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ARENA submission on the Post-2025 Market Design Issues Paper

This submission provides background information and insight from projects funded by the Australian Renewable Energy Agency (ARENA). In particular, it responds to each of the 5 key challenges identified in the Energy Security Board's (ESB) Issues Paper in the context of the transition to a higher penetration renewables grid, as well as the proposed assessment framework.

In summary -

- Proof of concept projects have contributed to innovations in technology, business models and grid management practices, and practical experience from these projects can inform market reform.
- Reliability, in the transition to renewables, can be achieved by a range of resources and grid management practices working in complementary ways. New generation and demand side resources can be significantly more modular and flexible than traditional large-scale investments, with substantially shorter investment lead times. These new dynamics needs to be catered for in market design, and efficiency can be achieved through simple and open markets for service delivery.
- The state of knowledge on DER integration is rapidly evolving and ARENA is supporting the industry through studies and projects which are maturing key smart grid functional elements. The Distributed Energy Integration Program is helping to address the whole of sector coordination challenge for DER reform.
- The capabilities of new inverter based technologies (including wind, solar and batteries) are not fully valued in the current market design. Addressing this issue can ensure that system security is achieved at the lowest cost in the transition to renewables.
- ARENA supports the ESB's proposed assessment framework for market design options and considers it important to also consider the durability of design options against a wide range of potential renewable energy penetration scenarios and how market processes

can intersect with proof of concept projects that can reduce costs and risks in the energy transition.

About ARENA

The Australian Renewable Energy Agency (ARENA) was established in 2012 by the Australian Government. ARENA's function and objectives are set out in the *Australian Renewable Energy Agency Act 2011.*

ARENA supports the Australian Government's energy and emissions reduction priorities by providing financial assistance to support innovation and the commercialisation of renewable energy and enabling technologies, helping to overcome technical and commercial barriers. We support research, inform policy decisions, and bring together people from across the energy sector, government, startups and universities to collaborate with one another, and share their knowledge.

ARENA not only provides funding but actively identifies and troubleshoots issues arising from the energy transition, from technological and commercial issues to regulatory and market barriers.

ARENA recently updated our investment priorities following consultation with industry and government and we have sharpened our focus to areas that can best assist with the energy transition. ARENA funding will be directed towards projects that support the integration of renewables in the electricity system; accelerate the development of Australia's hydrogen industry for domestic and export markets; and support industry to reduce emissions.

1. Driving innovation to benefit the consumer

<u>The role of proof of concept demonstrations</u>

ARENA's new investment priorities are geared towards future proofing our energy system and economy and helping to further unlock Australia's vast renewable resources. The first of these is focused on overcoming the challenge of integrating renewables into the grid as we switch to an electricity system that is more complex, more decentralised and more variable.

This effort builds on a large portfolio of work aimed at helping to deliver secure and reliable electricity. This portfolio includes 313 projects (with a total ARENA funding commitment of $732 million and a total project value of $2.8 billion) across the following focus areas:

- System security and reliability, 49 projects, $70.5m ARENA funds, $163m total project value
- Large scale batteries, pumped hydro and concentrating solar thermal power, 66 projects, $206m ARENA funds, $587m total project value
- Generation technologies, 25 projects, $190m ARENA funds, $1.22b total project value
- Distributed energy resources, 38 projects, $63.3m ARENA funds, $213.9m total project value
- Electric Vehicles and charging infrastructure, 4 projects, $21.64m ARENA funds, $66.8m total project value
- Solar PV R&D, 131 projects, $180.2m ARENA funds, $522.2m total project value.

A key part of ARENA's approach is to collaborate with market bodies to ensure our investments are targeted at the most commercially prospective ideas and the most pressing industry challenges. This is facilitated, in part, through knowledge sharing and collaboration under MOUs with AEMO and the AEMC. ARENA also has a major focus on knowledge sharing across government and industry and project outcomes are regularly shared through a broad range of events and communication channels.

Proof of concept trials can quickly and deliberately help demonstrate the feasibility and advantages of new technology, commercial and regulatory approaches. This can speed up and reduce the costs and risks inherent in reform and deliver a range of benefits for industry. Practical examples include:

- The ARENA-funded trial at Hornsdale Wind Farm 2 in SA demonstrated the feasibility of FCAS provision. This has led to the ongoing provision of these services providing additional revenue streams for the proponents and greater market competition and savings for customers.
- The AEMO-ARENA demand response trial has informed reforms to the Reliability and Emergency Reserve Trader scheme and the development of the Wholesale Demand Response Rule Change. As a participant in the trial, United Energy has demonstrated how network voltage control can provide effective emergency demand response and it is now looking to apply this approach to provide frequency control services.
- The ESCRI battery project has demonstrated the capability of grid connected batteries to provide a range of network and market services and highlighted opportunities for regulatory frameworks to better accommodate the delivery of these services.
- ARENA's support for 18 large-scale solar projects has significantly matured the large-scale solar industry in Australia such that solar PV is now among the lowest cost forms of electricity generation in Australia.
- Our Regional Australia's Renewables program demonstrated the technical viability and dependability of off-grid and microgrid renewable energy systems. This has provided the mining sector with the confidence to progressively increase the share of renewable energy in their supply systems, with substantial savings in diesel generation costs.

The *Independent Review into* the Future Security of the National Electricity Market[1] recommended two mechanisms to help realise the benefits of innovation:

- Recommendation 2.8 - Regulatory frameworks to facilitate proof-of-concept testing of innovative approaches and technologies.
- Recommendation 2.9 - A funding source for trials by the Australian Energy Market Operator and the Australian Renewable Energy Agency.

ARENA has worked closely with the AEMC on the development of potential regulatory sandbox frameworks building on our experience as Australia's renewable energy innovation agency. The ESB's recommendations for post 2025 market design are an opportunity to address the critical role that proof of concept trials can play in reducing risks and costs in the energy transition.

[1] https://www.energy.gov.au/[...]/independent-review-future-security-national-electricity-market

The benefits of outcomes-based regulation

ESB's issues paper recognises the importance of well designed market frameworks in promoting innovation. ARENA's experience suggests that where required system services are clearly defined and markets are open to new entrants, competition and innovation in service delivery can ensue. Looking forward, for example:

- Competitive energy services markets (including in retail) can ensure service offerings adapt to reflect the dynamic and varied nature of consumer interests in the electricity system, and the development of new technical approaches to service delivery.
- Over time, a broader range of system security services (e.g. primary frequency control, inertia, system strength etc.) could be opened to competition and innovation in service delivery.
- More outcomes-based economic regulation of networks could help overcome residual capital expenditure biases, supporting the adoption of demand side technologies and the procurement of grid support services from third parties.
- A level playing field for supply and demand side resources, such as has been set out in the AEMC's vision for a 'two-sided market'[2], could unlock significant new supplies of system services such as wholesale demand balancing, ramping and primary frequency control, reducing costs for consumers in the energy transition.
- As customer energy systems become increasingly complex (incorporating greater load flexibility, generation and energy storage) it will be increasingly efficient for market operations to focus on overall performance 'at the gate', rather than imposing specific requirements for individual behind-the-meter technology configurations.

Understanding and responding to customer values

ARENA-funded projects are demonstrating that many consumers are driven by a range of non-financial motives, while others are willing to take on greater risk (such as through spot price exposure) or cede control of assets such as batteries, water heaters or pool pumps, for the promise of greater financial returns. One of the great benefits of competitive retail markets is that they can respond to consumer preferences as they change over time, and enable increased customer value through innovative products and services. Allowing for the changing and varied nature of consumer interest in the electricity system should be a central consideration of post-2025 market design.

2. Investment signals to ensure reliability

Balancing variable renewable energy (VRE) generation

Over the past decade, rapid cost reductions in wind and solar have resulted in them becoming the lowest-cost source of bulk energy production. This advantage is likely to increase through the medium term as innovations in technology and project delivery continue, and manufacturing scale continues to increase. A critical role for future market design is to ensure the optimal utilisation of VRE as a lowest cost primary energy source, alongside dispatchable renewable energy and balancing resources.

[2] https://www.aemc.gov.au/[...]Wholesale%20demand%20response%20mechanism.pdf

There are several options for balancing variable renewables:

- **Spare renewable capacity** will allow higher output at times of low resources, at the expense of some of that capacity being idle at low-demand or high-resource times, providing firmer generation profiles.
- **Geographic and technology diversity**, enabled by transmission, can smooth out production across the day and seasonally however more work is required to determine the economic value of diversity at different system scales.[3]
- **Storage** will be a required part of the overall solution.
- Getting better at **forecasting** across all timescales should reduce the level of redundancy needed to manage forecast inaccuracies - which should reduce cost by increasing generator utilisation.
- **Demand flexibility** can substantially reduce the requirement for dispatchable generation and energy storage.

The right mix of renewable capacity, geographical diversity, storage and demand flexibility, at different system levels (e.g. residential, commercial, grid scale) is an optimisation problem, taking place under high uncertainty. Future market design arrangements will lead to the most efficient overall outcome if each alternative approach is provided with incentives that reflect the underlying system costs and benefits.

The ARENA-commissioned study, *Comparison of Dispatchable Renewable Energy Options - Technologies for an orderly transition,* examines wind and PV-driven batteries, pumped hydro and hydrogen storage, bioenergy, concentrating solar thermal and geothermal, and their potential future role in the energy market.[4] The analysis suggests different technologies and configurations suit different market needs. For example, batteries are more competitive for short-duration storage, whereas pumped hydro or concentrating solar thermal are more competitive for long duration storage.

Only some of the generators in an electricity system will need to be dispatchable and a system can have a mix of both VRE and dispatchable renewable technologies. The global literature on high renewable electricity systems illustrates how the required investment in balancing resources can be reduced through geographical diversity, full operability of VRE, and load flexibility:

- The variable nature of the wind and sunshine means that renewable energy generators will have a significantly higher rated capacity than the average plant output. This is clear from an analysis of the relationship between ‘renewable energy fraction’ and ‘renewable power fraction’ for daily operations at a portfolio of remote-area power systems funded

[3] WindLab’s analysis of correlation between states and technologies illustrates this (https://www.windlab.com/[...]/20190329_SEC_Conf_95-RE-NEM.pdf)
[4] https://arena.gov.au/projects/dispatchable-renewable-electricity-options/

by ARENA[5] and suggests that an efficient high-renewables market may result in a high level of VRE generator curtailment at the asset and/or network area level.

- Various international studies, as well as practical experience in ARENA-funded remote area projects, illustrate the technical and economic trade-off between geographic diversity, curtailment and storage and various control models.[6] [7]
- A United States study[8] indicates that full operational control (which the study calls 'full flexibility' operating mode) can use the inherent flexibility and responsiveness of inverter-based renewable generators to help manage ramp rates, including that arising from forecasting uncertainty. In turn, this can act to reduce the overall level of renewable curtailment compared to 'curtailable' operating mode (which is similar to the NEM's semi-scheduled registration category). This can reduce fuel costs, operations and maintenance costs, and air emissions.

These analyses suggest the current NEM arrangements for semi-scheduling will lead to inefficient under-utilisation of renewable capacity as the share of renewable energy grows. But equally, requiring all renewable generators to operate as scheduled generators (as currently defined) may lead to inefficiencies because it would not account for the benefits of diversity. Taken together, the economic value from full flexibility of VRE generators, combined with the economic cost of constraining VRE to follow a dispatch instruction regardless of conditions, suggest there would be value in reviewing the dispatch requirements for generators to effectively account for the stochastic nature of renewable resources.

The role of demand side flexibility

More flexible load means less storage is required to balance variable renewables than would otherwise be the case. A German study illustrates this point[9]. In the theoretical case where new demand is more flexible, there is a significant reduction in energy storage requirements. This illustrates the potential benefits of managed charging for new demand sources such as electric vehicles, and in the long term major sources of demand such as hydrogen electrolysis for large-scale industrial use and export.

ARENA's DER and demand response project portfolios are demonstrating the potential for new demand side resources to provide a range of services including network constraints management, frequency control and wholesale and emergency demand response. These projects are summarised at Attachment B.

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[5]Herteleer et al., 2018 (1): Renewable Power and Energy Fractions Revisited: Insights from ARENA's RAR Portfolio. Available at http://apvi.org.au/solar-research-conference/wp-content/uploads/2018/11/164_DI_Herteleer_B_2018.pdf

[6]Zerrahn et al., 2018: On the economics of electrical storage for variable renewable energy sources. https://www.sciencedirect.com/science/article/pii/S0014292118301107

[7] Herteleer et al., 2018 (2): Visions from the Future: The Interaction between Curtailment, Spinning Reserve Settings and Generator Limits on Australian Projects with Medium to High Renewable Energy Fractions. Available at https://www.eupvsec-proceedings.com/proceedings?top100&paper=45795

[8] Investigating the economic value of flexible solar power plant operation, October 2018. Energy and Environmental Economics Inc. https://www.ethree.com/[...]Investigating-the-Economic-Value-of-Flexible-Solar-Power-Plant-Operation.pdf

[9] Zerrhan et al 2018.

This suggests significant value for the future electricity system from greater consumer participation in energy and system services markets, enabled by more sophisticated design and operation of customer energy assets. The ESB's review is an opportunity to ensure future market design enables and supports this. The Wholesale Demand Response Rule Change Draft Determination provides a new opportunity for consumer participation in the energy market. The ESB's review could also examine the benefits in transitioning to a more 'two-sided market' in the longer term, as envisaged by the AEMC.[10]

Contract market innovation

ARENA is observing significant innovation around renewables-based firm capacity products including through combining of wind and solar, demand-side flexibility and energy storage.[11]

A key aspect of this trend is that these 'blended products' can be more modular, have substantially have shorter lead times for contracting and deployment than traditional generation investments (<12 months) and utilise customer-owned assets. This can make them more appealing to customers and smaller retailers due to lower costs and risks. This trend is in some ways analogous to 'just in time production' techniques which have led to substantial productivity benefits in other industries in recent years. A failure to recognise this trend could result in overly 'lumpy' supply side investments which could achieve reliability at a higher cost, and with less ability to adapt to changing circumstances, than a greater number of smaller more targeted investments, deployed 'just in time'.

Energy only market design

Several projects with ARENA funding have looked at the robustness of the electricity market design with high levels of renewables and comparative economics of different policy mechanisms in the NEM. For example Riesz et al. identified that energy-only markets could be viable with high proportions of short-run marginal cost generation (such as most renewables), provided certain conditions are met: limited market power, a well-functioning financial contract market, and review of the market price cap[12]. Least cost abatement papers by Jeppesen et al. and Brear et. al used the NEM's current design and current market price cap[13]. In contrast, Chattopadhyay et al. has suggested that adding a capacity component to the formal market design could provide a more economically efficient outcome with high levels of variable renewables where there is significant market power in the provision of thermal generation[14].

3. Integration of DER into the electricity market

The need for greater cross-sector collaboration on DER

Customer-owned energy technologies such as rooftop solar, home batteries and electric vehicles will grow to become an integral part of a reliable, affordable and lower-emissions electricity grid. The uptake of DER is forecast to dramatically increase and could comprise

[10] https://www.aemc.gov.au/[...]mechanism.pdf
[11] Limited public information exists, including https://kennedyenergypark.com.au/, https://flowpower.com.au/case-studies/ and https://www.energycouncil.com.au/[...market-delivers/
[12] https://ideas.repec.org/a/aen/eeepjl/eeep5-1-riesz.html
[13] http://dx.doi.org/10.1016/j.energy.2016.02.017
[14] https://www.sciencedirect.com/science/article/abs/pii/S0360544216300627?via%3Dihub

almost half of electric power capacity by 2050. The rapid uptake of rooftop PV and batteries is already impacting traditional grid management practices and market frameworks. ARENA is investing in studies and demonstrations that are exploring and firming up options for industry and that will provide solutions for critical DER integration challenges.

The Distributed Energy Integration Program (DEIP) is a collaboration of 13 government agencies, market authorities, industry and consumer associations aimed at maximising the value of customers' distributed energy resources for all energy users.[15] Prior to DEIP, there was no party or mechanism coordinating and prioritising effort across industry.

Access and pricing reform

A key feature of the energy transition is the blurring of the concepts of customer and supplier and the recasting of electricity networks as platforms for two-way service provision. Customers are taking advantage of new technologies to reduce their imports from the grid, while providing services back to energy and system services markets. This two way exchange is changing the drivers of cost and value for networks and customers and is highlighting limitations of current technical and economic regulatory frameworks.

DEIP members have agreed that current network access and tariff arrangements are unlikely to deliver DER investment and operation patterns that are in the long term interests of consumers. For example:

- DER services can be over or undervalued at different times and places (positive and negative externalities) and this distorts investment and operational decisions.
- DER may face increasingly arbitrary network constraints and this will result in a subsequent loss of value for all customers.
- The distribution of benefits of DER investment and operation can be inequitable.

To address this issue, DEIP has developed an access and pricing work package to coordinate activity across industry and target gaps in the current reform processes. The work package will examine how the economic regulatory framework could evolve to meet community expectations, which are changing as we move to higher penetration of DER. It aims to build consensus on equitable and efficient DER access/pricing models, supported by clearly defined customer centric market design principles. The outputs should be available from early 2020 and can inform ESB's consideration of options to address the above issues.

Network hosting capacity

ARENA has committed nearly $11.65m to projects and studies that are exploring how networks can increase network hosting capacity through the investment in grid-side and customer-side resources as well as supportive access and pricing reforms. These projects are included in the summary provided at Attachment B.

These projects are aimed at maturing key elements of the smart grid architecture that may underpin a future distribution system operator and distribution market operator function. A number of projects will help networks to understand the network impacts of DER through greater visibility and control. Focus has been on developing business models, software

[15] https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/

platforms, constraints envelopes, forecasting tools and value creation through markets to enable efficient outcomes for all customers.

Current regulatory frameworks for networks still appear to favour network capital expenditure and consumption-based customer participation. This latter issue is evidenced by the current rules, tariffs and investment tests which seek to regulate the optimal level of infrastructure to manage peak demand. However, many parts of the grid are seeing constraints being set in relation to peak solar generation, with the potential for this to extend to EVs and batteries. Discussions among DEIP members suggest that reforms may be needed to ensure networks have incentives to invest in an optimal level of hosting capacity. This is a key focus for DEIP discussions.

4. System security services and resilience

Grid connection challenges

Changing technical standards and information asymmetries make it increasingly hard for renewable generators to meet grid connection requirements, predominantly in weak parts of the grid. In addition to procedural challenges (e.g. imperfect or asymmetric information, evolving network conditions), renewable generators are increasingly installing synchronous condensers to meet local system strength requirements. Synchronous condensers add substantial cost to the individual project and, with limited scope for asset-sharing between generators, there is a risk of overspend and inefficient asset utilisation.

Industry reports this issue as a key short term barrier to investment in renewable generation and ARENA is looking at several projects that will help inform investors and industry. In particular, ARENA has funded a system strength study (led by a TNSP) to look at:

- The merits of centrally located synchronous condensers compared to project-specific solutions.
- The ability of emerging inverter technologies to increase the renewable energy hosting capacity of weak grids.

The first stream of work will examine the technical and economic case for installing synchronous condensers in “centrally planned” locations, as opposed to each renewable project installing its own synchronous condensers to meet its own grid connection requirements. Similarly, the inverter technology stream is hoping to demonstrate the ability of new inverter technologies to provide stable operation in post-contingency conditions without requiring a significant increase in fault levels.

In addition to this study, ARENA is considering battery projects that may demonstrate the potential for advanced inverters to improve or maintain system strength.

Batteries are viewed by some new technology proponents as potentially being a more favourable solution than synchronous condensers to system strength. This is because batteries can help address several other renewable integration challenges, such as dispatchability, congestion, and other essential system security services (e.g. frequency control services). Batteries are also expected to be a more commercially favourable solution in the medium term (next 2-3 years) following cost reductions and stronger revenue drivers. Conversely, some value

streams, like FCAS could reduce substantially in the coming years due to increased competition in that market.

Proof of concept funding is required to deploy and test new inverter and battery deployments at scale given technology and commercial risk. Further, the current regulatory framework for system services is not conducive to the development of shared asset models because of commercial tensions between participants, risk allocation issues and the limited incentives for network businesses to facilitate third party solutions. Addressing these issues presents an opportunity for market frameworks to support the efficient integration of VRE.

Shift of value from energy supply to 'system services'

There appears to be a broad consensus that the shift to a market designed in the context of low-cost VRE will need to formally define a greater range of system services which may risk becoming scarce in the transition (such as inertia, frequency control, system strength etc.). Due to their relative scarcity, it is likely that these will become an increasing proportion of total system trades and this will shape investment patterns in both supply and demand side resource development. While the value of these services in the long term is uncertain, open services markets, accompanied by continued innovation in technology and business models, can ensure adequate supplies at the lowest cost.

Enhanced markets for frequency response

Recent projects have shown that battery technology is capable of providing a faster and more precise frequency control service than traditional suppliers of FCAS. The ARENA-funded Hornsdale Wind Farm frequency control trial demonstrated the ability of wind farms to provide six of the eight frequency control market services. The remaining two are intended to be further examined in a subsequent trial at the Musselroe Wind Farm. A large-scale solar farm in the United States has similarly demonstrated the responsiveness and flexibility of solar PV, and its ability to provide ancillary services such as frequency control.[16] However, existing frequency control market structure do not fully incentivise the value of higher quality suppliers.

DER can provide this service[17], however there are challenges that still need to be worked through for market participation and performance/verification. These are currently being worked through in an ARENA-supported AEMO VPP trial.

The loss of synchronous generation, combined with greater demand and supply side variability, is expected to result in wider frequency ranges under normal operating conditions and more frequent, fast and deep frequency deviations during contingency events. This would both make the system less resilient to shocks, while increasing the requirements for regulating and contingency FCAS services, with associated costs for energy consumers. Analysis by AEMO[18] indicates a strong preference for primary frequency control (PFC) to complement Regulating and Contingency FCAS with modelling indicating an equivalent value of PFC producing a

[16] Demonstration of essential reliability services by a 300 MW solar photovoltaic power plant. NREL, CAISO and First Solar. https://www.nrel.gov/esif/partnerships-caiso-first-solar.html
[17] The Reposit Power VPP in Canberra is currently providing FCAS lower services via ActewAGL.
[18] https://www.aemc.gov.au[...]/Advice%20from%20AEMO%20-%20Primary%20frequency%20control.PDF

superior outcome in relation to the number and magnitude of excursions from the Normal Frequency Operating Band (NOFB).

ARENA considers that a flexible framework of incentives for primary frequency control can make use of the potential of batteries and other inverter based generation for fast frequency response (response in millisecond timescales). The total requirement for such capacity is relatively small (<500MW) compared to the many gigawatts of FFR capable batteries and other inverter based technologies that are expected to be deployed in the coming decades. Productive efficiency can be most efficiently achieved with an open and transparent framework of incentives that allows service provision to be optimised between energy and frequency control markets at the network connection point and across the market. This may include consideration of changes to the current causer pays framework or deviation pricing, combined with increased obligation for forecasting and scheduling of demand side resources as envisaged in the AEMC's above mentioned 'two-sided market' model.

System Integrity Protection Scheme (SIPS)

AEMO's ISP highlights the increasing benefit of interconnectors to ensure reliability of supply across the NEM and has highlighted priority projects to increase interconnection capacity. However, transmission projects can be expensive and have long delivery timeframes. System Integrity Protection Schemes (SIPS) provide a way to make full use of the interconnection capacity that is available, and that may be built in the future.

ElectraNet's ARENA-supported battery at Dalrymple (known as "ESCRI") demonstrated several innovative features. One of these innovations was ElectraNet integrating the battery into its SIPS. Under this scheme, the 30MW battery would respond upon receipt of a signal from the Heywood interconnector following a contingency event (e.g. loss of a generator). The response can either prevent loss of the interconnector or reduce the impact of losing the interconnector. The existence of this SIPS arrangement has reduced the occurrence of constraints across the Heywood interconnector, which it turn leads to reduced wholesale prices and improved access to interregional generation capacity. It is noted that the 100MW Hornsdale Power Reserve battery has also been integrated into ElectraNet's SIPS scheme.

This experience suggests there may be significant value (reliability, security and affordability value) in developing similar schemes in other regions where there is a high dependency on interconnectors.

While the economic benefits to SIPS-style battery applications are substantial, there are practical barriers for battery projects receiving incentives to participate in such a scheme. Given that any SIPS payment would originate from network service providers (NSPs), the time required to go through the regulatory process will affect the ability to take advantage of batteries, which can be built quickly. In addition, NSPs may not be incentivised to initiate a process that would result in paying independent power producers for these services.

5. Integration of variable renewable energy into the power system

The above sections describe some of what ARENA has learned of the challenges and potential for the integration of renewable energy into the electricity system. The challenge for Australia is to manage the energy transition at the lowest cost by ensuring the energy system can take

advantage of innovations in technology and management practices as they emerge. A low cost transition can be supported by simple and accessible markets and frameworks and research, development and demonstration to advance technology readiness, new commercial approaches and to inform policy reform and market development.

6. Assessment framework for post-2025 market designs

ARENA supports the ESB's proposed assessment framework for post-2025 market designs.

Assessing options against the full range of potential renewable energy penetration scenarios will provide assurance that options are durable to different long term emission reduction policies and technology developments.

With regard to assessment principle "L. supportive of innovation", it is appropriate to consider *how* measures complementary to market design, such as regulatory sandboxes and funding for proof-of-concept demonstrations, can support the evolution of technology, business models and regulatory frameworks. Further comments on this is provided in Section 1 of this submission.

Please contact Jon Sibley, Principal Policy Advisor (jon.sibley@arena.gov.au) if you would like to discuss any aspect of ARENA's submission.

Yours sincerely

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Attachment A - Summary of ARENA's Large-scale Battery Storage (LSBS) and Short Term Forecasting portfolios.

Large-scale Battery Storage

In general, these large-scale battery projects demonstrated (a) improved understanding of the battery's capacity to provide flexible capacity and grid stability services, (b) improved understanding of optimal value stacking and commercial agreements, (c) increased investor confidence and supply chain capability, (d) improved evidence base for regulatory reforms and (e) reduced costs pertaining to installation and integration.

Project title	Project Start Date	Key Demonstration Outcomes
ElectraNet Energy Storage for Commercial Renewable Integration (ESCRI) Phase 2 (South Australia) - Deployment and Testing	October 2018	The ESCRI project is the first LSBS project in Australia to operate in voltage source mode as a virtual synchronous generator while grid connected (grid forming). It generates revenue through energy arbitrage and contingency FCAS services. The ESCRI battery provides islanding service for the local network in conjunction with the Wattle Point Wind Farm and rooftop PV. It also provides System Integrity Protection Scheme (SIPS) between SA and Victoria and reduces constraint on the Heywood interconnector by providing Fast Frequency Response (FFR).
Gannawarra Energy Storage System (GESS)	January 2019	It is the first retrofit model where a LSBS was installed at an existing renewable energy generator site (solar farm). It generates revenue through energy arbitrage and Regulation FCAS service.
Ballarat Terminal Station Battery Energy Storage System (BESS)	November 2018	It is the first standalone battery-based energy storage asset in Australia. It generates revenue through energy arbitrage, Contingency and Regulation FCAS services. As it was built by an Australian Engineering, Procurement and Construction (EPC) company, it is developing the necessary skill-sets within the Australian market.
Lake Bonney LSBS	December 2019	This project aims to generate revenue through energy arbitrage, Contingency and Regulation FCAS services. It plans to reduce the curtailment of generation of Wind Farm by working in tandem with the automated bidding software that will be deployed alongside the battery. It also aims to reduce its Causer Pays Factor and firm its solar and wind portfolios to enable additional opportunities for Power Purchase Agreements (PPAs) with Commercial and Industrial (C&I) customers.

Short Term Forecasting

In general, the Short Term Forecasting projects aim to (a) demonstrate the ability for Market Semi-scheduled Generators to submit five-minute self-forecasts via AEMO's web based application programming interface (API) (b) demonstrate the ability for self-forecasting to be more accurate than the equivalent forecast produced by the Australian Wind Energy Forecasting System (AWEFS) or Australian Solar Energy Forecasting System (ASEFS) (c) explore the potential commercial benefits for Market Semi-scheduled Generators of investing in forecasting approaches (d) examine factors that affect the accuracy of the forecasting approach trialed. e.g. in different weather, operational conditions or geographies (e) improve the commercial and technical readiness of forecasting providers and technologies.

Project title	Project Start Date	Key Demonstration Outcomes
Windlab Ltd	December 2018	Applying machine learning algorithms and custom hardware (Light Detection and Ranging device) to refine the accuracy of short-term forecasts at two Windlab sites.
Industrial Monitoring & Control Pty Ltd	March 2019	Further developing CSIRO's cloud camera that is currently used in remote applications adapting it for large scale grid connected solar farms. The project will also develop the Solar Power Ensemble Forecaster product with Uni Sa and UNSW, utilising satellite based and statistical forecasting tools.
Meridian Energy Australia Pty Ltd	January 2019	Developing a real-time wind forecasting engine and demonstrating forecasts at horizons greater than 5 minutes ahead, prepared through numerical weather prediction and mesoscale models.
Solar and Storage Modelling Pty Ltd (Solcast)	January 2019	Delivering 8 stand-alone self-forecasting trials at semi-scheduled farms in the NEM over a two year period. Projects will leverage Solcast's global satellite based nowcasting services, combined with real-time solar farm SCADA data and sky-imagers to generate short-term power output predictions.
Advisian Pty Ltd	November 2018	Advisian Digital will develop ensemble machine learning models trained on historical data within a prediction framework that considers a wide range of variables, including cross-series information. They will be deployed at wind and solar farms in QLD & SA.
DNV GL Pty Ltd	December 2018	Deploying a multi-model wind forecasting approach at Ararat Wind Farm using on-site feedback data and weather models, plus development of advanced machine learning capability for short time horizons.
Fulcrum 3D Pty Ltd (Wind Project)	February 2019	Developing turbine agnostic real time models using wind data from site installed equipment to develop an accurate wind and operational forecast for each turbine.

Fulcrum 3D Pty Ltd (Solar Project)	September 2018	Fulcrum3D aim to generate and optimise solar farm forecasts, using ground based sky imaging devices (CloudCAMs) at Genex's Kidston 1 Solar Project. The CloudCAMs and other solar farm data will allow Fulcrum3D to submit self-generated forecasts into AEMOs market dispatch system.
Vestas Australian Wind Technology Pty Ltd	March 2019	Deployment of a forecasting tool that integrates plant level data and other sensors, alongside short-term weather forecasts and meteorological data to provide accurate generation forecasts.
Aeolius Wind Systems Pty Ltd	January 2019	Developing and demonstrating the capability and value of a long-range dual doppler based forecasting system to develop a precision wind power output forecast.
Proa Analytics Pty Ltd	December 2018	Demonstration of the Proa Forecasting System which uses skycam, satellite, live data and weather forecasts at three solar farms in different climate regions. The project will also infrared skycam and satellite techniques to improve cloud characterisation during both day and night.

Attachment of B - Summary of ARENA's demand response and DER portfolios including (VPPs and network hosting capacity projects)

Project title	Project Start Date	Key Demonstration Outcomes
CONSORT Bruny Island Battery Trial	Complete	The Network Aware Coordination (NAC) platform coordinate consumer energy systems to meet network capacity and voltage constraints and achieve the required network benefits, at minimal cost. The NAC provides appropriate price signals to consumer energy systems, which are incentivised to support the network when problems occur.
AGL Virtual Power Plant	February 2017	Demonstrating how multiple value streams can benefit from 'behind-the-meter' orchestration of a distributed fleet of residential batteries (e.g. network service providers, consumers, retailers, and wholesale market participants).
Horizon Project Highgarden	October 2017	Developing standard operating protocols and advanced meter infrastructure (AMI) to operate, maintain, and enable communications for high penetration DER environments. Demonstrating an advanced model for DER integration in 'fringe-of-grid' towns that have reached their current available solar PV hosting capacity.
ARENA-AEMO Demand Response RERT Trial	May 2017	Demonstrating and improving the commercial and technical readiness of new DR reserve capacity for maintaining reliability of the electricity grid. Providing an evidence base to inform the design of wholesale demand response mechanism.
Simply Energy VPPx Project	March 2018	Delivering up to 1200 Tesla Powerwall 2 batteries and providing 6 MW of orchestrated residential energy storage plus 2 MW of demand response capacity.
IT Reneawbles Open Source Grid Integration Model for the NEM	April 2018	Providing extensive scenario modelling capability of the NEM with an array of input assumptions, including focusing on the transition path from the current system to possible future scenarios. Enables insights into potential pathways for the evolution of the NEM and allow users to examine the impact of economic and regulatory factors (e.g. technology costs or changes in fuel prices), technological changes, (e.g. improvements in the performance of energy generation and storage electricity, transmission, and energy use efficiency) and specific large energy projects.
Indra Monash Microgrid	October 2018	Demonstrating a market-driven platform where both energy and power quality can be orchestrated via a smart embedded network environment with high DER penetration.

Ausgrid Demand Management for Replacement Needs	November 2018	Incentivising customers to permanently reduce their load on the network by focusing on encouraging the implementation of new solar power systems and efficient lighting retrofits.
Powercor Analysis of Options to Increase PV Hosting Capacity of Distribution Networks (NHC)	December 2018	Developing a robust methodology that demonstrates real-world challenges for DNSPs with increasing levels of DER, as well as identifying a defined list of opportunities available for networks to support higher levels of DER. The methodology will be accessible by publicly available software that takes into account real-world factors, with the results of the project fed back into the current CitiPower Powercor DER assessment process.
CSIRO National Low-Voltage Feeder Taxonomy Study (NHC)	December 2018	Producing the nation's first low-voltage network taxonomy to clearly articulate the characteristics of distribution systems in relation to the impact of higher levels of DER. The primary outcome is to clearly articulate the real world impacts felt by increasing DER penetration and what benefits are available to the grids.
Dynamic Limits DER Feasibility Study (NHC)	December 2018	Investigating whether dynamic data can increase DER capacity limits on the NSW distribution network (aka. Dynamics Limit Control Scheme). Considerations being assessed include scaling issues, data reliability and confidence, data retention, latency, customisation of network data formats for different end-users (subscribers, including network customers participating in these schemes), cyber security, management of subscriber authorisation. The study will detail, cost and plan an implementation of the scheme at larger scale on selected feeders in NSW.
Oakley Greenwood Pricing and Integration of Distributed Energy Resources (NHC)	December 2018	Developing a methodology to appropriately price DER services that allows them to be (economically) efficiently integrated into the supply chain. Creating appropriate market signals will assist in incentivising stakeholders to invest in locations where DER is most needed..
ANU Community Models for Deploying and Operating DER (NHC)	January 2019	Demonstrating the value community energy models can provide for customers, retailers and distribution networks through a technical, financial, regulatory, social and security and reliability lens.
Jemena Three Dynamic Grid-Side Technologies (NHC)	January 2019	Demonstrating three dynamic grid-side technologies: dynamic phase switching of customer loads on LV feeders to mitigate localised over-voltage; dynamic power compensation to adjust the output voltage and mitigate load unbalance at the source distribution transformer; and battery energy storage with Virtual Synchronous Generator (VSG) capability to mitigate power quality and network stability challenges caused by high DER penetration.

SAPN Advanced VPP Grid Integration (NHC)	January 2019	Developing a model to estimate network hosting capacity and demonstrate the ability to dynamically raise export limits for VPPs where/when/if there is sufficient network capacity. Co-designing an API and business rules for VPP grid integration, and quantifying the additional value created for the VPP operator through the use of dynamic export limits vs. the current static connection limits.
Solar Analytics Enhanced Reliability via Short Time Resolution Data (NHC)	January 2019	Developing automated acquisition and delivery of short-time resolution data to AEMO to help investigate DER behaviour during system disturbances.
University of Melbourne Advanced Planning of PV-Rich Distribution Networks (NHC)	January 2019	Developing analytical techniques to allow DNSPs to quickly assess PV hosting capacity, as well as providing planning recommendations for increasing PV hosting capacity.
University of Tasmania Optimal DER Scheduling for Frequency Stability Study (NHC)	January 2019	Demonstrating a method of effective and optimal coordination of DER to provide frequency stability to the grid. Relies upon developing detailed models of the network, a framework for VPP and aggregators to FCAS markets to identify what information DER aggregators need in order to provide FCAS services to the network, and extend the existing network-aware coordination (NAC) algorithm to optimise DER within network constraints in order to provide FCAS services.
Zepben evolve Project (NHC)	February 2019	Demonstrating the scalable capabilities and systems for coordinating DER throughout distribution networks by developing an API between DNSPs and aggregators, defining operating envelope engines for networks, and establishing a data platform with DNSP integration.
AEMO Virtual Power Plant Demonstrations	March 2019	Demonstrating new technical specifications for VPPs to deliver FCAS in the NEM; observation of VPPs stacking multiple value streams to improve commercial viability; and providing an evidence base to inform changes to regulatory settings or AEMO's operational processes.
GreenSync Decentralised Energy Exchange (deX) Program (NHC)	March 2019	Enabling higher shares of renewable energy to be connected to the grid while ensuring electricity is secure, reliable and available where and when needed.
United Energy Voltage-Controlled Frequency Regulation System (NHC)	May 2019	Demonstrating the use of Voltage Controlled Frequency Regulation System technology for delayed-raise (5-minute) contingency FCAS by providing voltage-reduction DR capability to ramp power output in response to frequency disturbances.