OMAN ELECTRICITY MARKET RULES

APPROVED METHODOLOGY

SCARCITY FACTOR TABLE METHODOLOGY

VERSION 4.1

EFFECTIVE DATE: 06/10/2025

1. INTRODUCTION

1.1 Scope, Purpose and Effectiveness of the Approved Methodology

Section M.2.2.1 of the Oman Electricity Market Rules (the Market Rules) requires the Market Operator to prepare, as an Approved Methodology, a methodology for establishing a Scarcity Factor Table. The Approved Methodology is termed the Scarcity Factor Table Methodology.

This document is the Scarcity Factor Table Methodology prepared by the Market Operator in accordance with Section M.2.2.1 of the Market Rules and approved by the Authority on 01 January 2025.

This Approved Methodology is effective on and from **06/10/2025.**

The Market Operator generally produces a Scarcity Factor Table for each calendar year by two months before the start of the year. However, if there is an entry or exit from the spot market of a Pool Unit or group of Pool Units with a capacity of 100MW or more that was not anticipated when the Scarcity Factor Table was prepared, then the Market Operator may produce an updated Scarcity Factor Table for approval by the Authority.

1.2 Market Rules Provision

Interested parties should read this statement in conjunction with the Market Rules and in particular Section M. This Approved Methodology has been produced in accordance with the provisions of the Market Rules. In the event of an inconsistency between the provisions of this Approved Methodology and the Market Rules, the provisions of the Market Rules shall prevail.

1.3 Review Procedure

The Market Operator may review this Approved Methodology from time to time and make changes, subject to the Authority's approval in accordance with Market Rules Section C.7.3.

1.4 Definitions and interpretation

Save as expressly defined, words and expressions defined in the Market Rules shall have the same meanings when used in this Approved Methodology. The rules of interpretation set out in Section B.3 of the Market Rules shall apply in the interpretation of this Approved Methodology.

References to particular sections relate internally to this Approved Methodology unless specifically noted. References to Market Rules sections are to the relevant sections of the Market Rules.

Table 1 – Defined terms

Term	Definition
Iteration	An iteration of the Model corresponding to a single modelled year with random forced outages and demand uncertainty.
Model	A Model procured by the Market Operator which is capable of carrying out Monte Carlo simulations with respect to forced outages on the Main Interconnected System
Modelled Unit	means a) a subdivision of a Production Block which can be dispatched by the Model; or b) a Demand Side Unit

Table 2 – Variable names

Variable	Description
ARM_e	Average Reserve Margin for Time Period e
AV_{iue}	Availability of Modelled Unit u in Time Period e for Iteration i
$Capacity_{ue}$	Capacity of Modelled Unit u in Time Period e
DM_e	Demand in Time Period e
DM_{ie}	Demand in Time Period e under Iteration i
DSF_m	Derived Scarcity Factor for Input Margin m
ICC_e	Interconnector Contribution in Time Period e
ISF_e	Initial Scarcity Factor for Time Period e
n	Number of Iterations
RM_{ie}	Reserve Margin in Time Period e for Iteration i
SAV_{ie}	System Availability in Time Period e for Iteration i
SCX_{ie}	Scarcity Index for Time Period e for Iteration i

Table 3 – Subscripts

Variable	Description
e	Time Period
i	Monte Carlo Iteration
m	A 5 MWh input margin step
u	Modelled Unit

1.5 Compliance with Approved Methodology

Compliance with this Approved Methodology is required under the terms as set out in the Market Rules. This Approved Methodology does not create any additional rights or obligations.

2. MONTE CARLO SIMULATION

2.1 Introduction

The Scarcity Factor at each level of margin is estimated using a Model which adopts a Monte Carlo approach. The Model projects the available capacity and demand in each hour of the Year, subject to stochastic forced outages and demand forecast error.

2.2 Model Inputs

2.2.1 Modelled Units

Production Facilities and Demand Side Units are mapped to notional Modelled Units for purposes of running the Model.

The Modelled Unit concept allows for simplification, where appropriate, of Production Blocks which comprise multiple Pool Scheduling Units (and which can operate in different Configurations). The Modelled Unit approach helps to prevent double counting of capacity across different Configurations of the same Production Block.

Each Modelled Unit u has an associated profiled capacity ($\text{Capacity}_{\text{ue}}$).

2.2.2 Time periods

The Model is run for a calendar year, using hourly Time Periods e, not 30-minute time periods like the Trading Period. At the end of the analysis the Scarcity Factor Table is adjusted for use with 30-minute Trading Periods under the Market Rules.

2.2.3 Forced Outages

Modelled Units have a defined forced outage rate. The Model schedules forced outages for each Modelled Unit randomly through the year to meet the forced outage rate over the year.

2.2.4 Demand

The Model uses a defined hourly demand profile across the year (DMe), developed from historical data. Forecasted Peak Demand and Average Demand are provided as inputs to the Model, and the Model adjusts the defined hourly demand profile to achieve provided Peak and Average Demand parameters. Where required under section 3.3 below the Peak and Average Demand will be adjusted to achieve the desired parameters.

Demand uncertainty is modelled using a normal distribution around the expected demand profile for each iteration i (DM_{ie}).

2.2.5 Interconnector Contribution

The Interconnector Contribution (ICCe) represents the flow (in MWh) between the Main Interconnected System (MIS) and all adjoining Systems in Time Period e, where a positive flow is a net import into the Main Interconnected System and a negative flow is a net export from the MIS.

2.3 Model Runs

A Model run should comprise at least n=600 Iterations of the modelled year with different forced outage and demand scenarios.

2.4 Model Outputs

2.4.1 Availability

The Availability ($\mathrm{AV_{iue}}$) of Modelled Unit u in Time Period e for each Iteration i is calculated as follows:

$$\mathrm{AV_{iue}} = \begin{cases} \mathrm{Capacity_{ue}} \text{ if no forced outage in Time Period e} \\ 0 \text{ if forced outage occurs in Time Period e} \end{cases}$$

where

1. $\mathrm{Capacity_{ue}}$ is the Capacity of Modelled Unit u in Time Period e

2.4.2 System Availability

The System Availability ($\mathrm{SAV_{ie}}$) is calculated as follows:

$$\mathrm{SAV_{ie}} = \sum_{u} \mathrm{AV_{iue}}$$

where

1. $\mathrm{AV_{iue}}$ is the Availability of Modelled Unit u in Time Period h for each Iteration i

2.4.3 Demand

The Demand ($\mathrm{DM_{ie}}$) for each Iteration i of each Time Period e is calculated within the Model as the expected demand profile for Time Period e plus the normally distributed demand uncertainty for Iteration i of each Time Period e.

2.4.4 Reserve Margin

The Reserve Margin ($\mathrm{RM_{ie}}$) of Iteration i in Time Period e is calculated as follows:

$$\mathrm{RM_{ie}} = \mathrm{SAV_{ie}} + \mathrm{ICC_{ie}} - \mathrm{DM_{ie}}$$

where

1. $\mathrm{SAV_{ie}}$ is the System Availability in Iteration i of Time Period e
2. $\mathrm{ICC_{ie}}$ is the Interconnector Contribution in Time Period e
3. DM_{ie} is the Demand in Iteration i of Time Period e

2.4.5 Average Reserve Margin

The Average Reserve Margin ($\mathrm{ARM_{e}}$) of Time Period e is calculated as follows:

$$ARM_e = \frac{\sum_{i=1 \text{ to } n} RM_{ie}}{n}$$

where

1. RM_{ie} is the Reserve Margin of iteration i in Time Period e
2. n is the number of iterations

2.4.6 Scarcity Index

The Scarcity Index (SCX_{ie}) for each Iteration i of each Time Period e is calculated as follows:

$$SCX_{ie} = \begin{cases} 1 \text{ if } RM_{ie} < 0 \\ 0 \text{ if } RM_{ie} \geq 0 \end{cases}$$

where

1. RM_{ie} is the Reserve Margin in iteration i of Time Period e

2.4.7 Initial Scarcity Factor

The Initial Scarcity Factor (ISF_e) for Time Period e is calculated as follows:

$$ISF_e = \frac{\sum_{i=1 \text{ to } n} SCX_{ie}}{n}$$

where

1. SCX_{ie} is the Scarcity Index for iteration i of Time Period e
2. n is the number of iterations

3. SCARCITY FACTOR TABLE CALCULATION

3.1 Initial Model Run

3.1.1 *Expected Demand*

The initial Model run should use as input the expected demand level.

3.1.2 *Counting Initial Scarcity Factors*

Using the initial Model run, count the number of Time Period e where $ISF_e > 0$.

If the number of such Time Period e is greater than or equal to 200, then fit a regression model as described in section 3.2;

Otherwise:

Where the number of such Time Period e is less than 200 then there are too few points to reliably fit a regression model. In that case the method described in section 3.3 should be followed.

3.2 Calculating the Derived Scarcity Factor

3.2.1 *Fitting a Curve*

Using the data from a Model run, for each Time Period e define a pair $(\mathrm{ARM_e}, \mathrm{ISF_e})$

1. Fit a least square generalised linear model of the form $f(ISF_e) = \beta \times ARM_e$, where
   1. ARM_e is the Average Reserve Margin in Time Period e as calculated in Section 2.4.5
   2. ISF_e is the Initial Scarcity Factor in Time Period e as calculated in Section 2.4.7
   3. β is the theoretical slope of the generalised linear function $f(ISF_e)$.

2. Estimate the Derived Scarcity Factor for a given level of Reserve Margin (RM_e) by applying the regression coefficient to the Reserve Margin value as follows:

$$\mathrm{DSF(RM_e)} = \mathrm{f}\left(\hat{\beta} \times \mathrm{RM_e}\right),$$

Where

- f(.) denotes the function fit in the generalised linear model in Step 1 above
- $\hat{\beta}$ is the least squares estimate of the theoretical slope of (β) of the generalised linear model fit in Step 1 above.

Figure 1 provides an illustration of such a curve. In this example, a generalised linear model with a logarithmic transform is used as follows:

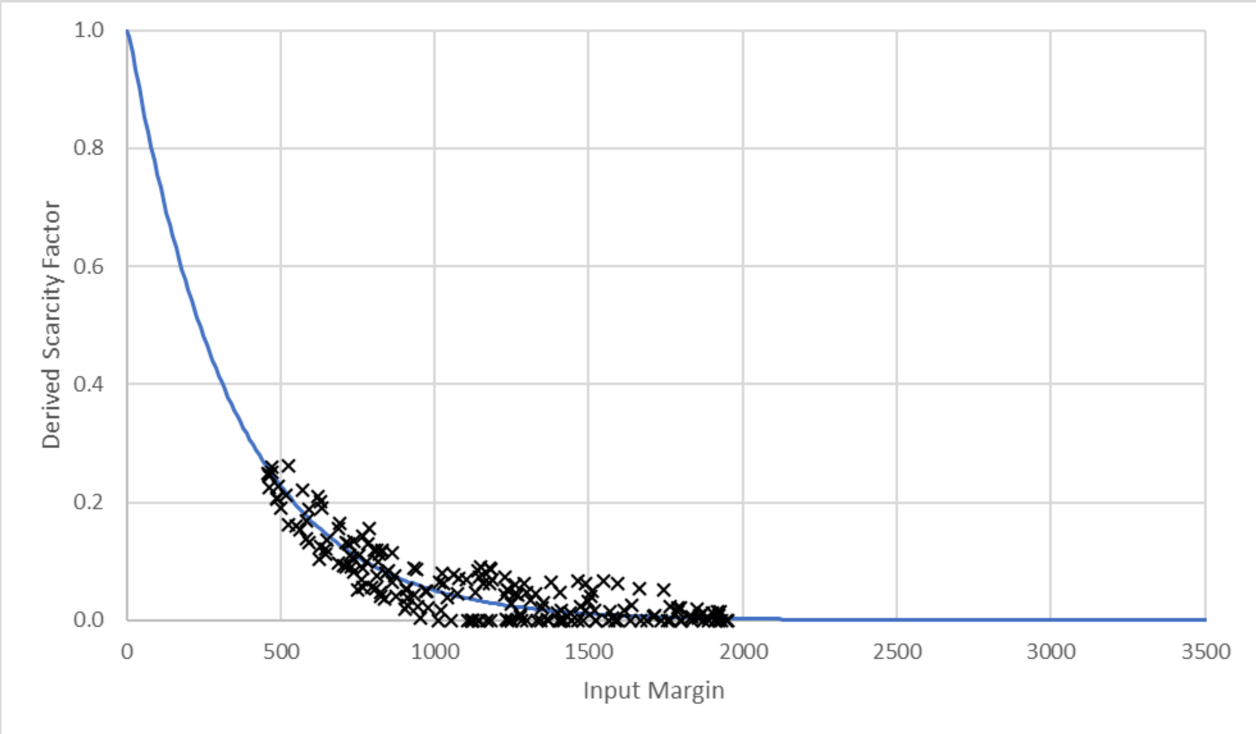
$$\ln(RM_e) = \beta \times ARM_e$$

The Derived Scarcity Factors ($\mathrm{DSF(RM_e)}$) would be calculated as follows:

$$\mathrm{DSF}(\mathrm{RM_e}) = \mathrm{e}^{\hat{\beta} \times ARM_e}$$

Where $\hat{\beta}$ is the least squares estimate of β.

Figure 1 – Illustration of fitted curve DSF(RM$_e$)



3.2.2 Derived Scarcity Factor

The Derived Scarcity Factor for each 5 MWh increment of Input Margin m is:

$$\mathrm{DSF}(m) = \mathrm{f}\left(\hat{\beta} \times \mathrm{m}\right)$$

Where $\hat{\beta}$ is the least square estimate of the slope of the generalised linear model fit under Section 3.2.1.

3.3 Method When Simulated Input Margins Are High

3.3.1 Demand Adjustment

Where the number of time periods e with $ISF_e > 0$ is less than 200, then the analysis shall be repeated from section 2.3 with an adjusted level of demand.

The Market Operator may perform several runs with different levels of demand adjustment as necessary to provide suitable ranges of Input Margins to successfully produce the curve.

For each run the expected Peak and Average Demand inputs for the simulated year are increased, which results in the Model calculating a revised hourly demand profile DM_e.

At minimum the level of demand adjustment should be an amount that the Market Operator judges will be sufficient to produce at least 200 instances of $ISF_e > 0$.

The Derived Scarcity Factor should then be calculated in accordance with section 3.2.

3.3.2 Additional Model Runs

Where, following a Model run with demand adjustment in accordance with section 3.3.1, the minimum value of Average Reserve Margin (ARM_e) for all hours in the Model Run is greater than 1000 MW, then one or more additional Model runs may be performed with larger levels of demand adjustment.

The level of demand adjustment used in the additional Model runs should be an amount that is equal to:

The demand adjustment from the previous demand adjustment Model run

plus the minimum value of ARM_e from the previous demand adjustment Model run

plus an additional amount of between 0 and 400 MW.

Following each additional Model run the Derived Scarcity Factor should be calculated in accordance with section 3.2.

The Market Operator may combine curves fitted to data from several demand adjustment Model runs and additional Model runs together to produce a Scarcity Factor Table that effectively covers a wide range of Input Margins.

3.4 The Scarcity Factor Table

The Scarcity Factor Table is the calculated value of DSF_m for each 5 MWh increment of Input Margin m. The table should be in the form set out below:

Table 4 – Form of Scarcity Factor Table

Input Margin (MWh)	**DSF** (decimal between 0 and 1)
…	…
x	a
y	b
z	c
…	…