



QUESTIONS ON NOTICE

1. COSTS ASSOCIATED WITH LACK OF VISIBILITY TO DEMAND SIGNALS BEYOND THE SWIS TRANSMISSION LEVEL AND SOLUTIONS

QUESTION ON NOTICE: (P5) - THE COSTS ASSOCIATED WITH THE LACK OF VISIBILITY TO DEMAND SIGNALS BEYOND THE SWIS TRANSMISSION LEVEL SIGNALS UNDER THE EXISTING REGULATORY FRAMEWORK SET OUT IN THE TECHNICAL RULES AND THE WEM RULES.

The CHAIR: The point you raised about responsiveness to system signals, I think, is a really interesting point to emerge from your submission; in that, at a grid scale, there can be responsiveness to signals that are being sent, but you do not have any visibility beyond transmission level. I am interested to understand the distribution scale connections. One of the things that you raise is the need to see them and then preferably to dispatch them. Could you elaborate on that a little? Maybe give us a bit of an overview of what that would take, because there is a smart meter rollout and there are a whole heap of costs as well that you have identified potentially around protection settings as these technologies come and you cannot see them and they start making the network jump around. If you could maybe give us a bit more of an understanding of what is going on at that distribution level, what you would like to see happen and what the potential costs associated with that could be, that would be great.

AEMO RESPONSE:

The costs associated with installing and operating equipment to provide visibility, coordination and control of consumer assets connected to the distribution system, and the manner in which these costs are funded, will ultimately depend on preferences regarding system security and consumer outcomes, and the role of responsible parties in achieving these outcomes.

To be able to anticipate supply and demand, AEMO (as the system operator) require visibility of system conditions and how they may change. Unlike other generation sources, such as utility-scale coal, gas, wind or solar generation, there are approximately a quarter of a million households generating electricity via rooftop solar PV systems that are not required to register with AEMO.

With increasing levels of localised, individual and relatively unpredictable generation coming into the power system, the continued safe, secure and reliable supply of electricity to consumers becomes more dependent on the visibility of these consumer assets as a generation source. However, AEMO does not typically have visibility of consumer assets connected at the sub-transmission level, and to gain this visibility could potentially entail onerous costs for AEMO and Western Power to implement.

Under the current regulatory framework, there is no general head of power that authorises either Western Power (as the network operator) or AEMO to exercise coordination and control of consumer assets in order to maintain system security in the SWIS. In addition, under the present regulatory and market frameworks, AEMO relies on the network operator to provide information in regard to connection to the power system. This means there is limited scope to collect information of the type needed to provide visibility, or for consumer assets as a generation source to be coordinated to provide safe, secure and reliable electricity to consumers.

As a first step, the party or parties who will have the authority and communication control for controlling consumer assets such as rooftop solar PV systems and/or battery storage systems must be identified (ie. consumers, Western Power, AEMO or others). The appropriate equipment can then be identified to support that party's or the parties' responsibilities. The equipment does not necessarily have to include a smart meter (which can provide some additional benefits to consumers).

Where authority and communication control is given to a party other than the asset owner, such as an aggregator, there will need to be an agreement with the asset owner (on an individually agreed basis) for control of their system.

To continue to fulfil its system operator function, AEMO would not need to have visibility, coordination and control of individual consumer assets connected to the distribution system. However, AEMO would need visibility, coordination and control at an aggregated level. At the individual level these responsibilities could sit with AEMO, the network operator or some other 'aggregator' and be managed as part of the network operator's or system operator's obligations for system security. Further work is required to determine the best approach for Western Australia that would deliver the best outcomes for consumers.

It is important to ensure that the Technical Rules and the WEM Rules address the respective functions and powers of Western Power (as the network operator) and AEMO in managing system security. For example:

- AEMO to receive, where necessary, sufficient data at the time of connection to Western Power's network to support AEMO's function of ensuring that the power system operates in a secure and reliable manner; or otherwise,
- Western Power to notify AEMO where Western Power determines that the performance of a connected asset (ie. a MicroGrid) will affect how AEMO performs its power system operation function; and
- AEMO to issue instructions to Western Power with regard to the operation of a connected asset (ie. MicroGrid); and
- Western Power and AEMO to document processes that support the day-to-day coordination of activities on the distribution and transmission networks.

Consideration must be given to preferred consumer outcomes when selecting equipment to enable visibility, coordination and control. This comes down to key policy decisions. For example, householders and businesses might be given access to technology to manage their behind-the-meter electricity usage and/or to trade their excess electricity via incentives schemes.

This cost may be imposed on customers themselves, while standards dictate which equipment is acceptable for connection and communication with the network. Individual customers might also be afforded the choice of engaging a third party who can supply technology and/or services for optimising electricity usage or arbitrage, such that the costs are carried by the third party and then passed onto consumers as part of a service fee.

To enable power system wide cost efficiencies, thought should be given to how rooftop solar PV systems and/or battery storage systems can contribute to the overall generation mix when determining solution options. In this way, consumer assets connected to the distribution system can be considered as part of planning for both supply adequacy and system security. This could replace the current arrangement of consumer assets being operated independently, with the power system being managed to mitigate the real-time impact of consumer assets on the power system. This can result in higher system costs which may then be passed on to all consumers.

For example, excess energy produced during low demand periods by rooftop solar PV systems might be aggregated within a MicroGrid or virtual power plant by a third party. The third party might store this excess electricity in a battery storage system and then release it back to the grid for use during peak periods under contract, through the energy market (including for ancillary services), or as part of a capacity obligation.

Given the range of policy options and potential technology deployments it is difficult to determine the total cost to enable visibility, coordination and control of DER. Table 1 below outlines where costs are likely to be incurred where the solution option sees AEMO, Western Power or some other third party carrying out the role of the aggregator, and where the asset owner (of the inverter for a solar rooftop PV system, battery or other DER) is either the end-consumer or



aggregator.

The table also highlights that technology manufacturers will necessarily play an important part in enabling the visibility and control of MicroGrids. As it is assumed AEMO will retain the system operator function and will continue to leverage existing communications and coordination / control systems with Western Power, these costs are not identified in the table.

Table 2 below outlines where costs are likely to be incurred for the implementation of smart meters as a means of supporting consumer choice, through the provision of real-time electricity usage information to the end-consumer and also consumption data ultimately provided to the electricity retailer (or aggregator). Smart meters record information and so are dependent on the quality of the communications to determine if they are sufficient for the system operator or network operator to manage system security. Therefore, smart meter coordination may be limited to a retail tariff offering and an additional controller would be required to enable the consumer to maximise their outcomes (ie. to allow demand management). The costs associated with a smart meter are separate to those to enable visibility, coordination and control of the DER.

Table 1 – Indicative requirements on relevant parties to accommodate the visibility, coordination and control of MicroGrids for system security

Technology required		Aggregator			Asset-owner		Technology Manufacturer (Inverter)	
		AEMO	Western Power	Third Party	End-consumer	End-consumer / Aggregator	Hardware	ICT
					Existing inverter	New inverter		
S Y S T E M S E C U R I T Y	<i>Secure communications (software and hardware)</i>	No cost (existing) • SCADA system • Remote Terminal Unit (RTU) Costs • Interface with inverter manufacture's database/server and use of data – new inverters or • Interface with third party RTU	No cost (existing) • SCADA system • RTU Costs • Interface with inverter manufacture's database/server and use of data – new inverters or • Interface with third party RTU	Costs • Install RTU • RTU integration with AEMO's / Western Power's SCADA systems • Interface with inverter manufacture's database/server and use of data – new inverters • Systems for load and consumption estimation and forecasting– existing inverters	• Cannot be reconfigured for secure communications for visibility • Retrofitting hardware or software is either not possible or prohibitively expensive	Costs • Purchase / use of inverter manufactured to updated technical standard to enable secure communications for visibility	Costs • Manufacture inverters to updated technical standard to enable secure communications for visibility • Inverter must be capable of SCADA system integration	Costs • Maintain database/server for data that is to be made available to aggregator • Database/server must be capable of linking to the aggregator's RTU
	<i>Control / coordination platform</i>	No cost (existing) • SCADA system • XA/21 Costs • Interface with third party control platform	No cost (existing) • SCADA system • XA/21 Costs • Interface with third party control platform	Costs • Install internet capable control platform • Control platform integration with AEMO's / Western Power's SCADA systems	• Cannot be reconfigured to enable control • Retrofitting hardware or software is either not possible or prohibitively expensive	Costs • Purchase / use of inverter manufactured to updated technical standard to enable control	Costs • Manufacture inverters to updated technical standard to enable control • Control platform must be capable of SCADA system integration	N/A
	<i>Protection systems</i>	Potential costs • When required for system level protection, circuit breakers, relays and sometimes communications (ie. inter-tripping schemes)	Potential costs • When required, circuit breakers, relays and sometimes communications (ie. inter-tripping schemes)	Potential costs • When required, circuit breakers, relays and sometimes communications (ie. inter-tripping schemes)	No additional cost – required as part of existing inverter technical standard	No additional cost – required as part of existing inverter technical standard	No additional cost – required as part of existing inverter technical standard	N/A

Table 2 – Indicative requirements on relevant parties to accommodate the visibility, coordination and control of MicroGrids for consumer choice

Technology required		Provider			Asset-owner		Technology Manufacturer (Smart Meter)	
		AEMO	Western Power	Third Party	End-consumer	End-consumer / Provider	Hardware	ICT
					Existing smart meter	New smart meter		
<i>C O C N H S O U I M C E E R</i>	<i>Smart Meter</i>	<p>No cost for smart meter</p> <p>Potential costs</p> <ul style="list-style-type: none"> Improvements to market settlement systems 	<p>Costs</p> <ul style="list-style-type: none"> Dependent on the capabilities of the smart meter Controller to enable demand management If aggregator, interfaces with systems for secure communications and control / coordination platform 	<p>Costs</p> <ul style="list-style-type: none"> Dependent on the capabilities of the smart meter Controller to enable demand management If aggregator, interfaces with systems for secure communications and control / coordination platform 	<p>Potential costs</p> <ul style="list-style-type: none"> Dependent on the capabilities of the smart meter Controller to enable demand management 	<p>Costs</p> <ul style="list-style-type: none"> Dependent on the capabilities of the smart meter Controller to enable demand management 	<p>Costs</p> <ul style="list-style-type: none"> Manufacture smart meter to a required technical standard (to enable prescribed capabilities) 	<p>Costs</p> <ul style="list-style-type: none"> Maintain database/server for data that is to be made available to the retailer or the aggregator Database/server must be capable of linking to the retailer's or the aggregator's RTU

2. FUNCTIONAL BOUNDARY – AEMO AND WESTERN POWER

QUESTION ON NOTICE: (P13) - FURTHER INFORMATION ABOUT THE OVERLAP OF TECHNICAL AND OPERATIONAL FUNCTIONS AND RESPONSIBILITIES BETWEEN AEMO AND WESTERN POWER IN THE SWIS.

The Chair: ...In your submission, you talk about the overlap of functions and responsibilities between AEMO and Western Power. From a technical operational sense, we would really appreciate a bit of an overview of that. We do not have the time, unfortunately, today, but if you could take that on notice, and perhaps also give us some thoughts on how overlapping could be resolved, it would be fantastic...

AEMO RESPONSE:

As the South West Interconnected System (SWIS) accommodates higher levels of Distributed Energy Resources in various configurations, including MicroGrids (and potentially Virtual Power Plants), the functional boundary between AEMO and Western Power as prescribed under the current regulatory framework is unlikely to support the effective management of power system security and supply reliability.

Where obligations are unclear or unallocated, the result can be uncertainty regarding how and when the parties must coordinate to deal with operational matters (particularly those affecting the transmission system and the distribution system simultaneously) and the longer term needs of the SWIS. Greater clarity will lead to process efficiencies and transparency, potentially reducing commercial risk for industry participants.

The current regulatory regime may be characterised as fragmented, complicated and uncoordinated in the sense that its operation relies on (the sometimes tenuous interlinkages between) many different instruments. The partial implementation of the previous state government's electricity reforms complicated matters further by either creating, or exacerbating, misalignment in the role responsibilities of AEMO and Western Power in regard to the secure and reliable operation of the power system - albeit implementation of the full reform was intended to resolve a number of these issues.

The new state government's reform program for constrained network access and Wholesale Electricity Market (WEM), when fully implemented, will largely address this misalignment. The future generation mix in the SWIS, which will include MicroGrids (and potentially Virtual Power Plants) will also necessitate more coordinated action and information flows between parties in regard to the boundary between power system operation and network operation than is presently the case. AEMO is currently assisting the Public Utilities Office as part of the reform process and as part of other initiatives to help determine the regulatory, operational and technical changes needed to support the future generation mix.

The following is a summary of the overlaps and gaps in the functional boundary between AEMO and Western Power under the current regulatory framework:

- There is a misalignment of role responsibilities for AEMO and Western Power under the Technical Rules as the consequence of partially implemented reform.
 - Revision to the frameworks for exemptions, performance standards, non-compliance and power system stability co-ordination require consequential changes to account for the power system operation function transferring to AEMO from Western Power in 2016.
 - AEMO is now subject to requirements imposed by the Technical Rules, but has no means to propose a change to that instrument.
- There are insufficient linkages between the WEM Rules, the Technical Rules and other relevant instruments. Consequently, the role responsibilities of AEMO and Western Power in relation to 'reliability' are unclear. This lack of clarity may not (and in some cases has not) been conducive to timely and efficient decision-making processes in relation to power system operation and wholesale market operation.

For example:

- Network reliability is not incorporated into processes to enable AEMO's shorter-term and real-time assessments of reliability of supply;
 - It is not clear which party is responsible for managing various matters on the distribution network that can ultimately effect the secure operation and reliability of the power system;
 - Not all operational scenarios are adequately addressed with regard to ensuring reliability of supply¹;
 - The current instruments are unlikely to contain sufficient prescription to accommodate Western Power's new business model under proposed changes to its access arrangement for 1 July 2017 to 30 June 2022 (AA4), and the impact of the changes on AEMO's responsibility specifically in relation to reliability of supply where there is less investment in 'poles and wires'.
- There is currently no scope in the regulatory framework for any party to undertake long-term power system planning for the SWIS, which increases uncertainty and precludes market information needed for long-term investment.
 - Western Power is fully responsible for generator connection, generator connection standards, generator technical compliance and transmission grid performance standards even though the outcomes of these responsibilities directly affect AEMO in the performance of its functions².

Regulatory amendment is required to allow AEMO and Western Power to implement appropriate technical and operational remedies, and provide them with suitable protections under legislation.

AEMO understands that the Public Utilities Office, as part of constrained network access and WEM reforms, will be working with industry to define the relationship, scope of functions (responsibilities and accountabilities) of AEMO and Western Power in regard to 'reliability'. This will ensure a consistency of approach and nomenclature for amendments made across the various instruments in the regulatory framework.

Subsequent actions might include:

- Amending the Technical Rules so that:
 - Requirements placed on Western Power (network service provider) and AEMO (as the power system operator) are aligned with the scope of functions for each party. Where requirements are imposed on both parties with regard to the same subject-matter, there must be sufficient detail regarding the coordination of activities, notifications and sharing of information.
 - Requirements to facilitate the visibility of technology connected to the network, to support aggregation and/or coordination by a third party.
- Amending the WEM Rules so that:
 - There are clear responsibilities on parties for the day-to-day coordination of transmission and distribution system operation for system security.
 - There are clear standards, processes and interventions in support of reliability of supply.
 - There is sufficient prescription on scope of activities to be undertaken by the distribution system operator, where such a new function is conferred.
 - There is sufficient prescription for scope of activities to be undertaken for long-term power system planning, where such a new function is conferred.

¹ Such as the resolution of a reliability of supply issue that can arise despite both parties are fulfilling their obligations under the Technical Rules and WEM Rules ie. Eastern Goldfields islanding event.

² In the National Electricity Market, Chapter 5 of the National Electricity Rules places obligations on AEMO for these functions.

- The development of amendments to the Technical Rules and the WEM Rules must be concurrent to accommodate linkages between the two instruments.
 - To provide for sufficient authorisations to enable any information collected by Western Power at the time of network connection to be used (to the extent necessary) under the WEM Rules by AEMO for power system operation. Such an arrangement will minimise the initial and on-going impost on network users for information provision.
 - To place clear requirements on the relevant parties to resolve reliability of supply and system security issues as they arise in real-time.
 - To transfer the accountability for generator connection standards and transmission grid performance standards, and for compliance monitoring of those standards, to AEMO.
- Options for a new change mechanism for the Technical Rules include:
 - Amend clause 12.50 of the Electricity Networks Access Code 2004 to enable AEMO to submit proposed changes to the Technical Rules.
 - Amend the Energy Industry (Rule Change Panel) Regulations 2016 to authorise the Rule Change Panel to administer the Technical Rules change process in addition to the WEM Rules change process. This will allow AEMO to submit proposed changes to the Technical Rules.
 - Amend the Technical Rules to carve out those clauses that place requirements on “System Management” (which is the term used to refer to AEMO’s power system operation function) and transfer those clauses to a new or existing instrument (ie. the WEM Rules).
- Amend legislation and/or subordinate legislation to ensure there are sufficient:
 - heads of power for any revised scope of functions of the relevant parties;
 - statutory protections;
 - cost recovery arrangements;in place for any new or revised activities of the relevant parties.

ADDITIONAL COMMITTEE QUESTIONS

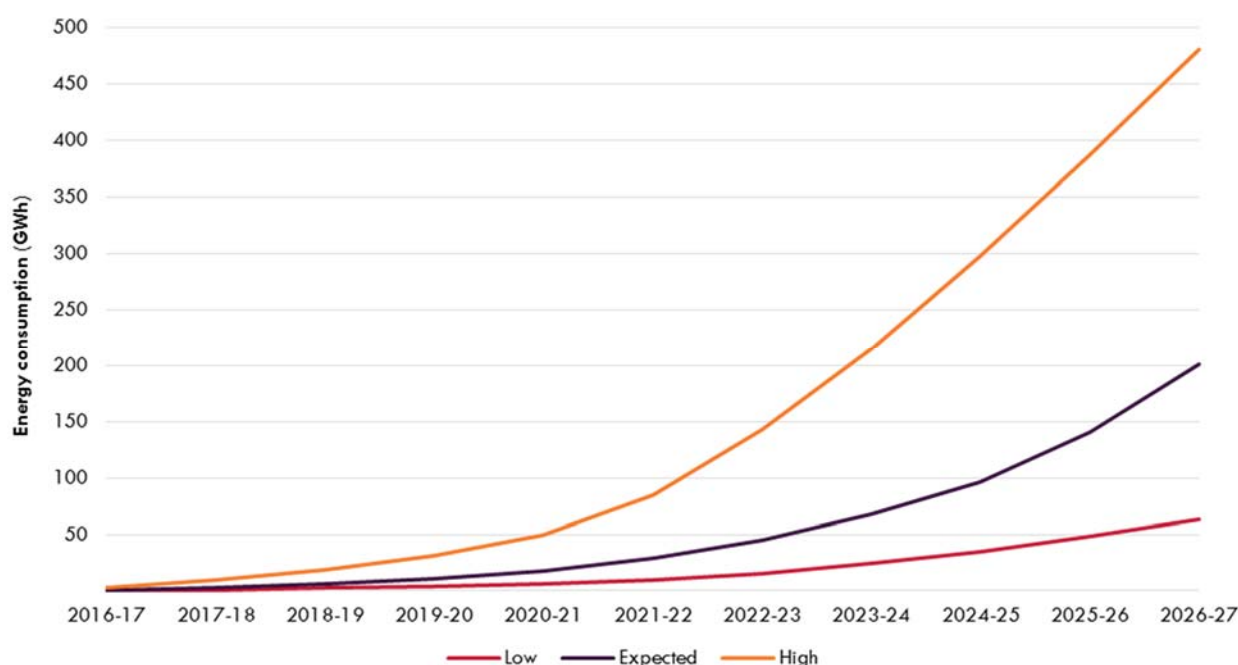
1. ESTIMATE OF ENERGY FOR ELECTRIC VEHICLES TO 2026

FURTHER INFORMATION: YOUR ESTIMATE OF THE POWER REQUIRED FOR ELECTRIC VEHICLES IN WA BY 2026 (GRAPH PAGE 8) SHOWS A LARGE DIFFERENCE BETWEEN THE LOW AND HIGH ESTIMATES- BASED ON AN AUGUST 2016 REPORT- DO YOU HAVE A MORE RECENT ESTIMATE OF FUTURE EV UPTAKE IN WA?

Electric vehicles

Figure 3 on page 8 of AEMO's submission (replicated below) shows a large difference between the low and high estimates for Electric Vehicle (EV) energy consumption as set-out in AEMO's 2017 Electricity Statement of Opportunities (ESOO).

Figure 3 - Electric vehicle contribution to operational consumption, 2016-17 to 2026-27 financial years



For the 2017 ES00³, the EV forecasts were based on the *AEMO Insights: Electric Vehicles* paper, developed by Energeia⁴. The range between the high and low forecasts for EV is relatively wide, due to uncertainty as noted in the executive summary of the Energeia paper:

More importantly, there are major uncertainties affecting the emergence of EVs that need to be investigated to better appreciate their likely impact on the energy system. These include:

- *The design, technology, and commercialisation of future public charging infrastructure.*
- *Potential development of government policies affecting transport, such as transportation fleet energy efficiency standards or local policy measures that further support EV uptake.*
- *Price and tariff structures to accommodate electric vehicles.*

³ AEMO (2017) 2017 Electricity Statement of Opportunities for the Wholesale Electricity Market, June. The report is available at - https://www.aemo.com.au/-/media/Files/Electricity/WEM/Planning_and_Forecasting/ES00/2017/2017-Electricity-Statement-of-Opportunities-for-the-WEM.pdf

⁴ AEMO and Energeia (2016) AEMO Insights: Electric Vehicles, August, pgs. 3-4. The report is available at - http://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEFR/2016/AEMO-insights_EV_24-Aug.pdf

- Heavy transport, which was outside the scope of the study.
- The role of electric vehicles in the future power grid, in particular their contribution of energy storage to households and the grid, and their contribution of network support services to address the management of frequency, energy, and voltage.

Over a 20-year projection, differences between actual and assumed incentives could shift operational consumption projections by more than the 3.8% total EV impact now forecast. These EV projections factor in the assumptions in the 2016 NEFR's strong and weak sensitivities to explore some of this uncertainty, resulting in variations in the projections of 20-year forecast growth in operational consumption from EVs of 6.2% and 2.4% respectively.

Table 2.1 in Section 3.2 of the Energeia paper contains the assumptions, which are NEM-based, but are also generally applicable to the WEM:

3.2 EV Sensitivities

The sensitivities adopted for the EV insights align with AEMO's 2016 NEFR sensitivities and include the additional considerations listed in Table 2.

Detailed assumptions underpinning the EV sensitivities are provided in Appendix A.

Table 2 – Additional EV Sensitivity Drivers

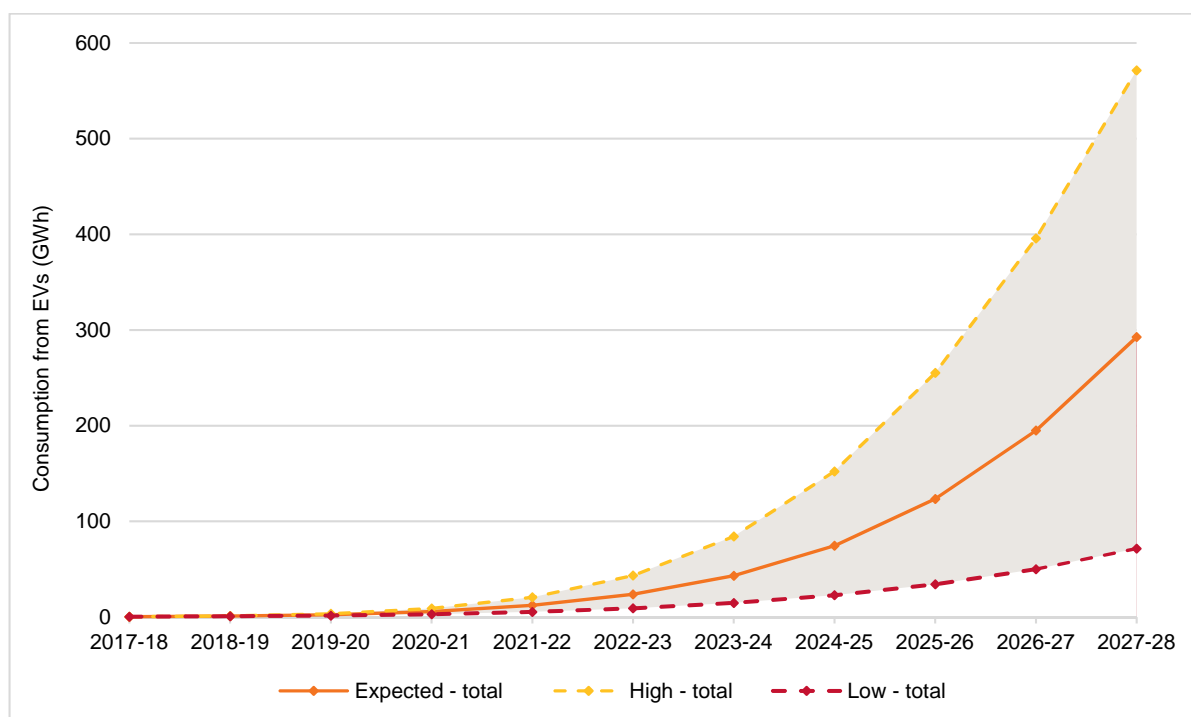
Driver	Weak Sensitivity	Neutral Sensitivity	Strong Sensitivity
Electric Vehicle Premiums	Reduce slowly (aligned to NEFR 2016 battery storage prices as per Appendix A)	Reduce at neutral rate (aligned to NEFR 2016 battery storage prices as per Appendix A)	Reduce quickly (aligned to NEFR 2016 battery storage prices as per Appendix A)
Tariff Settings (Home Charging)	Current controlled load tariffs (generally allowing overnight charging only)		
Tariff Settings (Fleet Charging)	Current business tariffs (allowing anytime charging)		
Model Availability	Capped at 35% of models in 2036	Capped at 55% of models in 2036	Capped at 75% of models in 2036
Vehicle Emission Standards	Commonwealth Government introduces international best practice emission standards (as fleet wide target) by 2030*	Commonwealth Government introduces international best practice emission standards (as fleet wide target) by 2026*	Commonwealth Government introduces international best practice emission standards (as fleet wide target) by 2022*
Carbon Price Application to Fuel Purchases for Passenger Vehicles	Passenger vehicles are exempt	Passenger vehicles are exempt	Applies from 2020 as per main NEFR sensitivities
Indirect EV Policy Support	None	Priority Lanes and Parking	Priority Lanes and Parking

* A fleet wide standard has been assumed, rather than a minimum performance standard, as the most economically efficient means of achieving best practice greenhouse gas emission

For comparative purposes, Figure 1 below shows an estimate of EV uptake based on the most recent data in AEMO's 2018 ESOO⁵. The EV forecasts were developed by ACIL Allen based on the EV uptake outlook and projection of the market share of EVs, using a logistical model.

⁵ AEMO (2018) 2018 Electricity Statement of Opportunities for the Wholesale Electricity Market, June. The report is available at http://wa.aemo.com.au/-/media/Files/Electricity/WEM/Planning_and_Forecasting/ESOO/2018/2018-WEM-ESOO-Report.pdf.

Figure 1 - Electric vehicle contribution to operational consumption, 2017-18 to 2027-28 financial year



The forecasts of EV uptake numbers were developed under the low, expected, and high growth scenarios, taking into account different population forecasts and EV cost reduction rates. The high-level assumptions used to forecast EV uptake are shown in Table 1 below.

Table 1 - EV uptake forecast - main assumptions

Assumption	Low scenario	Expected scenario	High scenario
Population	Low forecast scenario	Medium forecast scenario	High forecast scenario
Real percentage decline in EV costs	4%	7.5%	9%
Average distance travelled per day (km)	36.4	36.4	36.4
EV Range increase per year	3%	3%	3%

The EV proportion of the stock of registered vehicles was projected to reach 1.6%, 10.9%, and 19.4% by 2028 under the low, expected, and high growth scenarios respectively.

Projections for EV uptake assumed a slow start, due to limited infrastructure, the narrow range of models currently available, and the cost relative to conventional petrol or diesel vehicles. The market share of EVs has been projected to undergo a rapid growth phase driven by improvements in the relative financial attractiveness of EVs from the late 2020's.

The range between the high and low forecasting scenarios is relatively wide. This is partly due to uncertainty regarding decisions on industry policy, such as vehicle fleet emission standards, which could influence the EV uptake rate.



EV energy consumption is forecast to be 293 GWh by the 2027-28 financial year under the expected scenario, accounting for approximately 1.5% of total operational consumption. Under the high and low scenarios, EV energy consumption is forecast to reach 571 GWh (2.8%) and 72 GWh (0.4%) by the 2027-28 financial year respectively.

EVs are assumed to have a negligible impact on peak demand over the 10-year forecast period in AEMO's 2018 ESOO. The basis for this assumption is that new tariff structures are expected to discourage the charging of EVs during peak demand times, and the charging of EVs is unlikely to affect peak demand until there is a significant increase in the number of EVs in use. Synergy launched an EV home tariff plan in November 2017 to encourage charging of EVs during off-peak demand times (23:00 to 04:00 daily).

2. LEVEL AT WHICH NON-SYNCHRONOUS GENERATION CAPACITY CAN BE ACCOMMODATED BEFORE SWIS POWER SYSTEM SECURITY ISSUES ARISE (INCLUDING WORST-CASE SCENARIO)

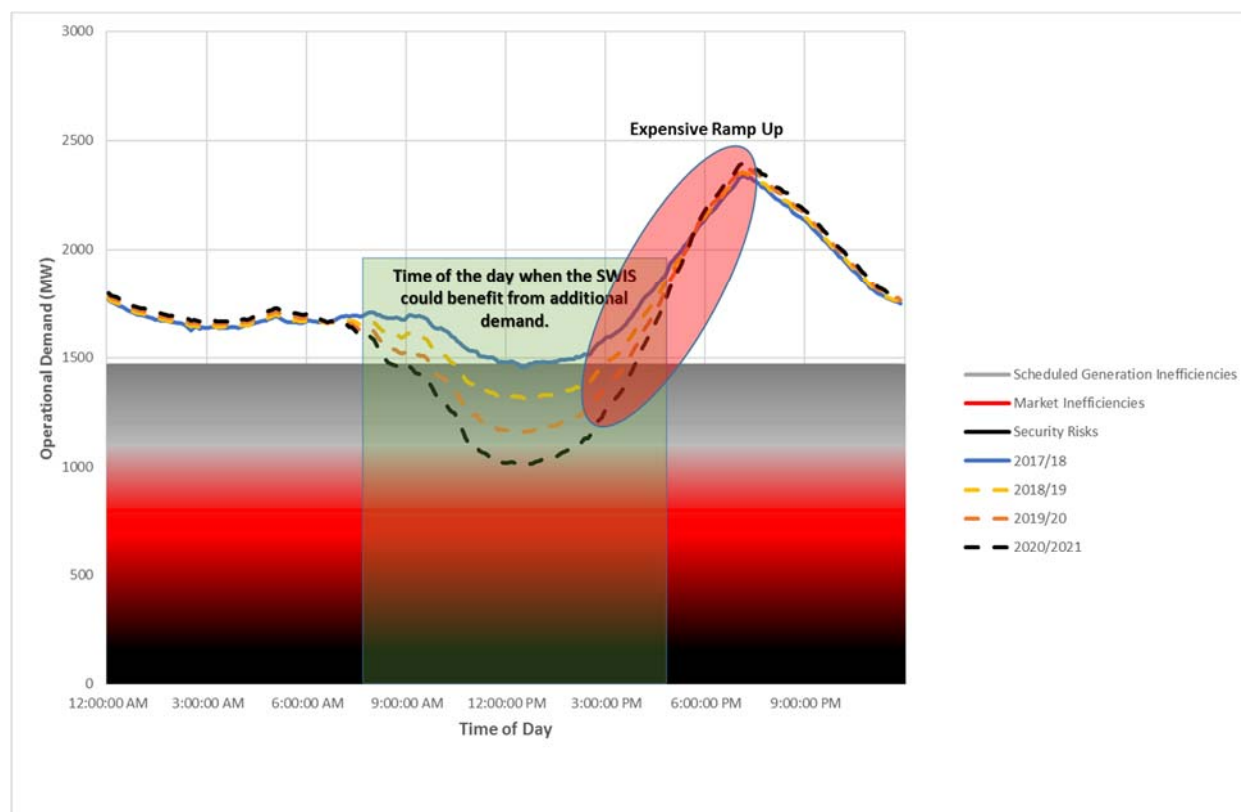
FURTHER INFORMATION (QUESTION 2): AEMO IS UNDERTAKING STUDIES (PAGE 16) TO “IDENTIFY THE LEVEL OF NON-SYNCHRONOUS GENERATION CAPACITY THAT CAN BE ACCOMMODATED IN THE SWIS BEFORE POWER SYSTEM SECURITY ISSUES ARISE”- WHEN WILL THESE STUDIES CONCLUDE AND WHAT RECOMMENDATIONS TO THE OPERATION OF THE SWIS AND THE INPUT BY DER DO YOU THINK IT MIGHT MAKE?

FURTHER INFORMATION (QUESTION 4): YOUR SUBMISSION (PAGE 19) SAYS THAT “THE WORST CASE OUTCOME OF SUCH A SCENARIO [LOW DEMAND SUNNY DAYS] IS A TOTAL SYSTEM BLACKOUT. THIS POINT MAY NOT BE FAR AWAY.” WHAT IS THE SOONEST DO YOU THINK THAT WA MIGHT FACE THIS SCENARIO?

Scenario - sunny day with low demand

The pattern of daily operational demand that is managed in real time by AEMO system controllers is changing, as shown in Figure 2 below, which depicts the ‘Duck Curve’. This demand profile is experienced more often during low-load days, typically a sunny autumn or spring weekend day, when solar rooftop PVs and the larger utility-scale solar systems are at maximum production within the SWIS.

Figure 2 – Typical ‘duck curve’ demand profile



The key challenge for the system operator is to lower scheduled generation (generally the fossil fuel generators) to minimum midday demand, then transition (ramp up) to the evening peak period. This period is characterised by almost no solar generation, and the situation may become more challenging as the result of limited wind generation during still afternoons during the solar ramp down.

There are three key operating zones shown in Figure 2:

- **Grey zone:** Baseload generation (mainly coal units) have a minimum generation limit below which they cannot generate. Also, baseload units are by design not built to cycle significantly up and down during the day, as this will cause mechanical and thermodynamical stress to their equipment in the long run and compromise cost efficiency and reliability in their operation.

Where baseload units are required to go below their minimum generation limit or the ramping is significant, they may choose to shut down operation and then restart in a few days' time. However, there are start-up efficiency and reliability impacts. The combination of all these issues is represented by the grey zone and is expected to increase costs for existing generators that would be expected to eventually be passed on to consumers⁶.

- **Red zone:** Synchronous machines (mainly fossil fuelled plants) that are connected to the power system provide kinetic inertia and system strength (known as stored energy). These things enable the power system to withstand disturbances and unplanned contingencies and to maintain frequency and the voltage within the required acceptable range dictated by the technical standards. The red zone in Figure 2 shows the potential limitations of minimum inertia that is required within SWIS at low-load periods, and may require AEMO to dispatch off asynchronous (eg. inverter-connected wind farm) generators.

Under the present wholesale market arrangements, those generators constrained off would generally be paid as if they were still running, which results in additional cost to the market. There are many factors that impact the maximum amount of asynchronous generation including the type and characteristics of the on-line thermal generation and system loading.

- **Black zone:** Power system operation below the red zone is presently unsustainable as would raise a high risk of significant system security and reliability issues.

It is very important to note that these three zones are indicative and assume no changes to the current technologies and market constructs employed in the SWIS for generation, ancillary services, monitoring and control of the existing generating fleet and DERs and MicroGrids.

The decreasing midday minimum load curves year-on-year show that AEMO is already facing de-commitment of baseload units on mild sunny weekend days, requiring AEMO to cycle these units from their minimum generation level to their efficient generation level in the evening in order to ramp up to the peak demand.

If the 'duck belly' continues to grow deeper, it can be expected that challenges to maintaining sufficient inertia within the SWIS will manifest with reasonably regular occurrence within three to five years. It is anticipated that, during periods of high solar generation, AEMO (as the system operator) may need to curtail inverter-based utility-scale wind farms and solar generation to enable a minimum amount of synchronous generation to stay online to ensure system inertia requirements are met.

Ultimately, if turning off utility-scale renewables is insufficient to ensure that the SWIS operates securely and reliably, rooftop solar PV systems may need to be controlled. Technologies such as smart meters are key enablers, allowing DERs to be monitored and, if necessary, turned down for security purposes. Demand response (when there is significantly increased demand during the day) and deployment of battery storage would be other potential solutions. As per AEMO's submission, changes are required to the regulatory framework, and market and technical arrangements, to facilitate these alternative solutions and opportunities.

⁶ Increasing levels of zero marginal cost renewables would be expected to put downward pressure on electricity prices. Extensive market modelling would be required to determine the overall impact on price.

Non-synchronous generation study

AEMO commissioned GHD in late 2017 to assess the impact of the increased level of non-synchronous generation on the security of the SWIS. Specifically, this study was performed to identify tipping points for system security, that is, to evaluate whether SWIS power system security might be at risk if the level of non-synchronous generation exceeds some critical capacity threshold.

Figure 2 incorporates the findings from the study for an indicative low demand, sunny day. The red zone illustrates the area where potential security issues may arise, and concurrently, identifies the level at which non-synchronous generation capacity can be accommodated before there is a high risk that security issues may arise. Due to the significance of this study and the recommended solutions in the study report, AEMO is currently conducting a peer review and will then share the outcomes with industry participants.

In the meantime, AEMO is working on initiatives to address the emerging opportunities and challenges resulting from DERs and the increased level of non-synchronous generation within the SWIS. These include:

- Developing a real-time inertia monitoring tool to enable the system operator to monitor risk, plus operational procedures to deal with power system conditions with low inertia levels.
- Actively monitoring the development of new technologies, particularly energy storage facilities.
- Working with Western Power to ensure its smart meter rollout includes future-proofing technologies that will facilitate Western Power and AEMO to actively monitor, coordinate and potentially control DERs in real time.

The low-cost energy produced by DERs during the middle of the day, which causes a downward pressure on wholesale electricity prices and operational challenges to AEMO (as the system operator), can also provide opportunities for policy-makers and industry. For example, excess energy produced during low demand periods might be bought and stored and then released back to the grid for use during peak periods as part of energy arbitrage. This could create more operational demand for synchronous generators to stay online and avoid the de-commitment and cycling of baseload generation, which will also ensure sufficient inertia is maintained within the system. The aggregation of DERs can also present an opportunity to provide ancillary services and thus increased competition, the prices of which have generally increased year on year.

3. STANDARDS FOR ROOFTOP SOLAR PV SYSTEMS

FURTHER INFORMATION: IN TERMS OF THE SAFETY OF ROOFTOP SYSTEMS, YOUR SUBMISSION SAYS (PAGE 17) “ROOFTOP SOLAR PVS SYSTEMS WERE NOT REQUIRED TO BE MANUFACTURED TO A SPECIFIED STANDARD IN REGARD TO THEIR RESPONSE TO POWER SYSTEM FREQUENCY DISTURBANCES.” WHAT PROPORTION OF THE ROOFTOP PV PANELS IN WA WERE MANUFACTURED BEFORE 9 OCTOBER 2016, WHEN AS4777.2-2015 COMMENCED OPERATION?

Rooftop solar PV inverters installed before 9 October 2016 were required to meet an earlier version of Australian Standard 4777 (AS4777–2005) that did not require a standardised response to system frequency. Consequently, inverters were sold with a broad range of default settings for under-frequency protection. This standard specifies the electrical installation requirements for inverter energy systems and grid protection devices with ratings up to 10kVA for single-phase units, or up to 30kVA⁷ for three-phase units, for the injection of electric power through an electrical installation to the electricity distribution network⁸.

Using data from the Clean Energy Regulator (CER), AEMO’s report *Response of Existing PV Inverters to Frequency Disturbances*⁹ dated April 2016 found that there was 451 MW of installed small-scale solar PV systems registered with the Clean Energy Regulator in the SWIS as at May 2015. As part of AEMO’s report, manufacturers provided data for frequency trip settings for 166 MW (37% of the total).

The normal operating frequency band (NOFB) for the SWIS is between 49.8Hz and 50.2Hz, and the single contingency frequency band is 48.75Hz to 51Hz¹⁰. With respect to these bands:

- Of the 166MW, for under frequency:
 - Approximately 17.9% of the inverters would disconnect at 48.75Hz (at the lower band of the NOFB for a credible generation event). This equates to around 29.8MW.
 - 100% would trip at < 47Hz.
- Of the 166MW, for over frequency:
 - Approximately 6.5% of the inverters would disconnect at 50.99Hz (at the upper band of the NOFB for a credible generation event). This equates to around 10.9MW.
 - 100% would trip at > 52Hz.

The findings may theoretically be extrapolated to the entire 451 MW, such that:

- 81MW of 451MW will likely trip for an under frequency event (single contingency).
- 29.3MW of 451MW will likely trip for an over frequency event (single contingency).

⁷ kVA (kilovolt-ampere) is a measure of ‘apparent power’ which is the product of volts (electrical pressure) and amps (electrical current).

⁸ See <https://ablis.business.gov.au/service/ag/australian-standard-as-4777-2005-grid-connection-of-energy-systems-via-inverters/31064>

⁹ Data provided by Western Power allowed off-grid PV to be excluded from the analysis for the SWIS. See <http://www.aemo.com.au/-/media/Files/PDF/Response-of-Existing-PV-Inverters-to-Frequency-Disturbances-V20.ashx>

¹⁰ See clause 2.2.1 of the Technical Rules.

Publicly-available CER data shows that 212,001 rooftop solar PV systems were installed in Western Australia (including, but not limited to, the SWIS¹¹) from 2001 to end-September 2016¹² under the Small-scale Renewable Energy Scheme^{13,14}.

More recently, AEMO has estimated (from CER data) that of the one million residential customers, more than a quarter (approximately 256,417) have rooftop solar PV systems installed, presently accounting for approximately 883MW of installed capacity in the SWIS¹⁵.

A 12-month transition period enabled inverters compliant with either AS4777.1–2005 or AS/NZS 4777.2–2015 to be installed. Therefore, if the ‘worst case scenario’ is assumed, where solar rooftop PV systems that are compatible with the earlier version of the standard were being installed right up until 9 October 2016, then:

- The portion of rooftop PV panels in the SWIS today that were manufactured in accordance with the earlier version of the standard and installed before 9 October 2016 would be around 82.7%.

The impact on the power system of solar rooftop PV systems installed in accordance with the earlier version of the standard, however, is material but manageable. The *relative level* of tripping off for over and under frequency (single contingency) events is likely to be:

- 130MW (or 14.7%) of the 883MW currently installed for an under-frequency event.
- 47.5MW (or 5.4%) of the 883MW currently installed for an over-frequency event.

As penetration of rooftop PV systems continues to grow, to avoid potential system issues it is necessary for all rooftop solar PV systems to stay connected to the network down to the lowest required frequency range (other SWIS generators must retain output down to 47Hz), and reduce output during periods of excessive over frequency (that is, when there is too much generation).

Standards Australia, with input from industry and AEMO, has revised the requirements for inverters used to connect small-scale PV systems and other technologies such as battery storage. The revised standard (AS/NZS 4777.2–2015) was published on 9 October 2016 and set requirements for inverters installed into the future. The new standard did not enforce any retrofitting of requirements to existing inverters.

All inverters installed from 9 October 2016 need to be fully compliant with AS/NZS 4777.2–2015, requiring that the PV system is capable of:

- zero-export to maintain the frequency (to avoid over-frequency); and
- remaining connected to the network for frequencies in the range of 47Hz to 52Hz.

There is almost twice as much installed capacity today attributable to rooftop solar PV systems compared to May 2015. The *relative level* of tripping off for over and under frequency events is not expected to worsen in future as the new standard (AS4777.2-2015) has come into operation.

¹¹ The inclusion of rooftop solar PV systems connected outside of the SWIS does not make a material difference to the calculations.

¹² See <http://www.cleanenergyregulator.gov.au/Infohub/Media-Centre/Pages/Resources/RET%20media%20resources/Cracking-the-small-scale-code---September-2016.aspx>

¹³ See <http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Small-scale-Renewable-Energy-Scheme>. To be eligible for small-scale technology certificates, small generation units (including solar photovoltaic panels, wind turbines, and hydro systems) must:

- be installed no more than 12 months prior to the creation of certificates, and have its panels and inverter, listed on the [Clean Energy Council list of approved components](#);
- meet Australian and New Zealand standards;
- use a [Clean Energy Council accredited designer and installer](#) and meet the [Clean Energy Council design and install guidelines](#)
- comply with all local, state, territory and federal requirements, including electrical safety; and
- be classified as small-scale, and a:
 - solar panel system that has a capacity of no more than 100kW, and a total annual electricity output less than 250MWh
 - wind system that has a capacity of no more than 10kW, and a total annual electricity output of less than 25MWh, or
 - hydro system that has a capacity of no more than 6.4kW, and a total annual electricity output of less than 25MWh.

¹⁴ This increased to 249,457 solar PV systems to end-December 2017. See <http://www.cleanenergyregulator.gov.au/Infohub/Media-Centre/Pages/Resources/RET%20media%20resources/Cracking-the-small-scale-code---December-2017.aspx>

¹⁵ AEMO (2018), *MicroGrids and Associated Technologies: Opportunities and challenges for power system and market operation*, Submission to the Economics and Industry Standing Committee, April, p.12.



This example highlights the necessity of moving quickly to identify technical challenges to the power system stemming from the take-up of new technology. As new installations are occurring daily, implementing standards and/or revising existing standards must be done in a timely manner in order to reduce any costs of retrofitting new technical capabilities.