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DER interoperability assessment framework

An assessment framework to develop interoperability policy for distributed energy resources in Australia

FTI CONSULTING

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Executive summary

Like many electricity markets in the world, the Australian National Electricity Market ("NEM") has seen a rapid uptake of distributed energy resources ("DER"), including solar PV and batteries, connected at the distribution level). Indeed, Australia is a world leader in the rollout of DER, with one in four Australian homes already having solar panels, the highest penetration in the world, and the trend towards decentralisation and fragmentation of the electricity market is expected to continue in the coming decades.

This poses a unique set of opportunities and challenges to policy makers and consumers: deployment of DER enables low-cost and low-carbon generation to meet consumer demand more cheaply, while displacing fossil fuel generation. DER can also empower consumers to actively participate in energy markets as "prosumers", and drive innovation in the products and services offered to them. However, DER tend to increase the complexity (and cost) of operating the power system in a secure and reliable manner, and may also put stress on the networks, driving a need for costly reinforcements and/or interventions by the market operator.

Harnessing the benefits of DER for consumers, while mitigating the costs, is a key challenge for policy makers. Technical standardisation has been widely cited as a solution to this challenge, and as the key to unlocking and maximising consumer benefits from DER, including within the Post-2025 Market Design - Final advice to Energy Ministers.[1] However, the degree of standardisation[2] implemented in the NEM needs to balance the potential benefits of technical standards (e.g. facilitating consumer switching, enabling consumers' DER devices to coordinate between themselves, giving the market operator visibility over DER assets to manage the system efficiently, enabling a more efficient use of existing networks), with the potential costs of technical standards (e.g. lock-in of suboptimal technologies, deterring innovation, and limiting competition). **Policy makers therefore need to understand the extent to which a degree of interoperability[3] among DER, facilitated by greater standardisation of certain elements of the supply chain, can help these consumer benefits to materialise, and how these benefits are distributed among consumers (including between DER owners and non-DER owners).**

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[1] ESB, Post-2025 Market Design. Final advice to Energy Ministers. Part B.

[2] This report focuses on the Common Smart Inverter Profile ("CSIP"), which currently serves as market guidance. Other standards, laws and regulations (AS/NZS 4777.2, AS 4755, and the wider legislation, e.g. on data privacy) are out of scope of this analysis.

[3] Interoperability is defined as the ability of DER to work with other components and interfaces in the NEM, including with other DER assets and interfaces with key parties (including AEMO, DNSPs, retailers, and, in the future, aggregators and VPPs).

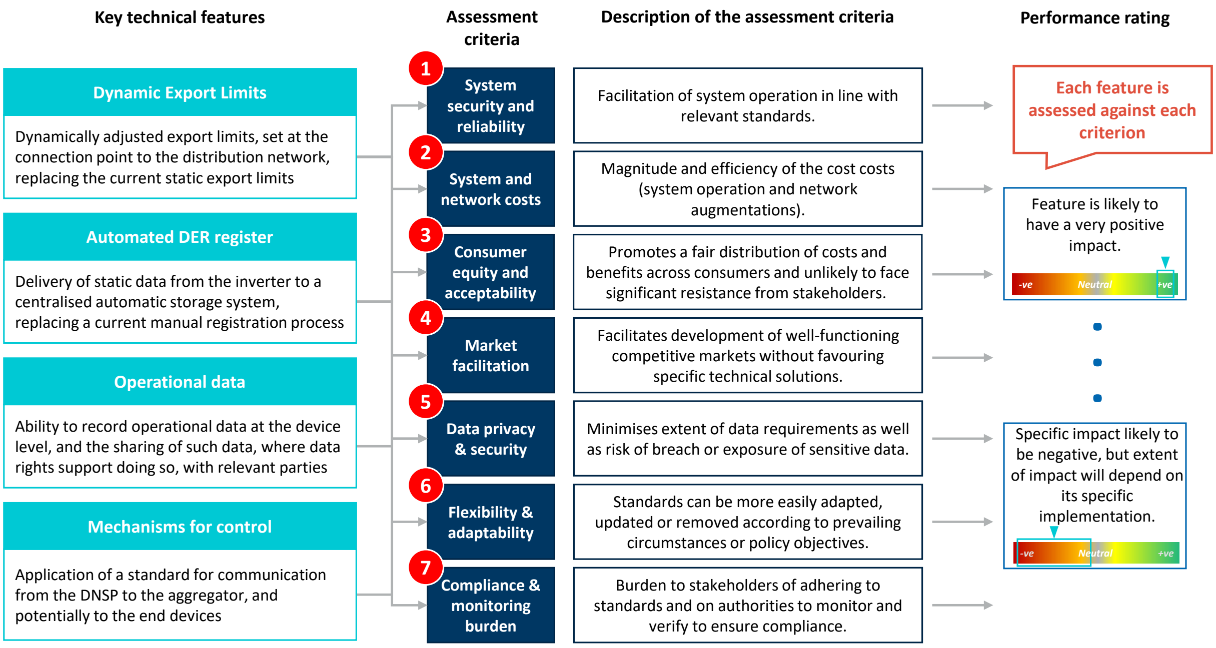
In this context, the Energy Security Board ("ESB") has commissioned FTI Consulting ("FTI") to develop an approach that would enable policy makers to evaluate the merits of potential technical standards, supporting greater DER interoperability for the benefit of consumers, and be consistent with the direction set out in the ESB DER Implementation Plan. **This report puts forward an assessment framework that can help policy makers to evaluate, in a structured, objective and consistent manner, the benefits, costs and risks of proposed technical standards to support DER interoperability for the benefit of consumers.**

Our work has been informed by engagement with stakeholders (including representatives from the market bodies Australian Energy Market Operator, Australian Energy Market Commission and Australian Energy Regulator, along with representatives from the Distributed Energy Integration Program workgroup), and by 'road testing' the assessment framework using four illustrative examples of technical standards where the decision on their implementation is not clear cut (and hence allows for a debate regarding the pros and cons of standardising the feature).

The assessment framework is anchored in the National Electricity Objective ("NEO") and includes seven criteria ranging from system security and reliability and costs through to market facilitation, data privacy, flexibility and compliance burden. All seven of the criteria ultimately relate to the consumer benefits (or costs) from potential technical standards for interoperability, and the framework should be seen as providing a tool for evaluating the merits of technical standards from a consumer perspective.

One of the criteria (#3 Consumer equity and acceptability) focuses specifically on the distributional impact of any potential technical standards for interoperability, and associated perception by consumers of their fairness. This is because a policy decision on DER interoperability that is not broadly acceptable to consumers risks causing significant resistance (or backlash) and, in turn, policy makers risk losing the 'social licence' for change, which would ultimately be detrimental to consumers who could face higher costs of managing the power system, as well as worse decarbonisation outcomes. This report illustrates the application of the framework by evaluating four different technical features against each of the seven criteria, as summarised in Figure 1 below (with the 'road-test' outcomes described in Section 4 and in more detail in 0).

Figure 1: Assessment framework: the process to assess four technical features against seven criteria



Source: FTI analysis

The evaluation process would, for standards where such analysis appears to be suitable and proportionate, be based on a cost-benefit analysis that quantifies those criteria that lend themselves to a quantification, augmented with a qualitative assessment for the remaining criteria (ensuring there is no double-counting of costs or benefits).

The assessment framework can apply to different types of technical standards, including (1) technical standards implemented as a single package of changes; (2) technical standards that have a number of discrete, sequential elements (in which case each 'step' could be evaluated separately through the framework); and (3) bolt-ons or variants of technical standards (where different options can be compared by putting each of them separately through the framework).

The key findings from our analysis and our discussions with stakeholders are summarised below.

- Key finding #1: The **list of seven criteria** in the assessment framework seems to provide a reasonable basis for evaluating potential technical standards for DER interoperability in the NEM. There do not seem to be any obvious gaps, and the potential for overlap in some of them (e.g. in relation to consumer cost impacts) can be addressed by ensuring that there is no double-counting of any quantitative impacts.
- Key finding #2: A **qualitative scoring** against each of the proposed assessment criteria, which combines a cost-benefit analysis and non-monetary factors, appears to be a preferred approach relative to a pure monetary or a pure points-based quantitative scoring. This is because some factors (e.g. consumer acceptability) cannot be monetised,[4] yet are relevant for the assessment, and because it seems arbitrary to score different

[4] It is also common for regulators and policy makers in other jurisdictions, for example Great Britain and the EU, to take into account non-monetary factors.

criteria against, say, a scale of 1 to 10 (doing so would face challenge and disagreement among stakeholders).

- Key finding #3: In relation to potential **weighting** of individual criteria, it seems that attributing mechanistic weights to each criterion would be arbitrary, and likely inaccurate. Rather, structured and principles-based regulatory discretion appears to be a reasonable approach towards combining the criteria in the assessment framework.
  - In addition, it seems that System security and reliability (Criterion 1) and System and network costs (Criterion 2) both appear to be **'hard' criteria** in the sense that only technical standards that support system reliability and security, and that pass an overall cost-benefit analysis, are likely to be appropriate to implement in the NEM.
  - By contrast, Criteria 4 to 7 (Market facilitation, Data privacy and security, Flexibility and adaptability and Compliance & monitoring burden) appear to be **'soft' criteria** in the sense that policy makers may be able to somewhat trade-off the performance on these criteria against each other.
  - Consumer equity and acceptability (Criterion 3) is a special case: it seems that a broad-based acceptability of technical standards for DER interoperability to end consumers is critical. Otherwise, policy makers risk losing the 'social licence' for change which could cause a significant delay to any reforms and less uptake of DER in the longer term, to the detriment of consumers (due to higher costs and worse decarbonisation outcomes).
- Key finding #4: The **wider policy choices** regarding market design are critical and can, to a significant extent, drive the outcomes of the assessment of potential standards. For example, the application of dynamic exports limits could score very differently depending on whether their use would be a paid-for service, or whether they would be a 'free' option for distribution network system providers ("DNSPs"). The implication is that technical standards cannot be seen and evaluated in isolation, but wider NEM policy choices (current and future) need to be taken into account when performing the assessment.
- Key finding #5: In assessing the impact of different standards, policy makers will need to **examine the very fine details** of each proposal before reaching a decision. In particular, the specific policy choices regarding implementation process, the impact on different consumer cohorts (and any associated mitigation actions), and the interactions with wider rules and regulations (e.g. data privacy laws), can lead to very different outcomes for the NEM. High-level descriptions of technical standards are not sufficient to decide on a course of action.
- Key finding #6: To reflect the co-dependency between technical features and standards, policy makers may need to **consider packages of standards/features together**, to ensure that different technical features obtain the correct scoring against the framework criteria. For example, a technical standard that automates DER registration may not,

per se, have significant benefits, but in combination with a standard for operational data collection and sharing, these two could be mutually reinforcing.

- Key finding #7: It seems important that policy makers carefully consider different **consumer use cases** in order to carefully disentangle the varied impacts that a single policy decision can have on different parties. In this report, we illustrated this by comparing the impacts on consumers with/without DER, consumers who are more/less active with DER, consumers who are seeking to switch their provider, and others. This is likely to be critical to support policy choices that are generally acceptable to consumers and therefore have a broad-based social licence for implementation.
- Key finding #8: Policy makers need to carefully consider the **roadmap for implementation** (including the timeframe and the scope of deploying any technical standards or technical features) due to the concerns regarding retrospective application of technical standards on consumers who would be disadvantaged by such actions. Some of these concerns can be resolved 'naturally' through the lifecycle of asset replacement, and this would need to be considered by policy makers as part of developing a roadmap for standard implementation.

1. Introduction and background

1.1. The Australian National Electricity Market ("NEM") is leading a period of transition as the share of generation from renewable intermittent resources, notably solar and wind, increases rapidly. Moreover, generation is now increasingly fragmented and connected at the distribution (as opposed to transmission) level. At the same time, the demand for electricity is also evolving, driven by factors such as decentralisation of consumption, digitalisation, deployment of small-scale generation and storage assets, and electric vehicles.

1.2. The rapid uptake of distributed energy resources[5] ("DER") poses a unique set of challenges, and also opportunities, for consumers and the NEM:

- Deployment of DER enables a **greater volume of low-cost renewable generation** to meet consumer demand, thus reducing overall costs to consumers. DER can also **empower consumers** and **drive innovation** that benefits consumers, for example by giving them a much stronger role in the power market and facilitating the development of entirely new markets. They are also likely to play a key role in the decarbonisation pathways, by helping consumers to reduce their reliance on fossil fuel power generation, and – provided these resources are used smartly – by potentially enabling network and system operators to manage the system more efficiently.
- On the other hand, DER tend to **increase the complexity** of operating the power system in a secure and reliable manner. This is driven by the volume of DER, the uncoordinated and fragmented nature of its deployment, as well as the speed at which innovative technologies evolve. At times, this complexity may translate into a more costly operation of the power system, for example where large volumes of DER put stress on the distribution and transmission networks, thus driving a need for costly reinforcements and/or interventions by the market operator.
- While the deployment and interoperability of DER can create direct benefits for **consumers with DER**, the impacts of the standards on **consumers who do not have DER** also need to be evaluated, to ensure there is an efficient and fair allocation of the costs and benefits of any new standards. For example, customers with active DER devices may benefit from their asset by exporting back into the grid, however any incremental costs to the DNSP incurred to communicate with DER devices (e.g. by developing a new platform) could, depending on the approach to cost allocation, be borne by all consumers, both with and without DER.

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[5] Distributed energy resources include generation and storage assets connected at the distribution level. In this report we focus on solar PV and batteries only.

1.3. Harnessing these benefits is, therefore, a key challenge for policy makers: some are likely to materialise to a greater extent (or, in some cases, perhaps only materialise) if there is a degree of interoperability[6] and standardisation across the market.

- For example, consumers can gain greater benefits from new markets if they are able to engage in the competitive processes, including by switching between different energy services providers, and by offering the flexibility provided by the DER to third parties in exchange for remuneration.
- Consumers can also benefit from greater interoperability of DER to the extent that their own assets can become better coordinated together (relative to a counterfactual situation where – for example – consumers' smart hot water system fails to coordinate effectively with the storage asset). In turn, these benefits are likely to be greater if there is a degree of portability of devices, data and software among different providers (i.e. an ability to switch DER assets across energy service providers).
- Similarly, DER may be extremely helpful to the system operator when dealing with both localised and system-wide stress events, but only if the system operator has visibility over and the ability to engage or call on some portion of the DER assets. A lack of interoperability in this context would reduce the system operator's visibility of DER assets, and hence reduce its ability to manage the system efficiently.

1.4. Technical standardisation is often cited as a solution to these issues, and as the key to unlocking and maximising consumer benefits from DER. Indeed, in the NEM, the Post-2025 market reform recommendations stressed the importance of "*introducing technical standards for DER that will smooth the customer experience and assist to ensure the security of the power system*".[7]

1.5. However, there are likely to be limits to how much standardisation is desirable or economically efficient. This is because excessive standardisation runs the risk of locking in suboptimal technological choices, deterring innovation once a standard has been adopted, and limiting competition between companies, all to the detriment of consumers.

A. Purpose of this report

1.6. In this context, the Energy Security Board ("ESB") is "*developing policy advice about interoperability to provide direction on technical standards (via relevant DEIP Interoperability […] workstreams)*".[8] To support this policy advice, the ESB has identified a pressing need to develop an assessment framework that would enable policy makers to evaluate the merits of potential technical standards for implementation in the NEM. This framework would, in a

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[6] There is a difference between DER interoperability and DER standardisation: DER interoperability can be facilitated by imposing a degree of standardisation in the system (e.g. such that DER supports system reliability and security, or such that consumers who own DER can switch their energy retailers). However, in other areas, flexibility and non-standardisation may be more appropriate, to encourage competition and innovation for the benefit of consumers.

[7] ESB, Post-2025 Market Design. Final advice to Energy Ministers. Part B.

[8] ESB, Post-2025 Market Design. Final advice to Energy Ministers. Part B.

structured, objective and consistent manner, evaluate the benefits, costs and risks of any proposed technical standards.

1.7. An assessment framework is considered by the regulatory authorities to be a potentially helpful tool to build structure into the consideration of potential technical standards and ensure that DER interoperability is deployed in a manner that maximises consumer benefits (recognising that there may be areas where standardisation is not appropriate or desirable). The assessment framework put forward in this report is intended to provide a basis for consistent and comprehensive evaluation of potential technical standards for interoperability.

1.8. The purpose of this report is to support the ESB in developing an assessment framework that would enable policy makers to identify technical standards that align with the interests of customers and policy objectives in the NEM, and is consistent with the direction set out in the ESB's DER Implementation Plan.[9]

1.9. In this report we therefore:

- Describe the opportunities and challenges that DER deployment poses to the NEM and to consumers;
- Set out a list of assessment criteria that appear to be relevant for deciding whether or not to implement a potential technical standard;
- Illustrate the application of those criteria by drawing on practical examples of potential technical standards to demonstrate the application of the framework, and to 'road test' the framework;
- Identify relevant trade-offs between different criteria; and
- Draw out lessons learnt regarding the practical application of the framework, the relative importance of the criteria and further considerations for policy makers.

1.10. For the avoidance of doubt, this report does not put forward any views on the merits or otherwise of any proposed technical standards (or indeed whether such standards should be put forward for potential consideration). Rather, we use them as tangible examples to support the discussion of the assessment framework itself.

1.11. We are also only focused on the Common Smart Inverter Profile[10] ("CSIP") and communications/operability, as this is a potential technical standard currently under development by the ARENA-led Distributed Energy Integration Program[11] ("DEIP"). We have not considered technical standards that are already in place, such as AS/NZS 4777.2. We

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[9] ESB, Post-2025 Market Design. Final advice to Energy Ministers. Part B (link) Figure 3 on page 73.

[10] The Common Smart Inverter Profile is an international standard that defines data communications and the interoperability of DER from engineering principles. The CSIP is appliable in international jurisdictions and leverages technical standard IEEE 2030.5 in some specifications. In this report we focus on the CSIP Australia (as opposed to other forms of CSIP, such as, for example that applied in California, US.

[11] DEIP is a cross industry collaboration of government, market agencies, industry and consumer groups that focuses on maximising the value of consumers' DER and reforms based on emerging DER issues. DEIP has three initial overarching workstreams: Dynamic Operating Envelopes, Access and Pricing and EV Working Group.

recognise that there are related pieces of work ongoing by other parties in parallel, such as AEMC DER governance work.

1.12. In this report we focus on the deployment of distributed solar PV and storage, as these are technologies that have seen the most significant uptake in the NEM to date. However, our work is also likely to be relevant for wider issues in the electricity distribution sector, including the rollout of electric vehicles and/or electric heating/cooling systems in buildings.

B. Restrictions

1.13. This report has been prepared solely for the benefit of the ESB for use for the purpose described in this introduction.

1.14. FTI Consulting accepts no liability or duty of care to any person other than ESB for the content of the report and disclaims all responsibility for the consequences of any person other than the ESB acting or refraining to act in reliance on the report or for any decisions made or not made which are based upon the report.

C. Limitations to the scope of our work

1.15. This report contains information obtained or derived from a variety of sources. FTI Consulting has not sought to establish the reliability of those sources or verified the information provided.

1.16. No representation or warranty of any kind (whether express or implied) is given by FTI Consulting to any person (except to the ESB under the relevant terms of our engagement) as to the accuracy or completeness of this report.

1.17. This report is based on information available to FTI Consulting at the time of writing the report and does not take into account any new information which becomes known to us after the date of the report. We accept no responsibility for updating the report or informing any recipient of the report of any such new information.

D. Structure of the report

1.18. This report has the following sections:

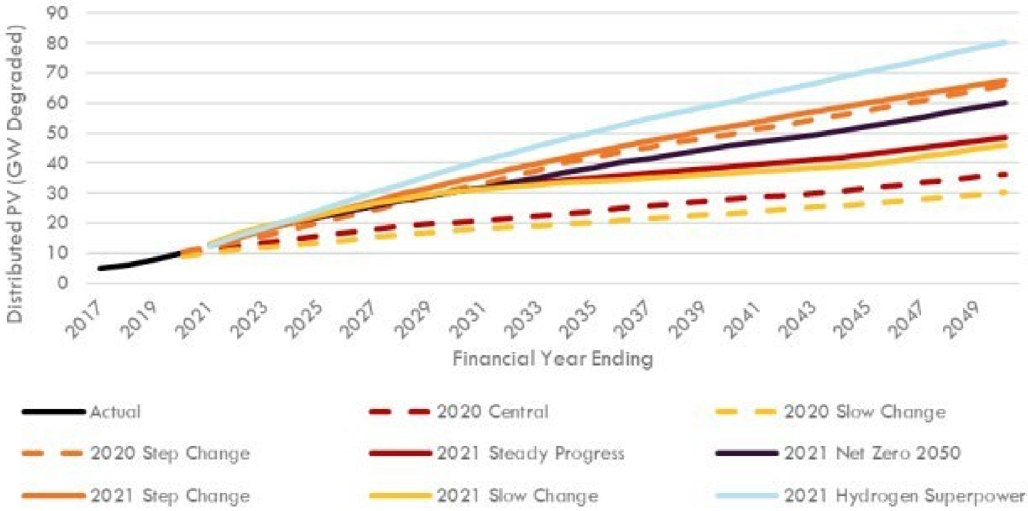
- Section 2 describes the challenges and opportunities that the deployment of DER presents to the NEM.
- Section 3 sets out the approach and methodology for developing an assessment framework for technical standards supporting DER interoperability.
- Section 4 illustrates the application of the assessment framework by drawing on four examples of technical features.
- Section 5 summarises our key findings regarding the assessment framework and sets out the next steps.

1.19. In addition, Appendix 1 builds on Section 4 and sets out four examples of potential technical features that could be considered for implementation in the NEM and illustrates how these features would be evaluated through the assessment framework.

2. DER in the NEM: challenges and opportunities

2.1. Australia is a world leader in the rollout of DER, driven by energy storage and very-low cost solar, as recently highlighted in Australia's Plan to Deliver Net Zero.[12] Over one in four Australian homes already have solar panels, the highest penetration in the world, and all of AEMO's Integrated System Plan ("ISP") scenarios include significant further growth in distributed solar capacity by 2050.[13] Up to 77% of daytime power demand is already provided by DER in South Australia and by 2025 distributed solar PV is set to meet 85% of demand.[14,15] AEMO's projections of further deployment of solar PV are shown in Figure 2 below.

Figure 2: NEM distributed PV installed capacity



Source: AEMO, 2021 Inputs, Assumptions and Scenarios Report, July 2021 (link).

2.2. The growth in distributed solar generation is expected to be accompanied by significant installations of distributed battery storage, as illustrated in Figure 3 below. This is driven by households seeking to manage their energy bills, benefit from additional security of supply, or increase the value of their generation assets (such as solar PV).

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[12] Australian Government, The Plan to Deliver Net Zero - The Australian Way, October 2021 (link).
[13] Australian Government, The Plan to Deliver Net Zero - The Australian Way, October 2021 (link).
[14] ESB, Post-2025 Market Design Final Advice to Energy Ministers – Part B, July 2021 (link).
[15] ESB, Final Advice to Ministers Infographic, July 2021 (link).

Figure 3: Behind-the-meter battery forecasts for the NEM

Source: AEMO, 2021 Inputs, Assumptions and Scenarios Report, July 2021 (link).

2.3. The integration of DER into the NEM has been the focus of the ESB's Integration of DER and flexible demand reform program,[16] which seeks to address the challenges presented by the rapid growth of DER in the NEM and to ensure that the potential benefits to consumers of DER are fully realised.

2.4. In the remainder of the section, we summarise the opportunities presented by the rollout of DER (Section A), and the associated challenges (Section B). We then discuss the role of technical standards in DER interoperability (Section C), and how policy makers might go about deciding which technical standards to implement (Section D).

A. Opportunities presented by the rollout of DER

2.5. The rapid growth of DER presents opportunities to improve the operation of the power system and benefit consumers, including through the following:

- **Lower consumer bills.** Consumers stand to directly benefit from lower energy bills, most obviously through the greater penetration of low marginal cost solar generation. This is likely to be the case both for DER owners (who can, through own generation, reduce their bills), but also for non-DER owners who would still likely benefit from lower average wholesale prices (insofar as these are passed through to retail prices). Customers can also be empowered to sell energy and network services back into the power system, as well as using storage and smart devices to 'shift' demand on the network from periods of high prices to periods of low prices, reducing system costs further (which ultimately reduces costs to consumers).[17] A more efficient use of the network can also help reduce the need to upgrade or reinforce the existing distribution networks, which would further reduce costs ultimately borne by consumers.
- **Additional consumer rewards for DER services.** As markets become increasingly two sided and flexible, there is greater opportunity for aggregators and retailers to compete

[16] ESB Post-2025 Market Design Final advice to Energy Ministers Part C, (link).

[17] However, not all owners of DER are necessarily active and engaged in the energy markets. Many consumers would be happy to 'install and forget' their DER, potentially benefitting from associated feed-in-tariffs.

and offer tariffs and services that reward consumers for offering their DER flexibility to the market.

- **Innovation and choice.** In turn, by explicitly monetising the flexibility of DER, aggregators and retailers can offer greater choice of services and products, and also to potentially deliver competition-driven cost savings to consumers.
- **System reliability and security.** From a system operation perspective, DER flexibility can help AEMO and Network Service Providers ("NSPs") to maintain a secure and reliable system, both during 'system normal' operation and during system stress events. While the individual contributions of households are not sufficiently material to impact the system alone, they can be aggregated together to act in a coordinated fashion, becoming a virtual power plant ("VPP"), which could then deliver network services to the NEM, such as Frequency Control Ancillary Services ("FCAS") and demand side response, in a similar manner to how more conventional thermal generators currently provide such services.
- **Efficient use of network capacity.** Smart DER usage can promote the efficient use of existing distribution network capacity, allowing greater volumes of cheap solar generation to flow into the power system when network conditions allow. Similarly, well-used storage assets can also help reduce the need for network reinforcements, by allowing excess generation to be stored when the network is congested and released when the network is underutilised. In this manner, smart DER usage can help reduce costly network augmentations that would have otherwise been needed to cope with the DER penetration levels.
- **Carbon emissions reduction.** In line with Australia's Plan to Deliver Net Zero,[18] DER allows consumers to play a key role in decarbonising the economy, by helping them to reduce their reliance on fossil fuel power generation and by potentially enabling more efficient use of energy resources.

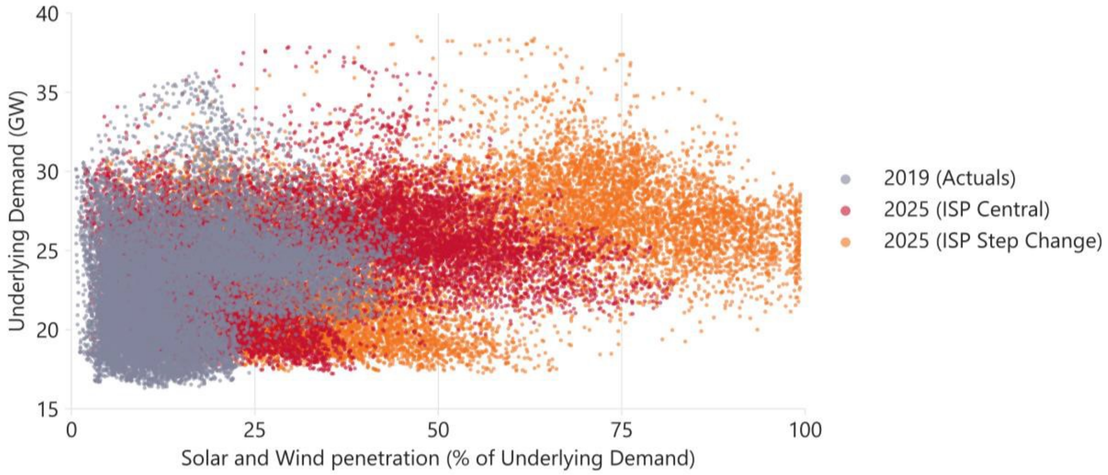
B. Challenges presented by the growth in DER

2.6. However, the growth in DER also presents challenges that must be addressed if the benefits described above are to be realised. This has been recognised and extensively discussed in the ESB's Post-2025 Market Design Final advice to Energy Ministers, some of the key elements of which are reflected in this section. The primary challenge comes from the growth of inverter-based resources[19] ("IBR") in the NEM, of which DER is a significant share, and the related displacement of large-scale thermal synchronous generation. As shown in Figure 4 below, AEMO projects that as early as 2025, solar and wind generation has the potential to meet

[18] Australian Government, The Plan to Deliver Net Zero - The Australian Way, October 2021 (link).
[19] Inverter-based resources include wind and solar generation, battery energy storage systems and direct current network links. AEMO (2020), (link).

100% of underlying instantaneous demand in the Step Change scenario, and over 75% in the Central scenario.

Figure 4: Penetration of solar and wind as a share of underlying demand



Source: AEMO (2020) Renewable Integration Study: Stage 1 report, April 2020.

2.7. This growth in IBR[20] in turn poses challenges to NEM system operation, which manifest themselves in the following (as illustrated in Figure 5 below):

- **Frequent market operator interventions.** Over the recent years, the NEM has seen a 10-fold increase in the number of occasions that the system operator has had to intervene outside of 'normal' market operations to maintain security and reliability.[21]
- **Variability and uncertainty in net demand ramps.** The challenges in operating the system are driven to a significant extent by growth in the uncertainty and variability over net demand by end consumers; indeed, this uncertainty (as measured by net demand ramps) is expected to triple over the next five years as solar and wind progress towards meeting 100% of demand by 2025.
- **Low minimum system demand.** As more consumers generate and store energy at home, the total load placed on the distribution and transmission networks decreases. Consequently, across the NEM average loads have fallen in recent years, with the trend particularly strong in areas of high rooftop PV uptake such as South Australia, Victoria and Queensland. This leads to a range of potential issues with system operation, including increasing the difficulty of managing voltage across the network and reducing the effectiveness of certain emergency frequency response procedures.[22]

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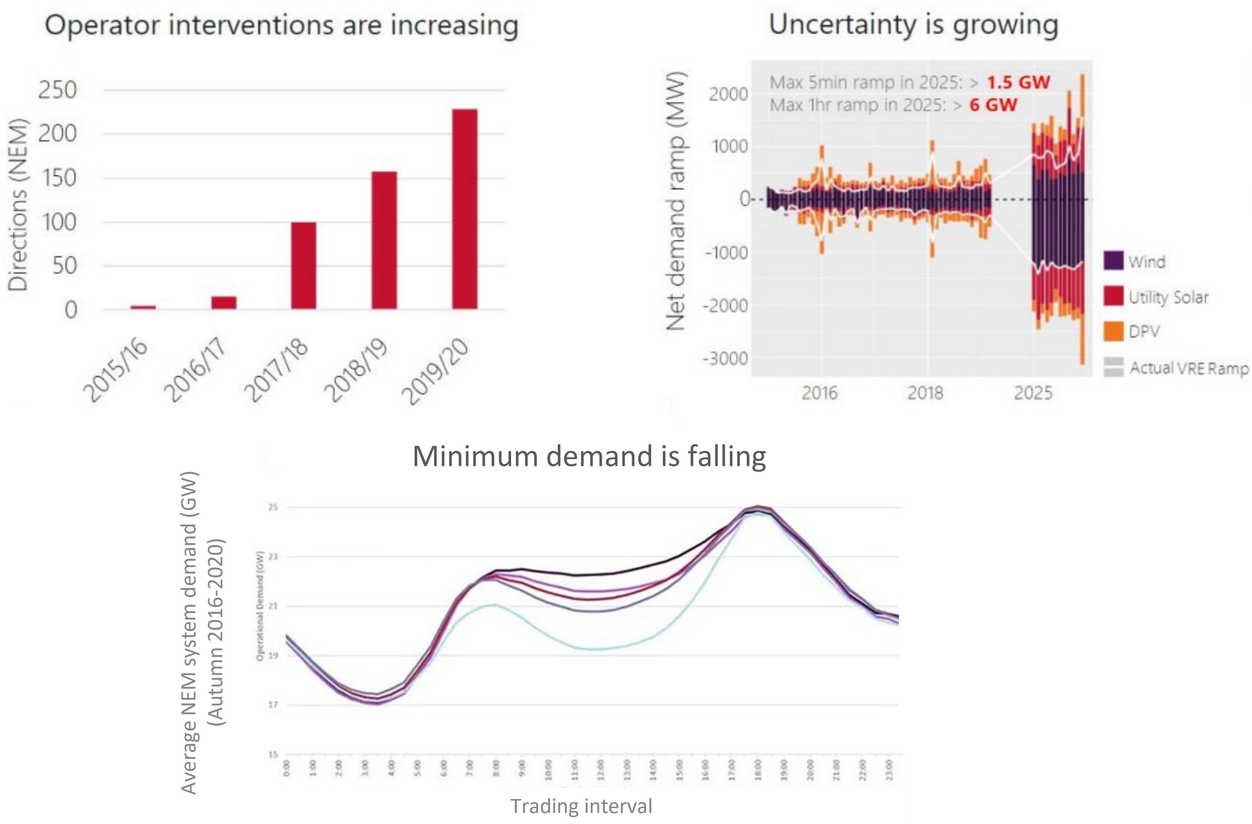
[20] While these challenges are presented by both DER and utility scale IBR, DER specifically sits behind-the-meter and is highly fragmented. It therefore presents specific challenges to network stability at the localised level and for the distribution networks.

[21] We also observe that frequency control performance declined in general since 2010. However, industry wide changes including the provision of mandatory primary frequency response and Automatic Generation Control ("AGC") adjustments, have resulted in NEM frequency performance significantly improving and performance metrics now remain well within their targets. AEMO, Frequency and Time Error Monitoring – Quarter 3 2021 (link).

[22] AEMO, Energy Explained: Minimum Operational Demand, August 2020 (link).

Figure 5: Challenges to the NEM system operation driven by IBR



Sources: (1) Lal, et al. Essential System Services in Grids Dominated by Renewable Energy (link) page 2. (2) AEMO, Energy Explained: Minimum Operational Demand, August 2020 (link).

2.8. In turn, large volumes of DER, if not managed in an efficient way, can increase the total cost of operating the electricity system, which would ultimately be borne by consumers.[23] In particular:

- **Curtailment and redispatch.** In the short term, the issues described above can lead to the system operator needing to curtail excess low-carbon generation (including DER) in locations where supply exceeds demand and the power cannot be transferred to other areas. In turn, other resources are required to potentially be turned on instead in other locations. This increases costs to consumers and may also increase total carbon emissions (if renewable energy is replaced with fossil fuel alternatives).
- **Network augmentations.** In the long term, frequent curtailment and redispatch may lead Distribution Network Service Providers ("DNSPs") to seek to augment the network, for example by investing in upgrades or constructing new distribution assets. Again, this increases total consumer costs as DNSPs seek to recoup their costs through network charges.

[23] The costs would likely increase both for DER owners (whose DER exports may be curtailed more frequently in a poorly coordinated system); and for non-DER owners (who would face higher energy bills due to the costs of managing the system and/or due to network augmentations that would be passed through all consumers, not just DER owners).

2.9. Consumers may react adversely to the factors above: both curtailment of DER exports (or of DER self-consumption in cases where curtailment measures restrict[24] that too) and increases in consumer bills due to more costly network reinforcements could be perceived by households as unfair. In turn, policy makers may lose the social mandate for energy market reforms, which could ultimately make the transition towards very high DER levels even more challenging and expensive to manage.

2.10. Further challenges are driven by AEMO's and DNSPs' limited visibility of behind-the-meter resources, compounded by non-compliance of some DER with required performance standards. This increases the uncertainty and variability of DER behaviour across the NEM, making the task of balancing supply and demand while maintaining a secure and reliable system more challenging.

C. The role of technical standards for interoperability

2.11. To deliver the potential consumer benefits from DER, and to mitigate the associated challenges, it is important that the NEM successfully and efficiently integrates DER such that consumers can operate (or set-and-forget) their devices more effectively, for example by improving coordination between DER devices within a household (say, a solar panel and a battery), or allowing consumers to switch energy services providers easily to unlock greater choice and value. This integration is likely to be more effective if at least some of the DER assets are interoperable – defined for the purposes of this report as the **ability of DER to work with other components and interfaces in the NEM for the benefit of consumers, including with other DER assets and interfaces with key parties** (including AEMO, DNSPs, retailers, and, in the future, aggregators and VPPs).[25]

2.12. Examples of successful DER interoperability outcomes include:

- **Consumer switching.** Ability for consumers to smoothly switch[26] their retailer (or aggregator), or to simultaneously procure services from multiple aggregators for different DER devices, facilitated by a degree of portability of DER data flows and communications among different aggregators and Original Equipment Manufacturers ("OEMs"). This is, in turn, likely to encourage innovation and unlock additional value to consumers from greater choice from retail contracts.
- **System operation.** The ability of the system operator (this could be AEMO or DNSPs) to call on (at least some) DER assets when dealing with both localised and system-wide stress events, via operational data flows and mechanisms to quickly constrain them.

[24] This is a legacy issue where some inverters can be switched off when curtailing the network, thus impacting self-consumption. Going forward, this is not expected to be a dominant issue.
[25] This includes both system-wide technical standards as well as 'minimum functionality' standards.
[26] We note that consumers' ability to choose their retailer is the outcome of not only technical interoperability of DER assets, but also of wider policy decisions, including data privacy laws and market design.

- **Use of network capacity.** More efficient use of network capacity during 'normal system operation' enabled by the capabilities of smart inverters. In particular, a more efficient use of network capacity can be facilitated by near real-time monitoring of DER performance and local system conditions.

2.13. Technical standardisation is often cited as a solution to deliver a high degree of interoperability of DER assets, and as the key to unlocking consumer benefits from DER. Indeed, in the NEM, the Post-2025 market reform recommendations stressed the importance of "*introducing* ***technical standards for DER*** *that will smooth the customer experience and assist to ensure the security of the power system*".[27]

2.14. In this context, Australian market bodies (including AEMO, AER, AEMC and ESB) have been collaborating with distribution networks, service and hardware providers, retailers, and aggregators to establish which technical standards would potentially be appropriate to implement within the NEM through the DEIP.

2.15. The DEIP coordinates collaboration across multiple DER work programs with a particular focus on interoperability, dynamic operating envelopes,[28] grid integration and the standards that facilitate these changes. The DEIP Interoperability work program in particular is supporting the implementation of standards applicable to the NEM to achieve an adequate level of interoperability among different elements of the electricity network. A key objective of this work program is to ensure *"all DER devices can communicate effectively and respond to provide communication-enabled grid support functions as required"*.[29]

2.16. The DEIP has developed a set of potential technical standards, which leverage international standards and adapt them to the Australian context. This takes the form of the Australian Common Smart Inverter Profile ("CSIP AUS").

2.17. The CSIP AUS, currently serving only as market guidance, focuses on the active management of DER by setting recommended operational and communications protocols. The CSIP focuses specifically on the technical specifications of visibility of DER and the provision of dynamic import and export limits.

2.18. The CSIP AUS leverages existing international standards (including IEEE 2030.5) and engineering principles to explicitly define functionality that is specific to the Australian context and to help the industry to unlock greater value of DER for the benefit of consumers. Figure 6 below summarises at a high level the interlinkages between DER communications standards and protocols applicable to Australia. As set out above, this report focuses on the development of an assessment framework for the applicability of features in the CSIP AUS standards. We have not focused specifically on the IEEE 2030.5 standard, nor on other Australian standards that have already been implemented, as part of this analysis.

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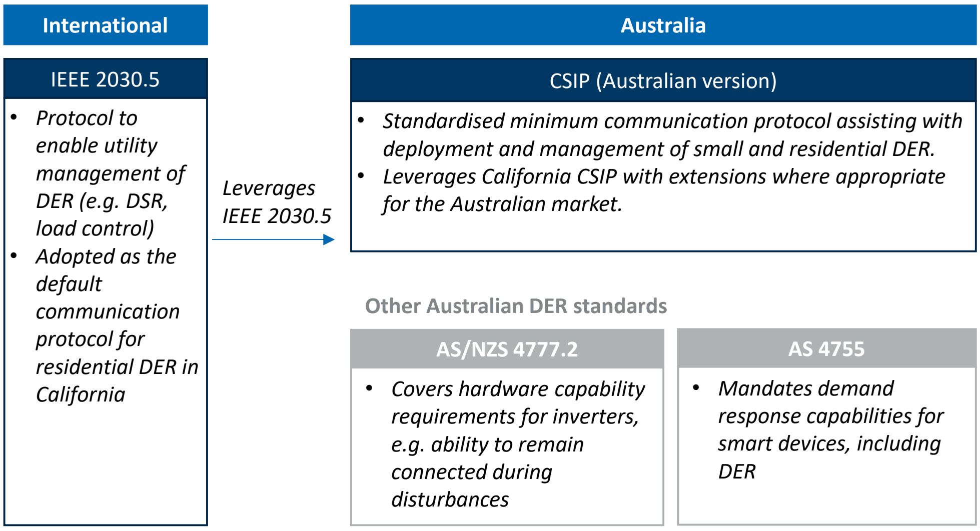
[27] ESB, Post-2025 Market Design. Final advice to Energy Ministers. Part B. Emphasis added.

[28] Upper and/or lower bounds for import and export of power from a particular connection point or a device, during a specific time interval.

[29] ARENA – DEIP Interoperability Steering Committee (link).

Figure 6: Selected Australian DER communication standards/protocols



Source: FTI analysis

2.19. As set out in Figure 6 above, the CSIP AUS draws on the international standard IEEE 2030.5, and also on the CSIP California, to develop a standardised communication protocol for residential DER, with a view to allow different DER assets to communicate with each other and with third party interfaces, in order to make Australia DER more interoperable.

2.20. The CSIP AUS is complex and includes a broad range of technical features that could potentially be mandated in the NEM. To navigate this, we have broken down the CSIP AUS into five categories of technical features, in collaboration with industry stakeholders, as set out in Figure 7 below. This figure also presents our initial analysis of the examples of relevant technical features that could be implemented.

Figure 7: Key categories of technical features within CSIP AUS

	1 Grid support DER functions	2 Mechanisms for control	3 Data	4 Registration	5 Cyber security
Description	• Features (autonomous or controllable) which can support the security and reliability of the power system	• The levels of communication which must comply with IEEE 2030.5 under CSIP • The interfaces through which entities and assets must communicate	• Measuring, collecting and reporting data relating to the performance of DER and the local network	• Registration of DER assets and their respective technical characteristics	• Protecting data shared between the aggregators, site hosts, and DERs and other entities.
Example features	• Grid import and export limits • Charge and discharge rate limits	• Protocols between the aggregator and DER • Range of DER which standards will apply to	• Monitoring data (power, voltage and frequency) • Operational status reports • Alarms	• Maximum rate of energy transfer • Maximum reactive power • Max apparent power • Min power factor displacement	• Data flows • Data storage • Device authentication • Request authorization

Source: FTI consulting analysis

2.21. As shown in Figure 7 above, five categories of technical features were identified as high-level groupings that may be applicable through standards:

- **Grid support DER functions** – Technical requirements or features that are defined for DER devices, inverters or connection points that support the security and reliability of the connecting distribution network and wider power system. Grid support DER functions typically seek to manage the impact DER is having on the network and use centralised communication to leverage DER to support the network.
- **Mechanisms for control** - The manner in which the DNSP, or system operator, communicates with or has visibility of the DER device.[30] Mechanisms for control represent the method upon which grid support DER functions are delivered to DERs. This is primarily via interfaces through which DNSPs and aggregators (and ultimately DER devices) communicate. These protocols may be through an aggregator's proprietary API/language or standardised based on IEEE 2030.5.
- **Data** - The measurement, collection and reporting of data specific to the DER device and site or connection point. A variety of data may be measured and/or collected relating to the physical performance of the DER as well as the resulting impact on the network. Data may be measured and recorded at differing intervals and is likely to include monitoring data (power, voltage, frequency), operational status reports (device activity, state of charge, enabled) or alarms.
- **Registration** - The static information or data that defines the technical characteristics of DER. Registration data specifies (for example) the size, number, type and model of DER devices and inverters, and aggregates this up to the connection point. Registration includes identifiers for the purpose of centralised registry or oversight.
- **Cyber security** – The protection of devices and data in relation to DER with the potential to be visible to other devices, aggregators, site hosts and centralised bodies. Cyber security standards and protocols protect these information flows and the hardware and software itself.

2.22. However, it does not follow that all of these technical features should be standardised in Australia. Indeed, there are limits to how much standardisation is desirable or economically efficient. This is because excessive standardisation may lead to suboptimal outcomes from consumers' perspective, including:

- **Picking losers.** By standardising technology choices, policy makers may inadvertently pick losers (instead of winners), if the choices being made do not meet consumer preferences in the long run.

[30] These mechanisms could also include the definition of default protocols/settings to use in the event of loss of communication.

- **Limited innovation.** If OEMs are required to meet prescribed technical specifications, they may no longer innovate products and offerings. In turn, aggregators and service providers may be limited in the products and services they offer to consumers.
- **Reduced competition.** Building on the reduced innovation risk described above, this can in turn reduce competition among OEMs (for consumers buying DER), as well as competition among aggregators/retailers (for consumers looking to sell services using their DER).

2.23. The following subsection examines how policy makers can approach the decision regarding which technical features or standards are desirable to implement.

D. Deciding upon which standards to implement

2.24. To reach an economically efficient and desirable level of technical standardisation, policy makers in Australia are now at a critical juncture, where they need to decide upon which of the technical standards or features to implement, and to what extent they are mandated. This is indeed one of the questions that the DEIP has been seeking to address through its API[31] standards workgroup.

2.25. Deciding on which technical standards or features to implement in the NEM is a complex matter for three reasons: first, the technical standards considered by the DEIP could be applied to a very wide range of issues; second, there are typically both pros and cons associated with any potential standard, and these will depend to some extent on how the broader system evolves; and third, the technical standards are likely to remain in place for an extended period of time, so their implementation needs to weigh up the needs of current and future consumers, and also consider the potential risk of inefficient technology lock-in.

2.26. Given the breadth of the technical standards considered by the DEIP, it is not immediately clear which areas would benefit from technical standards being introduced, and areas where technical standards could inhibit competition and innovation. Therefore, it is now becoming apparent that additional policy guidance is necessary to advise on how much and what type of standardisation is appropriate.

2.27. The following section aims to support the next step of this policy guidance by developing an **assessment framework** that could be used to evaluate a broad range of technical standards (or features) for potential implementation in the NEM.

[31] Application Programming Interface

3. Approach and methodology

3.1. As outlined in Section 2, the rapid deployment of DER across the NEM brings opportunities but also challenges. Policy makers are now at a stage where they need to decide which elements of the CSIP standard should be implemented in order to facilitate DER interoperability. In this section, we set out the process we followed in developing the assessment framework (Section A), followed by a description of the main criteria we have identified (Section B), and finally a description of the assessment process and the scoring methodology we applied against each of the criteria (Section C).

3.2. For clarity, this report does not seek to reach conclusions on which combination of features to implement, but instead presents and demonstrates the assessment framework and identifies trade-offs which policy makers are likely encounter when evaluating potential technical features for implementation in the NEM.

A. Approach to developing an assessment framework

3.3. DER interoperability and DER standardisation need to be seen as related concepts: to support a desired degree of DER interoperability, it may be necessary to impose a degree of standardisation on certain elements of the supply chain, such that DER supports system reliability and security, or such that consumers who own DER can switch their energy retailers. However, there may be other technical characteristics where a degree of flexibility and non-standardisation of how devices and interfaces inter-operate may be more appropriate, in order to encourage competition and innovation for the benefit of consumers.

3.4. To help policy makers adjudicate between areas where standardisation for the purposes of DER interoperability may be desirable, and thus achieve an appropriate balance of standardisation in the industry, we have, in conjunction with stakeholders, developed an assessment framework that seeks to provide policy makers with an objective set of criteria to assess potential standards or features of technical standards, and that seeks to help policy makers understand of the implications and trade-offs associated with specific aspects of technical feature design.

3.5. In developing this assessment framework, we have worked closely with the ESB, and a wider pool of industry stakeholders (representatives from the market bodies including AEMO, AEMC, AER, and from the DEIP workgroup), to define, test and then refine the criteria in the assessment framework.

3.6. The process through which we developed this assessment framework included the following steps:

- First, we identified an initial set of criteria, capturing a broad range of issues which policy makers may consider when assessing potential technical standards.
- Second, we worked with the ESB and industry stakeholders to identify a subset of technical features, which could be used to ‘road test’ and refine the assessment

framework. Specifically, through a stakeholder workshop (and subsequent bilateral feedback from workshop participants) we:

— Summarised key 'groupings' of technical features contained within the CSIP, to ensure the framework is applicable to a wide range of possible features; and

— Identified a subset of key technical features from across these groupings which are of interest to stakeholders, and where the decision on their implementation is not clear cut (and hence allows for an interesting debate regarding the pros and cons of standardising the feature).

- Third, we tested the framework on the subset of key features identified and presented our analysis to stakeholders. We then sought stakeholder input through a formal workshop, follow-up videoconference, and through direct bilateral feedback. The feedback on the features presented and our evaluation of their pros and cons was used to further refine the assessment framework and examine the trade-offs and tensions which are likely to arise between assessment criteria when applying the framework.

B. Assessment criteria

3.7. The starting point for the criteria that should be included in the assessment framework is the National Electricity Objective ("NEO"), as stated in the National Electricity Law ("NEL"). This objective[32] is "*to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:*

- *price, quality, safety and reliability and security of supply of electricity*
- *the reliability, safety and security of the national electricity system.*"

3.8. Through our analysis, testing and engagement with stakeholders, we have identified seven key assessment criteria.[33] These criteria are:

- Criterion 1: System security and reliability;
- Criterion 2: System and network costs;
- Criterion 3: Consumer equity and acceptability;
- Criterion 4: Market facilitation;
- Criterion 5: Data privacy and cyber security;
- Criterion 6: Flexibility, adaptability and innovation; and
- Criterion 7: Compliance and monitoring burden.

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[32] AEMC (link).

[33] Our initial assessment framework only identified six criteria; through discussions with stakeholders we added a separate criterion on the consumer equity and acceptability, evaluating the equity and acceptability of potential technical standards.

3.9. All of the seven criteria above ultimately relate to consumer benefits (or costs) arising from potential technical standards for interoperability. For example, reduced system security and reliability (Criterion 1) would increase the need for market operator interventions, the costs of which would ultimately be borne by consumers. Similarly, any costs related to the DNSP functionality required to integrate DER assets would, again, ultimately be borne by consumers. The distinction we make with Criterion 3 (Consumer equity and acceptability) focuses specifically on the distributional impact of any potential technical standards for interoperability, and associated perception by consumers of their fairness. We also emphasise that the assessment below should be performed by considering the impact of a standard on the entirety of the customer base, rather than solely for owners of DER. This is because, as we have noted previously, the decisions regarding the interoperability standards are likely to affect all consumers (e.g. through system-wide costs).

3.10. We discuss each criterion in turn below.

Criterion 1: System security and reliability

3.11. 'System security and reliability' evaluates the extent to which a standard facilitates efficient and effective system operation in line with both current standards and standards that may become increasingly relevant in future (for example, DNSP-provided dynamic operating envelopes). This helps to evaluate whether a standard is desirable from the system operation perspective, in terms of system security[34] and system reliability.[35]

3.12. Technical standards that perform well against this criterion are likely to improve the security and reliability of the NEM electricity system. For instance, dynamic grid import and export limits at household connection points would likely help to maintain voltage and thermal limits at a distribution network level, as well as allowing greater DER FCAS provision during 'system normal' operation.

3.13. Technical standards that score poorly instead increase the probability of power outages or system volatility that may require greater intervention to manage.

Criterion 2: System and network costs

3.14. 'System and network costs' considers the magnitude and efficiency of the cost burden imposed in relation to system operation and network augmentations. This criterion helps to evaluate the overall cost and benefit impact of potential technical standards and identify those standards where total benefits exceed total costs, in aggregate for all relevant market participants, over a pre-agreed period of time.

3.15. There are several strands to the magnitude of the cost impact, as the costs associated with this criterion need to include:

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[34] *"Power system security relates to: i) the technical parameters of the power system such as voltage and frequency; ii) the rate at which these parameters might change; and iii) the ability of the system to withstand faults. The power system is secure when technical parameters within defined limits."* Source: AEMC, Security website (link).

[35] *"A reliable power system has enough generation, demand response and network capacity to supply customers with the energy that they demand with a very high degree of confidence."* AEMC, Reliability Website (link).

- the short-term impact, for example on the cost of operating the system in real-time, including any directions or interventions by the system operator, such as through redispatch to manage network congestion. Similarly, there may be costs to DNSPs[36] to upgrade their existing functionalities, platforms and processes to communicate better with DER (and/or to collect, store and process any relevant data, if applicable); and
- The long-term impact, for example on the total cost of network reinforcements or upgrades (on the distribution and/or transmission network), as well as the total costs of meeting consumer demand (including all investments made by consumers behind meter).

3.16. In addition, both the direct and indirect costs need to be considered, for example in terms of the total cost of procuring essential system services by the market operator (a direct cost), and the indirect cost of imposing a technical standard, which may have a hidden or less visible cost impact on market participants. To evaluate the full costs, it is important to take into account the full market design context. For example, under the current NEM market design, the direct apparent cost of any DER curtailment is zero to the system operator, as it does not compensate consumers for curtailing their exports (although this might change in the future). This means that, if curtailment is used more frequently in the future (in part as a result of a technical standard being implemented), this apparent cost to the system operator will remain zero, but the impact on consumers needs to be recognised: consumers may be paid less for the – now reduced – volume of exports onto the grid.[37]

3.17. Strong performance against this criterion indicates that a standard delivers significant cost savings (e.g. on the total costs of managing the system), taking into account both the directly visible costs and the less visible costs, as discussed in the previous paragraph. For example, explicit monetary compensation for consumers who comply with a technical standard that increases the flexibility of DER, and thus allows the market operator to manage the system at a lower cost, would score well against this criterion.

3.18. By contrast, poor performance indicates that a standard creates a large cost burden relative to the benefits generated for consumers. For example, a technical standard whose aggregate costs exceed the aggregate benefits, would score poorly against this criterion.

Criterion 3: Consumer equity and acceptability

3.19. 'Consumer equity and acceptability' evaluates two main factors. Firstly, it considers how fairly the costs and benefits of a standard are distributed across individual consumers. Secondly, it

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[36] For clarity, the wider matter of distribution regulatory reform is beyond of the scope of this report.

[37] In practice, some of the times when the system operator is likely to curtail exports from DER are likely to coincide with periods of excess supply over demand, and hence wholesale prices being close to zero. In such circumstances, the net impact on consumers (insofar as the value of their exports is linked to the wholesale spot price) could be minimal. However, the impact on consumers could be very different if (1) exports are curtailed due to a congestion constraint, such that the zonal spot price is non-zero when the consumer is being curtailed (this divergence is due to the non-use of locational marginal pricing, another aspect of the wider market design of the NEM); or (2) there are feed-in-tariffs in place that 'top up' consumers relative to the prevailing wholesale spot prices.

considers the likelihood of significant resistance from consumers to the introduction of the standard. The objective of this criterion is to identify standards that are likely to be widely acceptable to the broad consumer population, which would in turn make it more straightforward for policy makers to implement such standards. Importantly, this criterion considers the impact of technical standards on all consumers, not only those with DER or those upon which the technical standards would directly apply to their device or operations.

3.20. We recognise that consumer equity and acceptability is not always a key criterion in economic assessments of this type; the economic view tends to focus on aggregate costs and benefits, and to assume that distributional issues can be resolved through supplementary policies. However, in the case of DER interoperability, it may be that a broad-based acceptability of technical standards to end consumers is critical. This is because a policy decision on DER interoperability that is not broadly acceptable to consumers risks causing significant resistance (or backlash) and, in turn, policy makers risk losing the '**social licence**' for change. This could cause a significant delay to any reforms and less uptake of DER in the longer term. This would ultimately be to the detriment of consumers, who could face higher (potentially indirect and less visible) costs of managing the power system with a low degree of interoperability, as well as poorer decarbonisation outcomes. On this occasion, we therefore propose to include this criterion in the assessment framework.

3.21. A strong performance against this criterion indicates that the distribution of costs is likely to be broadly acceptable to consumers and opportunities to participate in markets for generation and ancillary services are broadly seen as equitable. For example, if a DNSP identifies a need to temporarily curtail the export of power in a particular region (at a small cost to consumers, in exchange for the benefit of avoiding a large network reinforcement cost), a uniform curtailment across all (or most) classes of consumers may be seen as more equitable than curtailing a smaller subset of consumers who would bear a disproportionate share of the cost in terms of lost revenues from DER energy exports. As discussed previously, the market design context is critical here: if consumers were compensated for any curtailment (through constrained-off payments) instead of being simply cut off, then this could score better from an efficiency perspective.[38] However, any potential technical standards need to be evaluated in the context of the prevailing market design (or, if changes to the design are expected, in the context of the planned future market design).

3.22. Poor performance entails significant concentration of costs on a small number of consumers, or restricted participation in new markets for specific groups of consumers. For example, a technical standard that prevents specific OEM devices from participating in certain markets (and hence from earning revenues from those assets) may not be perceived as fair by consumers who had invested in good faith in those devices in expectation of a particular revenue stream.

[38] Alternatively, access to the distribution network could be rationed through price signals. This market design would effectively approximate a distribution locational marginal pricing regime.

3.23. Importantly, equity in this context should not be interpreted as identical treatment of all consumers. For example, if consumers who make an investment in a DER device that is compliant with certain technical standards and – as a result of that compliance – this unlocks additional options for the consumer to monetise the asset (e.g. through accessing new products or services from an aggregator), this outcome could score positively on the equity criterion. This is because the consumer is "duly discriminated" (in contrast to an "undue discrimination" which is not desirable) in respect of the choices that they have made.

3.24. Whilst this criterion focuses on the distributional impacts and consumer acceptability of a technical standard, it is important to note that all criteria are evaluated through a consumer lens (see also paragraph 3.9 above), since the outcomes across all criteria ultimately have direct impacts on consumers (both DER owners and non-DER owners).

Criterion 4: Market facilitation

3.25. 'Market facilitation' refers to the extent to which a standard facilitates the development of well-functioning competitive markets without favouring specific technical solutions. This includes the extent to which barriers to entry are created, the availability of information in the market, and the possibility of causing a 'lock-in' for a specific technology. The purpose of this criterion is to identify standards that encourage innovation in hardware, software and service solutions offered to consumers, support the development of new markets (again, both for devices and for services), and to encourage competition in such markets.

3.26. Strong performance against this criterion is indicative of the ability of a standard to support a competitive market for example by facilitating greater choice, innovation, and low barriers to switching (both devices and service providers). A technical standard that imposes a consistent mechanism for communication between DER by aggregators (e.g. through a common set of protocols) helps underpin the development of innovative products and retail contracts through which DER owners can provide flexibility services to DNSPs and the system operator, and be remunerated in return. Similarly, a technical standard that allows consumers to seamlessly (or close to) switch between service providers, access innovative products, and even maintain multiple relationships with retailers/aggregators and VPPs, would score well against this standard.

3.27. Weak performance indicates the likelihood that restrictions or limitations would be placed on competition within Australian markets, or that consumers become 'locked in' to arrangements with their current aggregators or retailers and could not easily switch. For example, a lack of standardisation of some consumer data could restrict portability of DER owners between retailers/aggregators, to the detriment of competition among those retailers/aggregators.

Criterion 5: Data privacy and cyber security

3.28. 'Data privacy and security' measures the extent to which data requirements are imposed and the risk that a breach or exposure of sensitive or personal data could occur. The objective of this criterion is to identify standards that support prevailing consumer data privacy rights, and also enable a desired degree of cyber security of the network.

3.29. Standards that perform well against this criterion are those with limited data requirements, or where data is transferred in a highly aggregated form, protecting individual households. For example, to support NEM-wide reliability, AEMO may only need to have visibility over certain data about the power flows on the network, aggregated at grid supply points (as opposed to granular household-level or device-level data).

3.30. Standards that perform poorly against this criterion impose the provision of detailed and time-specific data on household device usage, increasing the probability of hacks or sensitive data being visible to parties who could misuse the data. For example, standards that require specific OEMs to downgrade their security protocols, in order to facilitate interoperability with other DER would score poorly.

Criterion 6: Flexibility and adaptability

3.31. 'Flexibility and adaptability' covers the ability of a standard to adapt in line with the evolving power market, prevailing policy objectives and the future needs of consumers. The objective of this criterion is to help identify standards that are appropriately flexible and can therefore adapt over time, and in geographic terms, to meet the needs of current and future NEM consumers.

3.32. Hence, a technical standard performs well against this criterion if it allows for parameters to be updated easily to accommodate these shifts in priorities with minimal restrictions or negative consequences (such as increased costs, for example to upgrade hardware or software solutions). For example, standards that require DER to have a certain technical capabilities (e.g. to respond to instructions to change operating characteristics such as export power), and where the exact parameters can be set and adjusted remotely by a third party would perform well against this standard.

3.33. Poor performance would occur where standards require rigid application. For example, standards requiring functionality to be hard-wired into hardware or software may 'lock-in' particular solutions, hindering future agility in the power market. Similarly, a lack of standardisation of the equipment that communicates between consumers and aggregators, which would require a manual physical change if the consumer wishes to switch aggregators (e.g. an engineer visit the consumer's premises to change the equipment's settings, or to replace hardware) would score poorly on this criterion.

Criterion 7: Compliance and monitoring burden

3.34. Finally, 'Compliance and monitoring burden' covers the burden created by adherence to a new standard placed on stakeholders, as well as the burden placed on authorities to monitor compliance and to take action against non-compliance. The objective of this criterion is to help identify standards that do not create disproportionate burden on relevant stakeholders, and/or standards that help alleviate the current compliance and monitoring burden, for example on consumers or DNSPs.

3.35. A standard that performs well will create minimal burdens for stakeholders or authorities. For example, where compliance might be made self-evident through the continued smooth operation of devices, then such a standard would score highly.

3.36. Poor performance indicates that a standard requires ongoing, detailed, real-time reporting and monitoring to ensure that compliance is maintained, creating a substantial burden for stakeholders and authorities.

C. Assessment process

3.37. The assessment framework can apply to different technical standards, including:

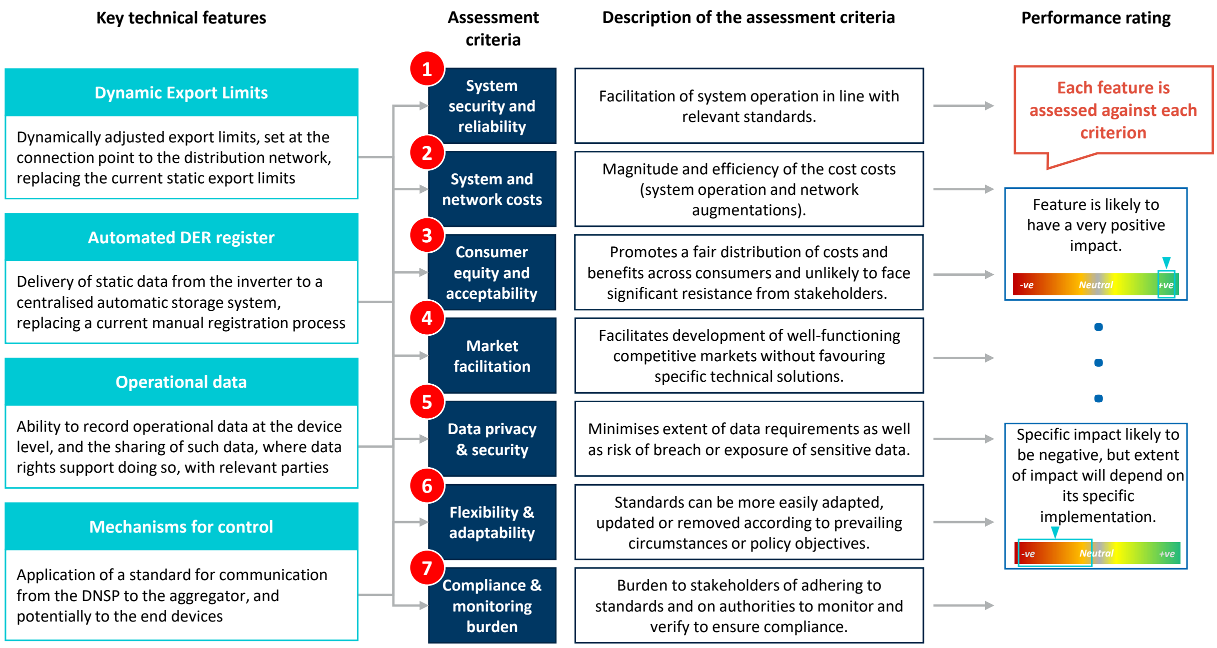
- Technical standards that are likely to take a long time to implement (potentially with stages along the way), but ultimately represent a single package of change. These would be evaluated in "one go" through the framework.
- Technical standards that have a number of discrete elements which are sequential, but their implementation could stop at any of the steps. In this case, each "step" could be evaluated separately through the framework, starting from step 1, and continuing for as long as each incremental step appears to benefit consumers.
- Variants or options of technical standards. To the extent that these are bolt-ons to other arrangements, these could also be evaluated individually through the framework. In this sense, the framework can also be used to compare and contrast different options/variants of technical standards by putting each of them through the framework and comparing the outcomes.

3.38. To illustrate the application of the assessment framework, we have evaluated four different technical features against each of the seven criteria. For each of the features we have followed the process summarised in Figure 8 and attributed a score for each of the criteria. These scores are qualitative in nature, and should be interpreted as follows:

- Scores towards the red region are negative and indicate that the feature scored poorly against that criterion.
- Scores towards the orange region are also negative, but less strongly (e.g. with some mitigation options available).
- Scores towards the grey region indicate a limited impact of the technical standard relative to the counterfactual status quo.
- Scores towards the yellow or light green region are positive, but not very strongly (as there are some risk factors that make the impact less positive).
- Scores towards the dark green region are positive and indicate that the features scored well against that criterion.
- The width of the blue box against the red-amber-green background indicates the uncertainty regarding the assessment, with wider boxes indicating a more uncertain

assessment (i.e. lack of confidence as to whether the impact is positive, negative or neutral), and narrower boxes indicating a more certain assessment (i.e. confidence that the impact is positive, negative or neutral, as indicated by the position of the box).

Figure 8: Assessment process



Source: FTI analysis

3.39. The evaluation process would start with a **'first pass' analysis**, where each of the seven criteria is assessed qualitatively and ranked using the scale as set out above. At this stage some of the assessments may be relatively uncertain as to the scale of the impact on consumers.

3.40. Based on the 'first pass' analysis, if the proposed technical standard appears to be important, and if additional analysis appears to be suitable and proportionate, then a more detailed **cost-benefit analysis** is performed. This analysis would be quantitative and encompass those criteria[39] that lend themselves to be quantified (in particular Criteria 1 and 2), and would be guided by the 'first pass' analysis (for example, focusing on specific areas of uncertainty that were previously identified). However, this quantitative analysis would be augmented with a qualitative assessment of those criteria that are not suitable for quantification. The final output would then be a cost-benefit assessment of a proposed standard where each of the seven criteria is evaluated either qualitatively or quantitatively as appropriate (ensuring there is no double-counting of costs or benefits).

3.41. While the assessment framework does not, in itself, define a specific roadmap for the implementation of prospective standards, it can be used to identify an optimal roadmap, for example by testing different variants (speeds) for the rollout, and comparing the outcomes

[39] The framework is not intended to work by testing individual cost-benefit analyses for each of the criteria individually, but rather by combining the quantifiable elements into a single assessment.

(see also paragraph 3.37 above for a description of different standards that can be put into the assessment framework).

3.42. The detailed evaluation of the four example technical features we have performed is presented in Appendix 1. In this evaluation we typically identified the pros and cons of different technical features against the seven criteria set out above. In some cases, it was also helpful to comment on the 'minimum expectation' for the criterion, to complement the analysis of the pros and cons. The following section summarises the four worked examples.

4. Illustration of the assessment framework

4.1. In this section we briefly summarise worked examples of four technical features, and their evaluation against the criteria of the assessment framework set out in the previous section. The full assessment is provided in 0. These four technical features are:

- **Dynamic Export Limits ("DELs")**, defined as dynamically adjusted export limits, set at the connection point of individual households to the distribution network, replacing the current static export limits (see Box 1 in 0 for the full definition);
- **Automatic DER registration (static data)**, defined as the delivery of static or nameplate data from the inverter to a centralised automatic storage system, replacing a current manual registration process (see Box 2 in 0 for the full definition);
- **Operational data**, defined as the requirement for DER devices to have the functionality to record certain DER operational data at the individual device level, and the sharing of such data in a standard and safe manner, where data rights support doing so, with AEMO, DNSPs, aggregators/retailers, or distributed energy resource management ("DERM") providers (see Box 3 in 0 for the full definition);
- **Mechanisms for control**, defined as the application of a standard (e.g. IEEE 2030.5) for communication from the DNSP to the aggregator, and potentially to the end devices, instead of the counterfactual where communication 'languages' could vary across aggregators and devices (see Box 4 in 0 for the full definition).

4.2. These four technical features have been selected in collaboration with the ESB's stakeholder group (including representatives from the market bodies including AEMO, AEMC, AER, and representatives from the DEIP workgroup). These features serve as good examples to (1) demonstrate how the framework can be used in practice; and (2) highlight likely trade-offs that will arise if particular standards are implemented. They should not be interpreted as actual technical features that may be put forward for potential implementation in the NEM; rather, they have been selected to 'road test' the assessment framework and to help identify relevant tensions and trade-offs between the criteria. Similarly, the assumptions we have made regarding the features' exact specification should not be interpreted as the preferred specifications for potential implementation in the NEM, but rather as illustrative assumptions to help make the discussion more tangible for the purposes of testing the application of the assessment framework.

A. Dynamic Export Limits

4.3. Dynamic export limits, in replacing their static counterparts, allocate an upper bound on export power for a specific time interval and connection point.[40] Less strict limits allow for

[40] DELs represent and impact only the DER generation that is exported onto the network and do not impact or intend to impact the DER device self-consumption (power or rate of flow).

greater export, while tighter limits may be imposed during periods of network congestion or minimum operational demand. In doing so, DELs can help the overall system to maximise DER exports when conditions allow it, and thus optimise the use of the distribution network.

4.4. As shown in the assessment summary in Figure 9 below, DELs have the potential to bring significant benefits in terms of system security and reliability (Criterion 1) and system and network costs (Criterion 2). This is driven by the expected impact of using DELs to actively manage power flows on the network, which is likely to increase the efficiency with which the networks are used and therefore improve both security and reliability, as well as lowering the overall costs of managing the power system.

4.5. The DELs are assumed to be implemented without any explicit remuneration to consumers for the flexibility services that this functionality provides. However, should this change in the future, this could encourage the development of new markets being created to help monetise the flexibility arising from the use of DELs. For example, consumers might be able to access innovative service products from aggregators that help them monetise the new flexibility. This would encourage innovation in the retail markets, and hence competition for consumers and switching (Criterion 4).

4.6. The application of DELs is, by construction, flexible and can be rolled out as needed over time and geographically to regions that would benefit the most (Criterion 5).

4.7. However, there are potential downsides in relation to the possible cost transfers between cohorts of consumers, and therefore the acceptability of DELs. The exact implementation of DELs is also likely to be highly complex, and the rules for applying such limits will be challenging to articulate in a way that is both economically efficient and acceptable to consumers (Criterion 3). In particular, the potential benefits and costs of DELs are likely to be spread unevenly across different cohorts of consumers (e.g. those with legacy inverters compared to those with new inverters; and those who are active and informed consumers relative to those who are more passive, etc).

4.8. Additional downsides relate to potential security issues, and the compliance and monitoring burden, although these seem relatively minor (Criterion 5 and Criterion 7).

Figure 9: Assessment summary of Dynamic Export Limits

Criteria	Summary pros and cons	Illustrative evaluation
1 System security and reliability	✓ Likely a positive impact on distribution system security and reliability (e.g. voltage and thermal management) ✓ May allow greater DER provision of ancillary services ✓ More efficient use of network capacity	-ve +ve
2 System and network costs	✓ Reduces costs associated with managing the system ✓ Avoids / reduces costs of network augmentations ? Impact on curtailment and substitution of paid-for services with DELs	-ve +ve
3 Consumer equity and acceptability	✓ Lower system management costs passed on via consumer bills and customers may be able to sell valuable DEL services if markets are created ? Legacy inverters may have to be upgraded; challenges with allocating limits across consumers × Potential cost transfers between legacy and new inverter owners perceived as unfair	-ve +ve
4 Market facilitation	? No explicit monetisation (and hence limited incentive for developing new markets) under current arrangements, but explicit compensation for DEL services could encourage innovation and competition × Risk that features may not be widely adopted internationally, potentially reducing OEM competition with Australian markets	-ve +ve
5 Data privacy & cyber security	? If strong cyber security protocols are in place, the incremental risk arising from DELs is low; If not, there is an increased risk to system stability and consumer revenues × Ability to control DEL increases risk associated with potential hacks	-ve +ve
6 Flexibility, adaptability & innovation	✓ DELs can be flexibly rolled out (over time and geographically) and are by definition adjustable × However, introduction may incentivise investment decisions (e.g. in batteries) that may lead to a degree of 'lock in'	-ve +ve
7 Compliance & monitoring burden	× Potential for increase in OEM compliance costs and compliance monitoring burden, e.g. if monitoring of real-time performance is required ? Some this can be mitigated via automatic registration features	-ve +ve

Source: FTI analysis

B. Automatic DER registration

4.9. Automatic DER registration, in replacing the current manual registration process, has the potential to improve visibility of the static data for network assets, and provide a continuous check on the settings applied to inverters. The automated and direct delivery of this information may reduce reliance on a manual process and thereby minimise inaccuracies and maximise the value of such information in supporting the management of power system security.

4.10. As shown in the assessment summary below, automatic DER registration has the potential to bring the greatest benefits in terms of system security and reliability (Criterion 1) and system and network costs (Criterion 2). This is driven by the assumed increase in accuracy and reliability of DER registration data and the resulting increase in quality of network data and system operator visibility of the network.

4.11. The most significant dependency in regard to the extent of the value of automatic DER registration is the relative counterfactual or the existing manual DER register. Further clarity on material gaps and inaccuracies on the current register would be required to confirm the magnitude of value that automatic DER register may provide. There is some evidence that certain distributed assets (notably solar PV) have not, at times, performed as expected, although the extent to which this could be mitigated via an automated DER register is unclear.[41]

4.12. The performance against consumer acceptability (Criterion 3) would need to be examined carefully, as consumers may save on some installation costs but potentially pay for more expensive hardware. It is also unclear whether consumers would accept potentially continuous monitoring of the static data on their device.

4.13. This standard is likely to have relatively limited impacts on data privacy and cyber security (Criterion 5), and potentially a somewhat positive impact in terms of reduced compliance and monitoring burden (Criterion 7), assuming the integration of manual and automated registers does not increase compliance costs (this should be assessed).

4.14. The automated DER register would – in itself – have limited impact on market facilitation (Criterion 4) and on flexibility and adaptability (Criterion 6), but in conjunction with other reforms, such as linking the DER register to wider market systems (such as settlement or operational data) or expanding the register to include additional assets such as electric vehicles, it could unlock further consumer benefits.

Figure 10: Assessment summary of Automated DER Registration

Criteria	Summary pros and cons	Illustrative evaluation
1 System security and reliability	✓ Increased DNSP awareness of DER characteristics should improve network security ✓ Increased compliance of DER, encouraged by greater visibility of assets, should improve network security	-ve +ve
2 System and network costs	✓ Greater visibility of DER should reduce SO system management costs and facilitate more efficient management of the network	-ve +ve
3 Consumer equity and acceptability	✓ Consumers may benefit from lower installation costs due to reduced burden on installers × Consumers may have to upgrade inverters to be able to automatically register × Cost of creating/maintaining database likely passed on to consumers × Consumers may view continued automatic monitoring with more suspicion	-ve +ve
4 Market facilitation	✓ Facilitates transfer of device registration between aggregators reducing switching costs/ barriers ? Facilitates the development of competitive markets, if able to integrate into market systems	-ve +ve
5 Data privacy & cyber security	✓ Automatic de-identification of data ✓ If strong cyber security protocols are in place, the incremental risk arising from DELs is low × If register is automatically linked to other systems, risk to customer data may be increased	-ve +ve
6 Flexibility, adaptability & innovation	✓ Once functionality is in place, DER register can extend to include newly required data × Automated processes may be more complex to update if significant changes are required	-ve +ve
7 Compliance & monitoring burden	✓ Once in place, automatic monitoring of device registration settings reduces compliance monitoring burden, both initially at installation and ongoing × If not all DER can register automatically, integration of automatic and manual register will be complex	-ve +ve

Source: FTI analysis

[41] The estimated range of non-performance ranges from 15 to 50%, depending on the exact event examined (e.g. over-frequency event, or reconnecting to the grid following a disconnection) and the expected response (e.g. the ramp time). See AEMO (2021), Behaviour of distributed resources during power system disturbance (link), page 4; and AEMO (2019) Final Report – Queensland and South Australia system separation on 25 August 2018 (link), page 6.

C. Operational data

4.15. The capability of DER devices to collect and share their operational data (such as active power flows) with other market participants represents a significant departure from the status quo in the NEM: there are currently no standards regarding data points, rates or timing and accuracy of operational (or active) DER data (for example, tracking power flows across the distribution networks at particular locations and with specific frequency). While retailers and OEMs have visibility over some operational data (e.g. metering), DNSPs do not have any real-time visibility over the active power on low-voltage networks.

4.16. Collecting and sharing selected operational data is likely to increase system security and reliability (Criterion 1) and has the potential to reduce the cost of system operations, driven primarily by the increased visibility of DER and hence more efficient management of the network. However, given the significant step up in functionality, process and systems that operational data would require[42] (for example to share, store and manage the data), there needs to be a careful consideration of the total system costs (Criterion 2) through an overall cost-benefit analysis.

4.17. In addition, this standard could help support the development of new products and markets. Similarly, increased data portability is likely to facilitate consumer switching in order to access more attractive retail deals (Criterion 4).

4.18. The implementation of this standard is also likely to be highly flexible (Criterion 6) because – once the capability is established – it may be possible to expand the type/granularity of data collected (noting, again, the associated costs of collecting, storing and managing greater volumes of data) and also adapt the sharing of the data as necessary and appropriate in line with the existing data privacy laws.

4.19. The impact of operational data on the total compliance and monitoring burden (Criterion 7) is uncertain, as there are factors going in both directions: some compliance aspects could be simplified through the use of operational data (for example cross-checking against nameplate static data), but others could be more complex (e.g. monitoring of parties who have visibility over consumers' data), with the overall balance of impact being uncertain.

4.20. The implementation of operational data would need to take place in line with the prevailing data privacy rules, to limit potential risks to privacy breaches (Criterion 5).

4.21. Consumer acceptability (Criterion 3) could potentially be negatively affected (although, as before, with highly uneven impacts across consumer cohorts). There are likely to be consumers who would benefit from the standard because they could actively switch retailer, access more innovate retail contracts and be remunerated for the data (and associated flexibility) provided to third parties. However, if the standard mandated an upgrade of legacy inverters, or if the standard was implemented in parallel with changes to data privacy laws

[42] These could be costs for retailers, DNSPs and/or other parties who may have visibility over the data.

(e.g. to reduce existing consumer privacy protections), then this could negatively affect consumer acceptability.

Figure 11: Assessment summary of Operational data

Criteria	Summary pros and cons	Illustrative evaluation
1 System security and reliability	✓ Increased DNSP and AEMO understanding of DER operational data (if indeed accessible to those parties), encouraged by greater visibility of assets, should improve network security	-ve +ve
2 System and network costs	✓ Greater visibility of DER should reduce SO system management costs and facilitate more efficient management of the network × Costs of handling data, with impact dependent on how much data is collected, shared and managed	-ve +ve
3 Consumer equity and acceptability	✓ Consumers may be incentivised to engage more actively in the market to manage DER and access contracts ? Appropriate balance of mandatory data sharing vs opt-in needs to be put in place × Costs of upgrading; and risk of lock-in if consumers cannot switch due to device not sharing data	-ve +ve
4 Market facilitation	✓ Facilitates the development of competitive markets, new products and services and switching ✓ Allows for more efficient wholesale market outcomes through facilitation of DER orchestration	-ve +ve
5 Data privacy & cyber security	✓ Consumers already share certain data; and incremental data sharing could be subject to opt-in ? Flow of additional data to third parties may add to the already-existing risks of privacy breach × Access to operational data may increase risk associated with potential hacks	-ve +ve
6 Flexibility, adaptability & innovation	✓ Once functionality is established, further operational data points may be collected if required. ✓ Allows for additional DER devices to be efficiently and automatically added to operational data system	-ve +ve
7 Compliance & monitoring burden	✓ May allow for automatic linkages between static (DER register) and operational data to ensure compliance across physical response and performance requirements ? Potential additional compliance burden on NSPs/AEMO/aggregators depend on the scale and scope of data collection and monitoring	-ve +ve

Source: FTI analysis

D. Mechanisms for control

4.22. There is currently no standard or indeed mechanism by which a centralised body (DNSPs or system operator) may communicate with aggregators or down to the individual DER device level. Aggregators themselves may communicate with end devices through their own proprietary interfaces, and, in turn, DNSPs communicate with the aggregator (or end devices), for example to deliver instructions to change the DEL, using aggregator-specific languages.

4.23. In this report we have tested whether the IEEE 2030.5 communication standard could be applied to all communications between the DNSP and aggregator (Option 1) and/or to all communications between the DNSP and aggregators, as well as between aggregators and devices (Option 2).[43]

4.24. As shown in Figure 12 below, requiring IEEE 2030.5 as the communication protocol under both Option 1 and Option 2 is likely to generate benefits in terms of network costs, and also some benefits (particularly under Option 2) in terms of system security and reliability. This is because DNSPs could utilise the standardised communication protocol at the interface with

[43] Both options would also include the definition of default protocols/settings to use in the event of loss of communication.

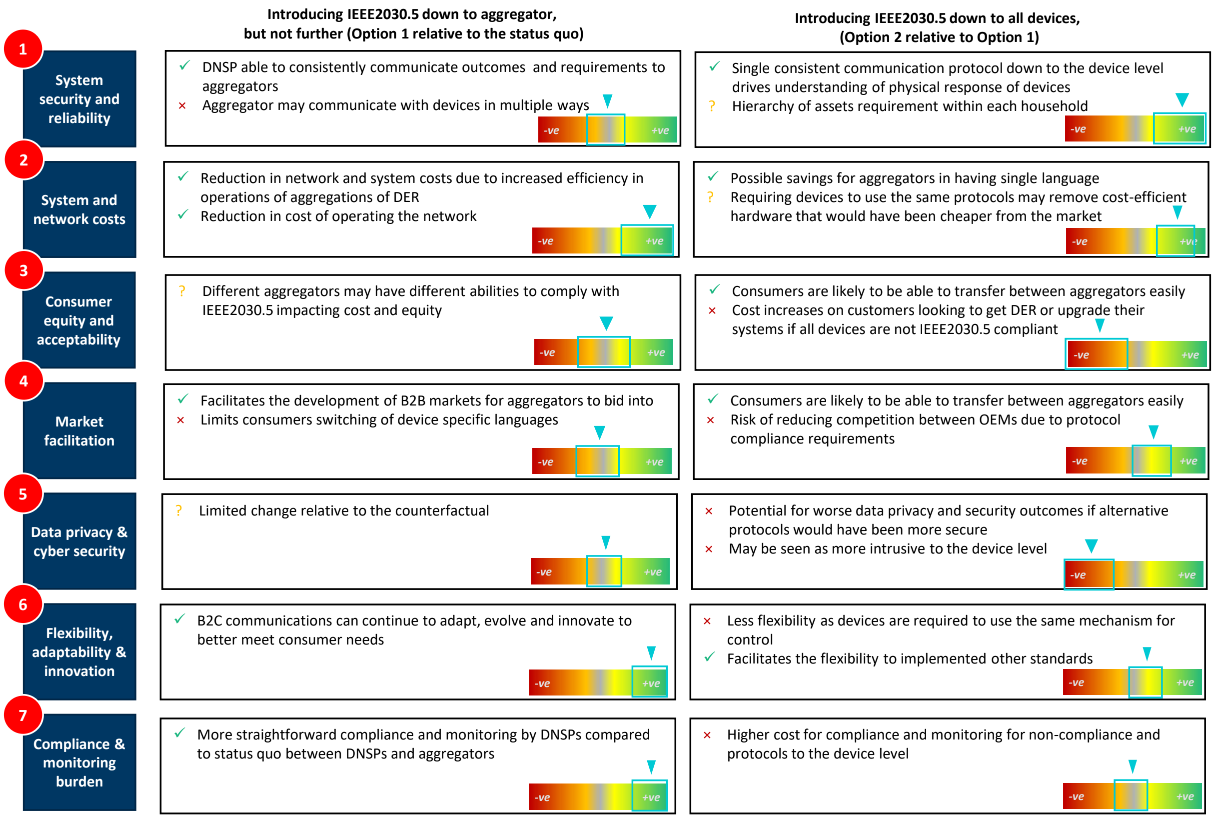
aggregators to deliver dispatch instructions (in Option 2, aggregators could then use the same protocol to communicate with the end devices). Devices and aggregators would therefore be able to better respond when providing network and system services that support system operations and stability.

4.25. Option 1 limits the requirement to use IEEE 2030.5 to the aggregator level, which means that aggregators can communicate with devices through their desired mechanisms. While this is likely to increase risk of miscommunication or decrease the efficiency of the delivery of instructions relative to Option 2, it does allow for increased variability of service providers and potential innovation in the communication protocols (as each of the providers can develop their own communication 'languages' However, the downside of Option 1 is that this freedom to develop own communication protocols inhibits consumer switching (by contrast, Option 2 promotes consumer switching).

4.26. Device manufacturers and aggregators would need to ensure their hardware and software systems comply with IEEE 2030.5. Different device manufacturers or aggregators may have different abilities to comply with the standard, which is likely to drive competition and consumer equity risks. For example, if some device manufacturers are restricted in their ability to participate in the market due to lack of compliance with the new technical standard, this may restrict the pool of offers to prospective consumers. Similarly, consumers whose aggregator needs to make additional investments to comply with the standard may be exposed to additional costs (to the extent that the investments made by the aggregator are passed through to consumers).

4.27. Our analysis also shows that different levels of the standard (in this case a 'minimum standard' in Option 1, compared to a 'higher standard' in Option 2) can score very differently in this framework. This suggests that (1) it is critical for policy makers to carefully define the technical feature and exactly how it is implemented in the market; and (2) there may be merit in evaluating multiple design options for a particular technical standard through the assessment framework. Doing so can help highlight initial trade-offs that could feed into a more detailed impact analysis, to help decide on the optimal level of standard (i.e. minimum standard vs higher levels of standard).

Figure 12: Assessment summary of Mechanisms for Control



Source: FTI analysis

4.28. The following section summarises the key findings from this evaluation and the implications for the design of the assessment framework for DER interoperability standards.

5. Key findings and next steps

5.1. In this section we set out our key findings regarding the assessment framework for DER interoperability standards and the underlying criteria, as set out in Section 1. This, in conjunction with stakeholder discussions, has been informed by a detailed analysis of four worked examples of technical features against each of the criteria, as summarised in Section 4, and set out in more detail in Appendix 1. As described earlier, the primary focus of this report is to identify an assessment framework that helps policy makers to select the right policy decisions on DER interoperability standards from the perspective of end consumers.

5.2. In the following subsections, we comment on the range of criteria that are included in the assessment framework (Section A) and on whether a qualitative or quantitative assessment is more appropriate (Section B). We also present our findings on the weighting of criteria (Section C), the importance of the wider market design context (Section D) and on the conflicts and tensions between the criteria that we have identified (Section E). Section F sets out the next steps for this analysis.

A. Range of criteria

5.3. Our analysis has indicated that the criteria put forward in the assessment framework are, broadly speaking, mutually exclusive and collectively exhaustive ("MECE"):

- **No gaps.** Having applied the seven criteria to specific examples of technical features of DER interoperability, and based on the discussion with a range of stakeholders, the consensus seems to be that the criteria we have included cover all relevant issues identified to date. In other words, we have not identified any significant gaps in the criteria,[44] and therefore consider that the list could likely be used for a wide range of technical standards.
- **Limited overlaps.** We have identified some overlap in terms of the cost impacts – for example, some costs (e.g. the cost of compliance with a new standard) could in theory be captured in Criterion 2 (as part of system and network costs[45]), or in Criterion 7 (compliance and monitoring burden). Where this is the case, we recommend that the cost is explicitly taken into account in the cost-benefit analysis under Criterion 2, and that this is not duplicated in evaluating the additional criterion (to avoid double-counting the impact). However, it seems that each of the criteria have a qualitative element that may not be captured through a cost-benefit analysis. Hence, the seven criteria still appear to be an appropriate framework to apply (rather than collapsing everything into one single cost-benefit analysis).

[44] See footnote 33 above.
[45] When capturing consumer costs, across all seven assessment criteria, it is appropriate to distinguish between cost impacts separately for DER-owners and non-DER, to ensure the distributional impacts are fully understood and evaluated.

Key finding #1: **The list of seven criteria in the assessment framework seems to provide a reasonable basis for evaluating potential technical standards for DER interoperability in the NEM.**

B. Qualitative vs quantitative framework

5.4. The assessment framework can be applied in a quantitative or in a more qualitative manner. There are two aspects to this:

- **Monetisation of the criteria** (i.e. evaluating the impact of a technical standard in dollar terms against each of the seven criteria). Based on our analysis, and in discussions with stakeholders, it appears that while some of the criteria can be evaluated in dollar terms (in particular Criterion 2 – system and network costs), this is not possible to do systematically for all the criteria in the framework. Therefore, there appears to be scope to apply a cost-benefit analysis approach to some elements of the framework, but this would need to be completed with an assessment of non-monetary impacts against other criteria. This appears to be relatively common: regulators in other jurisdictions recognise that not all criteria can be monetised, and resort to a dual approach that combines monetary and non-monetary factors.[46]

- **Scoring of the criteria using a points-based system** (i.e. attributing a score on a pre-determined scale, say from 1 to 10, based on the performance of the standard against each criterion). Based on our analysis, and in discussions with stakeholders, it appears that it would be arbitrary to score different criteria in this way and would be subject to a significant amount of challenge and disagreement among stakeholders. As such, a points-based system for scoring each criterion does not appear to be a reasonable approach to evaluating potential technical standards.

5.5. In our analysis, we have therefore applied a qualitative scoring mechanism which assesses the extent to which potential standards improve or worsen outcomes relative to the status quo. This mechanism could complement a monetised cost-benefit analysis, to the extent that certain factors can be expressed in dollar terms, but it seems important to include non-monetary factors as well.

Key finding #2: **A qualitative scoring against each of the proposed assessment criteria, which combines a cost-benefit analysis and non-monetary factors, appears to be a preferred approach relative to a pure monetary or a pure points-based quantitative scoring.**

C. Weighting of criteria

5.6. The seven criteria in the assessment framework each capture a different angle of the potential impact of a technical standard. It is often the case (and we elaborate on this further below) that the assessment identifies a particular feature scoring well on some criteria, but less well on others. There is therefore a question as to how these criteria are traded-off

[46] For example, in Great Britain, the energy regulator Ofgem evaluates both monetary and non-monetary criteria when evaluating the merits of potential large-scale energy infrastructure investments such as electricity interconnectors.

against each other. At a high level, the choice that policy makers face ranges from a mechanistic scoring (e.g. criterion X is worth 5 points and criterion Y is worth 10 points) at one end of the spectrum, through to having full discretion on the relative importance of each criterion, on a case by case basis, at the other end of the spectrum.

5.7. In practice, it is likely that neither of these two extreme approaches is appropriate. A mechanistic scoring approach is:

- **Arbitrary.** For example, it is unclear what it would mean for a standard to score 5 points on one criterion and 10 points on another criterion. There does not seem to be a clear basis for policy makers to be able to say that the latter criterion is twice as important as the former.
- **Likely to be inaccurate.** Following from the example above, it is highly unlikely that all stakeholders will agree on the relative weight attributable to different criteria. For example, the weight of Criterion 1 (system security and reliability) might be relatively high in South Australia due to the high penetration of DER and the system stability issues over recent years, but the weight itself might need to change over time as the DER penetration increases further. It appears unlikely that the assessment framework would be able to keep up with the changes in the system by adjusting the weight of the criterion over time to match the evolving challenges on the system.

5.8. At the other end, a policy of full discretion, where policy makers decide on the relative importance of different criteria for each technical standard separately, also fails to represent good regulatory practice: it is an opaque process that stakeholders are likely to find unacceptable, and it is also likely to be onerous and time consuming (as each standard is fought over individually).

5.9. Therefore, an approach where policy makers can exercise a degree of **regulatory discretion, subject to a structured process and pre-agreed principles**, seems likely to be a more balanced option for deciding on the implementation of potential standards. This approach is also likely to help facilitate and marshal discussion with stakeholders so that the merits of a standard can be discussed in certain contexts and trade-offs recognised in a set framework. Based on the worked examples (see Appendix 1) of specific technical features, we have identified the following insights in relation to the weighting of the criteria:

- Hard vs soft criteria.
  - Criterion 1 (System security and reliability), as anchored in the NEO, and Criterion 2 (System and network costs) both appear to be ‘hard’ criteria in the sense that only technical standards that support network reliability and security, and that pass an overall cost-benefit analysis, are likely to be appropriate to implement in the NEM.
  - Conversely, Criteria 4 to 7 (Market facilitation, Data privacy and security, Flexibility and adaptability and Compliance & monitoring burden) appear to be ‘soft’ criteria in the sense that policy makers may be able to somewhat trade-off the performance on these criteria against each other, for example by taking into account that a slightly

higher performance against one of these criteria can be traded-off against a slightly lower performance against another one of these criteria.

- Criterion 3 (Consumer equity and acceptability) sits in-between, as the DER interoperability reforms would be considerably easier to implement if there is a broad-based stakeholder consensus (including among consumers) on the benefits of the reforms. In this sense, it is a 'semi-hard' criterion - it may simply be politically impossible to implement reforms if there is significant stakeholder resistance. As discussed above in paragraph 3.20, this criterion underpins the overall social licence for change, and hence is likely to have a special status.

- Geographical and temporal 'weights'.
  - The importance of different criteria varies regionally and over time. For example, the impact of a standard on system reliability and security in South Australia (where the penetration of DER is the highest and where system security and reliability has been the most challenging to maintain in the recent years) is likely to be seen as much more important than in Queensland.
  - To the extent that the implementation of specific standards can be rolled out geographically and over time, it seems appropriate that policy makers recognise this variation and alter the implied 'weight' they attribute to different criteria in their decision-making process.
- Extreme scores.
  - There may be technical standards that score exceptionally well (or exceptionally poorly) on certain criteria. To take a stylised (and deliberately exaggerated) example, if a technical standard required that consumers share information on all their DER devices, as well as all their electric appliances, on a publicly accessible platform, this would attract such a poor scoring on Criterion 5 (Data privacy and security) that it would outweigh all other criteria, including any benefits for Criteria 1 and 2.
  - Based on discussions with stakeholders, it seems appropriate that if policy makers identify such extreme scores for certain standards, they could exercise their discretion and potentially allow such scoring to outweigh other criteria (even the 'hard' ones). For example, if a technical standard scores extremely poorly on cyber security, by exposing the entire DER network to extensive hacking risks, policy makers may choose that this outweighs any potential benefits to consumers (even in terms of Criterion 1 – system security and reliability, and Criterion 2 – system and network costs).

Key finding #3: **A structured approach where policy makers can use principles-based regulatory discretion appears to be a reasonable approach towards weighting the criteria of the assessment framework, while also noting that some criteria are more 'hard' and others more 'soft'.**

D. Market design context

5.10. The impact of certain standards on the NEM, and the scoring of such standards in the assessment framework set out in this report, can be highly dependent on the wider market design context. For example, the application of DELs could score either high or low, depending on the wider context:

- DELs could score highly against the market facilitation criterion if this standard was imposed in a way that enabled consumers to monetise the flexibility that DELs provide to the market. This is because DELs would be a paid-for service, for which aggregators could develop innovative products and act as market facilitators between end consumers and DNSPs (or AEMO) who would buy the flexibility services. In this context, DELs could also score relatively highly on consumer acceptability.
- Conversely, DELs could score poorly against the market facilitation criterion if this standard simply permitted relevant parties (e.g. DNSPs) to remotely adjust export limits without any direct financial compensation to the consumers affected (noting that consumers could nevertheless benefit, in aggregate, as a result of lower network augmentation costs and/or system management costs). In this context, DELs could also score relatively poorly on consumer acceptability.

5.11. Similarly, there are some overlaps and interactions between technical standards and wider legislation (e.g. data protection laws), which also need to be taken into account when evaluating potential technical standards.

Key finding #4: **The wider policy choices regarding market design are critical, and can, to a significant extent, drive the outcomes of the assessment of potential standards.[47] The implication is that the technical standards cannot be seen and evaluated in isolation, but the wider NEM policy choices (current and future) need to be taken into account when performing the assessment.**

E. Conflicts and tensions between criteria

5.12. Based on our analysis of the criteria (see Appendix 1), we have identified tensions or conflicts between the criteria, which policy makers will have to navigate. By this we mean that specific technical features that may be considered for implementation in the NEM may score well on some criteria, but as a result, score poorly on others (e.g. for example, if consumers had to lower their DER security standards in order to better support system security and reliability, this would indicate a tension between Criterion 5 and Criterion 1). Without explicit weighting (as discussed in Section C above), it falls to policy makers to decide how a positive score on one criterion should be compared relative to a negative score on another criterion. In this

[47] This observation applies in both ways: for example, if a technical standard was distortionary, then other policy decisions can be made to remedy this.

subsection we first summarise our key high-level observations. We then describe specific conflicts and tensions we have identified between criteria.

5.13. Through our work we have identified four key observations, as summarised in the following subsections.

Impacts are sensitive to specific and detailed design choices

5.14. In our analysis of the worked examples, we very quickly identified that a high-level description of a technical standard cannot easily be evaluated against the criterion. Rather, a very detailed description of the standard is required in order to perform a robust evaluation.

- For example, in considering the implementation of DELs, the impact on consumer acceptability will depend on the exact process through which these limits are allocated to consumers, how any changes are communicated and how they are understood by consumers. The impacts can also vary significantly across different cohorts of consumers.
- As a second example, the implementation of an automated data register for static data may not, in itself, deliver any significant impact on Criterion 4 (Market facilitation), but if the register is in turn linked into wider systems (e.g. live monitoring and settlement), then it could provide significant support for the development of competitive markets. Policy makers therefore need to consider whether a particular standard could serve as a 'starting point' and a prerequisite for the implementation of further reforms, and how such a standard could score in the assessment framework.

Key finding #5: **In assessing the impact of different standards, policy makers will need to examine the very fine details of each proposal before reaching a decision. High-level descriptions are not sufficient to decide on a course of action.**

Technical features may be co-dependent

5.15. Our analysis has identified examples where the impact of a specific technical feature (and hence the scores it obtains in the assessment framework) will depend on other features that are co-implemented:[48]

- For example, the application of DELs to consumers may only be beneficial for system security and reliability if there is a degree of standardisation on the mechanisms for control in order to communicate those DELs to consumers (in other words, if there is no standardised mechanism for control, then DNSPs or aggregators cannot communicate DEL requirements to the devices, even though the devices may have the DEL capability).
- Similarly, the deployment of an automated DER register may bring some limited benefits, but these could be much more significant if the register is linked to the wider systems and supplemented with the sharing of 'active' data on power flows.

[48] Co-dependency of features refers to the co-dependency of the technical capabilities. It does not refer to a co-dependency of standardisation. For example, the DELs and mechanisms for control to communicate the DELs are co-dependent features but DELs are not dependent on a standardised mechanism of control.

Key finding #6: **To reflect the co-dependency between technical features and standards, policy makers may need to consider packages of standards/features together, to ensure that different technical features obtain the correct scoring against the framework criteria.**

Variability of consumer preferences and conflicts with other criteria

5.16. Different consumer groups can be impacted in different ways by features and even within a given cohort of consumers, there may be very different appetites towards some of technical standards. We have identified a number of stylised consumer groups and assessed the impact of different technical features on those groups.

- For example, we identified differences in the acceptability of certain technical features among consumers who do not own any DER, those who own DER but only wish to use it for their own consumption (and do not wish to export onto the grid, and thus monetise the DER through wider markets), and those who are actively seeking to switch suppliers, etc. Similarly, developing technical standards that give (compliant) DER owners more choice in retail contracts is in principle a good outcome for that cohort of consumers, but this may need to be assessed in the context of potentially worsened distributional outcomes (and consumers' own perceptions of fairness). The main insight, however, is that it is not only the differences between consumer cohorts that need to be taken into account, but also differences within those cohorts: for example, the attitude towards sharing real-time operational data of DER can differ significantly within otherwise relatively homogeneous consumer cohorts. In general, we found that it is not immediately clear which cohorts benefit from a standard and which ones would lose out – it depends on the exact design of the technical standard and its implementation. This creates an additional layer of complexity for policy makers wishing to develop policies that gain broad stakeholder support and acceptability.
- In addition, consumer acceptability is a criterion that has the potential to be in tension with most (although not all) other criteria in the assessment framework. To take one key example: technical features that deliver the highest overall cost savings because they are most efficient can also be the most complex (for example an algorithm-optimised allocation of DELs among consumers), which makes it highly challenging for consumers to understand and accept such an allocation.

Key finding #7: **The implication for policy makers is that it is important to carefully consider different consumer use cases in order to carefully disentangle the varied impacts that a single policy decision can have on different parties. This is likely to be critical to support policy choices that are generally acceptable to consumers and therefore have a broad-based social licence for implementation.**

Need for a roadmap

5.17. One common theme that has emerged through analysis, and that needs to be addressed across many technical features, is the timeframe over which any standard should be implemented, and closely related to that, the treatment of legacy vs new assets.

5.18. Retrospective application of new technical standards to legacy assets is typically challenging to implement as it tends to be seen as unfair by consumers who had invested in good faith in expectation of particular outcomes (e.g. invested in solar PV in expectation of a particular revenue return). If a standard has a direct adverse financial implication for such consumers[49] (through reduced revenues or an additional cost to upgrade their DER), this is likely to lead to strong resistance. Conversely, exempting legacy assets from compliance is likely to reduce the benefits of the standard (e.g. in terms of network security and reliability, or because legacy consumers cannot switch suppliers and access new products). Finally, the roadmap also needs to consider the wider OEM supply chain: the time and cost that it takes to develop the supply chain to adopt and comply with any new standards.

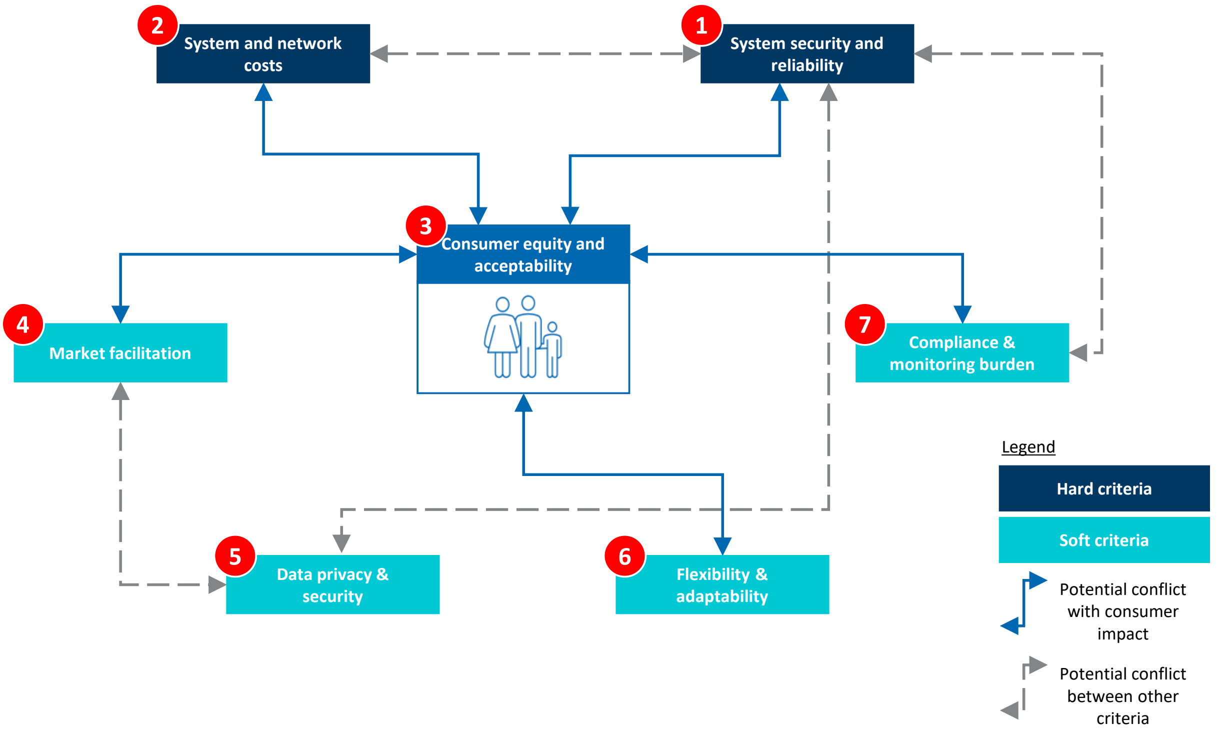
Key finding #8: **Policy makers need to carefully consider the timeframe and the scope of deploying any technical standards due to the concerns regarding retrospective application of technical standards on consumers who would be disadvantaged by such actions. Some of these concerns can be resolved 'naturally' through the lifecycle of asset replacement, and this would need to be considered by policy makers as part of developing a roadmap for the standard implementation.**

Specific conflicts and tensions identified

5.19. Some of the **specific conflicts and tensions** between criteria that we have identified are summarised in Figure 13 and described in more detail below (noting that this list should not be seen as exhaustive).

[49] This could be the case for example if technical standards were not backward-compatible.

Figure 13: Summary of conflicts and tensions between criteria



Source: FTI Consulting

Costs versus benefits

5.20. Technical standards that strengthen network reliability and security (Criterion 1) often come at a cost, which could be in the form of direct cost (e.g. more expensive DER devices due to the need of OEMs to comply with the standard), or in the form of compliance/monitoring burden on consumers.

5.21. This particular issue does not appear to be a 'tension' as such between the criteria, but rather a natural reflection of the costs and benefits of most policy decisions. This therefore appears to be relatively straightforward to assess through a cost-benefit analysis (which in any event would be necessary for any technical standard implementation).

System security and reliability versus consumer acceptability

5.22. We have identified examples of technical standards that could be perceived to be onerous by certain consumers, and hence would score poorly on consumer acceptability (Criterion 3). For example, requiring consumers to relinquish the high security standard of their existing DER device in order to increase interoperability would likely be unacceptable to many consumers.[50] To mitigate this, one option might be to allow consumers to opt out (even though this would depart from the notion of a standard applying to all consumers) from certain standards (for example standardised communications protocols) in order to make the standard more acceptable. However, this highlights a tension between the wished-for

[50] The parallel from a non-energy sector would be requiring Apple consumers to follow Android's, arguably lower, security standards, in pursuit of interoperability among mobile phone devices.

benefits (in this case system security and reliability) and consumer acceptability: if too many consumers exercise the opt-out option, then the benefits for system security and reliability will not materialise (or will materialise to a lesser extent). This highlights that any compromise on technical standards to achieve consumer acceptability risks reducing the quantum of benefits that could otherwise have been achieved.

5.23. Similarly, a technical standard that requires consumers to share more granular data with aggregators (e.g. more detailed, or more frequent information) may unlock greater system security and reliability benefits thanks to the greater visibility of DER it provides, but sharing such data with third parties may not be acceptable to consumers.

Total cost efficiency versus consumer acceptability

5.24. The cost efficiency of a particular standard may depend on its exact implementation. For example, DELs may be applied uniformly to all consumers in a wide region, or they may be tailored (almost on a household-by-household) basis, in order to optimise the power flows on the network and maximise the benefits in terms of avoided network reinforcement costs.

5.25. The uniform approach is likely to be less cost-efficient but could also be more acceptable for consumers, since the allocation of DELs could be easily explained (and consumers would understand that they are all being treated identically when the network is congested and everyone's export limits are reduced in the same way). By contrast, the latter, and potentially more cost-efficient approach where DELs are tailored specifically to individual households based on an optimisation algorithm is likely to be less acceptable to consumers (raising the inevitable question of – why am I being curtailed more than my neighbours). The degree of sophistication of individual consumers may play a role here (e.g. more sophisticated consumers may be willing to accept the algorithm-based approach), but there is nevertheless a key trade-off between the total cost efficiency of a standard and consumer acceptability. This is also closely related to the market design context, as discussed in Section 5D above.

Data privacy vs system security and reliability (and cost reduction)

5.26. Some of the technical standards (e.g. the technical capability of data sharing with third parties) may be critical to unlocking some of the network security and reliability benefits. For example, to manage the networks and the system more reliably, the relevant parties (AEMO or DNSPs) may need to have a degree of visibility of DER – indeed this is one of the main motivations behind the DER interoperability concept.

5.27. To the extent that consumers do not share their data (e.g. for privacy reasons) at the required level of granularity, this could limit the visibility of DER to relevant (authorised) third parties (e.g. DNSPs), and in turn negate some of the benefits that the standard could have unlocked. In practical terms, this means that lower DER visibility could reduce the benefits in terms of system security and reliability, or in terms of avoided network or system operation costs.

5.28. There is therefore a potential tension between consumers' data privacy and network security and reliability: the more consumers' data is protected, the less the wider system can benefit in terms of additional security and reliability. A balance of the two objectives would need to be identified.

Market facilitation versus consumer acceptability

5.29. The distributional impacts of technical standards can also play out in the way in which owners of compliant DER may access new products and new opportunities to monetise their DER, compared to the owners of non-compliant DER. For example, DER that is able to follow DEL instructions and is interoperable with other assets and wider market systems can unlock flexibility that can be rewarded through innovative contracts with an aggregator. This is a positive and desirable outcome for consumers in aggregate, because such a standard has encouraged innovation and competition among aggregators.

5.30. However, we see a risk that consumers who own non-compliant DER do not perceive this outcome as 'fair', for example because they recently invested in DER and now find themselves with outdated assets that do not allow them to access the new markets. In this sense, the new technical standard could be desirable (because it scores well against Criterion 4 – Market facilitation) and in fact fair (because consumers with compliant DER are rewarded appropriately), yet it may not be acceptable to all consumers.

5.31. In this context, it is important that policy makers correct identify what the 'fair' outcome is and do not inadvertently get swayed by the complaints of consumers who happen to own non-compliant DER.

Flexibility versus consumer acceptability

5.32. Our analysis has found that an inherent degree of flexibility in the standard can be desirable because it facilitates implementation and also allows the application of that standard to be targeted efficiently. For example, applying DELs in a flexible manner to areas that are experiencing the greatest operational challenges due to DER penetration is a desirable feature from the perspective of flexibility.

5.33. However, our analysis has also shown that this flexibility can, in itself, make the standard difficult to accept if consumers do not understand how the standard is applied. Continuing with the example of DELs, if the rollout of the DELs is indeed performed flexibly (meaning there are frequent and significant changes to the export limits to particular households), and if consumers do not understand the process (for example because from their perspective the process appears to drive random curtailment of their DER), then consumers may not see the standard as acceptable. As discussed in paragraph 3.20 above, there is a risk that this could damage the social licence for change within the wider consumer community, which in turn could lead to unnecessarily high costs and/or worse decarbonisation outcomes.

Cybersecurity versus market facilitation

5.34. Standards that link up many market systems (e.g. the static asset register, live data monitoring, settlements and the demand-side participation portal) are likely to help with system security and reliability and market facilitation and ultimately can help reduce the total cost of operating the power system. However, this interlinking of different markets could potentially increase the cybersecurity risks, as one single hack could affect a very wide portion of the market.[51]

5.35. There is therefore a potential tension to navigate between the desire to join up multiple markets (with an objective to maximise the opportunities for innovation and competition) and the potential associated cybersecurity risks.

Compliance burden and monitoring versus data privacy

5.36. Technical standards that automate the compliance and monitoring process, or at least help to reduce the burden of compliance monitoring (e.g. through greater information disclosure via continuous data sharing on electricity flows) have the potential to conflict with the desire for data privacy (e.g. if the regular data shared by the automated register is seen as intrusive). Again, this suggests that any data privacy concerns and rules may need to take into account the impact they have on the DER compliance burden, and vice versa.

F. Next steps

5.37. The assessment framework we have proposed in this report is a first step towards implementing DER interoperability standards, and it could benefit from an industry-wide discussion of the following issues:

- whether the assessment framework is correctly articulated and covers the appropriate range of factors that need to be considered for the future development of technical standards for DER interoperability;
- whether some standards could be considered for implementation at ‘minimum levels’, with no standardisation applied to more complex technical characteristics[52] (noting that both of these options could be assessed – as separate variants – through the framework set out in this report, and their scores could be compared to help policy makers choose what the appropriate ‘minimum level’ of a standard might be);
- how trade-offs between different criteria should be considered, and in particular whether the proposed approach of regulatory discretion, and no explicit weighting of criteria, is reasonable. Alternatives to this approach could include, for example, a mechanistic scoring approach to individual criteria (which appears arbitrary), or the exercise of regulatory discretion on a case-by-case basis taking into account market conditions or changes in prevailing policy priorities over time; and
- how policy makers should consider the (relatively limited) overlaps between criteria, and what alternatives could be considered to make the criteria fully MECE.

[51] In the short run, a standard that supports interlinking of multiple markets, and thus scores well on Criterion 4 – Market facilitation – could also increase the compliance and monitoring burden due to complexity of integrating systems.
[52] For example, a minimum level of standard could be applied relatively widely in order to support consumer switching, but less standardisation would apply to features where innovation is likely to happen.

5.38. The framework has been tested against four specific technical features to date, which have been selected as helpful issues for the 'road-testing' of the framework. Further feedback from stakeholders on the potential application of the framework to other issues, and in particular if such application identifies areas for refinement of the framework, would be valuable.

5.39. More broadly, this work would benefit from a consideration of the interaction between the assessment framework and ongoing work by the AEMC on the governance arrangements for technical standards. We also note that this assessment framework sits alongside the Consumer Risk Assessment[53] tool, but is applied differently: the framework in this report evaluates the impact of potential technical standards (which is a more generic evaluation); while the Consumer Risk Assessment tool evaluates, for example, the impact of new retail contracts on consumers (i.e. more concrete propositions to consumers).

[53] ESB post 2025 market Design Final Advice to Minister Part C, page 26 (link).

Appendix 1 Worked examples of the assessment framework

A1.1 This appendix presents worked examples of four technical features and their evaluation against the criteria of the assessment framework set out in the main body of the report. These four technical features are:

- Dynamic Export Limits;
- Automatic DER registration (static data);
- Operational data; and
- Mechanisms for control.

A1.2 These four technical features have been selected in collaboration with the ESB's stakeholder group (including representatives from the market bodies including AEMO, AEMC, AER, and representatives from the DEIP workgroup). These features serve as good examples to (1) demonstrate how the framework can be used in practice; and (2) highlight likely trade-offs that will arise if particular standards are implemented. They should not be interpreted as actual technical features that may be put forward for potential implementation in the NEM; rather, they have been selected to 'road test' the assessment framework and to help identify relevant tensions and trade-offs between the criteria. Similarly, the assumptions we have made regarding the features' exact specification should not be interpreted as the preferred specifications for potential implementation in the NEM, but rather as illustrative assumptions to help make the discussion more tangible for the purposes of testing the application of the assessment framework.

A1.3 Section 3B of the main body of the report set out the main seven criteria that we included in the proposed assessment framework, and the scoring mechanism that we have applied.

A1.4 In this Appendix, we also provide an additional level of detail in relation to Criterion 3, the impact on consumer equity and acceptability. Specifically, in order to fully explore the potential impacts of DELs on different consumer groups, we identify and separately consider the following consumer groups:[54]

- **No-DER consumer (Alex)**: A consumer with no DER, who purchases all electricity through the traditional retailer and consumer relationship. Alex does not actively engage in emerging markets, distributed energy technology and is unlikely to frequently swap retailers. Alex is not interested in purchasing any DER technology.
- **Passive DER owner (Blake)**: A consumer with DER assets (solar PV and storage) who does not have a smart inverter or a smart home energy management device. Blake may be unaware of or unlikely to engage with new DER technology options and happy to set-and-forget their DER. Blake only wishes to use the DER for their own consumption and

[54] There may be other relevant consumer groups to consider, such as consumers with electric vehicles. In this report we have only focused on the six categories listed above.

is not interested in providing flexibility services to third parties in order to monetise their DER assets.

- **Active DER owner (Charlie)**: A "prosumer" who is actively involved in energy markets and owns DER with a smart inverter and/or smart home devices. Charlie regularly reviews their DER assets, as well as their contract with the aggregator/retailers and actively seeks out new opportunities to monetise their DER assets.
- **No-DER-yet consumer (Denver)**: A consumer with no DER, who is nevertheless considering investing in DER. Denver may be interested in solar PV, storage, or both.
- **Switching DER owner (Eli)**: A consumer who already owns DER, and is considering switching their retailer/aggregator, and is willing to also contract with multiple service providers to manage their DER assets.
- **House buyer (Frankie)**: A consumer who is purchasing a new house which already has DER assets installed. Frankie has not previously owned any DER, but is not in principle averse to owning DER assets in their new home.

A1.5 In the remainder of this appendix, we set out four worked examples of selected technical features, and how their potential implementation would be assessed through the framework.

A1.6 In each of the subsections, we first describe the context and rationale behind the technical feature under consideration. We then set out the assumptions we have made when defining the technical feature, followed by an assessment against each of the seven criteria. We conclude by drawing out relevant lessons for policy makers.

A.1 Dynamic Export Limits applied at the connection point

A1.7 As discussed in Section 2 of the main body of this report, the rapid roll out of DER has presented a number of challenges to the operation of the NEM. This includes issues driven by growing behind-meter generation owned by end consumers, which manifest themselves in falling minimum loads and even a desire of some households to become net power exporters, particularly during the middle of the day when solar generation is highest.

A1.8 The existing distribution networks are not always able to absorb such reverse power flows, particularly if a number of households in a given neighbourhood all seek to export power at the same time (driven by the obvious correlation in weather patterns).

A1.9 In order to mitigate such issues and protect the network, DNSPs have sought to impose upper limits on the active power exports for each connection point.[55] For example, in South Australia the standard export limit for small connection points, such as those connecting households to the distribution network, is set to a maximum of 5kW per phase.[56] These are static limits that continuously limit the power export for each connection point at a single value.

A1.10 However, these limits could be set more dynamically allowing the overall system to maximise DER exports when conditions allow it. DELs allocate an upper bound on export power for a specific time interval and connection point, and these limits can vary over time.[57] Less strict limits allow for greater export, while tighter limits may be imposed during periods of network congestion or minimum operational demand.

A1.11 DELs (alongside Dynamic Operating Envelopes, see footnote 57) have been the focus of several recent trials including the Advanced VPP Grid Integration Project undertaken by South Australia Power Networks in partnership with Tesla.[58] The project included analysis of the capability of the network to increase export capacity made available to the VPP at a given point in time. By incorporating real-time measurements into the constraint engine, the average export capacity of the VPP reached 8kW/site and 6kW/site in winter and summer respectively. By varying available capacity on a daily basis, the average export capacity of the VPP increased significantly relative to South Australia's 5kW static export limit and thus allowed for a greater volume of renewable generation to be used to meet consumer demand.

A1.12 In this section we examine a technical feature that relates to the setting of DELs, as defined in Box 1 below.

Box 1: Definition of Dynamic Export Limits

In this report, we have defined Dynamic Export Limits as export limits, set at the connection point of individual households to the distribution network, in kW.

The DELs are assumed to be set by DNSPs based on network dynamics (such as solar radiation, temperature, network loads, congestion, thermal limits etc). To the extent that these network dynamics vary according to location within the distribution network, the DELs are assumed to be set and adjusted in advance (e.g. day-ahead) in order to capture these changing requirements.

[55] Connection point is defined as the point at which individual consumers are connected to the lowest voltage section of the distribution network. Typically this is where the energy meter sits.
[56] Advanced VPP Grid Integration report, p2 (link).
[57] Dynamic export limits are a subset of the more general concept of Dynamic Operating Envelopes. The latter would provide both upper and lower bounds for import and export of power during a specific time interval. However, in this report, we have considered only the upper bounds, i.e. the export limits.
[58] Advanced VPP Grid Integration report, p2. (link).

The DELs are assumed to be communicated by the DNSPs to the aggregator and from the aggregator to the smart inverter (or a device capable of receiving and enforcing communications).[59]

We have also assumed that (a) the standard applied to new inverters only; (b) the limits are allocated in a uniform manner that is easy to understand by consumers; (c) consumers are not explicitly remunerated for any DEL-related services they provide (instead, the status quo continues); and (d) DELs are used as a relatively standard day-to-day network management tool. Alternatives to these assumptions are discussed in the detailed assessment.

For our assessment, we assume that the counterfactual is the current export limit placed on consumers – a static export limit.[60]

A1.13 In the following subsections we evaluate the application of DELs against the seven criteria of our assessment framework.

Criterion 1: System security and reliability

1 System security and reliability	✓ Helps maintain system stability at a distribution network level (e.g. voltage and thermal limits) and at a system wide level (e.g. allow greater DER FCAS provision) during 'system normal' operation. ✓ In system stress events, flexible export limits could be used a 'backstop' to resolve a number of system issues (e.g. arrest spikes in frequency and voltage). × Internet connection used to communicate DELs can be unreliable.	Likely to have a positive impact on system security and reliability. -ve Neutral +ve

A1.14 As summarised above, we expect the overall impact of DELs on system security and reliability to be positive relative to the status quo arrangement of static export limits.

A1.15 From a system-wide security perspective, the potential for DNSPs to dynamically loosen export limits when system conditions allow could increase the capacity of DER to provide valuable Essential System Services ("ESS"), such as regulation FCAS. On a more localised level, DELs could be used to manage distribution network issues, such as high voltage levels, more flexibly than static limits.

A1.16 DELs may also be utilised during more infrequent system stress events. In this case, the potential for DNSPs to dynamically tighten export limits could help avoid excessive reverse flows on the distribution network and potentially avoid system stress events. For example, during the South Australia islanding event of January 2020, VPP in South Australia were very active in providing FCAS, and the potential for small-scale DER curtailment during contingency events is an area of current investigation.[61]

[59] Further discussed in Worked Example 4, Mechanisms for Control.
[60] This is a strong assumption. If the new standard changed the 'default' static export limit to zero, then this would act as a strong deterrent to consumers keeping existing static limits, and conversely would incentivise the uptake of DELs.
[61] Advanced VPP Grid Integration report, p29 & 33 (link).

A1.17 However, unreliable internet connections may represent a risk to system security if DELs cannot be suitably adjusted during system stress events (for example if households fail to respond to the DNSP instruction, via an aggregator, to reduce exports), although this can be mitigated through the use of 'default' DELs, which can be reverted to if internet connection is lost.

A1.18 In summary, it seems that the risk of unreliable internet connections is low relative to the potentially significant benefits of DELs for system security and reliability. The overall impact of DELs on system security and reliability is therefore likely to be positive.

Criterion 2: System and network costs

2 System and network costs		
	Short run (system and generation costs) ✓ Reduces costs associated with managing the system (e.g. ancillary / essential system services expenditure). ? Substitution of explicit paid-for essential system service procurement with DELs masks the total cost impact. ? DELs can enable more efficient use of network capacity, reducing curtailment of solar generation. However, stricter limits may increase curtailment. Curtailment will impact the total cost of meeting consumer demand, as more expensive generation would need to replace curtailed solar. **Long run (network and asset investment costs)** ✓ Avoids / reduces costs of distribution network reinforcements / upgrades that would otherwise have been necessary. ? Encourages investment in storage, which may or may not be efficient from a system-wide perspective.	Likely to be positively impacted by DELs.

A1.19 As with system security and reliability, we expect DELs to have a positive impact on both system operation and network costs.

- In the short run, DELs can help reduce the cost of managing the system through enabling greater DER provision of ESS (see paragraph A1.15 above). They can also encourage greater competition between ESS providers (e.g. aggregators), as the use of DELs can facilitate the development of new consumer products, which can then be monetised by aggregators in providing ESS (either through markets or via bilateral contracts with AEMO or with DNSPs).[62] In turn, the total cost of managing the system by the system operator ("SO") and by the DNSPs could be reduced as a result of DELs, and these cost reductions would ultimately flow through to consumers.
- Over the longer term, DELs can be used to reduce the need for costly distribution network reinforcement and upgrades, by enabling DNSPs to both utilise the capacity already available more efficiently and to limit exports to levels at which further reinforcement is not required. Again, the savings on network augmentations would ultimately flow through to consumers via lower network charges.

[62] Importantly, this benefit would only materialise if there was in fact potential for consumers to be remunerated for DEL-related services (as opposed to DNSPs simply applying DELs without any compensation).

A1.20 However, although DELs are likely to reduce direct SO and DNSP expenditure on system management and network augmentation, they may have a range of other, more indirect, impacts on system and network costs which may increase costs to consumers.

- In our definition of DELs, we have assumed that consumers are not explicitly remunerated for the provision of related flexibility services (see Box 1). This means that the application of DELs is a "free" option for DNSPs and the SO, which could create an incentive for the SO and DNSPs to over-utilise DELs, in order to minimise the use of paid-for services (e.g. ESS). Such an outcome would shift the cost burden of system management away from the SO/DNSPs (noting these costs are borne by the entirety of the consumer base) and directly onto those consumers who are subject to DELs, which may not be efficient (or fair). In the long run, any over-utilisation of DELs (if it appears to be "free" to the SO/DNSPs at the point of use) may lead to an inefficient delay or an avoidance of network augmentation costs, which would ultimately be to the detriment of consumers. A different market design, where consumers were in fact compensated for the DEL-related services they can provide, would make the cost impact more transparent.
- The total cost of generation may also increase as a result of such DEL use, as cheap rooftop solar generation at consumers' premises is curtailed via DELs (potentially more so in a world where the DEL curtailment is a "free" option for DNSPs/SO, compared to a world where consumers are paid for being cut off) and more expensive generation, such as coal and gas, is constrained on in its place. On a whole-of-system level, rooftop solar (or local non-scheduled generation of less than 30 MW) is considered as part of 'native demand'.[63] It is not, however, included as part of 'operational demand' or the quantity of demand that is met by supply through the NEM wholesale market dispatch. Therefore, if lower rooftop solar exports feed into the grid (e.g. because some of it is constrained off to manage distribution network congestion), this increases the operational demand level that is required to be supplied from the wholesale market. Because generators provide increasing stepwise offers for supply into the wholesale market, an increase in operational demand may increase the marginal cost of generation required to meet this demand. Reducing rooftop solar exports through DELs may therefore increase the wholesale price of supply that is ultimately borne by consumers.
- In order to manage household consumption within the operations of mandated DELs, batteries will provide the best flexibility to respond to changing export limits. This is because during periods of higher (or less strict) export limits, charged batteries are able to discharge instantly and maximise export. Conversely, during periods of lower (or stricter) export limits, the use of battery can limit the amount of 'wasted' energy produced by behind-meter solar PV. If the value of DELs in the market is at a level high

[63] AEMO, Demand Terms in EMMS data model p6. (link).

enough to send price signals for investment in battery storage, the level of investment in batteries may increase above the optimal level for the system. Whilst, ideally, the value of DEL remuneration should be set a level that optimises the uptake of DER, if over-investment occurs, then costs may increase to consumers.

A1.21 In summary, the use of DELs has the potential to reduce total system and network costs, particularly if these limits are ‘looser’ compared to the current static limits and enable better use of the existing networks. However, it is important to ensure that the costs of applying DELs are not ‘masked’ by making their use appear to be “free”. The cost-benefit analysis that would underpin this criterion therefore needs to explicitly take into account the costs and benefits of applying DELs in relation to the monetisation of related flexibility services, and in relation to any mandatory application of DELs (and the associated cost transfers and long-term incentives).

Criterion 3: Consumer Equity and Acceptability

3

Consumer Equity and Acceptability	
Impacts common to all consumer groups	✓ Lower system management costs passed on via consumer bills. × Direct cost of smart inverters to OEMs and consumers, if additional functionality is required to support DEL. × Consumers without storage will likely incur greater losses than those with storage.
Impacts on “Alex” (no DER)	No distinct impacts (but benefits from the system-wide reduction in costs)
Impacts on “Blake” (DER, passive, non-smart)	✓ Maintains maximum solar export subject to static export limits (cannot be curtailed further) × Won’t benefit from financial compensation for DEL services
Impacts on “Charlie” (DER, active)	✓ Receives financial compensation of DELs ✓ May upgrade DER to optimise DEL flexibility to earn revenue in the market × Cost transfer between Charlie and Blake as only curtailment of Charlie’s inverter is enabled × May be a challenge to explain to Charlie the reasons behind different DEL allocations
Impacts on “Denver” (prospective DER buyer)	✓ May make a decision to get or upgrade DER based on highest value DER service or whether static limits are applied × May be a challenge to explain to Denver the reasons behind different DEL allocations
Impacts on “Eli” (switcher)	✓ Opportunity to optimise financial compensation by transferring contracts or service providers ✓ Eli can access the historical data of their own consumption to determine best contract or service model to manage DER
Impacts on “Frankie” (house buyer)	✓ Opportunity to purchase house with DER in an area with high value DELs × May not be able to access historical information on value of DEL for that location × Complex DEL rules make the house purchase process even more complicated (another factor to consider), which may induce Frankie to simply buy a house without DER
Overall consumer impact – equity and acceptability	The distribution of costs risks being highly uneven among consumers, which can damage the 'social licence' for change. -ve Neutral +ve

A1.22 As summarised above, the overall consumer impact and therefore acceptability of DELs is likely to be highly complex issue. While significant monetary benefits could be realised by consumers in aggregate, there are important distributional impacts to consider, with potential benefits and costs spread unevenly across different consumer groups.

A1.23 The key factors driving acceptability to consumers include:

- The **net cost impact** on individual consumer groups (which can be evaluated through the cost-benefit analysis). Cohorts of consumers that would be worse off in net terms as a result of the standard may seek to be compensated, particularly if they made prior investments in 'good faith' and in expectation of a particular future revenue profile. For example, if a retrospective application of a DEL reduces the revenues that Blake or Charlie earn from their DER assets (e.g. if their DER is curtailed more frequently), they may not be supportive of this policy change. While Charlie is likely to see some countervailing benefits in terms of potential alternative revenue streams (particularly if the wider market design changed and consumers would be explicitly remunerated for the DEL-related services they can provide), Blake may only perceive a downside of the new standard.
- Consumers' own **understanding** of the impact of DELs on their net costs or benefits. For example, if the DELs are applied uniformly to all consumers in a wide region, this is likely to be more acceptable compared to a (potentially more cost-efficient) situation where DELs are tailored specifically to individual households based on an optimisation algorithm. The degree of sophistication of individual consumers may play a role here (e.g. more sophisticated consumers may be willing to accept the algorithm-based approach), as well as the communication from aggregators/retailers to consumers (with Charlie likely to be more receptive to more complex arrangements compared to Blake or Denver).
- **Consistency and forward visibility** of the impact of DELs. A highly variable application of DELs over time, which makes it very challenging for aggregators/retailers (and indeed consumers) to predict accurately the likely cost/benefit impact on individual households, may be difficult to accept for many consumers. In particular, Denver, who is considering whether to invest in new DER, and Frankie, who is buying a new house, will struggle to evaluate their potential personal investments and could be deterred from DER. Charlie (and to a lesser extent Blake) who already own DER are also likely to find it difficult to plan their personal finances if they have a low ability to predict their net cost/revenue position.
- The treatment of **new vs legacy inverters.** To the extent that legacy (non-compliant) inverters are treated differently from new (DEL-compliant) inverters, this is likely to pose a consumer acceptability challenge. This could cut both ways: non-compliant DER owners could benefit from more generous static export limits (particularly at times of network congestion), which new (DEL-compliant) DER owners could find unfair.

Conversely, non-compliant DER owners may not be able to offer flexibility services to aggregators/energy services providers, and thus find it unfair that they cannot access potentially more attractive contracts (even though this outcome is "fair" in the sense that consumers who can offer services are appropriately remunerated for them).

- The **education and information** provided to consumers. Limiting export onto the grid is a relatively new concept in the NEM, with most consumers to date unaffected by system security and network requirements. It is likely that understanding the rationale, impacts and outcomes will be important to consumer acceptability and without an appropriate level of depth of information provided, consumers may not be comfortable with the lack of control (actual or perceived) over their own assets.

A1.24 In summary, consumer acceptability is likely to need to be a key focus of any technical standardisation to support DER interoperability. In addition, cost-benefit analysis will need to consider specific cohorts of consumers individually, as the aggregate impacts on consumers are likely to mask significant distributional impacts.

Criterion 4: Market facilitation

4 Market Facilitation		Likely to have a positive impact on the creation of new markets
	✓ Encourages the development of competitive markets that may financially compensate consumers for offering valuable DEL services. ✓ More efficient operations of aggregations of DERs by optimising the provision of local DEL services. ? There is no explicit monetisation of DEL services under the current market design, hence DELs by themselves would not encourage innovation and competition in the market (although, as shown above, this could change if consumers were explicitly compensated for DEL-related services). × Risk that features may not be widely adopted internationally, potentially reducing OEM competition with Australian markets (e.g. note DEL is currently not part of the Californian CSIP).	-ve · Neutral · +ve

A1.25 The overall impact of DELs on market facilitation is likely to be positive, as DELs can play a significant role in the development of future markets and Distribution System Operator ("DSO") models. This can play out both at the distribution level (as DNSPs can apply the DELs to manage distribution networks), and at the NEM-wide level (as DELs enable the SO to incorporate distribution level dynamics into the central wholesale and ancillary service markets by allowing instructions to be sent and adhered to at the distribution level).

A1.26 The key challenge for this criterion is that the current market design does not allow for a monetisation of DEL-related flexibility services. This is because DNSPs are currently allowed to curtail export of power by residential consumers without providing any explicit compensation for doing so. Under the current market design, DELs would, by themselves, not bring any significant incentive for greater innovation and competition in the retail market.

A1.27 However, if the market design changed, and if consumers could be explicitly remunerated for being curtailed, then the implementation of DELs could encourage innovation and greater competition in the retail market, by supporting the development of new services and markets through which consumers could monetise the value of flexibility of their DER. For example, aggregators could introduce new retail contracts that reflect the flexibility that consumers are willing to offer into the wider market.

A1.28 Some steps have already been taken in this direction: as part of Project EDGE, a cross industry collaboration between AusNet Services, Mondo, AEMO and University of Melbourne, trials are being undertaken to test dynamic operating envelopes and the trading of local services. In the creation of this DER marketplace, the trial includes the potential valuing of DER services that enable network capex deferral, response to peak demand and generation, and over-voltage management.[64] DELs may therefore become a valuable part of network economic operating dynamics and structured standards are likely to further enable the development of associated markets.

A1.29 The benefit of DELs is also likely to be higher if, in the future, the DNSPs' role transitions to a full DSO role. In this configuration, there are likely to be additional opportunities for flexibility services to be provided by households via the DELs (e.g. to provide voltage management services to the DNSPs). A key prerequisite for these benefits to be realised is that there is a market or contractual mechanism through which the increased flexibility facilitated by the DELs can be valued by the DNSPs.

A1.30 A complication that may need to be addressed in more detail is the interaction among different assets within a given household, and how the DELs may apply if there are multiple retailers/aggregators/service providers that would effectively 'compete over' the DEL. Resolving this, for example by setting up rules for a hierarchy of assets behind a single connection point, would further facilitate the development of new markets for flexibility services.

A1.31 In terms of potential downsides, there is a risk that the hardware and software features required to adhere to CSIP DEL standards may not be widely adopted internationally, or at least in the first instance. While this has the potential to reduce OEM or technology competition in Australia, given the significant scale of the DER market across the NEM this is unlikely to be a significant issue. Australia, as one of the world leaders in DER, is a large market and OEM already comply with a wide range of standards (e.g. AS 2777), so an additional technical feature appears unlikely to be a cause for concern. Another downside is that if DEL services continued to be used as a "free" service by DNSPs, as we assumed, rather than being explicitly remunerated, this would limit any market facilitation benefit.

[64] Project EDGE Webinar #1 (link).

A1.32 In summary, the application of DEL standards could help facilitate market developments in the services and products (for the benefit of DNSPs/DSOs or AEMO) offered to consumers via retailers/aggregators, but this would require a change in the current market design that would enable explicit remuneration of consumers for being curtailed. Meanwhile, the risk of reduced competition among OEMs appears to be limited.

Criterion 5: Data privacy and cyber security

5

Data privacy & cyber security

- ✓ Assuming internet connected smart inverters are already in place, limited additional risk from DEL.
- ✓ If strong cyber security standards are in place, risks are likely to be limited.
- × Ability to control DEL increases risk associated with potential hacks, which may affect system security and consumer income if hack is successful.

If strong cyber protocols are in place, additional risk is low. If not, there is an increased risk to the system and consumer revenues.

-ve Neutral +ve

A1.33 The requirement to impose DELs increases data privacy and cyber security risks, as the application of the standard drives a potential ability for third parties (outside of the household) to constrain the electricity flows at the connection point. This is because the application of DELs requires a new set of communications to take place across internet connected smart inverters and devices, which increases the potential for hacks and exposure of system and consumer data. For example, a hacker could increase the DEL to very high levels to induce a network overload.

A1.34 However, strong and secure communications protocols, and compliance with existing data protection laws, decrease the likelihood of this risk materialising. Indeed, given that smart inverters already include a degree of cyber security protection as part of the standard hardware and software installed in new DER, the step-up in risk relative to the counterfactual is likely to be limited.

A1.35 In summary, it appears that the incremental risks to data privacy and cyber security from the application of DELs is relatively limited (as those risks exist and need to be managed independently of whether DELs are implemented).

Criterion 6: Flexibility and adaptability

6

Flexibility, adaptability & innovation

- ✓ Once functionality is in place, DEL can be deployed progressively (over time) into different segments (e.g. by region) of a distribution network, as they are needed.
- ✓ Specific limits are (by definition) flexible.
- ? If this triggers strong incentives to invest in lots of storage, this could lead to a lock-in path with inefficiently high amounts of storage.
- × If specific hardware solutions are required, there is a risk of lock-in or costly upgrades.
- × The flexibility and adaptability itself can be a challenge to consumer acceptability, if changes to the limits are not communicated appropriately.

Can be flexibly rolled out and are by definition adjustable, but there is a risk of lock-in and/or damage to consumer acceptability.

-ve Neutral +ve

A1.36 DELs are inherently flexible due to the dynamic allocation of network capability to the connection point and by updating export limits in response to changing network requirements on a near-real-time basis. For example, once the DEL technical capability is in place, DNSPs can start off with export limits that are close to (or at) the existing static limits, and progressively reduce or increase the export limits depending on the forecast weather and demand conditions, in order to help manage the overall network flows.

A1.37 In addition, DELs may be deployed across the network progressively as required by the local conditions facing each DNSP. For example, geographic regions with particularly high penetration of solar PV (e.g. South Australia) are likely to benefit from DELs before areas of the network with limited export congestion or constraints. Accordingly, DNSPs may choose to move away from static export limits, and towards DELs, on a location-by-location basis.

A1.38 However, the application of DELs creates a potential incentive for consumers to invest in additional hardware solutions to enable them to respond to changing export limits (and/or to mitigate against any changes they perceive as undesirable). For example, consumers with solar PVs may seek to guard against a potential reduction in the export limit by investing in behind-the-meter storage assets, such that electricity generated on-site can be stored, rather than curtailed by the DNSP. This kind of incentive creates a risk of technology lock-in if consumers are systematically incentivised to invest in behind-the-meter storage, and if such investment, in aggregate, is not efficient from the society's point of view. This would need to be captured through a comprehensive cost-benefit analysis (as described in Criterion 2 above) that reflects both the benefits of avoided network augmentations, compared to the potential additional investments in storage made by consumers.

A1.39 Finally, the inherent flexibility of the DELs can, in itself, become problematic if the rationale behind applying DELs is not communicated properly to the affected consumers. For example, if DNSPs start to roll out the application of DELs (thus replacing previous static limits) flexibly, in geographic terms and over time, consumers may not respond positively to being treated differently from others.

A1.40 In summary, the DEL standard is inherently flexible and adaptable, but these features in themselves need to be managed carefully in order to be acceptable to consumers.

Criterion 7: Compliance and monitoring burden

7 **Compliance & monitoring burden**	× Real-time monitoring of live performance may be a challenge, particularly if the real-time physical response is 'behavioural' in nature and cannot be prescriptively set in rules. Some aspects of compliance burden may be mitigated via automatic registration features. × Additional compliance issues for OEMs (i.e. building required functionality and certification).	There is potential for a significant negative impact, although some of this may be mitigated via automatic registration features. 

A1.41 The introduction of DELs, and the associated operational requirements, inherently increases compliance and monitoring burdens on the retailers/aggregators, and, ultimately on consumers, in order to ensure that the DELs are adhered to. We assume that the compliance requirement would need to be set at the individual connection point level. Similarly, there is likely to be an additional compliance burden on the OEMs in order to ensure that inverters comply with the new standard.

A1.42 This is likely to be an important factor within the NEM and DER context given the limited visibility of the distribution network at present. Ensuring compliance at the distribution level is likely to require a significant step up in operational monitoring.

A1.43 However, this is an area where the technical standards may need to be evaluated together as a 'package' with other standards: for example, if DELs were implemented jointly with operational data (see Appendix Section A3), then the monitoring burden of DELs could in fact be reduced through the operational data collection and sharing.

A1.44 Monitoring of real-time compliance to DELs might be a particular challenge if the physical response is 'behavioural' in nature (and cannot be accurately described in terms of physical metrics), if it applies differently to individual assets behind a single connection point (and hence there is need for a hierarchy among those assets to be translated into a joined-up outcome at the connection point), or if the DELs are highly differentiated over time and across individual households (as the case may be with highly complex DEL-setting rules, as opposed to the uniform DEL-setting approach we have assumed).

A1.45 In summary, DELs would likely increase the compliance and monitoring burden for consumers, aggregators/retailers and OEMs, both during implementation and on an ongoing basis. However, this appears to be a necessary and largely unavoidable factor in order to deliver some of the benefits of DELs, and the magnitude of the burden would in itself depend on other technical standards that might be implemented in parallel (e.g. operational data collection and sharing). In any event, the monitoring and compliance costs should be taken into account in the cost-benefit analysis of the proposed technical feature.

Assessment summary and lessons learnt

A1.46 As shown in the assessment summary below, DELs have the potential to bring the strongest benefits in terms of system security and reliability and system and network costs. This is driven by the expected impact of using DELs to actively manage power flows on the network, which is likely to increase the efficiency with which the networks are used. In addition, there are potential benefits in relation to new markets being created to help monetise the flexibility arising from the use of DELs. The application of DELs is also, by construction, flexible and can be rolled out as needed over time and geographically to regions that would benefit the most.

A1.47 The most significant downsides relate to the potential cost transfers between cohorts of consumers, and therefore the acceptability of DELs. The exact implementation of DELs is also likely to be highly complex, and the rules for applying such limits will be challenging to articulate in a way that is both economically efficient and acceptable to consumers. Additional downsides relate to potential security issues, and the compliance and monitoring burden.

Figure 14: Assessment summary of Dynamic Export Limits

Criteria	Summary pros and cons	Illustrative evaluation
1 System security and reliability	✓ Likely a positive impact on distribution system security and reliability (e.g. voltage and thermal management) ✓ May allow greater DER provision of ancillary services ✓ More efficient use of network capacity	-ve +ve
2 System and network costs	✓ Reduces costs associated with managing the system ✓ Avoids / reduces costs of network augmentations ? Impact on curtailment and substitution of paid-for services with DELs	-ve +ve
3 Consumer equity and acceptability	✓ Lower system management costs passed on via consumer bills and customers may be able to sell valuable DEL services if markets are created ? Legacy inverters may have to be upgraded; challenges with allocating limits across consumers × Potential cost transfers between legacy and new inverter owners perceived as unfair	-ve +ve
4 Market facilitation	? No explicit monetisation (and hence limited incentive for developing new markets) under current arrangements, but explicit compensation for DEL services could encourage innovation and competition × Risk that features may not be widely adopted internationally, potentially reducing OEM competition with Australian markets	-ve +ve
5 Data privacy & cyber security	? If strong cyber security protocols are in place, the incremental risk arising from DELs is low; If not, there is an increased risk to system stability and consumer revenues × Ability to control DEL increases risk associated with potential hacks	-ve +ve
6 Flexibility, adaptability & innovation	✓ DELs can be flexibly rolled out (over time and geographically) and are by definition adjustable × However, introduction may incentivise investment decisions (e.g. in batteries) that may lead to a degree of 'lock in'	-ve +ve
7 Compliance & monitoring burden	× Potential for increase in OEM compliance costs and compliance monitoring burden, e.g. if monitoring of real-time performance is required ? Some this can be mitigated via automatic registration features	-ve +ve

Key lessons learnt from the DEL assessment

A1.48 In this section we summarise key lessons learnt regarding the application of the assessment framework, as informed by the DEL worked example. The key insights relate to the system and network costs, the consumer equity and acceptability, and to market facilitation.

A1.49 The cost-benefit analysis of a prospective technical standard should comprehensively and systematically reflect a broad range of impacts, including:

- Short-term impacts on the system operation, including the direct impact on the cost of procuring ESS as well as the indirect cost of any mandatory compliance with standards;
- Short-term impacts on generation costs, including any redispatch costs associated with greater or lower curtailment of DER, and potentially also the carbon impact of such redispatch (e.g. if curtailed renewables are replaced with fossil fuel generation);

- Long-term impacts on the network costs, including any avoided upgrades and/or augmentations of both the distribution and transmission networks; and
- Long-term impacts on the wider incentives for consumers to make specific investments in response to the technical standard (for example by investing in additional storage in response to the DELs), and the degree of technology lock-in this creates.

A1.50 The cost-benefit analysis needs to carefully take into account the full range of impacts to ensure any cost impacts are not 'masked' (for example by mandating compliance with a particular standard, which makes the improved technical performance appear to be 'free' to certain parties, even though it imposes costs on others).

A1.51 The DEL test case has also shown that the most economically efficient choices (e.g. tailored DELs to optimise network usage) may not be the most acceptable ones from consumers' perspective. There is therefore a tension between total costs and consumer acceptability.

A1.52 In addition to the potentially significant cost impacts (both direct and indirect, and short-term and long-term), the analysis also needs to ensure that **transfers in costs** (e.g. between cohorts of consumers), and more generally the **distributional impact** on different cohorts of consumers, are adequately captured. Potential technical standards need to differentiate between legacy and new assets; the natural lifecycle over which assets tend to be replaced and hence 'naturally' transition to compliance; consumers' personal attitude and preferences towards DER; and potentially also the interaction with other non-energy markets (e.g. property markets). The DEL test case has shown that this is a highly complex area, with multiple conflicting impacts on different cohorts of consumers.

A1.53 In this context the concept of 'fairness' needs to be carefully applied: some technical standards could enable owners of compliant devices to monetise the value that the standard brings (e.g. additional flexibility). While owners of non-compliant devices may not be able to do so, this is arguably a fair outcome, and – to the extent that the benefits accrue to those parties that incur the associated costs (e.g. investment in a compliant inverter) – this should also be seen as efficient. There is nevertheless a tension between market facilitation and consumer acceptability, as owners of non-compliant devices may perceive the outcomes as being 'unfair'.

A1.54 The assessment of market facilitation is also a complex area and technical standards should consider multiple layers:

- markets for services provided by consumers with DER;
- markets for other services (e.g. ESS) which can also be provided by other assets, but where the participation of DER increases competition and thus tends to encourage innovation and/or reduce prices; and
- markets for the DER equipment itself (e.g. competition among OEMs).

A1.55 The DELs case has also shown that while an inherent degree of flexibility in the standard can be desirable because it facilitates implementation and also allows the application of that standard to be targeted efficiently (e.g. to areas that are experiencing the greatest operational challenges due to DER penetration), this flexibility can, in itself, make the standard difficult to accept if consumers do not understand how the standard is applied. There is therefore a tension between flexibility and consumer acceptability.

A.2 Automated DER Registration

A1.56 The uptake of DER is increasing across the NEM, both in terms of the number of sites with DER and the number of DER devices per site, and to varying extents across different parts of the networks. Visibility and understanding of what DER devices sit behind-the-meter and how these devices may operate under different network conditions (and in response to instructions from third parties such as the DNSPs) is becoming increasingly important on both a localised and system-wide level.

A1.57 In September 2018, the National Electricity Rules ("NER") were amended to mandate the development and maintenance of the 'DER register' as a centralised database of DER generation information. The aim of the DER register is to provide network businesses and AEMO with visibility of DER information to support the management of power system security, planning and forecasting, and operation.[65]

A1.58 The DER register provides static or nameplate information at the connection point to the relevant DNSP and AEMO. The DNSP is primarily responsible for the collection of DER register data and AEMO is responsible for hosting this centralised database across all NEM jurisdictions. DER installers also have regulatory obligations when installing devices to submit information to the DNSP or DER register as part of the DER connection process.

A1.59 There are three levels of information provided through the DER register:

- Level 1 – DER Installation: Information is provided in aggregate at the site or network connection point to identify the site or the address where the DER is installed. Key information provided at this level includes the National Metering Identifier ("NMI"), approved capacity, connection agreement number and number of phases with and without DER.
- Level 2 – AC Connection: Information is provided at the point at which the DC DER system connects into the AC system. This is typically the inverter. Each inverter is identified within the DER register by one NMI and one AC connection ID. Key information provided at this level includes the inverter OEM detail, device capacity (kVA), over or under frequency levels, inverter power response modes and voltage response models.
- Level 3 – DER Device: Information is provided at the individual device level that sits behind the inverter. Information at a device level includes specification of the type of device (solar, battery etc) and rated capacity (kVa).

[65] DER Final Report (link).

A1.60 Information included in the DER register is provided at the time of registration and is updated when new DER devices, inverters or other behind-meter hardware is installed. Despite regulatory and legislative requirements, there is some uncertainty as to the level of compliance and accuracy of the DER register. There is some evidence that certain distributed assets (notably solar PV) have not, at times, performed as expected, although the extent to which this could be mitigated via an automated DER register is unclear.[66]

A1.61 A technical standard that introduces automated registration of DER specifications would allow static or nameplate information to be sent directly from the inverter or device to a centralised system. The automated and direct delivery of this information may reduce reliance on manual processes, thereby minimising inaccuracies (if any exist) and maximising the value of such information in supporting the management of power system security.

A1.62 In this section we examine a technical feature that relates to the implementation of an automated DER registration system, as defined in Box 2 below.

Box 2: Definition of automated DER registration

In this report, we have defined automated DER registration as the delivery of static or nameplate information from the inverter to a centralised automatic storage system.

The automated registration information is assumed to supplement the existing DER register, by automating some of the current processes – such as communicating from the device to AEMO[67] (noting that the existing central register would remain in place). The automatic registration data points collected are assumed to be the same as the data points collected through the existing DER register.

In line with the aim of the current DER register, the automated DER registration information would be hosted in a centralised system by AEMO. This information would be used to gain greater visibility over low voltage generating systems and allow for better planning, operations, and visibility of the network.

We have also assumed that the automated DER registration information would not link to any market systems (e.g. to settlement systems). The existing data privacy requirements would also continue to apply.

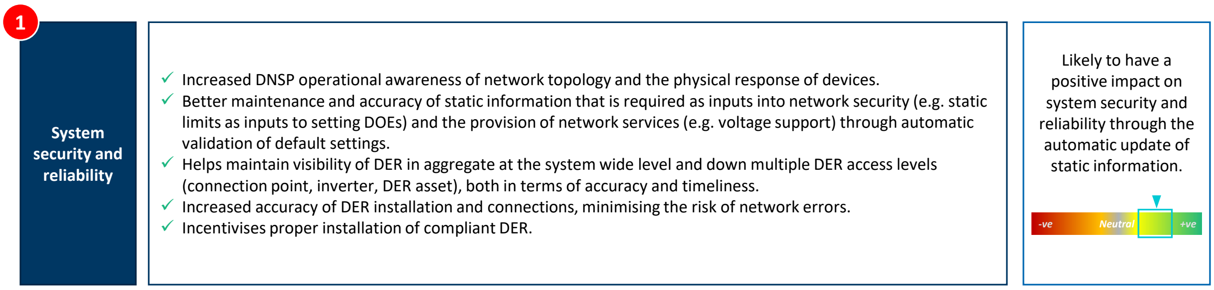
The counterfactual to the assessment of automated DER registration information is assumed to be the existing DER register and the existing information collection processes.

[66] The estimated range of non-performance ranges from 15 to 50%, depending on the exact event examined (e.g. over-frequency event, or reconnecting to the grid following a disconnection) and the expected response (e.g. the ramp time). See AEMO (2021), Behaviour of distributed resources during power system disturbance (link), page 4; and AEMO (2019) Final Report – Queensland and South Australia system separation on 25 August 2018 (link), page 6.

[67] The registration from DNSP to AEMO is already automated.

A1.63 In the following subsections we evaluate an automatic DER registration functionality against the seven criteria of our assessment framework.

Criterion 1: System security and reliability



A1.64 As summarised in the figure above, we expect the impact of automated DER registration on system security and reliability to be positive, relative to the status quo arrangement of manual registration. There appear to be no obvious disadvantages to the automation of the register.

A1.65 In terms of network visibility, benefits of the automated DER register would likely accrue at a system wide level as well as in individual distribution networks. Furthermore, automation would likely increase DNSPs’ operational awareness of network topology and the physical response of devices, allowing for more accurate and timely responses to network imbalances.

A1.66 It seems likely that the automation process could help improve the accuracy and maintenance of static information in the DER register that is required to inform network security measures. As a result, the provision of network services is also likely to benefit as greater reliance may be placed on registration data, including the validation of default inverter settings. This could, in turn, lead to more accurate forecasting of net demand across the NEM, and hence efficiencies in system operation.

A1.67 The simplification of the registration process may also lead to a greater number of successful DER installations and connections in the NEM than we see today. This is partly due to the potential for more accurate and timely installations, minimising the risk of network errors. However, a simpler process may also better incentivise consumers to properly install compliant DER, increasing the capacity available for system services.

A1.68 However, it is important to stress that the static data provided through the DER register (whether manual or automated) only provides a limited amount of information about the DER. Arguably, this information is less important compared to the operational data, such as power flows, metering and other non-static metrics. The benefits for system security and reliability from having greater visibility over the operational data are likely to be much more significant (and are considered in this Appendix, Section A.3).

A1.69 In summary, the overall impact of the DER register on system security and reliability is likely to be positive, driven by the increased visibility of DER and more accurate information on DER installations.

Criterion 2: System and network cost

2 System and network costs	✓ Greater visibility of DER should reduce SO system management costs. ✓ Continued monitoring of DER static information should result in greater DER compliance, reducing the complexity of managing the system. ✓ Better knowledge of DER may allow for more efficient management of the network, reducing the need for costly network investment.	Likely to have a positive impact on system and network costs. 

A1.70 As with system security and reliability, we expect automatic DER registration to have a positive impact on system and network costs, with no obvious downsides.

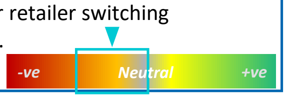
A1.71 At a system-wide level, the ongoing validation of static DER information should reduce the system management costs faced by the SO by providing greater visibility of the network. The improved knowledge of DER in the NEM afforded by this visibility may also allow for more efficient overall network planning and management, reducing the need for costly future network investments in upgrades or reinforcements.

A1.72 The continual monitoring of static information should also increase the proportion of compliant DER installations, reducing the complexity involved in managing the network and, by extension, the management costs.

A1.73 However, in order for there to be a significant reduction in system and network costs as a result of this increase data accuracy, the counterfactual (current DER registration process) must be inaccurate to a relatively significant scale (see paragraph A1.60 above and footnote 66).

A1.74 In summary, automatic DER registration appears to have the potential to decrease system and network costs and provide benefits to consumers. The scale or magnitude of these benefits (and hence the benefits net of the costs of developing an automated register) are dependent, however, on the extent to which the current manual DER registration process results in material gaps and inaccuracies in data or information.

Criterion 3: Consumer Equity and Acceptability

3	Consumer Equity and Acceptability
Impacts common to all consumer groups	✓ Lower system management costs passed on via consumer bills. × Cost of creating and maintaining the registration database likely to be passed onto consumers as a whole
Impacts on "Alex" (no DER)	No distinct impacts (but benefits from the system-wide reduction in costs)
Impacts on "Blake" (DER, passive, non-smart)	No distinct impacts as Blake's inverter is non-smart, and Blake will not upgrade to allow automatic registration
Impacts on "Charlie" (DER, active)	✓ May upgrade DER and benefit from lower installation costs × Direct cost of smart inverters to OEMs and consumers, if additional functionality is required to support automatic DER registration (this applies to Charlie's legacy assets, as they may need upgrading)
Impacts on "Denver" (prospective DER buyer)	? May benefit from lower DER installation costs, but face a higher direct cost of smart inverters (if more functionality is required). The overall balance of costs is uncertain. × May view an automated continual verification process with more suspicion compared to a one-off manual registration
Impacts on "Eli" (switcher)	✓ May benefit from smoother switching process if Eli's smart inverter can re-register with the new supplier (who in turn benefits from visibility of the DER)
Impacts on "Frankie" (house buyer)	✓ May gain more confidence that the previous owner's installation is correctly registered × May view an automated continual verification process with suspicion, hence be averse to buying a property with continually monitored DER
Overall consumer impact – equity and acceptability	Individual buyers may benefit from lower installation costs and easier retailer switching but there are aggregate costs associated with the automated register. 

A1.75 As summarised in the figure above, there are different impacts of an automated DER registration system on different cohorts of consumers, and the overall impact appears to be slightly negative, owing to the costs involved in developing the required functionality.

A1.76 At an individual level, consumers may need to upgrade their inverters to be eligible for automatic registration, if mandated for existing inverters. This would increase consumers' costs compared to the current DER registration process. For consumers who are installing or upgrading the DER, capex costs may increase if the devices with the new functionality are more expensive, but the installation costs are likely to decrease as a result of a more efficient registration process, with an overall balance of costs uncertain (and this would need to be examined further).

A1.77 At an aggregate level, the costs of developing and maintaining the automated system and the registration database would ultimately be borne by consumers. AEMO would be responsible for this process and the costs involved in maintaining it. Accordingly, under AEMO's cost recovery mechanisms, all electricity market consumers bear these costs regardless of their DER status.

A1.78 While automatic DER registration would likely bring positive consumer benefits at a system wide level (particularly if it mitigated significant inaccuracies in the current manual registration process), at an individual level there is minimal opportunity for different types of consumer to actively respond to maximise their own value as a result of this standard. For example, Eli is willing to change aggregator or retailer to maximise DER value but the DER register only includes static registration information. Therefore, changing contractual arrangements does not change the nameplate or static DER information and no additional value can be accessed.

A1.79 Finally, whilst the automated DER register may be attractive to most consumers in principle, there is a risk that – due to miscommunication or misunderstanding – some consumers might view an automated continual verification process with suspicion relative to a one-off manual registration. This suspicion could hinder uptake of DER devices with automatic registration capabilities within particular demographics.

A1.80 In summary, while there are potential system management and installation cost reductions for consumers, this would need to be evaluated, through a cost-benefit analysis, against the potential increases in costs (either of the devices themselves, or due to the centralised database management). Similar to system and network costs (Criterion 1), the value to consumers is likely to depend largely on the magnitude of increased efficiency in transitioning from the current registration process to the automated one. In addition, the automated nature of the register would need to be carefully communicated to consumers to avoid unnecessary misunderstandings that could hinder uptake of DER.

Criterion 4: Market facilitation

4

Market facilitation

- ✓ Supports the implementation of Flexible Trading Arrangements allowing for customers to have different retailers per DERs (or meters) by automatically mapping the relationship between National Metering Identifiers (NMIs), retailers (or aggregator) and device settings.
- ✓ Efficient mapping of VPP aggregators to connection points optimising the aggregator bidding into market systems.
- ✓ Facilitates transfer of device registration between aggregators reducing switching costs/ barriers.
- ? May increase the complexity of the potential integration of Demand Side Participation information and the DER register given the automatic collection of data.
- ? Facilitates the development of competitive markets as registration data if able to integrate into market systems.

Positive impact possible if effective mapping between market systems is implemented

A1.81 The overall impact of automating DER registration on market facilitation is likely to be positive, as automated DER presents opportunities to accelerate the development of future markets (although the automated DER register itself is unlikely to be sufficient in itself; rather it is likely to act as a stepping stone towards the development of new markets).

- **Two-way markets.** For example, potential efficiencies may be created if the automated DER register can be linked with other market systems (such as settlement, or to the operational data). The information collected in the DER register provides detail at the DER device level, behind the inverter and linked to the connection point. Linking these data points with future service providers ("FRMPs"[68], market ancillary service providers) may create efficiencies in a future scenario where distribution level or two-way markets materialise.

- **Multiple retailers per household.** Currently under consideration, the Flexible Trading Arrangements policy seeks to develop a behind-meter connection point arrangement that enables consumers to have multiple retailers or aggregators with different products and services. Creating linkages between market systems and DER registration information could support a flexible trading arrangement structure and more competition in the retail market.
- **Ancillary services at the distribution level.** Operational data from DER will play a central role in future markets. If DER is included in a distribution level dispatch, operational data would be key to deliver against energy or system service requirements. Automatic validation of real-time operating data against DER register data may benefit the development of this market model and allow for operating and real-time decisions to be made based on validated information. In this sense, the automation of the DER register is a stepping stone towards using operational data in developing future markets.

A1.82 Automated DER registration would also increase flexibility and choice for consumers. In particular, automatic registration could reduce the switching costs faced by consumers, allowing them to easily transfer device registration between aggregators.

A1.83 There are some potential downsides as well, for example if automated DER register was utilised to support market systems, it is unclear whether this might hinder the inclusion of Demand Side Participation in future market designs by increasing the complexity of the national DER register and the information required for participation.

A1.84 In summary, it seems that an automated DER registration process could support market facilitation. However, more significant benefits are likely to emerge from integrating the automated DER register with existing systems or future operational data.

Criterion 5: Data privacy and cyber security

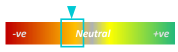
5

Data privacy & cyber security

✓ Automatic de-identification of data.
✓ If strong cyber security standards are in place, risks are likely to be limited.

× If register is automatically linked to other systems, risk to customer data may be increased.
× Automation of DER register may increase risk associated with potential hacks.

Risk will depend on cyber standards and level of integration with other systems.



A1.85 As summarised above, the increased risk to customer data posed by the automation of DER registration is likely to depend on the wider decisions related to cyber standards and the level of integration between the national DER register and other network systems, rather than on the implementation of the automated register per se.

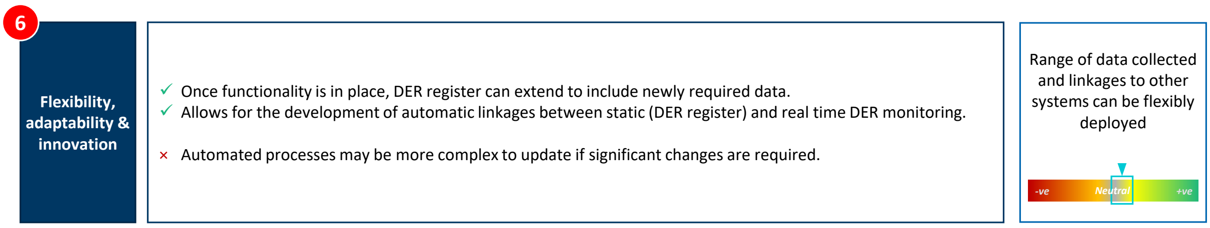
[68] Financially Responsible Market Participants – typically a retailer or aggregator.

A1.86 Relative to the counterfactual of the existing DER register, the automatic registration of DER places increased reliance on technology and wireless interfaces. By nature, this increases risks associated with potential hacks. However, strong cyber security standards are likely to limit this risk.

A1.87 A more substantial risk may present itself if the automatic DER register is linked with other market systems, particularly those with customer identifying metering or billing data such as Market Settlement and Transfer Solutions ("MSATS"). Existing customer data and privacy regulations should continue to be adhered to with assurances that while this may result in more parties having the capability to have visibility over consumer data, they are prohibited from viewing data that they do not have statutory rights to do so.

A1.88 Ultimately, while there seems to be a potential for cyber security risks to increase within an automated process, adhering to current protocols and strong security standards is likely to minimise these risks. However, risks may materialise if automatic DER registration information is linked to additional market systems in the future.

Criterion 6: Flexibility and adaptability



A1.89 Greater knowledge of the scale, type and location of DER present in the NEM, driven by automatic registration, may increase the flexibility and adaptability of the overall system.

A1.90 Once the initial functionality is established, the DER register could be extended to include newly required data, thereby adapting quickly to a changing DER landscape and maintaining accurate network topology for network operators. The system may also be enabled to create automatic linkages between the static DER register and real-time DER monitoring systems.

A1.91 However, this benefit may be partially offset if it is more complex to update the automatic registration process relative to updating the current manual approach. For example, significant updates to an established automatic process are likely to be complex and time-consuming (for example to upgrade the underlying software and hardware), and these might be more onerous than updates to its manual counterpart. This may need to be examined further.

A1.92 Overall, based on the above, the automatic DER registration process is likely to provide a benefit to flexibility and adaptability relative to the current process and this benefit is likely to outweigh the associated risks.

Criterion 7: Compliance and monitoring burden

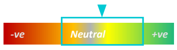
7

Compliance & monitoring burden

- ✓ Once in place, automatic monitoring of device registration settings reduces compliance monitoring burden, both initially at installation and ongoing
- ✓ May allow for the development of automatic linkages between static (DER register) and real-time DER monitoring ensuring compliance of registration and across real-time physical response.
- ✓ Reduced cost to installers (assuming the existing DER registration process is removed).

- × If not all DER can register automatically, integration of automatic and manual register will be complex.
- × Cost of creating and then maintaining the registration database.
- × Additional compliance issues for OEMs (i.e. building required functionality and certification).

Once implemented, automated registration with real-time monitoring is likely to reduce burden.



A1.93 The implementation of automatic DER registration has the potential to reduce compliance and monitoring burden, but there are also some aspects where this burden may simply be shifted to different parties (e.g. OEMs and database owners).

A1.94 Automatic registration could facilitate monitoring of device registration settings, reducing the compliance and monitoring burden faced during device installation and day-to-day operation. In addition, if the manual registration process is, at some point, removed entirely, device installation costs are likely to decrease.

A1.95 It is possible that this will be an important benefit given the context of the existing DER register and current compliance and monitoring processes, since there appear to be concerns among some stakeholders regarding the accuracy, completeness and timeliness of the data included in the current DER register.

A1.96 Further, if automatic DER registration progresses to integration and validation against real-time data, monitoring and compliance of the physical response of devices may be positively impacted through automatic validation.

A1.97 In summary, positive impacts on compliance and monitoring are again largely dependent on the compliance and monitoring burden created relative to the burden imposed by the existing process. However, if not all DER can automatically register, the integration of automatic and manual registration may further increase complexity.

Assessment summary

A1.98 As shown in the assessment summary below, automatic DER registration has the potential to bring substantial benefits in terms of system security and reliability, and system and network costs. This is driven by the assumed increase in accuracy and reliability of DER registration data and a resulting increase in quality of network data and SO visibility of the network.

A1.99 However, this depends on the extent of the value of automatic DER registration relative to the existing manual DER register. Further clarity on material gaps and inaccuracies of the current register would be required to confirm the magnitude of value that automatic DER register may provide.

Figure 15: Assessment summary of Automated DER Registration

Criteria	Summary pros and cons	Illustrative evaluation
1 System security and reliability	✓ Increased DNSP awareness of DER characteristics should improve network security ✓ Increased compliance of DER, encouraged by greater visibility of assets, should improve network security	-ve +ve
2 System and network costs	✓ Greater visibility of DER should reduce SO system management costs and facilitate more efficient management of the network	-ve +ve
3 Consumer equity and acceptability	✓ Consumers may benefit from lower installation costs due to reduced burden on installers × Consumers may have to upgrade inverters to be able to automatically register × Cost of creating/maintaining database likely passed on to consumers × Consumers may view continued automatic monitoring with more suspicion	-ve +ve
4 Market facilitation	✓ Facilitates transfer of device registration between aggregators reducing switching costs/ barriers ? Facilitates the development of competitive markets, if able to integrate into market systems	-ve +ve
5 Data privacy & cyber security	✓ Automatic de-identification of data ✓ If strong cyber security protocols are in place, the incremental risk arising from DELs is low × If register is automatically linked to other systems, risk to customer data may be increased	-ve +ve
6 Flexibility, adaptability & innovation	✓ Once functionality is in place, DER register can extend to include newly required data × Automated processes may be more complex to update if significant changes are required	-ve +ve
7 Compliance & monitoring burden	✓ Once in place, automatic monitoring of device registration settings reduces compliance monitoring burden, both initially at installation and ongoing × If not all DER can register automatically, integration of automatic and manual register will be complex	-ve +ve

Key lessons learnt from the Automated DER Registration assessment

A1.100 In this section we summarise key lessons learnt regarding the application of the assessment framework, as informed by the Automated DER Registration worked example. The key insights relate to: (1) the interactions between different technical features; and (2) the importance of clearly communicating the new technical standards to consumers.

A1.101 First, there appear to be important interactions between different technical features, such as the automated DER register process and the sharing of operational data. As discussed above, while there are some benefits (e.g. from network management) from the automation of the registration of static data, these benefits are likely to be much higher if the static DER register is also coupled with greater standardisation of active data, and even wider market systems (e.g. settlement or the demand response portal). For example:

- Automated DER registration can help make the retailer switching process smoother (and potentially avoid a manual re-registration), but the competition among retailers is likely to be more strongly dependent on those retailers being able to have visibility over consumers' active data.
- Similarly, automated DER registration does provide AEMO and DNSPs with better quality data on DER, which could help support forecasting and modelling functions, but again, these benefits are likely to be outweighed by those provided by sharing active data.

A1.102 From the policy-making perspective, this suggests that some technical standards (such as automated DER registration) may need to either be seen as a stepping stone towards other standards (e.g. towards automation of the collection of active data), or even as a prerequisite. In addition, policy makers may need to consider some technical features as packages rather than each of them in isolation.

A1.103 Second, the analysis of the automated DER registration has again highlighted the need to carefully communicate any new standards to consumers. Failure to do risks creating misunderstandings and potential reluctance for DER uptake which would be counterproductive.

A1.104 Overall, however, it seems that the impact of automated DER registration is unlikely to be significant, at least in comparison to some other technical standards such as operational data (examined in the following section of this appendix).

A.3 Operational data

A1.105 In traditional power systems, electricity flows from large-scale generators through transmission and distribution networks, to end consumers. Generation has therefore been primarily connected to high voltage transmission lines, upon which system operators typically have highly sophisticated oversight and operational control.

A1.106 In the NEM, AEMO receives SCADA[69] information on a generator's active power output at the generation unit and connection point level, on a four second basis. This allows the SO to maintain the security of the network and respond in real-time to any changes in network frequency by adjusting electricity flows onto the network.

A1.107 However, as the power system in the NEM transitions to a model with a decentralised and fragmented generation structure, the flow of electricity has changed significantly. The DER deployment has made power flows on the distribution networks more volatile, and sometimes even caused reverse power flows (i.e. net exports from households onto the network). Unlike the transmission network, DNSPs do not have real-time (or close to real-time) operational data or visibility of the distribution networks.

A1.108 In the NEM today, there are currently no standards as to data points, rates or timing and accuracy of operational (or active) DER data (for example, tracking power flows across the distribution networks at particular locations and with specific frequency). Parties that may currently have visibility over DER operational data are device manufacturers (OEMs) or aggregators/retailers who can offer products or services directly to consumers based on this data (for example, retailers have visibility over metering data for the purposes of billing).

A1.109 The consequences of this lack of visibility by DNSPs over DER include a range of system security, operating and planning risks. In addition, as the SO takes a more conservative approach to managing the system, this may manifest different ways: for example, tighter export limits or DELs might be required (to limit the exports by prosumers onto the distribution network), or there may need to be a very significant investment in distribution network infrastructure and augmentation in order to cope with the changing structure of power flows.

A1.110 In early 2021, the 'Distributed Energy Resource (DER) Visibility and Monitoring Best Practice Guide' (guide) was released as a guidance document that seeks to "*establish a common static and dynamic real time data set collected for new DER*" and "*increase confidence in the quality and performance of DER through the provision of real time system performance data*".[70]

[69] Supervisory control and data acquisition

[70] DER Visibility and Monitoring Best Practice Guide – (link)

A1.111 The guide defined data points to be collected at both the site and device level and recommended that the data be supplied to relevant operational and jurisdiction market bodies who would benefit from it in order to fulfil their regulatory and statutory duties. Operational (or as defined in the guide 'dynamic') data include both 'required' and 'optional' elements:

- Required data elements: site active/reactive power (exported), site active/reactive power (imported), DER generation active/reactive power, DER consumption active/reactive power, site voltage; and
- Optional data elements: site active/reactive power (imported and exported) per phase, DER generation and consumption active/reactive power per phase, battery state of charge, frequency.

A1.112 In this section we therefore examine a technical feature that relates to the collection and sharing of operational data, as defined in Box 3 below.

Box 3: Definition of Operational data

In this report, we have defined Operational data as the requirement on DER devices to have the functionality to record certain DER operational data at the individual device level and the sharing of such data in a standard and safe manner, where data rights support doing so, with AEMO, DNSPs, aggregators/retailers, or distributed energy resource management providers.

We have not listed the specific range of operational data that would be recordable, but for discussion purposes we have assumed it would be data, measured at the device level, on total import and export capacity and energy flow on the network.

The specific definition of operational data, including the data points and the frequency of data collection, would be driven by the defined operational requirements when implementing the standard (and justified by the entity requiring the data). A stepwise or incremental approach to mandating data requirements could be adopted (e.g. starting with a minimum volume of data collecting, and progressing further depending on operational need and the associated costs and benefits).[71]

We have also assumed that there are no linkages between operational data and registration, settlements, and metering data; although, as discussed in the assessment, there is a potential to implement linkages between operational data and the wider systems.

Regarding data sharing, the definition of operational data does not specify the parties or the granularity of the data that would be shared. We recognise that this is something that would likely be governed by wider data protection rules and laws. However, for discussion purposes, we envisage that some operational data could be made available to parties who have appropriate rights and permissions to access it (or have visibility over it). This could include:

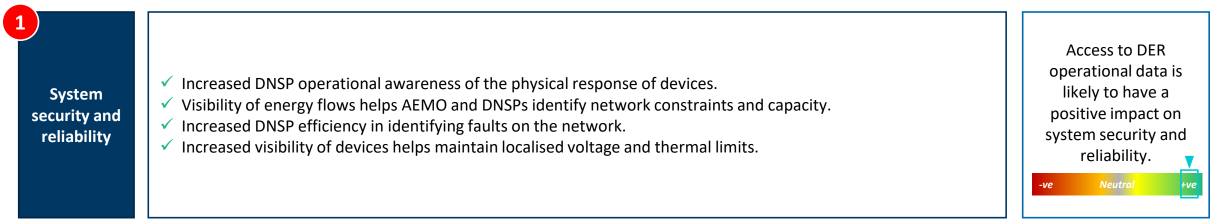
[71] For example, collection of data at 1-minute increments could be onerous, and would therefore need to be adequately justified by a needs case (and associated benefits).

- DNSPs and AEMO, as parties who have the right to access certain data as specified in the connection agreement related to supporting system security and reliability.
- Consumers, who, subject to consumer protections, privacy law and consumer data rights, should have the ability to access their own data collected from a device they own (directly or via an app).
- Other consumers, if nominated by the owner of the DER assets, in the context of specific circumstances such as a property transaction (for example, the prospective buyer of a property may wish to access historical data related to the DER and the seller of the property may wish to grant that access in order to maximise the value of the property being sold).
- The owner of the device IP (i.e. the manufacturer).
- Any other service provider the consumer nominates to support that device or a related device. For example, this could include aggregators, retailers or DERM providers, but only where they have clear access permissions and explicit consent[72] provided by the consumers, consistent with consumer protections, privacy and commercial agreements with the consumer.

The counterfactual to the assessment of Operational data is assumed to be that DER devices do not have any standardised functionality for recording certain DER operational data, nor any functionality for sharing such data, other than those provided as a minimum requirement in a standard connection agreement.

A1.113 In the following subsections we evaluate the Operational data functionality against the seven criteria of our assessment framework.

Criterion 1: System security and reliability



A1.114 As shown above, collection of and visibility over DER operational data (in line with the prevailing data access rules) is likely to have a positive impact on system security and reliability, with no obvious downsides.

[72] This is important for both privacy and competition as there may be multiple service providers who need visibility of the same data, and the service providers may change over time.

A1.115 At the local level, increased visibility of devices could improve the ability of DNSPs to maintain voltage and thermal limits. Near to real-time information allows DNSPs to monitor their networks and make decisions based latest power flow information, which should increase operational efficiency and decision making.

A1.116 Furthermore, the increased visibility of energy flows and capacity would increase the operational awareness in relation to the physical response of DER devices and allow DNSPs to identify (and resolve) faults on the network more quickly and accurately than they can at present.

A1.117 At the NEM-wide level, the collection of total import and export capacity and energy flow data would allow AEMO to identify network constraints and capacity more quickly and more accurately, facilitating better management of the system at the aggregate level.

A1.118 This is of particular importance in South Australia, as demonstrated by the negative electricity demand event on Sunday 21 November 2021. The total electricity supply of rooftop solar PV flowing back onto the network, combined with non-scheduled solar and wind generation, was greater than the electricity demand in South Australia.[73]

A1.119 In this instance, AEMO had forecast low demand levels and balanced the power system in South Australia through interconnector flows and scheduled generation to support system security and reliability. Given the lack of visibility of operational DER data, operators of distribution networks were unable to provide support to the network, resulting in an increased reliance on transmission level response and limiting consumer and DER access to revenues for services.

A1.120 Under an operational data standard, visibility of operational network power flow information would allow the SO to make better informed decisions, while data collected at the device level could improve the SO's and DNSPs' understanding of the physical response behind the connection point. It may be particularly useful for the SO or DNSPs to understand what type of DER devices exist on the network when considering what the physical response to network changes (such as constraints, weather) may be. This may be further facilitated by linking automatic registration data (as discussed in A2 above) and real-time operational data points.

A1.121 In summary, operational data is likely to have a highly positive impact on system security and reliability, in particular if DER deployment continues to increase and as minimum or negative demand events increase the complexity of local and system-wide operations.

[73] AEMO Newsroom (link).

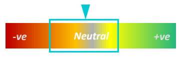
Criterion 2: System and network cost

2

System and network costs

- ✓ Reduction in costs associated with operating the network due to greater understanding of the behaviour of DERs on the network.
- ✓ Reduction in costs to maintain and upgrade the network.
- ✓ Reduction in compliance costs due to automatic monitoring of DER near real-time behaviour.
- ? Cost of handling data (e.g. storing the data on servers, backups, security, etc). This depends on the volume of data handled and stored at different levels of the network (individual devices, DNSPs servers, AEMO's databases, etc), and also on the frequency and reach of any monitoring (e.g. DNSPs may only actively monitor the network during times when system stress is anticipated, and potentially only a subset of devices).

Net impact depends on the volume of data handled relative to the benefits for the network



A1.122 While the sharing of energy flow and total import and export capacity data is likely to generate benefits in terms of lower system and network costs (as discussed in detail below), there is industry wide uncertainty on the cost of handling such data (the assumption being that at least some data will be shared with some parties at some points in time, in line with the prevailing data access rules).

A1.123 Increased efficiency driven by better visibility of the network is likely to help optimise operations and improve system quality, thereby reducing the costs of operating and managing the power system. These efficiencies and cost reductions are likely to be realised in the short, medium term and longer-term planning horizons:

- In the short term, improved decision making by DNSPs and the SO is likely to minimise the risk of system issues and cost effectively increase the network hosting capacity for DER. For example, through the provision of operational data, the SO may make the most economically equitable and efficient decisions in regard to the setting of DELs. This could allow less stringent or conservative limits to be applied.
- Over the medium and longer term, network and system costs may be significantly reduced through a reduction in network maintenance, upgrade and augmentation costs due to better understanding of the topology and the needs of the system such that the system can be run more efficiently with the existing distribution network.

A1.124 To collect and store DER operational data, it is likely that hardware and software upgrades and development will be required by OEMs and manufacturers, the costs of which would ultimately be passed onto consumers. Similarly, there may be costs to DNSPs to upgrade their existing functionalities, platforms and processes to communicate better with DER (and/or to collect, store and process any relevant data, if applicable). In the detailed design of the standard, the requirements in terms of the data points, data collection frequency, etc., will therefore need to be carefully evaluated, to ensure that any cost impacts would be proportionate to the benefits achieved.[74] It may be appropriate to stagger the implementation of the standard, starting with collecting only the minimum necessary data, and progressively expand the collection, storing and sharing of the data based on a clearly justified needs case (where the benefits of the extra data handling exceed its costs) by the entity requiring the data.

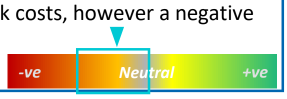
A1.125 It seems likely that as a result of the operational data standard, some connection-point-level data might eventually be shared with third parties (e.g. aggregators, DNSPs and/or AEMO), if the sharing and use of such data was indeed justified. This does not necessarily mean that all the DER devices would be continuously monitored; this could be the case perhaps only during times when the DNSP expects the system to come under stress (driven by weather forecasts). At times when operational data is collected and stored by third parties, there could be significant costs to managing such data (processing, storing, servers, backups etc) to the DNSP, AEMO and other aggregators or businesses. This is because, relative to the counterfactual of no data collection or access requirements, collection (and sharing) of operational data is a likely to represent a significant step up in functionality, process and systems.

A1.126 In summary, the operational efficiencies that would be gained by multiple stakeholders would need to be carefully considered against the cost requirements to build and maintain systems for collecting, storing and sharing data. It may be necessary to undertake an incremental cost-benefit analysis for different levels of operational data complexity (e.g. minimum data collection, more granular data, and more widely shared data), to allow for costs to be at all times assessed against operational and functionality benefits to consumers.

[74] The costs of handling operational DER data would increase with increases to the number of data points collected, the frequency of collection and the number of parties who have visibility over this data, all of which would need to be considered in setting the rules for data sharing.

Criterion 3: Consumer Equity and Acceptability

3

Consumer Equity and Acceptability	
Impacts common to all consumer groups	✓ Lower system management and network costs passed onto consumers × Capital expenditure required by NSP to receive and manage operational data, passed onto consumers, may not be acceptable
Impacts on "Alex" (no DER)	No distinct impacts (but benefits from the system-wide reduction in costs)
Impacts on "Blake" (DER, passive, non-smart)	× Blake owns a non-compliant device and may be less able to switch energy service provider because their device does not share its data. This creates a potentially undesirable lock-in × May view continued data validation process with increased suspicion and may wish to op out
Impacts on "Charlie" (DER, active)	✓ Charlie's new & compliant inverter may give access to more attractive retail contracts (unlike consumers with older devices who may – erroneously – perceive this as 'unfair')
Impacts on "Denver" (prospective DER buyer)	✓ Denver may be more incentivised to invest in DER given active management may lead to reduced costs × Clear protocols for the collection and communication of the increasing data requirements would be required to ensure Denver understands and accepts the requirements
Impacts on "Eli" (switcher)	✓ Eli may be incentivised to more actively manage DER given opportunity reduced costs ✓ Eli may have a new & compliant inverter that gives access to more attractive retail contracts × If Eli does not have an inverter with automatic monitoring, cost would be required to upgrade hardware/software
Impacts on "Frankie" (house buyer)	✓ Frankie may be incentivised to buy a home to access lower costs to actively manage DER × May view continued data validation process with increased suspicion, hence be averse to buying a property with continually monitored DER × May be subject to costs due to requirement to upgrade hardware/ software
Overall consumer impact – equity and acceptability	Consumers may benefit from lower system management and network costs, however a negative impact on consumers is possible give the operational, system and device upgrades required. 

A1.127 As illustrated in the figure above, operational data collection can bring benefits to a broad range of consumers, but with potentially highly uneven impacts across different cohorts. The overall impact on consumer acceptability is likely to be slightly negative due to the increased cost required from both a system management and individual consumer perspective.

A1.128 At an individual level, operational data provides the most benefits to consumers with new or compliant inverters, as retailers or aggregators can use operational data to optimise service offerings and retail contracts. The extent to which consumers may be offered a diverse range of services or contracts is likely to depend on who has visibility over this operational data. Consumers may have to actively 'opt in' to enable or allow this visibility between different service providers.

A1.129 Consumers without DER or a compliant inverter may also benefit more broadly from an overall reduction in costs to maintain the network. In the short term, however, these benefits to consumers without a compliant inverter are likely to be counteracted by a requirement to upgrade their hardware or software to a compliant inverter.

- If policy makers wish to implement an operational data standard in order to promote **system security and reliability**, it is likely that operational data would need to be mandated for a sufficiently large share of inverters, such that those system-wide benefits materialise. This would need to be assessed from a technical point of view, and could either allow consumers to replace their inverters over the natural lifecycle of the assets, or, potentially, mandate an upgrade of some of existing inverters. This latter approach is likely to have a greater cost and equity impact on consumers with DER but without a compliant inverter.
- If policy makers wish to implement an operational data standard in order to promote **market facilitation**, then it is unlikely that a complex operational data standard would need to be mandated (although a minimum standard that allows for data portability may be appropriate to facilitate consumer switching; in the absence of a minimum standard, consumers may be locked-in to their retailer, or competing 'ecosystems' with limited portability can emerge). This is because the incentives provided by the newly emerging markets should be sufficient to encourage an efficient level of uptake of compliant inverters. This structure may cause less consumer equity issues, as consumers would opt-in to receive benefits or opt-out to save on costs. Consumers without smart inverters, such as Blake, may save on up-front costs by not upgrading their device but be limited in the long term if they are not able to access the best retail contracts or switch energy service provider.

A1.130 The sharing aspect of operational data may also present a barrier for some consumers: there is a risk that due to misunderstanding, consumers may view the provision of operational data as an invasion of privacy or a step towards unwanted operational control. Clear protocols for collection and communication of data are likely to be important to avoid consumer resistance to the standard.

A1.131 In summary, while there are likely to be aggregate cost reductions to all consumers, these would need to be considered in the context of the cost to develop and maintain infrastructure for operational data collection. In addition, there are important considerations around the equity of operational data requirements and the key driving factor towards the implementation of this standard. The benefits for more efficient system management and system security and reliability would need to be communicated to all consumers regardless of their DER status.

Criterion 4: Market facilitation

4

Market facilitation

- ✓ Facilitates the development of competitive markets (e.g. among aggregators and VPPs) if consumer data is shared in a way that enables aggregators to develop new products and services, which in turn can make wholesale markets more efficient
- ✓ Facilitates the development of new products and services if data is shared between devices within a given household and prospective service providers can access this
- ✓ Consumers may be able to switch energy services providers without needing to change hardware/software settings on their DER (subject to data transfers between energy services providers being allowed)
- ✓ Allows for more efficient wholesale market outcomes through facilitation of DER orchestration.
- ✓ Allows for increased efficiency of aggregator or VPP optimisation of their DER portfolio.

- × Risk that data collection and hosting software requirements may limit the available technology vendors.

Likely to have a positive impact on market facilitation.

A1.132 The requirement to deliver and standardise DER operational data communication is likely to perform well against market facilitation relative to the status quo arrangements.

A1.133 In particular, establishing data monitoring platforms for the near real-time sharing of operational data for DER devices (to the extent that this is desirable, and consistent with prevailing data use and access rules), is likely to facilitate the development of competitive markets in which aggregators compete over consumers and can develop more complex products to meet consumers' individual needs.

A1.134 This is a key focus of the current Project EDGE trial. In building a proof-of-concept two-sided marketplace for DER, the trial is testing a more open access arrangement to data where aggregators optimise operations of DER and networks have visibility to this. As part of Project EDGE, Mondo, acting as the aggregator, is included in the wholesale dispatch process and seeks to deliver energy services against the wholesale price. To do so, operational data exchange between multiple parties is required.

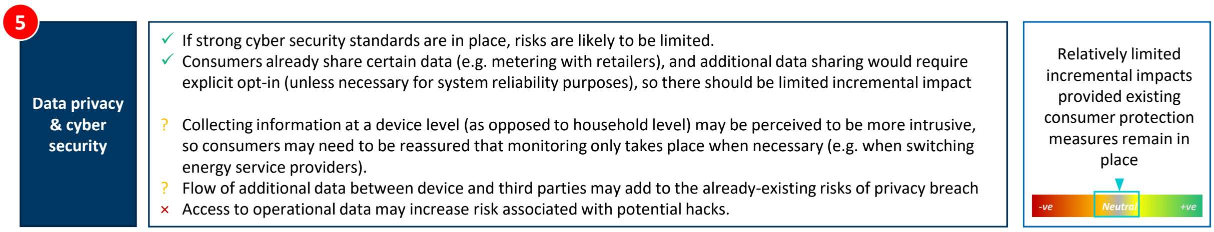
A1.135 However, the benefits of operational data are likely to be realised even without the need to develop a two-sided market, as aggregators and OEMs or device manufacturers may be able to use a greater understanding of consumer data to offer more products and services to consumers. This would empower consumers to take a more active role in managing their DER device(s) and corresponding retail contract, with more products available and standardisation of operational data enabling efficient transfer between service providers.

A1.136 Aggregators (and virtual power plants) may also be able to organise their DER portfolios more efficiently, potentially allowing them to take on greater numbers of customers and adjust quickly to changes in their portfolios.

A1.137 While there is a risk that operational data collection and hosting software requirements may limit the available technology vendors, this risk is likely to be small, primarily mitigated by the size and value of the Australian DER market.

A1.138 In summary, operational data is likely to have a positive impact on market facilitation. Collecting and sharing operational data may unlock future market frameworks upon which consumers have access to additional market and revenue sources, and may also encourage greater competition for consumers (by supporting switching).

Criterion 5: Data privacy and cyber security



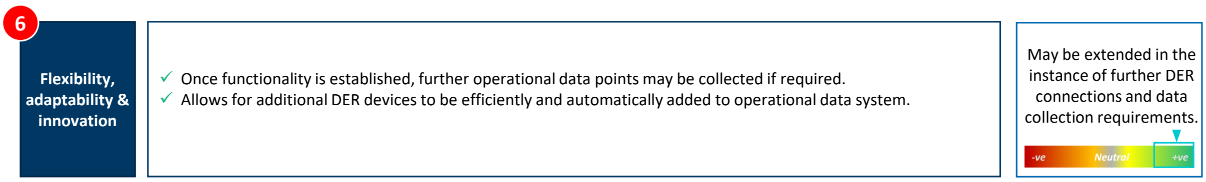
A1.139 As shown in the figure above, operational data sharing requirements build on existing data sharing processes, such as consumers sharing their metering data with retailers.

A1.140 While the sharing of additional data may be viewed by some consumers as more intrusive (even if fully compliant with the prevailing consumer privacy laws), any such data sharing is likely to require an explicit opt-in by consumers, which would help address consumer concerns regarding data privacy. It is assumed that only data that is necessary for basic network security and reliability will be mandated for sharing; other categories of data would likely require explicit consumer opt-in.

A1.141 An alternative design feature for operational data could feature the sharing of more disaggregated data among a wider range of parties. The rationale behind such a design would be to provide increased visibility of DER to a wider range of market participants to help adapt to power system changes and improve system security and reliability. However, this design would present a risk to consumer data privacy. Any resulting changes to data access permissions would require validation against legislation and consumer data privacy laws.

A1.142 In summary, data privacy and cyber security risks do increase with the provision and delivery of operational data. However, if strong cyber security protocols are in place and visibility of data is only granted in line with legislative and regulatory requirements, these risks should be largely mitigated. It would likely be important to consistently review operational data protocols as this is a significant change from existing DER operations.

Criterion 6: Flexibility and adaptability



A1.143 The flexibility and adaptability criterion scores positively as operational data standards may easily evolve with technology and system or network requirements.

A1.144 Once the functionality for data collection is established, additional operational data may be collected if enabled and required (and if consistent with prevailing data privacy laws). Manufacturers may therefore be incentivised to innovate to support additional data collection that allows them, or aggregators/retailers, to differentiate their product or service offerings to consumers. Similarly, the visibility over the operational data can be changed over time as the underlying data needs and permissions evolve.

A1.145 From a DNSP or SO standpoint, increasing visibility to a more granular level of data could be beneficial as network topology continues to evolve. The CSIP currently defines data collection at the site and device level. Once systems are in place, the operational data collection technology and standard are likely to enable greater visibility of increasing levels of granularity or frequency of data collection. Once again, however, the development (and standardisation) of the capability does not necessarily mean that this capability will be used. Any changes to the data sharing (in terms of granularity, type of data, visibility of the data to different parties, etc) would need to comply with the wider legislative context.

A1.146 In summary, an operational data standard is likely to enable flexibility, adaptivity and innovation, which in turn would benefit both consumers and networks or system operators. Relative to the counterfactual of existing processes, operational data is likely to drive innovation in product offerings and system management.

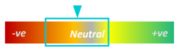
Criterion 7: Compliance and monitoring burden

7

Compliance & monitoring burden

- ✓ May allow for automatic linkages between static (DER register) and operational data to ensure compliance across physical response and performance requirements (e.g. cross-checking that volume of flows match the static data)
- ✓ Reduction in operational monitoring burden and costs with access to operational data (e.g. checking compliance with DEL physical response), which helps avoid the costs of alternative network monitoring devices
- ? Potential increased compliance monitoring burden on NSPs (and AEMO) to maintain systems to receive significant amount of data. The impact on these parties would depend on the frequency and scope of any monitoring they undertake (e.g. the burden could be limited if monitoring was only performed infrequently for a targeted subset of consumers)
- ? Potential additional compliance requirements placed on aggregators (if they are required to collect and report the data, e.g. to the DNSPs), and hence additional burden to monitor aggregators and data collection processes.
- ? Potential increased monitoring and regulatory requirements would be needed to ensure data quality (e.g. if the data is widely gathered – which may or may not be the case) and access security.

Some efficiencies may be created but potentially increased costs of compliance and monitoring (depending on the scale and scope of monitoring)



A1.147 As shown above, there is a degree of uncertainty in the impact of operational data on compliance and monitoring burden relative to the status quo.

A1.148 In terms of benefits, it appears likely that operational data may be utilised to ensure compliance in the physical response and performance requirements of devices, inverters, and connection points. This may be undertaken in real-time, through automatic linkages between static and operational data, or ex-ante, through compliance checks against connection agreements or regulations.

A1.149 There is also likely to be a reduction in operational monitoring burden as operational data at the device level may reduce the need to put in place alternative network monitoring devices, although this would need to be examined further.

A1.150 However, the magnitude of these benefits (and whether they can easily materialise) needs to be tested further. The amount of operational data points likely to be collected and provided to DNSPs and AEMO would be driven by the operational requirements and cost-benefit analysis assessment for each particular data requirement. The overall compliance and monitoring benefits are therefore uncertain and would need to be evaluated against the associated costs.

A1.151 Depending on the volume of data collected, there is a potential for an increase in the compliance monitoring burden on NSPs to maintain systems to receive and process the increased volume of data.

A1.152 In addition, regulation and monitoring of aggregators and hardware providers around data collection, and the provision of data to alternative third parties, will need to be developed. If operational data is utilised to monitor compliance against connection agreements and protocols, data quality would also have to be considered and new processes established.

A1.153 In summary, it appears that operational data standardisation could reduce compliance and monitoring burden in some areas, but potentially increase it in others (depending on the volume and type of data collected/shared and the range of parties involved). The overall balance would need to be investigated further.

Assessment summary

A1.154 As shown in the assessment summary below, operational data has the potential to score highly against most of the criteria in the assessment framework.

A1.155 It appears that operational data supports both the stability of the network and the development of future markets, but the potentially negative impact on consumer equity and acceptability poses questions with regards to the mandating or an opt-in/out implementation approach.

A1.156 The significant costs required to upgrade system hardware and software to deliver and support operational data on an ongoing basis presents a potential barrier for implementation of the standard (or may indicate a need to implement the standard only as a 'minimum' requirement). It seems that there would need to be a clear gateway process in the policy decision making to ensure that the granularity of operational data and the frequency of data collection is justified and proportionate relative to the expected benefits to consumers. For example, if a particular policy decision were to create costs to OEM vendors (and hence, ultimately, consumers) due to the more complex hardware requirements, this should be evaluated against the associated benefits to consumers.

Figure 16: Assessment summary of Operational data

Criteria	Summary pros and cons	Illustrative evaluation
1 System security and reliability	✓ Increased DNSP and AEMO understanding of DER operational data (if indeed accessible to those parties), encouraged by greater visibility of assets, should improve network security	-ve +ve
2 System and network costs	✓ Greater visibility of DER should reduce SO system management costs and facilitate more efficient management of the network × Costs of handling data, with impact dependent on how much data is collected, shared and managed	-ve +ve
3 Consumer equity and acceptability	✓ Consumers may be incentivised to engage more actively in the market to manage DER and access contracts ? Appropriate balance of mandatory data sharing vs opt-in needs to be put in place × Costs of upgrading; and risk of lock-in if consumers cannot switch due to device not sharing data	-ve +ve
4 Market facilitation	✓ Facilitates the development of competitive markets, new products and services and switching ✓ Allows for more efficient wholesale market outcomes through facilitation of DER orchestration	-ve +ve
5 Data privacy & cyber security	✓ Consumers already share certain data; and incremental data sharing could be subject to opt-in ? Flow of additional data to third parties may add to the already-existing risks of privacy breach × Access to operational data may increase risk associated with potential hacks	-ve +ve
6 Flexibility, adaptability & innovation	✓ Once functionality is established, further operational data points may be collected if required. ✓ Allows for additional DER devices to be efficiently and automatically added to operational data system	-ve +ve
7 Compliance & monitoring burden	✓ May allow for automatic linkages between static (DER register) and operational data to ensure compliance across physical response and performance requirements ? Potential additional compliance burden on NSPs/AEMO/aggregators depend on the scale and scope of data collection and monitoring	-ve +ve

Key lessons learnt from the Operational data assessment

A1.157 This section summarises the key lessons learnt regarding the application of the assessment framework, as informed by the operational data example. The key insights relate to: (1) the weighting of criteria; and (2) the sensitivity of the outcomes to detailed design choices.

A1.158 In relation to the weighting of criteria, the analysis above has shown that operational data can score positively against both system security and reliability (Criterion 1) and market facilitation (Criterion 4). However, depending on the importance that policy makers attribute to these two criteria, this may lead to different policy choices. For example:

- If system security and reliability is considered to be the most important driver behind standardising the collection and sharing of operation data, it is likely that this data would need to be collected from a sufficiently large share of the population, and the data may need to be highly granular (to support very accurate network visibility and management). This would impact on consumers and costs, as the standard may need to be mandated across a sufficiently large share of DER sites, therefore increasing the cost of implementation and the cost specifically to consumers with older inverters or those who are not active in the market.

- Conversely, if market facilitation is the most important driver behind standardising the collection and sharing of operation data, then the widespread adoption of compliant inverters, and the granularity of the data, may be of lesser importance (as consumers essentially would make choices in their own interest).[75] This could improve the scoring of the standard on consumer equity and acceptability (Criterion 3), particularly if consumers were able to opt-in or opt-out by choice, and depending on if they want to take an active role in future markets. This approach however would decrease the positive impact on system security and reliability.

A1.159 To fully evaluate the technical standard being considered, it therefore seems important that policy makers articulate explicitly what the key drivers of implementation are.

A1.160 In relation to the sensitivity of the outcomes to detailed design choices, the analysis above has shown that the evaluation of some of the criteria requires a more detailed understanding of the specificities of the standard being considered. For example, the impact of operational data on compliance and monitoring is not clear cut. We discussed above the potential benefits of reduced monitoring burden, but also some potential incremental costs, and set out some of the trade-offs. However, the assessment needs to be performed using a more detailed definition of the technical feature.

A1.161 Finally, the analysis of operational data has highlighted that some technical standards being considered can represent significant changes to network operations, regulatory frameworks, governance and roles and responsibilities. Therefore, when considering the impact of operational data against some of the criteria, in particular data privacy and compliance and monitoring, these need to be evaluated within the wider policy and market design context.

[75] The one exception to this might relate to a minimum level of standard required to facilitate consumer switching. In the absence of portability of consumer data for switching purposes, there is a risk of consumer lock-in to specific service providers.

A.4 Mechanisms for control

A1.162 The complexity of distribution network operations has been driven by the uptake in DER and the increasing two-way flow on the network. DER devices and the surrounding hardware and software infrastructure have likewise significantly evolved in their complexity. In turn, this makes it more complex for DNSPs and SOs to maintain visibility and oversight of their networks.

A1.163 A key foundation of DER system functionality, technical standards and, therefore, the potential benefits discussed throughout this report, is the ability to communicate between the DNSP or SO and the DER assets themselves. For example, the application of dynamic operating envelopes (and DELs discussed in Section A1) is predicated on the assumption that DNSPs (or the SO) can communicate with end devices to adjust the export limits in a dynamic way.

A1.164 The communication from DNSP to the DER device is the subject of the ARENA funded research trial *evolve*, a combined research project between The Australian National University and Zepben, a software developer for electricity distribution networks. The primary objective of *evolve* is to "*develop and demonstrate a system for coordinating DERs that will ensure the secure technical limits of the electricity distribution network are not breached*".[76]

A1.165 A key area of the evolve project focuses on the communications between DNSPs and DER devices, and the technical implementation and role of the aggregator.

A1.166 As discussed in Section A3, aggregators or device manufacturers (OEMs) often have visibility over (or in fact own) some the operational data at the device level. Through the same connection, aggregators or manufacturers maintain the relationship with the DER device to communicate and deliver specific instructions (e.g. a change in the DEL).

A1.167 At present, aggregators may communicate or have visibility over device data through their own proprietary APIs and interfaces. For a DNSP to have visibility over device data or to communicate with devices they need to go through the aggregator and thus communicate via the aggregator-specific (potentially distinct) languages. Conversely, for a DNSP to have visibility over device data, the owner of the data would also need to grant visibility of this data to the DNSP, as no regulatory or legislative requirement currently exists for the provision of this data.

A1.168 From the perspective of DER interoperability, the question at this stage is whether the mechanisms for control (i.e. the 'languages' that the DNSP uses to communicate with the aggregator, and in turn the aggregator uses to communicate with the end devices) need to be standardised:

- The implementation of a standards-based communication protocol between DNSPs, aggregators (and potentially devices) would allow DNSPs to communicate via a single

[76] evolve Project M5 Knowledge Sharing Report (link)

'language' to aggregators (and devices). This could in turn enable DNSPs to manage assets more effectively, for example by communicating a change in the DELs to all aggregators (and devices) in a single instruction. A communication standard could also enable scalability in the device market. This is of particular importance within the developing DER market across the NEM, as technology providers and aggregators increase in size and service complexity.

- However, standardisation may not be strictly necessary for DNSPs to communicate with aggregators and end devices: it may be technically possible for a DEL instruction to be 'translated' to multiple languages, without any downsides in terms of the efficiency of the communication process. Standardisation may also deter desirable innovation, for example in terms of the way in which DER devices communicate with each other behind the connection point.

A1.169 The CSIP, as well as Project evolve, identify the IEEE 2030.5 standard as the most appropriate standard for the Australian context. Specifically, Project evolve found that the IEEE 2030.5 communication protocol would support the development and scaling of the DER market in Australia through the following features:[77]

- *"The ability to communicate default controls*
- *An object model that supports both aggregator-mediated and direct-to-DER communications*
- *Monitoring functionality which provides both device visibility and network connectivity information*
- *The option to move to subscription-based communications and the potential for reduction in overall bandwidth requirements."*

A1.170 In this section we therefore examine a technical feature (and two variations) that relate to the potential application of the IEEE 2030.5 standard for communications or control between DNSP, aggregators and devices, as defined in Box 1 below.

Box 4: Definition of Mechanisms for control

In this report, Mechanisms for control is defined as the application of a standard (e.g. IEEE 2030.5) for communication from the DNSP to the aggregator, and potentially to end devices. In this example, the assessment framework is tested against two design variations of the standard: 1) IEEE 2030.5 mandated between the DNSP and aggregator only; and 2) IEEE 2030.5 mandated between the DNSP and aggregator, and between the aggregator and end devices. This standard would also include the definition of default protocols/settings to use in the event of a loss of communication.

Option 1 and Option 2 are shown below.

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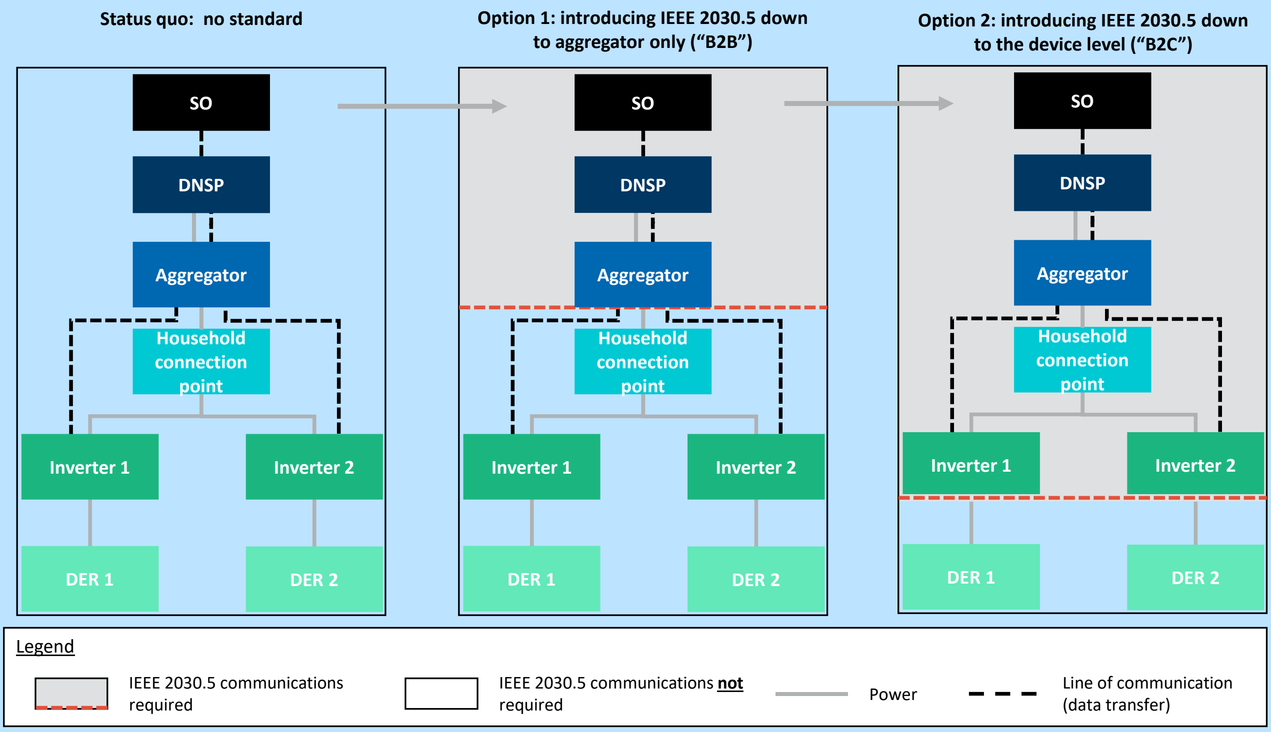
[77] evolve Project M5 Knowledge Sharing Report (link)

Illustration: Communication standards applied under different mechanisms for control options



Option 1 assumes that the aggregator may communicate with inverters or DER devices using any communication language or proprietary interface at their own discretion. The communication delivered to the devices is assumed to be able to follow through from the communication between the DNSP and the aggregator (e.g. by responding to a change in the DEL).

For the purposes of this assessment, it is assumed that neither the DNSP nor AEMO (as the system operator) have direct control of end devices. This assessment focuses only on the standard of communication rather than the mandating of control or roles and requirements of the DNSP, SO, Aggregator and device (as the latter would need be developed through operational or market requirements).

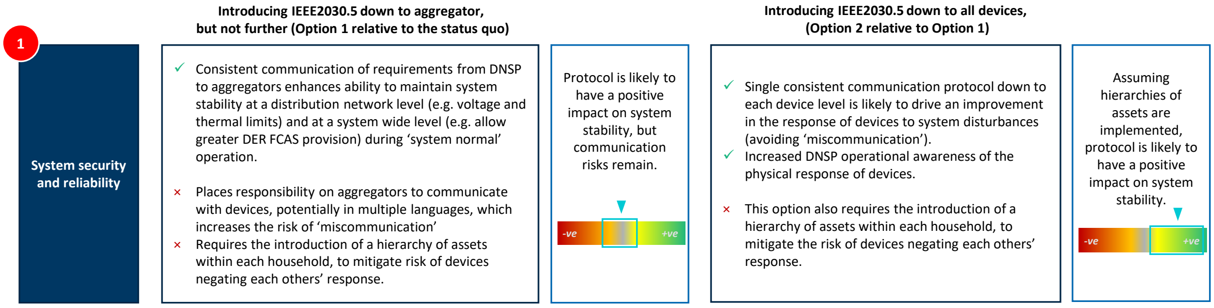
Neither Option 1 nor 2 enable communication directly from the DNSP to the device level (this would amount to bypassing the aggregator). This has been assumed based on the CSIP AUS and stakeholder feedback.

It is assumed that device control hierarchies are in place in a scenario where multiple devices sit behind a single connection point. Therefore, regardless of whether in practice aggregators send a single communication signal (to the connection point), or multiple signals (to each device individually), we assumed that there would be a mechanism in place to ensure that the behind-meter devices respond in a coherent manner, rather than, for example, try to 'compete' for the export capacity).

The counterfactual to the assessment of the IEEE 2030.5 under Option 1 is no standard being implemented. For Option 2, we assess the IEEE 2030.5 as an incremental change (expanding the communication standard down to the device level), relative to Option 1. The status quo counterfactual assumes DNSPs are able to communicate with aggregators and devices, however there is no standard language applied.

A1.171 In the following subsections we evaluate the Mechanism for control functionality against the seven criteria of our assessment framework.

Criterion 1: System security and reliability



A1.172 Both Option 1 and Option 2 enable consistent communication of network needs and requirements from DNSP to aggregator, allowing the DNSP to communicate protocols and requirements that support system stability. As discussed in Section A1, this can generate benefits at both a distribution network level and from a system-wide security perspective. For example, both Option 1 and Option 2 allow DNSPs to deliver a DEL instruction to aggregators, for them to pass through that instruction to individual devices.

A1.173 However, introducing IEEE 2030.5 down to the device level (Option 2) is likely to have a significantly more positive impact on system security and reliability relative to Option 1. This is because:

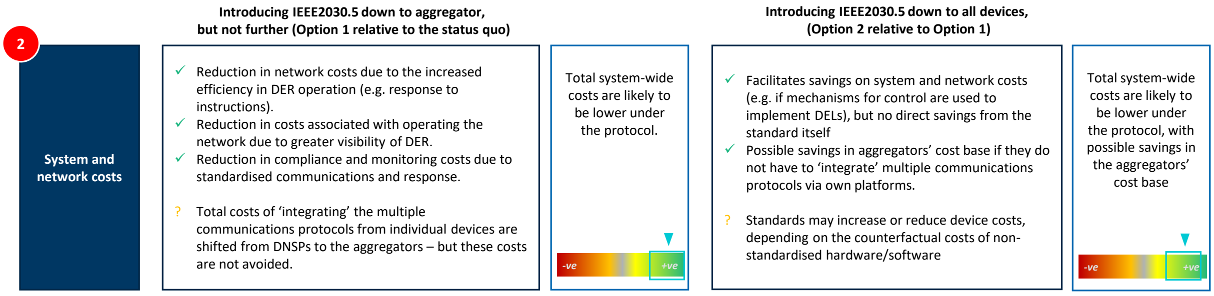
- Option 1 allows aggregators to communicate with devices in any way they wish. While some aggregators may choose to use IEEE 2030.5 for such communication, DNSPs will have no visibility or understanding if this is the case. Moreover, using multiple languages between aggregators and end devices increases the risk of miscommunication of instructions (which can have knock-on impacts on system security and reliability).
- By contrast, a single consistent communication protocol to the device level (Option 2) creates a degree of consistency across the communications process and is likely to drive operational efficiencies and limit the risk of miscommunication. Such consistency of communications provides DNSPs with greater clarity on the physical response of devices, therefore contributing to positive system security and reliability and operational outcomes.
- In Option 1, device manufacturers or OEMs will be the primary decision-makers regarding the communication language for different types of devices. While this may support competition among OEMs, and in turn encourage innovation, there is a risk that

aggregators would be required to maintain the functionality to communicate with devices in multiple languages, increasing risk of operational and communication errors.

A1.174 Both options are likely to require the implementation of a hierarchy of assets within each household to ensure that instructions such as DELs are met, in aggregate, at the connection point level. This functionality adds complexity to the control system but is likely to be increasingly required as modes of communication and the number of devices behind a single connection point increase.

A1.175 In summary, IEEE 2030.5 is likely to support system security and reliability under Option 1 and Option 2 relative to no standardised communications. However, the system security and reliability benefits are limited if IEEE 2030.5 is not mandated to the device level.

Criterion 2: System and network cost



A1.176 Introducing IEEE 2030.5 to the aggregator level (Option 1) or down to all devices (Option 2) is in both cases likely to have a highly positive impact on system and network costs. However, this needs to be considered against the costs that the aggregator would face in 'integrating' multiple languages (in Option 1) and against the costs of OEMs complying with IEEE 2030.5 for their devices (in Option 2).

A1.177 In Option 1, where the standard is implemented to the aggregator level only, cost reductions are primarily driven by an increase in the operational efficiency of DER. By allowing DNSPs to communicate through a single protocol, DNSPs' operational and monitoring costs are likely to reduce while the efficiency of the network increases, leading to lower overall system management costs.

A1.178 Relative to the counterfactual of no standardisation, Option 1 may transfer some costs from DNSPs to the aggregators. This is because the DNSPs' costs are reduced (thanks to the ability to communicate in a single IEEE 2030.5 language to all aggregators), but it is now the aggregators who need to be able to 'integrate' the multiple communication languages from end devices. This would need to be carefully assessed, to ensure that cost transfers and cost reductions are not conflated.

A1.179 In Option 2, there are likely to be some incremental benefits relative to Option 1 driven by further operational efficiencies. For example, aggregators may realise additional cost savings through using a single communication language on their own platforms and thus avoid the cost of 'integrating' multiple communication protocols. However, Option 2 would require that all devices use IEEE 2030.5, which may create a barrier to entry to OEMs who cannot comply (or are not willing to do so). In terms of overall costs, the net impact of Option 2 would depend on whether IEEE 2030.5 functionality is cheaper or more expensive than the alternatives, and this needs to be examined further.

A1.180 In summary, both options for Mechanisms for control are likely to reduce overall network and system costs. The cost impact would, however, also need to take into account the impact on competition among OEMs and the costs borne by aggregators for integrating multiple communication protocols.

Criterion 3: Consumer Equity and Acceptability

Consumer Equity and Acceptability	Introducing IEEE2030.5 down to aggregator, but not further (Option 1 relative to the status quo)	Introducing IEEE2030.5 down to all devices, (Option 2 relative to Option 1)
Impacts common to all consumer groups	✓ Lower system management and network costs passed onto consumers	✓ Lower system management and network costs passed onto consumers × May view the IEEE2030.5 standard at the device level with suspicion
Impacts on "Alex" (no DER)	No distinct impacts (but benefits from the system-wide reduction in costs)	
Impacts on "Blake" (DER, passive, non-smart)	No distinct impacts (may be subject to cost increases if new communications capabilities are required for existing devices, e.g. retrofitting hardware)	
Impacts on "Charlie" (DER, active)	✓ No direct cost to Charlie without a requirement to the device (only B2B) ? Charlie's aggregator may be better or worse off in order to comply with IEEE 2030.5, and this saving/cost could be passed on to Charlie's bills	× Charlie may be required to upgrade his DER devices if non IEEE 2030.5 compliant (or due to a need to hierarchise their assets), leading to short term cost increase
Impacts on "Denver" (prospective DER buyer)	✓ Denver may select from a range of DERs and aggregators (no direct cost impact)	× Competition and innovation may be limited by not all devices being IEEE 2030.5 compliant; Denver may have to pay more for new DER
Impacts on "Eli" (switcher)	? Eli may not be able to easily switch aggregators due to different languages ? Potential aggregator's costs to comply with IEEE 2030.5 which could be passed on to Eli's bills	✓ Eli is likely to be able to transfer aggregators easily due to all devices being IEEE 2030.5 complaint
Impacts on "Frankie" (house buyer)	? Frankie may find the DER choice more complex, as not all devices necessarily communicate with all aggregators	✓ No particular concerns for Frankie, as all new DER will be able to communicate with all aggregators
Overall consumer impact – equity and acceptability	Likely to be acceptable to consumers but some cost impacts on aggregators (pass through to consumers) may drive distributional impacts. -ve +ve	Selection of devices may be more limited, and upgrades of legacy assets may drive additional costs. -ve +ve

A1.181 As summarised above, introducing IEEE 2030.5 to the device level is likely to have a mixed impact on consumer equity and acceptability, with a wide variation among different consumer cohorts.

A1.182 The key factor driving consumer equity and acceptability of Option 1 and 2 is **the ability of different aggregators to comply with IEEE 2030.5**. Introducing a standard that all aggregators need to comply with is likely to impact each aggregator differently, depending on their ability to meet the standard. Different aggregators are likely to have different abilities to communicate via IEEE 2030.5 and for some parties this may require significant costly hardware and software upgrades.

- Under both Options 1 and 2, an increase in aggregators' costs may be passed on to the end consumer, and this could have distributional impacts on consumers.

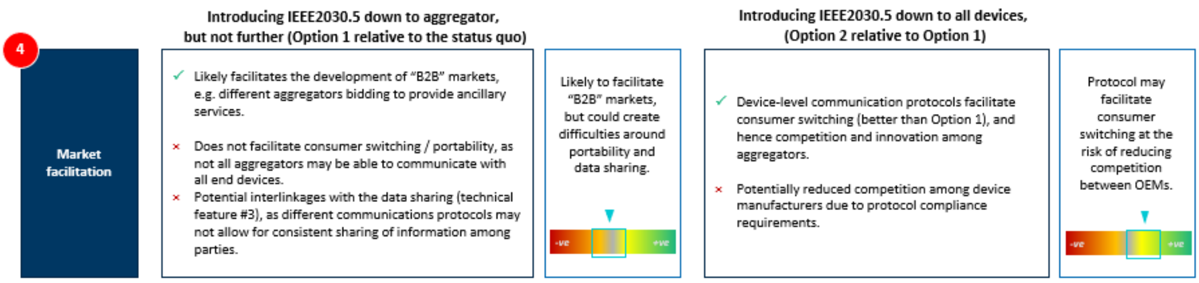
- Under Option 1, aggregators would be responsible for 'integrating' different languages from end devices using their platforms. This may lead some aggregators to only offer services to a subset of DER devices (e.g. those that the aggregator can communicate with). This can lock-in consumers to certain aggregators (if alternative aggregators cannot communicate with their DER) or reduce the switching options for the owners of some devices, thus negatively impacting consumer choice and acceptability.
- Under Option 2, this lock-in effect would be mitigated, but consumers may bear the cost of compliance being implemented down to the end device level (for example through more expensive DER hardware). In addition, if some DER devices or certain classes of assets are non-compliant, their availability and overall market optionality may decrease, leading to more a concentrated OEM market (which could in turn increase costs to consumers). Finally, if the communication standard is required for legacy devices, there is a significant risk of lock-out of devices with costs spread unevenly across new and legacy consumers.

A1.183 The performance of different protocols or mechanisms for control has not yet been tested within the Australian context. There are risks to consumer equity and acceptability:

- Under Option 1, if certain protocols are more efficient, then DNSPs may end up calling on such devices more often. This could have either a positive or negative effect on consumers, as they may be able to realise higher revenues but may be curtailed more often.
- Under Option 2, if there are protocols that deliver the same outcomes as IEEE 2030.5 but are cheaper, then the application of the IEEE 2030.5 standard would lead to inefficiently high costs in the market.

A1.184 In summary, mandating IEEE 2030.5 as the required communications protocol is likely to have a mixed impact across classes of consumers. Option 1 could lead to higher aggregator costs being passed through to consumers and to consumer lock-in to certain aggregators. Option 2 would likely mitigate the lock-in risk but could increase costs to consumers (via higher OEM costs to comply with the standard) and/or reduce competition among OEMs.

Criterion 4: Market facilitation



A1.185 As shown above, the application of a standardised communications protocol is likely to support the development of markets for active DER, however it may limit competition at the device and aggregator level.

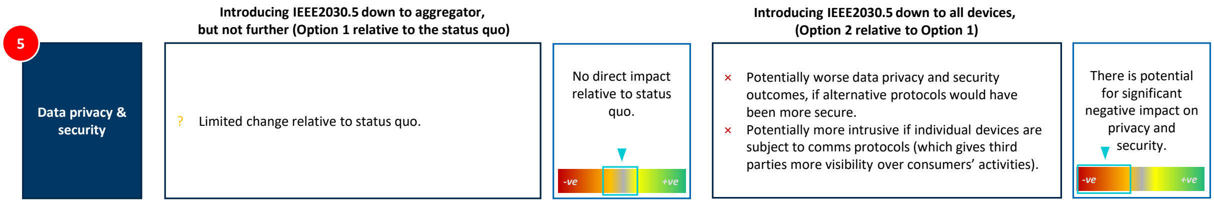
A1.186 The application of IEEE 2030.5 down to the aggregator level (Option 1) facilitates a consistent communication of instructions to all aggregators. This could bring benefits under a potential future DSO model, where aggregators may be able to provide bids for network or ancillary services to the DSO. Standardised communication protocols are likely to facilitate and accelerate the development of distribution level markets, as DSOs receive consistent communications they can process and assess relative to each other.

A1.187 Consistency of DNSP-to-aggregator communication protocols may also encourage the development of aggregator-to-aggregator relationships. In a sophisticated market, enabling aggregators to receive real time control signals from another aggregator may allow for further optimisation of bids and network services. This may be of particular interest within a constrained network where aggregators want to trade out-of-market services based on the geography of the DER devices under their remit. It is possible these opportunities would be further enhanced under Option 2, with standardised communications across all aggregators and end devices.

A1.188 The application of IEEE 2030.5 is also a key factor driving consumer switching between aggregators. Under Option 1, not all devices may be able to communicate to all aggregators or OEMs, which can lead to consumers being locked-in to certain aggregators. Conversely, Option 2 is likely to mitigate the lock-in risk and instead encourage switching and competition in the retail market. However, the IEEE 2030.5 compliance requirements may drive a decrease in device competition.

A1.189 Ultimately, the application of IEEE 2030.5 is likely to have a positive impact on market facilitation driven by the large value opportunity in the development of distribution level markets. There are specific risks associated with Option 1 (limited opportunities for switching) and with Option 2 (limited device level competition), which would need to be evaluated further.

Criterion 5: Data privacy and cyber security

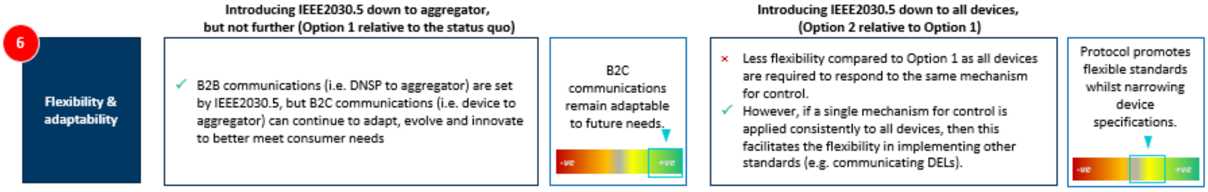


A1.190 Introducing IEEE 2030.5 to the aggregator level (Option 1) is likely to have limited impact on data privacy and cyber security outcomes relative to the status quo. This is because data privacy and cyber security are driven by wider standards and would not be significantly affected by the introduction of a new standard for communications.

A1.191 In Option 2, the introduction IEEE 2030.5 to the device level might negatively impact data privacy and cyber security outcomes relative to Option 1, for example if alternative communications protocols would have been more secure than IEEE 2030.5. This could occur in cases where OEMs or aggregators were no longer allowed to use their proprietary (and potentially more secure) software to communicate with their devices.

A1.192 Overall, the implementation of IEEE 2030.5 would need to be considered carefully to ensure that the standard does not inadvertently worsen the cyber security and data privacy outcomes for consumers. One option to examine could be to implement the IEEE 2030.5 as the default ‘minimum’ protocol, which OEMs could supplement with additional security features.

Criterion 6: Flexibility and adaptability



A1.193 The flexibility and adaptability criterion scores positively under Option 1, but has a mixed score under Option 2.

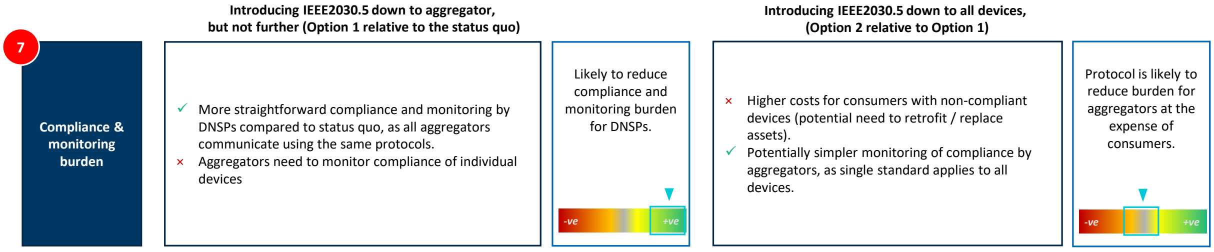
A1.194 By mandating IEEE 2030.5 only to the aggregator, Option 1 retains the flexibility for aggregator to device (or B2C) communications to vary. This provides aggregators and OEMs/manufacturers the flexibility to innovate through communications and protocols to deliver improved and more attractive products and services to consumers.

A1.195 In contrast, Option 2 provides no flexibility in terms of the communications protocols to end devices. This would limit OEMs’ ability to develop new communications protocols to improve their products and services.

A1.196 The application of IEEE 2030.5 down to the device level (Option 2) gives the DNSPs a greater level of certainty that the communications delivered to the aggregator will also be delivered to the device (without any ‘translation’ issues along the way). By making the communication process more streamlined (by being standardised), this can provide policy makers additional flexibility in how other technical standards are rolled out. For example, to implement DELs, end devices need to be able to receive (and respond to) the DEL instruction from the DNSP. Streamlined communication protocols to the device level arguably make it easier to implement the DELs, as they remove a potential layer of ‘translation’ complexity.

A1.197 In summary, mandating IEEE 2030.5 to the aggregator or to the device level is likely to improve flexibility and adaptability outcomes. Option 2 in particular identified a trade-off in that standardisation may limit the flexibility at the device level but may create new opportunities for other technical standards to be implemented.

Criterion 7: Compliance and monitoring burden



A1.198 Mandating the use of IEEE 2030.5 (or indeed any other communication protocol), tends to increase the overall compliance burden by creating a new requirement that relevant parties (aggregators or consumers) need to comply with. In addition, Option 1 and Option 2 have very different impacts on the compliance and monitoring burden to market participants.

A1.199 Applying IEEE 2030.5 to the aggregator level (Option 1) is likely to:

- reduce the monitoring burden of DNSPs as they are able to communicate using the same protocols across all aggregators. In particular, DNSPs are not required to understand alternative aggregator-specific protocols to ensure communications were delivered and received accurately;
- Transfer the compliance and monitoring burden from DNSPs to the aggregators, who are now responsible (instead of DNSPs) to manage and monitor communications with end devices; and
- Have a limited impact on end consumers, who do not face any direct compliance costs as they do not need to upgrade their DER to meet the requirements of IEEE 2030.5.

A1.200 In Option 2, where IEEE 2030.5 is applied at the device level, the costs to the aggregators of monitoring compliance of end devices are likely to be reduced, as there is a single technical standard that needs to be complied with. However, consumers with non-compliant devices may need to retrofit or replace their device if the standard is applied to legacy devices as well as to the new DER.

A1.201 Overall, the impact of mechanisms for control on the compliance and monitoring burden appears to be mixed, and the net impacts need to be evaluated further.

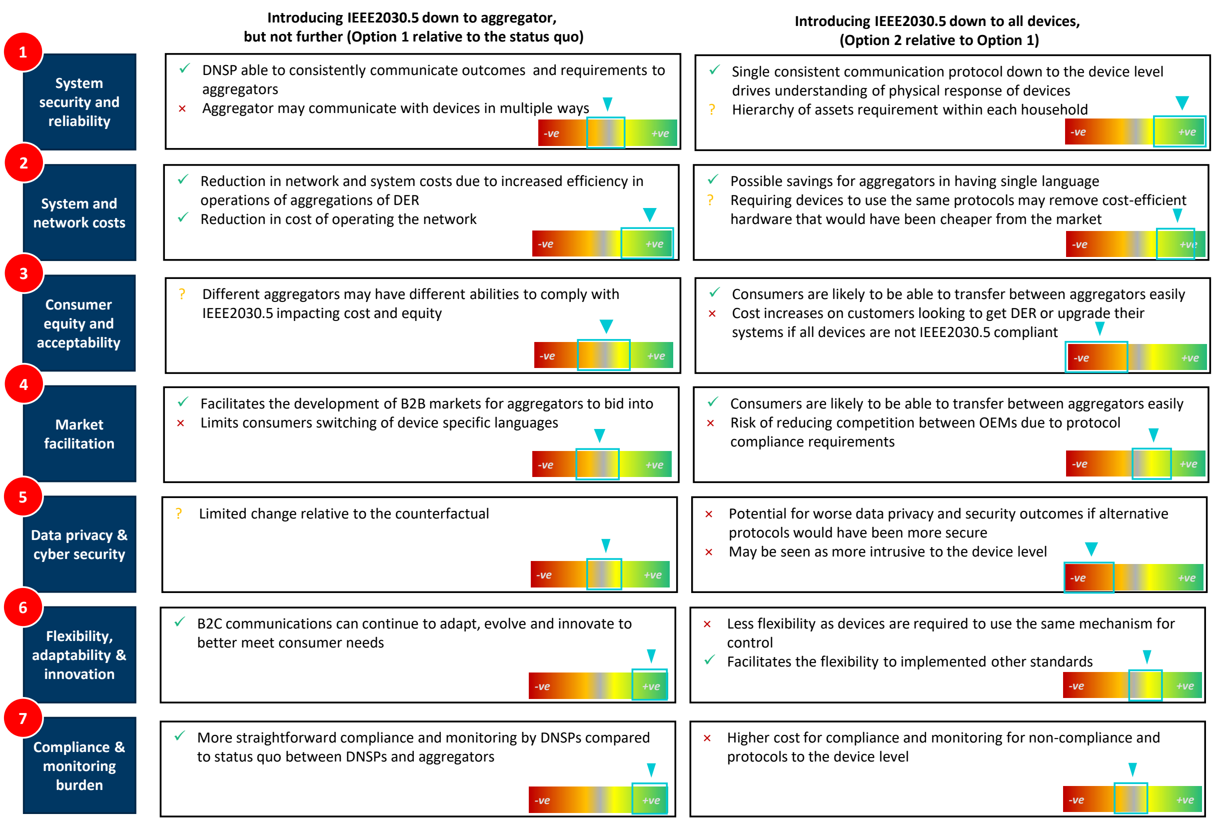
Assessment summary

A1.202 As shown in the assessment summary in Figure 17 below, requiring IEEE 2030.5 as the communication protocol under both Option 1 and Option 2 presents benefits for network costs, as there are likely to be cost reductions facilitated by more efficient communications (and hence operation) in the system.

A1.203 Option 1 (where the mechanisms for control are standardised down to the aggregator level) scores more positively than Option 2 (where the standard applies all the way down to the device level) in terms of consumer acceptability (Criterion 3), flexibility (Criterion 6) and compliance (Criterion 7). This is driven primarily by the increased rigidity of implementing the standard to the device level which is likely to lead to concerns among consumers regarding device compatibility and choice, as well as data privacy and security.

A1.204 Conversely, Option 2 (where the standard applies all the way down to the device level) scores better on system security and reliability (Criterion 1), and on market facilitation (Criterion 4). This is because greater consistency in overall communication protocols improves the interoperability of DER for the benefit of efficient system operation, in line with current and future standards, such as DOEs. In relation to market facilitation, the application of the standard down to the device level facilitates consumer switching, and thus encourages more competition in the retail market.

Figure 17: Assessment summary of Mechanisms for Control



Key lessons learnt from Mechanisms for Control assessment

A1.205 In this section we summarise key lessons learnt regarding the application of the assessment framework, as informed by the Mechanisms for Control worked example. The key insights relate to the assessment of minimum versus higher level standards.

A1.206 We have evaluated two technical options of Mechanisms for Control: a 'minimum' standard that creates a degree of consistency in the communications between DNSPs and the aggregators (Option 1), and a higher level standard (where the consistency in communications is extended down to the individual device level). The application of the framework highlights that two criteria in particular - system security and reliability (Criterion 1) and market facilitation (Criterion 4) - benefit from a higher level of technical standard, i.e. they score better under Option 2 compared to Option 1.

A1.207 For policy makers, this suggests that different levels of technical standards may perform very differently in the assessment framework. This has two implications:

- First, it is critical to carefully define the technical feature and exactly how it is implemented in the market. In the example here, it would not be sufficient to discuss 'consistent communications protocols' in general; it is important to articulate exactly which parties are subject to the new standards.
- Second, there may be merit in evaluating multiple design options for a particular technical standard through the assessment framework. Doing so can help highlight initial trade-offs that could feed into a more detailed impact analysis, to help decide on the optimal level of standard (i.e. minimum standard vs higher levels of standard).

A1.208 Finally, this feature has highlighted the potential need to examine other sub-variants of mechanisms for control: for example, policy makers may wish to examine whether some minimum degree of standardisation at the device level (e.g. of the data collected) could be appropriate in order to achieve narrowly defined objectives such as consumer switching. This has not been explored in detail in this report, but it shows that the assessment framework could be used as a way of framing further detailed policy questions.