, as well as to provide stakeholders with a better understanding of the potential impact of solar PV on the electricity system and market.

4.9 The EMA has also worked with SERIS based on inputs provided by industry stakeholders to provide an indicative forecast of the pipeline of solar PV projects, which is estimated to be **40 to 50 MWp for the 2H 2016 and 60 to 70 MWp for 1H 2017**. This will provide more visibility to the industry on the potential growth of solar PV in Singapore.

4.10 The EMA will continue to study how we can work with SERIS and the industry to refine the information and facilitate the deployment of solar PV in Singapore.