

## Notice of Market Rules Modification

<b>Paper No.:</b>	EMC/RCP/127/2022/371
<b>Rule Reference:</b>	Chap 5 Sec 6.1; Chap 6 Sec 3.2 & 9.2; Chap 8
<b>Proposer:</b>	EMC, Market Admin
<b>Date Received by EMC:</b>	27 December 2021
<b>Category Allocated:</b>	2
<b>Status:</b>	Approved by EMA
<b>Effective Date:</b>	21 February 2024

This paper proposes to incorporate solar generation forecasts in the Market Clearing Engine (MCE) to produce market schedules.

The Power System Operator (PSO) plans to upgrade its Energy Management System (EMS) to incorporate solar generation forecasts by 2023. The PSO would then be able to provide EMC with a set of solar forecasts, which EMC can use to derive the loss-adjusted end-of-period load forecasts for the MCE.

As with the existing load forecasts, the PSO will be providing the following solar forecast files to EMC:

- Very Short-term Photovoltaic Forecast (VSPVF) - On a half-hourly basis, a forecast of the average solar forecast for each half-hourly period for the next 7 hours.
- Short-term Photovoltaic Forecast (SPVF) - On a daily basis, a forecast of the average solar forecast for each half-hourly period for the next 14 days

EMC will transform these into nodal load forecasts for each dispatch period and use them as input for the MCE to produce market schedules.

With solar generation factored into the market clearing process, the MCE can produce more accurate schedules for dispatchable resources.

Rule modifications are proposed for the PSO to provide solar generation forecasts and for EMC to use them, together with existing load forecasts, in the market clearing process.

The RCP discussed these proposals at its 127<sup>th</sup> meeting and the panel **unanimously supported** the proposed recommendation to incorporate solar generation forecasts in the MCE to produce market schedules.

<b>Date considered by Rules Change Panel:</b>	10 March 2022
<b>Date considered by EMC Board:</b>	27 March 2022
<b>Date considered by Energy Market Authority:</b>	14 April 2022
<b>Proposed rule modification:</b>	See attached paper
<b>Reasons for rejection/referral back to Rules Change Panel (if applicable):</b>	

RCP PAPER NO. : **EMC/RCP/127/2022/RC371**

SUBJECT : **INCORPORATION OF SOLAR GENERATION FORECASTS IN THE MARKET CLEARING ENGINE**

FOR : **DECISION**

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**SENIOR ECONOMIST**

REVIEWED BY : **POA TIONG SIAW**  
**SVP, MARKET ADMINISTRATION**

DATE OF MEETING : **10 MARCH 2022**

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### Executive Summary

This paper proposes to incorporate solar generation forecasts in the Market Clearing Engine (MCE) to produce market schedules.

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As with the existing load forecasts, the PSO will be providing the following solar forecast files to EMC:

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The RCP discussed these proposals at its 127<sup>th</sup> meeting and the panel **unanimously supported** the proposed recommendation to incorporate solar generation forecasts in the MCE to produce market schedules.

## 1. Introduction

This paper proposes to incorporate solar generation forecasts for the Market Clearing Engine (MCE) to produce market schedules.

## 2. Background

Solar energy is the most promising renewable energy source in Singapore for electricity generation. The cumulative installed capacity of solar photovoltaic (PV) systems in Singapore has grown steadily and is expected to increase significantly in the near future. By 2030, Singapore's goal is to harness 2 gigawatt-peak (GWp) of solar energy, roughly tripling the current solar energy capacity.

One major difference between the deployment of solar energy for electricity generation and other non-intermittent generation sources, such as spinning generators, is that the output of solar PV fluctuates depending on environmental and weather conditions such as cloud cover and humidity. For instance, extensive cloud cover on rainy days can cause significant drops in solar power output.

As solar energy gradually becomes a more significant portion of the energy generation mix, EMC will need better visibility of solar energy generation to determine optimal schedules for dispatchable sources to meet the demand.

## 3. Analysis

### 3.1 Existing Load Forecasts from PSO

The Power System Operator (PSO) currently produces half-hourly system load forecasts and monthly forecasts of peak system load for use by the wholesale electricity market and for the purpose of outage planning. These forecasts enable assessments to be made of the adequacy of supply and security of the system in the short and medium term.

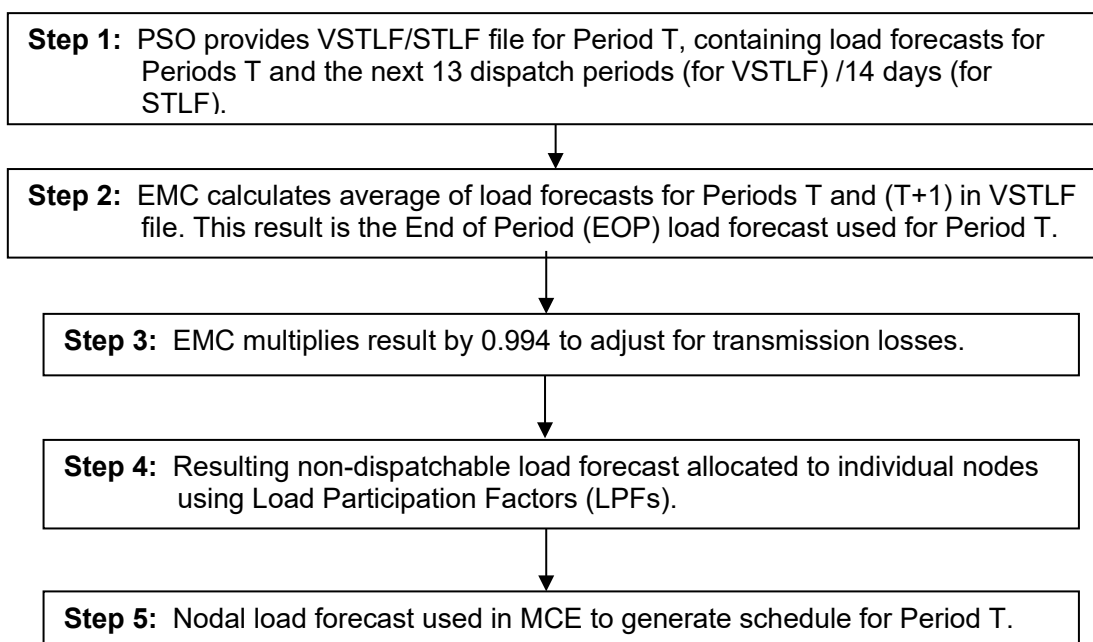
In accordance with the System Operation Manual (SOM), the PSO uses software modules of the Energy Management System (EMS) to prepare the following load forecast files:

- Very Short Term Load Forecast (VSTLF) - On a half-hourly basis, a forecast of the average system load for each half-hourly period for the next 7 hours (i.e., 7 hours x 2 periods = 14 load forecasts).
- Short Term Load Forecast (STLF) - On a daily basis, a forecast of the average system load for each half-hourly period for the next 14 days (i.e., 14 days x 48 periods = 672 load forecasts)

The load forecasts in the VSTLF and STLF files forecast the total gross generation required from generation registered facilities to meet system load, which includes transmission losses and the station/auxiliary load consumed by the generators themselves for each dispatch period.

EMC transforms the load forecasts from the PSO into nodal load forecasts for each dispatch period, which are used as an input in the MCE to produce market schedules. Figure 1 below illustrates this process.

**FIGURE 1<sup>1</sup>: Processing load forecast file to produce nodal load forecast for Period T<sup>2</sup>**



***Illustration for EMC’s current processing of forecasts (Step 1 to Step 3 of Figure 1)***

Period	Step 1: VSTLF Load Forecast (Provided by PSO)	Step 2: EOP Load Forecast (Calculated by EMC)	Step 3: Adjustment for Transmission Loss
1	6000 MW	6100 MW	6063 MW
2	6200 MW	6350 MW	6312 MW
3	6500 MW	6400 MW	6362 MW
4	6300 MW	...	...
...	...	...	...

**3.2 Proposed Incorporation of Solar Forecast in the MCE**

In 2017, Energy Market Authority (EMA) awarded a consortium led by the National University of Singapore (NUS) to develop solar forecasting capabilities. The consortium uses techniques in weather prediction, remote sensing, machine learning, and grid modelling to improve the accuracy of solar PV output forecasts and grid management.

The PSO is in the process of upgrading its Energy Management System (EMS) to incorporate the solar forecasting system produced by the consortium by 2023. Upon completion of the EMS upgrade, the PSO will be providing a separate set of half-hourly system solar forecasts, which EMC can use to derive the loss-adjusted end-of-period load forecasts for the MCE. As with the existing load forecasts, the PSO will be providing the following solar forecast files to EMC:

<sup>1</sup> In Step 2, the average of the two figures is the expected gross generation that is required at the end of Period T. In Step 4, the LPFs are node-specific and reflect the share of total load occurring at nodes for respective periods.

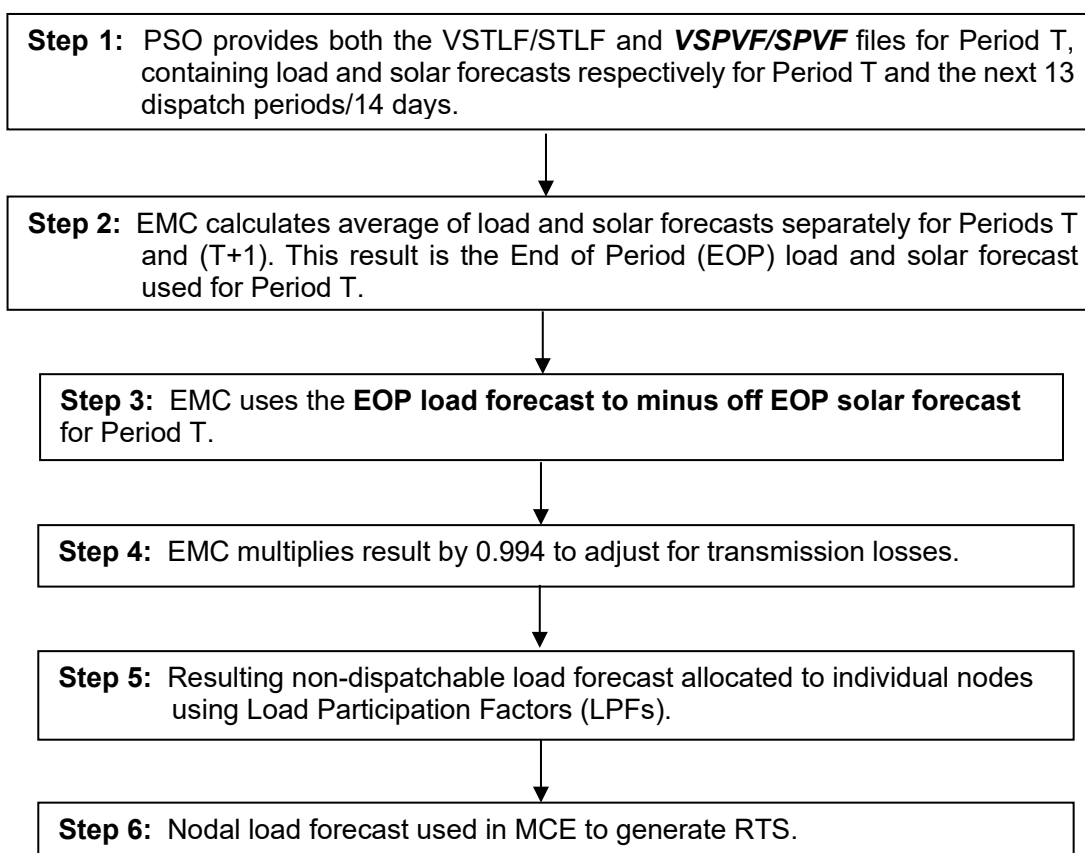
<sup>2</sup> The VSTLF forecasts the average gross generation required over a half-hour dispatch period. The RTS determines the generation required at the end of a dispatch period (at a discrete point in time). The process of averaging the VSTLFs of two consecutive periods is necessary to turn forecasts of average gross generation in the two dispatch periods into an estimate of the gross generation at the end of the first dispatch period.

- Very Short-term Photovoltaic Forecast (VSPVF) - On a half-hourly basis, a forecast of the average solar forecast for each half-hourly period for the next 7 hours (i.e., 7 hours x 2 periods = 14 solar forecasts).
- Short-term Photovoltaic Forecast (SPVF) - On a daily basis, a forecast of the average solar forecast for each half-hourly period for the next 14 days (i.e., 14 days x 48 periods = 672 solar forecasts)

EMC will transform the load and solar forecasts from the PSO into nodal load forecasts for each dispatch period, which are then used by the MCE to produce the relevant schedule.

Figure 2 below illustrates the process, using both VSTLF/STLF and VSPVF/SPVF files, for the RTS.

**FIGURE 2: Processing load forecast and solar forecast file to produce system load forecast for Period T**



**Illustration for EMC processing of Load Forecast and Solar Forecast (Step 1 to Step 4 of Figure 2)**

Period	Step 1		Step 2		Step 3	Step 4
	VSTLF Load Forecast	VSPVF Forecast *	EOP Load Forecast (1)	EOP Solar Forecast* (2)	EOP Forecast * (1)-(2)	Adjustment for Transmission Loss
1	6000 MW	100 MW	6100 MW	120 MW	5980 MW	5944 MW
2	6200 MW	140 MW	6350 MW	145 MW	6205 MW	6168 MW
3	6500 MW	150 MW	6400 MW	140 MW	6260 MW	6222 MW
4	6300 MW	130 MW	...	...	...	...
...	...	...	...	...	...	...

\*New Process

#### 4. Proposed Rule Modifications

The following rule modifications are required to allow EMC to include solar generation forecasts into the market clearing process:

- a) On a daily basis, for the PSO to produce solar generation forecasts, by dispatch period, for the following 14 days.
- b) For EMC to include solar generation forecasts into its nodal load forecast methodology and procedures.
- c) Clarification on the components of load forecasts to be provided by the PSO.

Currently, the load forecast produced by the PSO is used by the market clearing engine to represent the load required to be met from generation registered facilities and load registered facilities that are subject to central dispatch. It is the total Singapore load net of estimated output from non-dispatchable generation facilities including solar. With the solar forecast incorporated into the MCE, it would no longer be necessary for the PSO to net off the output of solar from the load forecast. A rule change is proposed to clarify this.

- d) For EMC to publish solar generation forecasts.

Currently the system demand published by EMC represents the total load as provided in the PSO load forecasts. With solar forecast incorporated into the MCE, the total load would not correctly reflect the generation required to be provided from generation registered facilities. The EMC proposes to have both load forecast and solar forecast published to provide transparency.

Table 1 below provides a summary of the proposed modifications to the market rules. The detailed modifications are set out in Annex 1.

**TABLE 1: Summary of Proposed Modifications**

S/N	Chapter/ Section	Proposed Changes	Reasons for Changes
1	Chapter 5 Section 6.1.1	Clarified that the load forecasts provided by the PSO should not net off the output from intermittent generation facilities.	Solar's output is no longer required to be net off from the load forecasts.
2	Chapter 5 Section 6.1.1.5  (New Section)	Added the requirement for PSO to produce half hourly forecasts for solar generation for the following 14 days.	To include the requirement for solar forecasts, on top of the existing load forecasts, to be produced by the PSO.
3	Chapter 5 Section 6.1.4	Added that there would be no compensation from the PSO for any financial loss to MPs owing to inaccuracy of solar generation forecasts.	To align with the inclusion of solar generation forecasts.
4	Chapter 6 Section 3.2	Added the requirement for EMC to establish system and procedures and equip staff with the necessary skills to transform solar forecasts (and load forecasts) from the PSO into nodal load forecasts.	To align with the inclusion of solar generation forecasts.
5	Chapter 6 Section 9.2.4	Included solar generation as information to be published by EMC.	To require EMC to publish information on solar generation.
6	Chapter 8	Added the definition of solar generation.	To define solar generation.

## 5. Legal sign off

The text of the proposed modifications to the Market Rules set out in Annex 1 has been vetted by EMC's internal legal counsel, whose opinion is that the proposed modifications reflect the intent of the modification proposals as expressed in the third column of the table in Annex 1.

## 6. Consultation

The proposed modifications were published for consultation on 28 December 2021, and we have received comments from PacificLight and Senoko Energy that pertain to similar issues.

### Comments from PacificLight

PLP supports the recommendation to incorporate solar generation forecasts in the MCE which will provide greater transparency to the market. We would propose that in order to ensure robustness of the estimate, that an annual review of the forecast is conducted against actual generation data with the results circulated to Market Participants.

### Comments from Senoko Energy

Senoko strongly supports this initiative as it will give the market a better understanding of the impacts of solar generation on the SWEM, allowing MPs to better plan their resources to meet demand.

Senoko proposes the provision of additional data:

- Actual solar generation: To allow MPs to track / back test the correlation between system demand, solar output and USEP.
- Mean absolute percentage error (MAPE): To track and ensure that solar forecasts provided are within the bounds of acceptable accuracy. If MAPE is beyond (example, 30%), there should be actions in place to reduce this number.

### EMC's Response

*EMC notes the comments received and agrees on the need for greater transparency and accuracy of solar forecast data. Following implementation of this rule change, EMC shall collaborate with the PSO to continually monitor the accuracy of solar forecasts against actual solar generation data, circulating our findings to market participants.*



## 7. Implementation Effort Estimate

A summary of the implementation effort estimate is provided in Table 2 below. The total cost is estimated to be **\$689,865** and the total time required is estimated to be **53 calendar weeks**.

**TABLE 2: Implementation Effort Estimate**

Task	EMC Internal Cost, \$	External Vendor Cost, \$	Calendar Weeks Elapsed
Sourcing of Vendor	-	-	8
Change Requirement Scoping and Analysis / Documentation	29,700	18,550	7
Design / Development / Testing / Deployment / Documentation	174,724	250,372	34
Project Management	82,896	-	
Critical Information Infrastructure (CII)	43,604	56,019	
Penetration Test by Certified Pen Tester (2 Rounds)	-	34,000	4
<b>Subtotal Cost / Time</b>	<b>330,924</b>	<b>358,941</b>	<b>53</b>
<b>Total Cost / Time</b>		<b>689,865</b>	<b>53</b>

## 8. Conclusion

This paper proposes to incorporate solar generation forecasts in the MCE to produce market schedules.

As solar energy gradually becomes a more significant portion of the energy generation mix in Singapore, EMC will need better visibility of solar generation to determine the load required to be met from dispatchable resources. We thus propose changes to be made for the PSO to provide EMC with separate half-hourly solar forecasts, with which EMC will be able to derive more accurate load forecasts for the MCE to schedule dispatchable resources.

## 9. Decision at the 127<sup>th</sup> RCP Meeting

The RCP discussed these proposals at its 127<sup>th</sup> meeting held on 10 March 2022. The panel unanimously supported the proposed recommendation to incorporate solar generation forecasts in the MCE to produce market schedules.

## 10. Recommendations

The RCP unanimously recommends that the EMC Board:

- a) **adopt** the proposed modifications to the Market Rules as set out in **Annex 1**
- b) **seek the EMA's approval** of the proposed modifications to the Market Rules as set out in **Annex 1**; and
- c) **recommend** that the proposed modifications to the Market Rules, as set out in **Annex 1**, come into force
  - i. **53 weeks** after the date on which the approval of the Authority is published by the EMC;  
or
  - ii. upon completion of the Energy Management System upgrade to incorporate the solar forecasting system,whichever is later.

## ANNEX 1: Proposed Modifications to Market Rules

Existing Market Rules (1 July 2021)	Proposed Rule Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
<b>Chapter 5</b>	<b>Chapter 5</b>	
<b>6 FORECASTS AND ASSESSMENTS</b>	<b>6 FORECASTS AND ASSESSMENTS</b>	
<b>6.1 <u>FORECAST PREPARED BY THE PSO</u></b>  <div style="border: 1px solid black; padding: 5px;"> <p><b>Explanatory Note: The PSO produces half-hourly forecasts for the next 2 weeks (for outage scheduling and market use) and monthly forecasts of daily peak load for the next 12 months (used for outage planning). Both forecasts contribute to assessments of security requirement compliance over the following year. It is understood that the Authority, and not the PSO, will be doing longer term forecasting to support system investment planning.</b></p> </div> <p>6.1.1 The <i>PSO</i> shall produce the following forecasts for Singapore on an on-going basis:</p> <p>6.1.1.1 on a daily basis, a forecast of the following 14 day’s <i>load</i>, by <i>dispatch period</i>, net of the <i>PSO</i>’s estimate of the output of any <i>generation facilities</i> that are not <i>registered facilities</i>, with the forecast for the first 7</p>	<b>6.1 <u>FORECAST PREPARED BY THE PSO</u></b>  <div style="border: 1px solid black; padding: 5px;"> <p><b>Explanatory Note: The PSO produces half-hourly <u>load forecasts and solar generation forecasts</u> for the next 2 weeks (for outage scheduling and market use) and monthly forecasts of daily peak load for the next 12 months (used for outage planning). Both forecasts contribute to assessments of security requirement compliance over the following year. It is understood that the Authority, and not the PSO, will be doing longer term forecasting to support system investment planning.</b></p> </div> <p>6.1.1 The <i>PSO</i> shall produce the following forecasts for Singapore on an on-going basis:</p> <p>6.1.1.1 on a daily basis, a forecast of the following 14 day’s <i>load</i>, by <i>dispatch period</i>, net of the <i>PSO</i>’s estimate of the output of any <i>generation facilities</i> that are not <i>registered facilities</i> <u>or intermittent generation facilities</u>, with the forecast for the first</p>	<p>To clarify that the load forecasts provided by the <i>PSO</i> should not net off the output from intermittent generation facilities.</p>

Existing Market Rules (1 July 2021)	Proposed Rule Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
<p>days being provided to the <i>EMC</i> in accordance with section 6.1 of Chapter 6;</p> <p>6.1.1.2 on a daily basis, a forecast of any <i>load shedding</i> expected in the following 7 days, by <i>dispatch period</i>, such forecast to be provided to the <i>EMC</i> in accordance with section 6.1 of Chapter 6;</p> <p>6.1.1.3 on a monthly basis, a forecast to be <i>published</i> no later than 5 <i>business days</i> before the end of each month of the peak daily <i>load</i> for each <i>dispatch day</i> in the next 12 months; and</p> <p>6.1.1.4 such additional forecasts of <i>load</i>, by <i>dispatch period</i>, as may be required by sections 6.1 and 8.1 of Chapter 6.</p>	<p>7 days being provided to the <i>EMC</i> in accordance with section 6.1 of Chapter 6;</p> <p>6.1.1.2 on a daily basis, a forecast of any <i>load shedding</i> expected in the following 7 days, by <i>dispatch period</i>, such forecast to be provided to the <i>EMC</i> in accordance with section 6.1 of Chapter 6;</p> <p>6.1.1.3 on a monthly basis, a forecast to be <i>published</i> no later than 5 <i>business days</i> before the end of each month of the peak daily <i>load</i> for each <i>dispatch day</i> in the next 12 months; <del>and</del></p> <p>6.1.1.4 such additional forecasts of <i>load</i>, by <i>dispatch period</i>, as may be required by sections 6.1 and 8.1 of Chapter 6; <u>and</u></p> <p><u>6.1.1.5 on a daily basis, a forecast of the following 14 day's solar generation, by dispatch period, with the forecast for the first 7 days being provided to the EMC in accordance with section 6.1 of Chapter 6.</u></p>	<p>To include the requirement for solar forecasts, on top of the existing load forecasts, to be produced by the PSO.</p>

Existing Market Rules (1 July 2021)	Proposed Rule Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
<p>6.1.4 Notwithstanding section 13 of Chapter 1, no <i>market participant</i> shall be entitled to compensation from the <i>PSO</i> for any financial loss sustained by the <i>market participant</i> due to the <i>market participant</i> having been <i>dispatched</i> on the basis of <i>load</i> as forecasted pursuant to section 6.1.1 rather than on the basis of actual <i>load</i>.</p>	<p>6.1.4 Notwithstanding section 13 of Chapter 1, no <i>market participant</i> shall be entitled to compensation from the <i>PSO</i> for any financial loss sustained by the <i>market participant</i> due to the <i>market participant</i> having been <i>dispatched</i> on the basis of <i>load</i> <u>and <i>solar generation</i></u> as forecasted pursuant to section 6.1.1 rather than on the basis of actual load and <u>actual <i>solar generation</i></u>.</p>	<p>Consequential changes to align with the inclusion of solar forecasts.</p>
<b>Chapter 6</b>	<b>Chapter 6</b>	
<b>3 EMC RESPONSIBILITIES</b>	<b>3 EMC RESPONSIBILITIES</b>	
<p><b>3.2 <u>FORECASTING SYSTEMS</u></b></p> <p>3.2.1 The <i>EMC</i> shall establish such systems and procedures, and train such staff, as may be necessary to allow the <i>EMC</i> to transform, on a regular basis as required by sections 7.2.1 and 9.1.1, <i>load</i> forecasts for Singapore received from the <i>PSO</i> for each <i>dispatch period</i> into <i>nodal load forecasts</i> for the same <i>dispatch period</i>. The methodology, including revisions thereto, for transforming <i>load</i> forecasts for Singapore received</p>	<p><b>3.2 <u>FORECASTING SYSTEMS</u></b></p> <p>3.2.1 The <i>EMC</i> shall establish such systems and procedures, and train such staff, as may be necessary to allow the <i>EMC</i> to transform, on a regular basis as required by sections 7.2.1 and 9.1.1, <i>load</i> <u>and <i>solar generation</i></u> forecasts for Singapore received from the <i>PSO</i> for each <i>dispatch period</i> into <i>nodal load forecasts</i> for the same <i>dispatch period</i>. The methodology,</p>	<p>To include solar forecasts into the EMC’s forecasting system and procedures.</p>

Existing Market Rules (1 July 2021)	Proposed Rule Changes (Deletions represented by strikethrough text and additions represented by double underlined text)	Reasons for Modification
<p>from the <i>PSO</i> into <i>nodal load forecasts</i> shall be published by the <i>EMC</i>.</p>	<p>including revisions thereto, for transforming <i>load and solar generation</i> forecasts for Singapore received from the <i>PSO</i> into <i>nodal load forecasts</i> shall be published by the <i>EMC</i>.</p>	
<p><b>9.2 THE REAL-TIME SCHEDULING PROCESS</b></p> <p>9.2.4 The <i>EMC</i> shall, in accordance with the <i>market operations timetable</i>, <i>publish</i> the following information as it pertains to each <i>dispatch period</i>:</p> <p>9.2.4.1 total <i>load</i>;            9.2.4.1A total load curtailment of all <i>LRFs</i> with <i>REB</i>            9.2.4.2 total transmission losses;            ...</p>	<p><b>9.2 THE REAL-TIME SCHEDULING PROCESS</b></p> <p>9.2.4 The <i>EMC</i> shall, in accordance with the <i>market operations timetable</i>, <i>publish</i> the following information as it pertains to each <i>dispatch period</i>:</p> <p>9.2.4.1 total <i>load</i>;            9.2.4.1A total load curtailment of all <i>LRFs</i> with <i>REB</i>  <u>9.2.4.1B total <i>solar generation</i></u>;            9.2.4.2 total transmission losses;            ...</p>	<p>To include solar generation as part of the information to be published by EMC.</p>
<p><b>Chapter 8</b></p>	<p><b>Chapter 8</b></p>	
<p><b>1 DEFINITIONS</b></p>	<p><b>1 DEFINITIONS</b></p>	
<p>[New Section]</p>	<p><u>1.1.xxx <i>solar generation</i> means the electrical power output from <i>intermittent generation facility</i> including <i>solar photovoltaic systems</i>, usually expressed in <i>megawatts (alternating current)</i></u>;</p>	<p>To define solar generation.</p>