Australian Government
Australian Renewable Energy Agency

ARENA

ARENA submission

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House of Representatives inquiry into modernising Australia's electricity grid

This submission provides background information on Australian Renewable Energy Agency (ARENA) projects relevant to the *House of Representatives Inquiry into Modernising Australia's Electricity Grid.*

The Inquiry terms of reference include investigation into:

- The means by which a modern electricity transmission and distribution network can be expected to ensure a secure and sustainable supply of electricity at the lowest possible cost.
- The current technological, economic, community and regulatory impediments and opportunities to achieving a modern electricity transmission and distribution network across all of Australia, and how these might be addressed and explored.
- International experiences and examples of electricity grid modernisation in comparable jurisdictions.

To assist the Committee with its investigation, this submission provides information relevant to each of these topics. The submission details ARENA's project portfolio and relevant experience with renewable energy generation; storage; and interactions with the electricity network and demand for electricity from consumers and industry. The submission also outlines ARENA's broader approach to enabling affordable, reliable electricity supply with a high proportion of renewable energy.

About ARENA

ARENA was established with the aim of improving the competitiveness and increasing the supply of renewable energy and enabling technologies in Australia.

ARENA provides financial assistance for research, development, demonstration and deployment of renewable energy and enabling technologies. This assistance is designed to accelerate the commercialisation of these technologies by helping to overcoming technical and commercial barriers.

A key part of ARENA's role is to collect, store and disseminate knowledge gained from the projects and activities it supports for use by the wider industry.

To date, ARENA has invested $1.1 billion in support of 232 projects (including 190 active and 42 complete) with a total value of $2.7 billion.

In summary:

- ARENA is focused on innovation for secure, reliable, cost-effective renewable energy to facilitate the transition to a higher level of penetration;

- the future of electricity most likely involves generation from a mixture of sources;
- the increased use of renewables in the electricity grid introduces integration and regulatory challenges;
- much of the technology to overcome these challenges already exists, however, there is scope for significant improvements and the opportunity to develop new technologies;
- the electricity market will need to adapt to the characteristics of new sources of generation - for example, renewables are more likely to be distributed, variable in output and have low inertia compared to traditional sources.

1. The means by which a modern electricity transmission and distribution network can be expected to ensure a secure and sustainable supply of electricity at the lowest possible cost.

Australia's electricity supply relies on a mixture of energy sources, each with their own technical characteristics. This is supported by a complex transmission and distribution network. It is not simply a question of generating enough electricity and supplying it to customers. Rather, a modern electricity network requires the capability to deliver power in a flexible manner, responding to demand in the short (microseconds to seconds), medium (minutes to hours) and long term (days to weeks or seasons).

Different technologies have different capabilities to deliver such flexibility. They also necessitate different integration requirements. As we continue to shift towards a higher share of renewables in the electricity grid, and therefore a higher level of sustainability, the technical integration of different energy sources becomes more important. ARENA's portfolio contains projects that support this transition, whilst maintaining a secure and reliable electricity supply at a competitive cost. In addition to the development of renewable technologies to supply electricity, ARENA's portfolio includes projects that advance energy storage technologies, which can quickly ramp output up and down, and smarter control systems that are better able to manage supply in response to demand – or in the case of demand response, adapt consumption to match available supply.

Managing supply in response to demand

A secure electricity supply requires a grid that has the flexible capacity to deliver varying power depending on demand. The time-scale over which changes in this demand occur necessitate different technology capabilities.

Responding to short-term demand

On a second-by-second basis, supply and demand must be managed across the network to control frequency and voltage. This can be achieved with the use of inertia from synchronous generators. These systems feature a rotating part, wherein the speed of rotation can be regulated to match the frequency and voltage of the grid. Wind turbines do not fulfil this role as a stand-alone technology, as their rotation speed can vary with wind speed. Traditionally, synchronous power is provided by coal and gas thermal generators, however, alternative technologies can also be used. Synchronous renewable energy generation includes bioenergy, pumped hydro and concentrating solar thermal. Although less well established, inverters provide the means to deliver frequency and voltage control services from wind, battery and solar sources, and super-capacitors and flywheels are capable of providing short bursts of power to enable short-term energy response.

Responding to medium-term demand

Matching supply and demand on a second to hour time-scale to respond to rapid changes in energy use requires rapid change in generation of power. This can be met with the use of gas or coal-fired peaking plants, however an alternative is the storage of renewable energy. One option is pumped hydro energy storage (PHES), which depending on reservoir size can store enough power for 2-8 hours use or more. Another is the use of battery technology which depending on type can store electrical power for up to 8 hours. A number of other technologies exist, such as compressed air energy storage, superconducting magnetic energy storage, molten salts and chilled water or ice, however they are not as widely deployed. In addition to approaches that look to increase the supply of energy, increasing the responsiveness of demand through improved management programs can balance out medium-term fluctuations. Overseas experience suggests demand response could constitute 10% or more of overall peak capacity when supported by appropriate commercial frameworks. Increasing the productivity and efficiency of energy consuming appliances, equipment and systems can reduce the overall need for electricity supply capacity, including the capacity needed to respond to medium-term peaks.

Responding to long-term demand

A modern electricity grid should have the capacity to respond to changes in demand on day to week-long time periods and even on a seasonal basis. This might be in response to events that cause a change in power demand such as a heat wave, or events that cause a change in power supply such as bad weather damaging a generation plant or transmission infrastructure. Meeting these needs depends on having sufficient overall capacity to provide power in relatively rare scenarios.

Sustainable electricity supply from renewables

Flexible capacity includes storage, demand response, and generation that can be ramped up and down to help balance supply and demand. As renewables like wind and solar PV get cheaper, ARENA is placing an increased focus on flexible capacity technologies to balance out variability in supply and demand. Following a request from the Prime Minister, ARENA announced on 1 February 2017 it is interested in expressions of interest for projects involving flexible capacity and large scale storage. This includes concentrating solar thermal, battery storage, pumped hydro, biomass and demand management technology.

Bioenergy

Both bioenergy and concentrating solar thermal plants use steam turbines connected to synchronous generators and can therefore provide synchronous power in much the same way as non-renewables. The availability of biomass is a restriction on the amount of power that can be generated, particularly considering that is not usually economically viable to transport the feedstock over long distances.

Many biomass feedstocks have the potential to be stored over a long time-scale, allowing energy resources to be stockpiled and called on in periods of high demand. Factors that need to considered include; storage locations and costs (point of collection can be zero cost), compositional changes, the impact of weather and temperature changes, and storage method.

ARENA's portfolio includes a number of projects that advance the supply of electricity from biomass, for example:

- Unitywater, 'Unitywater sewage waste to energy feasibility study' - Demonstrates the treatment of waste sewage water to capture biogas for the production of electricity.
- Renergi Pty Ltd, 'Advanced biomass gasification technology' - Conversion of biomass such as agricultural waste into gas that can be used in electricity production.
- Queensland University of Technology, 'Utilising biogas in sugarcane transport and milling' - Improving the efficiency of waste sugar bagasse biomass conversion to energy year-round.
- Rural Industries Research and Development Corporation, 'The Australian biomass for bioenergy assessment project' - Provides a national database of biomass resources for bioenergy across Australia, including analysis of feedstock availability, type and economics.

Concentrating Solar Thermal (CST)

CST works by concentrating solar radiation using lenses or mirrors onto a single receiver point. Solar energy is captured as heat, which can then be stored as thermal energy or transferred to generate electricity via steam turbines, providing electricity generation with characteristics very similar to traditional generators. The technology is mature and worldwide and CST deployment has increased dramatically over the past 10 years, however large-scale facilities require a large capital commitment. Concentrating systems can also be used with a photovoltaic receiver to directly convert sunlight into electricity.

CST projects supported by ARENA include:

- CSIRO, 'Australian Solar Thermal Research Initiative' - A collaboration of Australian research institutions on highly innovative projects that aim to reduce the cost of delivery of CST.
- Vast Solar Pty Ltd, 'Vast Solar 6MW concentrating solar thermal pilot project' - A commercial-scale demonstration of CST energy capture, storage and conversion to electricity.

Pumped Hydro Energy Storage (PHES)

PHES works by pumping water from a lower reservoir to an upper reservoir during periods of low demand, and releasing this water back through turbines during periods of high demand to generate electricity. The use of turbines enables PHES to respond to fluctuations in frequency and voltage. Whilst the technology is mature and proven, projects do require a long lead-time and a high capital expenditure, as well as a suitable location. The storage time for pumped hydro depends on the scale of reservoirs, however it is typically enough to store energy for up to 8 hours, which allows response to demand in the medium term in addition to the short term.

ARENA has recently announced future commitments to PHES projects including feasibility studies to expand the pumped hydro component of the Snowy scheme, and to investigate sites for pumped hydro in Tasmania. These commitments are under negotiation. Contracted commitments include related studies:

- Genex Power Ltd, 'Kidston pumped storage project' - A feasibility study to explore the potential of a pumped storage hydroelectric power plant at the site of a disused gold mine.
- The Australian National University, 'An atlas of pumped hydro energy storage' - An assessment of grid integration, environmental impacts and a comparison with other storage technologies on an atlas of potential sites for short-term, off-river pumped hydro energy storage.

Wind and solar

Although not currently widely deployed, inverter technology is available and under development that would allow power generated from wind and solar to regulate frequency and voltage. Wind and solar power generation may also take advantage of the wide geographic dispersion of Australia's electricity network to produce energy more consistently. Situating wind and solar farms in different regions spreads the risk of low power production because of local weather conditions, and if they are part of the same grid, power is produced with less variability than several small, individual farms.

ARENA projects that seek to address gaps in current knowledge include:

- University of Technology Sydney, 'Networks renewed' - Aims to improve voltage management by assessment of the integration of novel inverter technologies.
- Neoen, 'Hornsdale wind farm stage 2, frequency control ancillary services trial (FCAS)' - Trialling of wind-to-FCAS technology, providing knowledge for renewables FCAS regulation and grid integration.

Battery storage

As the cost of battery production falls, this type of storage becomes more economically attractive. Batteries are also modular, giving a low minimum capex and allowing storage capacity to be built on a smaller scale (including behind-the-meter at commercial and residential premises). At current prices, they tend to be more expensive than pumped hydro or thermal storage when built at large scale with more than a few hours' storage. There is some uncertainty about the lifetime of batteries, particularly in Australian climate conditions. Many different types of battery exist, with different components having different advantages and disadvantages in terms of safety, economics and environmental impacts.

The advancement of battery technology forms a significant portion of the ARENA portfolio, including the following projects:

- AGL Pty Ltd, 'Energy storage for commercial renewable integration' - Examines the role of batteries, flywheels and compressed air systems in the integration of renewables into the South Australian electricity system.
- University of Adelaide, 'Energy storage test facility and knowledge bank' - Construction of a mobile energy storage test facility, to allow the real-life analysis of a range of systems and scenarios on factors such as grid stability.
- University of Technology Sydney, 'Lithium-sulfur batteries for large-scale energy storage' - The development of batteries with advanced energy density, service life and operational safety properties.
- IT Power, 'Testing the performance of lithium ion batteries' - Analysis of commercial battery performance, demonstration of operation in electricity grids and a comparison to current and advanced lead-acid batteries.

Hydrogen

Electricity can be stored by using it to convert water into hydrogen and oxygen via electrolysis. When required, the two gases are then recombined in a fuel cell to produce water and electricity. Hydrogen is safe to store; the only limit on capacity is the size of the storage tank; technology for storage is well established; and there is no waste or emissions at the end-point. The cost and efficiency of electrolysis, storage and transport of hydrogen remain barriers to cost-effectiveness; there is currently no infrastructure to support hydrogen storage at scale; and although hydrogen is safe (risks are comparable to LPG or natural gas for example), it may not be as easily accepted by the general public.

ARENA has funded a solar fuels roadmap which investigated potential pathways for hydrogen production, and currently funds some R&D in thermal conversion pathways through the Australian Solar Thermal Research Initiative.

Smart control systems

Not only is the large-scale generation of power through the electricity grid becoming more complex, the consumption of power is also changing with the introduction of small-scale energy production such as roof-top solar photo-voltaics (PV), behind the meter storage (either as batteries or thermal storage) and more advanced controls for equipment and appliances. Customers can now become producers of electricity, and the two-way flow of electrical energy on the grid needs to be managed both in a technical and financial sense.

Electricity networks need to be able to predict demand and respond with the most efficient and economical delivery. This could be through the use of virtual power stations, or micro-grids. Virtual power stations are control centres that can regulate supply and demand for an aggregation of smaller, distributed energy resources (DERs). Microgrids are discrete energy systems, usually comprising distributed generation (such as solar PV), energy storage (such as from batteries) and demand management, and provide an opportunity to prototype systems. Both virtual power stations and microgrids can be operated either independently of or in conjunction with the National Electricity Market and grid.

ARENA supports a number of such projects, including:

- CSIRO, 'Virtual power station 2' - The second generation virtual power station, able to test load, generation and energy storage coordination on a pilot scale.
- AGL Pty Ltd, 'Virtual power plant' - Interconnection of solar battery storage with residential and business rooftop solar PV, and energy management through a cloud-based control system.
- Carnegie Wave Energy, 'Garden Island microgrid project' - Construction of a microgrid comprising solar PV, battery storage and wave energy generation, and a control system to switch between independent and grid-linked operation.
- Hydro Tasmania, 'Rottnest Island water and renewable energy project' - Development of an advanced control system and dynamically controlled resistor which integrates wind and solar power generation with the island's desalination plant. Renewable energy will be used to produce clean water at times when supply exceeds demand.
- Brookfield Energy Australia, 'Delivering higher renewable penetration in new land and housing developments through off-grid microgrids' - Exploration of commercial and regulatory barriers in residential microgrids.

2. The current technological, economic, community and regulatory impediments and opportunities to achieving a modern electricity transmission and distribution network across all of Australia, and how these might be addressed and explored.

ARENA's project portfolio includes activities that facilitate greater penetration of renewable energy into the electricity grid, develop customer-focused or behind-the-meter solutions, and address knowledge gaps to help develop market rules, regulations and network practices.

Technological impediments and opportunities

ARENA plays a critical role in supporting technological progression to allow renewables to play a larger role in the electricity grid. This includes projects that improve the efficiency of renewable energy production, demonstrate the feasibility of renewables on a large scale and the integration and control of renewable energy in the existing grid, as well as completely innovative projects. Many technologies are already available, however may not be at a point of commercial readiness. Barriers to commercialisation include the cost of energy production, efficiency and grid integration. ARENA's portfolio includes ventures that aim to address these challenges, thereby increasing the penetration of renewable energy in the electricity network.

Regulatory impediments and opportunities

In addition to funding technology development, ARENA is taking a strategic approach to commercialising new technologies by helping inform the energy market through the introduction of A-lab. This is an innovative forum, designed to bring together stakeholders from research, industry and market representatives to fast-track collaborative solutions to current impediments surrounding regulation and systems relevant to renewable energy in the electricity market. The innovation frames that have so far been identified in the A-lab process are shown in Figure 1.

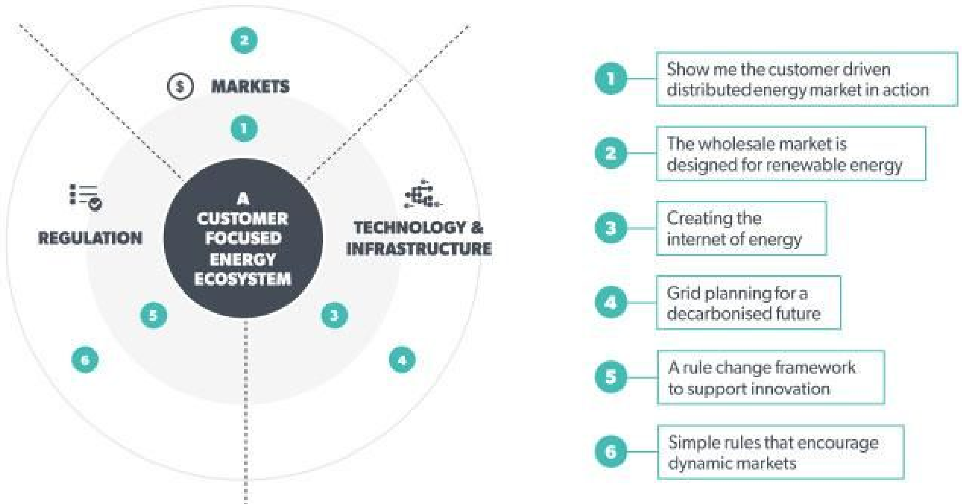

Figure 1 *The six innovation frames identified by ARENA's A-lab energy system innovation program.*

Innovation frame 1, 'show me the customer drive distributed energy market in action', has led to the decentralised energy exchange project. The initiative examines the capacity and cost effectiveness of a distributed energy trading platform, and how residential and small to medium enterprises might operate as both consumers and suppliers.

Achieving a modern electricity transmission and distribution network across all of Australia

Australia's population distribution means that for residents and industries in remote locations, connection to a centralised grid may not be the most efficient or economic practice. Off-grid solutions could instead provide access to renewable energy for electricity, displacing energy from diesel generators, which are typically used in isolated regions.

In addition to microgrids, discussed in the previous section, ARENA supports off-grid projects such as:

- Neoen, 'DeGrussa solar project' - Off-grid supply of solar energy to the DeGrussa Copper Mine.
- Lord Howe Island Board, 'Lord Howe Island hybrid renewable energy system' - Implementation of a hybrid system to provide solar PV and wind energy, battery storage and stabilisation and demand response technology.

3. International experiences and examples of electricity grid modernisation in comparable jurisdictions.

ARENA's legislative mandate focuses on the Australian domestic marketplace. As such, ARENA does not have a strong international engagement role and does not formally collect and analyse project information from overseas. This noted, A-lab stakeholders have examined international examples of electricity grid modernisation, particularly schemes to better incorporate distributed energy resources (DER). These range from ideas that involve major changes in the landscape of the current electricity grid, to more incremental proposals. A summary of these are included below.

New York

The New York Department of Public Service is implementing a program to transition towards a higher level of distributed energy resources within the New York electricity grid. A number of measures have been identified including:

- distribution planning that allows for an increased reliance on DER, accurate valuation of DER and enhanced coordination between distribution and transmission
- coordination of multi-directional power flows including enhanced load and network monitoring
- changes in market operations to include new market participants, products and services
- data access at a much more granular level that preserves customer privacy and security
- the development of key technology such as management systems, geospatial models, sensing and control, optimisation tools and a communications network to link these devices
- demonstration of business models that reliably inform consumers.

Texas

The Electric Reliability Council of Texas has investigated expanding its platform for distributed energy resource owners, particularly aggregators, to participate in the existing wholesale market, including to provide ancillary services.

Hawaii

In order to increase network stability, the Hawaii Public Utility Commission ended net metering for solar PV (where customers could use the equivalent electricity that they generate at any time), and moved to a feed in tariff (where customers are paid for the electricity that they produce in real-time at real-cost). This was combined with a generous tariff rate, and a strategy to enhance the value of the DER market, for example by incentivising the provision of grid support services.

California

The California Public Utility Commission requires the state’s utilities to develop plans for the integration of DERs, including consideration of a range of DER adoption and non-renewable decommission scenarios, criteria for optimal DER location and determination of a DER threshold.

Germany

German company Sonnenbatterie has launched a DER trading platform enabling solar PV and Sonnen battery owners to sell surplus power through a virtual grid. Access is through a monthly subscription, and as all providers own the same system, integration is straightforward.

GridWise (U.S.A.)

The Pacific Northwest National Laboratory manages GridWise, a program involving over 150 electricity market stakeholders, that was created to promote integration of DERs into the grid. Aims include exploring the potential of better data usage, identifying the requirements for enhancing data exchange, and developing steps to facilitate this. The program’s focus is on ‘transactive energy’ techniques to manage the economics and market of the existing electricity system. One trial, the Olympic Peninsula Project, measured customer’s behaviour and response to a dynamic pricing system which was dependent on the grid’s real-time load.