THE LANTAU GROUP

Comparable Costs of Operating Electricity Markets in Different Jurisdictions

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The purpose of this report is to assist the ERA in their revenue determination by examining the costs of operating electricity markets in different jurisdictions and comparing them to the historical costs and those costs proposed by AEMO for the Western Australian Market. This analysis uses publicly available information from several jurisdictions to analyse overall market operation costs; costs split by function; and cost drivers; and to understand the roles and functions of employees in other jurisdictions to assess the impact of scale efficiencies and resourcing strategies.

The scope of this report reinforces and extends upon a previous report issued in 2019, which looked at the fifth allowable revenue process or AR5.[1]

In December 2021, AEMO provided market participants with an indicative view of its forecast expenditure and the resulting market fees for AR6. The final AEMO expenditure requirement and market fees are to be published and communicated to market participants after the ERA publishes an issues paper and formally commences public consultation.

1.2. OVERALL RESULTS

We collected data and information for this study from eight markets, including WA, spanning ten different market and system operators, as set out in Table 1. Where possible we separated out the role of market operator and system operator. In some cases, these roles were performed by independent companies and in others the two roles were not separately reported. The markets studied were selected based on similarities to Western Australia and based on the availability of relevant public data. However, Western Australia is not directly comparable to any other market due to its specific and unique design, functions, size, and the timing and direction of impending reforms. Nonetheless, the comparison to other jurisdictions is useful in demonstrating the costs of performing similar duties and to help in understanding what is driving the costs in these jurisdictions.

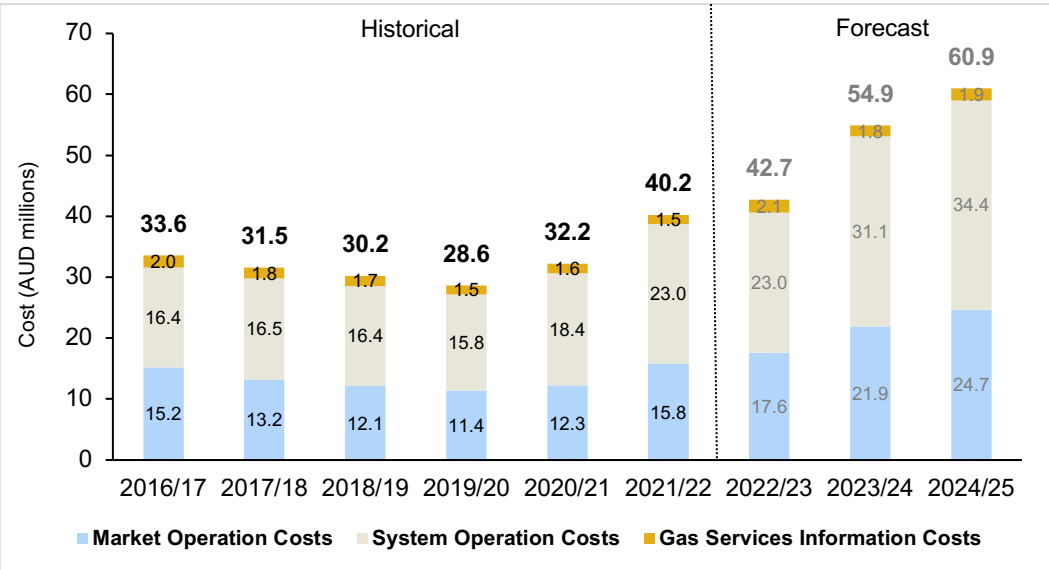
1 The Lantau Group, 2019, "Comparable Costs of Operating Electricity Markets in Different Jurisdictions".

Table 1: Markets Studied

Market	Market Operator	System Operator
Australia, WEM (WA)	AEMO WA	AEMO WA
Australia, NEM (ACT, NSW, QLD, SA, TAS, VIC)	AEMO NEM	AEMO NEM
Singapore	EMC (Energy Market Company)	EMA PSO (Energy Market Authority, Power System Operator Division)
New Zealand	NZX	Transpower
UK	Exelon	Not included in study
Korea	KPX	
USA (DE, IL, IN, KY, MD, MI, NC, NJ, OH, PA, TN, VA, WV + DC)	PJM[2]	
USA (CT, MA, ME, NH, RI, VT)	ISO New England	

Figure 1 shows that consolidated annual AEMO WA operational costs are expected to almost double from FY 2020/21 to FY 2024/25.

Figure 1: Trend in AEMO WA Market and System Operations Costs (AUD millions)

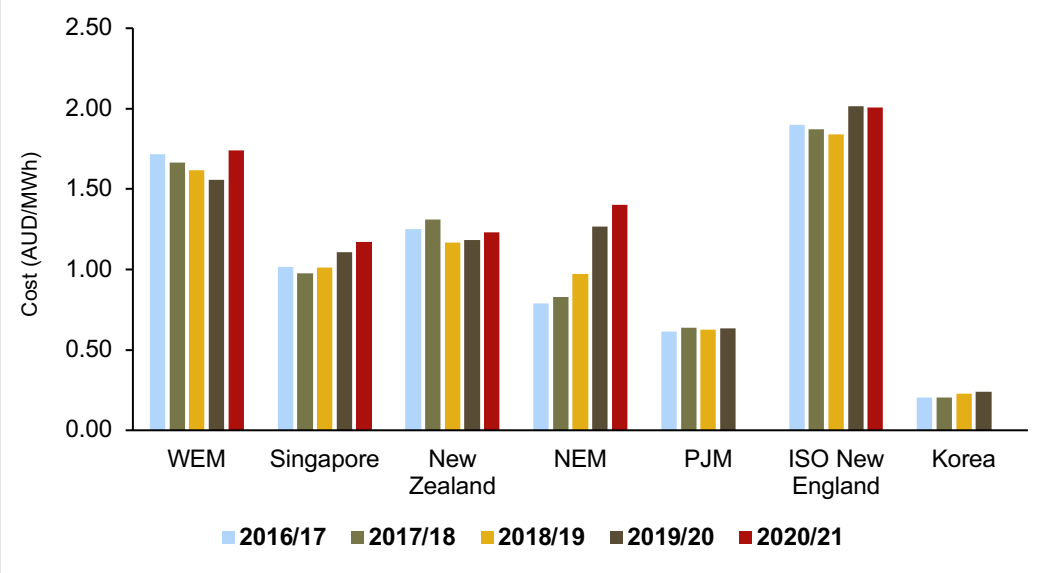


Source: Current/Forecast Data - AEMO AR6 Financial Templates – Final Submission (No Links); Historical Data - AEMO AR5 Allowable Revenue Data.

2 The initial "PJM" originally stood for Pennsylvania, New Jersey, and Maryland, the three original state participants in a near century old power pool. Many more US states now participate in PJM, and the old power pool has evolved into a competitive wholesale electricity market. The PJM Interconnection is the largest electricity wholesale market in the US, and one of the largest in the world.

Figure 2 shows that AEMO WA's costs are higher than almost all other jurisdictions on a megawatt-hours of consumption basis, with the exception being ISO New England in the United States.

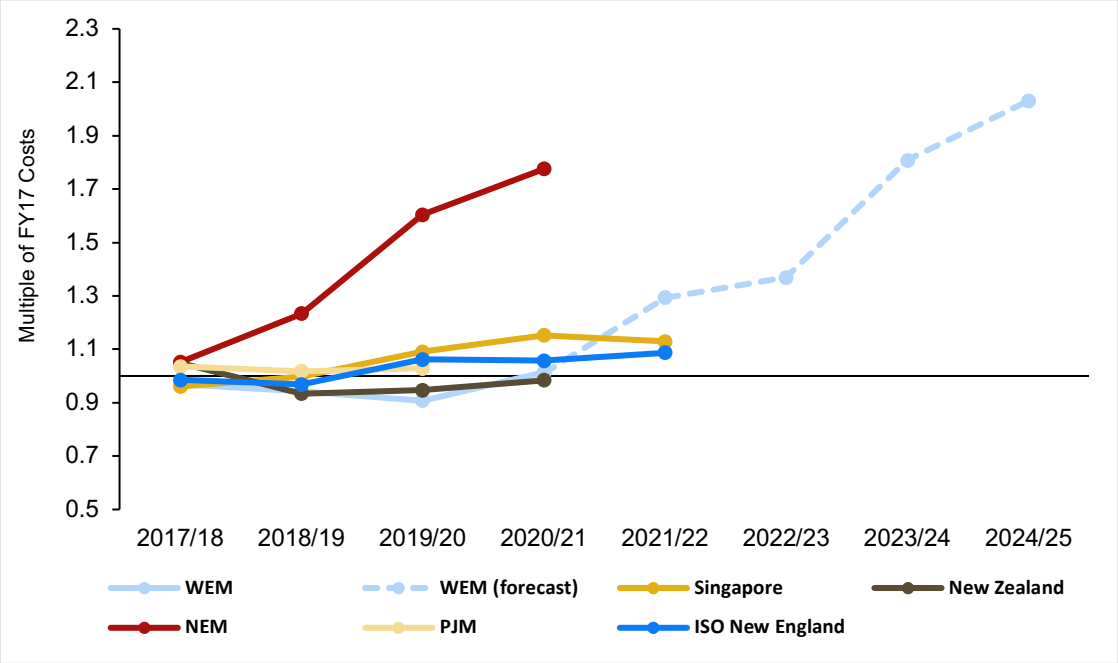
Figure 2: Comparison of Costs per MWh (in AUD) of Combined Market and System Operations



Source: Publicly available annual report data adjusted to Australian Dollars

Figure 3 provides an overall comparison of cost efficiency over time by totalling the yearly annual market and system operation costs and dividing by the yearly consumption for that jurisdiction. These figures are normalised to 2016/17 (i.e., expressed as a ratio wherein 2016/17 is set equal to 1), the earliest year of the dataset. This shows the percent change in costs compared to the benchmark year. AEMO WA's costs are forecast to grow far above FY 2016/17 levels, reaching 2.03 times this level by FY 2024/25. Growth of this kind has not been common when looking at other jurisdictions, except AEMO NEM, which has completed significant market reforms since FY 2016/17.

Figure 3: Total Cost per MWh of Combined Market and System Operations (Normalised)



Source: Public Data, TLG analysis

Note: The values demonstrated above are calculated by dividing the total market and system operator cost by the total system demand. These values differ from the market fees, which also include the costs for ERA.

1.3. COMPLEXITY

We consider complexity to be an important facet of the comparison across jurisdictions. The resources and therefore costs of market operation and system management are related to how complex these functions are to carry out on a day-to-day basis for the operational staff.

In Figure 4, using a qualitative assessment of each jurisdiction we have assigned a rating of market operations complexity that could plausibly influence costs (beyond pure scale effects).

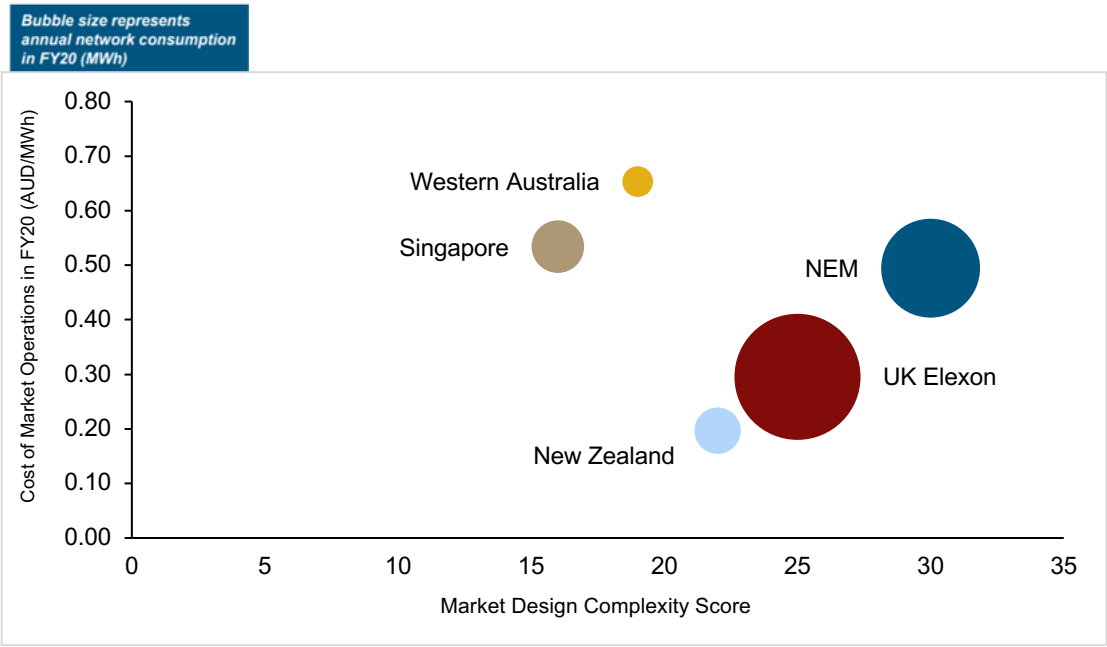
Note that these ratings are subjective and are in no way definitive, however we do believe that overall they (more or less) capture the relative complexity of each market.

The full market operations complexity rating criteria (e.g. number of stakeholders and level of commercial participation and trading) are listed in Table 9.

This process was repeated for system operations complexity, with different criteria such as network constraints and rooftop solar penetration. The full criteria are listed in Table 14.

The results are presented here in Figure 5.

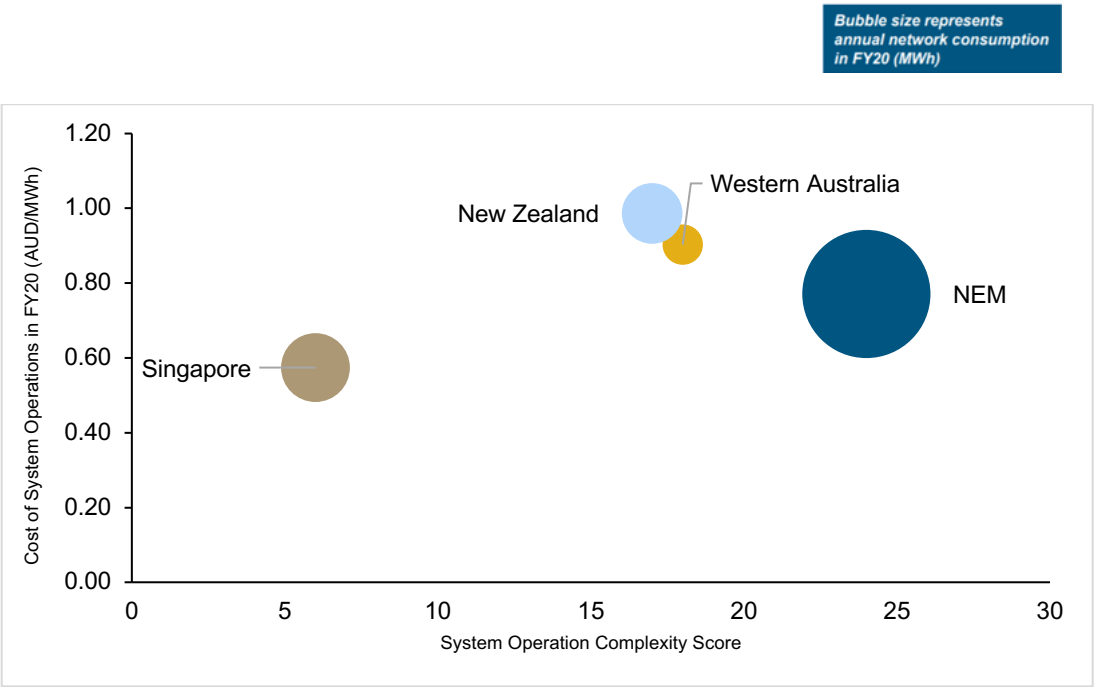
Figure 4: Cost of market operations as a function of market design complexity and annual network consumption in FY2020



Source: Public Data, TLG analysis

Figure 4 indicates that whilst the WEM has low annual network consumption and rates quite low on market design complexity, its cost of market operations in FY20 was greater than all of the other jurisdictions considered.

Figure 5: Cost of system operations as a function of system operation complexity and annual network consumption in FY2020



Source: Public Data, TLG analysis

Figure 5 indicates that whilst the WEM has low annual network consumption, it rates quite high on system operation complexity and system operation costs in FY20, when compared to the three other jurisdictions.

2. INTRODUCTION

2.1. OVERVIEW

The Wholesale Electricity Market (WEM) rules set out the allowable revenue process for Australian Energy Market Operator (AEMO) in Western Australia (WA). Every three years AEMO is required to make a submission to the Economic Regulation Authority (ERA) with a forecast of expenditures. AEMO WA is currently in the process of their sixth allowable revenue process (AR6).

The WEM rules allow AEMO to recover the costs of providing the following services in WA:

- Providing the WEM with market and system management services, as set out in clause 2.22.A.1 of the WEM Rules.
- Providing the Gas Services Information (GSI) services, as set out in rule 107 of the GSI Rules, which includes the Gas Bulletin Board and other information services provided by AEMO to gas market participants.
- Facilitating implementation of the WA Government's WEM reforms including constrained network access reforms, and undertaking any activities in support of reforms as outlined in clauses 1.20.1 and 1.20.2 of the WEM Rules.

For the Market Operations, System Management and Gas Services Information, allowable revenue typically includes the following cost categories:

- Employee benefits and expenses;
- Accommodation;
- Supplies and services;
- IT and telecommunications costs;
- Borrowing costs; and
- Depreciation and amortisation.

The requirement on AEMO to facilitate implementation of WEM reforms is a recent addition to AEMO's allowable revenue services.

2.2. SCOPE

The ERA engaged The Lantau Group (TLG) to undertake research and provide advice on the costs of operating electricity markets in different jurisdictions and to compare these costs to those proposed by AEMO for the Western Australian Market.

In particular, the ERA requested information concerning:

- The high-level range of costs of operating electricity markets in different jurisdictions, including system management;

- Understanding why the costs to perform similar functions differ across jurisdictions and what are the main drivers for costs in different jurisdictions;
- Comparisons of the costs of common market operation activities in different jurisdictions; and
- Understanding the roles and functions of employees in other jurisdictions to assess the impact of scale efficiencies and resourcing strategies.

We gathered publicly available information from several different markets to develop a clearer understanding of costs and how to compare them given the significant inter-market differences in market design, operation and evolution.

2.3. CHANGES TO SCOPE SINCE 2019

TLG completed a similar engagement for the ERA in 2019.[3] The scope for this engagement is relatively unchanged from the 2019 edition of the benchmarking report. There are no significant changes to the underlying sources of data. However, additional reported years of data serve to extend the length of the data set, allowing us to compare both longer-term cost trends across jurisdictions, alongside comparisons of current costs.

The markets studied are largely the same as in 2019, except for Ireland (SEMO) being replaced by ISO New England in the United States. SEMO was excluded due to a lack of comparable data being available, while ISO New England was added to the comparison set at the request of the ERA.

Although data from 2019 and earlier is unchanged, reported costs may have changed from the 2019 Benchmark report, since we have used a common set of exchange rates (13 January 2022) to convert all reported costs into Australian dollars. All cost figures are in nominal Australian dollars.

2.4. MARKETS COMPARED

We analysed eight markets including WA, spanning ten different market and system operators, as set out in Table 2. Where possible we separated out the roles of market operator and system operator. In some cases, these roles were performed by independent companies and in others the two roles were not separately reported.

Table 2 indicates that there was not sufficient data available to separate out the roles of system and market operator.

3 The Lantau Group, 2019, "Comparable Costs of Operating Electricity Markets in Different Jurisdictions".

Table 2: Markets Studied

Market	Market Operator	System Operator
Australia, WEM (WA)	AEMO WA	AEMO WA
Australia, NEM (ACT, NSW, QLD, SA, TAS, VIC)	AEMO NEM	AEMO NEM
Singapore	EMC (Energy Market Company)	EMA PSO (Energy Market Authority, Power System Operator Division)
New Zealand	NZX	Transpower
UK	Exelon	Not included in study
Korea	KPX	
USA (DE, IL, IN, KY, MD, MI, NC, NJ, OH, PA, TN, VA, WV + D.C.)	PJM	
USA (CT, MA, ME, NH, RI, VT)	ISO New England	

The markets studied were selected based on similarities to Western Australia and due to the availability of public data. However, Western Australia isn't directly comparable to most other markets due to its specific and unique design, functions, size and the timing and direction of impending reforms.

Singapore and New Zealand do resemble WA as mostly islanded systems, while New Zealand further exhibits the lower customer density and narrow transmission networks, which are core features of the WEM. Ideally, we would have also included a small, isolated system (for example, Hawaii, which was previously considered in the 2019 edition) to improve our understanding of the effects of scale and isolation has on costs. For this report, a concerted effort was again made to include Hawaii in the scope of analysis. However, there was a lack of reliable cost numbers, and the market design context is very different.

The comparison to other jurisdictions is useful in demonstrating the costs of performing similar duties and to help in understanding what's driving the costs in these jurisdictions.

2.5. APPROACH

Benchmarking aims to inform views on the credibility of costs and the potential for realising cost savings, based on comparisons with others who perform similar functions. The essence of benchmarking is to develop comparisons that are as close to "apples-to-apples" as possible, either through judicious screening and curation or through quantitative or qualitative adjustments for differences in key situational factors and underlying cost drivers. In the case of comparing the cost of market and system operations across countries or markets, a fully quantitative adjustment focussing on underlying differences in cost drivers is not possible given currently available public information.

Accordingly, we have undertaken this research in two ways:

- Comparison at a high level of AEMO's operations in WA against eligible markets utilising publicly available information; and
- Drilling down, where possible, on markets (and functions within markets) that appear most relevant in comparison to WA, with the intent to refine high-level comparisons and increase available insight.

Published information varies widely across other jurisdictions, with some, like New Zealand, being highly transparent, and others, like Singapore, being much less so. Additionally, the differences in market design, market complexity, grid complexity, scale of operations and the institutional structuring of the organisations, makes direct comparisons with WA challenging. We have thus drawn on our experience and discussions with local experts in these different markets to draw out relevant comparisons and lessons.

We have updated this final report to reflect the latest proposed operations cost estimates from AEMO as of May 2022, in response to the draft determination made by the ERA.

2.6. LIMITATIONS

2.6.1. Purchasing Power

Table 3 shows the cost of a representative bundle of consumer goods and services across the benchmarked markets, normalised so that the cost in Australia is AUD 100. A similar product would be cheaper in the UK for example, costing only AUD 93.

Table 3: Purchasing Power Parity

Jurisdiction	PPP in 2021 (AUD = 100)	Currency
Australia (WEM and NEM))	100	AUD
UK (Elexon)	93	GBP
New Zealand (NZX and Transpower)	97	NZD
Singapore (EMA and EMC)	84	SGD
USA (PJM and ISO New England)	91	USD

Source: OECD Stats; https://stats.oecd.org/Index.aspx? DataSetCode=CPL

All benchmarked costs are reported in nominal Australian dollars, where currency conversions are made using the market rate available on 09 January 2022. No adjustments for possible differences in purchasing power have been made.

2.6.2. Data Constraints

In all market analyses we are restricted to publicly available data. Reporting requirements differ across jurisdictions, with variances in the interpretation, aggregation and types of data that are publicly disclosed. We have relied on expert judgement and conversations with market and system operators to make a best judgement in how to make suitable comparisons across markets. Where comparisons have not been suitable, or would rely on unverified assumptions, we have omitted that data. For example, in jurisdictions where system and market operator costs are jointly disclosed, we have not tried to disaggregate these costs ourselves.

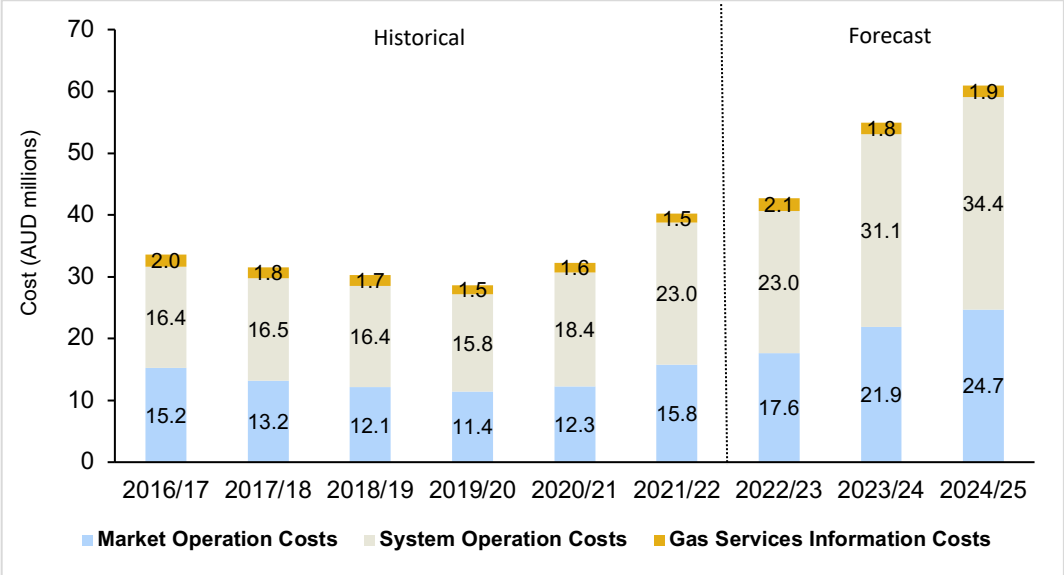
We also highlight the following additional complications and caveats with data:

- Misalignment of financial years across markets.
- Different treatment of line items and inconsistent accounting methods across markets.
- Currency conversion to AUD uses a single exchange rate, which can distort trends over time.
- Purchasing power parity relative to (Western) Australia also varies across markets and across time.
- FY17 is used as a baseline in many cases although there could have been abnormally low or high expenses for any operator.

2.7. AEMO WA Overview

Figure 6 shows AEMO's actual total costs incurred for the period 2016/17 through to 2020/21, along with proposed annual costs through to 2024/25, the end of AR6. While costs have been stable over the last six years, costs are forecast to grow rapidly, with costs in 2024/25 projected to be almost double those of 2020/21. The growth in total costs is driven by large increases in both WEM market and system operations budget forecasts, while gas services information costs will continue to be a negligible share of total operating costs for AEMO in WA.

Figure 6: Trend in AEMO WA Market and System Operations Costs



Source: Current/Forecast Data - AEMO AR6 Financial Templates – Final Submission (No Links); Historical Data - AEMO AR5 Allowable Revenue Data.

TLG benchmarked the most recently available data using actual costs for 2018/19, 2019/20 and 2020/21 and 2021/22 (interim). Forecasted costs were used for the years 2022/23, 2023/24 and 2024/25.

Comparing historic to forward looking costs for AEMO WA also forms part of the assessment of market operations and system management expenditure.

2.8. COST DECOMPOSITION

As shown in Figure 7, the data are sorted into AEMO WA's three major operational roles:

- Market Operations;
- System Management; and
- Gas Services Information.

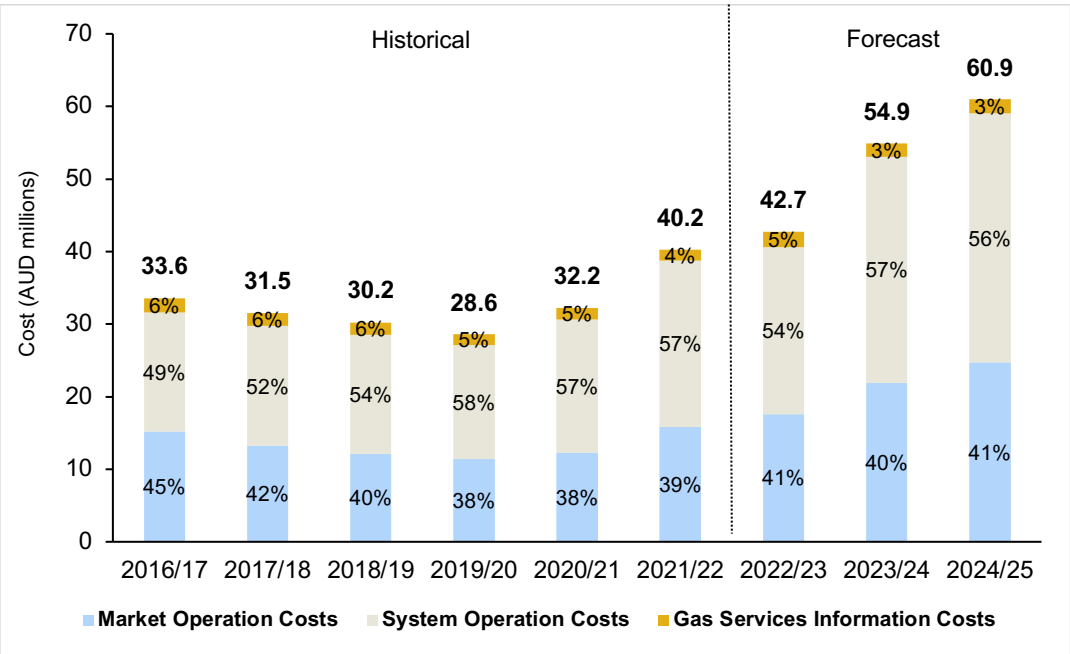
The total cost for each of the three operational roles comprises of five expense categories:

- Employees Benefit Expense;
- Borrowing Costs;
- Accommodation Costs;
- Depreciation;
- Supplies and Services; and
- IT and Telecoms.

The most noticeable trend was the ongoing decline in costs attributable to WA AEMO's Market Operations role. These costs were 45% of overall operational costs in 2016/17 but they had reduced to 38% of overall operational costs by 2020/21. Costs for the other two main roles: System Management and Gas Services Information, remained steady up to 2020/21. However, the forecast shows steep increases in Market Operations and System Management costs, increasing in step, such that the percentage share of total annual operational costs is largely unchanged from 2020/21 to 2024/25.

Overall, total costs declined slightly from AUD $33.6 million in 2016/17 to AUD $32.2 million in 2020/21. However, costs have increased in each of the last two years. The forecast is for significant cost increases in two of the next three years, rising to AUD $60.9 million by 2024/25.

Figure 7: AEMO WA Historical and Forecast Costs Split by Operational Role

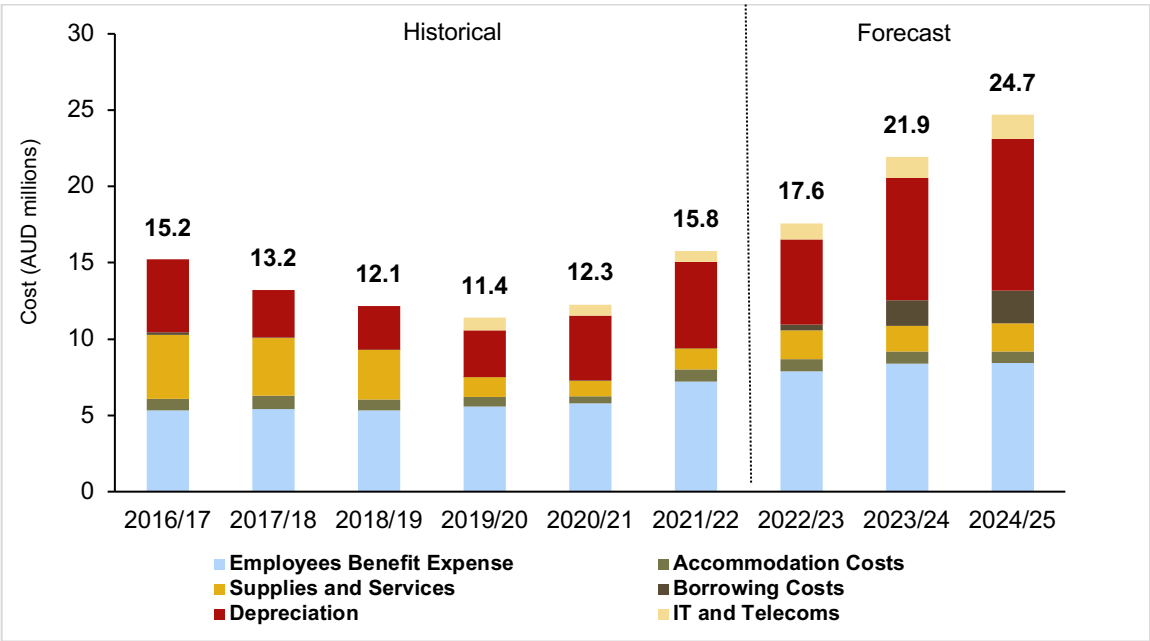


Source: Current/Forecast Data - AEMO AR6 Financial Templates – Final Submission (No Links); Historical Data - AEMO AR5 Allowable Revenue Data.

We further broke down these costs by expense category to identify generally where the cost increases stemmed from over time for AEMO's WA market and system operations.

Figure 8 shows that market operations costs are projected to increase 101% from 2020/21 to 2024/25. Depreciation accounts for the largest component of cost growth, increasing from AUD $4.3 million to AUD $9.9 million. Notably, employee benefit expenses increase from AUD $5.8 million to AUD $8.4 million but decrease from 47% to 34% as a share of the total.

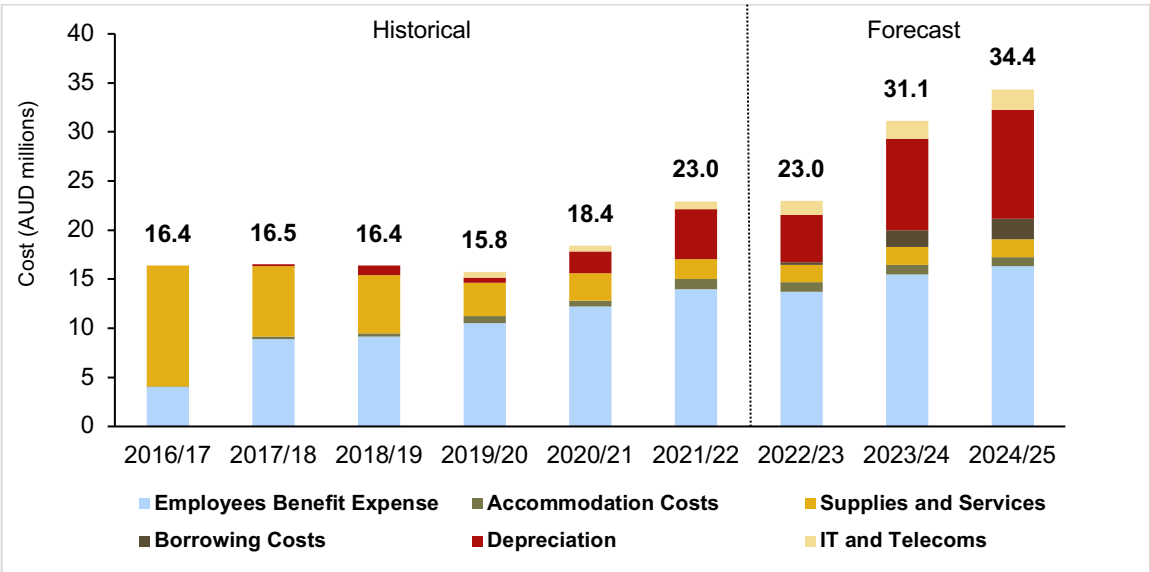
Figure 8: Cost Breakdown by Category AEMO WA (Market Operations)



Source: Current/Forecast Data - AEMO AR6 Financial Templates – Final Submission (No Links); Historical Data - AEMO AR5 Allowable Revenue Data.

Figure 9 demonstrates that system management costs are projected to increase 87% from 2020/21 to 2024/25. Employees Benefit Expense, Depreciation and IT and Telecoms all show significant growth in this period. Depreciation alone increases from AUD $2.2 million to AUD $11.1 million, contributing half of the cost growth to 2024/25.

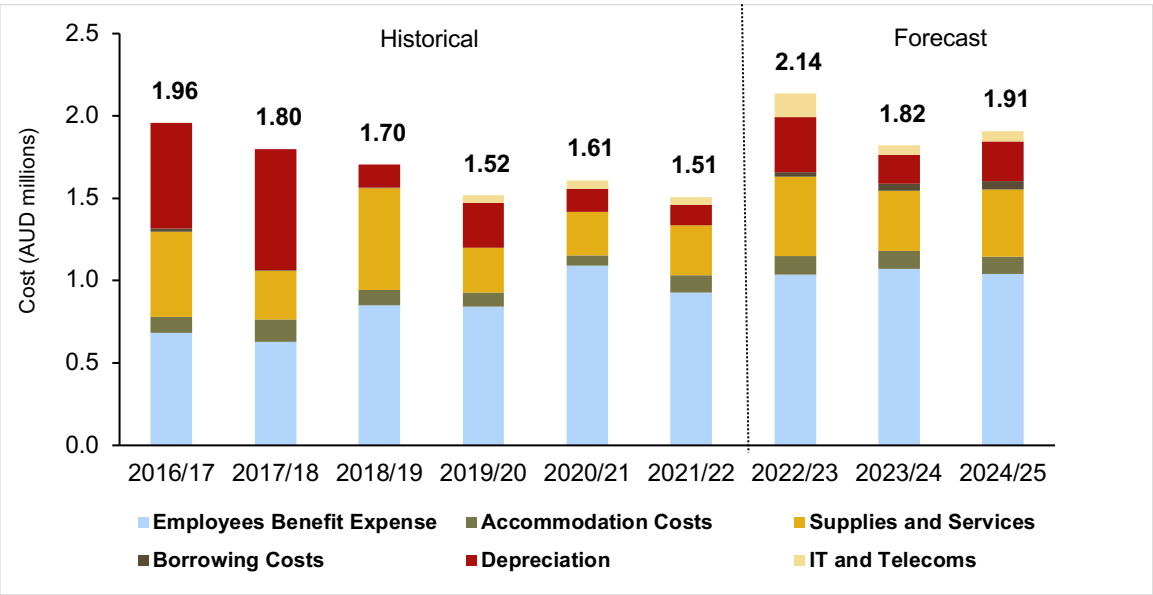
Figure 9: Cost Breakdown by Category AEMO WA (System Management)



Source: Current/Forecast Data - AEMO AR6 Financial Templates – Final Submission (No Links); Historical Data - AEMO AR5 Allowable Revenue Data.

Figure 10 shows that gas services information costs are projected to increase 19% from 2020/21 to 2024/25. Total costs at this point will remain AUD $50k lower than 2016/17. For depreciation, note the opposite trend to the market and system functions, a decrease from AUD $640k in 2016/17 to a low of AUD $120k in 2021/22 before increasing again to AUD $240k in 2024/25.

Figure 10: Cost Breakdown by Category AEMO WA (Gas Services Information)

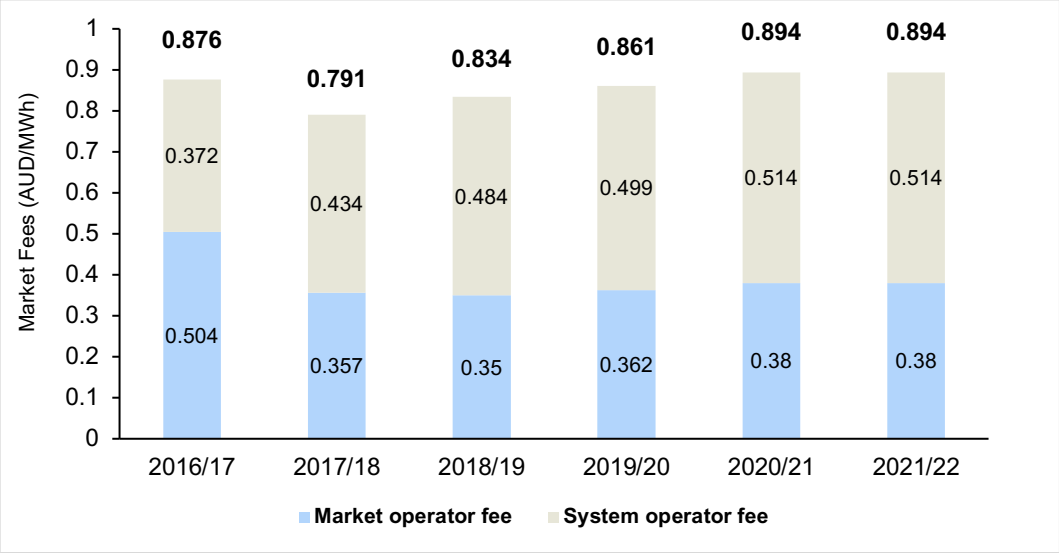


Source: Current/Forecast Data - AEMO AR6 Financial Templates – Final Submission (No Links); Historical Data - AEMO AR5 Allowable Revenue Data.

We discuss all the major cost increases for market and system operation in Section 4 and Section 5 respectively. We do not further investigate Gas Information Services due to its relatively small share of costs overall and the far lower cost increase compared to other operational roles.

Figure 11 shows that market fees have remained more or less steady in the WEM and were unchanged between 2020/21 and 2021/22. The system operator fee is somewhat higher than the market operator fee, mirroring the difference in the share of total costs.

Figure 11: Historical WEM Market Fees for Market and System Operator Functions ($/MWh)



Source: AEMO Western Australia Wholesale Electricity Market AEMO Budget and Fees (2016/17, 2018/19, 2020/21).

2.9. OPERATIONAL HEADCOUNT

From the data AEMO provided the ERA, we were able to summarise the full-time employee count allocated to each operational role, detailed in Table 4. Headcount increased significantly in percentage terms for the Gas Services Information function, however the absolute numbers are probably too small to infer meaningful trends from the resulting percentage changes alone. In future iterations of the benchmarking analysis, it would be useful to have data available to map increased headcounts to new roles, services, or performance requirements.

Table 4: AEMO WA Operational Head Count*

FTE Count	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	Change (from 2016/17 to 2021/22)	Change in FTE (from 2016/17 to 2021/22)
MO	14.7	16.8	17.3	16.4	18.3	19.7	24.7	29.8	31.6	+34%	+5.0
GSI	1.7	2.8	3.6	3.3	2.7	2.7	2.7	2.7	2.7	+59%	+1.0
SM	29.6	35.0	37.6	32.1	35.6	38.5	40.3	48.0	51.2	+30%	+8.9
Total	46.0	54.6	58.5	51.8	56.6	60.9	67.7	80.5	85.5	+32%	+14.9

Source: ERA Data; AEMO AR6 Proposal – WA Labour Supporting Document

*The AEMO WA reporting method for employee count is aligned to be consistent with documented planning for AR5 (2019/20-2021/22), with only WEM-facing employees included rather than both WEM and NEM-facing employees based in WA as was the case in AR4 (2016/17-2018/19). Hence, the FTE counts stated for AR4 are noticeably lower than the 2019 report. MO = market operations; GSI = gas services information; SM = system management

2.10. AEMO COMMENTS ON BENCHMARKING COMPARISON

In AEMO's response to ERA's draft determination, AEMO provided commentary on the benchmarking of their operational costs compared to other jurisdictions. Generally, we agree with AEMO's feedback however, we think it's useful to provide additional context to our draft report.

Comparing AEMO's costs to other markets is tricky since no other market, or system, or market operator's responsibilities is the same. Each jurisdiction faces unique challenges, and each jurisdiction has unique differences in possible responses to these challenges. New Zealand's capacity mix is vastly different to WA, and New Zealand does have the benefit of large amounts of hydro storage/generation, which may make operating the system '*easier'* (or make the challenge of operating the system less susceptible to change) than operating the WA system with its large volume of intermittent capacity and the rapid rate at which intermittent capacity has been added to the system. On the other hand, New Zealand has its own unique challenge of operating an energy system that relies on adequate sources of water and has experienced periods of prolonged water scarcity due to weather. Likewise, the operation of the energy market in New Zealand is different, with New Zealand having a nodal market, making some aspects of market and system operations more complex, and perhaps other aspects simpler, than WA's single node energy market. Importantly, though these challenges in New Zealand have largely remained the same for decades. The shift to increasing renewable energy has been slower in New Zealand, at least in part due to the lower quality irradiance, limiting the viability of wider-scale solar development.

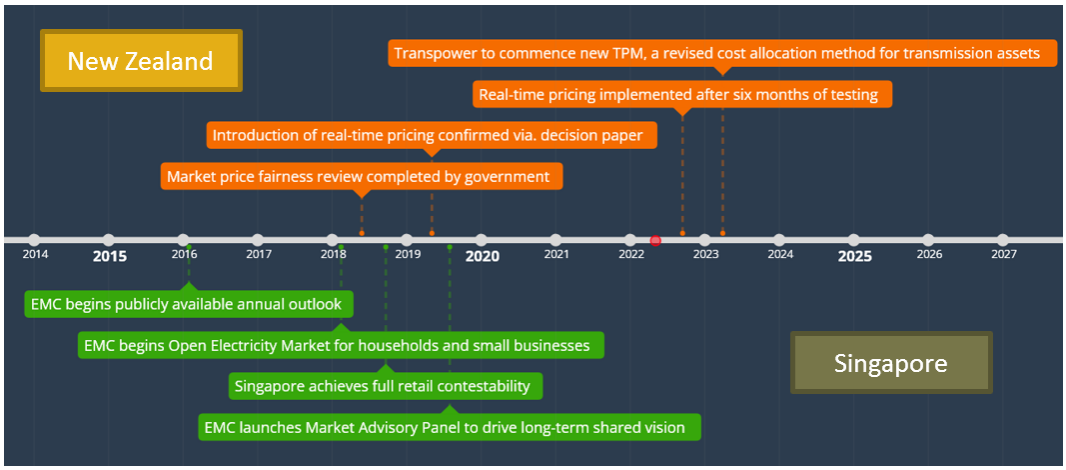
Even given differences amongst the markets, comparing the cost of each market on a dollar per megawatt hour remains the most informative available basis for comparison. The most basic purpose of the system and market operator is to facilitate the delivery of electricity to customers. Looking at the operational cost on a megawatt hour basis shows the cost of delivering this most basic function. We can then consider other factors to contextualise AEMO's point on the smaller scale of WA's overall operations.

In their response AEMO made the following point:

AEMO acknowledges Lantau's findings on the relative complexity of the new WEM compared to overseas, but highlights that it is the change in complexity between the existing arrangements and new WEM that drives risk and the need for additional resources, rather than the degree of complexity itself. This is particularly relevant in the short-to-medium term. [4]

The international jurisdictions studied in the benchmarking also experienced changes that introduced complexity into their markets. Some notable changes that occurred in New Zealand and Singapore are shown in Figure 12.

Figure 12: Changes in the New Zealand and Singapore markets between 2016 and 2023



However, many of the reform elements that AEMO is seeking funding for are already features in the compared markets and therefore, the rate of change isn't demonstrated in their corresponding costs. AEMO's comment would indicate that AEMO's subsequent operational costs should be markedly lower and more in line with their international counterparts once the AR6 funded reforms are implemented.

4 Response to the ERA's AR6 Draft Determination AEMO 2022 page 8

3. BENCHMARKING AGAINST COMBINED MARKET AND SYSTEM OPERATORS MORE GENERALLY

3.1. OVERVIEW

AEMO in WA includes both market operations and system management, as does AEMO in the National Electricity Market (NEM). In this section, we expand the comparisons to include several other markets, namely:

- **AEMO WA** and **AEMO NEM**;
- **PJM** – one the largest and most sophisticated markets;
- **ISO New England** – a large but geographically concentrated market;
- **New Zealand** – for comparison we combine the costs of NZX market operations and Transpower's system operations;
- **Singapore** – for comparison, we combine the costs of EMC's market operations and the EMA's PSO division's system operations; and
- **Korea** – the Korea Power Exchange (KPX) is similarly structured to AEMO WA, AEMO NEM and PJM.

In subsequent sections, we benchmark AEMO's WA market operations and system operations costs separately.

3.2. MARKET SUMMARIES

No other market is structured or has fully equivalent roles and responsibilities as AEMO WA. Table 5 gives an overview of the different jurisdictions, their operational structure, and information about the network and underlying geography.

Table 5: Summary of Jurisdictional Structures

Jurisdiction	Separate or Combined MO and SO	Single or Multi-Jurisdictional	Transmission Length (km)	Jurisdictional Area (km^2)	Annual Consumption (TWh)
Australia, WEM	Combined, but disaggregated	Single	~8,000	~260,000	17.63
Australia, NEM	Combined, but disaggregated	Multi	~40,000	~1,700,000	178.03
UK Elexon	Separate	Single	~7,200	~240,000	290.44
New Zealand	Separate	Single	~10,000	~270,000	39.84
Singapore	Separate	Single	~1,000	~700	51.33
Korea	Combined	Single	~25,000	~100,000	514.51

Jurisdiction	Separate or Combined MO and SO	Single or Multi-Jurisdictional	Transmission Length (km)	Jurisdictional Area (km^2)	Annual Consumption (TWh)
USA, PJM	Combined	Multi	~135,000	~540,000	789.24
USA, New England	Combined	Multi	~13,000	~180,000	140.84

Source: Public data, TLG analysis

Note: Table 8 provides a further summary of market operation features and relative complexity

3.2.1. National Energy Market (NEM)

Alongside the WEM, AEMO manages the NEM, which serves the eastern and south-eastern sections of Australia from the state of Queensland in the north through New South Wales (NSW), Victoria and South Australia and the island state of Tasmania via a HVDC cable in the south. The Australian Capital Territory sits within NSW and is part of the NEM.

The NEM was introduced in 1998, initially involving New South Wales, Victoria, and South Australia. Queensland joined in 1999 and Tasmania in 2005. The NEM is a zonal or regional energy-only market (with no separate payment for capacity as exists in many international markets). AEMO was established in July 2009 to assume market operation and system management of the NEM, while also assigned to operate Australia's gas markets. Today, AEMO supports extensive external financial risk management instruments and significant vertical integration of generation with retailing, which serves to hedge the inherent risks of the spot market. The boundaries of the spot market regions align closely with the jurisdictional boundaries of the participating states. Network, generation, and retailer ownership within the NEM is a mix of private and public entities, with some states fully privatised and others retaining significant public ownership.

3.2.2. PJM Interconnection

The PJM Interconnection (PJM) in the United States started about a century ago as one of the first formal power pools supporting electricity trading across multiple independent regulated monopoly utilities. Just over twenty years ago, PJM evolved to become a regional transmission system operator and bid-based wholesale electricity market. PJM operates one of the most complex electricity markets in the world, with nodal energy pricing, ancillary services, regional capacity markets and financial transmission rights. Enhancing coordination between electricity and US gas markets has also become an increasing point of complexity and focus.

PJM is the largest electricity market in the United States. PJM has forty-six times higher electricity consumption than the WEM (four and a half times higher electricity consumption than the NEM) and has annual operational costs of around AUD 500 million (eighteen times higher than WEM and more than double the NEM).

PJM has complex jurisdictional accountabilities. PJM covers all or parts of the states of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia, as well as the federal region of Washington DC. Each state has its own regulatory commission. PJM also is accountable to the US Federal Energy Regulatory Commission (FERC), which oversees interchanged power flows across state boundaries.

PJM employs about 60 people (as compared to AEMO's approximately 20 in WA) in market operations associated roles, despite being approximately 46 times bigger (MWh basis), thus providing a useful indication of potential scale economies. PJM operates on a profit neutral basis; thus, total revenues and expenses must equal each other over the long term.[5] PJM is permitted to retain up to six percent of PJM's stated rate (fee) revenue as a financial reserve.

3.2.3. UK Elexon

Elexon is the market operator for the entire wholesale market in Great Britain (GB) and, as such, manages the operation of the Balancing and Settlement Code (BSC). The BSC is a set of rules to facilitate the balancing of supply and demand in the electricity market and applies to all market participants. Elexon employs 175 people in market operations on a budget of AUD 94 million, eight times higher than the WEM. Elexon's role is to:

- enable electricity to be traded bilaterally, and ahead of time, between willing buyers and sellers in an open and competitive wholesale market (outside the BSC);
- ensure that total electricity generation and demand are balanced in real time, through a Balancing Mechanism operated by National Grid, as the GB Transmission System Operator; and
- establish any differences ('imbalances') between the amounts of electricity that are traded and the actual electricity that is generated/consumed, and ensure that these are paid for, through a post-event imbalance settlement process operated by Elexon.

Elexon was established in mid-2000 ahead of the commencement of the New Electricity Trading Arrangements (NETA). The Balancing and Settlement Code introduced as part of NETA originally covered England and Wales and then was subsequently extended to Scotland in April 2005 as the British Electricity Trading and Transmission Arrangements (BETTA).

5 PJM Learning Center. (2022). https://learn.pjm.com/who-is-pjm/how-does-pjm-make-money#:~:text=The%20simple%20answer%20is%20that,other%20over%20the%20long%20term.

3.2.4. New Zealand

Market Operations

New Zealand's regulator, the Electricity Authority (EA) contracts out the various services required in running an electricity market. The market operations budget for EA is approximately AUD 9 million, 25% lower than the WEM. This contracting process is competitive with contracts awarded for approximately five to eight-year terms, but these can be extended. New Zealand Exchange (NZX) is contracted to provide the majority of the services required in running an electricity market. New Zealand Exchange has been the market operator since 2009 through the acquisition of The Marketplace Company (M-co), which had been the market operator since the market commenced in 1996.

System Operations

As with market operations, the EA assigns the role of system operator through a competitive tendering process. Transpower is the system operator as well as the network owner. The system operation role is funded through an incremental and unavoidable cost approach. This means Transpower can only seek funding for the system operations role for costs that *uniquely* relate to that function. As an example, Transpower normally must deploy SCADA across its network in its role as network owner. It is therefore only the *incremental cost of SCADA used for system operations* that is charged to the system operator function.

3.2.5. Singapore

Market Operations

EMC is a privately owned, for-profit company that operates Singapore's energy market called the National Electricity Market of Singapore (NEMS). The EMC operates with 73 full-time equivalent employees and have a market operations budget of approximately AUD $30 million, two-and-a-half times the WEM. EMC's budget and fees are annually determined through a transparent process involving publishing a draft budget, inviting public and stakeholder feedback, providing project level budgets to the industry Rules Change Committee for comment, and formal budget submissions to the regulator the Energy Market Authority (EMA) for approval. Importantly, the EMA determines an overall price cap for a 5-year period and EMC's annual budget is effectively advice to the market on how this fee cap is being spent. The market operator's costs are recovered through nominal fixed fees and through a market fee levy.

System Operations

In Singapore the system operator is part of EMA, the regulatory body. This unusual arrangement was put in place at the time of industry restructuring as part of what was otherwise a comprehensive plan to open ownership of the sector to the private sector – including a contracted for-profit private sector market operator – without international ownership restrictions. The budget and fees of the system operator are governed by the market rules.

3.2.6. Korea

The Korea Power Exchange (KPX) is similarly structured to AEMO WEM, NEM and PJM in the sense that KPX is both the market and system operator. Today, it has 470 full-time equivalent employees and a market and system operations budget of AUD $125 million, about five times higher than the WEM. KPX was established in 2001 following reforms to move from a vertically integrated state-owned Korean Electric Power Corporation (KEPCO) into a privatized industry operating in a competitive power market. Korea generates around 515 terawatt-hours (TWh) of electricity annually, making it twenty-nine times larger than the WEM (around three times larger than the NEM).

Like the WEM, the Korean electricity market is cost-based and has a capacity payment arrangement. However, Korea's originally planned market reforms (including substantial industry privatisation) largely stalled in 2001. While there have been ongoing enhancements to systems and the market, the Korean market is not nearly as developed as the NEM or PJM. Its inclusion in the benchmarking aims to provide additional insight into the contribution of market design sophistication, number of stakeholders, and overall market structure, amongst other differentiating factors.

3.3. BENCHMARKING RESULTS

The markets compared vary widely from the largest (PJM), with around 800 terawatt hours of electricity sold each year, to the WEM, which is the smallest market by far and is less than half the size of the closest market, New Zealand. The sizes of each market in terms of annual grid consumption relative to the WEM are presented in Table 6.

Sales are stagnant or in decline across most jurisdictions in the last five years, which could be a combination of customers adopting off-grid solutions and ongoing efficiency gains to appliances. On the other hand, Singapore and PJM appear to have a slight upward trend in sales.

Table 6: Relative Size of Each Market (Annual Consumption in TWh)

	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Relative to WA (2020/2021)[6]
AEMO WA	18.4	17.9	17.6	17.4	17.6	-
AEMO NEM	184.5	184.6	184.0	181.2	178.0	**10x**
UK Elexon	307.8	306.8	304.6	294.7	N/A	**17x**
Singapore	49.1	50.0	51.1	51.2	51.3	**3x**
New Zealand	39.9	39.9	40.0	39.9	39.8	**2x**
Korea	520.9	537.1	529.9	516.0	N/A	**29x**
PJM	791.2	772.3	804.9	N/A	N/A	**46x**
ISO New England	139.6	144.1	141.5	136.0	N/A	**8x**

Source: Public data, TLG analysis

3.4. SCALE AND SCOPE SYNERGIES

AEMO assumed the role of the WA's energy market operator from 30 November 2015 and the role of WA's system operator from 1 July 2016. AEMO's total costs of market and system operations are bundled in the NEM but are separated in the WEM[7].

One could reasonably expect that the costs of integrating the WEM into AEMO have been expended by now and recent and future budgets should reflect the benefits of scale and scope economies arising from the merger. It is useful to bear in mind that mergers are often premised on synergies that are both difficult to estimate ex-ante and usually require some combination of time, effort, and investment to realise ex-post. McKinsey notes that "managers in about 60 percent of mergers deliver the planned cost synergies almost totally, in about a quarter of all cases they are overestimated by at least 25 percent." [8]

6 Rounded to integer values.

7 To disaggregate costs for the NEM into market operations and system management costs, the proportion of these costs in the overall WEM budget was calculated for each historic/current year and applied to split the total NEM budget cost.

8 https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/where-mergers-go-wrong

The difficulties in realising expected synergies do not lie merely in managers' efforts post-merger but also in the challenges associated with estimating prospective synergies in the first instance. These synergies are even more difficult to estimate over time when the world is also changing, which the energy world is clearly doing, as the counterfactual becomes more uncertain. Furthermore, any evidence of any efficiency benefits is confounded by the fact that the WEM is expected to adopt and implement (through new systems and processes) a number of significant wholesale market changes.

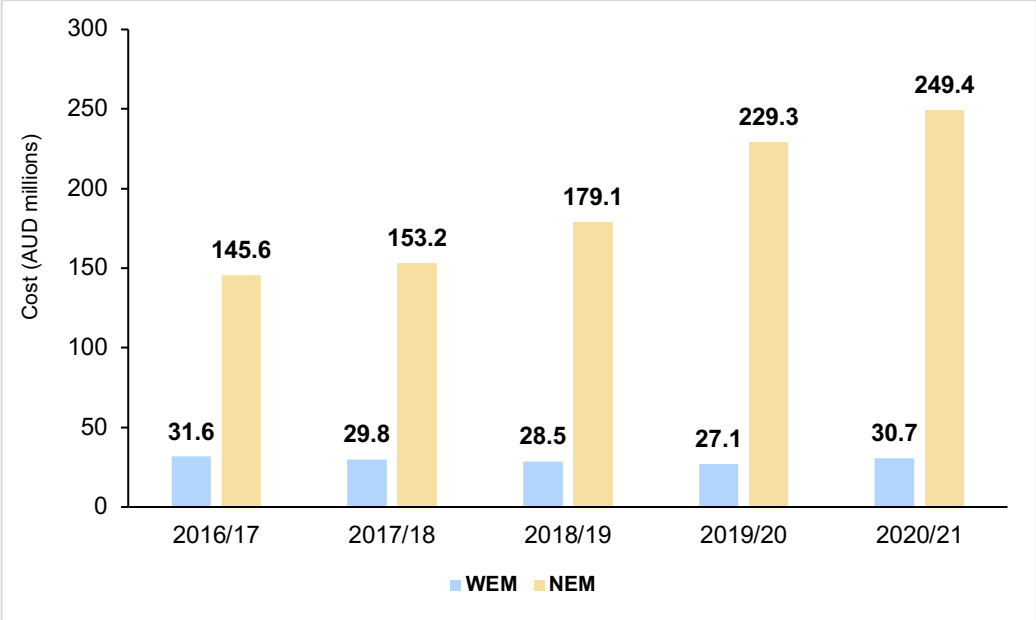
Given this dynamic complexity in underlying cost drivers, benchmarks fulfil a useful role in identifying focus areas for further review and highlighting unexpected or unusual trends. They also highlight where different approaches to governance or regulation may be necessary given the multi-factored nature of cost drivers and the likelihood of different benefit and cost outcomes associated with market design details.

3.4.1. Overall Benchmark Results

Initially, we simply consider a direct benchmark comparison of AEMO's WA and NEM operations as they are most consistent in terms of accounting breakdowns and roles.

Figure 13 shows that over the last five years, consolidated operational expenses in the NEM (market, system and gas services information combined) have increased by 72%, while expenses in the WEM have decreased by 4%. This is mostly due to the significant changes implemented in the market operations and system management functions over this period in the NEM. In the next three-year period, it is forecasted that NEM costs will increase, though at a steadier rate, whereas WEM costs will mirror the recent trajectory of the NEM and rapidly rise as they start to undertake a swathe of similar changes.

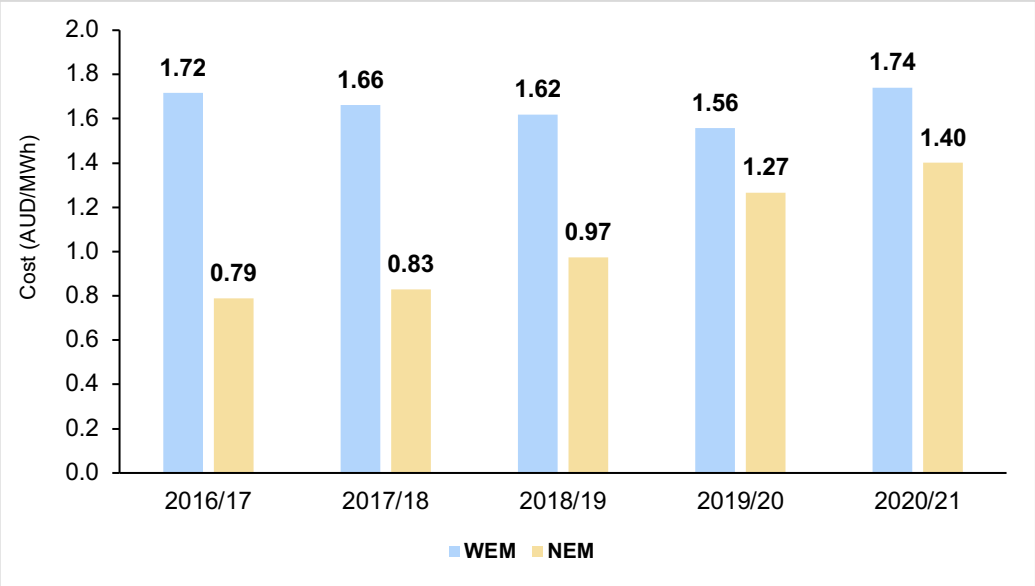
Figure 13: Total Cost NEM vs. WEM



Source: AEMO Data, TLG analysis

Figure 14 shows that the NEM has maintained lower costs per unit of consumption than the WEM, despite the significant growth in total NEM expenditure over the past five-year period. However, the cost efficiency gap has closed from 0.93 AUD per MWh in 2016/17 to just 0.34 AUD per MWh in 2020/21.

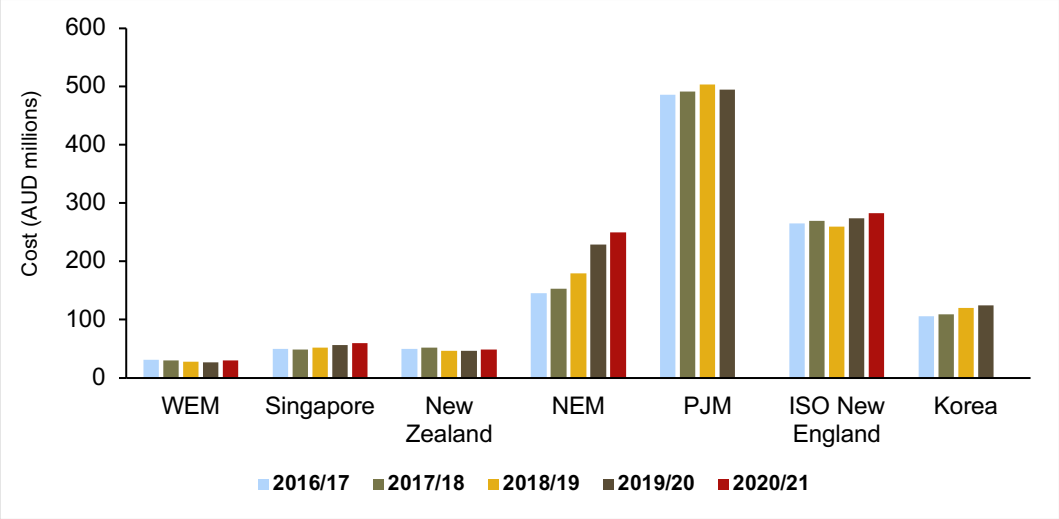
Figure 14: Total Cost NEM vs. WEM (per MWh basis)



Source: AEMO Data, TLG analysis

When expanding to include other jurisdictions, Figure 15 demonstrates that the rapid growth trend of the NEM is not observed anywhere else. Korea is the only other market to have a cost increase each year over the benchmark period. In fact, most markets experienced either stable or declining consolidated operational costs over the past five years.

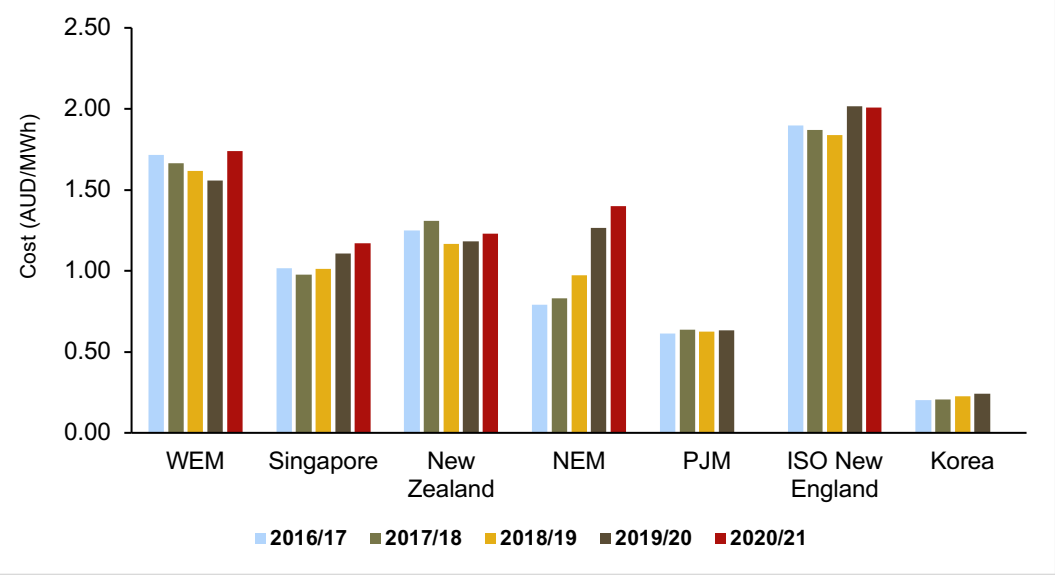
Figure 15: Comparison of Total Costs of Combined Market and System Operations



Source: Public Data, TLG analysis

Figure 16 adjusts these expenses for differences in consumption (i.e., scale); showing that the WEM has the second highest costs in the sample of six markets behind only ISO New England. Mirroring the result above, the NEM's costs per MWh have increased at a faster rate than other jurisdictions, from 0.79 AUD/MWh in 2016/17 to 1.4 AUD/MWh in 2020/21. Korea sets a strong benchmark in cost efficiency for market operators with a value of 0.24 AUD/MWh in 2020/21, eight times lower than the highest cost market (ISO New England at 2.04 AUD/MWh). The similarity in profiles, with and without scale adjustment, demonstrates how consumption is relatively flat for these markets over the five-year period. None of them are, for instance, high-growth developing markets.

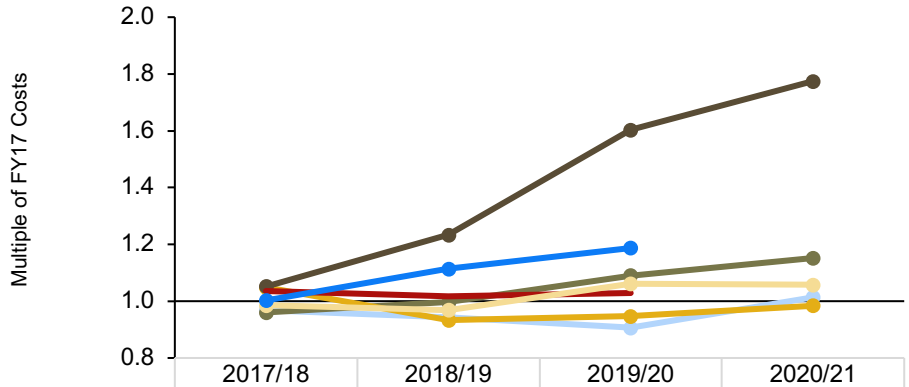
Figure 16: Comparison of Costs per MWh (in AUD) of Combined Market and System Operations



Source: Publicly available annual report data adjusted to Australian Dollars

Figure 17 shows the growth rates more explicitly, by normalising combined costs to 2016/17 levels on a unit of consumption basis. This allows us to see more clearly that over the past five years, total costs in the NEM have almost doubled, while total costs in the WEM have been stable. Apart from the NEM and Korea, all markets in the benchmarking study cluster tightly around 1.0, again showing flat costs per unit consumption.

Figure 17: Comparison of Costs per MWh (in AUD) of Combined Market and System Operations; Normalised to FY 2016/17



	2017/18	2018/19	2019/20	2020/21
WEM	0.97	0.94	0.91	1.01
Singapore	0.96	1.00	1.09	1.15
New Zealand	1.05	0.93	0.95	0.98
NEM	1.05	1.23	1.60	1.77
PJM	1.04	1.02	1.03	
ISO New England	0.99	0.97	1.06	1.06
Korea	1.00	1.11	1.19	

Source: Public Data, TLG analysis

4. BENCHMARKING MARKET OPERATIONS COSTS

AEMO is both the system and market operator in WA. We focus specifically in this section on AEMO's market operations costs by comparing AEMO's market operations function to other market operators. Accordingly, we evaluated the costs and organisation of the following market operators in additional detail:

- Singapore Energy Market Company (EMC);
- New Zealand Exchange (NZX);
- Korea (KPX);
- UK – Elexon; and
- Eastern Australia, NEM (AEMO).

The chosen market operators are split between smaller markets closer in size to WA (Singapore and New Zealand) and larger markets (Eastern Australia, Korea and UK). We focused on jurisdictions with an existing and mature energy market that have clearly defined market operation providers. Therefore, other potential smaller isolated but highly developed jurisdictions, such as Hawaii, were not included in the benchmarking.

4.1. OVERVIEW OF SELECTED MARKET OPERATORS

4.1.1. Singapore EMC

EMC is a privately owned, for-profit company that operates Singapore's energy market called the National Electricity Market of Singapore (NEMS). EMC's budget and fees are annually determined through a transparent process involving publishing a draft budget, inviting public and stakeholder feedback, providing project level budgets to the industry Rules Change Committee for comment, and formal budget submissions to the regulator (EMA) for approval. Importantly, the EMA determines an overall price cap for a 5-year period and EMC's annual budget is effectively advice to the market on how this fee cap is being spent. The market operator's costs are recovered through nominal fixed fees and through a market fee levy.

4.1.2. New Zealand Exchange

The regulator contracts out the various services required in running an electricity market. This contracting process is competitive with contracts awarded for approximately 5-to-8-year terms but can be extended. New Zealand Exchange is contracted to provide majority of the services required in running an electricity market. New Zealand Exchange has been the market operator since 2009 through the acquisition of M-co, the market operator since the market commenced in 1996.

At present there are three companies that perform market operator functions in New Zealand as identified in Table 7.

Table 7: Market Operation Contracts in New Zealand

Service Contract	Provider
Clearing Manager	NZX
Extended Reserve Manager	NZX
Pricing Manager	NZX
Reconciliation Manager	NZX
Wholesale Information and Trading System Manager (WITS)	NZX
Stress Testing	NZX
Registry Manager (Retail Switching)	JADE
Financial Transmission Rights (FTR) Manager	EMS, a division of Transpower

Source: Service Provider and Electricity Authority websites

4.1.3. UK Elexon

Great Britain's electricity market is regulated by the Gas and Electricity Market Authority, operating through the Office of Gas and Electricity Markets (Ofgem). Elexon administers the Balancing and Settlement Code, which was launched in March 2001.

Elexon is a not-for-profit company that operates the balancing energy market in Great Britain, whilst also providing metering services. Elexon is funded by participants who have signed up to the balancing and settlement code. Elexon's fees comprise both fixed and variable charges.

4.2. Relevant Similarities and Differences

In seeking comparable jurisdictions, we focused on three differentiating factors:

- the scope or breadth of the market operational role;
- the overall complexity of the market design; and
- the overall market size.

Of the above noted markets, we consider New Zealand and Singapore as the most comparable to WA's WEM, due to their scale, design, and structure. Despite these similarities, New Zealand and Singapore are still materially different to the WEM. Both are co-optimised energy-only markets, and they are each two and three times the size of the WEM, respectively.

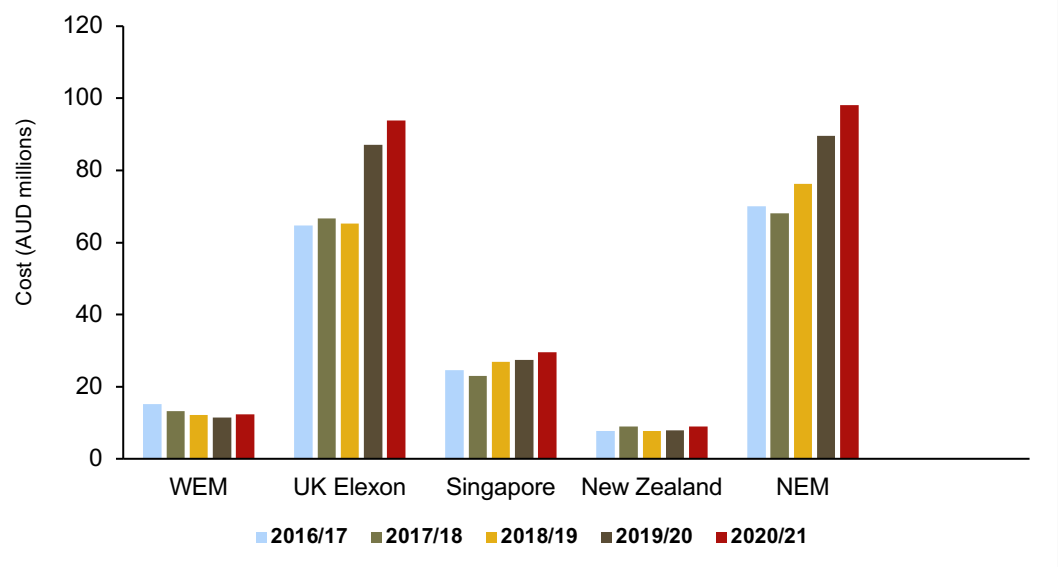
Table 8: Operational Parameters of Benchmarked Market Operators

	WA	Singapore	New Zealand	UK	NEM
Breadth of Role					
Operations	✓	✓	✓	✓	✓
Rule making	✗	✓	✗	✗	✗
Surveillance	✗	✓	✗	✓	✗
Gas monitoring	✓	✗	✗	✗	✓
Market Design Complexity					
Energy	✓	✓	✓	✓	✓
Capacity	✓	✗	✗	✓	✓
Co-optimised	✗	✓	✓	✗	✓
Pricing	Postage sta mp	Nodal	Nodal	Contract-based/ Balancing	Nodal
Market Size					
Annual Demand (GWh)	~18,000	~51,000	~40,000	~295,000	~180,000
No. of Participants	86	57	>300	464	>500
Size of transmission network (km)	~7,800	5,817	~11,300	8,760	~40,000
Number of customers	~1.1 million	~1.57 million	~2 million	~21.6 million	~9 million

Source: Published data, TLG analysis

Figure 18 shows that market operations costs have generally increased over time across jurisdictions, except for the WEM, in which costs have decreased in 2020/21 compared to their 2016/17 levels. Market operations costs for UK Elexon increased from AUD $65 million in 2016/17 to AUD $93 million in 2020/21, with growth evenly split over employee benefit expenses, accommodation costs and supplies/services. In the NEM, market operations costs increased from AUD $70 million to AUD $98 million. For both these markets, the last two years of the period saw greater jumps than the first three years.

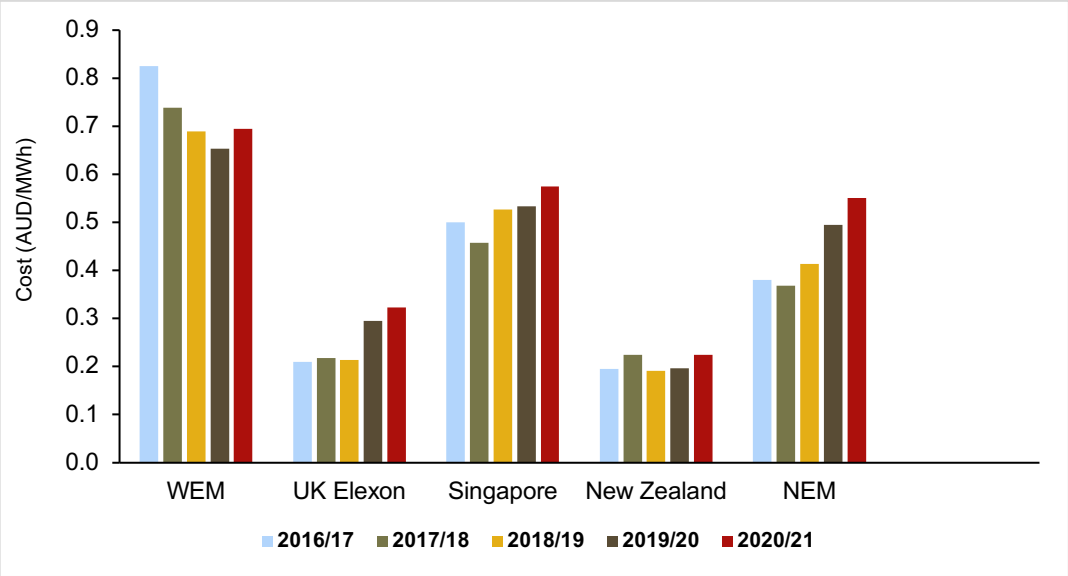
Figure 18: Total Cost for Market Operations in Other Jurisdictions



Source: Publicly available annual report data adjusted to Australian Dollars

Figure 19, which expresses market operations costs on a unit of consumption basis, again shows that all jurisdictions experienced an increase in costs between 2016/17 and 2020/21 except the WEM. New Zealand has the lowest costs when adjusting for scale, which defies the theory that a smaller grid would lack efficiencies of scale in terms of diminishing resources needed to run an electricity market. In Section 4.1.2, we further investigate why New Zealand's market operator NZX are so cost efficient. UK's Elexon is the market operator with the largest consumption in the sample and indeed shows the next lowest costs after New Zealand.

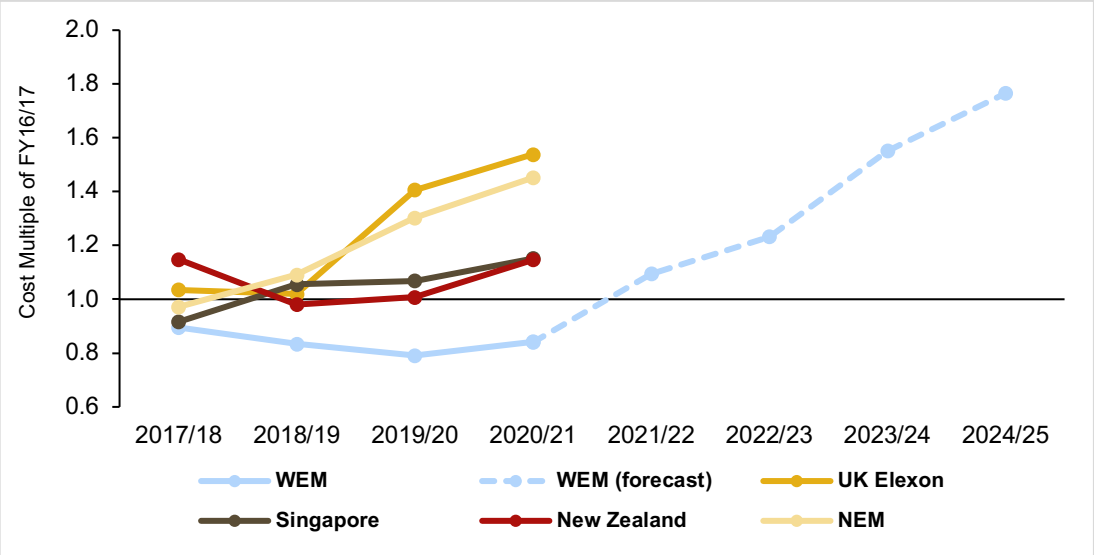
Figure 19: Cost of Market Operation Based on MWh Consumption



Source: Publicly available annual report data adjusted to Australian Dollars

Figure 20, which expresses market operations costs on a unit of consumption basis normalised to 2016/17 levels, shows a split between WEM, with decreasing costs, and NEM, Elexon, Singapore and New Zealand, with increases in costs (less pronounced for the latter two markets). However, over the next three years, forecast market operations costs in the WEM are expected to increase more in step with comparator markets to a level 77% above the baseline.

Figure 20: Cost of Market Operation Based on MWh Consumption; Normalised to FY 2016/17

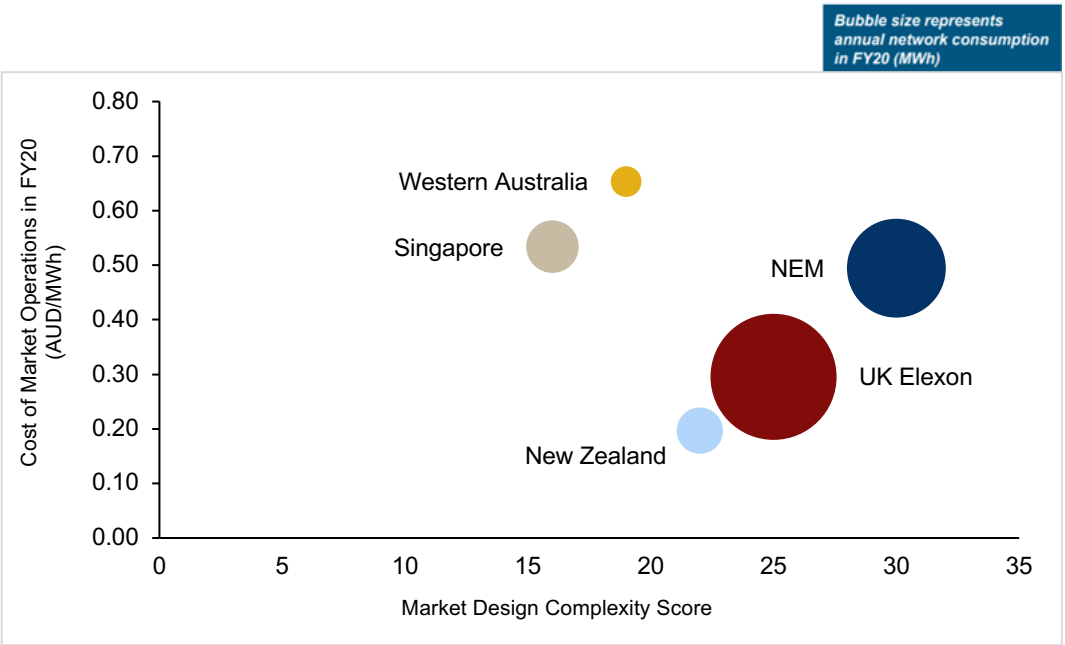


Source: Publicly available annual report data adjusted to Australian Dollars

Figure 21 shows the relationship between a subjective market operations complexity score and the cost of market operations per MWh. The size of the bubble in each case indicates market size, as measured by annual MWh consumption.

Figure 21 shows that there is no relationship between market operations complexity and market operations cost. In particular, despite having relatively high costs per unit consumption, the WEM is not a particularly complex market to operate, with only Singapore showing a lower complexity score among the benchmarking sample of market operators.

Figure 21: Cost of market operations as a function of market design complexity and annual network consumption in FY2020



Source: Public Data, TLG analysis

Table 9 shows how the complexity scores were derived.[9] The NEM was judged the most complex market to operate, due to narrow trading intervals and gate closures, multiple jurisdictions with many stakeholders and generators, and having more ancillary market products traded than peers. While the nature of complexity scores involves judgement, the scores provide a basis for a useful, high-level comparison of market complexity that does not strike us as especially controversial.

9 All criteria rated on a scale of 1 (very simple) to 5 (very complex).

Table 9: Determination of a Market Complexity Score for Different Jurisdictions

	Number of products traded	Generation mix	Spot trading intervals	Gate closure	Number of jurisdictions	Private sector involvement	Number of stakeholders & participants	Total
WEM	3 7 (Energy, Capacity and 5 AS Markets)	3 Varied (Thermal Dominant)	4 5-min Dispatch / 5-min Settlement	2 15 minutes	1 1	3 Medium - High	3 Medium (AEMO, ERA, ~80 Market Participants)	19
NEM	5 9 (Energy + 8 AS Markets)	4 Varied (Thermal Dominant)	4 5-min Dispatch / 5-min Settlement	5 None (67 second functional limit)	4 5 (NSW, VIC, QLD, TAS, SA)	4 High	5 Very High (AEMO, AER, >500 Market Participants)	30
New Zealand	3 6 (Energy + 5 AS Markets)	2 Varied (Hydro dominant)	3 5-min Dispatch / 30-min Settlement	2 30 minutes	5 ~70 Regions of Nodal pricing	2 Medium	5 Very High (EA, NZEC, NZX, >300 Market Participants)	22
Singapore	3 4 (Energy, Primary Reserve, Contingency Reserve and Regulation)	1 Largely Homogeneous (Gas)	2 30-min Dispatch / 30-min Settlement	1 65 minutes	1 1	4 High	3 Medium (3 Operators / Regulators, ~30 Market Participants)	16
UK Elexon	3 6 (Energy + 5 AS Markets)	4 Varied (Thermal/Nuclear/ Wind all significant)	3 5-min Dispatch / 30-min Settlement	1 60 minutes	5 14 (operator-specific regions; low price variance)	4 High	5 Very High (National Grid, Ofgem, Elexon,1000s of Participants)	25

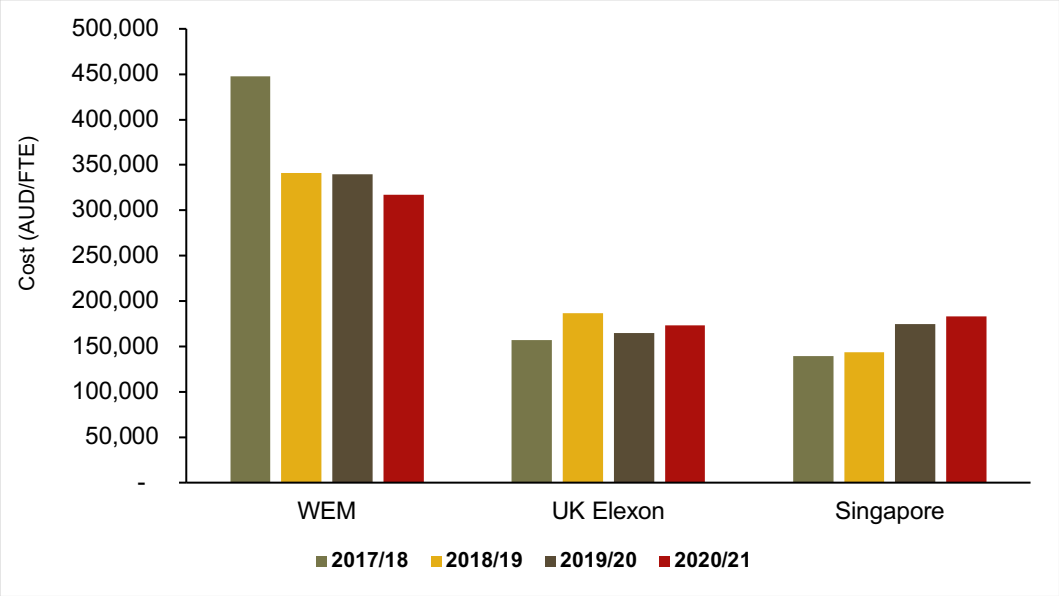
Source: Public Data, TLG analysis

4.3. EMPLOYEE COSTS AND BENEFITS

As shown in Figure 8, employee costs to carry out AEMO WA's market operations are approximately one half of the total annual operating expenditure for that function.

Figure 22 shows that employee costs and benefits for AEMO WA market operations have declined by one-third over the period from 2017/18 to 2020/21, with most of this change having taken place in the first year. However, costs at over AUD 300k per head are still higher than UK Elexon and Singapore, which lie in the range of AUD 150-200k per head over the period. The full time equivalent (FTE) count for AEMO WA may be understated (such that cost per employee will be overstated), as some Perth office employees split time between WEM and NEM activities but do not appear in the WA cost budget. The calculation inputs to determine employee cost efficiency are presented in Table 10.

Figure 22: Employee Costs and Benefits per FTE Comparison



Source: Public data, TLG analysis

Table 10: Comparison of Employee Costs, FTE and Employee Cost per FTE

	2016/17	2017/18	2018/19	2019/20	2020/21
WA AEMO					
Full Time Equivalent (FTE)	11.2*	12.1*	15.6*	16.4*	18.3*
Employees Benefit Expense ('000 AUD)	5,344	5,420	5,317	5,574	5,803
Employee cost per head ('000 AUD)	477*	448*	341*	340*	317*
Singapore EMC					
Full Time Equivalent (FTE)		64	71	73	73
Employees Benefit Expense ('000 AUD)		8,929	10,212	12,761	13,361
Employee cost per head ('000 AUD)		167	159	175	183
UK Elexon					
Full Time Equivalent (FTE)	144	146	124	174	175
Employees Benefit Expense ('000 AUD)	24,000	25,468	23,472	28,732	30,386
Employee cost per head ('-000 AUD)	144	146	124	165	174

*The AEMO WA reporting method for employee count is aligned to be consistent with documented planning for AR5 (2019/20-2021/22), with only WEM-facing employees included rather than both WEM and NEM-facing employees based in WA as was the case in AR4 (2016/17-2018/19). Hence, the FTE counts stated for AR4 are noticeably lower than the 2019 report.

4.4. Deeper Comparisons Between AEMO WA and EMC Singapore

This section provides a closer comparison of the budget and the employee functions of the electricity market operators in Singapore (EMC) and Western Australia (AEMO). The availability of employee breakdowns and cost breakdowns for EMC relative to other jurisdictions allowed for this detailed look at Singapore relative to the WEM.

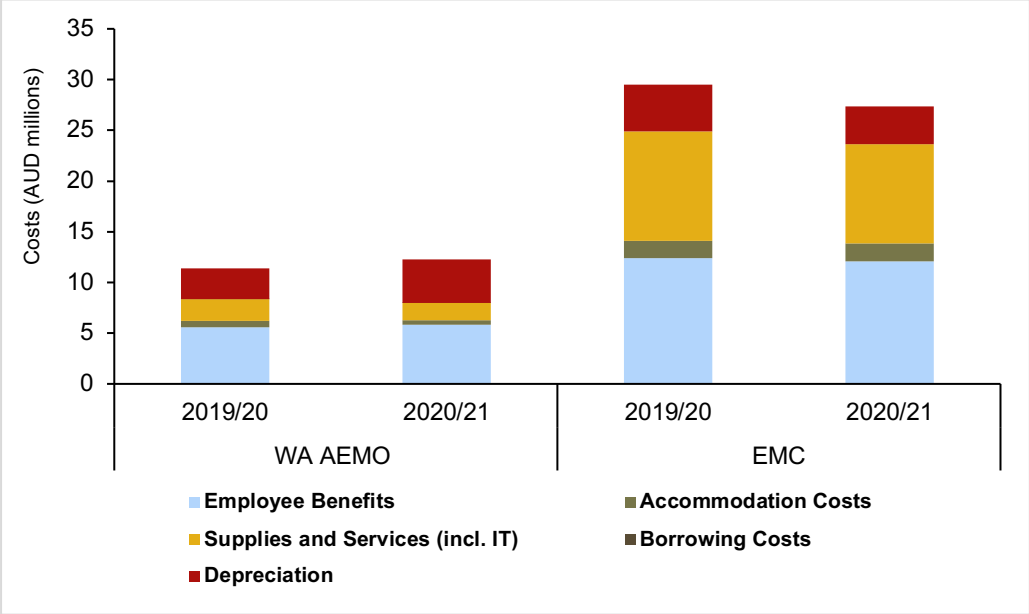
Table 11 gives a line-item breakdown of employee benefits expense category into the relevant components for AEMO WA and Singapore EMC. This shows that despite performing similar functions, market operators can structure their employee benefits in rather different ways, as required by employment law or regional expectations. It also reinforces that a simplistic like for like comparison between the two jurisdictions is likely to lead to misguided observations.

Table 11: Comparison of Employee Costs, FTE and Employee Cost per FTE

Categories	AEMO WA	Singapore EMC
Salaries	Salaries Overtime	Salaries 13th Month Pay
Bonus	Performance Pay	Performance Bonus
Leave	Annual Leave Provision Long Service Leave Other paid leave	n/a
Pension Contribution	Superannuation	Central Provident Fund
Tax	Payroll tax	n/a
Welfare/Benefits	Allowances	Staff Welfare
Insurance	Salary Continuance Insurance	
Others		

Figure 23 shows the breakdown of market operations expenses into the five main categories (IT is recombined with Supplies & Services for ease of comparison), comparing the percentage split for AEMO WA and Singapore EMC across 2019/20 and 2020/21 respectively. Currently, WA AEMO has a higher share of employee benefit expenses (47% of the total) compared to Singapore EMC (43%), and likewise the share of depreciation for AEMO WA (35%) is much greater than Singapore EMC (16%), but Singapore EMC has a far higher share of supplies and services costs (36%; compared to 14%)

Figure 23: AEMO & Singapore EMC Market Operator Cost Breakdown



Source: Publicly available annual report data adjusted to Australian Dollars

In Table 12, there is a breakdown of employee functions for the Singapore market operator EMC. This shows that the Information Technology and Market Operations department are proposed to grow by 3 FTE each in the current financial year. This accounts for most of the overall growth in employee numbers from 73 FTE to 82 FTE.

By contrast, AEMO WA market operations workforce is proposed to grow from 18.3 FTE to 19.7 FTE in FY2021/22, with essentially all the growth from an addition of 1.3 FTE within Market Reform, in anticipation of upcoming changes to market operations. An analogous department does not exist in the EMC.

Table 12: Employee Count by Department

Department	FY 2020/21 Approved	FY 2021/22 Proposed	Change
Singapore, EMC			
CEO Office	3	3	-
Corporate Services	10	10	-
Market Administration	7	8	+1
Information Technology	21	24	+3
Information Security	5	6	+1
Market Operations	18	21	+3
Market Assessment Unit	5	6	+1
Communications	2	2	-

Department	FY 2020/21 Approved	FY 2021/22 Proposed	Change
Human Resources	2	2	-
Total	73	82	+9
WEM			
Market Operations	10.0	10.0	-
Reserve Capacity	7.9	8.0	+0.1
Market Reform	0.4	1.7	+1.3
Total	**18.3**	**19.7**	**+1.4**

Source: EMC's NEMS Budget for the Financial Year Ending 30 June 2021; AEMO AR6 Proposal – WA Labour Supporting Document

5. BENCHMARKING SYSTEMS OPERATIONS COSTS

5.1. OVERVIEW

In some markets, typically due to the way the industry was owned and structured before reforms commenced, the system operator function is with the transmission grid operator. For example, the UK's system operator recently became a separate subsidiary of National Grid Gas (NGG), having previously been a ring-fenced division. In New Zealand, system operations are part of Transpower, the national transmission company. In Singapore, the system operation function – quite unusually – is a division of EMA, the industry regulator.

5.2. SYSTEM OPERATORS REVIEWED

In this section, we take a deeper look at three system operators:

- New Zealand: Transpower
- Singapore: Power System Operator (PSO)
- Australia NEM: AEMO

We focussed particularly on smaller systems for the comparison of System Operations costs.

5.2.1. New Zealand: Transpower

New Zealand's electricity regulator, the EA, assigns the role of system operator through a competitive tendering process. Transpower is both the system operator and the network operator. The system operation role is funded through an incremental and unavoidable cost approach. This means Transpower can only seek funding for the system operations role for costs that uniquely relate to that function. As an example, Transpower will deploy SCADA across its network in its role as network owner. However, it is only the *incremental cost of SCADA used for system operations* that is to be charged to the system operator function.

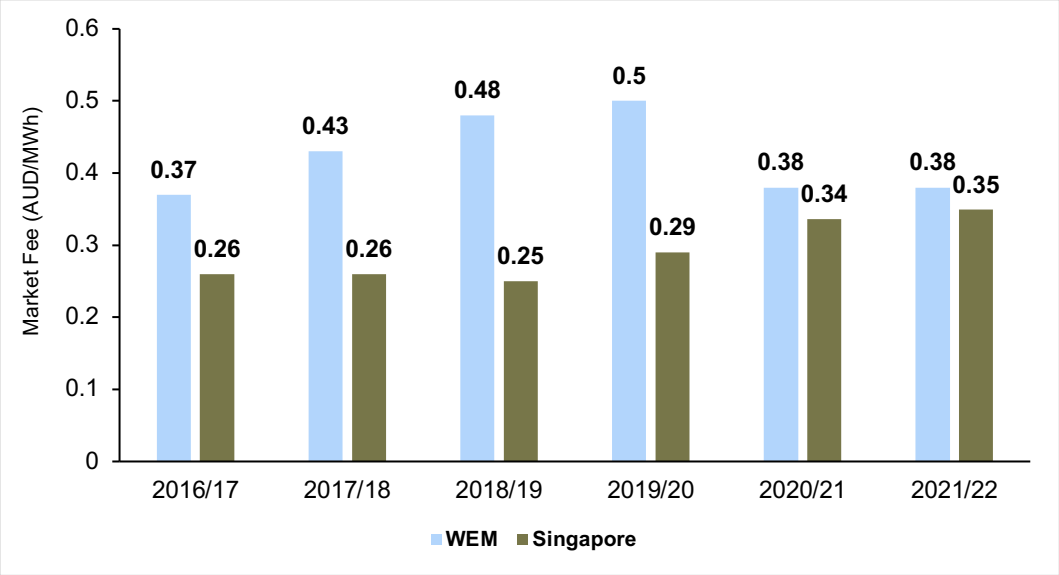
5.2.2. Singapore Power: Power System Operator

In Singapore the power system operator (PSO) is a subsidiary of the Electricity Market Authority (EMA), the regulatory body. The budget and fees of the system operator are governed by the market rules. Under the market rules, it is mandatory in the event of under or over recovery at the end of each fiscal year to publish the revised expenditure and revenue requirements as well as a schedule of fees for the remainder of the current five-year fiscal period.

We compare AEMO WA to PSO directly here (in brief), as there is sufficient data available and there are similarities in scope and size of the power network.

Over the past five years, Singapore's market fees increased by 30%, whereas WEM's fees have been more volatile but ended up at similar levels to 2016/17. This is shown in Figure 24. However, market fees in the WEM are scheduled to increase.

Figure 24: Market Fee for System Operation WA and Singapore (AUD/MWh)



Source: Energy Market Authority; adjusted to Australian Dollars

Table 13 shows that PSO's expenditures increased at an average annual rate of about four percent from the FY 2016/17 year to FY 2020/21. Fees increased at a somewhat lower rate of 2.8 percent due to increased electricity sales growth.

Table 13: Singapore's PSO Budget and Fees (in $SGD)

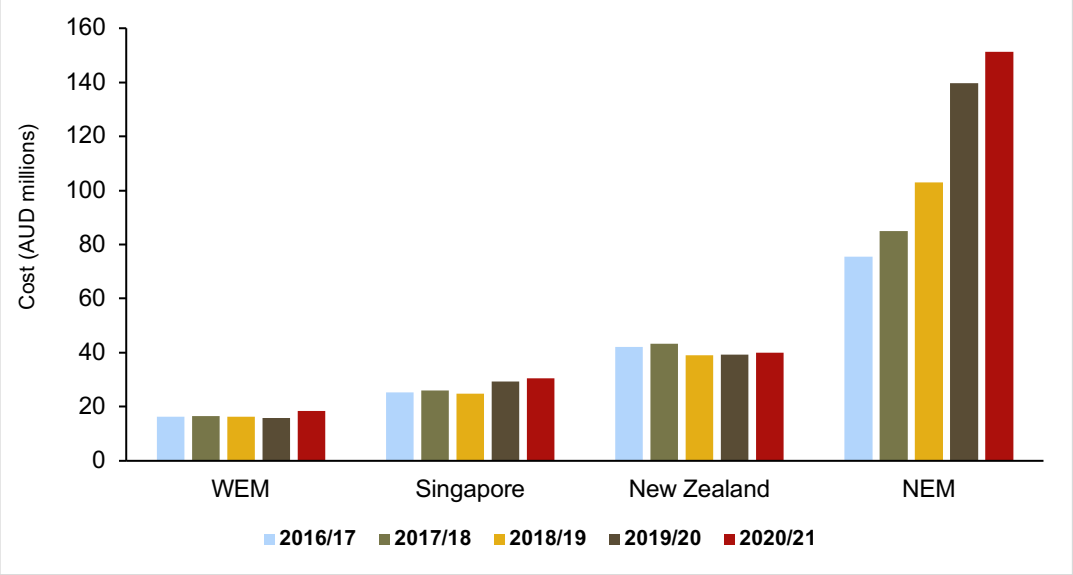
	FY 2016/17	FY 2017/18	FY 2018/19	FY 2019/20	FY 2020/21
PSO finalised expenditure and revenue requirement for 5-fiscal year period ($'000)	24,781	26,837	27,483	28,212	29,300
Previous year's audited adjustments	(450)	(1,976)	(3,692)	-	-
PSO finalised expenditure and revenue requirement for each FY	24,331	24,861	23,791	28,212	29,300
Projected Electricity Sales (GWh)	48,664*	49,643*	50,596	51,566	52,563
Estimated PSO Fees ($/MWh)**	$0.2500	$0.2504	$0.2351	$0.2736	$0.2787

Source: Energy Market Authority

5.3. BENCHMARKING RESULTS

As shown in Figure 25, costs in the NEM almost doubled over the past five-years, while all other jurisdictions remained more or less stable. Singapore and the WEM saw small increases, while in New Zealand, costs declined marginally over the five-year period.

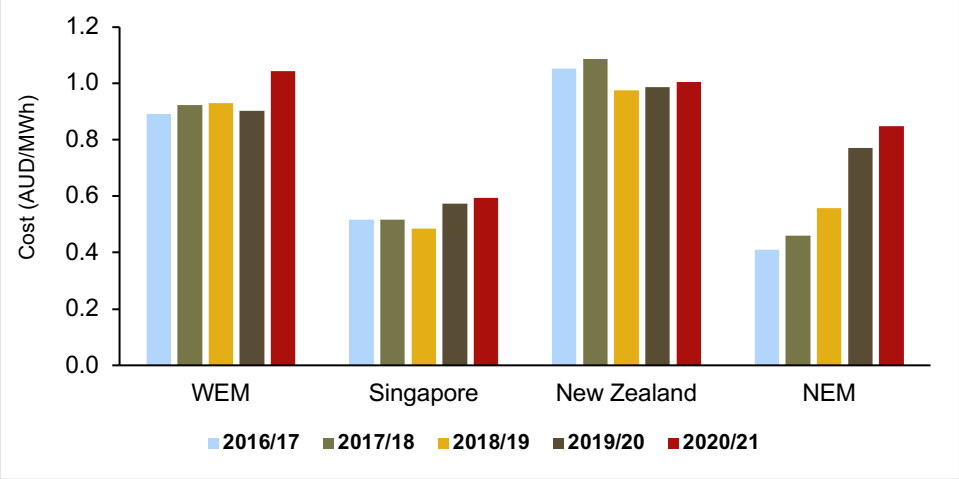
Figure 25: Comparison of System Operations Cost (Total)



Source: Publicly available annual report data adjusted to Australian Dollars

Figure 26 expresses these costs on a unit of consumption basis, with both the WEM and New Zealand having similar costs per unit. These were markedly higher than those of Singapore. While the NEM started off with similar costs to Singapore its costs were closer to those of the WEM and New Zealand by 2020/21.

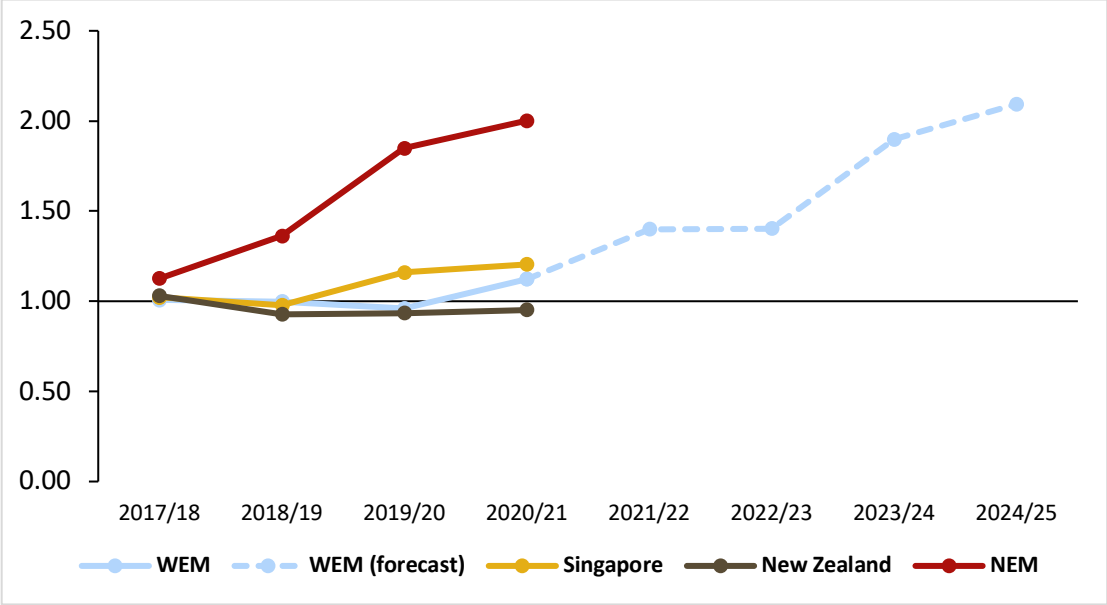
Figure 26: Comparison of System Operations Cost (per MWh)



Source: Publicly available annual report data adjusted to Australian Dollars

Figure 27 shows costs per MWh normalised to 2016/17 levels. This reinforces the historic rate of system operations cost growth in the NEM relative to other markets. The NEM is a clear outlier in the benchmarking sample, approaching two times its 2016/17 cost base by 2020/21, whereas the other markets cluster around one showing a flat cost trajectory. However, with upcoming reforms, the WEM is expected to almost double its own system operations cost growth by 2024/25.

Figure 27: Comparison of System Operations Cost (per MWh); Normalised to FY 2016/17



Source: Publicly available annual report data adjusted to Australian Dollars

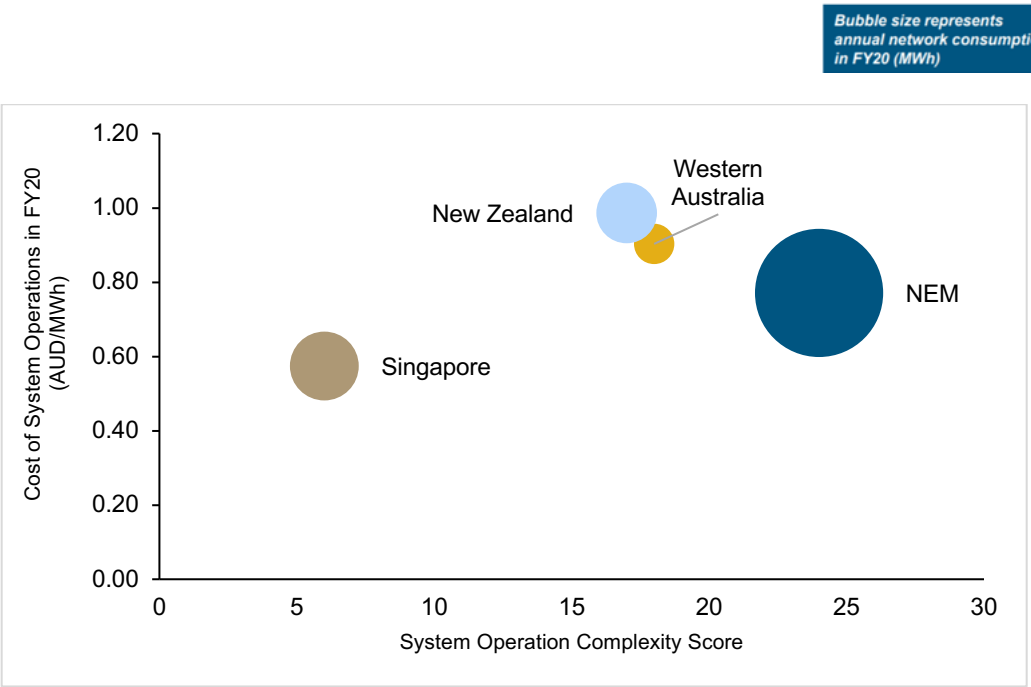
In Figure 28, we see the annual network consumption, subjective system operations complexity score[10] and cost of system operations per MWh simultaneously. This bubble chart shows that there is no discernible relationship between system operations complexity and system operations cost: the least complex and most complex markets represent the two lowest cost markets per MWh of the four markets in the benchmarking sample. There also appears to be no discernible relationship between annual network consumption and system operations complexity.

The WEM, with a score of 18/35, can be considered a moderately complex system to operate, of similar complexity to New Zealand (17/35). Singapore shows the lowest score (5/35) among the sample, the lowest possible score with a 1/5 assigned for every criterion. This is due to the confined, singular, and monopolistic nature of the Singapore power network.

10 All criteria rated on a scale of 1 (very simple) to 5 (very complex).

The NEM was judged the most complex system (24/35) based on three criteria receiving a 5/5 complexity rating: (high) number of generators, (long) transmission length, and (high) propensity for extreme weather events.

Figure 28: Cost of system operations as a function of system operation complexity and annual network consumption in FY2020



Source: Public data, TLG analysis

Table 14: Determination of a System Complexity Score for Different Jurisdictions

	Network Constraints	Rooftop Solar Penetration	Share of Renewable Generation (non-hydro)	Number of Generators	Length of Transmission Line	Extreme Weather Events	Total
WEM	3	4 33% of households	2 10%	3 71	3 8,000 km	3 8 Extreme Weather Events (2011-20)	18
NEM	2	4 36% of households	3 21%	5 557	5 40,000 km	5 23 Extreme Weather Events (2011-20)	24
New Zealand	3	1 2% of households	4 40%	4 ~170	3 10,000 km	2 6 Extreme Weather Events (2011-20)	17
Singapore	1	1 0.1% of households	1 0.5%	1 15	1 1,000 km	1 1 Extreme Weather Event (2011-20)	6

Source: Public Data, TLG analysis

6. GAS SERVICES INFORMATION

The Gas Services Information funding in WA is particularly challenging to benchmark due to the difficulty in finding comparable functions amongst other jurisdictions. The Gas Industry Company (GIC), in New Zealand, has a similar role as AEMO WA in so far as providing information on the state of the gas industry, gas availability and forecasting gas demand/production. However, New Zealand's GIC has additional roles that go beyond the Gas Information Services, such as oversight of a gas spot market.

The clearest similarity between GIC's role and the WA Gas Services Information is providing efficient, competitive, and confident gas markets (of which information disclosure is a sub-set). This is funded partly through market fees with the remainder through a levy on industry participants.

GIC gas information services are captured under Gas Governance (see Table 15). which has a total fee of NZ$2.5 million. This compares to the much narrower role performed in WA, which has an annual fee of around AUD$1.5 million.

Table 15: Gas Industry Company (GIC) Work Programme and Levy, FY2021/22

Gas Industry Company Sub-Function	Annual Budget for FY 2021/22 (NZD)
Gas Governance	2,517,134
Facilitating Industry Systems and Processes	1,066,030
Trusted Advisor to Government and Industry	1,188,203
Total Work Programme Costs	**4,771,367**
Less: Approximate Market Fees	1,299,000
Levy Funding Requirement	**3,472,367**

Source: Gas Industry Company - Consultation on Gas Industry Co FY2022, Work Programme and Levy

Accordingly, the AEMO WA Gas Services Information costs are lower than that of the benchmarking comparator of New Zealand Gas Industry Company, albeit they enjoy a much narrower scope of roles and responsibilities, which confounds the analysis.

APPENDIX A: MARKET STRUCTURES

A.1 NEW ZEALAND ENERGY MARKET

A.1.1 Service Provider Contracting (Electricity Authority)

The Electricity Authority contracts a range of market operation service providers to operate the electricity markets. They aim to create fit-for-purpose market services that increase market efficiency, ensure effective market operation, and facilitate market development.

The service provider roles are summarised below and then covered in more detail in the Market Operator and System operator sections.

Clearing Manager

The clearing manager is responsible for ensuring that industry participants pay or are paid the correct amount for the electricity they generated or consumed and for market-related costs.

NZX manages the clearing and settlement arrangements for the wholesale market. This entails the monthly settlement of all trades on the spot and financial transmission rights markets, and the billing for all transmission ancillary services. In addition, NZX actively monitors the risk exposure of market participants to the spot market and ensures sufficient prudential security is available to meet their market obligations.

Extended Reserve Manager

NZX's role as Extended Reserve Manager (ERM) is to select and monitor blocks of load that can be automatically disconnected during large under-frequency events in the electricity system.

Financial Transmission Rights (FTR) manager

The FTR manager is responsible for the creation and allocation of financial transmission rights (FTRs). The FTR manager:

- creates inter-island and intra-island FTRs;
- allocates FTRs to industry participants via regular auctions;
- manages the FTR register, in which all FTR holdings are publicly listed;
- registers parties who wish to participate in FTR auctions; and
- undertakes other activities associated with operating, promoting and developing the FTR market.

Energy Market Services (EMS), a division of Transpower, is contracted as the FTR manager.

Pricing Manager

The pricing manager is responsible for calculating and publishing the spot prices at which electricity market transactions are settled. Over 12,000 spot prices every day are published by the pricing manager to market participants through WITS (Wholesale Information and Trading System).

On a daily basis, NZX calculates the half-hour energy and reserve market settlement prices at approximately 270 grid locations. These prices are also used by the sector across a range of areas such as derivative contract valuation and price scenario forecasting. NZX uses a suite of established procedures and analytical tools to ensure a robust and accurate price is calculated.

Reconciliation Manager

Ensuring that industry participants (electricity generators or buyers) are allocated their correct share of electricity generation or consumption is a key role in operating an efficient market.

NZX in its reconciliation role is responsible for allocating all quantities of electricity consumed to purchasers and all quantities of electricity supplied to generators. NZX uses the metering information supplied by market participants to scale, calculate and allocate unaccounted for electricity. Quantity information calculated in this process is used for monthly spot market settlement.

Registry Manager

The registry manager oversees the registry to facilitate switching of retail customers.

The main processes that the registry manager oversees are:

- the maintenance and validation of installation control point (ICP) information, both current and historical, via online and batch functions;
- a notification facility that advises all affected participants of changes made to ICP information;
- a delivery mechanism for the switching protocols;
- the provision of ICP look-up facilities to authorised participants, both online and in batch (file) mode; and
- the provision of compliance reporting.

Part 11 of the Code details the management of information held by the registry and outlines the process for switching customers between retailers, metering equipment providers and distributors.

Jade Software Corporation (New Zealand) Limited is contracted as the registry manager.

System Operator

The system operator is responsible for co-ordinating electricity supply and demand in real time in a manner that avoids fluctuations in frequency or disruption of supply.

Wholesale Information and Trading System (WITS) Manager

The wholesale information system manager runs the wholesale information and trading system (WITS) used by industry participants to upload their bids and offers.

NZX operates the trading and information system used to support the 24-hour buying and selling of spot market electricity. The Wholesale Information and Trading System (WITS) processes around 25,000 market orders per day and publishes information such as dispatch schedules, transmission constraints and nodal prices.

Stress Testing

NZX, as an independent registrar, manages the stress test collection and reporting process. Electricity market participants purchasing electricity from the clearing manager, and consumers directly connected to the national grid, are required under the code to produce a spot price risk disclosure statement no later than five working days before the beginning of the quarter. This disclosure statement is used to indicate their risk exposure to the market spot price.

A.1.2 Market Operator (NZX)

The market operator is responsible for the following areas:

Pricing Manager

- The primary role of the pricing manager is to calculate financial binding prices for the wholesale electricity market.
- Prices are calculated using the system operator's Scheduling, Pricing and Dispatch (SPD) model. This is the same model used by the system operator to forecast prices and dispatch generation.
- Prices are calculated the day after trading for all grid exit points and grid injection points, for every half hour trading period.
- Prices are published on WITS.
- The pricing manager also manages the pricing error claim process.

WITS (Wholesale Information Trading System)

WITS is the wholesale information trading system, it:

- Allows participants to upload offers and bids for the wholesale electricity market;

- Provides access to pricing information published by the system operator and pricing manager. Besides prices, participants can also view their forecast cleared generation, HVDC flows, transmission constraints and SPD infeasibilities; and
- Provides access to the clearing manager portal. Participants use this portal to receive invoices, statements and prudential information.

Reconciliation Manager

The reconciliation manager is responsible for calculating the quantity of electricity purchased and generated by each participant in the wholesale electricity market.

- On a monthly basis, calculate purchase and generation quantities for every trading period and grid location.
- Key inputs to this calculation include:
  - Metered grid quantities; and
  - Participant quantity submissions (referred to as "volume submissions").
- As part of the calculation process the reconciliation manager will:
  - Adjust volume submissions to account for electrical losses within a network;
  - On a monthly basis, convert non-half hourly volume submissions to a half hourly basis. This is achieved using a 'profile' either provided by the participant or as calculated by the reconciliation manager; and
  - Calculate unaccounted for electricity and apportion this to participants. Unaccounted for electricity is where there is a difference between metered grid quantities and total participant quantity submissions.

Clearing Manager

The clearing manager has the following key functions:

- Ensuring participants maintain the minimum amount of prudential security defined in the Code. This includes calculating minimum prudential security amounts on a daily basis and monitoring each participant's security holdings.
- Preparing invoices and statements for participant purchases and sales of electricity to the wholesale electricity market. Invoices also cover ancillary services (as provided by the system operator), and financial transmission rights (FTRs).

Ensuring the orderly payment of invoices as required to settle the market

A.1.3 System Operator (Transpower)

As the System Operator, Transpower is responsible for managing the real-time power system and operating the wholesale electricity market.

The System operator is regulated by the Electricity Authority in accordance with the Electricity Industry Participation Code (the Code).

The organisation of Transpower's System Operations group is based on the time-focus of the various tasks needed to be undertaken:

- Real Time
- Short to Medium Term
- Medium Term
- Long Term

Real Time

The System Operations Manager and the team of system co-ordinators and support staff have the task, in real time, of managing the power system, in accordance with the rules and regulations, which define the market structure in New Zealand, and meeting the performance objectives that the system operator is required to achieve.

Short to Medium Term

The Engineering Manager provides support functions for the real time group. This includes all the necessary investigations and planning to ensure that the ultimate delivery of the system operator function in real time is well planned and understood prior to its real time implementation. A key function is the security planning to ensure the "lights stay on", if possible, in real time.

Medium Term

The Business Manager is responsible for the overall risk management within the system operator group. In addition, there is a requirement for monitoring the compliance and performance of the System Operator to ensure it meets its performance objectives, as required by the Electricity Authority.

Long Term

The Market Manager is required to plan and develop new systems both in terms of IT and Telecommunication products, and of market and system operations tools. This will allow Transpower to deliver the system operator function to the Electricity Authority and all industry parties more efficiently.

A.2 SINGAPORE ENERGY MARKET

The *Electricity Act* was enacted in 2001 to govern the electricity sector and the electricity market. The act provided for the licensing of generation, transmission, retail, market support services and wholesale market operator licensees. It enabled the establishment of the wholesale electricity market via the market operator and the Market Rules.

The rights and obligations of the participants in the wholesale market are set out principally in the Singapore Electricity Market Rules, and in the electricity licences and codes of practice issued by the EMA. The major themes are transparency, equity, and ownership of the Market Rules by the market participants. The Market Rules are, in effect, a contract between each market participant and EMC. The objectives (or guiding principles) of the Market Rules are:

- To establish and govern efficient, competitive and reliable markets for the wholesale selling and buying of electricity and ancillary services in Singapore;
- To provide market participants and the Market Support Services Licensees (MSSLs) with non-discriminatory access to the transmission system;
- To facilitate competition in the generation of electricity; and
- To protect the interests of consumers with respect to price, reliability, and quality of electricity service.

The Market Rules govern the following areas:

- Participation
- Administration, supervision, and enforcement
- System operation
- Market operation
- Settlements

Governance of the market is achieved through the rule change process, market surveillance and compliance, and dispute resolution and compensation.

The objectives of the governance structure are to fairly and efficiently:

- Evolve the rules;
- Settle market related compensation claims;
- Settle market disputes; and
- Provide incentives to comply with the rules.

On 1 January 2003, the National Electricity Market of Singapore (NEMS) commenced operations. It is a real-time energy-only spot market, trading energy, reserves of three classes and regulation at each half hourly interval.

Key features of NEMS are:

- It produces a real time, physically feasible, security constrained, dispatch;
- Relies on generation self-commitment;
- Uses nodal pricing; and

- Co-optimizes energy, reserves and regulation.

The real-time prices determined by the market reflect the fundamentals of demand and supply taking into consideration the power system and market constraints. Prices determined in NEMS send signals to investors for generation planting and influence consumer consumption patterns.

A.2.1 Market Operations (EMC)

EMC is the sole market company licensed by EMA to operate and administer Singapore's wholesale electricity market called the National Electricity Market of Singapore (NEMS). Besides operating and administrating the NEMS, EMC also schedules generating units and settles accounts of market participants. Its key activities include calculating prices, scheduling generation, clearing, and settling market transactions, as well as supporting governance of the market.

The EMC's functions are to:

- Operate and administer the wholesale market;
- Prepare schedules for generating units, loads and the transmission system;
- Settle accounts of market participants;
- Facilitate the planning and augmentation of the transmission system;
- Provide information and other services to facilitate decisions for investment and the use of resources in the electricity industry; and
- Exercise and perform the functions, powers and duties assigned to the EMC under the Electricity Act, its electricity licence, the market rules, and applicable codes of practice.

Under the market rules, some of the EMC's functions are required to be carried out by persons, panels or committees appointed by the EMC. These are:

- **Energy Market Company Board** - The market rules assign certain functions, powers, and duties specifically to the EMC Board and prohibit it from assigning or delegating them. These include voting on rule changes.
- **Dispute Resolution Counsellor and Dispute Resolution Panels** - The dispute resolution counsellor is responsible for managing the dispute resolution process described in the market rules and for facilitating the resolution of individual disputes. The dispute resolution counsellor is also responsible for selecting a group of people onto a roster from which persons may then be selected to form a dispute resolution panel in respect of individual disputes. The dispute resolution counsellor is appointed by the EMC Board and is required to act independently of the marketplace.
- **Rules Change Panel** - The principal tasks of the rules change panel are:

- To review any proposed changes to the market rules (including any changes that it may itself have proposed) and to provide recommendations in this regard to the EMC Board;
- To review proposed market manuals and the system operation manual, and any changes to them;
- To review the EMC's and PSO's budgets and fees (the PSO budget fee review was removed in 2010 through a rule change); and
- Market Surveillance and Compliance Panel - The market surveillance and compliance panel is an external panel established by the EMC Board to monitor the conduct of market participants and MSSLs in the wholesale market and the structure and performance of the wholesale electricity market itself. It is assisted by the EMC's internal market assessment unit.

Market Operations

EMC's Market Operations department provides the trading platform for generators and retailers to sell and buy electricity. The market operates continuously and establishes prices and quantities every half-hour for the energy, reserve and regulation products traded.

A key function of the Market Operations department is to determine the real-time dispatch schedule for the Power System Operator to issue the dispatch instructions to the applicable generators. A dispatch schedule is determined based on the offers submitted by generators and the forecast demand for electricity, taking into account the physical configuration of the transmission system.

EMC is the counterparty for all electricity transactions and acts as the central clearinghouse and settlement agent for all market transactions and fees. To ensure that the market remains financially secure, it operates a prudential settlement regime.

The Market Operations department also studies market price trends and market outcomes and provides market data and analyses to market participants and the public via EMC's website.

EMC also acts as the contracting party for the ancillary services necessary to ensure the reliability and security of the physical supply of electricity.

Market Administration

EMC's Market Administration team manages the market rules change process. It conducts analyses of rule change proposals and advises the market Rules Change Panel (RCP), the EMC Board and the EMA.

The team analyses market issues and explores new concepts using economic, legal, engineering and cost-benefit frameworks with the objective of improving the operational and economic efficiency of the market.

The team regularly engages and consults with market participants, the Power System Operator, and other stakeholders. It also prepares annual two-year work plans for the RCP based on a formal survey of all market participants.

Proactive management of the evolution of the market framework ensures that the market structures remain relevant and that new sources of efficiency continue to be identified.

The team also registers participants and generation and load facilities for the wholesale market.

Market Assessment

EMC's Market Assessment Unit (MAU) manages the market surveillance, compliance, and dispute resolution processes. It advises and supports three external and independent governance bodies, namely the Market Surveillance and Compliance Panel (MSCP), the Dispute Resolution Counsellor (DRC) and the Dispute Resolution and Compensation Panel (DRCP).

The MAU enforces compliance with the market rules through its surveillance activities, investigations of alleged rule breaches and supporting and advising the independent MSCP on enforcement actions. It monitors the outcomes of the wholesale electricity market as well as the behaviours of market participants to check that the market functions efficiently and identifies areas of inefficiency. It provides market training to and advises the MSCP on the state of competition and efficiency of the wholesale market for the panel to recommend changes or remedial actions to the Authority to address areas of inefficiency.

The MAU assists the DRC to set up and maintain dispute management systems among market participants. It provides market training and operational support to the DRC and DRCP members on all dispute-related matters.

A.2.2 System Operator (Power System Operator)

In Singapore, the Power System Operator (PSO), is a division of the Regulator, EMA. The PSO is responsible for the reliable supply of electricity to consumers, as well as the operation of the power system in Singapore.

As the natural gas and power systems are closely interlinked, PSO also oversees the operation of the natural gas transmission system.

To ensure future electricity generation and transmission capacities remain adequate and reliable, PSO carries out power system studies. Additionally, it assesses the impact of new generating plants as well as the expansion plans of electricity and gas transmission licensees.

In addition to operating the real time system, the Power System Operator also performs the following additional tasks.

System Planning

Detailed system planning is needed to ensure Singapore's power system remains secure and reliable. This involves looking into large-concentrated and small-distributed generating plants, electricity transmission network, control, and communication facilities.

To ensure a secure and reliable power system, system planning is critical. PSO takes measures to ensure that the current and future electricity and natural gas systems are adequate. This includes the:

- Review of Plans for the Development of the Transmission Network;
- Design and Impact Assessment of Proposed Generating Plants;
- Inter-dependency of Gas and Electricity System;
- Interruptible Load Facility; and
- Operating Reserve Policy.

System Operation

Teams of system operators monitor and control the electricity generation and transmission system, as well as the gas transmission system around the clock. Working on eight-hour shifts, each team is led by an experienced Control Manager and assisted by four Technical Executives. The Power System Operation Procedures and Singapore's Electricity Emergency Plan outline the standards and procedures that industry players must comply with to maintain a secure and reliable electricity system.

They are tasked to:

- Control the generating operators' output and regulate system frequency;
- Regulate system voltages and direct power flows through the Transmission System;
- Liaise with the market operator and market participants on dispatch schedules & compliance to dispatch instructions; and
- Supervise the operation of the natural gas transmission system as there is high interdependency between this and the power system.

When there is a power system disturbance, officers on duty will activate contingency plan to stabilise, before returning the power system to a normal operating state. If there is an electricity supply disruption, crisis management plans will be activated to restore supply.

Supporting the National Electricity Market

PSO works with various market participants to ensure compliance with operational standards and obligations. These include both market administration and market operation activities as described below:

- Agreements with Market Participants: Market Participants in the National Electricity Market of Singapore (NEMS) are required to enter into regulatory agreements with the PSO.
- Facility Registration: Every market participant is required to provide up-to-date data of its facilities to the PSO, including the physical characteristics, ratings and operational limits of all relevant equipment/facilities connected to the PSO-controlled system.
- Market Operations: Details of power system information, such as network status, outage schedules and load forecasts that are sent to the EMC.
- Electricity Market Compliance Monitoring: The PSO ensures all non-compliance notices issued to market participants are shared with the Market Surveillance and Compliance Panel via the Market Assessment Unit of the EMC.
- Ancillary Services: Ancillary services deal mainly with balancing the power supply and demand over short time intervals throughout the power system. These services, regulation and reserves are essential to ensure the reliable operation of the power system.
- Outage Co-ordination: The PSO is responsible for coordinating the outage schedules of registered generation facilities, generating stations and transmission facilities. This also covers new or retrofitted facilities for construction, testing, commissioning/re-commissioning, and maintenance/repair.
- Power System Adequacy & Security Assessment: The PSO assesses the adequacy and security of the PSO-controlled system on a daily and monthly basis.

A.3 PJM

PJM Interconnection, L.L.C. (PJM) is a Regional Transmission Organization (RTO) that covers the transmission grid of all or parts of in Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia, forming part of the Eastern Interconnection portion of the overall US power system.

The main roles of PJM are:

- To operate a centrally dispatched and competitive wholesale power market;
- To coordinate and direct the operation of the transmission grid; and
- To plan transmission expansion improvements to maintain grid reliability in this region.

PJM manages all aspects of the grid and the wholesale market, including all services administrating the purchase and sale of energy, transmission services, and ancillary services.

The electricity industry in the PJM Region is subject to a complex series of government policies and legislation at the federal, state, and local levels.

The U.S. Department of Energy (DOE) develops national energy policy, administers federal funding for energy research, and approves construction of international transmission lines thereby advancing the national, economic and energy security of the United States. As a federal agency, DOE is also responsible for establishing and maintaining energy standards and practices across the country.

The Federal Energy Regulatory Commission (FERC) is an independent commission that has regulatory powers in electricity, hydropower, and natural gas and oil markets. It also regulates interstate electricity and gas markets. Under the Energy Policy Act of 2005, FERC is required to adopt and enforce standards that ensure the reliability of the national grid through the North American Electric Reliability Corporation (NERC).

There are two other independent federal agencies that are pertinent to electricity sector: The Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC). EPA enforces federal environmental protection legislation and works in conjunction with state-level environmental departments. NRC is responsible for regulating the nuclear industry, ensuring safe operation and decommissioning of nuclear power plants.

State governments formulate the overall energy policies for its state based on their generation resources and environmental circumstances which sets fuel mix and environmental targets, such as State Renewable Portfolio Standards (RPS), Emissions Tax, Cap-and-Trade, Feed-in Tariff, Mandated Power Purchase Agreements, Loan Programs, Grant Programs, and Tax Incentives.

All the states in PJM have regulatory commissions in forms of Public Utility Commissions (PUCs) and Public Service Commission (PSC), which have the responsibility to regulate energy and other utilities within the jurisdiction. States regulate all retail electricity rates and services as well as decisions on siting and construction of electricity generation and transmission through these PUCs.

A.3.1 Market Operations

In its role as market operator, PJM balances the needs of suppliers, wholesale customers, and other market participants and monitors market activities. The market operator provides the following services:

- Energy Markets, which include the sale or purchase of energy in PJM's Day-Ahead Market and Real-Time Market;
- Capacity Market, or Reliability Pricing Model (RPM) Auction;
- Ancillary Services: Regulation Market, Synchronized Reserve Market, Black-start Service, Reactive Services; and
- Financial Transmission Rights (FTRs) market.

Energy Markets

The largest of the PJM markets is the Energy Market, comprising around 63% of the wholesale electricity costs. The Energy Market is divided into the Day-Ahead and Real-Time Markets to meet consumers' demands both in real time and in the near term.

The Day-Ahead Market is a "forward" market, where prices are set for energy that will be delivered the next day. Hourly prices are calculated based on generator offers, bids from power consumers and market-related financial transactions.

PJM matches offers from the lowest- to highest-priced seller until it meets the bid-in demand for electricity, plus some reserves. All cleared bids and offers establish a financial position in the Day-Ahead Market. Any deviations from cleared quantities in the Day-Ahead Market are settled in the Real-Time Market.

The Real-Time Market serves electricity needs in real time. The Real-Time Market is a spot market. Supply and demand are paired, and prices are calculated every five minutes for more than 10,000 different pricing points based on actual grid operating conditions.

PJM continually follows fluctuations in generation, demand, and transmission, sending an electronic signal every five minutes to let suppliers know what their electricity output should be. If a supplier is committed to run by PJM and follows dispatch instructions, it will be compensated. Suppliers are paid the day-ahead price for whatever they were scheduled for, and the real-time price for any generation that exceeds the scheduled amount. If a supplier deviates from PJM's instructions, it may be charged a penalty.

Capacity Market

The capacity market represents about 20% of wholesale electricity costs. The capacity market is also called the Reliability Pricing Model or RPM. PJM's capacity market was implemented to secure enough power supplies three years into the future to ensure sufficient supply will be available to meet peak demand.

Each year, PJM administers a competitive auction to obtain these future power supplies at the lowest price.

Market participants whose future capacity is sold at the auction are said to "clear" the auction. Cleared generation resources are required to offer power into the energy market for the year for which they are committed. Cleared capacity is also required commit to serve PJM's emergency needs whenever called upon.

The capacity market provides PJM consumers the assurance of reliable power in the future. In return, power resources receive a dependable flow of income to help maintain their existing capability, attract investment in new resources and to encourage companies to develop new technologies and sources of electric power.

Ancillary Services Markets

Balancing the system means matching supply and demand while maintaining a system frequency of 60 Hertz. PJM market operator provides to types for ancillary services markets:

- **Regulation:** Used to control small mismatches between load and generation.
- **Reserves:** Used to recover system balance by making up for generation deficiencies if there is loss of a large generator.

Financial Transmission Rights

Financial Transmission Rights or FTRs allow market participants to offset potential losses (hedge) related to the price risk of delivering energy to the grid. FTRs are a financial contract entitling the FTR holder to a stream of revenues (or charges) based on the day-ahead hourly congestion price difference across an energy path.

FTRs are a method to bypass congestion charges associated with PJM's Locational Marginal Pricing or LMP. They give market participants the ability to attain better price certainty when delivering energy across the grid.

FTRs are worth the economic value determined by the day-ahead hourly congestion prices. The FTR serves as a benefit, or credit, to the holder if it represents a flow of energy in the same direction as the congested flow. The FTR serves as a liability, or charge, to the holder if it represents a flow of energy in the opposite direction as the congested flow.

A.3.2 System Operations

In its role as System Operator, PJM is responsible for:

- Managing PJM transmission grid and interregional grid; and
- Planning and directing needed transmission expansions and upgrades to provide efficient, reliable, and non-discriminatory transmission service.

PJM does not own any transmission or generation assets. In its role as system operator PJM is responsible for the real-time balancing of electricity supply and demand across its members state boarders. PJM performs *what if* scenario evaluation throughout each day to assess network conditions based on data from hundreds of thousands of points on the grid every four seconds.

PJM tests the transmission system to ensure the network performs to national and state standards. When transmission improvements are required, PJM collaborates with the transmission owners to develop the required changes.

The system operator is responsible for the Regional Transmission Expansion Plan (RTEP). This plan provides a 15-year outlook that identifies transmission system additions and improvements needed to keep supplying electricity in PJM's region. PJM's annual RTEP Report describes transmission study input data, processes, and results, as well as PJM Board-approved transmission upgrades and process changes during the previous year.

The PJM systems operations control room is responsible for transmission operations, reliability coordination and balancing authority. These tasks are separated into the following roles:

- **Balancing authority master coordinator**: Responsible for load forecasting, generation outage processing, next stage generation scheduling and interchange coordination.
- **Balancing authority generation dispatcher**: Responsible for real-time generation and load balancing, reserve monitoring and deployment, and generator dispatch.
- **Master dispatcher**: Responsible for transmission system security, transmission outage coordination and voltage control
- **Reliability engineer**: Responsible for next day outage analysis, interacting with neighbouring areas and providing technical support.

A.4 KOREA POWER EXCHANGE

Korea Power Exchange (KPX) was established in 2001 in accordance with the Electricity Utility Act charged with (i) operating a fair and transparent electricity trading market and system; and (ii) establishing a long-term plan for electricity supply and demand.

KPX has three major roles:

- Market Operation: the operation of the electricity market, including bidding, metering, settlement, payment, and enacting and revising market rules.
- System Operation and Real-time Dispatch: Short- and long-term transmission network stability assessment, power system operation planning, and preparation for contingencies; and balancing the real time supply and demand.
- Short-term and long-term electricity supply and demand planning: KPX assists the government in short- to long-term planning and in developing demand forecast modelling.

KPX operates under three key departments, each responsible for planning, development and operation.

Figure 29 presents the overview of KPX functions in three key system operation roles:

Figure 29: Organisation Chart of KPX

Source: https://new.kpx.or.kr/menu.es?mid=a20102020000 (accessed 5 April 2022)

A.4.1 Market Operator

Electricity Market Operation

KPX conducts market operations from cost evaluation, bidding, settlement, metering, market surveillance and information disclosure, dispute resolution in accordance with the Electricity Market Operational Rules.

Renewable Energy Certificate (REC) Market Operation

With the introduction of the Renewable Portfolio Standards (RPS) in 2012, KPX's roles have expanded to cover the operation of Renewable Energy Certificate (REC) market and the management of the RPS compliance costs. In addition, KPX administers the auctions for REC trades, linking REC off-takers (gencos subject to RPS) and REC suppliers (renewable projects).

Electricity Market Operation Council

Electricity Market Operation Council is an organisation established to ensure objective and fair market operation. The members of the council consist of industry experts from various stakeholders from both public and private sectors.

Three major committees operate under the council: Rule Revision Committee, Cost Evaluation Committee and Dispute Mediation Committee.

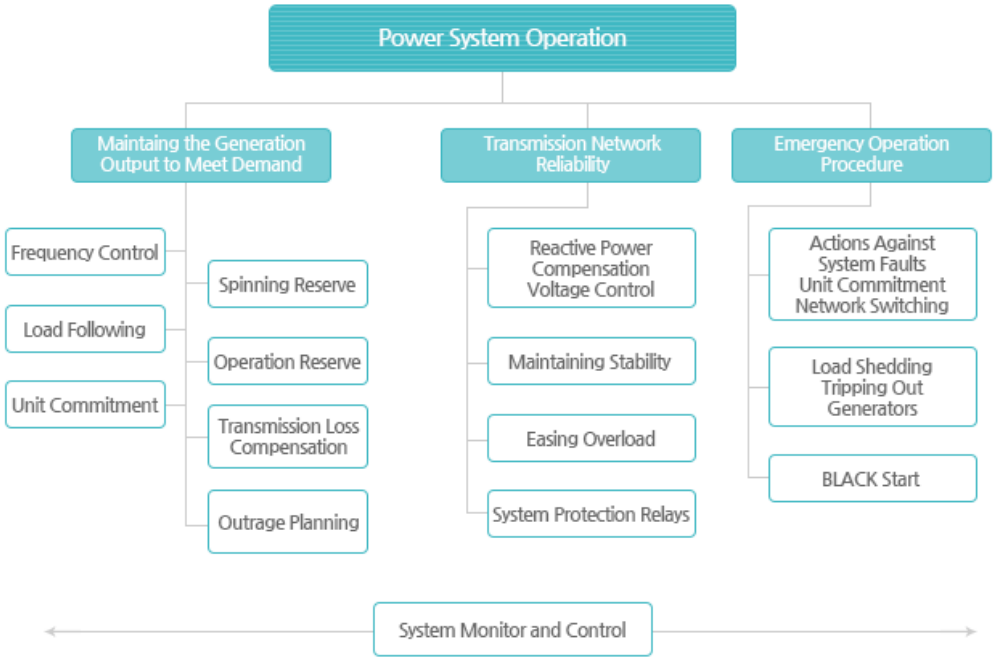
- Rule Revision Committee: The Electricity Market Operational Rules is the most important set of rules that forms the basis of standards, procedures, and methodologies to implement the objective of market rules. The relevant team of KPX submits the rule draft and the committee reviews and decides. The committee consists of 9 members, chaired by the CEO of KPX.
- Cost Evaluation Committee: Current electricity market is a Cost-Based Pool, and the market price is essentially set at pre-assessed variable costs of a marginal plant on a least cost basis. Thus, it is important that the Cost Evaluation Committee evaluates cost components of the market operation in a fair and transparent manner. Cost evaluation is primarily focusing on variable costs and capacity payment for respective plant, and it has expanded to cover costs, compensation, and penalties relevant to the operation of Renewable Portfolio Standard (RPS) in recent years. The committee consists of 8 members, including the chairman.
- Dispute Mediation Committee: This committee resolves disputes arising from KPX's market and system operations. KPX manages a pool of experts, comprised of those in the power industry with various background in legal, engineering, accounting and economics. Three members are selected from the pool by the parties involved in the dispute for dispute resolution.

A.4.2 System Operator

Grid Operation and Load Dispatch

KPX operates the power system required to transmit the electricity to load centres. Figure 30 presents the overview of KPX functions in three key system operation roles in maintaining System Adequacy, Transmission Network Reliability, and Emergency Operation Procedures.

Figure 30: Overview of System Operation Functions of KPX



Source: KPX

In essence, the KPX's functions are to:

- Monitor and control of the power system;
- Maintain the balance of electricity supply and demand;
- Operate the electricity market efficiently;
- Operate the power system reliably;
- Prevent outage and timely restoration; and
- Control system voltage and frequency.

To carry out these functions, KPX sets dispatch plans to prevent overload, and establishes contingency plans to ensure system reliability based on failure analysis, power flow analysis, optimisation of system stability, scheduled maintenance and failure preventive system analysis.

KPX is charged with establishing appropriate countermeasures in case of major transmission network failure of a large-scale generation facility, by installing a control circuit that can immediately block out the selective unit from the system and other generating units can back up as normal operation.

One of the important roles is to monitor and identify vulnerable parts of the grid and to reinforce them in order to ensure supply reliability. To carry out this role, KPX prepares power restoration plans and recovery measures in case of power failure, develops in-house capabilities for continuous monitoring of the grid system, and conducts regular trainings of KPX staff and personnel of member companies.

Real Time Balancing of the Supply and Demand

At any time, KPX ensures real-time balancing of supply and demand by controlling the output of all the generators so that the generation cost is minimized throughout the operation following load changes. KPX secures 4 GW of adequate reserve at all times.

Short Term Supply-Demand Operation

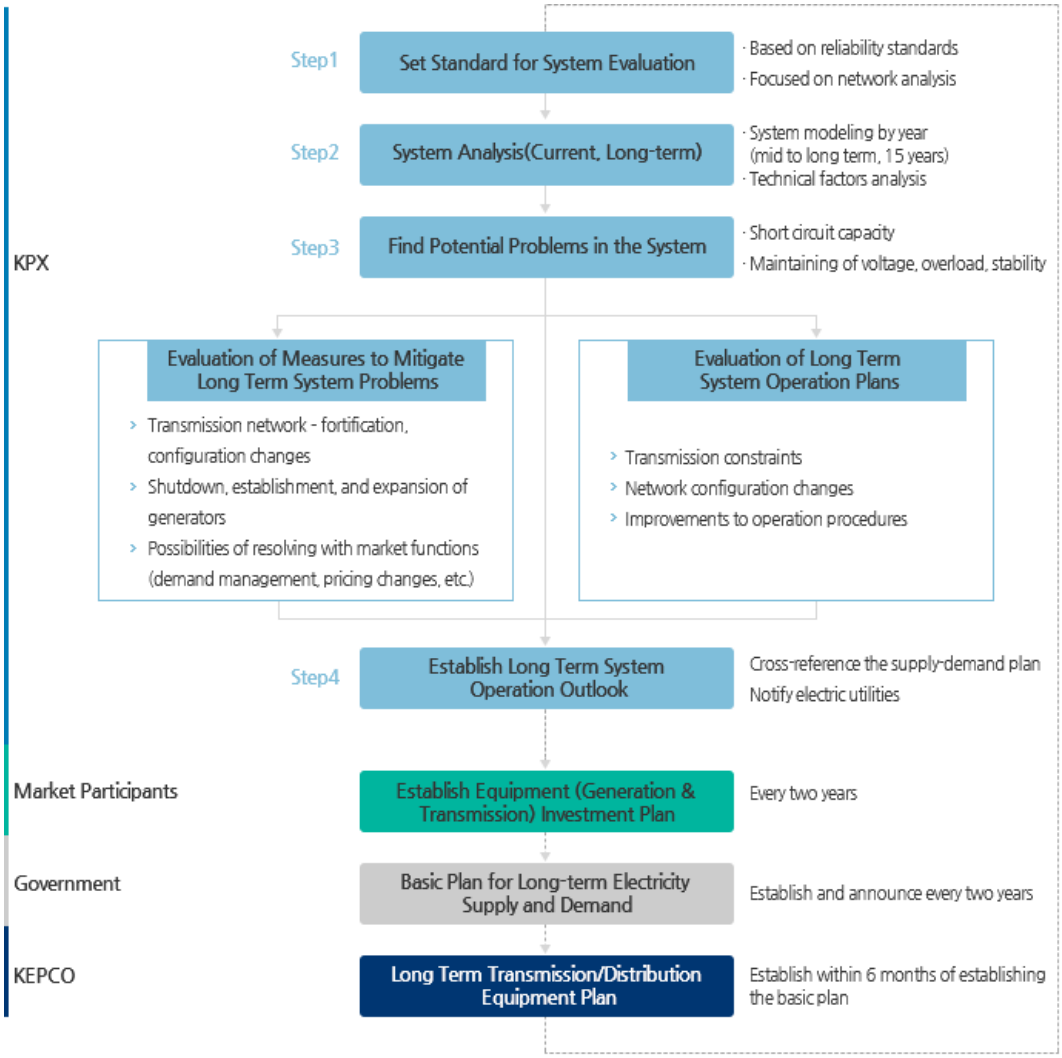
KPX establishes annual, monthly, and daily power supply and demand for efficient system operation. Economic trend and demand pattern analysis form a critical part of demand forecasting, and KPX takes a main role in setting scheduled maintenance plans for generating units.

A.4.3 Long-term Supply and Demand Planning

In support of the government's long-term electricity supply and demand planning, KPX assists the government in short- to long-term planning and in developing demand forecast modeling.

Figure 31 overlays the role of KPX in preparing the Basic Plan of Electricity Supply and Demand.

Figure 31: Process Diagram of Setting Long-term System Planning



Source: KPX

APPENDIX B: MARKET OPERATIONS SUPPLEMENTARY DATA

Table 16: Market Operations Cost Breakdown by Cost Category for Each Jurisdiction

		2016/2017	2017/2018	2018/2019	2019/2020	2020/2021
WA AEMO	Employees Benefit Expense	$5,343,827	$5,420,437	$5,317,122	$5,574,313	$5,802,618
	Accommodation Costs	$733,592	$885,471	$733,228	$621,874	$466,235
	Supplies and Services*	$4,218,896	$3,772,066	$3,274,844	$1,308,324	$1,004,834
	Borrowing Costs	$147,957	$28,114	$6,013	$7,803	$8,377
	Depreciation	$4,768,275	$3,120,054	$2,813,625	$3,049,167	$4,259,005
	IT and Telecoms	$-	$-	$-	$829,521	$719,208
	Total	**$15,212,547**	**$13,226,141**	**$12,144,831**	**$11,391,002**	**$12,260,277**
Singapore EMC	Employees Benefit Expense	$-	$10,698,485	$9,557,730	$12,761,020	$13,361,636
	Accommodation Costs	$-	$1,741,371	$1,671,508	$1,064,635	$1,600,602
	Supplies and Services	$-	$9,403,405	$7,955,043	$9,754,808	$10,751,665
	Borrowing Costs	$-	$-	$-	$-	$-
	Depreciation	$-	$5,088,558	$3,723,615	$3,730,914	$4,656,865
	Others	$-	$-	$-	$-	$-
	Total	$-	**$22,907,897**	**$26,931,820**	**$27,363,513**	**$29,529,279**
UK Elexon	Employees Benefit Expense	$23,999,857	$25,467,653	$23,471,819	$28,731,885	$30,386,156
	Accommodation Costs	$7,349,177	$7,756,187	$7,443,417	$12,243,681	$12,985,723
	Supplies and Services	$32,445,647	$32,616,524	$33,466,563	$45,196,772	$49,651,505
	Borrowing Costs	$-	$-	$-	$-	$-
	Depreciation	$-	$-	$-	$-	$-
	Others	$873,293	$873,293	$873,293	$873,293	$873,293
	Total	**$64,667,973**	**$66,713,657**	**$65,255,092**	**$87,045,630**	**$93,896,677**

Source: TLG Analysis

*Some portion of Supplies and Services will be reclassified as IT and Telecoms, a new expense category introduced in AR6.