Benefits of CER Compliance

CER Technical Standards

Australian Energy Market Commission | 23 Aug 2023

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Executive summary

AEMO and other parties have previously identified market and network issues that have resulted from poor compliance with the current inverter standard in relation to distributed Photo-Voltaic (DPV) generation in AS/NZS 4777:2020 (the 2020 standard), which came into effect in December 2021.

The AEMC reviewed the issue of non-compliance, deriving a series of recommendations[1], and requested Oakley Greenwood to provide a report (this report) that estimates the benefits of compliance with its recommendations.

While there is a range of factors that will increase the compliance of inverter installations[2], the benefits of compliance are shown to be strongly positive.

The benefits of improved compliance are:

- Increased stability of DPV during fault conditions:
  - reducing the need for contingency services within each region
  - allowing greater flows between regions as regional stability constraints are impacted to a lesser degree than would be the case with less compliance
- Increased voltage and reactive power support in the distribution network, allowing increased DER hosting and fewer restrictions on DPV exports
- Other benefits at the network level related to power quality.

Stability of DPV and FCAS

There is a general requirement on connected equipment to be able to tolerate a reasonable amount of disturbance without disconnecting and exacerbating a fault condition. For generation, this is referred to as "ride through" of faults and for distributed generation, failure to "ride through" is called "shake off". In this report we will use the more general term of "ride through".

AEMO, in their 2023 report, "*Compliance of Distributed Energy Resources with Technical Settings*"[4], noted that 50% of inverters that were installed to the earlier standards failed to ride through faults while inverters set to the 2020 standard generally rode through faults. When DPV was a small proportion of total generation, the failure to ride through was a small issue. DPV is now a significant proportion of generation, particularly on sunny days, which requires AEMO contract increased contingency services, in case there is a fault.

1 See AEMC, Review into consumer energy resources technical standards, Draft report, 27 April 2023, www.aemc.gov.au.
2 Further information on these factors is provided in section 6.

The AEMO report indicated their estimates of the increased FCAS requirements should compliance not improve and we have extrapolated the AEMO estimates in Figure 1.

The expected increase in FCAS costs should DPV fail to ride through as the current rates would increase to around $52million per year, using current FCAS pricing.

This would amount to a cumulative cost of $450 million across the period to 2035/36.

Note that the costs of FCAS for future years is uncertain with countervailing factors, that are discussed in section 3.1, below. The change in value is, however, symmetrical and changes the total value but not the sign of the benefits.

Therefore, we conclude the increase compliance is likely to significantly reduce the costs of FCAS across the modelled period.

An additional benefit that would accrue from assured compliance is that refurbished inverters would have better ride through characteristics. This would represent an improvement in ride through characteristics for the DPV fleet, reducing the FCAS requirements due to DPV.

Figure 1 FCAS cost of non-compliance ($mill)

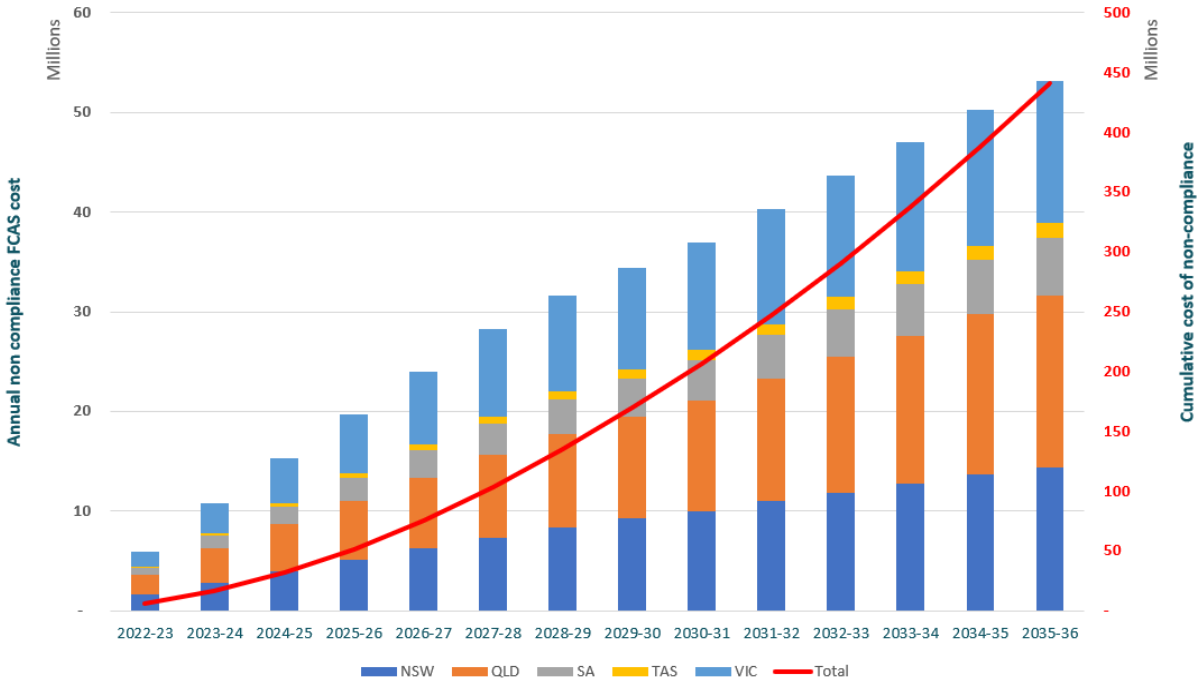


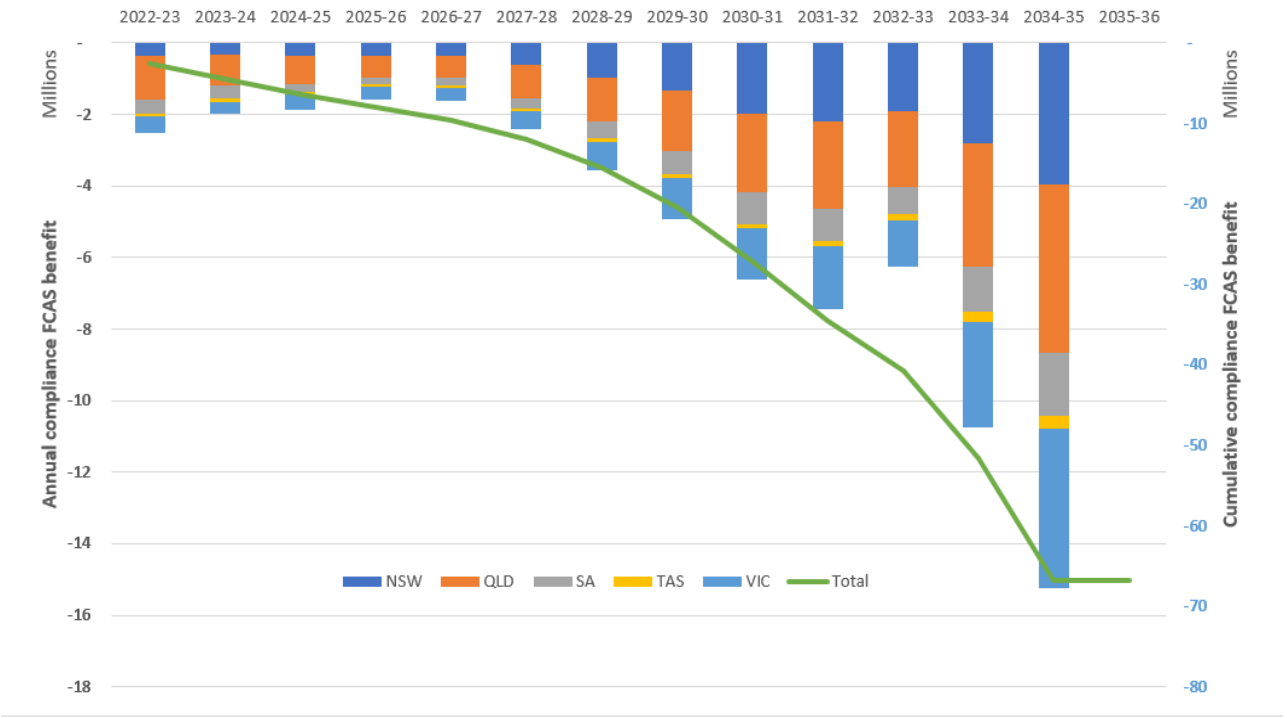
Figure 2 shows the expected savings in FCAS costs assuming inverters are replaced every 10 years. Note that, in the full report, we also assess a 15 year cycle.

The benefits of replacements depend on the amount of DPV installed each year, in this case 10 years before. The benefit therefore increases proportionally to the rise in DPV installations in recent years. Note there was a temporary lull in installations due to Covid.

The cumulative benefit of improved compliance is around $65 million.

Together, therefore, the combined benefit of the avoided increase in FCAS costs with the benefit of reduced FCAS due to refurbishment means that improved compliance has a cumulative benefit that is greater than $500million.

Figure 2 Change in FCAS costs if refurbished inverters are compliant



AEMO noted in their report, and in their meeting with us, that there was also a related impact where the reduction in stability due to the failure to ride through could require AEMO to limit interconnector flows to protect adjacent regions. While this is a work in progress for AEMO, and not yet quantifiable, AEMO expressed concern that this could occur quickly as DPV became a greater proportion of generation. AEMO noted that improved inverter compliance would reduce this impact, although they had not completed their studies.

Ability of DPV to support the network

While the AS/NZS 4777:2015 inverter standard, implemented by October 2016, included the ability for inverters to provide reactive support and respond to voltage variations, it was defaulted to off on the basis that it would be implemented as networks developed the systems to use it. The 2020 standard, which took effect in December 2021, requires that the capabilities be enabled at the time of installation and set based on the location of the installation.

Incorrect settings of the volt-var capability therefore impact DNSP operations, particularly the management of feeder loads and voltage rise, but also in the provision of reactive support within the distribution network. We interviewed a selection of DNSPs from each region and found that the issues to be addressed, and the associated compliance problems, were specific to each region.

For example, in Victoria, the AMI metering had allowed some networks to identify the issue early and they had already commenced remediation actions. They were able to say that compliance for theses settings in Victoria is already around 70% of installations and is rising to 80%. The benefit of implementing the AEMC recommendations is therefore only a small increase in compliance. The value of the increased export from our modelled limitations is, however, relatively high. We estimate the cumulative benefit in Victoria to be around $750,000.

In contrast, for South Australia and Queensland, the lower penetration of smart meters meant that DNSPs needed to infer compliance from system events and boundary meter measurements. There is therefore a real benefit in rules and procedures that would provide networks with an assurance that installations would be compliant. Both of these states are now offering the option of dynamic export limits to new customers, however, which means that the benefit will be in increasing the average export limits that can be achieved, which can be low. The combination of a low increase in potential exports and lower values for the export, however, means that the economic benefit is estimated to be around $15,000 for Queensland and $40,000 for South Australia.

New South Wales is not proposing to introduce dynamic esports in the shorter term. The benefit if increased compliance is therefore the forestalling of lower export limits for new customers. This is a substantial benefit of around $6.4 million due to the larger increase in average exports and higher CECV values in New South Wales.

In total therefore we expect an economic benefit of around $7.2million due to the impact of increased compliance on the ability of DPV to provide support to networks.

1. Introduction

The primary access provisions of the National Electricity Rules (NER) were developed with larger, dispatchable plant in mind. This means that the rules that apply to most distributed Photovoltaic (DPV) generators have not, in the past, included specific requirements to support the power system during dispatch.

A key feature of the market design is that connected generation plant should not make a problem worse. This would imply that DPV should:

- Be able to ride through short duration events, such as disturbances caused by network or generation faults.
  - This is generally described for DPV as not being "shaken off"
  - The issue here is that older settings on inverters do not ensure ride-through of system faults. The risk of DPV disconnection during periods of high DPV generation requires AEMO to increase its contingency management reserves (FCAS) to cover the potential loss of supply.
- Have some capability to assist in the rapid restoration of the power system, which requires some controlled reconnection. This is less relevant for individual DPV but relevant for groups of DPV along a feeder.
- Not prevent the connection of other plants for technical (not output) reasons. This is an issue where the inability of DPV to ride through faults prevents additional DPV being connected or where inability to manage volt-var issues restricts the exports along a feeder.
- Be able to have their output curtailed when there is an excess of output in a particular network area (this is semi-scheduled dispatch for variable renewable energy, in the main).

1.1. New standards

As DPV is now becoming a significant proportion of generation in the NEM, standards have been developed to redress these issues.

The AS/NZS 4777:2020 standard (the 2020 standard), which became mandatory in December 2021 requires:

- The inverter to ride through system faults and not worsen the impact of the initial fault, and
- The volt-var capability of the inverter be defaulted to "on".

It should also be noted that:

- Inverters manufactured to the AS/NZS 4777:2015 standard (the 2015 standard) had the ability to respond to volt-var issues at the connection but this functionality was set to "off" with the intention that it would be enabled when the local DNSP required it. While there has been some progress in bringing this capability to market, networks and households have found that the costs of amending this setting exceeds the benefits at the household level because a home visit is required to adjust the settings.
- The application of the 2015 standard also created jurisdictionally based menu items as the process to enable the volt-var settings was to be at the jurisdictional or DNSP region level. This has exacerbated compliance issues where installers continue to select the jurisdictional settings rather than the new Australia wides settings that can be simply set based on regions[3].

3 There are specific settings for the mainland portion of the NEM, for Tasmania and for Western Australia.

2. The issue to be addressed by the AEMC recommendations

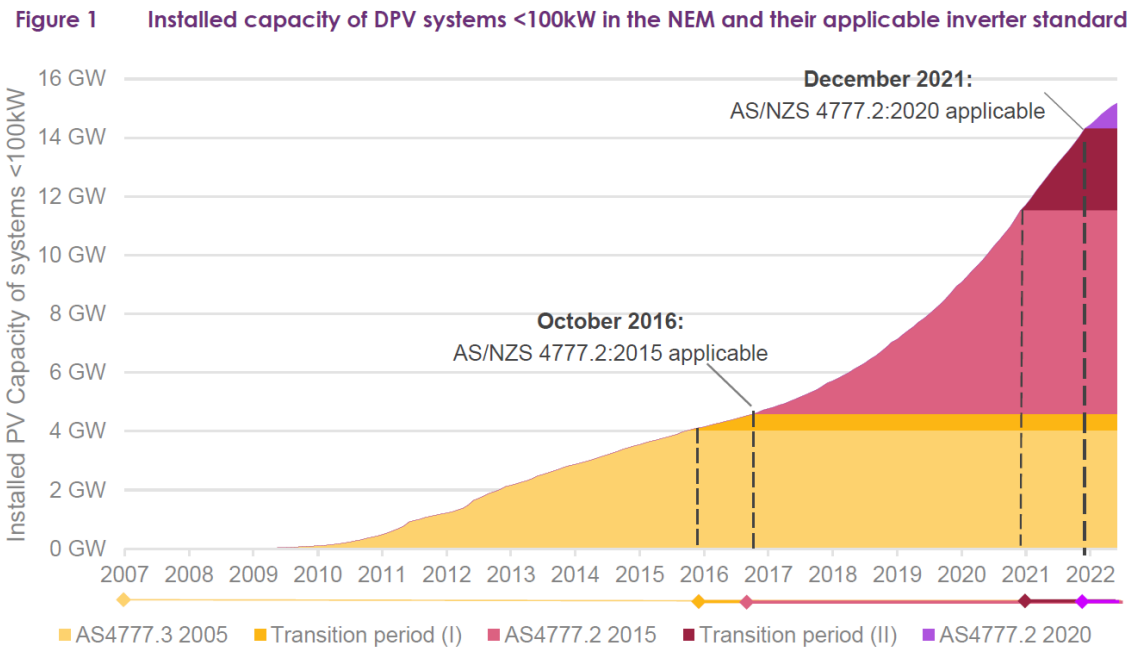
While the new standard has applied since December 2021, many installations are not using the correct settings to apply the new standard. Analysis reported by AEMO[4] (the AEMO report), see Figure 3, shows that the bulk of the DPV currently installed is set to the 2015 standard. The AEMO report also stated that most of the new installations post 2021, where the 2020 standard is mandated, are still being set to use the 2015 standard, with some not even applying that standard in the inverter settings.

This issue, which manifests at the time the inverter is installed, is what the AEMC is seeking to address.

The nett effect of this error in installations is that the expected improvements in ride-through and the ability of networks to rely on the volt-var response of inverters are not actually taking place. This means that:

- Around 50% of all inverters continue to "shake-off" during system events, which exacerbates the frequency fall. Until this "shake-off" issue is addressed:
  - AEMO must procure increased amounts of FCAS raise services, which increases market costs to consumers
    - This applies to the three current FCAS markets and will apply to the new fast response ancillary service as well
  - The market stability constraints applied to interconnectors will need to account for this risk
  - The problem will continue to increase as more DPV is installed, to the extent those installations are non-compliant.

Figure 3 AEMO report on application of AS/NZS 4777



4 AEMO reported on the issue in their report "Compliance of Distributed Energy Resources with Technical Settings", published April 2023. This information was provided to assist the AEMC with its proposed recommendation. Oakley Greenwood have relied on the information in that AEMO report in preparing this valuation.

- DNSPs are not able to rely on the volt-var response of inverters. This means that DNSPs cannot access reactive support from these installations and output control based on monitored voltage. The lack of output control is one of the causes of restrictions being put in place on the amount of export from DPV that can be allowed and, in some cases, the number of installations that can be connected in the local network area without risking problematic voltage rise in that part of the network or breaching of thermal limits on feeders.

2.1. Responsibility for compliance

The AEMO report notes that both AEMO and the DNSPs have undertaken some efforts to redress these issues. This has included discussions with manufacturers through which some have committed to addressing these issues. In fact, some manufacturers are able to remotely identify incorrect settings and, in some cases, even correct them remotely, though not all manufacturers that can make these changes are willing to do so on a voluntary basis without explicit acceptance by the site owners.

When discussing their attempts to address this issue with industry participants, AEMO therefore considers that:

> *this [approach for improving compliance] is limited to voluntary contributions and cooperation. AEMO recognises that the lack of [specified] roles and responsibilities limits stakeholders' power to resolve non-compliance (AEMO report, page 6).*

The AEMC recommendations are therefore focused on providing AEMO and DNSPs with the necessary powers and to allocate responsibilities to other industry participants to address these issues.

3. Modelling the impacts

Oakley Greenwood have been asked to provide an assessment of the benefits that would result from increased compliance with the AS/NZS 4777:2020 standard.

It was noted in the AEMO Report that there are three key areas where problems manifest. These are discussed below.

3.1. FCAS, primarily raise FCAS

The issue impacting FCAS is that inverters that are incorrectly set up tend to shake off or fail to ride through a fault. The error is most often the use of the 2015 standard, although there are other reasons that contribute to DPV not riding through faults.

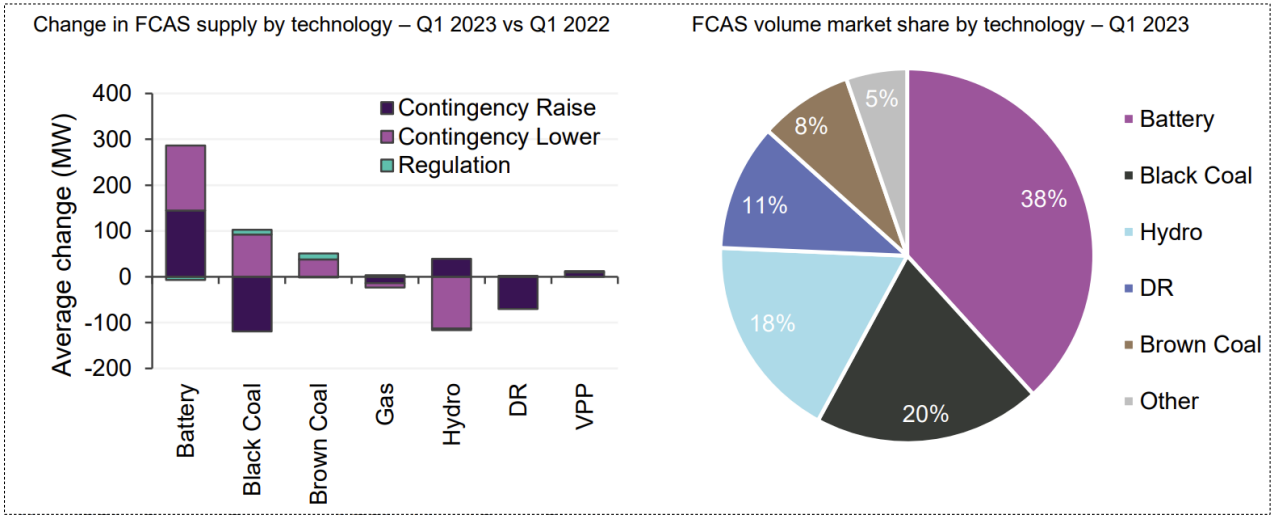
The impact of the set-up errors, according to AEMO, is that around 50% of inverters fail to ride through a fault. This means that the amount of each of the three frequency raise ancillary services procured needs to be increased so that there are sufficient ancillary services to compensate for both the initial fault and the inverters that fail to ride through.

For the purposes of modelling, we have assumed:

- There is no learning during the modelled period. For example, it is possible to assume that the proportion of new inverters that are installed with the correct settings will simply increase over time as installers became more aware of the new standard. This would lower the benefits of the AEMC's recommendations as the business as usual. In fact, AEMO has noted that the current level of technical compliance has increased, although the exact cause of this is not known. We have discussed this issue later in section 6 under the topic of Attribution. Given the lack of data, we have not modelled a learning effect.
- 3 FCAS markets for raise services
  - There will eventually be a fourth market for fast frequency response to compensate for the lack of inertia that is developing in the grid. The timing and nature of this market has not been decided.
  - We have, therefore, ignored this fourth market but this means that we have understated the costs imposed by non-compliance (and the benefits of the AEMC's recommendations). The addition of a fourth market would increase the benefits in proportion to the relative capacity required by that market.
- FCAS raise service pricing remains the same as current prices
  - As the volume impact (MWs) is the same in all three markets, we have used an average of the prices for the three services across the 12 months to 31 May 2023.

- The impact of the increased requirements on FCAS pricing is unclear. While costs were higher in 2022, AEMO reports that the cost have come down during 2023[5]. In addition, while an increased requirement could cause the costs to increase, the major source of raise services is now storage[6]. This source is getting larger, displacing black coal and gas, which are the traditional sources, see Figure 4. This implies that the cost could remain low.

Figure 4 Change in the provision of FCAS



- As the outcome is proportional to pricing, we considered that it was unnecessary to perform sensitivities for price variations in the FCAS markets.
- A range of different prices could be trialled, but this will only change the magnitude of the result, not the sign.

- Given that no learning effect is being assumed, the BAU case is the impact of the degree of compliance of new DPV.
  - The impact of the errors continuing is that the probability of new inverters failing to ride through faults will remain the same as in the existing fleet.
  - This allows us to model the impact of new inverters on FCAS by simply assuming the effect will be essentially the same as it is now.
- The impact of the increased compliance is mainly on reducing FCAS costs
  - The impact of improved compliance is that new inverters would not add to the requirement for FCAS. Note that for simplicity we assumed that this would be the case if 90% of new systems were compliant.

5 AEMO Quarterly Energy Dynamics Report, April 2023.
6 Ibid.

- In addition, refurbished inverters, which would be installed with the correct settings, would reduce the need for FCAS by replacing inverters that would have "shaken off".
- This impact can be calculated by understanding the number of systems that have been installed to the 2015 or earlier standards, and then assuming a useful life after which replacement with a compliant meeting would be expected to take place. We assumed a 10-year cycle of refurbishment, although we note that SAPN use a 15-year life in their calculations[7]. We have tested the impact of the two refurbishment cycles and the longer cycles reduces the benefit of the AEMC's recommendation but there still is a material benefit.

3.2. Stability impact on interconnection

A concern raised by AEMO in their report was that the failure DPV to ride through faults can impact stability limits. This reduces the operating envelope of the power system, and can necessitate interconnector limits being reduced in periods with large amounts of DPV generation. This has been assessed first in South Australia, where reduced interconnector limits are already leading to important market impacts, including reducing the allowable windows where planned network outages can be undertaken.

AEMO is working with TNSPs to assess the impacts of DPV shake-off on interconnector limits in other places, and the associated constraints are expected to be updated progressively in the coming 6-48 months. Early evidence indicates that if compliance can be improved rapidly (achieving and maintaining at least 90% compliance for new installations by December 2023), market impacts could be minimal, while if non-compliant new installations continue at a higher rate, market impacts could become severe in high DPV generation periods. The degree and cost of these impacts are difficult to quantify accurately at this time, and will remain so until full network studies to assess the impact of DPV shake-off on limits have been completed. It is possible that these impacts could prove to be the most significant and most costly impacts of poor compliance with disturbance ride-through requirements.

This impact has not been modelled but the reduction in the risk of a general stability problem will be a benefit of higher compliance of inverters. This means that the benefits of the AEMC's recommendations are understated in this analysis.

3.3. DPV hosting (volt-var capability)

The AEMO report noted another impact of incorrect inverter settings (including failure to use regional setting A, which is for the mainland NEM states) is that volt-var capability is not established, which reduces hosting capacity. This is the consequence of the PV at these sites not responding to voltage rise, meaning they cannot provide reactive support or participate in flexible exports. A consequence of this is that these installations are likely to have their exports limited and, where flexible exports are allowed, the upper limit of the exports for customers on flexible exports is likely to be lower than they otherwise would be due to the non-compliant systems that are on the same circuits.

7 This was noted by SAPN staff during a discussion with Oakley Greenwood on volt-var impact of incorrect settings.

Discussions with SAPN elicited key points on this issue:

- SAPN noted that customers with the correct settings are being offered dynamic operating envelopes (DOEs) as an alternative to fixed export limits, and that:
  - Eighty five percent of customers select the DOE option.
  - The actual export from these sites is generally higher than they would have been if the customer had not chosen to adopt the correct settings as a precursor to going onto the DOE, and had instead accepted a fixed export limit.
  - The efficiency of the DOE is reduced where installations on the same feeder are not using the latest standard (and therefore, are required to stay on a static limit). This means that customers on the DOE on these feeders will have reduced exports, the corollary being that a general increase in compliance will increase the level of exports for customers on a DOE.

In general, it was difficult to get precise information on the DPV limitations that are currently in place and that would be in place if the systems were more compliant. This is due to both the differences between the networks – the fact that the penetration of DPV is different in each region – and the information available to the DNSPs. As each network is addressing their own situation, their plans are different and, in most cases, still being developed.

As a result, we deduced some modelling parameters that are based on our discussions with a selection of DNSPs. For the purpose of modelling, we have based our approach on the following considerations:

- Absent the level of compliance targeted in the AEMC's recommendations, fewer customers will have compliant volt-var settings enabled.
- Both SA and QLD are both well-advanced in their development and introduction of DOEs, and both are likely to impose relatively low static limits on new customers who do not otherwise take up DOE. In this context, we have been informed that the benefit of increased compliance is that it will enhance the effectiveness of their DOEs, as increased compliance will:
  - Increase the export limits that are applied as part of the DOE (relative to the 'do nothing' case), enabling more energy to be exported back into the network; and
  - Reduce the proportion of time when more constrained export limits (for example, 6kW instead of 9kW) need to be applied to customers on DOEs, again, enabling more energy to be exported back into the network.
- In NSW, increased compliance would, in theory, lead to delays in the application of tighter static limits on new customers connecting to the network, relative to a situation where compliance was not to improve over time.
- In Victoria, the feedback from a selection of DNSPs was that compliance was already at relatively high levels, primarily due to the prevalence of smart metering (and the associated information streams that are available to the DNSP in Victoria), hence the AEMC's recommendations are unlikely to materially change the situation faced by network operators in Victoria; and

- In Tasmania, it is our understanding that there are no particularly pressing issues related to hosting capacity, which is a foundational condition for the use of DOEs
- With increased compliance, an increasing number of sites will respond to volt-var conditions:
  - The export limits that currently apply can be maintained and may be increased as the penetration of inverters applying the new standard increases
  - 80% to 85% of customers are choosing to be on DOE, where the network has established them
  - The increased compliance of all installations to 90% or more, will increase the permissible exports from sites with DOE to nearer the top of the export ranges (10kW) from a lower level (around 6kW) and also delay any reductions in fixed export limits
- While we are unable, at this time, to quantify the relationship between these factors, we can
  - estimate some values for the purposes of our investigation and
  - apply reasonable sensitivities to gauge the range of values that could apply.
- The benefit that accrues is the increase in the amount of energy that can be exported from a site with volt-var capability, valued at the Customer Export Curtailment Value (CECV).

We note that the increase in export limits for each site would also have the effect of increasing the total amount of DPV generation able to be exported. While this could be a benefit of the AEMC's recommendations, it is not clear how that benefit could be quantified. We have therefore not modelled this impact, focusing instead on the economic benefits.

The level of exports that we used for modelling, based on these considerations is shown in Table 3, in section 5.

4. Results – FCAS analysis

The results of the FCAS analysis are shown below. They show that the AEMC recommendations, if adopted, would provide a significant benefit, even if only the FCAS benefit were to be taken into account. Specifically, absent the compliance that would result from the AEMC's recommendations, the costs of FCAS will rise markedly. If new PV installations are compliant, this increase will be avoided; if older systems become compliant when they are refurbished, it will have the effect of reducing FCAS costs as compared to their current levels.

Together these two impacts would lead to an overall benefit of around $500 million.

4.1. The outcome that could be expected without increased compliance

If compliance is not increased, the annual FCAS costs are likely to rise by around $440 million cumulatively. This is shown in Table 1 and Figure 5, overleaf.

Table 1 Expected costs without improved compliance

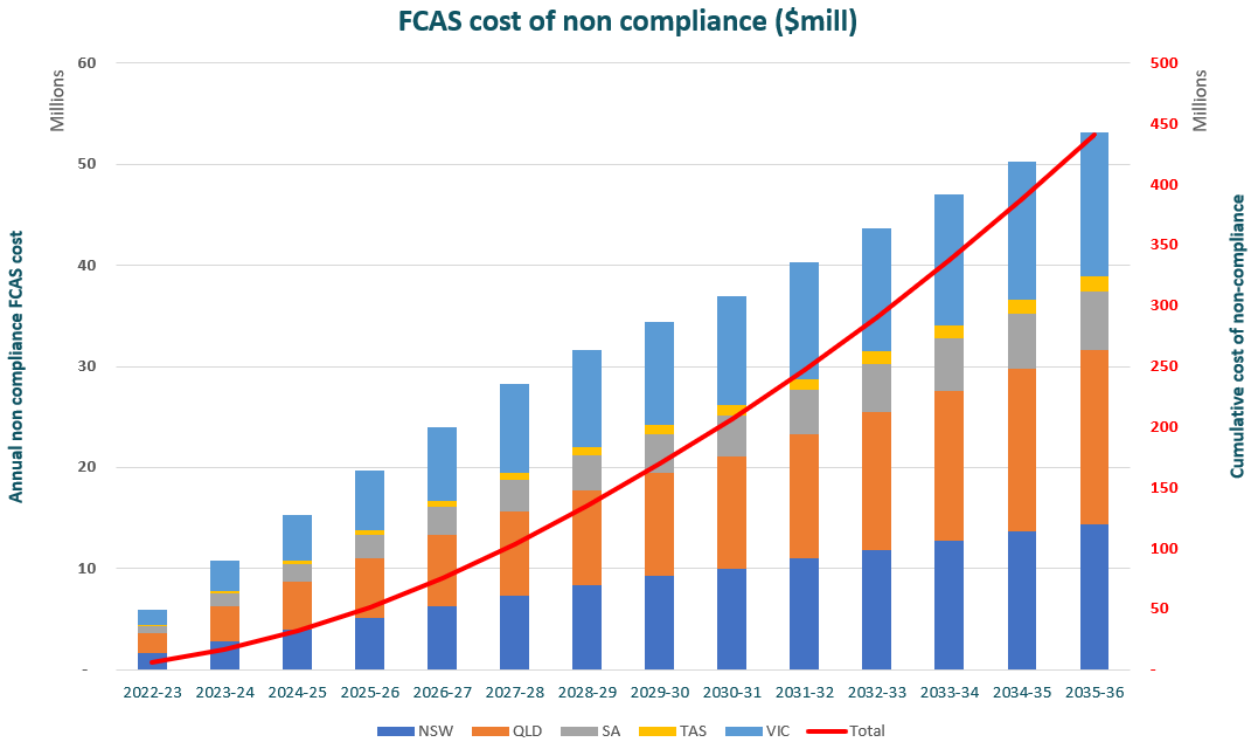
Annual non compliance FCAS cost

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	1,601,042	2,818,504	3,953,337	5,111,520	6,246,790	7,355,265	8,394,620	9,253,483	10,035,600	10,971,584	11,879,791	12,763,266	13,626,944	14,395,556
QLD	1,955,594	3,423,475	4,701,755	5,964,160	7,136,455	8,256,714	9,297,385	10,187,284	11,013,548	12,266,917	13,575,466	14,868,970	16,137,160	17,277,659
SA	760,942	1,271,345	1,757,840	2,223,887	2,675,574	3,113,344	3,522,241	3,814,684	4,071,004	4,430,389	4,784,927	5,132,388	5,467,060	5,758,260
TAS	143,360	271,847	389,487	509,386	624,939	737,432	844,696	929,644	1,010,261	1,121,105	1,226,466	1,327,964	1,424,683	1,508,910
VIC	1,477,375	2,964,457	4,445,603	5,904,347	7,338,700	8,760,559	9,602,963	10,231,502	10,804,045	11,493,429	12,189,886	12,889,856	13,600,290	14,257,890
Total	5,938,313	10,749,628	15,248,022	19,713,301	24,022,459	28,223,314	31,661,905	34,416,596	36,934,458	40,283,424	43,656,535	46,982,443	50,256,137	53,198,275

Cumulative non compliance FCAS cost

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	1,601,042	4,419,546	8,372,883	13,484,403	19,731,193	27,086,458	35,481,078	44,734,561	54,770,161	65,741,746	77,621,536	90,384,802	104,011,746	118,407,302
QLD	1,955,594	5,379,069	10,080,824	16,044,984	23,181,439	31,438,153	40,735,538	50,922,821	61,936,369	74,203,287	87,778,753	102,647,722	118,784,882	136,062,542
SA	760,942	2,032,287	3,790,128	6,014,015	8,689,589	11,802,933	15,325,175	19,139,858	23,210,863	27,641,251	32,426,178	37,558,566	43,025,626	48,783,886
TAS	143,360	415,206	804,694	1,314,080	1,939,019	2,676,451	3,521,147	4,450,791	5,461,052	6,582,157	7,808,623	9,136,587	10,561,270	12,070,180
VIC	1,477,375	4,441,832	8,887,435	14,791,782	22,130,483	30,891,042	40,494,004	50,725,506	61,529,551	73,022,980	85,212,866	98,102,722	111,703,011	125,960,902
Total	5,938,313	16,687,941	31,935,963	51,649,265	75,671,723	103,895,037	135,556,943	169,973,539	206,907,996	247,191,420	290,847,955	337,830,399	388,086,535	441,284,810

Figure 5 Costs expected without improved compliance



4.2. Outcomes that could be expected if compliance is assured

Where the recommendations are effective, the costs of FCAS would not increase and the benefits of refurbished installations becoming compliant would cause a reduction in FCAS costs. These reductions are expected to be between $30 and $67 million, based on the relationships identified in the AEMO report. The range is due to the expected refurbishment cycles for inverters. If refurbishment occurs after 10 years, the benefit occurs faster and therefore is cumulatively higher. If a longer refurbishment cycle is assumed, the benefit is lower cumulatively. Figure 6, below, shows the annual change in FCAS costs by NEM jurisdiction through 2035-36 as well as the cumulative, NEM-wide benefit state over that period assuming a 10-year inverter replacement cycle. The four tables on the following page show the annual and cumulative state-level and NEM-wide FCAS cost reductions for both a 10-year and a 15-year inverter replacement cycle.

Figure 6 Reduced FCAS benefit if compliance is assured

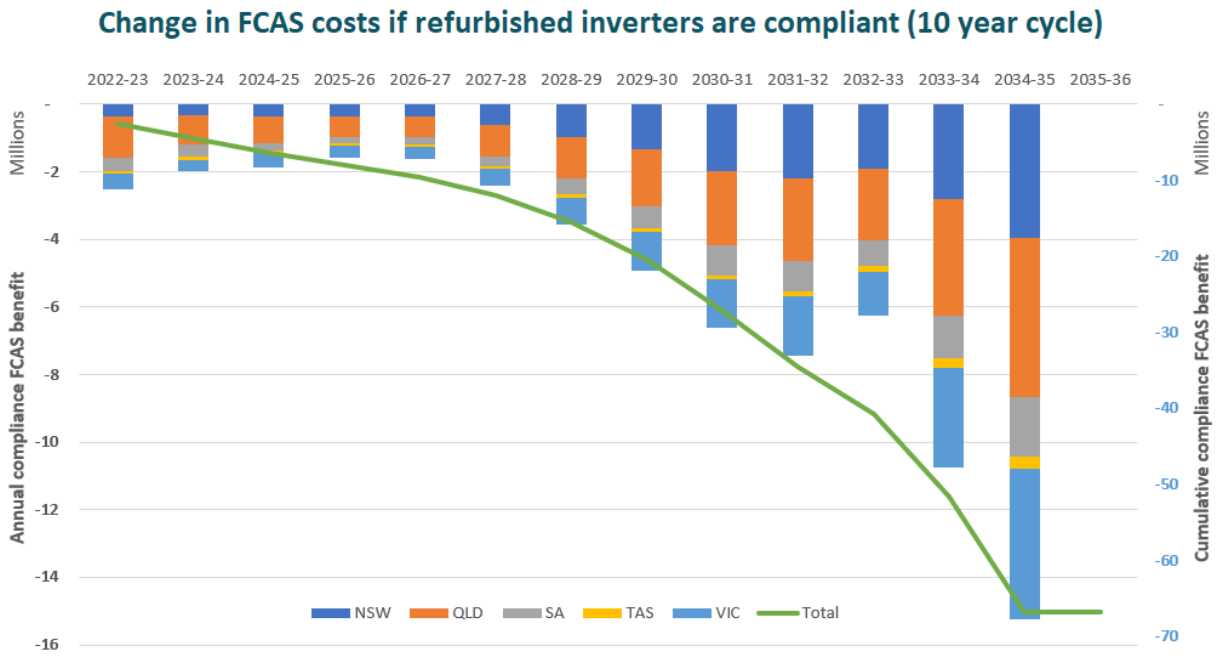


Table 2 Benefits of compliance of FCAS due to refurbishment of inverters

Annual compliance FCAS benefit with refurbishment after 10 years

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	- 358,420	- 307,632	- 365,036	- 368,722	- 367,952	- 616,843	- 961,782	- 1,343,092	- 1,991,300	- 2,194,090	- 1,917,712	- 2,818,504	- 3,953,337	-
QLD	- 1,217,876	- 870,704	- 793,838	- 610,359	- 601,089	- 917,486	- 1,226,278	- 1,687,921	- 2,189,738	- 2,454,473	- 2,103,874	- 3,423,475	- 4,701,755	-
SA	- 387,729	- 353,671	- 206,572	- 184,936	- 218,073	- 316,871	- 482,935	- 640,709	- 892,011	- 878,980	- 777,540	- 1,271,345	- 1,757,840	-
TAS	- 82,469	- 129,796	- 80,152	- 43,251	- 60,187	- 65,512	- 81,508	- 95,740	- 115,439	- 155,202	- 154,039	- 271,847	- 389,487	-
VIC	- 482,273	- 317,585	- 429,047	- 377,394	- 363,782	- 482,582	- 818,878	- 1,148,210	- 1,433,960	- 1,762,677	- 1,313,062	- 2,964,457	- 4,445,603	-
Total	- 2,528,766	- 1,979,389	- 1,874,645	- 1,584,661	- 1,611,083	- 2,399,293	- 3,571,380	- 4,915,672	- 6,622,448	- 7,445,422	- 6,266,227	- 10,749,628	- 15,248,022	-

Cumulative compliance FCAS benefit with refurbishment after 10 years

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	- 358,420	- 666,052	- 1,031,088	- 1,399,809	- 1,767,761	- 2,384,603	- 3,346,385	- 4,689,478	- 6,680,777	- 8,874,867	- 10,792,578	- 13,611,082	- 17,564,419	- 17,564,419
QLD	- 1,217,876	- 2,088,580	- 2,882,418	- 3,492,777	- 4,093,866	- 5,011,352	- 6,237,630	- 7,925,551	- 10,115,289	- 12,569,762	- 14,673,637	- 18,097,112	- 22,798,867	- 22,798,867
SA	- 387,729	- 741,400	- 947,972	- 1,132,908	- 1,350,981	- 1,667,852	- 2,150,787	- 2,791,496	- 3,683,507	- 4,562,487	- 5,340,027	- 6,611,372	- 8,369,212	- 8,369,212
TAS	- 82,469	- 212,265	- 292,417	- 335,668	- 395,855	- 461,366	- 542,874	- 638,614	- 754,053	- 909,255	- 1,063,294	- 1,335,141	- 1,724,628	- 1,724,628
VIC	- 482,273	- 799,858	- 1,228,905	- 1,606,299	- 1,970,081	- 2,452,663	- 3,271,541	- 4,419,751	- 5,853,711	- 7,616,388	- 8,929,450	- 11,893,908	- 16,339,511	- 16,339,511
Total	- 2,528,766	- 4,508,155	- 6,382,800	- 7,967,461	- 9,578,544	- 11,977,837	- 15,549,218	- 20,464,890	- 27,087,338	- 34,532,759	- 40,798,987	- 51,548,615	- 66,796,637	- 66,796,637

Annual compliance FCAS benefit with refurbishment after 15 years

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	- 2,832	- 11,521	- 57,028	- 304,716	- 451,044	- 358,420	- 307,632	- 365,036	- 368,722	- 367,952	- 616,843	- 961,782	- 1,343,092	- 1,991,300
QLD	- 2,353	- 16,248	- 101,892	- 297,018	- 714,059	- 1,217,876	- 870,704	- 793,838	- 610,359	- 601,089	- 917,486	- 1,226,278	- 1,687,921	- 2,189,738
SA	- 5,092	- 18,026	- 47,319	- 100,955	- 471,808	- 387,729	- 353,671	- 206,572	- 184,936	- 218,073	- 316,871	- 482,935	- 640,709	- 892,011
TAS	- 172	- 1,176	- 11,216	- 15,970	- 25,702	- 82,469	- 129,796	- 80,152	- 43,251	- 60,187	- 65,512	- 81,508	- 95,740	- 115,439
VIC	- 3,196	- 8,351	- 36,599	- 169,529	- 351,490	- 482,273	- 317,585	- 429,047	- 377,394	- 363,782	- 482,582	- 818,878	- 1,148,210	- 1,433,960
Total	- 13,645	- 55,321	- 254,054	- 888,189	- 2,014,102	- 2,528,766	- 1,979,389	- 1,874,645	- 1,584,661	- 1,611,083	- 2,399,293	- 3,571,380	- 4,915,672	- 6,622,448

Cumulative compliance FCAS benefit with refurbishment after 15 years

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	- 2,832	- 14,353	- 71,381	- 376,097	- 827,141	- 1,185,560	- 1,493,192	- 1,858,228	- 2,226,950	- 2,594,902	- 3,211,744	- 4,173,526	- 5,516,618	- 7,507,918
QLD	- 2,353	- 18,601	- 120,493	- 417,511	- 1,131,570	- 2,349,445	- 3,220,150	- 4,013,988	- 4,624,347	- 5,225,436	- 6,142,922	- 7,369,200	- 9,057,121	- 11,246,859
SA	- 5,092	- 23,118	- 70,437	- 171,392	- 643,200	- 1,030,929	- 1,384,600	- 1,591,172	- 1,776,108	- 1,994,181	- 2,311,052	- 2,793,987	- 3,434,696	- 4,326,707
TAS	- 172	- 1,347	- 12,563	- 28,534	- 54,235	- 136,704	- 266,500	- 346,652	- 389,903	- 450,090	- 515,602	- 597,109	- 692,849	- 808,289
VIC	- 3,196	- 11,547	- 48,146	- 217,675	- 569,165	- 1,051,438	- 1,369,023	- 1,798,070	- 2,175,464	- 2,539,246	- 3,021,828	- 3,840,706	- 4,988,916	- 6,422,876
Total	- 13,645	- 68,967	- 323,020	- 1,211,209	- 3,225,311	- 5,754,077	- 7,733,466	- 9,608,111	- 11,192,772	- 12,803,855	- 15,203,148	- 18,774,528	- 23,690,200	- 30,312,648

5. Results – Hosting Capacity (volt-var) analysis

The modelling of the benefits of the correct volt-var settings shows benefits, but at a significantly lower level than the benefits due to the reduction in FCAS provided by DPV ride through.

Table 3, overleaf, shows:

- the expected number of new systems each year, based on AEMO data
- the expected export limits that we have modelled, based on our discussions with a selection of DNSPs (see the discussion in section 3.3).
- the annual benefits expected to accrue for each year in each state if the AEMC recommendations are adopted and result in increased compliance in each region. It should be noted that these results are the maximum benefits that could occur, as they assume that improved compliance alleviates all curtailed energy, whereas the reality is that improved compliance will only reduce the level of curtailment that would otherwise take place.

The values in the various states differ because:

- NSW is introducing dynamic exports later than the other states. This means that the expected reduction in fixed export limits would have greater impact and the increased exports due to compliance, which would slow the reduction in export limits in NSW, has a higher impact.
- Victoria, while identifying the issue of non-compliance early and instituting remedial actions would still face reduced export limit and therefore compliance will still have an effect, albeit significantly lower due to current compliance levels.
- Queensland and South Australia are introducing dynamic exports for all new installations. Around 80% to 85% of new customers accept dynamic exports. This means that the benefit of compliance is the increased level of average export per household. As most of the installations already have high exports due to their use of dynamic exports, which only improve slightly with more general compliance.

The total cumulative benefit is estimated to be $6.5 million, based on the 2022/23 CECVs. These values are based on the short-run marginal costs of the marginal generator in each half hour, and are quite low in the middle of the day when compliance would increase export from rooftop PV, due to the predominance of low-cost generation (mainly large-scale solar plant) at those times.

Table 3 Annual benefits of increase export due to compliant installations

New systems

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	748	1,318	1,848	2,390	2,920	3,439	3,924	4,326	4,692	5,129	5,554	5,967	6,371	6,730
QLD	632	1,106	1,519	1,926	2,305	2,667	3,003	3,290	3,557	3,962	4,385	4,803	5,212	5,581
SA	248	414	573	725	872	1,015	1,148	1,244	1,327	1,444	1,560	1,673	1,782	1,877
TAS	33	63	91	119	146	172	197	217	235	261	286	309	332	352
VIC	612	1,229	1,843	2,448	3,042	3,632	3,981	4,242	4,479	4,765	5,054	5,344	5,638	5,911

BAU Export limits

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
NSW	6.00	6.00	6.00	4.00	4.00	4.00	4.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50
QLD	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
SA	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Vic	6.00	6.00	6.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Tas	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

Value per system of increased exports

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36
NSW	0.35	1.10	1.34	39.86	45.34	39.91	27.60	146.84	161.51	159.98	131.76	159.22	152.76	158.15
QLD	0.27	0.85	0.65	0.57	0.61	0.75	0.43	0.31	0.26	0.29	0.27	0.24	0.22	0.21
SA	1.56	5.09	4.57	4.71	5.49	4.51	3.24	2.39	2.24	2.48	1.68	1.04	0.97	1.24
VIC	0.50	1.58	1.69	23.76	25.04	23.45	16.64	14.48	15.52	17.09	12.01	9.70	9.54	13.19

Total value of increased exports each year

	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	Total
NSW	261	1,450	2,470	95,260	132,403	137,218	108,333	635,203	757,724	820,567	731,747	950,004	973,161	1,064,308	6,410,110
QLD	167	936	991	1,103	1,410	1,998	1,291	1,015	922	1,153	1,175	1,160	1,155	1,155	15,632
SA	387	2,110	2,619	3,415	4,787	4,576	3,723	2,976	2,978	3,576	2,614	1,741	1,725	2,336	39,564
VIC	306	1,938	3,107	58,151	76,187	85,182	66,227	61,415	69,493	81,428	60,694	51,823	53,786	77,948	747,685
Total	**1,122**	**6,434**	**9,187**	**157,929**	**214,787**	**228,974**	**179,574**	**700,609**	**831,117**	**906,724**	**796,231**	**1,004,728**	**1,029,828**	**1,145,748**	**7,212,990**

6. Attribution

The preceding analyses document the value of compliance with 2020 Inverter standard for ride-through and volt-var standards. The AEMC has put forward a number of recommendations to increase the likelihood that new and refurbished inverters will be compliant.

It does not follow, however, that the value that will be created by compliance to those standards can be attributed entirely to the AEMC's recommendation of those standards.

For example, South Australia's flexible export program gives a residential consumer that installs a PV system the choice of enrolling in a dynamic operating envelope, which allows up to 10kW of export per phase, depending on the available network capacity at the customer's location throughout the day, the capacity of the customer's inverter capacity and the reliability of the customer's internet connection, or a fixed export limit of 1.5kW per phase.

To qualify for the dynamic arrangement the customer's inverter needs to meet technical requirements that provide essentially the same functionality as the AEMC's recommended technical standards. In this case, the customer is making an active choice based on his/her own assessment of the relative benefits and costs of the available options. Unless SAPN's technical requirements for its DOE arrangements were made after the AEMC published its recommended technical standards, it would be hard to attribute the value provided by SAPN's DOE arrangements to the availability of the AEMC technical standards. Further, even if the AEMC's recommended (as compared to mandatory) technical standards were published prior to SAPN offering flexible export limits, it would still be hard to attribute the value of compliance to those standards where the customer is given a choice. Rather, it is arguably still the customer's perception of relative costs and benefits of the two options that is the factor that is responsible for the choice and the availability of the functionality that creates the value.

The AEMO report also notes actions already being taken by OEMs to increase compliance. In conjunction with DNSPs in Victoria, where the issue was identified earlier due to higher quality local metering which allowed remediation to commence earlier, compliance has increased to around 70%. The selection of Victorian DNSPs we spoke to are predicting that compliance in Victoria will increase to 80%, so the 90% target in the AEMC proposals is not a large increase. AEMO is currently updating their report and have noted in conversation that they consider that general compliance across the NEM and WEM may already may have risen to around 40%.

We consider that there will be a range of causes for increased compliance, including:

- attention to the topic caused by system events,
- the AEMO report indicating the size and likely impacts of the problems and
- the AEMC investigation into the issue and recommendations to mitigate the causes of the problem.

As noted in the introduction, a major benefit of the AEMC reforms may be clarifying the roles and responsibilities of various parties in ensuring compliance and accelerating benefits that may already be in train.