EMCa

energy market consulting associates

Report on the benchmarked costs of ancillary services in different jurisdictions

for

Economic Regulation Authority

February 2020

This report has been prepared to assist the Economic Regulation Authority to inform its annual report to the Minister for Energy on the effectiveness of the Wholesale Electricity Market in meeting its objectives.

To the extent that this report utilises quantitative data, it relies on information provided to EMCa or obtained from EMCa's sources. EMCa disclaims liability for any errors or omissions, for the validity of information provided to EMCa by Economic Regulation Authority and stakeholders to this review, for the use of any information in this report by any party other than the Economic Regulation Authority and for the use of this report for any purpose other than the intended purpose.

Energy Market Consulting associates

802/75 Miller St, North Sydney NSW 2060

and

Level 1, Suite 2 572 Hay St, Perth WA 6000

AUSTRALIA

Email: **contact@emca.com.au**

Web: www.emca.com.au

About EMCa

Energy Market Consulting associates (EMCa) is a niche firm, established in 2002 and specialising in the policy, strategy, implementation and operation of energy markets and related network management, access and regulatory arrangements. EMCa combines senior energy economic and regulatory management consulting experience with the experience of senior managers with engineering/technical backgrounds in the electricity and gas sectors.

Authorship

Prepared by:	Ignatius Chin, with input from Yenren Liu, Yen-Shong Chiao, Doug Goodwin
Quality approved by:	Paul Sell
Date saved:	28/02/2020 4:07 PM
Version:	v1

[This page intentionally blank]

Table of Contents

Executive Summary

Introduction

EMCa has been engaged by Economic Regulation Authority (ERA) to undertake research and provide advice on the comparable costs of ancillary services in different jurisdictions. This advice is intended to assist the ERA in undertaking its annual review of the effectiveness of the Wholesale Electricity Market (WEM) in meeting the WEM objectives.

Purpose of this report

The purpose of this paper is to present EMCa's analysis on ancillary services cost trends and benchmarking across selected jurisdictions.

The jurisdictions we have studied are:

- the WEM;
- the NEM (National Electricity Market) Australia;
- the National Electricity Market of Singapore (NEMS);
- the New Zealand Electricity Market (NZEM);
- the CAISO in California, USA;
- ERCOT in Texas, USA; and
- the PJM Interconnection, USA.

In this report, we have:

- Provided a high-level range of ancillary costs in electricity markets in different jurisdictions;
- Where feasible, provided explanation as to why the costs to perform similar functions differ between different jurisdictions and what are the main drivers of costs in different jurisdictions;
- Provided the benchmarked cost of ancillary services in electricity markets in different jurisdictions;
- Articulated how the analysis can be used to help inform an efficient cost to deliver ancillary services; and
- Presented how the cost of ancillary services in other electricity jurisdictions considered has changed over time, particularly where in a jurisdiction there has been a significant change in the penetration of rooftop PV and grid-connected wind and solar farms.

Our approach for this study

Ancillary services in the WEM and the other jurisdictions we have studied consists of frequency control ancillary services (FCAS) and non-FCAS.

FCAS consists of the following types, and their functional characteristics are as follows:

- **Regulation** – this ancillary service is known as **Load Following Ancillary Service** in the WEM. Regulation is a mechanism in real-time to ensure that supply and demand are continuously balanced. Regulation is generally provided by generators which are capable of being regulated under centralised Automatic Generation Control (AGC) to maintain system frequency. There are two types of Regulation ancillary service, namely **Regulation Up** (known as **LFAS Up** in the WEM) and **Regulation Down** (known as **LFAS Down** in the WEM).
- **Contingency Raise** – this ancillary service is the capacity held in reserve to respond rapidly should an online facility experience a sudden forced outage (e.g. generation trip or network outage). In the WEM, this is equivalent to **Spinning Reserve**. In some other jurisdictions, Contingency Raise can consist of both Spinning Reserve and **Non-spinning Reserve**.
- **Contingency Lower** – this service is generally provided by a generator which can rapidly decrease output should a sudden loss of load occur (for example, due to system fault). In the WEM, this service is known as the **Load Rejection Service**.

The non-FCAS we have studied is the Black Start service. This service allows parts of the power system to be re-energised by Black Start equipped generation capacity following a system wide blackout.

Our approach for benchmarking the ancillary service costs consists of the following two aspects:

- Like-for-like comparison of WEM's ancillary service types across selected jurisdictions; and
- Measuring and comparing the ancillary services costs.

Like-for-like comparison

In this aspect of the study, we compare each ancillary service type between jurisdictions on a like-for-like basis. Our method for such comparison involves mapping the ancillary services types in the WEM to those in other jurisdictions based on the shared functional characteristics (discussed above). This mapping in set out in Table 1.

Table 1: Mapping of ancillary services types based on functional characteristics

Ancillary service type	WEM	NEM
Regulation Up	LFAS Up	Regulation Raise
Regulation Down	LFAS Down	Regulation Lower
Contingency Raise	Spinning Reserve	Contingency Raise
Contingency Lower	Load Rejection	Contingency Lower
Black start	Black Start	Black Start

Ancillary service type	Singapore	NZ
Regulation Up	Regulation	Frequency Keeping
Regulation Down		
Contingency Raise	Reserve	Instantaneous Reserve
Contingency Lower		Overfrequency
Black start	Black Start	Black Start

Ancillary service type	CAISO	PJM	ERCOT
Regulation Up	Regulation Up	Regulation	Regulation Up
Regulation Down	Regulation Down		Regulation Down
Contingency Raise	Spinning Reserve Non-Spinning Reserve	Synchronized Reserve Non-synchronized Reserve	Responsive Reserve Nonspin reserve
Contingency Lower			
Black start	Black Start	Black Start	Black Start

Source: EMCa analysis

Measurements of the ancillary services cost and benchmarking methodology

We consider it necessary to benchmark an FCAS type using two measures:

- the **Normalised Price** – this is a measure of how expensive an FCAS type is compared to the other jurisdictions. This is derived by normalising the Price (i.e. the amount spent on the FCAS type per MWh procured) to the WEM unit wholesale electricity cost.[1] Such normalisation is necessary because the FCAS price is generally a function of the opportunity cost of the underlying wholesale electricity cost.[2] The Normalised Price of an FCAS type in a jurisdiction represents what the Price would have been if the jurisdiction has the same unit wholesale electricity cost as the WEM. For our analysis, we used the 2018 WEM unit wholesale cost as the base for the normalisation. The unit of a Normalised Price is dollars per MWh procured.
- the **Procured Quantity Percentage** – this is a measure of the procured quantity of the FCAS type as a percentage of the system load energy. It is necessary to measure the procured quantity in percentage terms because it is likely that the procured quantity is a function of the system size of a jurisdiction. Measuring the Procured Quantity Percentage allows us to consider the extent to which the WEM may have procured an efficient amount of FCAS type compared to other jurisdictions (if other factors were equal).

For a non-FCAS (we have studied the Black Start in this review), it would not be feasible to measure the benchmark based on the Normalised Price and Procured Quantity Percentage. This is because a Black Start ancillary service: (a) is not generally not

[1] That is: (a) calculate the Price of an FCAS type of a jurisdiction as a percentage of the unit wholesale cost of that jurisdiction; and then (b) multiply the percentage from step (a) by the WEM unit wholesale cost.

[2] That is, a jurisdiction with higher underlying wholesale electricity cost tends to have high FCAS prices.

procured in MWh quantity; and (b) is generally not priced in terms of the opportunity cost to the underlying wholesale electricity cost. Rather, we consider it more meaningful to measure Black Start benchmark simply in terms of the unit Cost. That is, the expenditure on the service per MWh of system load energy. The unit for Black Start Cost is dollar per MWh system load energy.

Using the above measures allows us to benchmark and present the trend for each of the ancillary service types.

We calculated the benchmark using the results from 2016 to 2018 (adopting recent years' data). We present trends from 2013 to 2018.

Summary of our findings

Our findings are as follows:

- FCAS (collectively) is more expensive (in terms of the Normalised Price) in the WEM compared to the other jurisdictions. In terms of each of the FCAS types:
    - LFAS (both Up and Down and combined) is much more expensive compared to its counterparts in the other jurisdictions.
    - Contingency Raise (Spinning Reserve) in the WEM is also more expensive compared to its counterpart in the other jurisdictions apart from ERCOT.[3]
    - Normalised Load Rejection Service Price in the WEM is similar to that in the NEM but the range in the NEM is wider.
    - For the LFAS Up and Spinning Reserve combined[4], the WEM Normalised Price is also higher compared to its counterparts in the other jurisdictions.
- The procured quantity of FCAS (collectively, in Procured Quantity Percentage terms) is high compared to the other jurisdictions (except Singapore). For each of the FCAS types:
    - The Procured Quantity Percentage for LFAS (both Up and Down and combined) in the WEM is high compared to its counterpart in all other jurisdictions.
    - The Procured Quantity Percentage of Spinning Reserve in the WEM is low compared to Contingency Raise in most other jurisdictions. Possible reasons includes (a) LFAS Up in the WEM can be used for providing Spinning Reserve while this is not the case for some of the other jurisdictions; (b) high Contingency Raise requirements in Singapore, NZ and CAISO and ERCOT due to large contingency requirements; (c) high solar/wind penetration in the CAISO and ERCOT[5].

---

[3] Note that Contingency Raise in some jurisdictions include Spinning and Non-spinning Reserves.

[4] This is measure is used for two reasons: (a) different jurisdictional boundary definition between Regulation and Contingency Raise; and (b) in some jurisdictions (including the WEM), LFAS Up (or Regulation Up) can be used for Spinning Reserve.

[5] Mostly wind in ERCOT.

    - The Procured Quantity Percentage of Load Rejection Service in the WEM is high compared to the Contingency Lower in the NEM. This is due to the differences in principles and methodology used to set the quantities.
    - For the LFAS Up and Spinning Reserve combined, the WEM Procured Quantity Percentage is also higher compared to its counterparts in the other jurisdictions apart from ERCOT.
- The Normalised Regulation Prices (Up, Down and combined) are trending upwards in the WEM. This is in contrast with the trends in the NEM, Singapore and NZ which are experiencing downwards trends. The downward trends in those markets are contributed by: (a) new entrants and reduced pricing impacts of constraints in the NEM; (b) market power investigation in Singapore; and (c) more competition in NZ.
- The Normalised Spinning Reserve Price in the WEM is trending up reflecting the increasing Spinning Reserve Margin Values. Similar upwards trends are also observed in the NEM, CAISO and ERCOT due to a variety of reasons including increased renewable penetration.
- For the LFAS Up and Spinning Reserve combined, the Procured Quantity Percentages are also trending upwards in the WEM, NEM, CAISO and ERCOT. This is also due to a variety of reasons including increased renewable penetration.
- There is a moderate relationship between system size of a jurisdiction and the FCAS Procured Quantity Percentage. This, and also the isolation of the WEM, would partly explain the high FCAS Procured Quantity Percentage in the WEM.
- There is also some relationship between FCAS Prices and rate of the penetration of wind/solar in a jurisdiction.
- Taking into account the purchasing power of consumers in the jurisdictions (that is, comparing costs in the different jurisdictions on the basis of Purchasing Power Parity), we found that FCAS is less affordable compared to the other jurisdictions.
- Black Start Cost[6] in the WEM is low compared to most other jurisdictions.
- Based on observations on the other jurisdictions, we found some of these common features are notably absent in the WEM:
    - Dynamic ancillary services quantity requirements;
    - Co-optimisation of the energy and ancillary services; and
    - Five-minute dispatch.
- If designed properly, these features would have the potential to deliver improved efficiency in ancillary services price and quantity.

Conclusion

We find that the ancillary services Prices and the percentage quantity in the WEM are both high compared to the other jurisdictions.

Some features of ancillary services that are common in the other jurisdictions are absent in the WEM. While these are not definitive reasons for the high Prices and quantities, incorporating them into the WEM (if properly designed) is likely to enhance Price and

[6] Cost, as opposed to Price, is the expenditure per MWh system load energy (rather than per MWh of quantity procured).

volume efficiencies in the WEM ancillary services market. We note that the work program of the Energy Transformation Strategy is working towards delivering the above features to the WEM.

Based on observations from the other jurisdictions, the following are some additional ideas for enhancing the efficiency of ancillary services delivery in the WEM. They may be used for reference for future market reform programs:

- Market for Non-spinning Reserve capacity – this is because the Non-spinning reserves were found to be generally cheaper;
- Ancillary services using demand side resources – greater participation to encourage competition;
- Pay for performance for ancillary services providers – e.g. rewarding Regulation providers for speed and accuracy in following AGC signals. This would incentivise more efficient utilisation of Regulation resources;
- Cost allocation for Spinning Reserve based on not just generation amount but also reliability of the generators. This would incentivise more efficient utilisation of Spinning Reserve resources;
- Lowering ancillary services quantity requirements and implementing a scarcity pricing model. This may promote volume efficiency in the ancillary services market; and
- Self-supplied ancillary service – allowing a party who has an obligation to buy ancillary service to self-supply (either through own resource or bilateral arrangement), and centrally allocate the balance by AEMO.[7] This would allow efficiency from the self-supply arrangement (if any) to be realised.

[7] For example, a generator may be obliged to buy 100 GWh of Spinning Reserve a year. Through the self-supply arrangement, the generator buys 30 GWh through bilateral contracting with a Spinning Reserve provider, and discharges its remaining Spinning Reserve obligation through AEMO's central allocation process.

1 Introduction

1.1 Purpose of this paper

The purpose of this paper is to present EMCa's analysis on ancillary services cost trends and benchmarking across selected jurisdictions. These selected jurisdictions include:

- the WEM;
- the NEM (National Electricity Market) Australia;
- the National Electricity Market of Singapore (NEMS);
- the New Zealand Electricity Market (NZEM);
- the CAISO in California;
- ERCOT in Texas; and
- the PJM Interconnection.

This report shows the results of the analysis and provides commentaries on those results.

1.2 Structure of this report

The structure of this report is as follows:

- In **Section 2**, we discuss our approach;
- In **Section 3**, we present the benchmarking and trend results with commentaries;
- In **Section 4**, we provide a summary of the ancillary services in the NEM;
- In **Section 5**, we provide a summary of the ancillary services in the NEMS;
- In **Section 6**, we provide a summary of the ancillary services in the NZEM;
- In **Section 7**, we provides a summary of the ancillary services in North America – including CAISO in California, ERCOT in Texas and the PJM;

- **In Section 8**, we discuss our observations and conclusions.

We have also included a number of appendices providing additional information and analysis.

2 Background and approach

2.1 Introduction

Our approach for benchmarking the ancillary service cost consists of the following aspects:

- Like-for-like comparison of WEM's ancillary service types across selected jurisdictions; and
- Measuring and comparing the ancillary services costs.

Based on the above, we have:

- Provided a high-level range of ancillary costs in electricity markets in different jurisdictions;
- Where feasible, provided explanation as to why the costs to perform similar functions differ between different jurisdictions and what are the main drivers of costs in different jurisdictions;
- Provided the benchmarked cost of ancillary services in electricity markets in different jurisdictions;
- Articulated how the analysis can be used to help inform an efficient cost to deliver ancillary services; and
- Presented how the cost of ancillary services in other electricity jurisdictions considered has changed over time, particularly where in a jurisdiction there has been a significant change in the penetration of rooftop PV and grid-connected wind and solar farms.

2.2 Ancillary services Wholesale Electricity Market (Western Australia)

In the WEM, the following Ancillary Services are defined in the Market Rules[8]:

- **Load Following (LFAS)** is the primary mechanism in real-time to ensure that supply and demand are continuously balanced. It compensates for variations in load and intermittent generation relative to what AEMO anticipated when issuing Dispatch Instructions for the Trading Interval and also compensates for normal generation deviations. LFAS is provided by generators which are capable of being regulated under centralised Automatic Generation Control (AGC) to maintain system frequency.
- **Spinning Reserve** is capacity held in reserve to respond rapidly should an online facility experience a sudden forced outage. This service can be provided by spare on-line generation capacity, Dispatchable Loads and interruptible loads (i.e. loads that reduce automatically if the system frequency drops).
- **Load Rejection Reserve** is generation which can rapidly decrease output should a sudden loss of load occurs (for example, due to system fault). This service can be particularly important overnight when generating units can be operating at minimum loading and are unable to decrease their output in the time frame required.
- **Dispatch Support** ensures that voltage levels around the power system are maintained, and includes other services required to support the security and reliability of the power system that are not covered by other Ancillary Services.
- **Black Start (or System Restart)** allows parts of the power system to be re-energised by Black Start equipped generation capacity following a system wide black out.

Currently there is no ancillary services market in the WEM apart from the LFAS markets.

AEMO allocates the cost of Ancillary Services between Market Participants on the following basis[8]:

- The monthly cost of Load Following is allocated amongst Market Participants in proportion to their monthly share of contributing quantity (metered load and Non-Scheduled Generation[9]).
- The monthly cost of Spinning Reserve is borne by generators in proportion to the deemed risk that the generator imposes on the system, based on the output of the generator in each Trading Interval during the month.
- The monthly costs for Load Rejection Reserve, Dispatch Support and System Restart are recovered from Market Customers[10] in proportion to their monthly metered consumption.

[8] AEMO, Wholesale Electricity Market Design Summary, 24 Octo 2012, https://aemo.com.au/-/media/files/pdf/wem-design-summary-v1-4-24-october-2012.pdf

[9] Included intermittent generators – see section 2.29.4 of the WEM Rules.

[10] Predominantly retailers.

2.3 Our benchmarking approach

2.3.1 Like-for-like comparison of ancillary services

The functional characteristic for each ancillary service type is set out in Table 2.

Table 2: Functional characteristics of each ancillary service type

	Ancillary service type	Functional characteristic
Frequency control ancillary service (FCAS)	**Regulation Up**	Mechanism in real-time to ensure that supply and demand are continuously balanced (using upwards generator adjustment or downward load adjustments)
	Regulation Down	Mechanism in real-time to ensure that supply and demand are continuously balanced (using downwards generator adjustment or upwards load adjustments)
	Contingency Raise	Capacity held in reserve to respond rapidly should an online facility experience a sudden forced outage (e.g. generation trip or network outage)
	Contingency Lower	Generation which can rapidly decrease output should a sudden loss of load occurs (for example, due to system fault)
Non-FCAS	**Black Start (or System Restart)**	Service to allow parts of the power system to be re-energised by Black Start equipped generation capacity following a system wide blackout.

Source: EMCa analysis

As illustrated, the ancillary service types consist of the frequency control ancillary services (FCAS) and non-FCAS.

The FCAS are where most of the expenditures are incurred, hence, they are the focus of our analysis. However, we will also provide coverage on the Black Start ancillary services which are a type of non-FCAS.

In some jurisdiction, the Regulation Up and Regulation Down are combined into a single Regulation ancillary service type.

Our method for like-for-like comparison involves identifying the functional characteristic of the WEM's ancillary services type, and then mapping these ancillary services types to those in other jurisdictions based on their shared functional characteristics.

We have selected the jurisdictions for benchmarking based on the availabilities of ancillary services types with those functional characteristics.

The mapping is set out in Table 3.

Table 3: Mapping of ancillary services types based on functional characteristics

Ancillary service type	WEM	NEM
Regulation Up	LFAS Up	Regulation Raise
Regulation Down	LFAS Down	Regulation Lower
Contingency Raise	Spinning Reserve	Contingency Raise
Contingency Lower	Load Rejection	Contingency Lower
Black start	Black Start	Black Start

Ancillary service type	Singapore	NZ
Regulation Up	Regulation	Frequency Keeping
Regulation Down		
Contingency Raise	Reserve	Instantaneous Reserve
Contingency Lower		Overfrequency
Black start	Black Start	Black Start

Ancillary service type	CAISO	PJM	ERCOT
Regulation Up	Regulation Up	Regulation	Regulation Up
Regulation Down	Regulation Down		Regulation Down
Contingency Raise	Spinning Reserve Non-Spinning Reserve	Synchronized Reserve Non-synchronized Reserve	Responsive Reserve Nonspin reserve
Contingency Lower			
Black start	Black Start	Black Start	Black Start

Source: EMCa analysis

Although an ancillary services type across jurisdictions may share the same functional characteristics, their definitions may not be exactly the same. For example, the Contingency Raise for the WEM is Spinning Reserve, while the equivalent in CAISO[11] consists of both Spinning and Non-spinning Reserves.

2.3.2 Measurement of ancillary service cost

Cost measurement for FCAS

We measure the cost for an FCAS type in a jurisdiction using the **Normalised Price**.

In order to compare the FCAS cost between jurisdictions, there is a need to meaningfully measure them. To do this, there is a need to differentiate **Cost** (with capital C) from **Price**.

Cost for an FCAS type is defined as the total expenditure per MWh system load energy.

Price for an FCAS type, on the other hand, is defined as the total expenditure per MWh of the quantity procured.

It is more meaningful to compare the Price rather than Cost. This is because a larger size market tends to incur lower Cost compared to a smaller size market (because the quantity procured[12] as a percentage of the system load tends to be smaller than in a large size market – see discussion in section 3.10). Comparing Costs of an FCAS type

[11] Electricity market in California, USA. To be discussed in detail later.

[12] For an FCAS type.

across two markets with different sizes is therefore less meaningful for our analysis. The Price "normalises" the market size effect.

However, using Price also has limitations. This is because FCAS Prices tend to be opportunity costs of the underlying unit wholesale energy cost (dollar per MWh). A market with higher unit wholesale energy cost tends to have a higher FCAS Price. Therefore, comparing two Prices for an FCAS type across two jurisdictions with different underlying unit wholesale energy costs is still not sufficiently meaningful.

In order to normalise against the wholesale price difference, it is necessary to measure the **Price of an FCAS type as a percentage of the unit wholesale cost**.

For comparison between jurisdictions, we use the **Normalised Price** for an FCAS type for a jurisdiction. The Normalised Price for an FCAS type is defined as the "Price in terms of the percentage of the unit wholesale cost" multiplied by the WEM unit wholesale cost in 2018. This allows the Price of an FCAS type in a non-WEM jurisdiction to be normalised to the 2018 WEM unit wholesale cost.

A Normalised Price for an FCAS type allows the Prices from two jurisdictions to be compared after considering the unit wholesale cost difference between the two jurisdictions.

For analysis for the Cost and Price, see Appendix A and B respectively. Appendix C contains the analysis for the Price of each FCAS type as a percentage of the unit wholesale cost

Procurement quantity measurement for FCAS

There is also a need to compare the quantities of an FCAS type procured across jurisdictions. This allows us to consider the extent to which one jurisdiction has procured an efficient quantity of an FCAS type compared to another jurisdiction, or other factors that might drive the 'efficient' quantity.

The quantity procured for an FCAS is likely to be driven at least by the system size. It is therefore also meaningful to measure the procurement quantities as a percentage of the system load energy.

For the purpose of this report, we call the "procurement quantities as a percentage of the system load energy" the **Procured Quantity Percentage**.

Cost measurement for Black Start service

In this report, we will compare the Black Start service (i.e. non-FCAS) using Cost rather than Price. This is because Black Start, unlike the FCAS, is not procured in MWh and is unlikely to be priced in terms of the opportunity cost of the underlying wholesale energy cost.

2.3.3 Currency

To facilitate comparison between jurisdictions, we have converted all Costs and Prices into Australian Dollars using the average currency exchange rate from 2010 to 2019. We use a fixed exchange rate in order eliminate the effect of currency movements in our comparisons over this period.

An exception is made for our analysis relating to FCAS contribution to electricity affordability. This analysis requires purchasing power of consumers in the relevant jurisdictions to be considered. This analysis therefore uses the exchange on a Purchase Power Parity basis for currency conversion. This analysis is discussed in section 3.12 of this report.

2.3.4 Markets in North America: Day-Ahead Market and Real Time Market

Electricity markets in North America typical consists of both Day-Ahead Markets and Real Time Markets.

As the traded values are generally far higher in the Day-Ahead Markets[13], we use the Day-Ahead market data for our analysis in this report.

[13] For example, see Table 2.1 of the *2018 Annual Report on Market Issues & Performance* (CAISO). Also see page ii of the *2018 State of The Market Report for The ERCOT Electricity Markets*

3 Benchmarks and trends

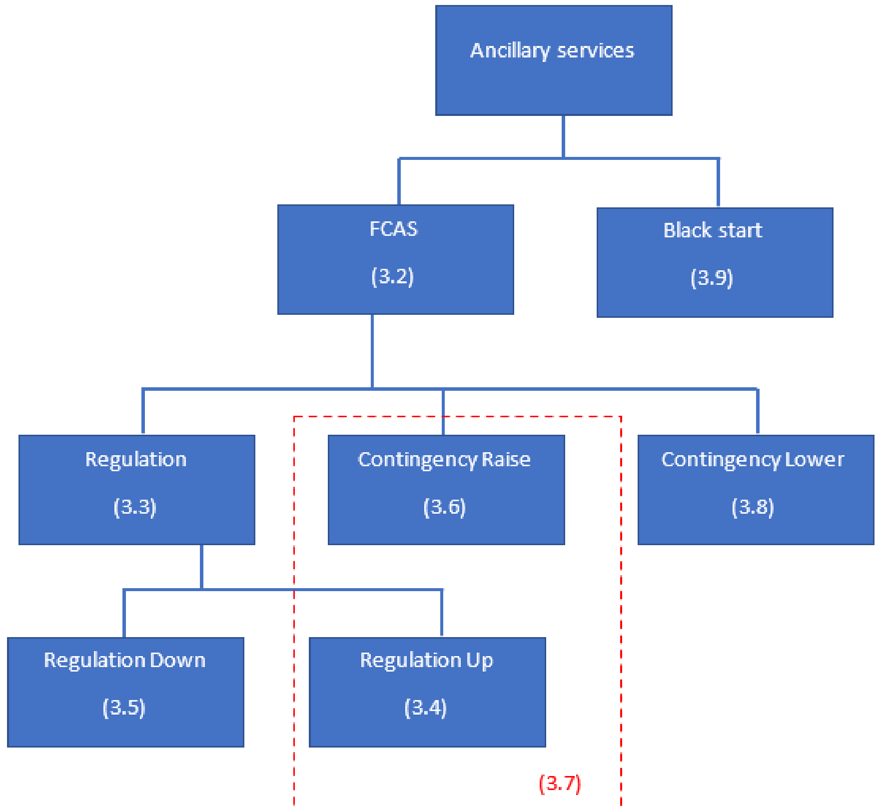
3.1 Introduction

This chapter presents, for each jurisdiction we have studied, the benchmarking results and trends of ancillary services. The trends and benchmarks are presented in terms of the Normalised Price as well as the Procured Quantity Percentage.

We also discuss the drivers for the trends, and for the differences between jurisdictions in terms of the Normalised Price and Procured Quantity Percentage.

The relationships between ancillary service types, and the section which we present the benchmarking and trend results are set out in Figure 1 (the numbers in the brackets are the sections).

Figure 1: Ancillary service types and the sections which the benchmark and trends are discussed (in brackets)



Source: EMCa analysis

We note that:

- The equivalence of Regulation in the WEM is Load Following Ancillary Service (LFAS).
- The equivalence of Regulation Up and Regulation Down in the WEM are LFAS Up and LFAS Down respectively.
- Contingency Raise includes Spinning Reserve, and Non-spinning Reserve in some jurisdictions. The WEM has Spinning Reserve.
- Contingency Lower is equivalent to the WEM's Load Rejection Ancillary Service.

As noted above, in addition to discussing the results for each ancillary service type individually, we also discuss the results for the sum of the Regulation Up and Contingency Raise. We discuss the results for Regulation Up + Contingency Rise collectively for two reasons:

- In some jurisdictions including the WEM, Regulation Up capacities can also be used for providing Contingency Raise service; and
- The boundaries between Regulation Up and Contingency Raise may vary from jurisdiction to jurisdiction.

In this section 3 of this report, we show:

- the trends of the Normalised Price for each FCAS type for each jurisdiction for 2013 to 2018;

- the benchmarked Normalised Price and range for each FCAS type for each jurisdiction;
- the trends of the Procured Quantity Percentage for each FCAS type for each jurisdiction for 2013 to 2018;
- the benchmarked Procured Quantity Percentage and range for each FCAS type for each jurisdiction;
- the trend, benchmark and range of Cost of the Black Start service.

We also provide commentaries on the trends and benchmarks.

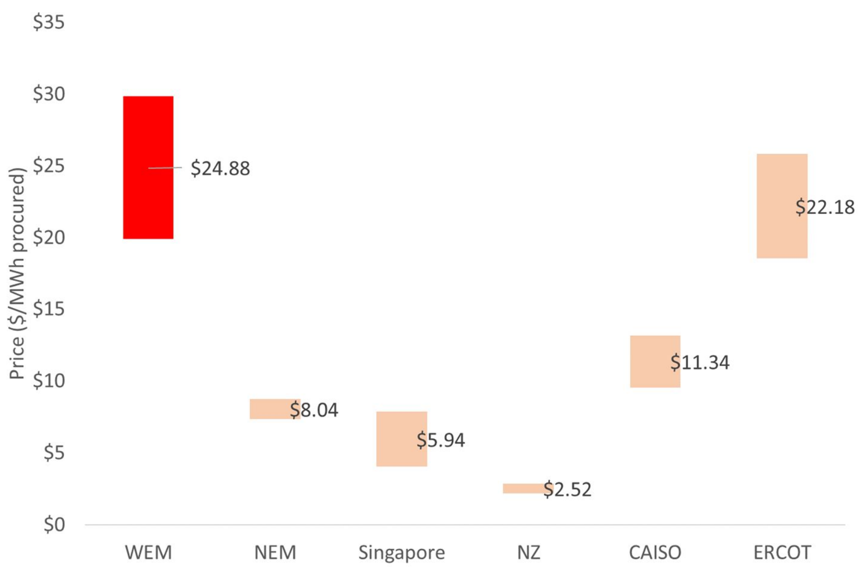
Other relevant analyses are also presented in this section, including examining the relationship between solar/wind penetration and ancillary services Price (see section 3.11).

3.2 Frequency control ancillary service (FCAS)

3.2.1 Price benchmarking

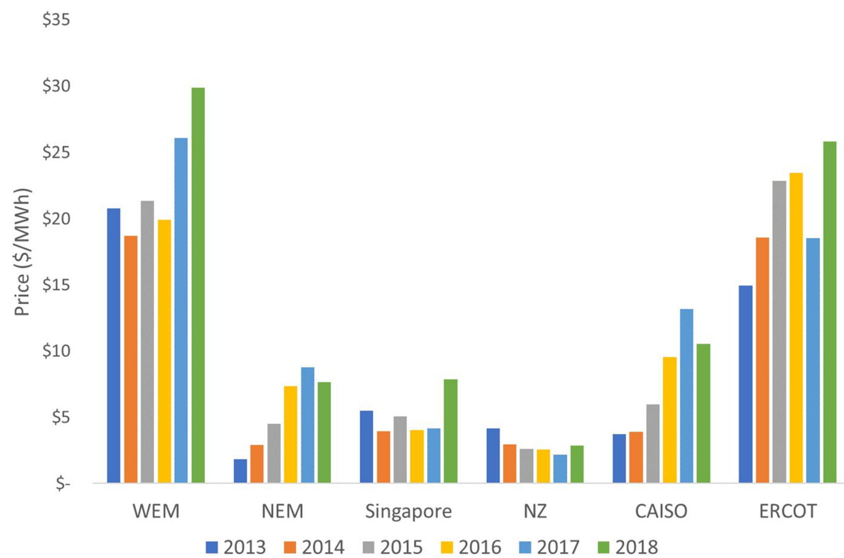
The benchmark result of FCAS is illustrated in Figure 2. Figure 3 sets out the Normalised FCAS Prices from 2013 to 2018.

Figure 2: Range and benchmark of Normalised FCAS Price



Source: EMCa analysis

Figure 3: Normalised FCAS Price trends



Source: EMCa analysis

FCAS is more expensive in the WEM compared to the other jurisdictions. These high Normalised FCAS Prices are driven by the high Regulation and Contingency Normalised Prices which are discussed later in this document.

The Normalised FCAS Prices are also upward trending in the WEM, NEM, CAISO and ERCOT, reflecting the trends for the Normalised Regulation and/or Contingency Raise Prices in these jurisdictions.

In the case of the NEM, the upward trend is driven by a series of specific events including[14]:

- Closure of Northern Power Station in South Australia in 2016;
- Closure of Hazelwood Power Station (Victoria) in 2017;
- Tasmania limited in providing FCAS in 2017; and
- Basslink outage in 2018.

In the cases for the NEM, CAISO and ERCOT, the trend appears to also correlate with the increased penetration of renewable energy. This is discussed further in section 3.11.

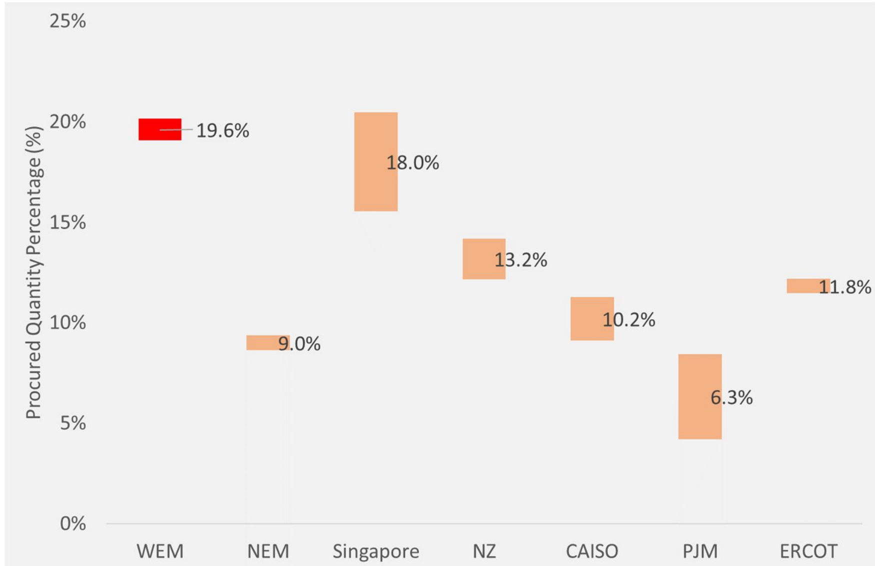
3.2.2 Procured Quantity Percentage benchmarking

Figure 4 illustrates the benchmarks and ranges for the FCAS Procured Quantity Percentage. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 5.

---

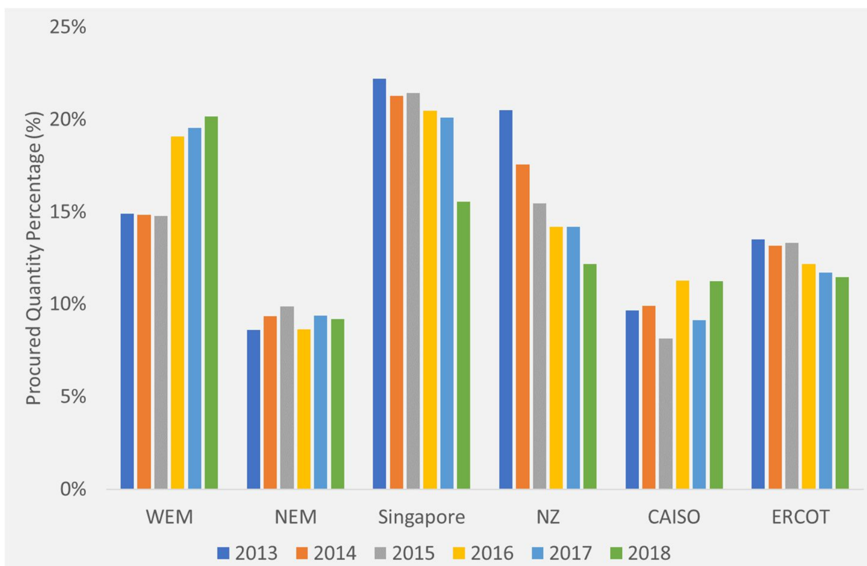
[14] AER, *Wholesale electricity market performance report*, December 2018, Figure 2.11, https://www.aer.gov.au/system/files/Wholesale%20electricity%20market%20performance%20report%20-%20December%202018_0.pdf

Figure 4: Range and benchmark – FCAS Procured Quantity Percentage



Source: EMCa analysis

Figure 5: FCAS procured Quantity Percentage trends



Source: EMCa analysis

With the exception of Singapore, in recent years, the FCAS Procured Quantity Percentages in the WEM are high compared to the other jurisdictions and they have markedly increased. This is driven by the high Regulation quantity requirement as discussed in sections 3.3, 3.4 and 3.5.

The large FCAS Procured Quantity Percentages may be partly explained by the small size of the WEM. This is discussed further in section 3.10 of this report.

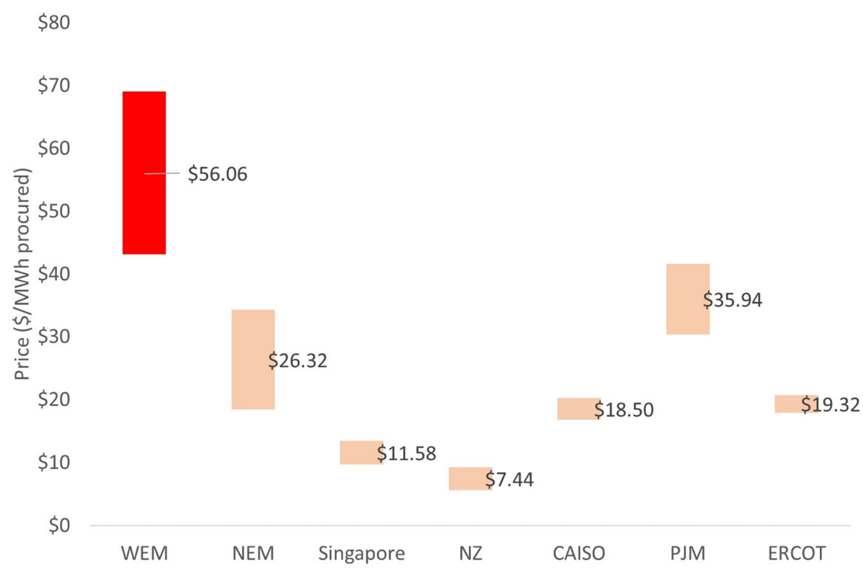
In addition, the isolation of the WEM with lack of interconnection to other power systems may also be a factor contributing to the large FCAS procurement quantity requirement.

3.3 Regulation

3.3.1 Price benchmarking

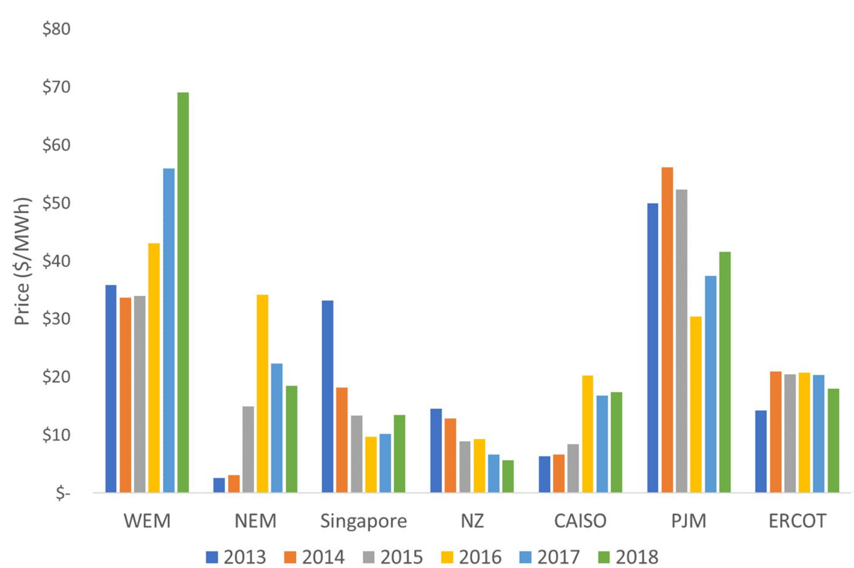
The benchmark result of Regulation is illustrated in Figure 6. Figure 7 sets out the Normalised Regulation Price trends from 2013 to 2018.

Figure 6: Range and benchmark of Normalised Regulation Price



Source: EMCa analysis

Figure 7: Normalised Regulation Price trends



Source: EMCa analysis

Regulation is known as the Load Following Ancillary Service (LFAS) in the WEM.

The Normalised Regulation Prices in the WEM are very high compared to the other jurisdictions. The prices are also upward trending. The high and upward trending prices are a result of the prices offered by market participants in the LFAS market. The Normalised LFAS Price increased significantly in 2016[15]. A driving factor may have been increases in gas prices.[16]

With the exception of PJM, the Normalised Regulation Prices in other jurisdictions were significantly lower compared to the WEM. One of the possible drivers is that the boundaries between Regulation and Contingency Raise may vary between jurisdictions. Unlike the NEM, Singapore and New Zealand (NZ), the Regulation Up (or LFAS Up) in the WEM can also be used for Contingency Raise (or Spinning Reserve)[17]. In order to address the issues of differences in Regulation Up-Contingency Raise boundary definition, in section 3.7, we also benchmark and compare the Normalised Prices of Regulation Up and Contingency Raise combined. In the same section, we also benchmark and compare the corresponding Procured Quantity Percentages.

Unlike the WEM, the Normalised Regulation Prices in the NEM, Singapore and NZ have been downwards trending in recent years. In the case of the NEM, we note the Price decreased in 2017[18] for two reasons:[19]

- Additional supply from new technologies towards the end of 2017 (the HPR and EnerNOC); and
- Reduced pricing impact of the South Australian 35 MW FCAS constraint[20].

In the case of Singapore, after the Regulation price hit an all-time high in January 2007, the Market Surveillance and Compliance Panel (MSCP) conducted an investigation. This appears to have had an impact in changing market participants' offer behaviours and kept the price low. See section 5.5 for further discussion.

In the case of NZ, the cost of Regulation decreased since 2015 when increased competition was introduced. See section 6.3.1 for further details.

In the case of CAISO, we see a significant increase in the Normalised Regulation Price in 2016. This was due to the CAISO increasing the amount of Regulation capacity procured to manage variable renewable resources.[21]

The Normalised Regulation Price was relatively flat in ERCOT.

In PJM, the Normalised Regulation Price was relatively high (but still lower than the WEM's). In the PJM report[22], it was recognised that that the Regulation market structure

---

[15] Period covering 1 April 2016 to 31 31 March 2017.

[16] AEMO (System Management), *Ancillary Services Report 2017/18*, Section 4, page 20

[17] See section 9.9.2(i) of the WEM Rules.

[18] Year 2017/18.

[19] Reliability Panel AEMC, *Annual Market Performance Review 2018,* pages 74 and 75.

[20] For system security purposes, AEMO requires the local procurement of 35 MW of Regulation FCAS in South Australia at times when the separation of the region at the Heywood Interconnector is a credible contingency.

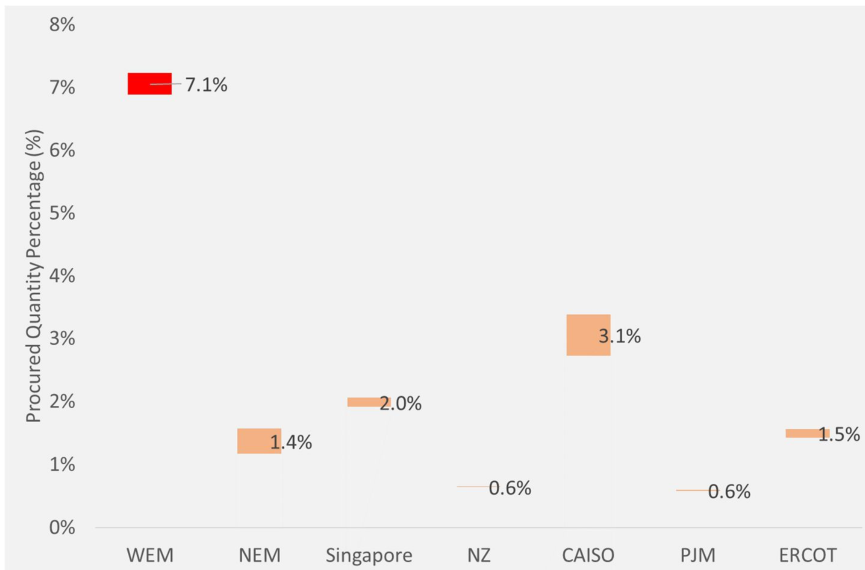
[21] CAISO, *2016 Annual Report on Market Issues & Performance*, section 6 (pages 141) and section 6.3 (page 148)

was “uncompetitive” and the design was “flawed”. The design was considered flawed because it “*has failed to correctly incorporate a consistent implementation of the marginal benefit factor in optimisation, pricing and settlement. The market results continue to include the incorrect definition of opportunity cost. The result is significantly flawed market signals to existing and prospective suppliers of regulation*”.[22] The report, however, still considers the market performance to be competitive.[23]

3.3.2 Procured Quantity Percentage benchmarking

Figure 8 illustrates the benchmarked procured Regulation quantity as a percentage of system load energy. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 9.

Figure 8: Range and benchmark – Regulation Procured Quantity Percentage

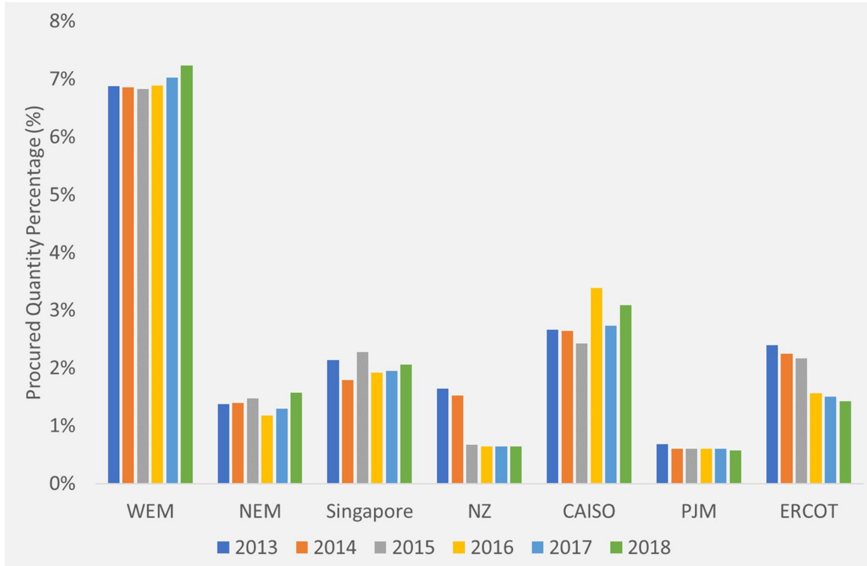


Source: EMCa analysis

[22] PJM, *2018 State of the Market Report for PJM*, Section 10, page 445.

[23] Table 10-3 of the report.

Figure 9: Regulation Procured Quantities Percentage trends



Source: EMCa analysis

It can be observed from the above figures that Regulation Quantity Percentages are very high in the WEM compared to other jurisdictions. We note that the WEM sets static Regulation (LFAS) quantity requirements on a year to year basis[24]. This is in contrast with NEM, CAISO[25] and ERCOT[26] where Regulation quantity requirements are set on a more dynamic basis taking into account changes of the quantity requirement from time to time. This may partly explain the high LFAS quantity in the WEM.

We also note that the high Regulation quantity requirements may also be attributed to the lack of (a) energy and ancillary services co-optimisation and (b) a five-minute dispatch arrangement. We note the WA Government's work program under the Energy Transformation Strategy (ETS) is seeking to address these issues.[27]

In the case of NZ, we note that the Regulation quantity requirement was low compared to most jurisdictions with a significant drop from 2015. This was partly attributable to the upgraded control system to allow Frequency Keeping Control (FKC) mode in the HVDC. See section 6.3.1 for further discussion.

As discussed earlier in this section, due to jurisdictional differences in boundary definitions between Regulation and Contingency Reserve, we have benchmarked and

---

[24] Fixed at 72 MW each for both LFAS Up and LFAS Down from 2013/14 to 2018/19. From 2019, LFAS Up and Down were set to be 85 MW (5.30 AM and 7.30 PM) and 50 MW (7.30 PM to 5.30 AM).

[25] CAISO, *2018 Annual Report on Market Issues & Performance*, page 145

[26] Potomac Economics, *2018 State of the Market Report for the ERCOT Electricity Markets*, page 39

[27] For documents relating to the ETS work program, see the webpage of the Energy Transformation Strategy: https://www.wa.gov.au/government/document-collections/taskforce-publications

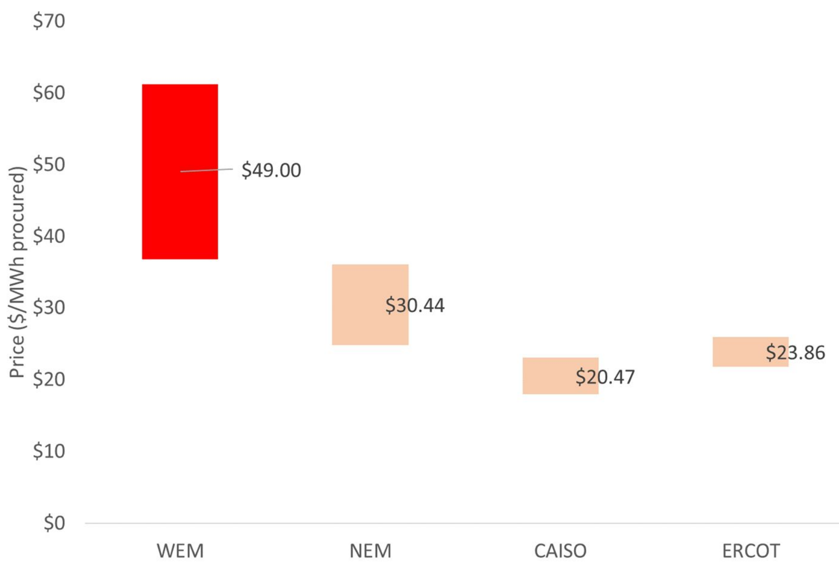
compared the combined Regulation Up[28] and Contingency Raise[29] in section 3.7 of this report.

3.4 Regulation Up

3.4.1 Price benchmarking

The benchmark result of Normalised Regulation Up Price is illustrated in Figure 10. Figure 11 sets out the Normalised Regulation Up Price trends from 2013 to 2018.

Figure 10: Range and benchmark of Normalised Regulation Up Price

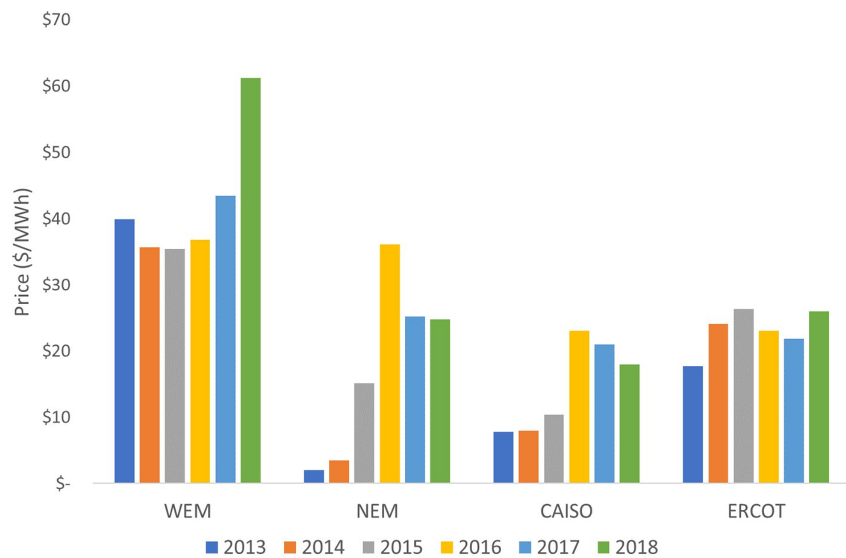


Source: EMCa analysis

[28] Equivalent to LFAS Up in the WEM.

[29] This includes the equivalent of Spinning Reserve in the WEM. In other jurisdictions, it may also include the Non-spinning Reserves.

Figure 11: Normalise Regulation Up Price trends



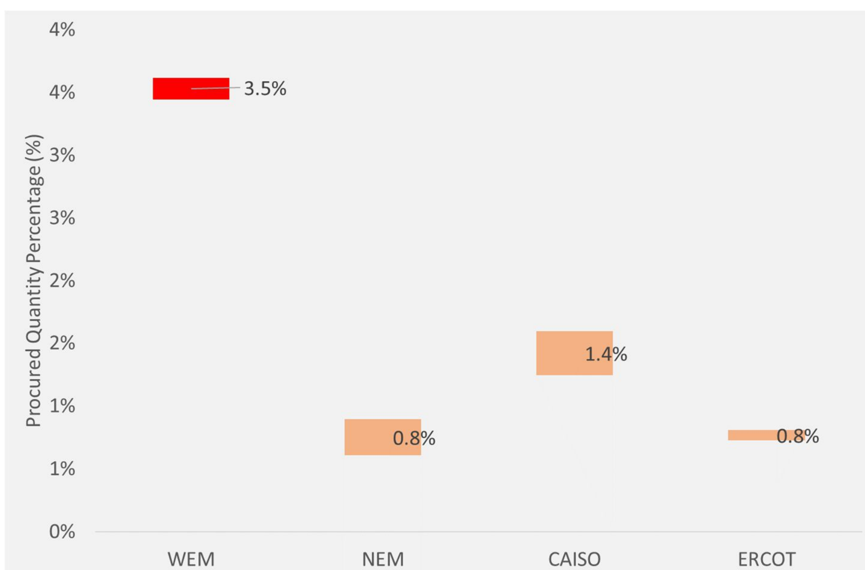
Source: EMCa analysis

The pattern and drivers for the Regulation Up Price are similar to that for Regulation (see discussion in section 3.3).

3.4.2 Procured Quantity Percentage benchmarking

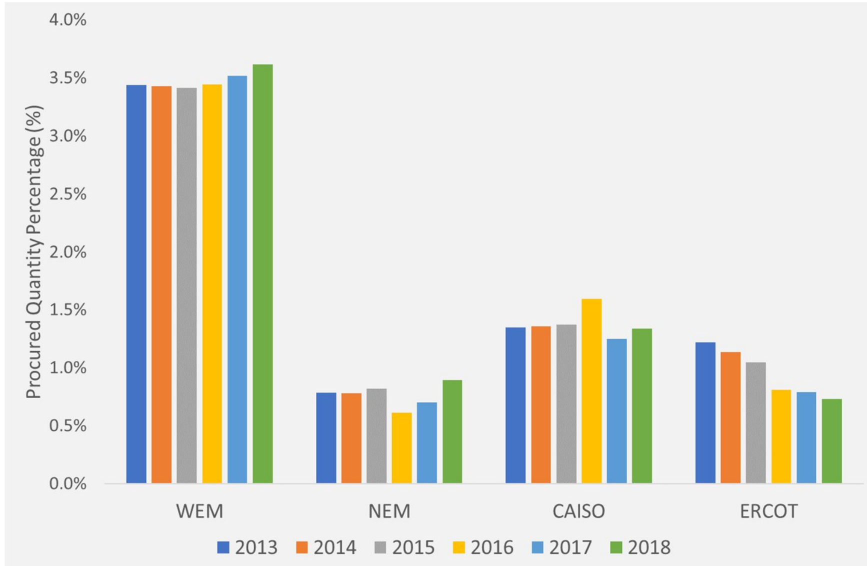
Figure 12 illustrates the benchmarked Regulation Up Procured Quantity Percentage. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 13.

Figure 12: Range and benchmark – Regulation Up Procured Quantity Percentage



Source: EMCa analysis

Figure 13: Regulation Up Procured Quantities Percentage trends



Source: EMCa analysis

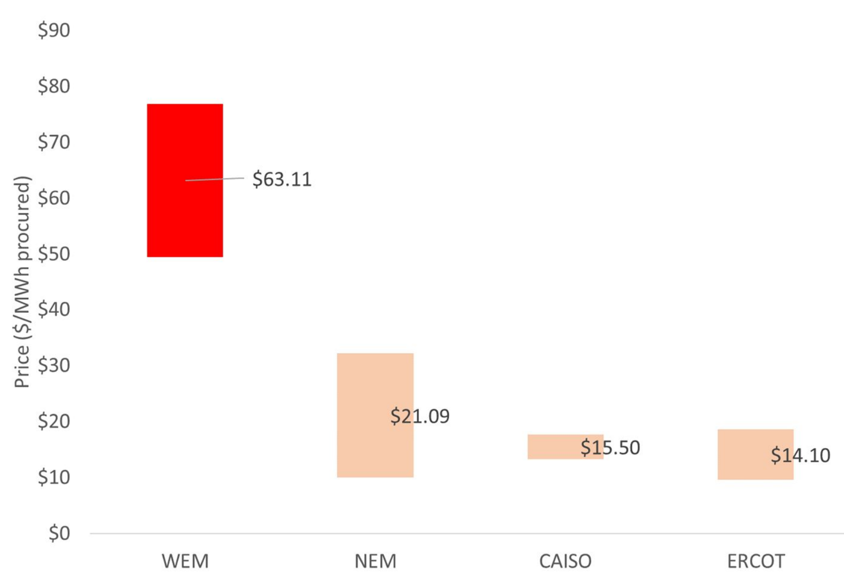
The pattern and drivers for the Regulation Up quantity requirements are similar to that of Regulation (see discussion in section 3.3).

3.5 Regulation Down

3.5.1 Price benchmarking

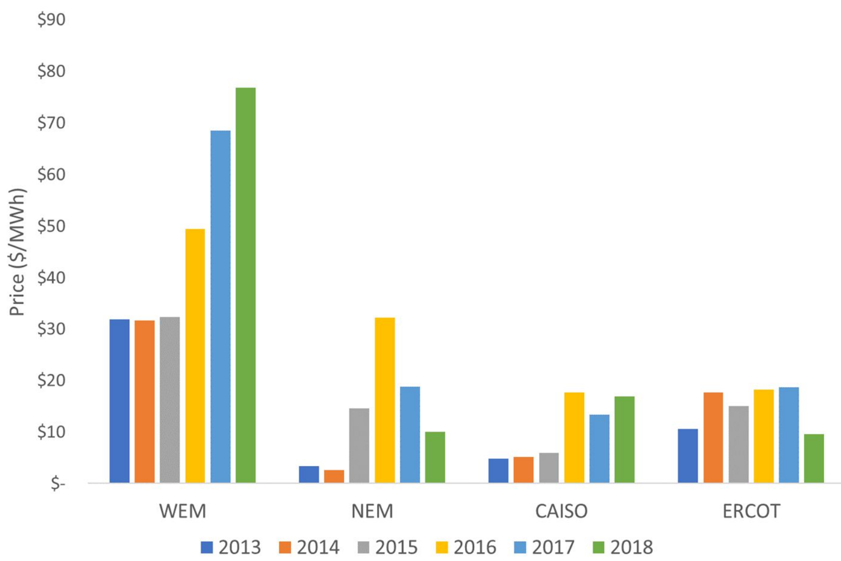
The benchmark result of Normalised Regulation Down Price is illustrated in Figure 14. Figure 15 sets out the Normalised Regulation Down Price trends from 2013 to 2018.

Figure 14: Range and benchmark of Regulation Down Price



Source: EMCa analysis

Figure 15: Normalise Regulation Down Price trends



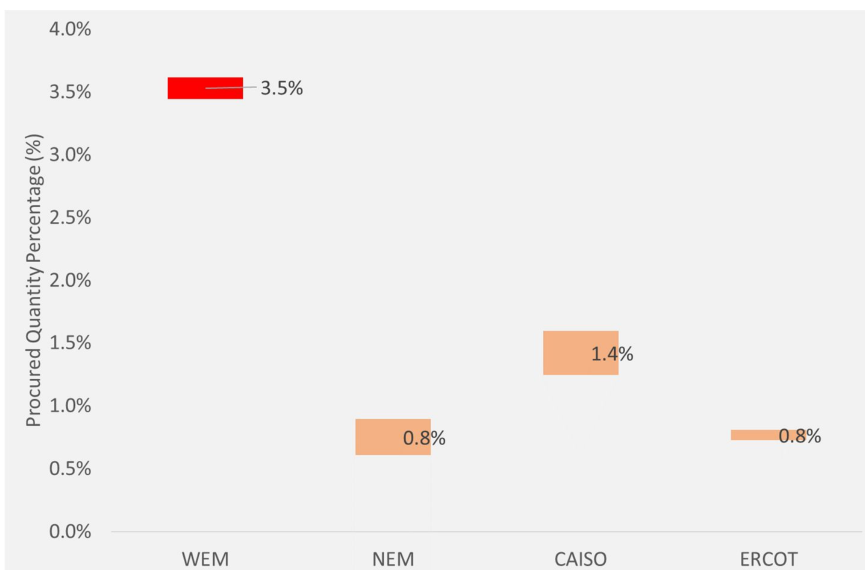
Source: EMCa analysis

The pattern and drivers for the Regulation Down Price are similar to that for Regulation (see discussion in section 3.3).

3.5.2 Procured Quantity Percentage benchmarking

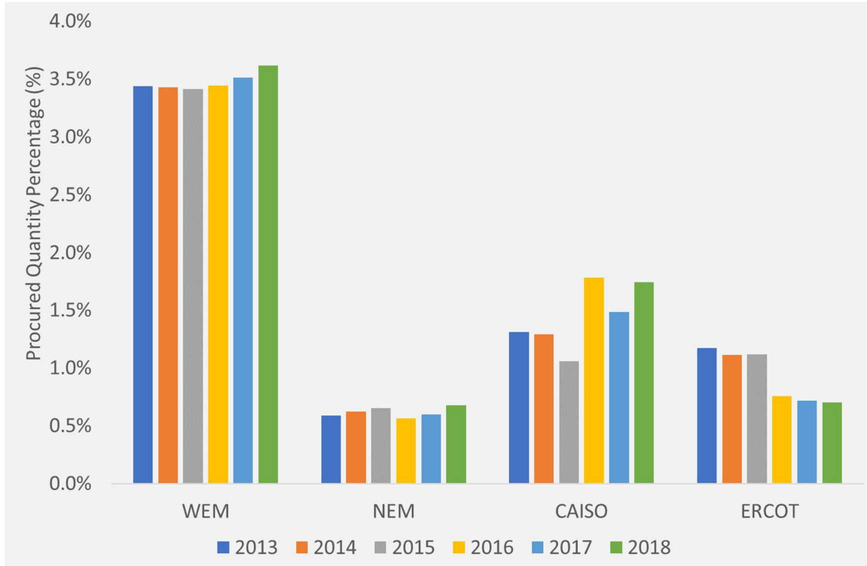
Figure 16 illustrates the benchmarked Regulation Up Procured Quantity Percentage. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 17.

Figure 16: Range and benchmark – Regulation Down Procured Quantity Percentage



Source: EMCa analysis

Figure 17: Regulation Down Procured Quantities Percentage trends



Source: EMCa analysis

The pattern and drivers for the Regulation Down quantity requirements are similar to that for Regulation (see discussion in section 3.3).

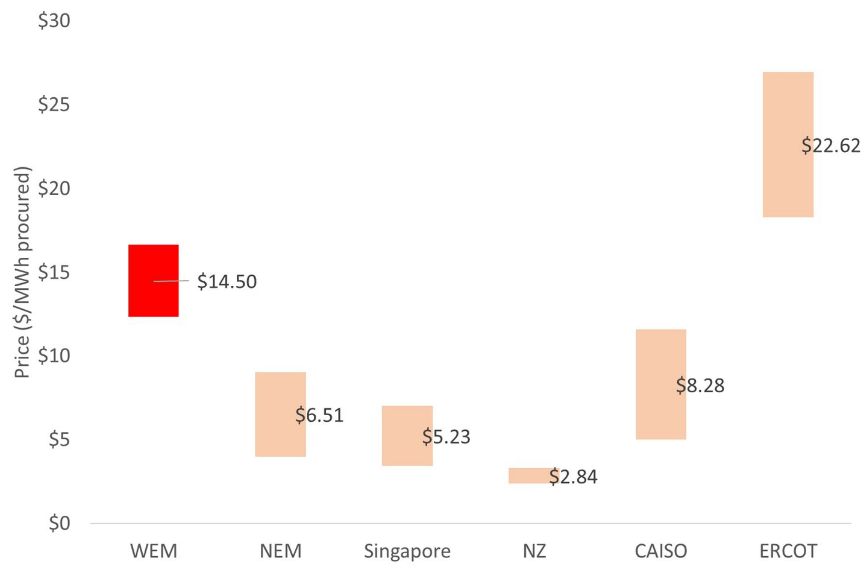
3.6 Contingency Raise

Contingency Raise is equivalent to the Spinning Reserve in the WEM. In Singapore, CAISO, PJM and ERCOT, it includes the Spinning and Non-spinning Reserves.

3.6.1 Price benchmarking

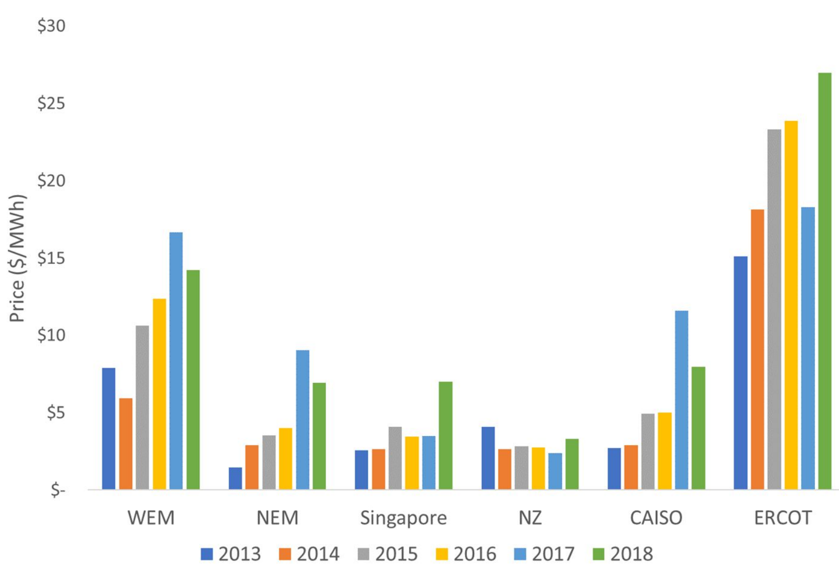
The benchmark result of Normalised Contingency Raise Price is illustrated in Figure 18. Figure 19 sets out the Normalised Contingency Price trends from 2013 to 2018.

Figure 18: Range and benchmark of Normalised Contingency Raise Price



Source: EMCa analysis

Figure 19: Normalise Contingency Raise Price trends



Source: EMCa analysis

The Contingency Raise in the WEM was significantly more expensive compared to the other jurisdictions, with the exception of ERCOT.

In the WEM, the Prices trend upwards reflecting the Spinning Reserve Margin Values.

In the NEM, a series of events (as discussed in section 3.2) also causes the upward trend in the Contingency Raise Prices.

In CAISO, the Contingency Raise price experienced a large increase due to “*increased operating reserve requirements and tight supply conditions in the summer months*.”[30]

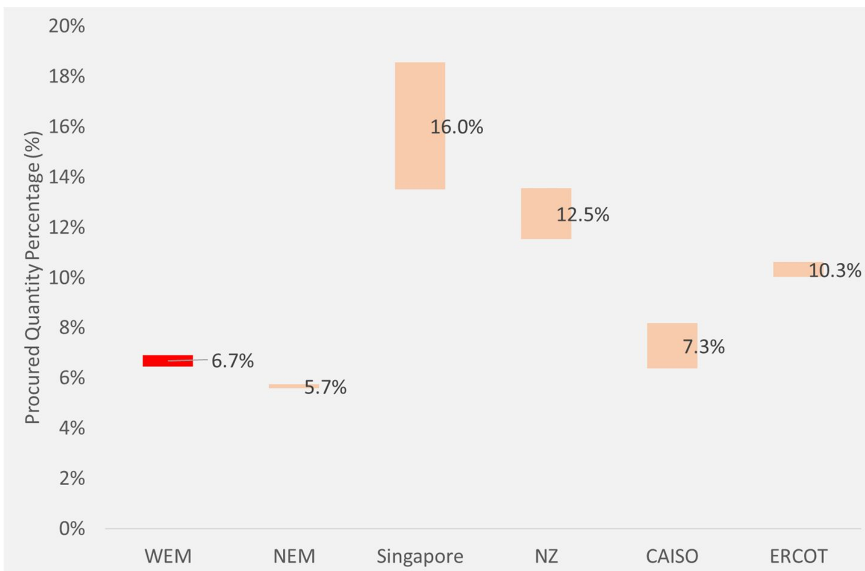
The Contingency Raise Prices for ERCOT are high compared to other jurisdictions for two reasons:[31]

- ERCOT has a relatively higher Spinning Reserves requirement compared to its peak load; and
- ERCOT has a higher fraction of its energy provided by renewable resources, which requires more Reserves to be deployed.

3.6.2 Procured Quantity Percentage benchmarking

Figure 20 illustrates the benchmarked Regulation Up Procured Quantity Percentage. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 21.

Figure 20: Range and benchmark – Contingency Raise Procured Quantity Percentage

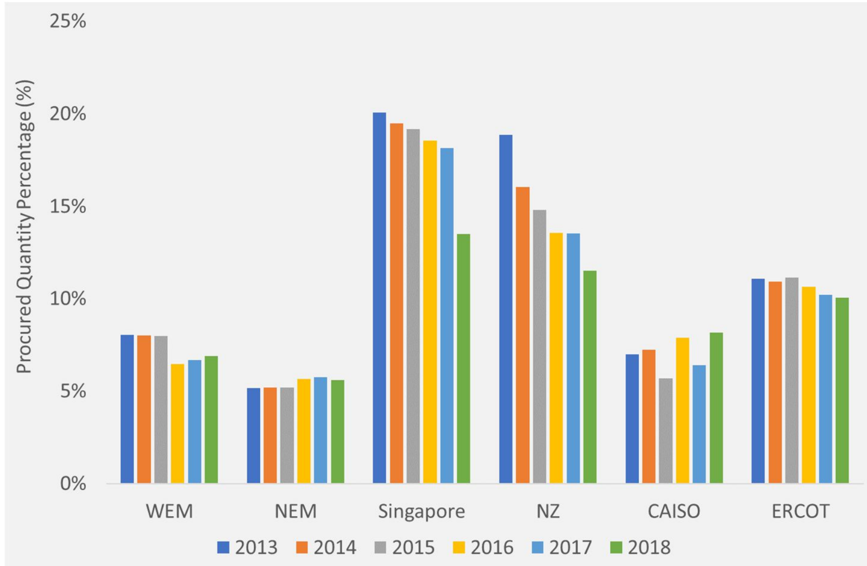


Source: EMCa analysis

[30] CAISO, *2017 Annual Report on Market Issues & Performance*, section 6.3, page 147.

[31] Argonne National Laboratory, *Survey of U.S. Ancillary Services Markets*, January 2016, section 9,2, page 28

Figure 21: Contingency Raise Procured Quantities Percentage trends



Source: EMCa analysis

As illustrated in the above figures, WEM compares favourably in terms of Contingency Raise Procured Quantity Percentage. A possible reason for this is that LFAS Up (Regulation Up) capacity in the WEM can be used to provide Contingency Raise (i.e. Spinning Reserve). This is not the case in the NEM, Singapore and NZ.

In Singapore, the Contingency Raise volume requirement is high because some generating units are large relative to the system load. Similarly, NZ also has a high Reserve quantity requirement (relative to system load energy) due to the relative risk represented by unit size and the contingency event risk of the HVDC.

In CAISO, the increased Contingency Raise requirement in 2018 was caused by a revised NERC[32] reliability standard (BAL-002-2) which increased the size a contingency event.[33]

As discussed earlier, high renewable penetration in ERCOT has contributed to the requirement for high Contingency Raise quantity requirements.

3.7 Regulation Up + Contingency Raise

As discussed earlier, due to jurisdictional differences in boundary definitions between Regulation Up (equivalent to the WEM's LFAS Up) and Contingency Raise (equivalent to the WEM's Spinning Reserve), we have benchmarked and compared these two ancillary services combined.

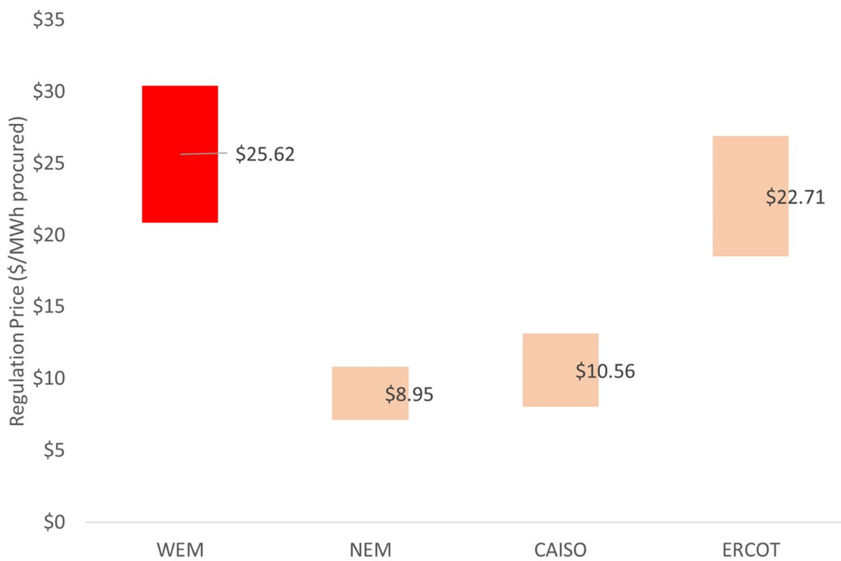
[32] North American Electric Reliability Corporation

[33] CAISO, *2018 Annual Report on Market Issues & Performance*, section 6, page 141

3.7.1 Price benchmarking

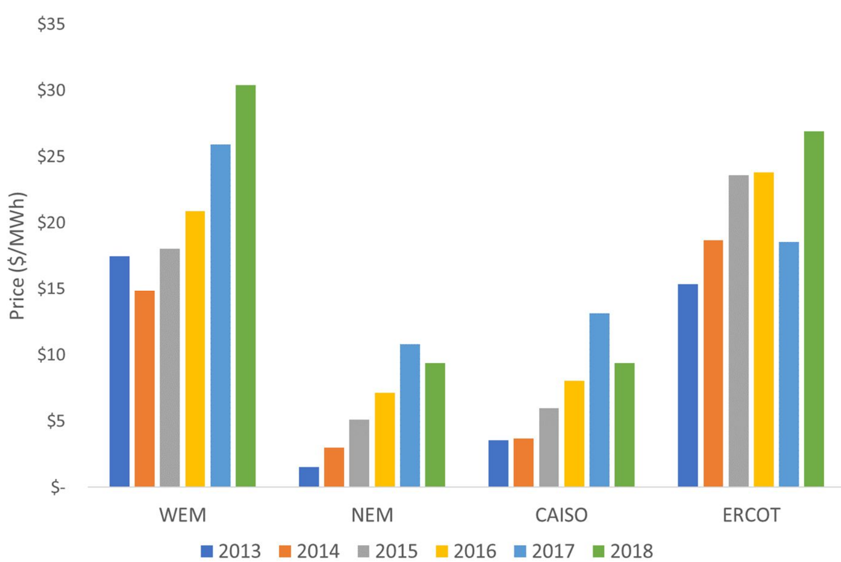
The benchmark result of Regulation Up + Contingency Raise is illustrated in Figure 22. Figure 23 sets out the Normalised Regulation Up + Contingency Raise Price trends from 2013 to 2018.

Figure 22: Range and benchmark of Normalised Regulation Up + Contingency Raise Price



Source: EMCa analysis

Figure 23: Normalise Regulation Up + Contingency Raise Price trends



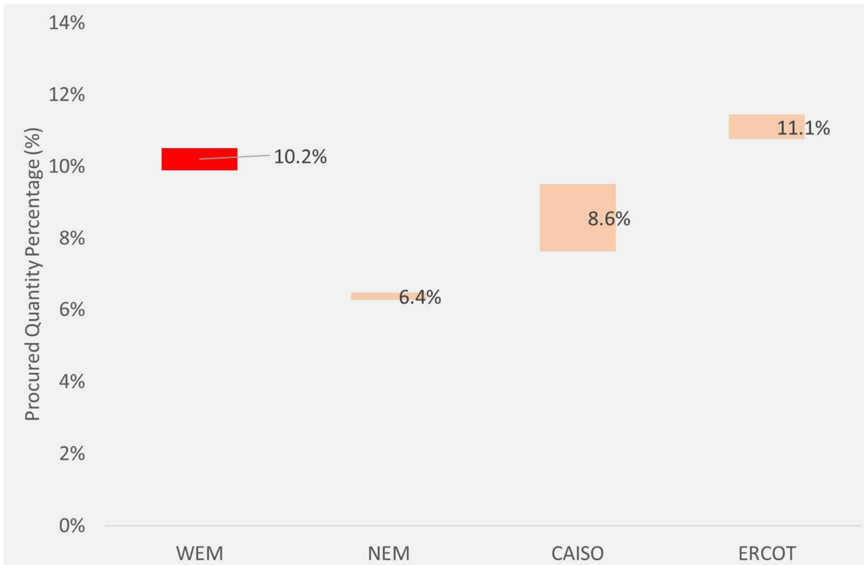
Source: EMCa analysis

As in the separated cases for Regulation Up and Contingency Raise, we note that the combined Regulation Up + Contingency Raise was also more expensive in the WEM compared to other jurisdictions.

3.7.2 Procured Quantity Percentage benchmarking

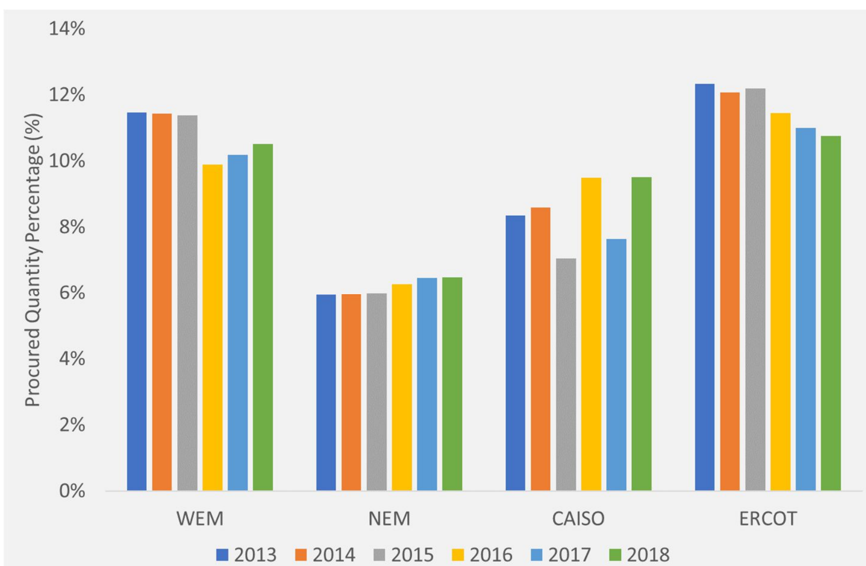
Figure 24 illustrates the benchmarked Regulation Up + Contingency Raise Procured Quantity Percentage. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 25.

Figure 24: Range and benchmark – Regulation Up + Contingency Raise Procured Quantity Percentage



Source: EMCa analysis

Figure 25: Regulation Up + Contingency Raise Procured Quantity Percentage trends



Source: EMCa analysis

The Procured Quantity Percentage for the combined Regulation Up + Contingency Raise is high compared to the NEM and CAISO. As discussed earlier, the high renewable penetration in ERCOT contributes to the high quantity requirements.

3.8 Contingency Lower

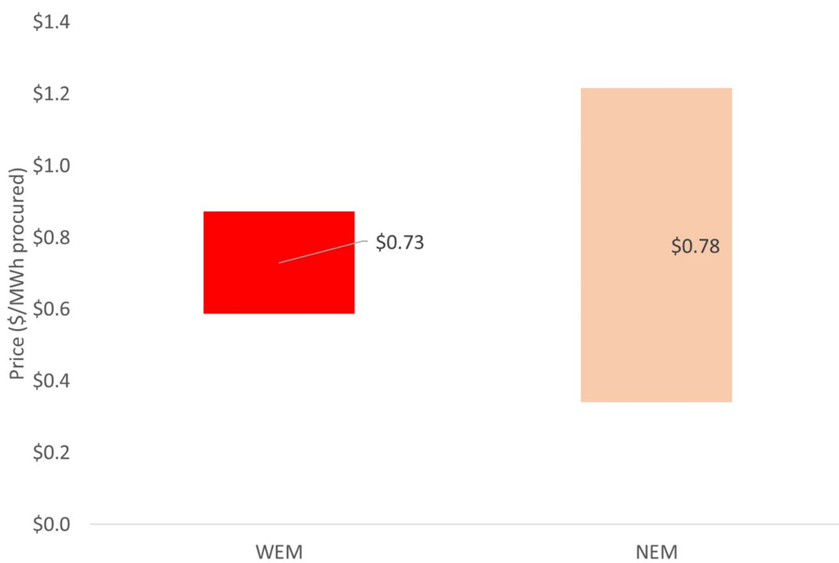
Contingency Lower is equivalent to Load Rejection Service (or Load Rejection Reserve or LRR) in the WEM. Load Rejection Services are provided by generators that are selected to be shut down quickly in the event of lost load, such as when a transmission line trips. This service is required in order to maintain system frequency within acceptable limits.

3.8.1 Price benchmarking

The benchmark result of Contingency Lower is illustrated in Figure 26. Figure 27 sets out the Normalised Contingency Lower Price trends from 2013 to 2018.

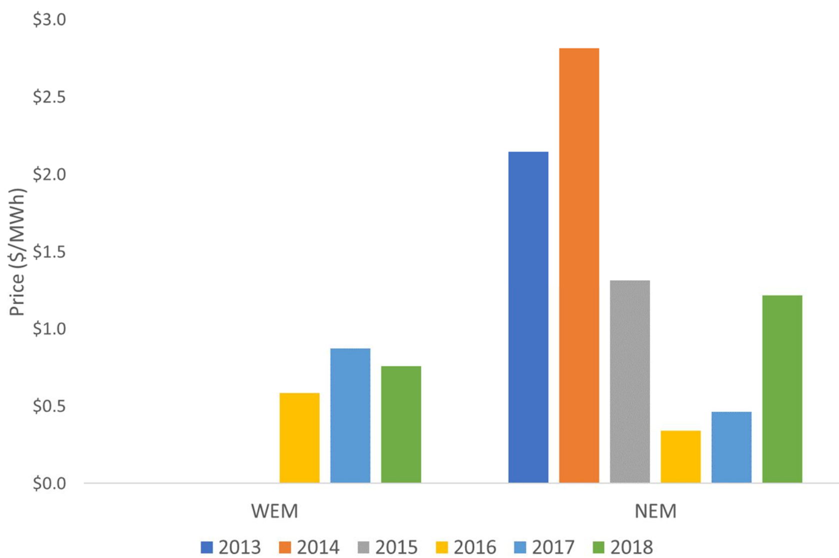
NZ's equivalent for Contingency Lower is Over frequency service. Unlike the cases for the WEM and NEM, procured quantity data is not available for Over frequency in NZ hence it was excluded from our analysis.

Figure 26: Range and benchmark of Normalised Contingency Lower Price



Source: EMCa analysis

Figure 27: Normalise Contingency Lower Prices



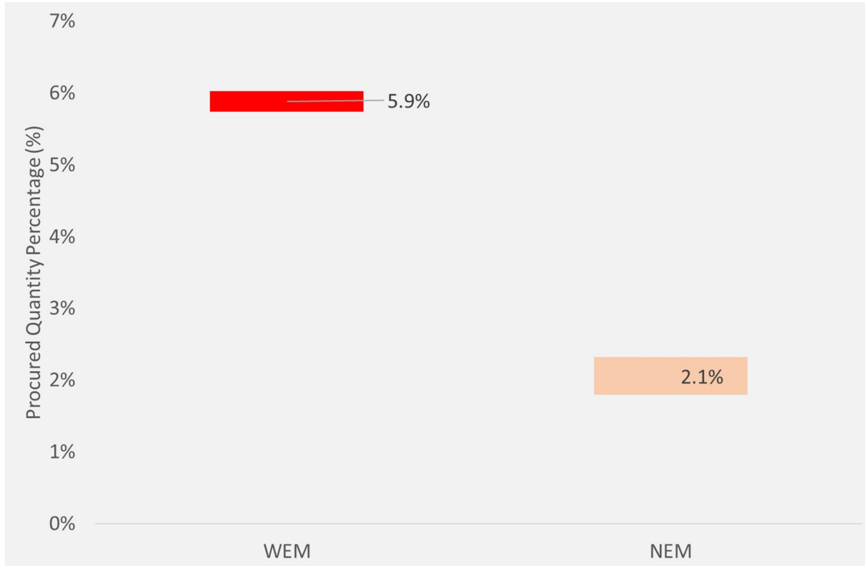
Source: EMCa analysis

As observed above, the benchmarked Price for Contingency Lower is similar to the average price in the NEM in the same period. The Price in the WEM is an administered price determined by modelling while the Price in the NEM reflects the actual market clearing prices. The series of events (as discussed in section 3.2) may have contributed to the upwards trend in the NEM from 2016 to 2018.

3.8.2 Procured Quantity Percentage benchmarking

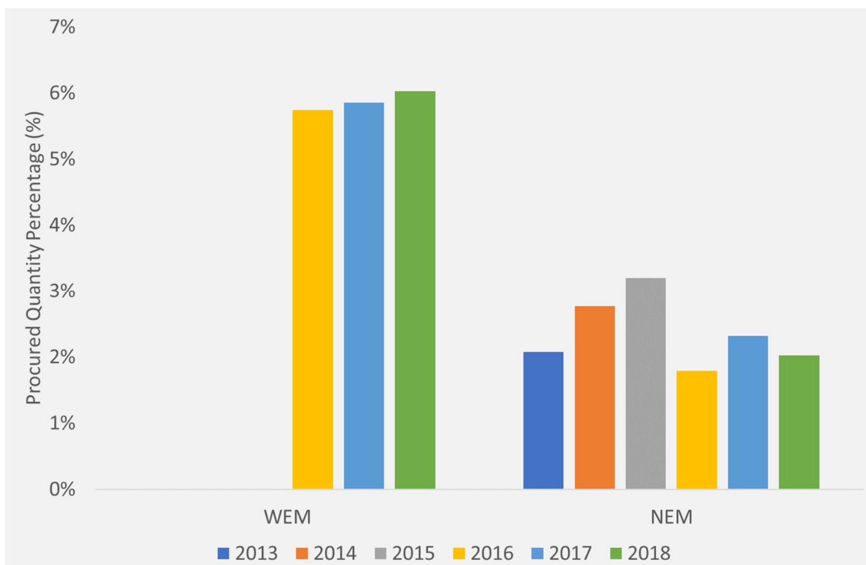
Figure 28 illustrates the benchmarked Contingency Lower Procured Quantity Percentage. The Procured Quantity Percentage trends from 2013 to 2018 are set out in Figure 29.

Figure 28: Range and benchmark – Contingency Lower Procured Quantity Percentage



Source: EMCa analysis

Figure 29: Contingency Lower Procured Quantity Percentage trends



Source: EMCa analysis

The above figures show that the Contingency Lower Procured Quantity Percentages in the WEM are high compared to the NEM.

In the WEM, the Load Rejection (i.e. Contingency Lower) requirement is set based on section 3.10.4 of the WEM Rules. This rule requires the following principles to be satisfied:

- the level sufficient to keep over-frequency below 51 Hz for all credible load rejection events; and
- may be relaxed by up to 25% by System Management where it considers.

Based on these principles, the Load Rejection requirement is set to be 120 MW. This typically reflects the loss of a transmission line. *"This may be a radial line feeding the Eastern Goldfields region under specific conditions, or a single line feeding a particular customer."*[34]

Similarly, the Contingency Lower (i.e. equivalent to Load Rejection in the WEM) requirement in the NEM is set based on "*the loss of the largest load/transmission element on the system*".[35] Based on this, the average quantity of Contingency Lower procured from 2013 to 2018 ranges from approximately 400 MW to 700 MW.

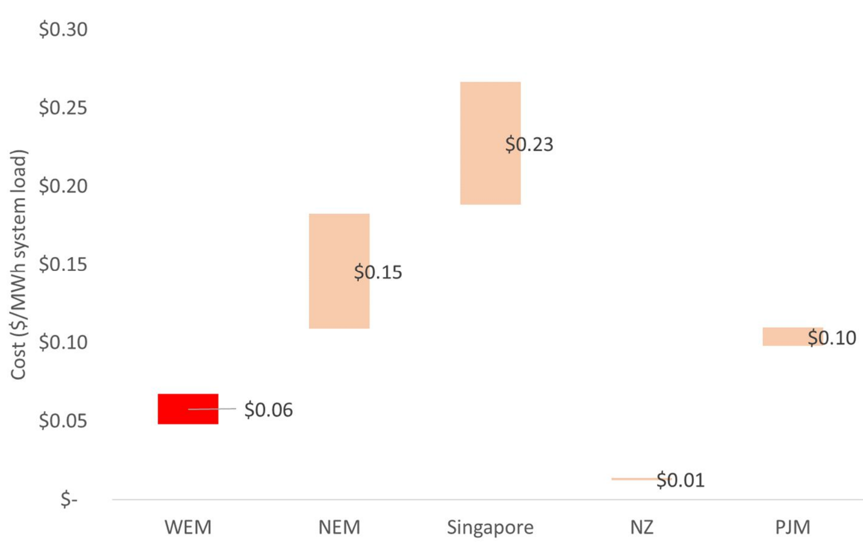
The quantity procured (as percentage of system load energy) is lower in the NEM compared to the WEM.

We also note that AEMO is conducting a trial for a dynamic LRR requirement. The objective of the trial is to improve efficiency in providing LRR while ensuring that system security is not compromised. If the trial is successful, AEMO will use the experience to influence the requirements in the 2020-21 Financial Year.[36]

3.9 Black Start Cost benchmarking

Figure 30 shows the Black Start Cost (per MWh system load energy) benchmark. Figure 31 shows the Cost trend.

Figure 30: Range and benchmark of Black Start Costs



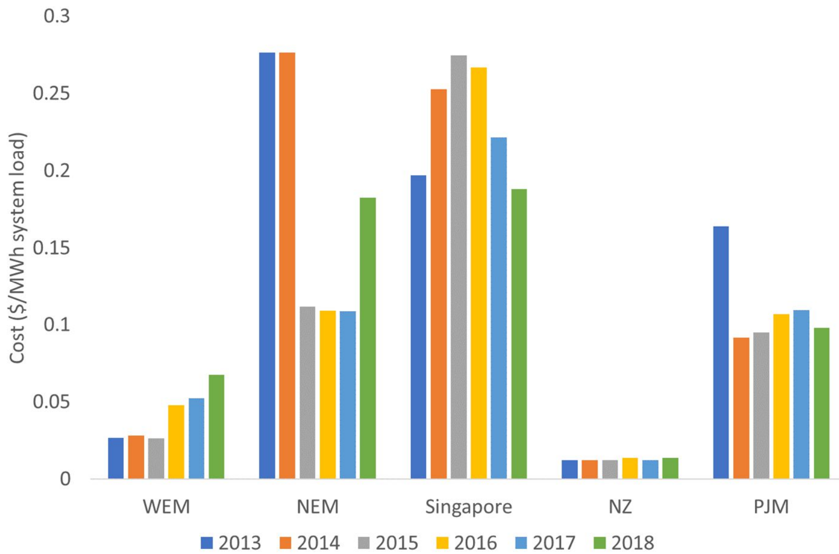
Source: EMCa analysis

[34] AEMO, *Ancillary Service Report for the WEM 2018-19*, section 4.3

[35] AEMO, *Guide to Ancillary Services In The National Electricity Market*, April 2015, page 12

[36] AEMO, *Ancillary Services Report for the WEM 2019*, June 2019, section 5.3

Figure 31: Black Start Cost trends from 2013 to 2018



Source: EMCa analysis

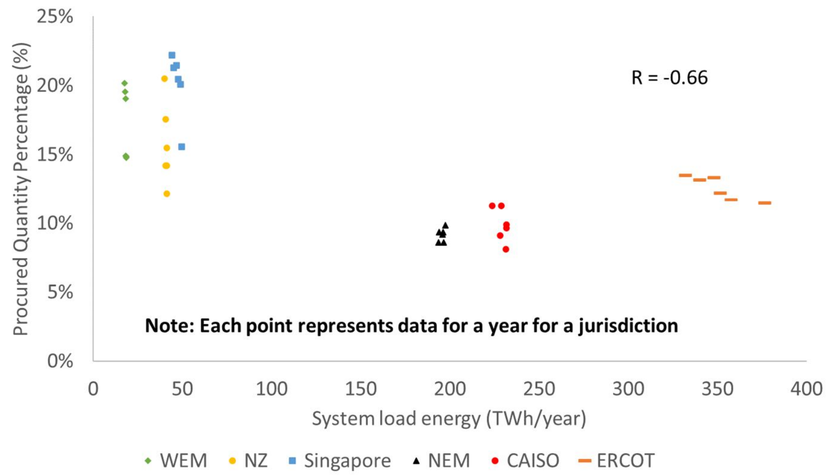
As illustrated, WEM compares favourable against the other jurisdictions.

3.10 FCAS Procured Quantity Percentages vs market size

Figure 32 illustrates the relationship between the FCAS Procured Quantity Percentage and the system size (electricity consumption) of the jurisdiction. Based on the observed data, there is a moderate relationship between the FCAS Procured Quantity Percentage and system size. This partly explains the large FCAS Procured Quantity Percentage in the WEM relative to other jurisdictions.

Despite this, we consider opportunities exist to reduce the existing WEM FCAS procurement quantity level. See discussion in Section 8.1.

Figure 32:FCAS Procured Quantity Percentage vs system loads energy 2013 to 2018



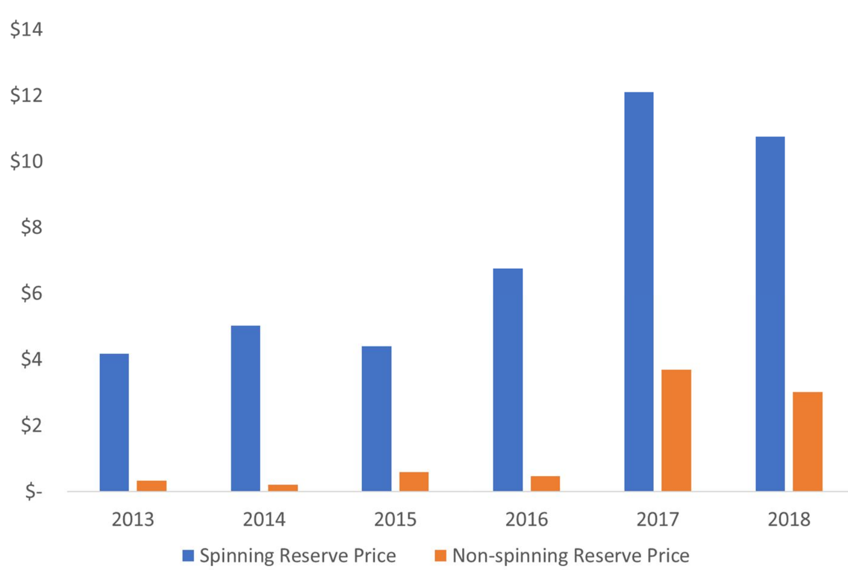
Source: EMCa analysis

3.10.1 Spinning vs Non-spinning Reserves

Figure 33 shows the Spinning Reserve versus Non-spinning Reserve Prices for CAISO.

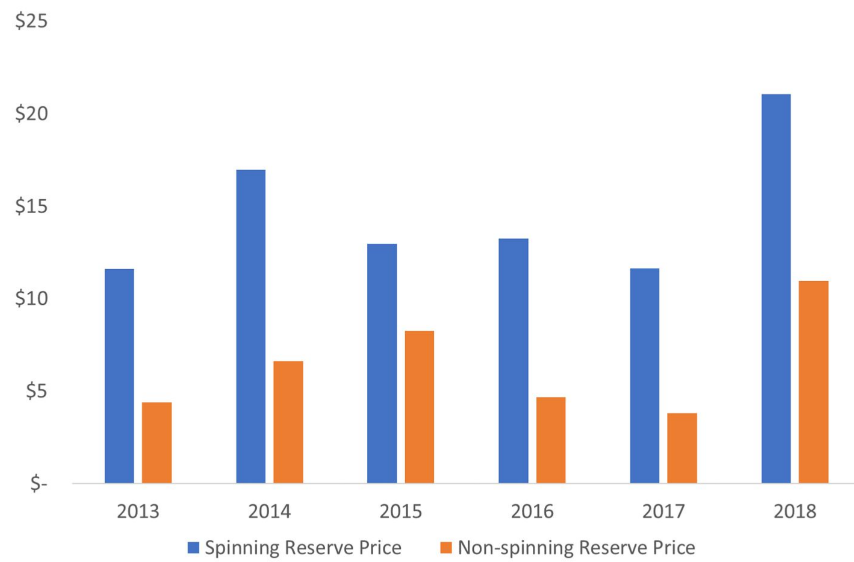
Figure 34 shows the Spinning Reserve versus Non-spinning Reserve Prices for ERCOT.

Figure 33: CAISO – Spinning vs Non-spinning Reserve Prices



Source: EMCa analysis

Figure 34: ERCOT – Spinning vs Non-spinning Reserve Prices



Source: EMCa analysis

As illustrated, Non-spinning Reserves are typically provided at cheaper price compared to Spinning Reserve. This was possibly due to lower operating cost for a non-spinning facility.

Therefore, having non-spinning facilities operating in a power system can reduce its ancillary services costs.

3.11 Renewable penetrations and ancillary service prices

While solar/wind penetration is not the only factor driving ancillary services prices, there appears to be some relationship between the solar/wind penetration rates and ancillary services Prices in the NEM and CAISO.

In ERCOT, the penetration is predominantly wind. The relationship between the penetration rate and ancillary services price is weaker.

3.11.1 NEM

Figure 35 show the relationship between the Normalised ancillary service Price and solar/wind penetration rate in the NEM.

Figure 36 shows the relationship between the Normalised FCAS Price and solar/wind penetration rate in the NEM.

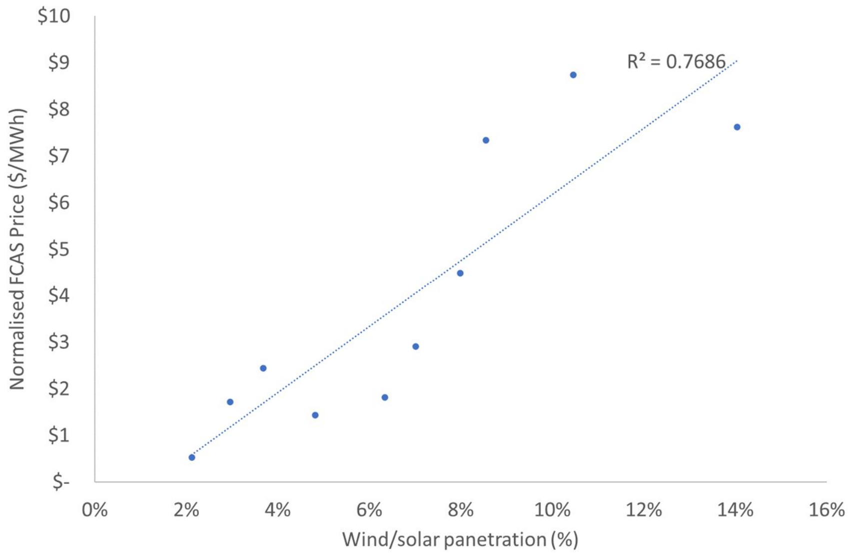
There appears to be some relationship between the price and the penetration rate.

Figure 35: NEM Normalised ancillary Prices vs wind or solar penetration[37]

Source: EMCa analysis

[37] Include rooftop solar generation

Figure 36: NEM Normalised FCAS Price vs wind/solar penetration



Source: EMCa analysis

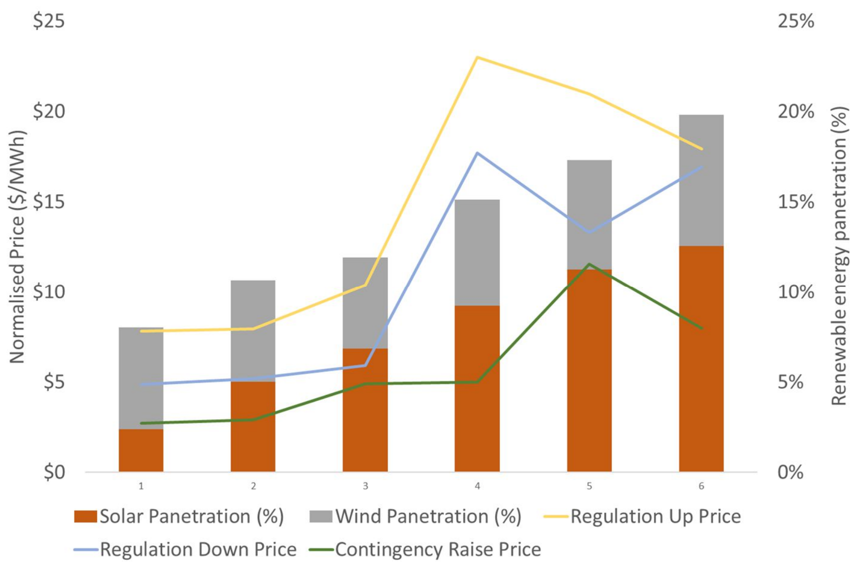
3.11.2 CAISO

Figure 37 show the relationship between the Normalised ancillary service Price and solar/wind penetration rate in CAISO.

Figure 38 shows the relationship between the Normalised FCAS Price and solar/wind penetration rate in CAISO.

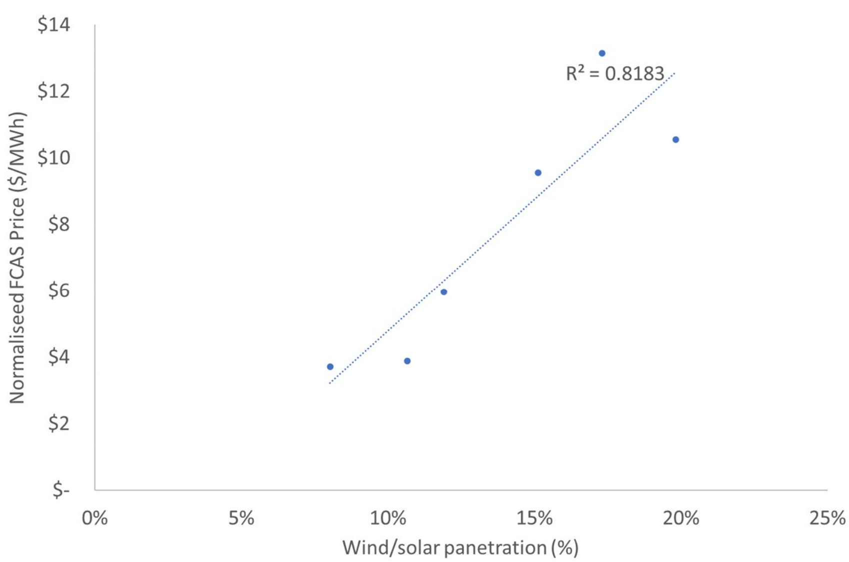
There appears to be some relationship between the price and the penetration rate.

Figure 37: CAISO Normalised ancillary services Prices vs wind or solar penetration[38]



Source: EMCa analysis

Figure 38: CAISO Normalised FCAS Price vs wind/solar penetration



Source: EMCa analysis

3.11.3 ERCOT

Figure 39 show the relationship between the Normalised ancillary service Price and solar/wind penetration rate in ERCOT.

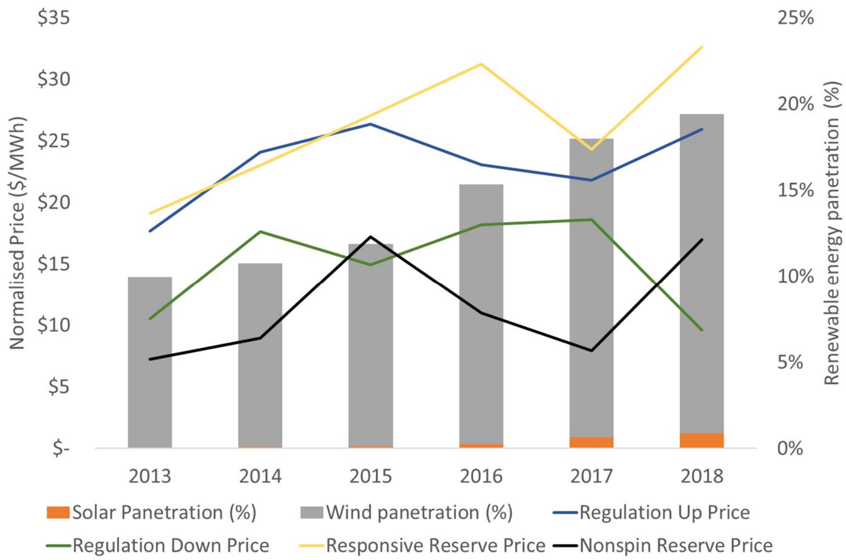
Figure 40 shows the relationship between the Normalised FCAS Price and solar/wind penetration rate in ERCOT.

---

[38] Exclude rooftop solar generation due to lack of data

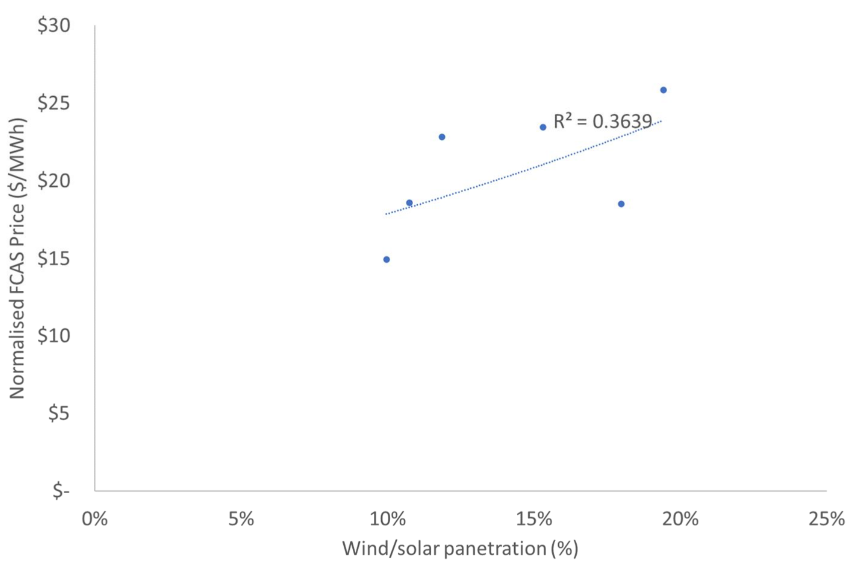
The relationship between the Normalised Price and solar/wind penetration rate in ERCOT is not as strong as those in NEM and CAISO.

Figure 39: ERCOT Normalised ancillary services Price vs wind or solar penetration



Source: EMCa analysis

Figure 40: ERCOT Normalised FCAS Price vs wind/solar penetration



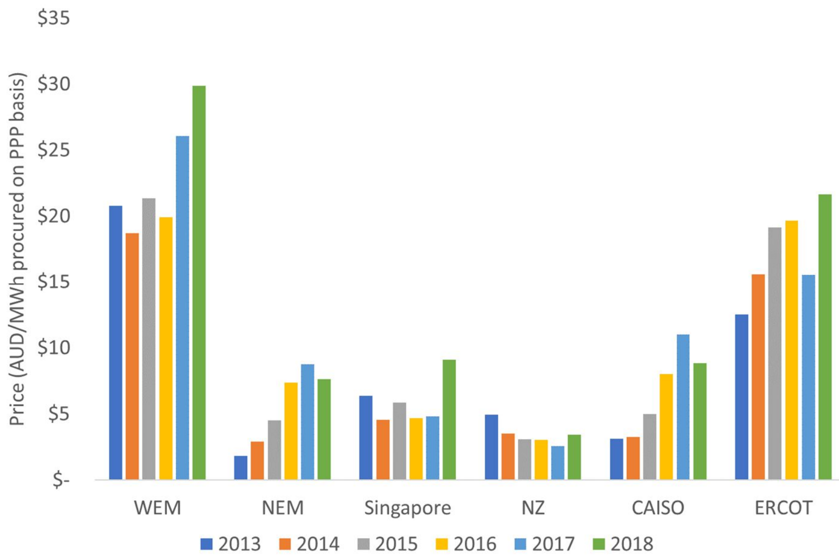
Source: EMCa analysis

3.12 Contribution of FCAS Price to affordability of electricity

In this section, we compare the FCAS Price in term of its contribution to affordability of electricity in the WEM. We make this comparison by converting Normalised FCAS Prices to Australian Dollars on Purchase Power Parity (PPP) basis. This allows the Normalised Prices to be assessed considering the purchasing power of consumers within the relevant jurisdictions.

The FCAS Normalised Price on a PPP basis is shown in Figure 41.

Figure 41: FCAS Normalised Price on a PPP basis



Source: EMCa analysis

As illustrated, the Price of FCAS was less affordable in the WEM compared to other jurisdictions except ERCOT.

4 National Electricity Market Australia (NEM)

4.1 Ancillary services in the NEM

The NEM Ancillary Services can be grouped under one of the following three major categories:

- Frequency Control Ancillary Services (FCAS);
- Network Support & Control Ancillary Services (NSCAS); or
- System Restart Ancillary Services (SRAS).

FCAS is a market ancillary service where it is traded under a market arrangement. On the other hand, NSCAS and SRAS are non-market ancillary services where they are procured under contracting arrangements.

4.1.1 Frequency Control Ancillary Services (FCAS)

FCAS are used by AEMO to maintain the frequency on the electrical system, at any point in time, close to 50 Hz as required by the NEM frequency standards.

There are two FCAS types in the NEM:

- **Regulation** – Regulation frequency control can be described as the correction of the generation/demand balance in response to minor deviations in load or generation.
- **Contingency** - Contingency frequency control refers to the correction of the generation/demand balance following a major contingency event such as the loss of a generating unit/major industrial load, or a large transmission element.

The two FCAS types are subdivided into eight markets as summarised in Table 4. AEMO ensures that sufficient FCAS are procured at any given time.

Table 4: FCAS markets in the NEM

FCAS type	FCAS market
Regulation	• **Regulation Raise**: Regulation service used to correct a minor drop in frequency. • **Regulation Lower**: Regulation service used to correct a minor rise in frequency.
Contingency	• **Fast Raise (6 Second Raise)**: 6-second response to arrest a major drop in frequency following a contingency event. • **Fast Lower (6 Second Lower)**: 6-second response to arrest a major rise in frequency following a contingency event. • **Slow Raise (60 Second Raise)**: 60-second response to stabilise frequency following a major drop in frequency. • **Slow Lower (60 Second Lower)**: 60-second response to stabilise frequency following a major rise in frequency. • **Delayed Raise (5 Minute Raise)**: 5-minute response to recover frequency to the normal operating band following a major drop in frequency. • **Delayed Lower (5 Minute Lower)**: 5-minute response to recover frequency to the normal operating band following a major rise in frequency.

Participants must register with AEMO to participate in each distinct FCAS market. Once registered, a service provider can participate in an FCAS market by submitting an appropriate FCAS offer or bid for that service, via AEMO's Market Management Systems.

An FCAS offer or bid submitted for a raise service represents the amount of MWs that a participant can add to the system, in the given time frame, in order to raise the frequency.

An FCAS offer or bid submitted for a lower service represents the amount of MWs that a participant can take from the system, in the given time frame, in order to lower the frequency.

During each and every dispatch interval of the market, National Electricity Market Dispatch Engine (NEMDE) must enable a sufficient amount of each of the eight FCAS products, from the FCAS bids submitted, to meet the FCAS MW requirement.

4.1.2 Network Support & Control Ancillary Services (NSCAS)

NSCAS are primarily used to:

- Control the voltage at different points of the electrical network to within the prescribed standards.
- Control the power flow on network elements to within the physical limitations of those elements.
- Maintain transient and oscillatory stability within the power system following major power system events.

NSCAS is provided to the market under long term ancillary service contracts negotiated between AEMO (on behalf of the market) and the participant providing the service.

4.1.3 System Restart Ancillary Services (SRAS)

SRAS are reserved for contingency situations in which there has been a complete or partial system blackout and the electrical system must be restarted. This can be provided by two separate technologies:

- General Restart Source: a generator that can start and supply energy to the transmission grid without any external source of supply.
- Trip to House Load: a generator that can, on sensing a system failure, fold back onto its own internal load and continue to generate until AEMO is able to use it to restart the system.

Like NSCAS, SRAS is also provided to the market under long term ancillary service contracts negotiated between AEMO (on behalf of the market) and the participant providing the service.

4.2 Cost recovery

4.2.1 FCAS

Recovery for contingency services is pro-rated over participants based on the energy generation or consumption in the trading interval.

The recovery of payments for the Regulation services is based upon the “causer pays” methodology. Under this methodology the response of measured generators and loads, to frequency deviations, is monitored and used to determine a series of causer pays factors.

4.2.2 NCAS and SRAS

NSCAS payments are recovered fully from market customers while SRAS payments are recovered from both customers and generators on a 50/50 basis.

5 National Electricity Market of Singapore (NEMS)

5.1 Ancillary services in the NEMS

In Singapore, the ancillary services, which are procured through a mix of the real-time spot market and annual contracting, include:

- **Reserve**: procured from the spot market which co-optimises energy, Regulation and Reserve;
- **Regulation**: procured from the spot market which co-optimises energy, Regulation and Reserve;
- **Reactive support and voltage control**: provided by generation units through contracting;
- **Black Start**: procured through contracting;
- **Fast Start**: initially procured through contracting; but now procured from the spot market which co-optimises energy, Regulation and Reserve;
- **Reliability Must-Run**: procured through contracting; but no contract in place since market commencement in January 2003.

Unless indicated otherwise, all dollars quoted in this chapter are in Singapore dollars.

5.1.1 Regulation

Regulation, or "load-following", is required to cover second-to-second variations in load away from estimated load. This is a normal operational requirement.

Regulation is procured in real time based on offer prices from generators. The Power System Operator (PSO) sets the Regulation requirements. At the market start, it was set at 100 MW. Several small increments were made over the years and in 2018, it was increased from 111 MW to 119 MW. The Regulation price in a dispatch period depends upon changes in supply conditions, such as offer prices, volume of outages and available capacity, as well as energy prices due to co-optimisation. Generators and consumers share the cost of Regulation.

5.1.2 Reserve

The quantities of Reserve required by the PSO for each dispatch period is determined by the expected size of a contingency. It is calculated dynamically taking account of:

- the size of largest unit generating energy;
- the stability of the unit under contingencies; and
- the correlation of unit failure with other contingencies.

In a change from 2003, Fast-start capability services were incorporated into the Contingency Reserve class requirements and therefore purchased directly from the wholesale market. This change followed the philosophy of procuring services from the market in a competitive manner when possible. The discontinuation of dedicated Fast-Start services added an additional generation capacity available to the supply of Reserve.

Three classes of Reserve were provided for in the system when the market started: Primary, Secondary and Contingency. This is illustrated in Table 5.

In October 2017, the Primary and Secondary Reserve classes were combined into a single Primary Reserve class.

Table 5: Class of Reserve in Singapore

Classes	Response time to reach scheduled MW[39]	Duration	Changes since market start
Primary Reserve	8 seconds	At least 30 seconds	Secondary Reserve combined with Primary Reserve into a single Primary Reserve in October 2017
Secondary Reserve	30 seconds	10 minutes	
Contingency Reserve	10 minutes	30 minutes	Fast Start incorporated into Contingency Reserve in 2003

There are different Reserve provider groups for each class of Reserve. These groups represent the reliability of different Reserve sources in providing Reserve, and their effectiveness in curtailing falls in system frequency. For example, some generating stations may have a poor record for response. Reserve provider grouping is a means of correcting this variability.

All Reserve providers are assigned by the PSO to a Reserve provider group for each class of Reserve they provide.

[39] After being triggered

5.1.3 Other ancillary services

Other ancillary services such as Reliability Must-Run service, reactive support and voltage control service and Black Start capability, while important, form a small part of the total value of the market. In many cases, they can be provided by only a few sources. It is not likely to be worthwhile creating spot markets for these services. Instead, they are supplied under contracts negotiated with market participants by the Energy Market Company (EMC) acting on behalf of and under direction from the PSO.

5.2 Co-optimisation of energy, Regulation and Reserve

Since a generation company's capacity may be available for energy, Reserve and Regulation, the Market Clearing Engine (MCE) must consider the optimal trade-off between the offers for Reserve, Regulation and energy. In solving for each class of Reserve and Regulation for a dispatch period, the MCE simultaneously finds the lowest cost solution (in terms of the offers made) that trades off between these products for the various facilities. Within the MCE, optimisation of the supply of energy must account for the minimum running level of generation units that provide Reserve/Regulation. The overall optimal solution may result in a unit being run "out of merit" for energy so that the unit is available for Reserve/Regulation.

Offers for Reserve from a generator can only be made in association with a corresponding offer for energy. Part of the standing capability data for the plant is a function relating its Reserve capability to its energy capability. This relationship is entered into the MCE.

5.3 Ancillary services cost recovery

The cost of Reserve is recovered from all generation facilities operating in that half-hour dispatch period by a levy that varies according to the contribution of each facility to the requirement for Reserve. A variant of the "runway" model is used to calculate the allocation to each dispatchable facility. The model weighs the cost more heavily to the facilities generating higher quantities, and on those with a poor reliability history.

The cost of Regulation is recovered from load and the generating facility being dispatched.

The costs of supplying the other ancillary services are recovered from market participants as part of the monthly energy uplift charge.

5.4 Drivers of ancillary services Prices and quantity requirements

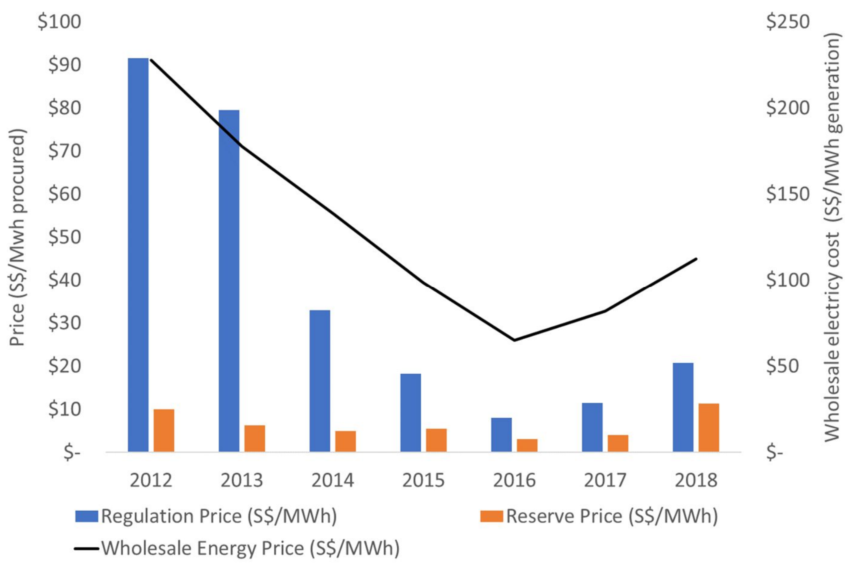
5.4.1 Ancillary service prices

The prices of Reserve and Regulation of each dispatch period are determined by demand and supply of that dispatch period. Generally, a market with abundant supply of

Regulations and Reserves relative to demand market forces tend to lead to lower prices. Conversely, tight market conditions would lead to higher prices.

Further, co-optimisation may result in the prices of energy, Reserve and Regulation being dependent on each other as a generation company trades off among the three by offering different price/quantity pairs. Therefore, Reserve and Regulation prices tend to move in tandem with energy prices. This is illustrated in Figure 42.

Figure 42: Regulation and Reserve average prices vs average Wholesale Electricity Price



Source: EMCa analysis

Note: Regulation and Reserve Prices are in dollar per MWh procured (volume weighted average). The wholesale electricity cost is the generation volume weighted average of the Wholesale Electricity Price in the NEMS.

As illustrated in the above figure, the energy prices rebounded strongly in 2017 and 2018 from the lows in 2016 and the Reserve[40] and Regulation prices all moved in line with the energy prices. In addition, the upward adjustments in the Regulation requirements in 2017 and 2018 were seen to have contributed to the increases in the Regulation prices.

5.4.2 Ancillary services quantity requirements

Regulation and Reserve requirements are set dynamically for each dispatch period by the PSO, based on system security rules e.g., load-linked Regulation requirements and the N-1 criteria for Reserve. The requirement rules and the real-time operations are transparent to ensure and considered effectiveness.

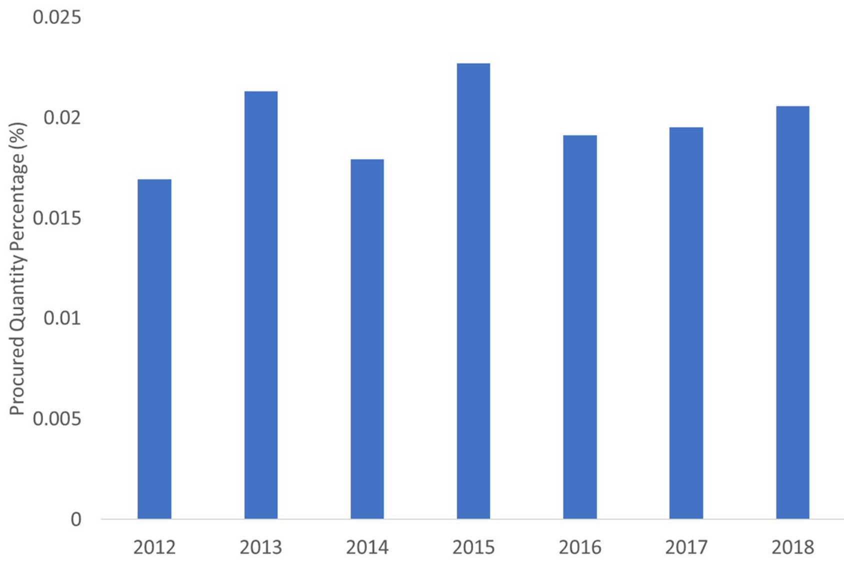
With an N-1 contingency requirement, Reserve is a significant factor in the Singapore system since some generating units (e.g., 600MW thermal units at the time the market

[40] Including all Primary, Secondary and Contingency Reserves.

started) are large relative to the total load. Figure 21 shows that Singapore's procured Reserve relative to system load tend to be larger compared to other jurisdictions.

Figure 43 shows the quantities for Regulation procured in Singapore from 2013 to 2018 as percentage of system load. As illustrated, the year to year variations were low during this period.

Figure 43: Singapore –Regulation Procured Quantity Percentage



Source: EMCa analysis

Generation companies provide the supply for each dispatch period based on available capacity and the trade-off strategies.

5.5 Spikes in Regulation prices caused by changes in offer behaviours

Following the upward trends in energy and other ancillary services, the Regulation prices recovered 2 years in a row to $20.76/MWh in 2018 (illustrated in Figure 42); but remained well below the historical high in 2007 of $118/MWh. The 2007 experience and the lessons learned from it remain relevant to date.

In January 2007, the monthly average Regulation price rose to an all-time high of $719/MWh. The high prices prompted a contestable consumer to request for the Market Surveillance and Compliance Panel (MSCP) to conduct an investigation, as the contestable consumer viewed that this outcome was unacceptable in a competitive market. The MSCP and the Energy Market Authority (EMA) examined the matter.

In its findings issued in March 2007, the MSCP concluded that the increase in Regulation prices was mainly due to changes in supply conditions, i.e., the offer behaviour of market participants.

It appeared that the EMA studies and MSCP investigation led to changes in market participants' offer behaviours and in October the Regulation prices fell to a new low monthly average of $11/MWh.

5.6 Renewable energy

Singapore has limited land resources; utility-scale solar PV and wind generation are not viable at present. The generation output of solar PV is not subject to the market-based scheduling and dispatch.

The installed PV capacity has grown from 0.4 MW as at the end of 2008 to 300.3 MW as at the end of the Q3 2019. The installed capacity for the 5 years to Q3 2019 is shown in Table 6.

Table 6: Installed PV capacities in Singapore

Installed PV capacity	MW
Q3 2019	300.3
Q32018	187.2
Q32017	146.8
Q32016	118
Q32015	48.5

Source: https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Statistics/47RSU.pdf

The penetration is low and the real-time system security management with the ancillary services remains adequate. This has minimal impact on ancillary services prices.

As more solar PV installation is expected in the coming years, moving to 5-minute dispatch will help alleviate the system security issues arising from higher intermittent renewable energy generation.

6 New Zealand Electricity Market (NZEM)

6.1 Introduction

The New Zealand power system has an installed capacity of about 9500 MW to meet a national peak demand of 7200 MW and an annual consumption of 43 TWh per annum (2019). The installed generating capacity is comprised of hydroelectricity (54%), natural gas (20%), geothermal (10%), wind (7%), coal (6%), oil (2%), and other sources (mainly biogas, waste heat and wood). New Zealand has two main islands - the South Island which generates mostly (98%) from hydroelectric sources and the North Island with a wider spread of generation sources with geothermal, natural gas and hydroelectricity all generating a share of between 20-30%. The North and South Island power systems are interconnected by a 1200 MW HVDC link (2 poles of 600 MW). The North Island comprises about two thirds of the national demand and provides about 60% of generation capacity. In recent years generation has been better than 80% renewable predominately hydro, geothermal and wind. The generation fleet is composed of some 220 generating sites with generators ranging from a largest 400 MW single shaft to predominantly machines sized at less than or equal to 100 MW.

Unless indicated otherwise, all dollars quoted in this chapters are in NZ dollars.

6.2 The New Zealand Electricity Market (NZEM)

The New Zealand Electricity Market (NZEM) was established in 1995. All electricity is traded at a wholesale level in a spot market. The market operation is managed by several service providers under agreements with the Electricity Authority. The physical operation of the market is managed by Transpower New Zealand Ltd in its role as the System Operator.

The Market is based on a 30-minute trading period. In each trading period the System Operator dispatches generator’s trading period offers to meet demand side bids in a least cost optimisation of energy and ancillary services within the existing system security constraints and reliability requirements. Dispatch of generation is continuous within each trading period against the offered generation.

The highest-priced bid offered by a generator required to meet demand for a given half-hour sets the spot price for that trading period. The dispatch and spot price incorporate the costs of the market priced ancillary services (Frequency Keeping and Instantaneous Reserves).

Electricity spot prices can vary significantly across trading periods, reflecting factors such as changing demand (e.g. lower prices in summer when demand is subdued) and supply (e.g. higher prices when hydro lakes and inflows are below average). Spot prices can also vary significantly across locations, reflecting electrical losses and constraints on the transmission system (e.g. higher prices in locations further from generating stations) and ancillary service.

6.3 Ancillary services in the NZEM

The Electricity Authority is charged with ensuring the efficient and economic operation of the NZEM. Routine performance reviews of the Service Providers provide ongoing and regular monitoring of most aspects of the market including ancillary service costs and pricing. It is significant that there are no current specific reviews of ancillary service costs on the Electricity Authority's agenda suggesting that these are not of current concern.

On behalf of the Electricity Authority, the System Operator is required to procure by contract ancillary services. Frequency Keeping and Instantaneous Reserves are offered, priced and dispatched through the wholesale market SPD (Scheduling Pricing and Dispatch) model. In the New Zealand electricity market ancillary services consist of:

- Frequency Keeping Service;
- Instantaneous Reserve Service;
- Over Frequency Reserve Service;
- Voltage Support Service; and
- Black Start Service.

6.3.1 Frequency Keeping Service

The purpose of frequency keeping is to balance any generation and demand inequalities with the objective of maintaining the grid frequency at or near 50 Hz under normal operating conditions and managing frequency time error. Factors that contribute to inequalities under normal operating conditions include unanticipated load changes, differences in generator ramping, and the inherent inaccuracies between the modelled and actual system conditions.

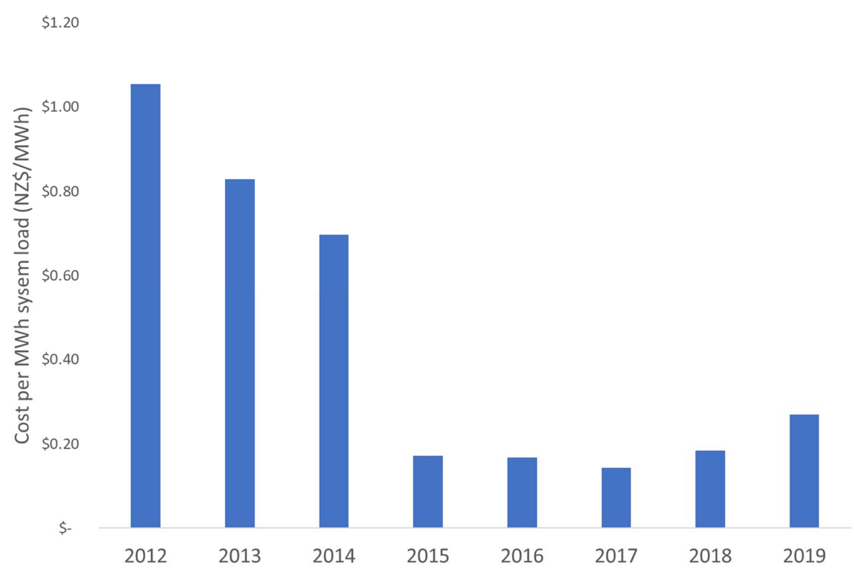
In 2016 the upgraded control system for the HVDC allowed the implementation of frequency keeping using the optimised capability of the HVDC and single and multiple frequency keepers. With the HVDC in FKC (Frequency Keeping Control) mode the system requires 15 MW in each island to provide frequency keeping services. Without FKC the system requires 25MW in each island to provide frequency keeping services. FKC is the normal mode of operation.

Key performance requirements are as follows:

- when there is a grid frequency error, ensure the relevant frequency keeping site responds to eliminate the grid frequency error;
- ensure the relevant frequency keeping site provides an average response rate of at least 10 MW per minute when the grid frequency error is greater than 0.2 Hz (that is, when the grid frequency is outside the normal band) over all of the ancillary service agent's single provider frequency keeping periods;
- use reasonable endeavours to continuously maintain the frequency of the grid as close as possible to 50 Hz, but at all times to within the normal band;
- use reasonable endeavours to continuously maintain frequency time error as close as possible to zero but at all times within the limits specified in clause 7.2C(1) of the *Electricity Industry Participation Code 2010*[41]; and
- Return frequency time error to zero at least once every day.
- These requirements may be met by Backup Single Frequency Keeping services or Multiple Frequency Keeping Services. Historically a single power station was allocated the frequency keeping service. Changes were implemented in 2015 to enable frequency keeping to be carried out by multiple facilities.

As illustrated in Figure 44, the cost of Frequency Keeping (per MWh system demand) has decreased significantly since 2015 when multiple frequency keepers introduced competition to the frequency keeping service.

Figure 44: Frequency Keeping Cost per MWh system load



Source: EMCa analysis

As a result of the FKC from the HVDC link, the quantity of Frequency Keeping (Regulation) procured as percentage of system load is low compared to other jurisdictions. This is illustrated in Figure 9.

[41] https://www.ea.govt.nz/code-and-compliance/the-code/

6.3.2 Instantaneous Reserve Service

The purpose of Instantaneous Reserve is to manage frequency recovery after an under-frequency event, with the objective of arresting the frequency fall, and recovering the frequency after an under-frequency event. Instantaneous Reserve requirements are specified in two categories, fast instantaneous reserves (FIR) and sustained instantaneous reserves (SIR) characterised by response times. Interruptible Load, and Tail Water Depressed plant may be offered as Instantaneous Reserve. Instantaneous Reserve is dispatched to cover the risk presented by the largest generating unit dispatched (where capacity is above 60MW). In New Zealand the risk also includes the contingency event from the HVDC link (600MW on a single pole). Costs for Instantaneous Reserve are allocated on a flat cost per MWh basis to the contingency event causers (i.e. generation/HVDC link flow above 60 MW).

Key Performance requirements includes:

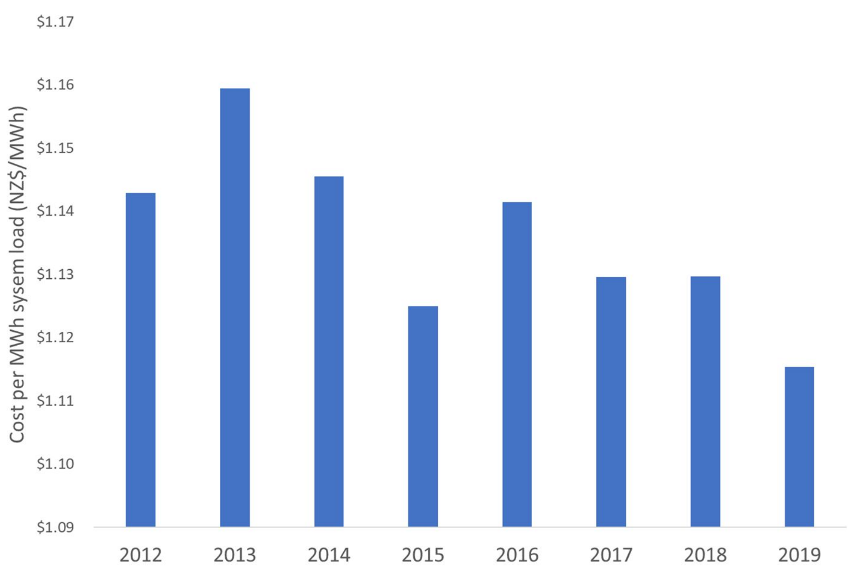
- for FIR, the actual Instantaneous Reserve response (in MW) from the ancillary service agent's equipment over intervals no greater than six seconds; and
- For the SIR, either the average Instantaneous Reserve response (in MW) at no greater than 60 seconds, or the actual Instantaneous Reserve response (in MW) at no greater than 10 seconds, from the ancillary service agent's equipment.

The cost of Instantaneous Reserve (per MWh system load) is illustrated in Figure 45. As observed, the costs are generally downward trending. These costs are a reflection of:

a) the degree to which system capacity was met by hydro stations (more hydro stations supplying Reserve after 2015 resulting in cheaper Reserve price) and

b) changes to the way the contingency risk from the HVDC link was managed and accounted for after 2016 (i.e. resulting in less contingency risk from the HVDC).

Figure 45: Instantaneous Reserve Cost per MWh system load



Source: EMCa analysis

The quantity of Instantaneous Reserve (i.e. Contingency Raise) procured relative to system load (i.e. the Procured Quantity Percentage) is illustrated in the Figure 21. The quantities for NZ were high compared to other jurisdictions. This relates to the relative risk represented by unit size and the contingency event risk of the HVDC. A similar effect can be seen in the Reserve procurement for Singapore.

6.3.3 Over Frequency Reserve Service

The purpose of Over Frequency Reserve is to manage frequency recovery after an event that might otherwise cause the grid frequency to exceed 52 Hertz in the North Island or 55 Hz in the South Island. For such an event, the system operator's objective is to arrest the rise in frequency and recover it to the normal band.

Performance requirements include:

- when armed, automatically disconnects the generating unit to which it is fitted within half a second of the frequency of the grid rising to or above the required frequency for that generating unit; and
- if the system operator has remote arming and/or disarming control of the relay equipment, immediately arms or disarms (as appropriate) when it receives a remote arming or disarming signal from the system operator's co-ordination centre.

In 2018, the cost of Over Frequency ancillary services was around $0.04/MWh. This is small compared to Frequency Keeping and Instantaneous Reserve.

Over Frequency ancillary services are procured by the System Operator through competitive purchase contracts rather than through a near real time bid-offer arrangement as in the case of the NEM.

6.3.4 Voltage Support Service

The purpose of voltage support is to provide additional reactive power resources of the static or dynamic type, depending on the location and network loading conditions, to contribute to network voltage control when dispatched.

6.3.5 Black Start Service

The purpose of Black Start is to maintain equipment that can initialise the supply for the progressive relivening of the grid following a partial or total blackout.

6.4 Future Key Influences

Transpower describes five key factors identified in Te Mauri Hiko – Energy Futures with potential significant influence on the future of electricity in New Zealand:

- Climate change – increasing concerns will drive more aggressive policies to cut emissions
- Economic, political and security uncertainty – the potential for global political and social unrest can have a significant impact on an open, trade-based economy like New Zealand
- Disruptive technologies – technology offers significant opportunity, from electrification driving demand, to the ability to smooth demand through batteries and networks, through to new technology to manage and maintain the network.

- Population growth and urbanisation – New Zealand continues to experience strong population growth and a continued concentration in key urban areas which will drive demand and change its geography.
- New Zealand's unique energy circumstances – the combination of a winter demand peak, an isolated grid and high existing renewable generation makes New Zealand unique and requires special attention.

Of these factors those that may significantly drive ancillary services costs or requirements are seen to be:

- The penetration of renewables - wind (currently 7%) and solar (<1%). The impact on ancillary services cost is minimal at this penetration rate;
- The HVDC operational mode[42];
- The capability of disruptive technologies – retail level management of batteries and domestic installations (including EV's)[43].

[42] For example, whether one pole of the HVDC covers the risk of the other pole.

[43] For example, the available of load control technology at retail level.

7 North America ancillary services markets

7.1 Introduction

In addition to providing power to end users, the power system operator is responsible for ensuring the reliability of the system's operation. To this end, the electricity market must maintain a set of ancillary services to ensure that the system always maintains a balance between power supply and demand when running in real time, and that the system has sufficient Operational Reserve capacity to respond to unexpected events in the system. A large part of these ancillary services, i.e. Regulation, Spinning, and Non-spinning Reserves are usually purchased through market-based mechanisms.

There are currently nine different electricity markets in North America (U.S. and Canada) as shown in Figure 46. Each market is managed by a Regional Transmission Organization (RTO) or Independent System Operator (ISO). Each RTO/ISO is responsible for managing the transmission infrastructure in its territory, operating the energy and ancillary services market, and maintaining the reliability of the system. Each power market provides its own set of ancillary services. The precise definition of ancillary services, requirements and market mechanisms vary from market to market. However, despite the differences between markets, the ancillary services procured from market basically can be divided into two categories: Regulation and Operating Reserve.

Figure 46: Electricity Markets in North America

Source: CAISO, http://www.caiso.com/about/Pages/OurBusiness/Opening-access.aspx

Regulation service is used to constantly and automatically balance small fluctuations in supply and demand in real time. Generation units that are providing Regulation service must be able to respond to automatic generation control (AGC) signals from the system operator and change their output accordingly on very short time scales, typically on the order of one to several seconds. Some markets (AESO, IESO, ISONE, MISO, NYISO, and PJM) offer only a single Regulation product, while others (CAISO, ERCOT, and SPP) offer separate products for Regulation Up (capacity that is available to increase output) and Regulation Down (capacity that is available to decrease output). Some markets (PJM) have also created a separate market product for fast-frequency Regulation, which is typically provided by storage and demand response resources that can change output faster than traditional generators. Demand-side resources that are able to respond to AGC signals are also able to provide Regulation services.

Operating Reserves can be further divided in to two sub-categories: Spinning Reserves and Non-spinning Reserves. Spinning Reserves, in some markets also referred to as Synchronized Reserves, or Responsive Reserves, are intended to help the system respond quickly to forced outages or other contingency events. Spinning Reserves are provided by generation units that are online but are not generating at full capacity and can therefore increase their output quickly to provide additional capacity to the system. Typically, generation units must be able to fully ramp up their generation within 10 minutes after receiving dispatch instructions to do so, depending on the details of the market design. Demand-side resources can also provide Spinning Reserves if they are able to similarly reduce their load within 10 to 15 minutes of receiving an instruction. Non-spinning Reserves, sometimes referred to as Supplemental Reserves or Non-Synchronized, are also intended to help the system recover from unplanned contingencies. Non-spinning Reserves can be provided by generation units that are offline, as long as they are able to start up and increase their output to the target level within a predefined period of time, usually 10 to 30 minutes, depending on the market design. In addition, CAISO can also procure any surplus online (i.e. spinning) units for meeting its Non-spinning Reserves requirements. Therefore, the amount of Non-spinning Reserve capacity in a system is often calculated inclusive of any surplus Spinning Reserve capacity. The total sum of Spinning and Non-spinning Reserves may be collectively referred to as Primary Reserves or Contingency Reserves.

There are several other ancillary services that are not procured in the ancillary services market. These include Black Start capabilities, reactive supply and voltage control, and Reliability Must-Run services.

As many generation units require input energy in order to start up and begin operation, power systems must maintain a Black Start capability so that they are able to restore operations in the event of a system-wide power outage. Such Black Start generators typically rely on small diesel generators or energy storage resources to provide the initial energy needed for start-up.

Reactive power supply and voltage control are achieved by managing the amount of reactive power in an alternating-current power system. The provision of this service ensures that system voltages are maintained within a desired range and also seeks to minimise the congestion caused by reactive power in a transmission network, i.e.to maximise the transmission of real power. Because the loss of reactive power is large during transmission, the support of reactive power should also be provided by resources located in the local location of the system's power demand concentration.

Black Start services and reactive support are procured through long-term contracts with resources that provide these services through RTO/ISO.

In order to ensure the reliability of the system operation, especially where the load is concentrated and transmission is limited, RTO/ISO requires some generating units to provide basic guaranteed power generation and ancillary services, such units are called Reliability Must-Run units. The RTO/ISO's operational planning department, through reliability studies, selects qualified generating units and signs long-term service contracts with their owners.

Unless indicated otherwise, all dollars quoted in this chapters are in US dollars.

7.2 California Independent System Operator (CAISO)

7.2.1 Energy and ancillary services market in California

CAISO is the system operator for the electricity market in California. It serves approximately 30 million customers for most of the area in the state of California, controlling across 26,000 miles of transmission lines with an installed generation capacity of 71,740 MW. CAISO started operation in 1998.

Energy and ancillary services are co-optimised in the Day-Ahead Market and the 15-minute Real Time Unit Commitment Market. Real time dispatch is in 5-minute intervals. An objective of the CAISO market function is to minimise the cost of production based on resource offers. Resources can self-schedule energy, and self-provide ancillary services. For extra-long and long-start-up resources, a Day-Ahead commitment is physically binding. For other resources, the Day-Ahead Market commitment is financial. The Reliability Unit Commitment (RUC) physically commits resources for reliability based on forecasted demand, and is published simultaneously with the Day-Ahead Market. The Day-Ahead Market closes at 10:00 am on the day prior to the operating day, and posts results by 1:00 pm. Energy, start-up and minimum load bids are submitted into the Real Time Market, which closes 75 minutes prior to operating hour. Real-Time bids are incremental or decremental to Day-Ahead bids. Resources can change their bid between Day-Ahead and Real-Time regardless of whether they have a schedule or not.

7.2.2 Ancillary services in CAISO

CAISO currently has markets for Regulation Up, Regulation Down and Contingency Reserve – which consists of Spinning Reserves and Non-spinning Reserves.

Regulation

Regulation Reserves must be able to respond to AGC signals in the CAISO balancing area. In CAISO, there are separate ancillary services for both Regulation Up and Regulation Down. The Regulation Reserves must be provided by generating units equipped with AGC devices and energy storage devices, demand response load within the CAISO control area. To implement FERC[44] order 755, CAISO has introduced Regulation Mileage and accuracy to measure the Regulation performance so as to provide additional compensation to resources with better Regulation performance.

Contingency Reserve

Spinning Reserves must be synchronised with the grid, able to ramp up to their committed capacity output within ten minutes, and able to run for at least two hours.

Non-spinning Reserves must be able to respond within ten minutes and able to run for at least two hours.

7.2.3 Ancillary services requirements in CAISO

The CAISO control area is illustrated in Figure 47. The control area procures ancillary services from the resources within the area itself as well as from resources outside the CAISO control area (the extended area) through the inter-ties.

As seen in Figure 47, the CAISO control area is divided into three subregions to represent possible transmission congestion within the CAISO control area. The subregions are NP15, ZP26 and SP15.

Congestion may also occur between the CAISO control area and the extended area.

Based on combinations of possible congestion scenarios, additional subregions may be formed. Each subregion is configured such that there is no transmission congestion within it. The ten possible subregions include:

1. **NP15**;
2. **NP15_EXP**: NP15 combined with the extended area;
3. **SP15**;
4. **SP15_EXP**: SP15 combined with the extended area;
5. **NP26** which consists of combined ZP26 and NP15;

[44] Federal Energy Regulatory Commission.

6. **NP26_EXP**: NP26 combined with the extended area;
7. **SP26** which consist of combined ZP26 and SP15;
8. **SP26_EXP**: SP26 combined with the extended area;
9. **CAISO**: The entire CAISO control area which consists of combined NP15, ZP26 and SP15 (also called the CAISO System Region); and
10. **CAISO_EXP**: The CAISO control area combined with the extended area (also called the CAISO Expanded Region).

In addition to the ancillary services requirement for the entire CAISO control area, each of the subregions can also have individual requirements for the relevant congestion scenario. This ensures that various ancillary services can be called in an effective manner when a transmission congestion occurs. The subregions allow constraints to be expressed in the co-optimisation process. To ensure the reliability of the system operation, 100% of the Regulation Reserve and at least 50% of the Contingency Reserve must come from within the CAISO control area.

Figure 47: Map of the CAISO control area

Source: Survey of U.S. Ancillary Services Markets, https://publications.anl.gov/anlpubs/2016/01/124217.pdf

The system's requirements for ancillary services are determined by the hours of operation. The system's requirements for Regulation Reserves are set according to the NERC (North American Power Reliability Coordination Committee) reliability criteria, usually a percentage or fixed value of the peak load, and now a value between ±300 and ±400MW is often used as a requirement for Regulation Reserves (including Regulation Up and Regulation Down). According to NERC's reliability standards, the system's requirement for the total Contingency Reserves, i.e. the sum of the Spinning and Non-spinning Reserves, is taken from the larger of the following: (a) 12% of forecast load of the operating hour and (b) the largest single system contingency. Spinning Reserve must account for at least 50% of the total Contingency Reserves requirements.

7.2.4 Market clearing process

In the CAISO market, all ancillary service bids may be accompanied by an energy bid in the DAM (Day-Ahead Market), and must be accompanied by an energy bid in the Real Time Market (RTM). CAISO determines its ancillary service needs on the basis of forecast demand within the CAISO control area, and obtains these ancillary services either through self-scheduling resources or through participation by resources in the CAISO Ancillary Services Market. Ancillary service bids are evaluated simultaneously with energy bids in the Integrated Forward Market (IFM) to clear bid-in supply and demand. The Integrated Forward Market co-optimises energy and ancillary services. The capacity of a resource with energy and ancillary service bids is optimally used to provide energy or reserved for ancillary service provision in the form of ancillary service awards. If needed, additional ancillary services Reserves can be purchased for the next operating hour or 15 minutes in advance in the Real time Market (RTM). As a means to minimise the total procurement cost of ancillary services, CAISO allows a rational buyer or cascading purchase algorithm. This enables CAISO to, when economic to do so: (a) purchase more Regulation Up Reserve for meeting the Spinning Reserve requirement, and (b) purchase more Regulation Up Reserve and Spinning Reserve to meet the Non-spinning Reserve requirement.

7.2.5 Pricing and Settlement

The ancillary services marginal price (ASMP) is generated by the co-optimisation of energy and ancillary services. Different ancillary services products may have different ASMP across the whole system or in different subregions. They represent the marginal costs to provide an additional unit of the product service in the subregion. In the case of a shortage of supply, CAISO will use a virtual resource with scarcity prices to help co-optimisation to clear the market. The virtual resource has an infinite capacity, and its price is set by CAISO based on the product's shortage demand curve, usually $1000/MWh. Resources selected to provide ancillary services in Day-Ahead and Real Time markets will be paid for the Reserve capacity based on the corresponding ASMP. The cost of the market purchase of ancillary services is shared by the load serving entities (LSE) in proportion to their actual load in the system. LSE can also reduce or negate their obligations to contribute towards the ancillary services cost by self-providing the services. Ancillary service energy dispatched in the Real Time Market (RTM) is settled by the RTM Locational Margin Price (LMP) (i.e. nodal energy price).

7.3 Electric Reliability Council of Texas (ERCOT)

The Electric Reliability Council of Texas (ERCOT) is located in Austin, Texas and serves approximately 24 million customers in the state of Texas, controls across more than 46,500 miles of transmission lines with an installed generation capacity of 86,000 MW. ERCOT began operation in 2000.

7.3.1 Energy and ancillary services in ERCOT

To maximise overall system benefit, the ERCOT Day-Ahead Market simultaneously co-optimises energy, ancillary services and congestion hedging products by maximising bid-based revenues and minimising offer-based costs, subject to resource and network constraints. ERCOT's Day-Ahead Market is voluntary and does not solve to meet load forecast. Energy offers in the Day-Ahead Market are financially binding and awarded hourly. The Day-Ahead Market closes at 10:00 am and posts results by 1:30 pm. A daily Reliability Unit Commitment (RUC) run ensures enough generation is online to meet the load forecast. The Real Time Market uses Security Constrained Economic Dispatch (SCED) that re-dispatches current generation at least-cost. Qualified Controllable Load Resources can submit demand response bids for the Real Time Market.

7.3.2 Ancillary services in ERCOT

ERCOT currently procures Ancillary Services of Regulation Up, Regulation Down, Responsive Reserve, and Non-spinning Reserve though markets.

Regulation

Regulation Reserves are deployed by ERCOT in response to changes in the system frequency and are used to maintain system frequency within a predetermined range. Regulation must immediately increase/decrease output in response to AGC signals. In ERCOT there are separate Regulation Up and Regulation Down Reserves.

Responsive Reserve Service

Responsive Reserves must be able to respond quickly to changes in system frequency. Must respond within "the first few minutes of an event that causes a significant deviation from the standard frequency.

Non-spinning Reserves

Non-spinning Reserves must be able to become synchronised with the grid, ramp to a specified output level within 30 minutes, and generate at that level for at least one hour. Reserve capacity that is already synchronised with the grid can also provide this service, as can demand-side resources that can reduce their load.

7.3.3 Ancillary services requirements in ERCOT

ERCOT has only one ancillary services region that spreads across the entire ERCOT service territory.

The system requirements for Regulation Up and Regulation Down are determined as the largest of:

1. The 98.8th percentile of Regulation-up/down deployments over the last 30 days;
2. The 98.8th percentile of Regulation-up/down deployments in the same month of the previous year;
3. The 98.8th percentile of the positive/negative net load changes over the last 30 days; or
4. The 98.8th percentile of positive/negative net load deployments in the same month of the previous year.

This base value may be further adjusted as necessary because of increased wind penetration and other circumstances.

Requirements for Responsive Reserves are calculated in four-hour blocks on the basis of forecasted load and wind patterns. Interruptible load resources can provide Responsive Reserves, but their contribution is limited to 50% of the total requirement in each hour.

The system requirement for Non-spinning Reserves is determined by first calculating the 95th percentile of net load uncertainty from both the previous 30 days and the same month of the previous year. Net load is defined as total load minus wind generation, and net load uncertainty is defined as the difference between the realised net load and forecast net load. ERCOT then subtracts the Regulation Up requirement from this 95th percentile to obtain the Non-spinning Reserves requirement. During on-peak hours (hours 07:00 through 22:00 Central time), ERCOT also maintains a minimum Non-spinning requirement that is equal to the largest single unit in the system. The Non-spinning requirement is also never permitted to exceed 2000 MW during all hours of operation.

7.3.4 Market clearing process

In the Day-Ahead Market (DAM), ERCOT establishes an Ancillary Services Plan and publishes relevant system information each day by 06:00 hours Central time. This Ancillary Services Plan identifies the ancillary service obligations of all Qualified Scheduling Entities (QSEs) during each hour of the following day. QSEs can meet their obligations either through self-schedule, bilateral trades with other QSEs, or purchases from ERCOT through the DAM. QSEs must submit their bids and offers for ancillary services by 10:00 hours Central time. The DAM is executed between 10:00 and 13:30 hours Central time, at which point results are posted. QSEs then have the opportunity to make bilateral trades with other QSEs based upon the results of the Day-Ahead Market; any such trades must be reported to ERCOT by 1430 hours Central time.

7.3.5 Pricing and Settlement

ERCOT's Day-Ahead market produces a system-wide Market Clearing Price for Capacity (MCPC) for various ancillary service products per operating hour on the operating day. Resources committed to provide ancillary services are paid at the product's MCPC. The cost of market paid for buying ancillary services is prorated by the non-self-schedule obligations of each QSE.

In real-time operations security constrained economic dispatch (SCED) is conducted every five minutes and two price-adders are calculated on the basis of the Reserve levels that are realised during each settlement period—currently every 15-minute interval. One adder is calculated based on the realised level of online Reserves and the other is calculated based on the sum of the realised levels of online and offline Reserves. These adders are then added to the LMP-based energy price that is paid to generating entities and charged to load-serving entities in each settlement period. If the Responsive Reserve level falls below a 2000 MW minimum contingency in any period, ERCOT sets the price adder to the administratively determined value of lost load (VOLL) in the system, which is currently $9000/MWh[45].

7.4 PJM Interconnection (PJM)

PJM Interconnection is located in Valley Forge, Pennsylvania and serves approximately 65 million customers in all or part of 13 US states and the District of Columbia, controls across more than 81,000 miles of transmission lines with an installed generation capacity of 176,546 MW. PJM began its operation in 1997.

[45] Potomac Economics, *2018 State of The Market Report for The ERCOT Electricity Markets*, footnote 13

7.4.1 Energy and ancillary services in PJM

PJM simultaneously co-optimises the energy, Regulation, Primary and Synchronized Reserves to minimise the cost of production. The Day-Ahead Market is a forward market in which hourly prices are calculated for the next operating day based on generation offers, demand bids and scheduled bilateral transactions. The Day-Ahead offer and bid period ends at 10:30 am EPT[46], results are posted by 1:30 pm EPT and rebidding is open from 1:30 pm EPT to 2:15 pm EPT. PJM operates a 24-hour market in which the market day starts at midnight. PJM performs a Reliability Assessment & Commitment (RAC) that is performed after the Day-Ahead Market closes, and as-needed until the operating day begins. The Real Time Market is a spot market in which prices are calculated at a five-minute interval based on grid conditions. PJM also operates a Day-Ahead Scheduling Reserve Market that is used to ensure energy Reserves are available to deal with unexpected system conditions during the operating day. The PJM Capacity Market, called the Reliability Pricing Model (RPM) procures long term capacity resources three years ahead where committed dispatchable resources are obligated to offer into the Day-Ahead Market.

7.4.2 Ancillary services in PJM

PJM currently has markets for Regulation, Synchronized Reserves, and Primary Reserves.

Regulation

Regulation Reserves must be able to increase or decrease their output in response to AGC signals within five minutes in order to maintain target system frequency. There are two important Regulation signals: Regulation signal A and D. Regulation signal A is a function of total ACE[47]. Signal D was specifically developed for energy storage devices with limited storage capabilities. It is designed so that storage can provide more signal-correcting output in the short-term with less storage needs. The resource is monitored for accuracy at a ten-second scan rate; payments are reduced for poor accuracy.

Synchronized Reserves

Synchronized Reserves must be synchronised with the grid and able to convert their capacity into generation within ten minutes of receiving a signal from the system operator.

Primary Reserves

The Primary Reserves product in PJM represents the combined quantity of available Synchronized Reserves and Non-synchronized Reserves (also available within ten minutes).

---

[46] Eastern Prevailing Time.

[47] ACE is the difference between scheduled and actual electrical generation, accounting for variations in the system's frequency. The main goal of Regulation is to keep the ACE within acceptable bounds. https://learn.pjm.com/three-priorities/buying-and-selling-energy/ancillary-services-market/regulation-market.aspx

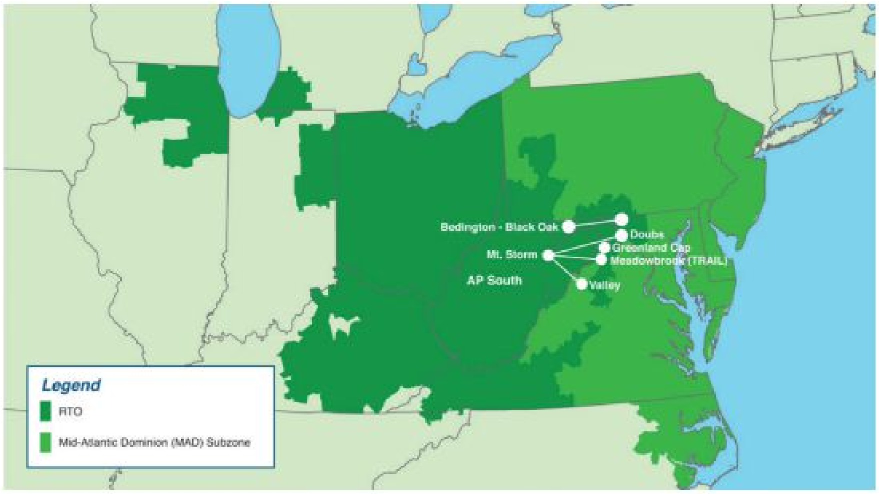
7.4.3 Ancillary services requirements in PJM

PJM consists of two regions for Reserve products:

1. PJM RTO
2. PJM Mid-Atlantic Dominion (PJM MAD)

The PJM RTO region spans the entire PJM territory (including PJM MAD), while PJM MAD is a sub-region covering the eastern portion of the PJM territory. PJM applies a unified Regulation requirement for the whole PJM RTO region. Owing to potential deliverability issues, PJM also established the PJM MAD sub-region for Synchronized Reserve and Primary Reserve services, as illustrated in Figure 48.

Figure 48: PJM RTO Zone and MAD Subzone geography: 2017



Source: 2017 State of the Market Report for PJM (Figure 10-1)

There is no separate Regulation requirement for the PJM MAD sub-region, only a single requirement for the entire PJM RTO.

There are two separate Synchronized Reserve requirements for the entire PJM RTO and for the PJM MAD sub-region. The requirement for the entire PJM system is equal to the greater of (a) the Reliability First Corporation (RFC)-imposed minimum requirement and (b) the largest contingency on the system. The requirement for the PJM MAD sub-region is equal to the largest contingency in PJM MAD.

There are two separate Primary Reserve requirements for the entire PJM RTO and for the PJM MAD sub-region. The requirement for the entire PJM system is equal to 150% of the largest contingency on the system. The requirement for the PJM MAD sub-region is set to a predefined value, usually 1700 MW (2016 figure).[48]

Because there is no explicit requirement for Non-synchronize Reserve, if the Synchronous Reserve price is lower than the Non-synchronous Reserve price, PJM can purchase more Synchronize Reserves to satisfy the Primary Reserve requirement.

[48] Argonne National Laboratory, *Survey of U.S. Ancillary Services Markets*, section 7.3.3.

7.4.4 Market Clearing Process

Ancillary service prices and cost-related data must be supplied by 18:00 hours Eastern time one day ahead of operation and are applicable for the entire 24-hour period. For Regulation market resource owners also submit specific offers for Regulation capability and Regulation performance. All data can be revised until 60 minutes before the operating hour. Sixty minutes prior to the operating hour, PJM executes the Ancillary Services Optimizer (ASO) to jointly optimise energy, Synchronized Reserves, Primary Reserves, and Regulation on the basis of forecasted system conditions to determine an economical set of inflexible Reserve resources to commit for the operating hour. In the Real Time Market, PJM collaborates to optimise energy and ancillary services every 5 minutes.

7.4.5 Pricing and Settlement

PJM optimises the RTO dispatch profile and forecasts LMPs to calculate an hourly Regulation Market Clearing Price (RMCP), Regulation Market Performance Clearing Price (RMPCP), and Regulation Market Capability Clearing Price (RMCCP). For each hour, RMCP is the sum of RMPCP and RMCCP.

PJM calculates real time prices for Synchronized Reserves and Primary Reserves (Primary Reserve includes both Synchronized and Non-synchronized Reserves) simultaneously with the LMP every five minutes in real time. For each 5 minutes, PJM calculates Synchronized Reserve Market Clearing Price (SRMCP） and Non-Synchronized Reserve Market Clearing Price (NSRMCP） for the entire system PJM-RTO and sub-region PJM-MAD. The various ancillary service market clearing prices are calculated every 5 minutes, but when settled, the average of the 12 five-minute prices within an operating hour is used as the market clearing price for that hour.

When there is no Synchronized Reserve shortage, the prices will be determined by the cost of the marginal Synchronized Reserve resource, which is defined as the Synchronized Reserve offer plus any opportunity cost for this resource relative to forgone energy or other ancillary service payments. When there is no Primary Reserve shortage, the prices will be determined by the cost of the marginal Primary Reserve resource, which is defined as the opportunity cost for this resource relative to forgone energy or other ancillary service payments. When there is a shortage in Synchronized Reserves, then the price will be the sum of the Primary Reserve and Synchronized Reserve penalty factors. When there is a shortage in Primary Reserves, the Primary Reserves price will be equal to the penalty factor of the location where the shortage occurred.

Load Service entities (LSE) are obliged to assume the obligation of the system ancillary service requirements, and the share of the obligation is determined according to the LSE's share of the total load in the PJM-RTO. LSE has one of three ways to fulfill its obligations: (a) self-schedule the entity's own resources, (b) bilateral contracts to purchase services from other participants, (c) buying in the ancillary services in the PJM market.

8 Observations and Conclusion

8.1 Observations from the other jurisdictions

Based on the jurisdictions we have studied, we found the following features in other jurisdictions but notably absent in the WEM:

- **Dynamic ancillary services quantity requirements** – currently the quantity requirements for LFAS and Load Rejection are determined on a static basis, typically once a year. In practice, the ancillary services quantity requirements change from time to time to reflect the operating condition of the power system. Allowing the quantity requirements to be determined on a regular and timely basis is likely to allow lower quantities overall to be procured. This is a feature in the NEM, Singapore, CAISO and ERCOT.
- **Co-optimisation of energy and ancillary services** – co-optimisation typically involves an algorithm seeking to achieve least cost dispatch of the energy and ancillary services in a power system while maintaining power system security. This process may involve complex trade-offs, particularly as the ability for a generator to provide ancillary services will be influenced by its current production level. The WEM currently does not have such a co-optimisation arrangement. If designed properly, a co-optimisation arrangement should deliver improved price and volume efficiency in the WEM's ancillary services market. Co-optimisation is common in the jurisdictions that we have studied including the NEM (using the NEMDE), Singapore, NZ, CAISO (using the Integrated Forward Market), ERCOT and PJM (using the Ancillary Services Optimizer).
- **Five-minute dispatch** - a shorter dispatch interval (i.e., increasing the frequency with which dispatch instructions are issued to generators) allows better decision making by participants through provision of timely and accurate information closer to real time. This allows participants to adjust dispatch positions more swiftly to reflect physical facility limitations. If dispatch

instructions are issued more frequently, the ability of the energy market to match supply to fluctuating demand is improved, shifting the boundary between the Balancing Market and LFAS. This has the potential to reduce reliance on potentially more expensive LFAS. Five-minute dispatch is a feature in the Real Time-Market (RTM) in US electricity markets including in CAISO, PJM and ERCOT. It is also a feature in the NEM.

We note that the work program of the Energy Transformation Strategy is currently working towards delivering the above features to the WEM. If designed properly, the WEM with the above features is likely to deliver improved efficiency in the ancillary services prices and quantity requirements.

In addition to the above, we also note the following features in the other jurisdictions which may bring about improved price and quantity efficiencies in the WEM ancillary services market. The WEM may wish to explore these features for implementation in the future:

- **Market for Non-spinning Reserve capacity** – as illustrated in section 3.10.1, Non-spinning Reserve is generally cheaper and can reduce the cost of FCAS in an electricity market. The Non-spinning Reserve is approximately equivalent to the Ready Reserve in the WEM. Having a market for the Non-spinning Reserve (and by extension co-optimising it with the energy and other ancillary services) could improve price and volume efficiency in the ancillary services market.
- **Ancillary services using demand side resources** – provision of ancillary services by demand side resources is still limited in the WEM. Facilitating greater participation in the ancillary services market could bring about more competition hence giving downwards pressure on ancillary services costs.
- **Pay for performance** – in Singapore, the energy Reserve providers are categorised into the Reserve provider groups based on their effectiveness characteristics. There is a payment incentive structure for these Reserve providers based on the group they are in.[49] In some of the US jurisdictions (including CAISO and PJM), there are incentive systems to reward Regulation providers for speed and accuracy in following AGC signals. These are known as Regulation Mileage. We consider pay for performance is likely to bring about price and volume efficiency for WEM ancillary services.
- **Cost allocation for Spinning Reserve based on not just generation amount but also reliability of the generator** – this arrangement has been adopted in Singapore. This should incentivise better performance of generators and hence better utilise the Contingency Reserve capacity in the power system.
- **Lowering ancillary services requirement and implementing a scarcity pricing model** – it may be possible to be less conservative in setting the ancillary services requirements amounts, and to supplement these amounts with scarcity pricing arrangements to allow more Reserve to be provided in time of

[49] https://www.emcsg.com/marketdata/guidetoprices

need. To ensure power system security, minimum requirements to ensure robustness of the power system may need to be mandated.[50]

- **Self-supplied ancillary service** – allowing a market participant who is obliged to pay a share of ancillary service cost to self-supply ancillary service for discharging such obligations. The market participant can self-supply through its own resources or through a bilateral arrangement with a provider. The ancillary services cost net of the self-supply arrangement would be allocated centrally by AEMO. Such an arrangement would allow efficiency from the self-supply arrangement (if any) to be realised. This should improve the price and volume efficiency in the ancillary services market.

8.2 Conclusions

Using the appropriate measures, we have compared the WEM ancillary service costs against those in the NEM, Singapore, New Zealand, CAISO, EROT and PJM.

We found that the ancillary services Price paid by the WEM is high compared to other jurisdictions. We also found that the ancillary services quantity procured (as percentage of system load energy) are generally high compared to the other jurisdictions.

While the following are not definitively the reasons for the WEM's high ancillary service Prices and procured quantities, the following features in other jurisdictions are notably absent in the WEM:

- Dynamic ancillary services requirement amount;
- Co-optimisation of energy and ancillary services; and
- Five-minute dispatch.

These factors may have contributed to the high Prices and procured quantities.

We note that the work program of the Energy Transformation Strategy is working towards delivering the above features to the WEM. We anticipate that these initiatives, if design properly, would improve the Price and volume efficiency of FCAS in the WEM.

Based on our observations on the practices of the other jurisdictions, we have also discussed other ideas for improving the efficiency of ancillary services delivery in the WEM. They may be used as a reference for future market reform program. These ideas are set out in section 8.1 of this report.

[50] Mandatory requirement has also been recommended by GHD in its advice to the Energy Transformation Implementation Unit (ETIU). GHD, *Essential System Services Framework Review*, https://www.wa.gov.au/sites/default/files/2019-08/GHD-Advisory-Report-Essential-System-Services-Technical-Framework-Review_1.pdf

Appendix A: Ancillary Services Costs

This appendix sets out the Cost for each ancillary service type for each jurisdiction from 2013 to 2018. For an ancillary service type for a year within a jurisdiction, Cost is defined as the expenditure (in dollar) divided by the system load energy. Costs are generally high in the WEM compared to other jurisdictions.

Figure 49: FCAS Cost

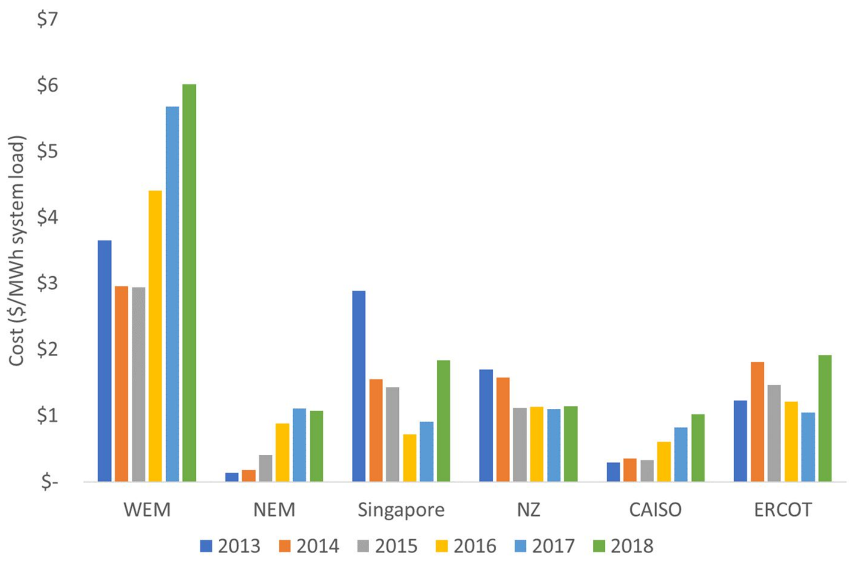


Figure 50: Regulation Cost

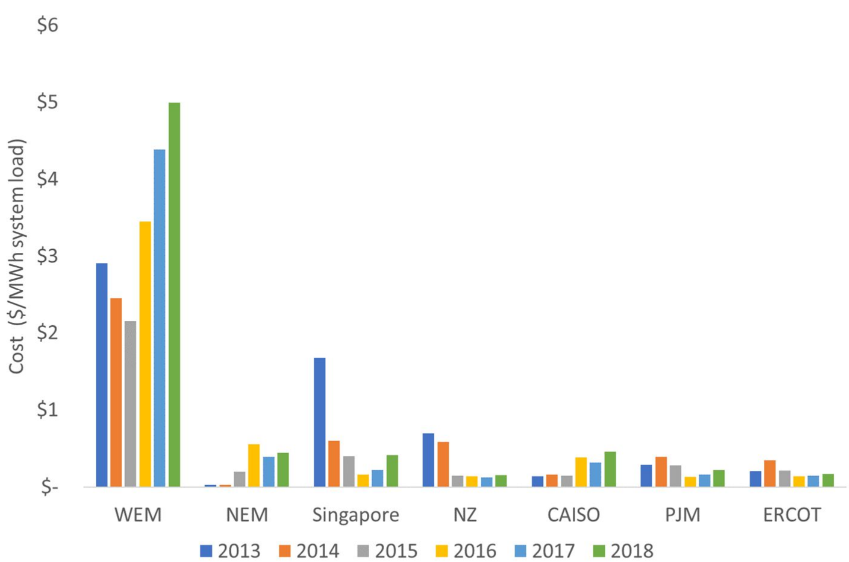


Figure 51: Regulation Up Cost

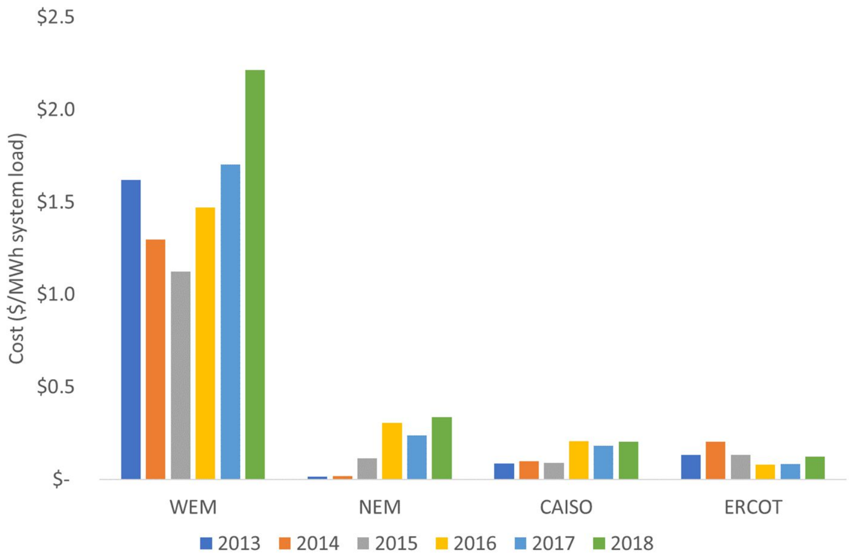


Figure 52: Regulation Down Cost

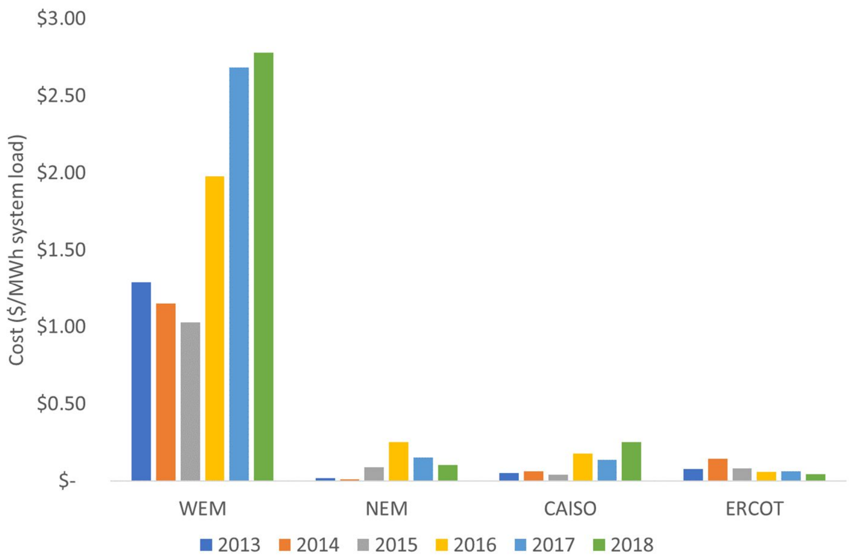


Figure 53: Contingency Raise Cost

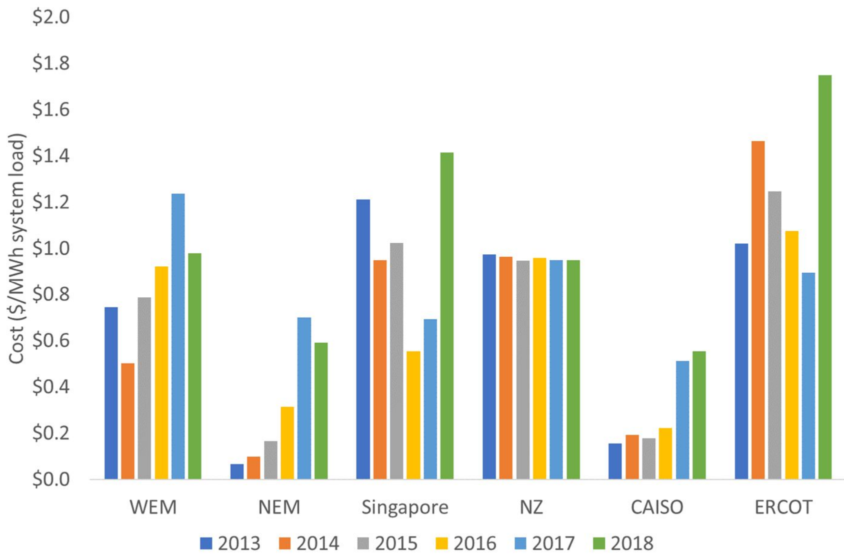


Figure 54: Regulation Up + Contingency Raise Cost

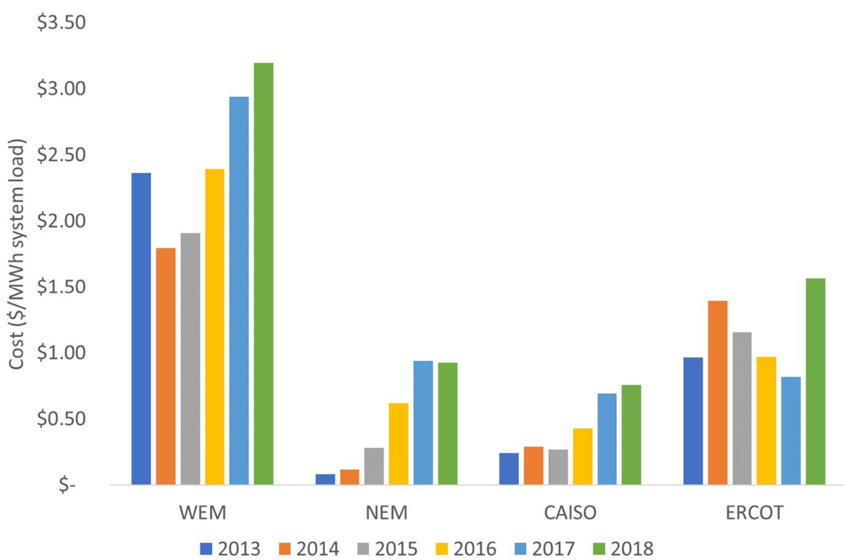
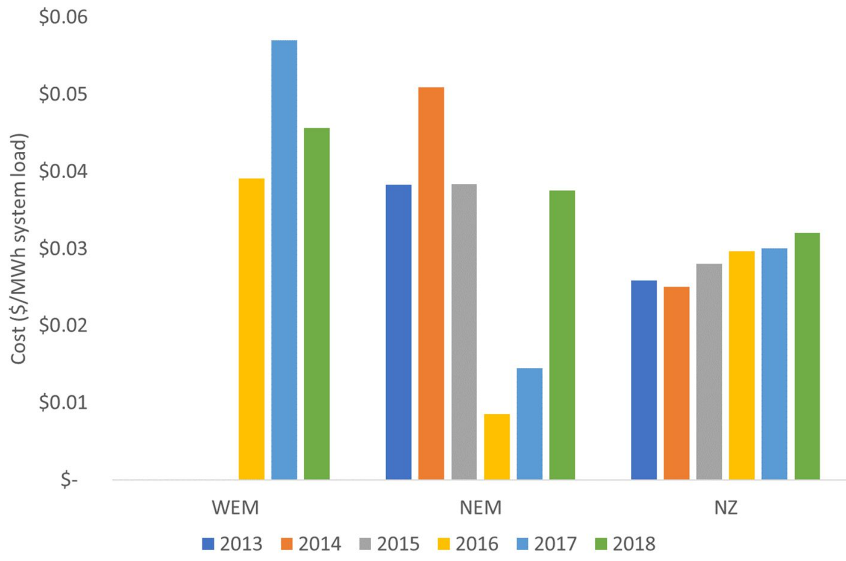


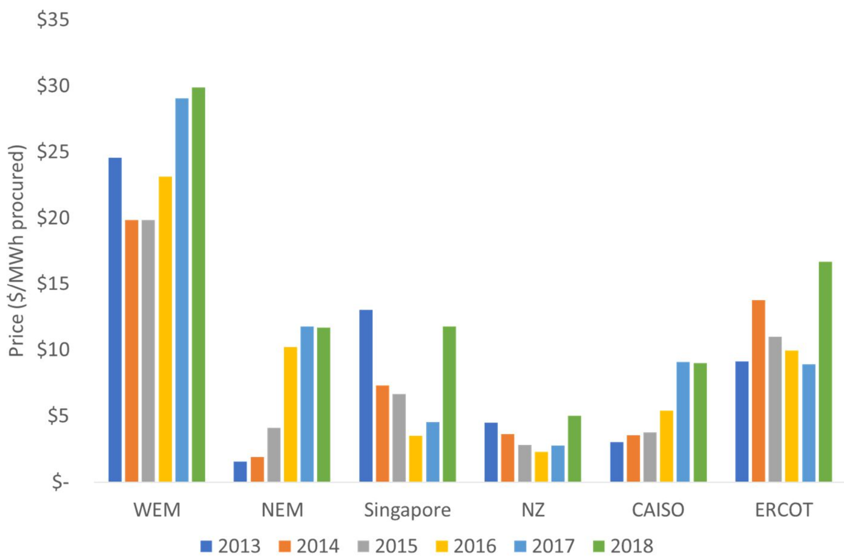
Figure 55: Contingency Lower Cost



Appendix B: Ancillary Services Prices

This appendix sets out the Price for each ancillary service type for each jurisdiction from 2013 to 2018. For an ancillary service type for a year within a jurisdiction, Price[51] is defined as the expenditure (in dollar) divided by the procured ancillary service quantity. Prices are generally high in the WEM compared to other jurisdictions.

Figure 56: FCAS Price



[51] Note that this is different from the Normalised Price discussed earlier in this document.

Figure 57: Regulation Price

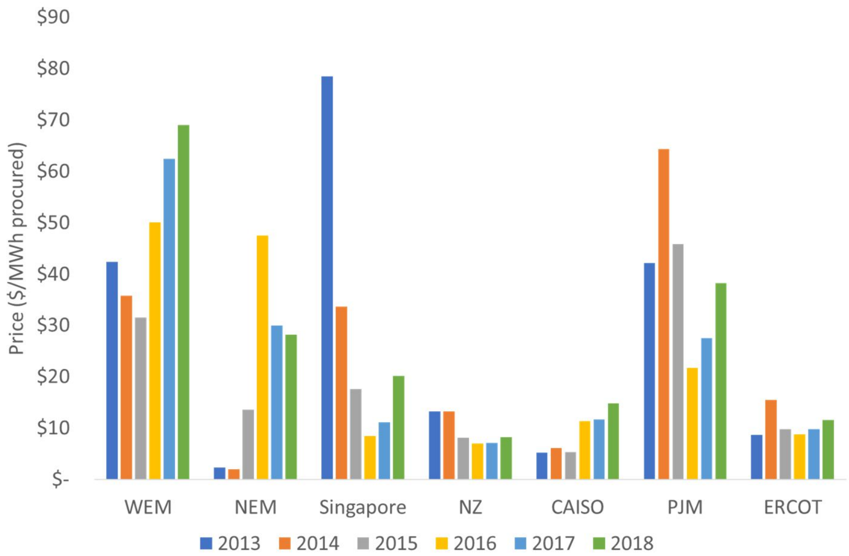


Figure 58: Regulation Up Price

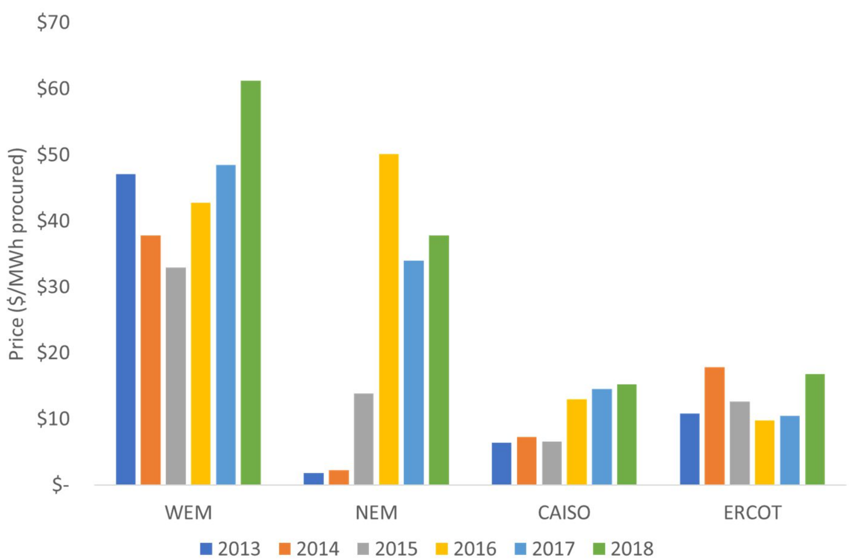


Figure 59: Regulation Down Price

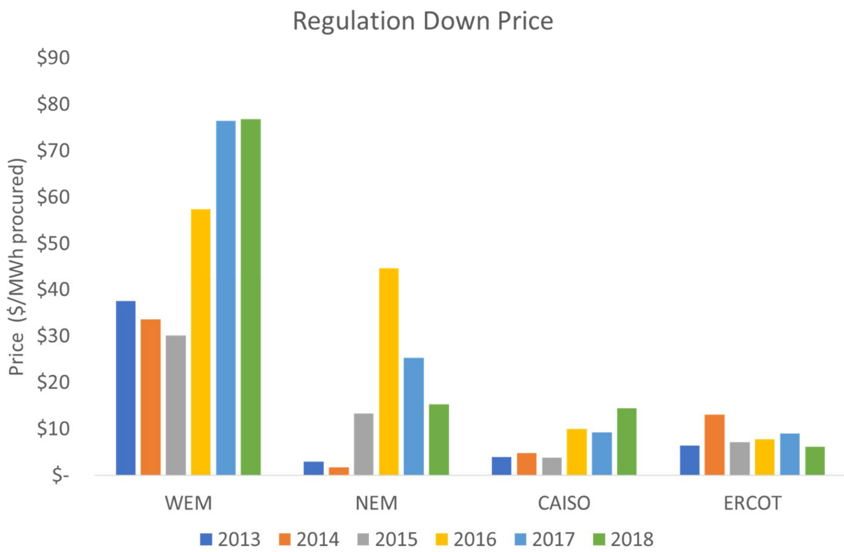


Figure 60: Contingency Raise Price

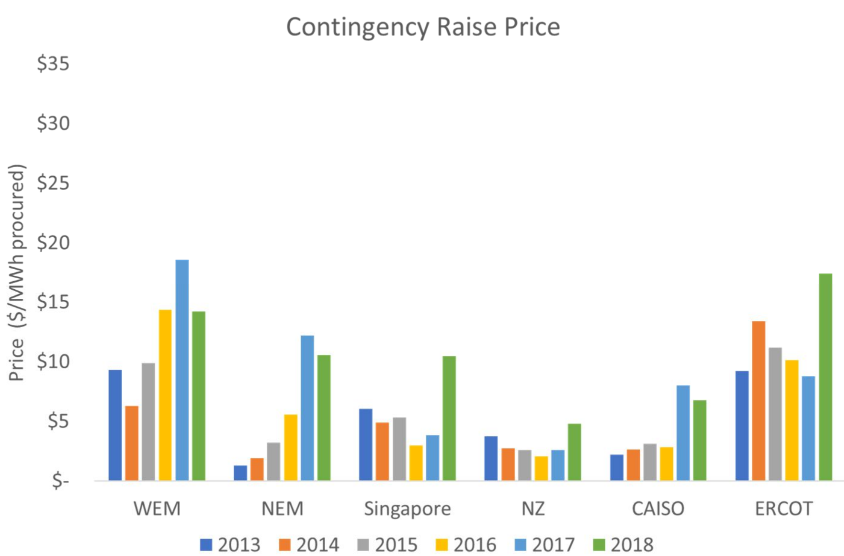


Figure 61: Regulation Up + Contingency Raise Price

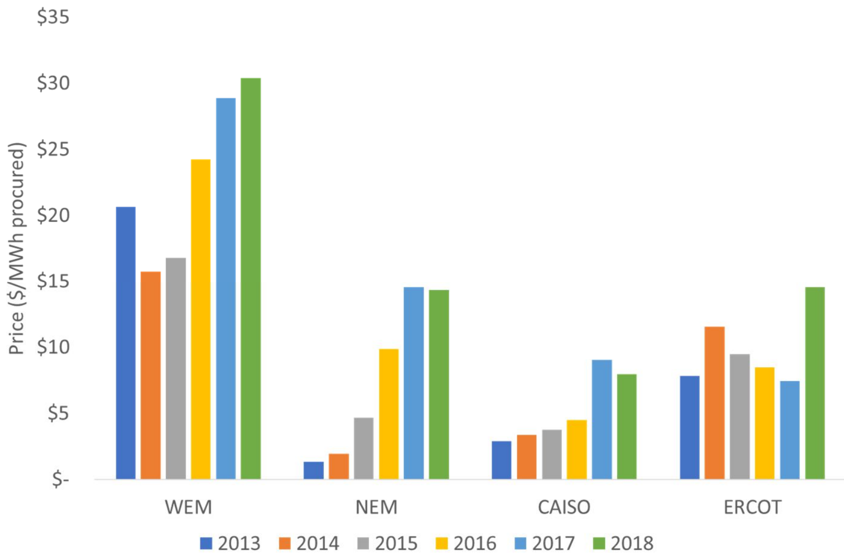
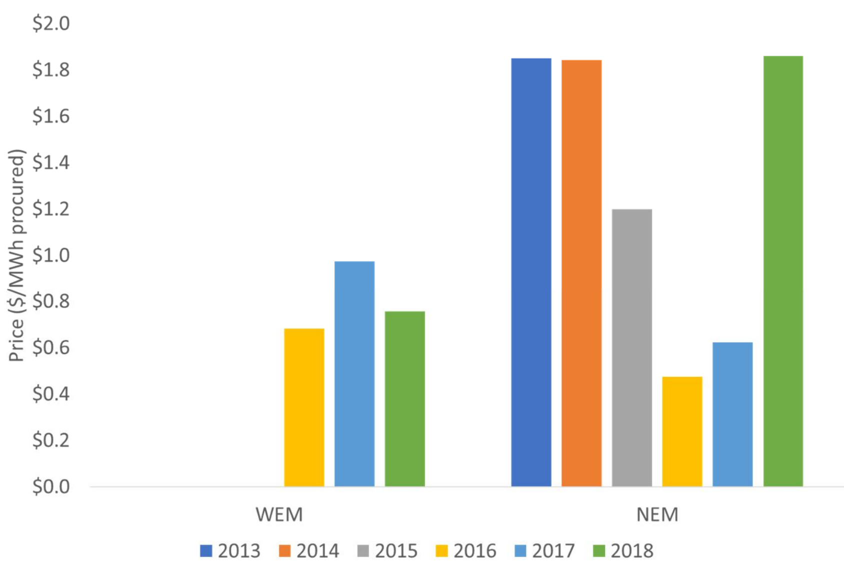


Figure 62: Contingency Lower Price



Appendix C: Ancillary services Price as percentage of wholesale unit cost

This appendix sets out the Price (as percentage of wholesale unit cost) for each ancillary service type for each jurisdiction from 2013 to 2018. The percentages are generally high in the WEM compared to other jurisdictions.

Figure 63: FCAS Price as percentage of wholesale unit cost

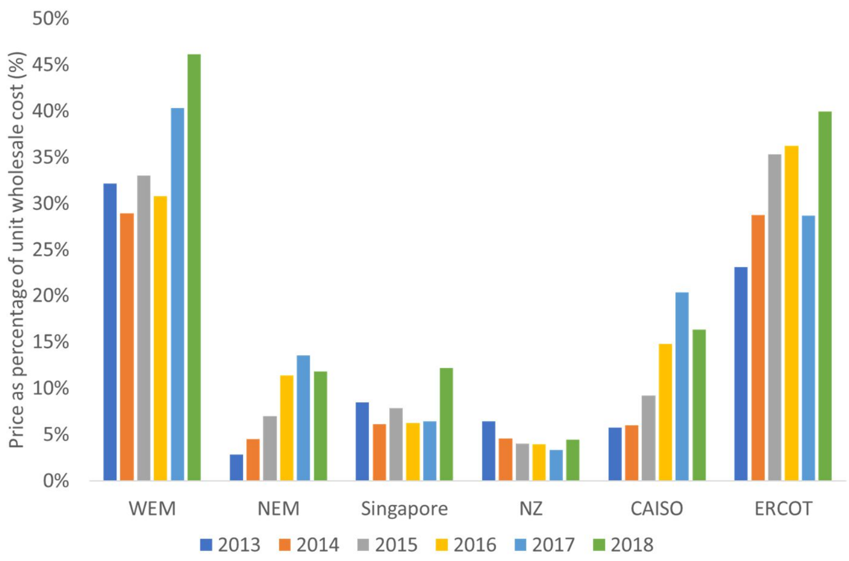


Figure 64: Regulation Price as percentage of wholesale unit cost

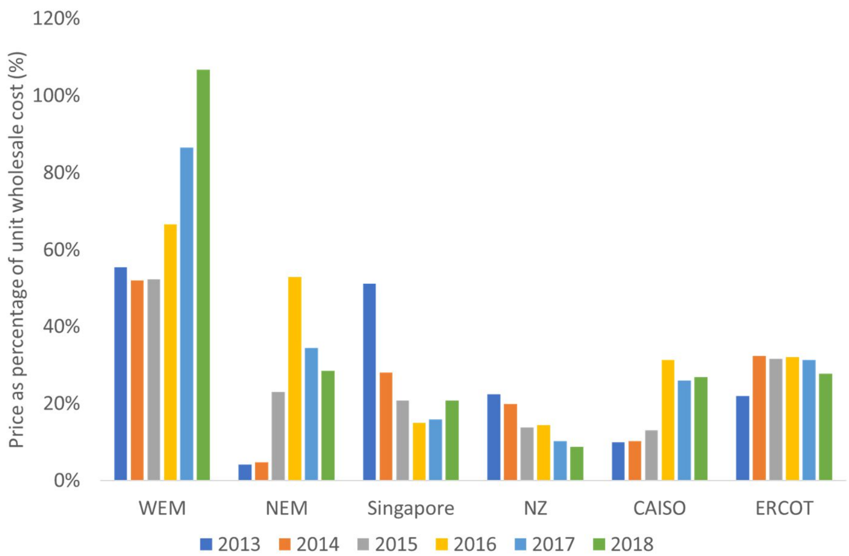


Figure 65: Regulation Up Price as percentage of wholesale unit cost

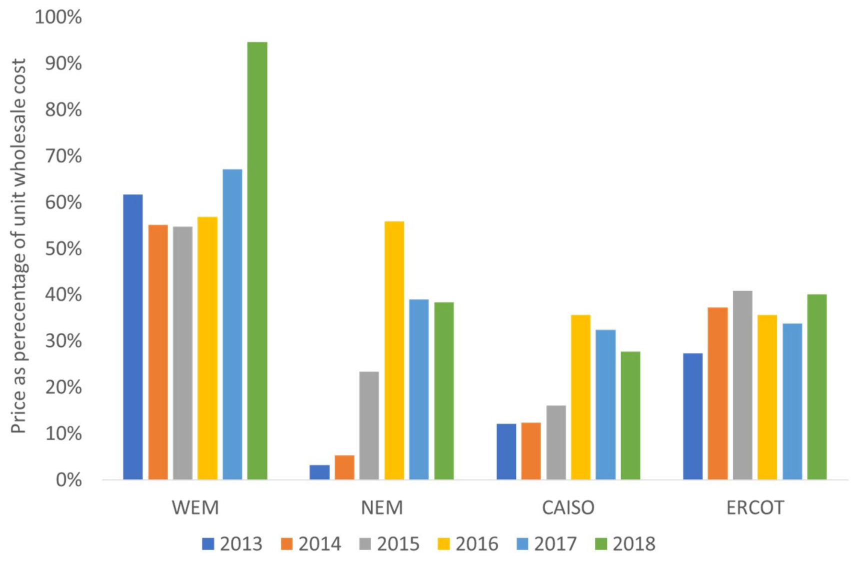


Figure 66: Regulation Down Price as percentage of wholesale unit cost

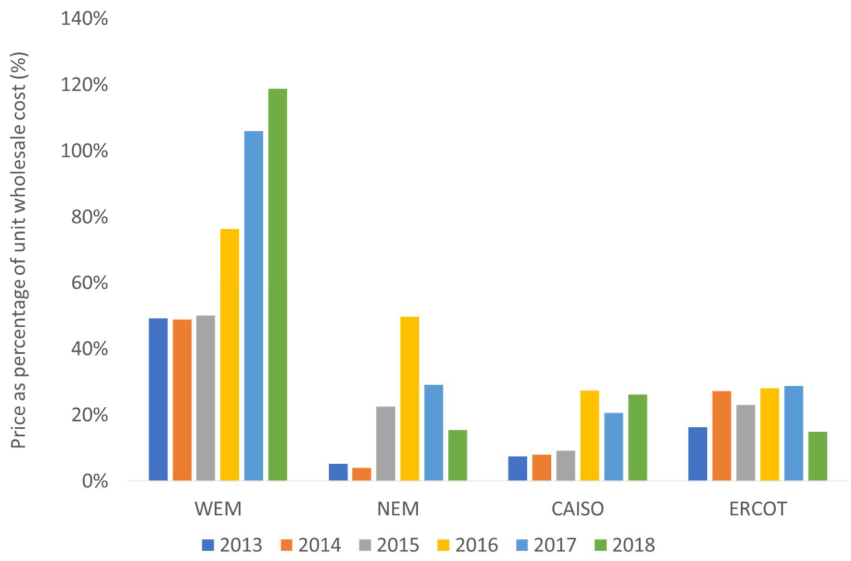


Figure 67: Contingency Raise Price as percentage of wholesale unit cost

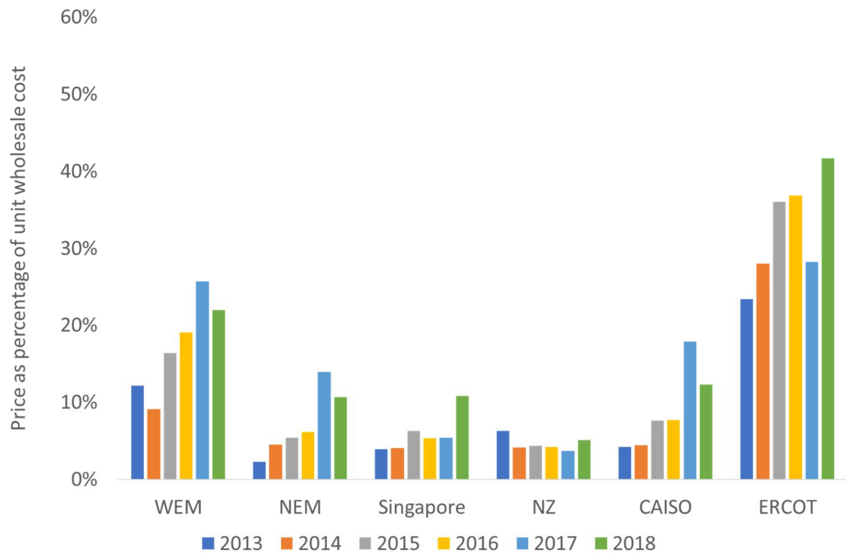


Figure 68: Regulation Up + Contingency Raise Price as percentage of wholesale unit cost

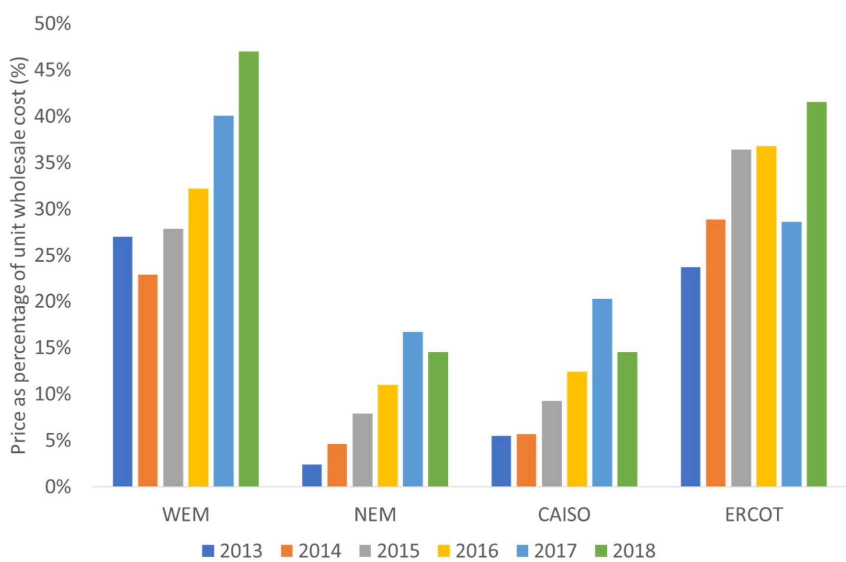


Figure 69: Contingency Lower Price as percentage of wholesale unit cost