ENHANCEMENTS TO THE REGULATORY FRAMEWORK FOR INTERMITTENT GENERATION SOURCES IN THE NATIONAL ELECTRICITY MARKET OF SINGAPORE

CONSULTATION PAPER

Closing date for submission of comments and feedback:

28 January 2014

28 October 2013

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EXECUTIVE SUMMARY

1. The Energy Market Authority ("EMA") is undertaking a comprehensive review of the regulatory framework for intermittent generation sources to maximise the deployment of these energy sources in Singapore when the technologies become commercially viable. These generation sources differ from conventional generation sources because their output depends on environmental factors and weather conditions. Based on experiences in other jurisdictions, the intermittency could result in blackouts and power disruptions if it is not properly addressed. This consultation paper puts forth a suggested approach with the objective of seeking feedback from the industry and the public.

2. In doing the review, the EMA has sought to identify and address the potential issues that an intermittent generator investor may face. This includes providing clarity on the licensing framework, the installation procedures as well as the electricity market registration and participation process. In addition, the EMA intends to streamline the market registration procedures to make it easier for consumers with small embedded intermittent generation sources to be paid for excess energy injected into the grid.

3. From a system-wide perspective, given the intermittent output of such generation sources, the EMA has also reviewed how the overall system security and stability can be maintained when the uptake for such technologies increases. There are several options that the EMA has considered. One way is to impose a hard cap on the total amount of intermittent generation capacity in the system. The cap is currently set at 350 MWp. As part of this review, the EMA's assessment is that the hard cap option will limit the future growth potential of intermittent generation sources in Singapore and hence is not favoured in the longer term. A better option is a "dynamic pathway" to allow the entry of such technologies by ensuring sufficient reserves in the system to manage the intermittency of these sources, subject to the physical and technical limits of reserves availability in the system. This is a more sustainable framework as it could facilitate the increasing entry of such technologies when they become commercially viable.

4. The dynamic pathway framework involves the setting of two key thresholds: the Intermittent Generation Threshold ("IGT") and the Intermittent Generation Limit ("IGL"). The IGT is the amount of intermittent generation sources the system can accommodate based on the existing amount of reserves **procured**, while the IGL is the maximum intermittent generation capacity based on the largest possible amount of **available** reserve in the system. After careful evaluation, the EMA has decided to raise the IGT from 350 MWp to 600 MWp. The IGL is subject to further review as it depends on the extent and pace of developments such as energy storage solutions and interconnections with regional power grids.

5. Besides the negative externalities due to intermittency, EMA recognizes that there are positive externalities associated with intermittent generation sources like solar energy. One example is peak load shaving, as solar energy is produced in the day which typically coincides with the system peak demand. This puts downward pressure on pool prices, as consumers with solar panels effectively draw less energy from the grid when

there is solar production. Because of the marginal pricing system used in the market, a drop in pool price benefits the broader consumer base. Hence, there is merit to consider whether a portion of the resultant consumer surplus arising from peak load shaving can be shared with the owners of embedded intermittent generation sources. As such, the EMA is considering the implementation of a pricing mechanism to address this. Specifically, the EMA is reviewing how the Demand Response scheme can be enhanced to recognise the peak load shaving effect, as well the how the reserves changing methodology can be modified for intermittent generation sources. By recognising both positive and negative externalities, the aim is to set the right pricing signals to facilitate optimal deployment and investment of intermittent generation sources.

Consultation Process

6. This paper constitutes part of the EMA's consultation process to determine the implementation approach to facilitate the deployment of intermittent generation sources.

7. The EMA invites comments and feedback to the consultation paper. Please submit written feedback to EMA_PPD@ema.gov.sg by 28 January 2014 (5pm). Alternatively, you may send the feedback by post/fax to:

   Policy Department
   Energy Planning and Development Division
   Energy Market Authority
   991G Alexandra Road, #01-29
   Singapore 119975
   Fax: (65) 6835 8020

8. Anonymous submissions will not be considered.

9. The EMA will acknowledge receipt of all submissions electronically. Please contact Ms Lyana Yeow at 6376 7624 or Ms Leow Rui Ping at 6376 7759 if you have not received an acknowledgement of your submission within two business days.

10. The EMA can facilitate meetings with stakeholders on an individual basis to discuss their feedback to this consultation paper. Please contact EMA via EMA_PPD@ema.gov.sg if you wish to arrange a meeting.

11. The EMA reserves the right to make public all or parts of any written submissions made in response to this consultation paper and to disclose the identity of the source. Any part of the submission, which is considered by respondents to be confidential, should be clearly marked and placed as an annex which the EMA will take into account regarding the disclosure of the information submitted.

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1.1. Objective of the Consultation Exercise

1.1.1. The EMA is reviewing how the regulatory framework for intermittent generation sources can be enhanced, with the objective of maximising the potential of intermittent generation sources when the technologies are commercially viable, while ensuring that system security and stability are not compromised. This consultation paper puts forth a series of proposed changes to the regulatory framework to seek feedback from the industry and public.

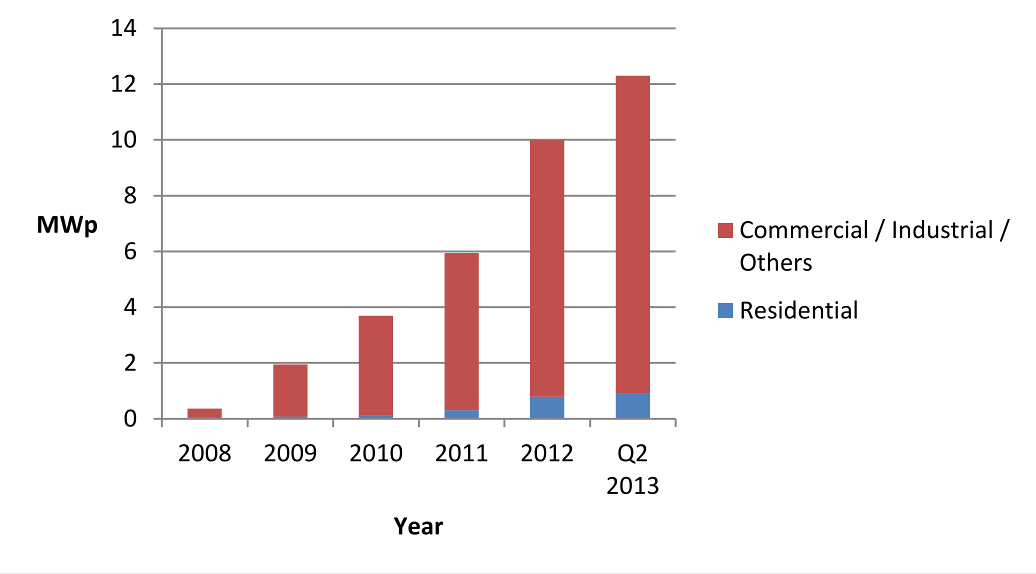
1.2. Overview of Intermittent Generation in Singapore

1.2.1. An intermittent generation source is defined as any source of energy that is non dispatchable in the National Electricity Market of Singapore ("NEMS") because the power output cannot be controlled or varied at will. Examples of intermittent generation sources include renewable sources of energy ("renewables") such as solar energy and wind energy[1].

1.2.2. Given Singapore's geophysical landscape, not all renewables can be harnessed for energy production. Of all the renewable options, solar energy has the highest potential for Singapore, as the country is located within the tropical sunbelt with relatively good irradiance levels. Figure 1.1 shows the growth of the intermittent generation capacity in Singapore. At present, the only intermittent generation source in Singapore connected to the grid is solar photovoltaic (PV) technology, which stands at approximately 12 MWp as of June 2013. About 92% of the total solar PV installed capacity was installed by commercial and industrial consumers, while the remaining 8% were installed on residential premises.

[1] Intermittent generation sources integrated with technological solutions such as storage would not be classified as intermittent if they can demonstrate that they are dispatchable.

Figure 1.1: Trend in total solar PV installed capacity in Singapore from 2008 - Q2 2013



Source: Energy Market Authority

1.2.3. The EMA has already implemented several initiatives to facilitate the entry of solar energy in Singapore, which are summarised below.

a. *Streamlining of procedures for selling excess solar energy to the grid.* Previously, selling back excess solar energy to the grid require the installations' owners to register with the operator of Singapore's electricity market, the Energy Market Company ("EMC"), similar to how other generators are registered in the market. Since 2007, the EMA has waived this requirement for *residential* consumers with installations smaller than 1 MW. This was further extended to *non-residential* non-contestable consumers ("NCCs") in 2011, making it easier for small consumers to be paid for any solar energy they supply to the grid.

b. *Publication of Handbook for solar PV system[2].* In 2009, the EMA and the Building Construction Authority ("BCA") published a handbook for solar PV installations to provide information on licensing, market and technical requirements and building and structural issues related to the implementation of solar PV systems. This handbook serves as a useful guide for residential dwellers and building developers when considering the deployment of solar PV installations.

1.2.4. As the cost of generation using renewables declines with technological improvements and economies of scale in production, a greater uptake of solar deployment is expected. This review seeks to enhance the NEMS framework and the system infrastructure to facilitate the entry of such technologies when they become commercially viable, taking into consideration the characteristics of such intermittent generation sources (refer to Sections 1.3 and 1.4).

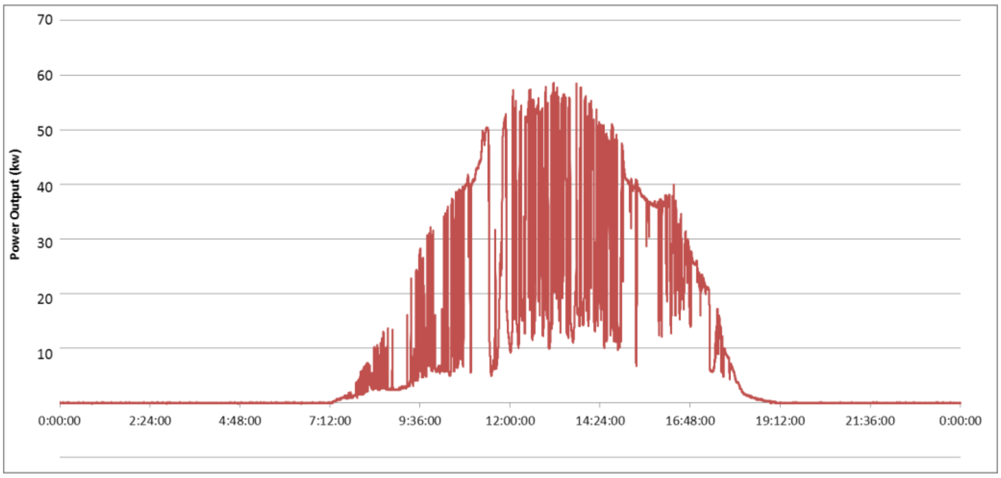
[2] http://www.ema.gov.sg/images/files/EMA%20Solar%20Handbook_Apr%202011.pdf

1.3. Characteristics of Intermittent Generation

1.3.1. Electricity generated from intermittent renewable energy sources produces no emissions. Using such sources also enhances Singapore's energy security as it reduces the amount of fuel imports for power generation. Sources such as solar energy can also reduce overall peak electricity demand, given that the peak energy usage in Singapore coincides with periods when solar energy can be produced.

1.3.2. Another key characteristic of an intermittent generation source is that its output is variable and dependent on weather conditions, as compared to a conventional generator that produces a stable output. The intermittency power output from a 63 kWp solar PV on a typical day in Singapore is shown in Figure 1.2. The output is largely dependent on environmental factors and weather conditions, such as the amount of irradiance, cloud cover and shadows. For example, a moving cloud could cause a sudden drop in solar energy output, which means that conventional generators need to be on standby to make up for the shortfall. As such, intermittent generation sources impose a cost on the system because the Power System Operator ("PSO") needs to ensure that sufficient reserves are available online to cater for changes in output of such generation sources. Managing the intermittent nature of such technologies is a challenge that needs to be addressed, especially given that this has caused power disruptions and contributed to grid instability in other jurisdictions with more significant amounts of such energy sources in their fuel mix.

Figure 1.2: Variability in output of a solar PV installation in Singapore on a typical day



Source: Energy Market Authority

SECTION 2 LICENSING

2.1. Licensing Framework for Intermittent Generation Sources

2.1.1. The EMA has reviewed the licensing framework application for intermittent generation sources. Under the current regulatory framework, any person who engages in the generation of electricity with a generating unit having a name-plate capacity of between 1 MW or more but less than 10 MW, is required to hold a wholesaler licence; and any person who engages in the generation of electricity with a generating unit having a name-plate capacity of 10 MW or more, is required to hold a generation licence. While the definition of “name-plate capacity” is clear for conventional generating sets, the EMA has received feedback from the industry that the definition is less clear for intermittent generation sources, given that there are two capacities for such sources – the Direct Current (“DC”) and the Alternative Current (“AC”) capacities.

2.1.2. Consistent with how the EMA treats conventional generation sources - which are based on AC capacities – the aggregate of the AC capacities of intermittent generation sources at the point of connection[3] to the grid will be used to determine the threshold for licensing requirements. For solar PV panels, the aggregated AC capacity of the inverters will be used. By measuring the AC capacity of intermittent generation at the inverter, rather than the DC capacity of each solar PV panel, this would also be aligned with the current practice of measuring conventional generation capacity based on its AC name-plate capacity. Given this context, with respect to the regulatory framework for intermittent generation sources, all references to ‘intermittent generation (installed) capacity’ would refer to the aggregate capacity at the AC inverters.

2.1.3. The EMA has also reviewed the licence conditions for the wholesaler and generation licences and has assessed that the licensing framework is generally applicable for intermittent generation sources. Where an intermittent generation facility assesses that it would require exemptions from specific licence conditions, they may submit waiver applications to the EMA for approval.

[3] The point of connection refers to the point where the intermittent generation facility is connected to the SP PowerAsset’s (SPPA) substation.

SECTION 3 PROCEDURES FOR INSTALLING INTERMITTENT GENERATION SYSTEMS

3.1. Procedures for Installing Intermittent Generation Systems

3.1.1. Currently, all electrical installations, including those with intermittent generation (e.g. solar PV system) are required by the EMA to be operated and maintained by Licensed Electrical Workers ("LEWS") to ensure that the installations are safe for use. Under the current arrangements, before the connection and operation of any intermittent generation sources parallel to the grid, the LEW appointed by the owner of the installation is required to consult SP PowerGrid ("SPPG") on the connection scheme and the technical requirements. This is followed by the LEW applying to SPPG for the installation to be connected to the grid. More details on the connection process and technical requirements can be found in the following documents:

a. Handbook "How to Apply for Electricity Connection", published on SP Services ("SPS")'s website: http://www.singaporepower.com.sg/irj/portal/resources

b. The Transmission Code and Metering Code, published on the EMA's website: http://www.ema.gov.sg/page/89/id:132/

3.1.2. In turn, SPPG keeps a registry of all grid-connected intermittent generation, which contains details such as the location as well as capacities of the respective installations. This registry is important because it allows the EMA to track the aggregate amount of solar installations and their corresponding locations in the system for the purpose of ensuring power system stability, both at the localised level as well as the system level. The registry will also be used to allocate the relevant reserves costs to the respective intermittent generation owners based on their installed capacities.

3.1.3. Owners of intermittent generation sources will also be required to inform SPPG before they disconnect or retrofit their grid-connected systems. This is to ensure that disconnected systems will be removed from the registry so that they will not be allocated reserves charges. Likewise, retrofitted systems with increased (or decreased) generation capacities will have the allocation of their reserves charges adjusted accordingly. In addition, LEWs will also be required to inform SPPG of any retrofitting works or disconnections.

SECTION 4 MARKET PARTICIPATION AND MARKET SETTLEMENT

4.1. Overview of Market Participation and Market Settlement

4.1.1. Under the existing Market Rules, all generators are required to be registered as Market Participants ("MP") with the EMC if they are at least 1 MW, or if they want to be paid for any energy injected into the grid in the case of embedded generators of less than 1 MW.

4.1.2. The EMC administers the market registration process in accordance with the procedures set out in the Market Rules and Market Manuals. To register as a MP, interested parties are required to submit and enter into, among other documents and agreements[4], the following:

4.1.2.1. *PSO / MP agreement*. This establishes a contractual relationship between PSO and each Market Participant, to enable the parties to enforce obligations under the contract law.

4.1.2.2. *MP / MSSL agreement.* This is for the provision of meter readings for wholesale market settlement.

4.1.3. Generation facilities below 10 MW are required to be registered as Generation Settlement Facility ("GSF") for settlement of excess energy exported into the grid. Generation facilities above 10MW are required to be registered as Generation Registered Facility ("GRF") for dispatch by the PSO and settlement in the wholesale electricity market. For both GSFs and GRFs, a PSO Data Form must be completed to provide the PSO with the technical specifications of the generation facility. This is for monitoring purposes and for feeding inputs into the market clearing engine to determine prices and dispatch schedules (if applicable). GSFs and GRFs are then paid their respective nodal prices for electricity injected into the grid.

4.1.4. However, the above requirements have been waived for NCCs with generation sources less than 1 MW[5]. In Feb 2011, the EMA allowed NCCs (both residential and non-residential) with generation less than 1 MW to enjoy "simplified credit treatment". Under this arrangement, this group of consumers can get paid for excess energy injected into the grid without having to register with EMC.

4.1.5. The following section clarifies the requirements for market registration and settlement for the injection of excess electricity by intermittent generators. In

[4] Refer to EMC's *Guide to Participation in the Singapore Wholesale Electricity Market* for an overview of the procedures and requirements for registration as a Market Participant. The guide is available at: https://www.emcsg.com/f143,68842/EMC_Registration_Guide.pdf

[5] For more details, refer to EMA's Decision paper on "Review of Policy on Generation with Less than 1MW in Installed Capacity", dated 28 Feb 2011. The paper is available at: http://www.ema.gov.sg/media/com_consultations/feedback_files/4d6b4bd4976e5Decision_Paper_REVIEW_OF_POLICY_ON_GENERATION_WITH_LESS_THAN_1MW_final_28Feb2011.pdf

reviewing this, the EMA's key considerations are to ensure that the rules create a level playing field among different generation technologies, while facilitating the entry of intermittent generators.

4.2. Simplifying the Market Registration and Settlement Process for Intermittent Generators (and other Embedded Generators ("EGs")) Less than 1 MW

4.2.1. The EMA has received feedback from CCs with embedded generation less than 1 MW (including intermittent generation sources) that the current market registration process may be onerous, given the obligations imposed by the numerous market agreements.

4.2.2. The EMA intends to simplify the market registration process for consumers with small generation (including intermittent generators) less than 1 MW. Examples of the proposed streamlined market registration process for generating units less than 1 MW includes signing simplified PSO-MP and MSSL-MP agreements, a simplified PSO data form[6] as well as waiver of conditions not applicable to such generators such as the putting up of the security deposit.

4.2.3. As a further enhancement for consumers with intermittent generation sources less than 1 MW who register directly with EMC, they will be automatically granted price neutralisation[7] and net-treatment of non-reserves[8] charges applicable for EG. This means that there is no need for this group of consumers to first apply to the EMA to be granted EG status to enjoy the above benefits.

4.2.4. The EMA is also reviewing how to enhance the simplified credit treatment to allow CCs with embedded intermittent generation sources less than 1 MW to be paid through SPS. A separate consultation paper will be issued on this.

4.3. Market Participation for Intermittent Generators Above 1MW

4.3.1. As more intermittent generation sources enter the system, there is a need to review how they interact with the market for the purpose of dispatch and price setting. Currently, all generators above 1 MW, depending on their installed capacity, need to be registered in the NEMS as GSF or GRF. One key difference between the two groups is that the latter class of market participants are required to submit half-hourly offers and are subject to dispatch. In particular, as the output of intermittent generation sources are dependent on weather conditions and are therefore

[6] Data such as output will still be required for the purpose for analysis, such as determining whether there is geographical diversity.

[7] Price neutralization refers to the equalization of price differential between the electricity injection and withdrawal nodes using a credit/debit factor. The purpose is to allow EGs that generation electricity for its consumption to offset generation against their associated load so that only excess generation at each node is paid at the respective energy price, or excess load is charged at (USEP + Hourly Energy Uplift Charge ("HEUC")) in the energy settlement.

[8] Non-reserves charges refers to the EMC fees, PSO fees, Monthly Energy Uplift Charge ("MEUC"), Market Support Services (MSS) fess, and intermittency charges (if applicable – refer to section on reserves charging).

essentially not controllable, it is not practicable for such generation facilities to submit price-quantity offers into the market.[9] In addition, in Singapore's context, intermittent generation sources are likely to be individually small (and are therefore not registered as MPs), but cumulatively they could have a significant impact on the demand forecast.

4.3.2. One possible arrangement is for the PSO to centrally forecast the aggregate output of all intermittent generation sources in the system. The forecasted output of all intermittent generators will be subtracted off the total system forecast demand. This lowers the forecasted system demand, and is analogous to incorporating the forecasted output as generation offered into the market. This method of centralized forecasting has the advantage of allowing the PSO to have a better overview of the aggregate output for the purpose of ensuring system security; as compared to individual intermittent generation sources submitting their own injection forecast into the market (refer to Section 6 for more details).

4.3.3. Similar to other GSFs and GRFs, payment for the export of electricity will be based on their respective nodal prices, less the applicable reserves and non-reserves charges.

[9] The exception is for intermittent generation sources with storage facilities, where the requirements to submit offers and be subject to dispatch will still apply.

SECTION 5 INTERMITTENT GENERATION THRESHOLD AND LIMIT

5.1. Overview of Intermittent Generation Threshold and Limit

5.1.1. Because of the variable nature of intermittent generation sources, both regulation and spinning reserves are critical to ensure system stability during periods of low output levels. For example, a solar PV panel may be producing 1 MWh of energy in a particular period on a sunny day, but a sudden cloud cover may cause the PV output to drop quickly, therefore requiring the need for regulation and/or spinning reserves to make up the shortfall. Otherwise, there could be blackouts and power disruptions.

5.1.2. There are several ways to address this concern. One option is to impose a hard cap on the total amount of intermittent generation sources to limit the impact on the system. The current limit of 350 MWp exists as part of the current regulatory framework for intermittent generation sources. Once the cap has been reached, the EMA will not allow the further entry of such sources into the grid. The deployment of intermittent generation sources within limits of the hard cap can be done on a "first-come-first-serve" basis or through an auction mechanism where owners of such generation sources bid for permits to install. However, this option would mean that the growth potential of the intermittent generation will be restricted by the hard cap, which will limit the deployment of such technologies when they become commercially viable. In addition, this option raises the question of what is an appropriate allocation method: a "first-come-first-serve" allocation would restrict the entry of newer technologies and therefore would increase the barrier of entry for more efficient sources, while methods such as an auction could potentially raise the cost of entry for these generation sources and create uncertainty for investors.

5.1.3. Another option is a "dynamic pathway" to allow the entry of such technologies, while always procuring sufficient reserves to manage the intermittency of such sources subject to the technical limit of reserves availability. This means that similar to other generation technologies, intermittent generation sources bear their share of the costs of the reserves in accordance to the cost allocation mechanisms for each category of reserves. The EMA's preference is to adopt this option as there are several advantages in doing so: firstly, from the perspective of market design, it is more equitable as this allows various generation sources to compete on a more level playing field by allocating the appropriate system costs to the respective technologies. Secondly, this option will be more sustainable in the longer term as the growth potential of intermittent generation capacity will not be limited by a hard cap. In addition, by pricing the costs of reserves correctly, it provides the incentives for investors to evaluate technologies like energy storage and other solutions which can help mitigate intermittency. Such a market-based mechanism would encourage investment decisions that deliver a more efficient outcome for all stakeholders.

5.2. Intermittent Generation Threshold ("IGT")

5.2.1. The dynamic pathway option will have two key thresholds. The first threshold is the IGT, which is the amount of intermittent generation capacity that the system can accommodate based on the existing amount of reserves procured. Below the IGT, intermittent generation will share the costs for that amount of reserves with the other generation sources, based on the current cost charging mechanism which exists in the wholesale electricity market (refer to Section 6 for more details on how reserve costs are allocated). After careful evaluation, the EMA intends to raise the IGT from 350 MWp to 600 MWp[10]. This threshold will be regularly reviewed and could be further increased in future. To facilitate planning and investment decisions for intermittent generation sources, the IGT and aggregate capacity of such technologies in the registry maintained by SPPG will be made known to the industry.

5.2.2. The IGT level is dependent on two factors. The first factor is the amount of reserves procured to cater for the failure of the single largest generation facility in the system. Should the reserves requirement to cater for the outage of the largest generation facility change over time, the IGT limit can be correspondingly adjusted. Secondly, the IGT is also dependent on the diversity of intermittent generation output across geographical locations. A low correlation of output of intermittent generation sources across geographical locations will generally mean a higher diversity, which would allow the IGT to be increased. For example, a cloud cover may reduce solar output in the eastern part of Singapore, but solar output in the western part could be unaffected. Hence, the same amount of reserves can support the installations of more intermittent generation sources, which results in a higher IGT.

5.3. Intermittent Generation Limit ("IGL")

5.3.1. The second threshold relevant to the dynamic pathway option is the IGL[11], which is defined as the total amount of intermittent generation that the power system can support, based on the total amount of reserves capacity that can be called on at any point in time. As more intermittent generation sources enter the system, the IGT will first be reached. Beyond the IGT, more reserves may be procured solely for the purpose of managing the intermittency of the incremental capacity. As there is a limit on the amount of reserves that can be procured (given the total size of all the relevant facilities in the system that can provide reserve), the IGL will eventually be reached, where no further intermittent generation capacity can be allowed into the system.

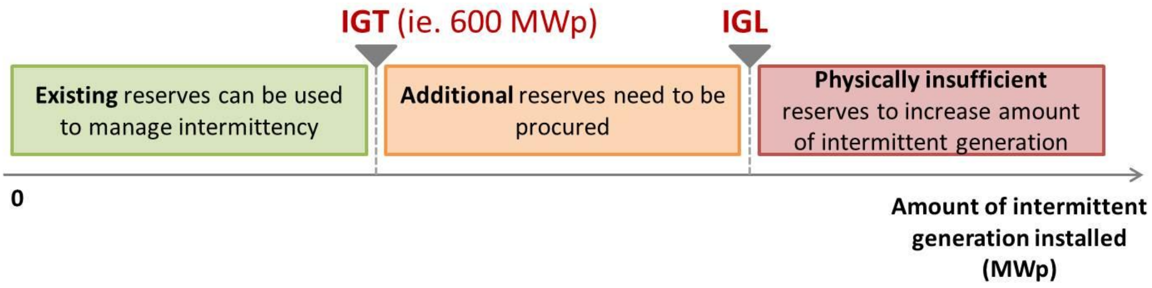
5.3.2. The EMA is currently reviewing the IGL, which is subject to further review as it depends on the total reserves capacity available in the system and the geographical diversity of intermittent generation sources, as well as the extent and pace of

[10] IGT comprises the total intermittent generation installed capacity of both residential and non-residential systems.

[11] IGL comprises the total intermittent generation installed capacity of both residential and non-residential systems.

developments such as energy storage solutions. The illustration of the concept of IGT and IGL is shown in Figure 5.1.

Figure 5.1: Illustration of the dynamic pathway option, IGT and IGL.



5.4. Localised Network Limit

5.4.1. While there are system-wide thresholds comprising the IGT and IGL, localised limits at specific geographical regions may exist. This can be due to the physical constraints of each network ring[12], where there is a limit to the amount of intermittent generation sources it can support. Therefore, depending on the limit of the network ring in that area, the permissible capacity of intermittent generation installations in each location may differ. The EMA is currently doing a detailed review on the network constraints together with SPPG and the Experimental Power Grid Centre. Should the reviews indicate that there are such constrained network rings, the EMA will make known in advance the locations of the relevant network rings, so that potential owners of intermittent generation sources can factor that into their investment decisions.

[12] The network ring refers to the connection of substations/nodes to form a network circuit.

SECTION 6 PRICING MECHANISM TO RECOGNISE BOTH POSITIVE AND NEGATIVE EXTERNALITIES

6.1. Overview of Pricing Mechanism

6.1.1. As described in Section 1, intermittent generation sources such as solar energy can bring about positive as well as negative externalities. There are advantages to recognizing and pricing such externalities to incentivise the optimal level of investments and deployment of such technologies in Singapore.

6.1.2. The pricing mechanism to quantify the benefits of positive externalities and the costs of negative externalities will only be applied to non-residential consumers (both CCs and NCCs), as such consumers are in a better position to manage the commercial risks of their investments, including the relevant payments for the positive externalities and the charges for the negative externalities. In addition, existing non-residential consumers who have already made investments in intermittent generation technologies prior to the implementation of the pricing mechanism will be given a one-off choice to opt out of the pricing mechanism.

6.1.3. Specifically, non-residential consumers who (a) have an existing embedded intermittent generation installed prior to 1 January 2014; or (b) submits their application to SPPG before 1 January 2014 and with a commissioning date before 1 April 2014, are eligible to opt out of the pricing mechanism. Such consumers will have two months upon the release of the EMA's final determination paper to decide whether they would like to opt out. The benefits from the positive externalities and the costs from the negative externalities should be taken as a single pricing mechanism, i.e. consumers who have chosen to opt out of the pricing mechanism will not be paid for the positive externalities nor do they have to pay for the negative externalities.

6.1.4. For eligible consumers who have chosen to opt out, they would be subjected to the pricing mechanism (a) if they retrofit their intermittent generation systems such that re-commissioning by SPPG would be required in the process; or (b) 20 years from the commissioning date of their existing intermittent generation systems, whichever occurs earlier.

6.2. Recognising the Positive Externalities of Intermittent Generation

6.2.1. One pricing mechanism that the EMA is exploring to recognise the positive externalities brought about by intermittent generation is through the Demand Response ("DR") scheme, which will be implemented in the NEMS[13]. The scheme rewards consumers for withdrawing less from the grid during periods of high prices (which typically occur during periods of tight demand-supply conditions) by paying

[13] Details can be found in the EMA's Final Determination Paper on "Implementing Demand Response Programme in the National Electricity Market of Singapore" dated on 28 October 2013.

such consumers when their load reductions result in a drop in pool price. For example, given that solar energy is produced in the day which typically coincides with the system peak demand, it brings about the peak load shaving effect as it reduces the overall system demand, and thus puts downward pressure on pool prices. Consumers with solar panels effectively draw less energy from the grid as the solar production offsets a portion of their own load. Because of the marginal pricing system used in the market, a drop in pool price benefits the broader consumer base. Hence, there are grounds to consider sharing a portion of the consumer surplus generated from the drop in pool prices with those who contributed to the drop (including DR consumers as well as consumers with embedded intermittent generation sources). The EMA is exploring how the DR scheme can be further enhanced to enable these consumers with embedded intermittent generation sources to be eligible for DR payments. Embedded intermittent generation sources which are eligible for payments for injection into the grid[14], for the purpose of the enhanced DR scheme, are treated as generators and will not be eligible for the proposed DR payments.

6.2.2. The current DR scheme requires participating consumers to be dispatchable. Given the intermittent output of solar, it is not practicable for individual consumers to forecast their output to participate in the DR scheme. One way for consumers with intermittent generation sources to participate in the DR scheme is to use the aggregate forecasted output as a way to measure the drop in withdrawal of energy from the grid (and the corresponding decrease in pool price) for such consumers. This helps to value the “peak load shaving” benefit brought about by such consumers. Under the DR scheme, there is a price floor based on 1.5 times the prevailing balanced vesting price. For alignment, consumers with intermittent generation sources are eligible for DR payments (if there is a demonstrated drop in pool price) only when pool price is above the price floor. This is consistent with the concept of rewarding such consumers only during periods where there are peak shaving benefits for the whole system, while during other periods they would have been compensated for the avoided cost of their retail price. In addition, a 200 MW cap exists for the DR scheme (including the participation of Interruptible Load (“IL”)). Given that DR and IL consumers are dispatchable and subject to a compliance regime while not so for those with embedded intermittent generation sources, these loads will be cleared in the market first, followed by the intermittent generation output of eligible consumers with embedded intermittent generation sources[15], capped at 200 MW.

<u>Illustration of the Enhanced DR Scheme with Embedded Intermittent Generation Sources</u>

6.2.3. The following example shows how the enhanced DR scheme can work.

[14] Either through registration with EMC or SPS under the simplified credit treatment scheme

[15] There would be no compliance requirements for the aggregate embedded intermittent generation output participating in the proposed enhanced DR scheme.

Half-hourly parameters	Quantities / Price	Remarks
Intermittent generation output per half hour dispatch period for eligible consumers with embedded intermittent generation sources	30 MWh, or 60 MW per half hour dispatch period	This is equivalent to 60 MW of intermittent generation forecasted output per half hour dispatch period.
Amount of Demand Response load cleared in the market (without the consumers with embedded intermittent generation sources) per half hour dispatch	50 MWh, or 100 MW per half hour dispatch period	This is the amount of dispatchable reduction by consumers who have offered into the market as part of the DR scheme.
Actual USEP	$470/MWh	This is the actual price paid by consumers for electricity bought through the wholesale market.
Counterfactual USEP	$500/MWh	This is the price re-run by the market clearing engine, without the demand response reduction and the output by eligible consumers with embedded intermittent generation sources (i.e. 100 MW + 60 MW)[16].
Amount of consumer surplus to be shared with demand response consumers and eligible consumers with embedded intermittent generation output	$16,000	This is based on the 1/3 consumer surplus sharing mechanism, assuming the load which benefits from the pool price drop (or the non-regulatory load) is 1600 MWh (i.e. 1/3 * $30/MWh * 1600 MWh)
Payment to eligible consumers with embedded intermittent generation sources	$6,000 (or $200/MWh)	This is the proportionate share of payments to consumers with embedded intermittent generation sources (i.e. 30/80 * $16,000), up to the DR cap of $4500/MWh.
Peak shaving payments to eligible consumers with embedded intermittent generation sources	$0.10/kW	This is a new line item proposed to be added to the wholesale market for the purpose of allocating to market participants. In this example, it is derived by dividing $6,000 by the total embedded intermittent generation sources participating in the Externalities Pricing Mechanism, 60,000 kW

[16] As an illustration of the principle where the DR and IL consumers are cleared first before eligible consumers with embedded intermittent generation sources, suppose there was 150 MW of DR and IL load cleared, then only 50 MW (or the equivalent) of the intermittent generation output of eligible consumers with embedded intermittent generation sources will be calculated for DR payments, due to the prevailing 200 MW cap for all DR and IL loads..

Half-hourly parameters	Quantities / Price	Remarks
		(or 60 MW in this example).

6.3. Pricing Negative Externalities of Intermittent Generation Sources

6.3.1 On the other hand, intermittent generation sources impose a cost on the system by requiring reserves, or back-up capacity from conventional generators, to manage the fluctuations in output of intermittent generation sources. The following sections describe how the pricing of negative externalities could potentially be implemented in the electricity market, including an overview of the existing procedures for how the costs of reserves are allocated.

6.4. Overview of Current Reserves Charging in the NEMS

6.4.1 Generating units participating in the NEMS are subject to reserves charges. Reserves, or back-up capacity, are required to ensure the reliable supply of electricity to consumers and the secure operation of the power system. There are two broad categories of reserves in the NEMS: regulation and spinning reserves. The PSO determines the half-hourly quantities of regulation reserves to cater for load variation while spinning reserves is based on the expected size of possible contingency events, taking into consideration the output of the largest generating unit scheduled in each dispatch period. The reserves are procured through the electricity market, where prices are determined on a half-hourly basis. The costs of the reserves are subsequently allocated to the relevant stakeholders, broadly based on the "causer-pays" principle where participants pay their share of the costs they impose on the system. More details of each category of reserves are provided below.

Regulation Reserves

6.4.2 Generation output needs to match the load requirements at any point of time in the power system in order to maintain system stability. Regulation reserves refer to the amount of generation capacity needed to balance the minute-to-minute variations in actual load compared to the forecasted demand.

6.4.3 The costs of regulation reserves are recovered from all loads and the first 5 MWh of each generation facility in each half hour dispatch period, on the basis that it is due to the fluctuations in loads and small variations in generation output that create the need for providing regulation reserve in the first place.

Spinning Reserves

6.4.4 Spinning reserves refer to the amount of generation capacity required to correct any imbalances in the system and maintain reliability of supply. Because the output of generation units may change without warning (such as the case of an unexpected outage or tripping of a conventional generation plant or due to the variability of output of intermittent generation sources), some reserves capacity is required in the system. Three classes of reserves are provided: primary reserve (8 seconds), secondary reserves (30 seconds) and contingency reserves (10 minutes), in accordance with the amount of time which providers of such reserves are required to respond. Generation units and consumer loads participating in the IL scheme are eligible to provide for spinning reserves.

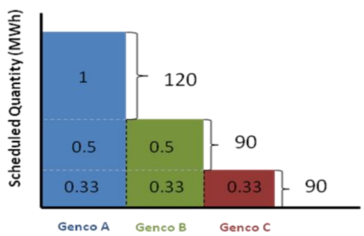
6.4.5 The costs of spinning reserves are recovered from all generation facilities scheduled (less the first 5 MWh of each facility, which is allocated the cost of regulation reserve) operating in that half-hour through a methodology that varies according to the generation output based on the "modified runway model. This model assigns a cost to each scheduled generation facility based on its generation output and its reliability measured by its probability of failure ("POF"). All things being equal, a generation facility scheduled with a larger generation output will be assigned a higher costs of reserves (as more reserves need to be procured in the event of tripping of this facility) compared to another with a smaller output. At the same time, a generation facility with a poor reliability history will be assigned a higher costs of reserves (as there is a higher probability of tripping of this facility) compared to a more reliable generation facility.

Illustration of Modified Runway Model

Each gencos' share of total reserve cost, or its **Reserve Responsibility Share (RRS),** is determined by:

- ***Scheduled capacity*** (ie. energy & reserves) for that particular trading period;
- ***Reliability of the generating unit*** (also known as POF).

Assuming that the total reserves requirement is 300 MWh*,



RRS_A = 1*120 + 0.5*90+ 0.33*90 = 195 out of 300

RRS_B = 0.5*90 + 0.33*90 = 75 out of 300

RRS_C = 0.33*90 = 30 out of 300

- Genco A being the largest unit scheduled to provide energy bears the largest portion (195/300=0.65) of the total reserve cost.

6.5. Benefits of Aggregating Intermittent Generation Sources for Reserves Calculations

6.5.1 Given the limited land availability for large scale installations of intermittent generation sources, the deployment of such technologies in Singapore are likely to be distributed (e.g. energy from solar PV panels is primarily used to offset the consumption of the consumers' load) and relatively smaller in scale compared to conventional generation sources. The costs of the regulation and spinning reserves are currently allocated to the specific generating units, i.e. each generation facility will pay the regulation and spinning reserves based on its output and its reliability. While this method has worked well for conventional generation sources because it provides the appropriate incentives for a generation company to size their generation capacity economically and to maintain the reliability of the generation facilities, it may not be appropriate to assign cost to the individual generating units based on the "modified runway model" for intermittent generation sources, because the output of such sources cannot be controlled and are dependent on external factors such as weather conditions. Instead, a better approach is to use the aggregate output of intermittent generation sources for the purpose of assigning the costs of reserves.

6.5.2 Consider the case of a 20 MW solar PV generation facility situated in the western part of Singapore. Under the existing reserve charging mechanism, it will be assigned the equivalent of its POF under the "Modified Runway Model" for the purpose of allocation of reserves charges. As its output is dependent on the solar irradiance, this will result in fluctuations in output. Hence, it is likely to be assigned a higher POF vis-à-vis a conventional generation source of a similar size, and therefore face higher reserves charges. However, if the output of this facility is aggregated with the output of intermittent generation sources in other parts of the island, the POF of these intermittent generation sources could be lowered due to the possible geographical diversity. For example, the cloud cover that could have caused the output of that 20 MW solar PV generation facility to drop may not affect solar installations situated in other parts of Singapore. This would reduce the reserves charges for this group of generators.

6.5.3 Hence, the EMA proposes to consider the aggregate output of all intermittent generation sources for the purpose of assigning regulation and spinning reserves costs. Under the "modified runway model", the aggregate output of intermittent generation sources will be modelled as one pseudo intermittent-generator. A pseudo intermittent generator, being an aggregate output of all intermittent generation sources, would have taken into account the diversity of the intermittent sources.

6.6. Determining the POF of Intermittent Generation Sources for Reserves Calculations

6.6.1 The application of the concept of POF on intermittent generation sources will also require refinement. At present, the POF is calculated based on the number of tripping of conventional generation facilities over a defined period of time. This is essentially a reliability matrix built into the "modified runway model" to provide the correct incentives for generation facilities to be as reliable as possible. All things being the same, a generation facility with a lower POF will be allocated a lower share of reserves compared to another with a higher POF. As unscheduled outages are not applicable for the case of intermittent generation sources, an equivalent methodology needs to be developed for the purpose of assigning the POF for such technologies to ensure that the reserves costs of the various generation technologies (whether conventional or intermittent generation sources) are allocated in an equitable manner. One way of establishing such a POF is to measure the deviation of the actual output of intermittent generation sources from the forecasted output and to assign the equivalent POF that can be comparable to other generation sources[17]. Over time, the deviation of the actual output from the forecasted output would likely decrease for several reasons, such as the use of improved forecasting techniques as well as the benefits of geographical diversification through the "portfolio approach". This will provide a basis for lowering the POF for intermittent generation sources and potentially reduce the reserves costs allocated to such technologies.

6.7. Reserves Costs Allocation for Intermittent Generation Sources

6.7.1 In the case when the intermittent generation capacity is within the IGT, no additional reserves need to be procured. This means that the costs of existing reserves are shared among all generation sources, including intermittent generation sources.

6.7.2 When the intermittent generation capacity crosses the IGT, additional spinning reserves would have to be procured to manage the intermittent effects, at periods when existing reserves are unable to support the generation output. In such cases, the incremental cost of procuring such reserves will be fully allocated to the intermittent generators to account for the negative externalities they impose on the system.

6.7.3 In the case of regulation reserves, one possible way to account for intermittency is to modify the current regulation reserves allocation to incorporate the historical minute-to-minute variations of the generators' output. In this way, the regulation reserves allocation methodology will be more equitable as all things being equal; generators with greater variations in output would be subject to higher regulation reserves charges.

6.7.4 The relevant share of regulation and spinning reserves costs will be allocated to intermittent generation sources based on their installed capacity as indicated in the intermittent generation registry maintained by SPPG. Two additional line items "Share of Reserves Charges for Intermittent Generation Sources" and "Additional Intermittent Reserves Charges" will be reflected in the settlement procedures in the NEMS. The former is the charges allocated to intermittent generation sources when the total installed intermittent generation capacity is within the IGT, while the latter is the cost of procuring incremental spinning reserves for managing capacity above the IGT but below the IGL.

6.7.5 For consumers with intermittent generation sources, there is no requirement for them to register as MPs. Instead, their relevant share of regulation and spinning reserves costs will be charged to their retailers or the MSSL (for CCs buying through the MSSL at wholesale prices and all non-residential NCCs). This proposed method of settlement for reserves costs have the advantages of lowering the barrier

[17] The PSO will consider allowing intermittent generation sources the option to submit their respective POFs (which must be verifiable to the satisfaction of the PSO) for the purpose of allocation of reserve charges.

of entry of such technologies by not requiring them to be registered as market participants, as well as allowing retailers to work out commercial arrangements with such consumers, which may enable consumers to reduce payment uncertainties and hedge their reserves costs.

6.7.6 The following two examples show how the reserve charges are allocated for a particular retailer's customers (with intermittent generation sources) when the intermittent generation capacity is within the IGT and when it exceeds the IGT but below IGL. The figures used are solely for illustration purpose only.

Illustration of Reserves Costs Allocation for Intermittent Generation Sources below IGT

6.7.7 The example below shows the settlement parameters when the aggregate intermittent generation capacity is 100 MW.

Half-hourly parameters	Quantities / Price	Remarks
Intermittent generation forecasted output per half hour dispatch period	25 MWh	This is based on an aggregate system-wide 100 MW installed capacity, assuming a 50% output for that half hour dispatch period. The first 5 MWh is subjected to regulation reserves charge, while the remaining 20 MWh will be allocated a charges based on the "Modified Runway Model".
Regulation reserves charges	$500	This represents the charges assigned to all intermittent generation sources for regulation reserves, based on a regulation price of $100/MWh.
Primary reserves charges	$100	This represents the charges assigned to all intermittent generation sources for primary reserves based on the output of the "Modified Runway Model".
Secondary reserves charges	$100	This represents the charges assigned to all intermittent generation sources for secondary reserves based on the output of the "Modified Runway Model".
Contingency reserves charges	$300	This represents the charges assigned to all intermittent generation sources for contingency reserves based on the output of the "Modified Runway Model".
Total reserves charges	$1,000	This represents the total reserves charges assigned to all intermittent generation sources for that half hour.
"Share of Reserves Charges for Intermittent Generation Sources", or the Reserves charges per kW of	$0.011 /kW	This is the line item proposed to be added to the wholesale market for the purpose of allocating the reserve costs to market participants. In this example, it is derived by

intermittent generation		dividing $1000 by 90,000 kW subject to reserve charges (or 90 MW which is the aggregate intermittent generator capacity, less those of residential consumers and those who have chosen to opt out which in this example is assumed to be 10 MW).
"Additional Intermittent Reserves Charges"	$0 /kW	There is no additional regulation and/or spinning reserves procured in this case as the total installed intermittent generation is within the IGT.
Total Reserves Charges allocated to Intermittent Generation Sources	$0.011/kW	This is derived by adding the "Share of Reserves Charges for Intermittent Generation Sources" and the "Additional Intermittent Reserves Charges".
Reserves charges allocated to Retailer A for that half hour	$222	Suppose that Retailer A has customers with a total of 20 MW of installed intermittent generation capacity subject to reserve charges, the charges is derived by multiplying the total reserves charges allocated to intermittent generation sources by the total capacity subject to reserve charges.

<u>Illustration of Reserves Costs Allocation for Intermittent Generation Sources beyond IGT</u>

6.7.8 The example below shows the settlement parameters when the aggregate intermittent generation capacity is 640 MW.

Half-hourly parameters	Quantities	Remarks
Intermittent generation forecasted output per half hour (up to the IGT)	160 MWh	This is based on an aggregate system-wide installed capacity of 640 MW, assuming a 50% output for that half hour. The first 5 MWh is subject to regulation reserve charge, while the remaining 155 MWh will be allocated a charges based on the "Modified Runway Model".
Regulation reserves charges (up to IGT)	$500	This represents the charges assigned to intermittent generation sources (up to the IGT) for regulation reserves, based on a regulation price of $100/MWh.
Primary reserves charges	$5,000	This represents the charges assigned to intermittent generation sources (up to the

(up to IGT)		IGT) for primary reserves based on the output of the "Modified Runway Model".
Secondary reserves charges (up to IGT)	$5,000	This represents the charges assigned to intermittent generation sources (up to the IGT) for secondary reserves based on the output of the "Modified Runway Model".
Contingency reserves charges (up to IGT)	$8,500	This represents the charges assigned to intermittent generation sources (up to the IGT) for contingency reserves based on the output of the "Modified Runway Model".
Total reserves charges (up to IGT)	$19,000	This represents the total reserves charges assigned to intermittent generation sources (up to the IGT) for that half hour.
"Share of Reserves Charges for Intermittent Generation Sources", or the Reserves charges per kW of intermittent generation	$0.03/kW	This is the line item proposed to be added to the wholesale market for the purpose of allocating reserve costs to market participants. In this example, it is derived by dividing $19,000 by the total intermittent generation capacity 630,000 kW subject to reserve charges (or 630 MW, which is the aggregate intermittent generator capacity, less those of residential consumers and those who have chosen to opt out which in this example is assumed to be 10 MW).
Primary reserves charges (beyond IGT)	$1,200	This assumes 40 MW of additional primary reserves is required at prevailing cost of $30/MWh.
Secondary reserves charges (beyond IGT)	$1,200	This assumes 40 MW of additional secondary reserves is required at prevailing cost of $30/MWh
Contingency reserves charges (beyond IGT)	$2,800	This assumes 56 MW of additional contingency reserves is required at prevailing cost of $50/MWh.
Total reserves charges (beyond IGT)	$5,200	This represents the additional reserves charges assigned to intermittent generation sources (beyond the IGT) for that half hour.
"Additional Intermittent Reserves Charges"	$0.00825/kW	This is the line item proposed to be added to the wholesale market for the purpose of allocating reserve costs to market participants. In this example, it is derived by dividing $5,200 by the total intermittent generation capacity 630,000 kW subject to reserve charges (or 630 MW, which is the

		aggregate intermittent generator capacity, less those of residential consumers and those who have chosen to opt out which in this example is assumed to be 10 MW).
Total Reserves Charges allocated to Intermittent Generation Sources	$0.03825/kW	This is derived by adding the "Share of Reserves Charges for Intermittent Generation Sources" ($0.03/kW) and the "Additional Intermittent Reserves Charges" ($0.00825/kW).
Reserves charges allocated to Retailer A for that half hour	$765	Suppose that Retailer A has customers with a total of 20 MW of installed intermittent generation capacity subject to reserve charges, the charges is derived by multiplying the total reserves charges allocated to intermittent generation sources by the total capacity subject to reserve charges.

SECTION 7 CONCLUSION

7.1. The EMA is reviewing the regulatory framework for intermittent generation sources in the NEMS. The enhanced regulatory framework seeks to maximize the potential to deploy intermittent generation in Singapore by lowering the barriers of entry of such technology when it becomes commercially viable. The proposed changes and enhancements identified in this consultation paper will facilitate the integration of intermittent generation, while safeguarding system stability and reliability of electricity supply to consumers.

7.2. This paper has raised a number of enhancements that the EMA wishes to seek the views of the public and the industry, including the following:

a. Streamlining of the market registration procedures for intermittent generation sources less than 1 MW (Section 4);

b. Central forecasting by the PSO for all intermittent generation sources for the purpose of price setting and reserve procurement in the market (Section 4);

c. Implementation of the dynamic pathway framework based on the IGT and IGL, in comparison to the hard cap limit framework (Section 5); and

d. Implementation of the pricing mechanism, including the enhancement to the DR scheme and modifications to the reserve charging methodology for intermittent generation sources (Section 6).

7.3. The indicative timeline of the EMA's consultation process for the proposed framework for intermittent generation is summarised in Table 7.1.

Table 7.1: Indicative timeline for the EMA's consultation process

	Process	Date
1	Issue of the EMA's Consultation Paper	28 October 2013
2	Feedback from stakeholders on the Consultation Paper due	28 January 2014
3	Issue of the EMA's Final Determination Paper	Q2 2014

REQUEST FOR COMMENTS AND FEEDBACK

EMA invites comments and feedback to the consultation paper. Please submit written feedback to EMA_PPD@ema.gov.sg by 28 January 2014 (5pm). Alternatively, you may send the feedback by post/fax to:

Policy Department
Energy Planning and Development Division
Energy Market Authority
991G Alexandra Road, #01-29
Singapore 119975
Fax: (65) 6835 8020

Anonymous submissions will not be considered.

EMA will acknowledge receipt of all submissions electronically. Please contact Ms Lyana Yeow at 6376 7624 or Ms Leow Rui Ping at 6376 7759 if you have not received an acknowledgement of your submission within two business days.

EMA reserves the right to make public all or parts of any written submissions made in response to this consultation paper and to disclose the identity of the source. Any part of the submission, which is considered by respondents to be confidential, should be clearly marked and placed as an annex which the EMA will take into account regarding the disclosure of the information submitted.