Review of ARENA's Reliability Portfolio

A report for the Australian Renewable Energy Agency

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Executive Summary

Progress towards achieving higher shares of renewable energy in electricity supply will bring numerous challenges and opportunities. ARENA's purpose is to accelerate Australia's shift to affordable and reliable renewable energy and so help the sector navigate changes as the sector evolves. To this end, as part of its funding strategy ARENA funds projects that help equip the sector to overcome challenges related to reliability of supply as the energy system transitions towards higher shares of renewable energy.

HoustonKemp has been commissioned to assesses the contribution of the portfolio of ARENA projects that target the sector's reliability needs and identify areas where ARENA should focus its funding efforts to target reliability needs into the future.[1]

The evaluation assesses the contribution of the portfolio of 118 projects[2] across four dimensions, namely:

- technology coverage – the extent to which the portfolio covers an appropriate range of technologies;
- innovation phase coverage – the extent to which the portfolio covers an appropriate range of innovation phases that are aligned with the timing of future reliability needs;
- reliability needs coverage – the extent to which the portfolio appropriately addresses the future reliability needs of the sector; and
- affordability impacts – the extent to which the portfolio maximises its potential contribution to improving affordability.

[1] These findings relate to the contribution of the evaluated projects to reliability outcomes. Many projects we have assessed may also contribute to other ARENA outcomes and impacts. The estimation of this contribution was outside the scope of the evaluation.

[2] The assessment considers those projects in the portfolio as at 10 July 2019.

To undertake our analysis, we allocate each of the projects within the portfolio to one of 16 project groups. These groups classify the projects based on the mechanism by which they contribute to the reliability needs of the sector and broadly align with underlying technologies.

Below we set out the key findings from our evaluation and our recommendations relating to ARENA's achievement of their reliability outcomes.

The portfolio covers all key current technologies

Our assessment of technology coverage concludes that ARENA has distributed funding across all key technology types and allocated higher levels of funding to areas of particular need and impact.

ARENA has dedicated the largest share of funding to projects focused on the coordination and integration of multiple technologies. The focus on these areas aligns with our view that technological coordination is the area of the portfolio where ARENA funding has had, and will continue to have, the largest impact on the affordability of electricity for customers.

More specifically, our findings from the assessment include:

- funding from ARENA has led to significant progress in the body of knowledge relating to distributed energy resources (DER), particularly with regards to distributed solar PV and battery storage;
- ARENA's 2017 funding round aimed at demand response has filled a previous gap in the portfolio, and the broader sector, in this area – we suggest that further funding in this area should be deferred until the findings of the current funded projects are established to inform the future direction;

- we suggest that limited further funding be dedicated to solar thermal projects above that currently committed (eg, ASTRI and Vast Solar) until findings from these projects indicate that the economic and practical challenges that previously funded projects have encountered can be overcome; and
- we suggest that ARENA consider whether the proportion of funds directed towards standalone power systems (SAPS) to contribute to reliability outcomes should be reduced in the future as challenges exist in generalising learnings from SAPS to the wider grid.

Section 4.1 provides further detail on our technology coverage assessment.

The portfolio covers all key reliability needs

To conduct the evaluation, we establish a list of the key reliability needs for the sector as variable renewable energy (VRE) penetration grows into the future – see section 2.1.3.

Our assessment of reliability needs coverage finds that the portfolio covers all key reliability needs that are within the funding mandate of ARENA. We find that the reliability needs that receive the most funding are broadly aligned with the most pressing needs of the sector, namely commercial models for renewable or enabling technologies, regulatory barriers, storage integration and firming of the output of variable renewable energy generators.

We find that the high proportion of projects that relate to interactions between project proponents and other bodies (ie, interactions with financial markets, regulators or the community) is consistent with our view that ARENA's most significant contribution to meeting future reliability needs is through coordination of stakeholders in the sector.

We find that the portfolio has a lower relative contribution towards reliability needs that arise at high proportions of renewable penetration, such as dispatchable renewable generation and inertia and system strength support.[3] While these reliability needs can be met with existing technologies, we expect there is potential scope for ARENA funding to drive further efficiencies in the deployment of new technologies to meet these needs.

Potential affordability impacts are most significant for projects aimed at coordinating existing generation and storage technologies

We find that ARENA has allocated substantial funds towards the areas with the most significant affordability impacts. It follows that we find that ARENA has allocated resources effectively within the portfolio to generate affordability impacts.

Figure E1 sets out the results of our comparison of the potential affordability impacts of each project group in the portfolio. In this figure we compare two key metrics developed for the assessment, namely:

- the potential affordability impact – a measure of the potential contribution of the project group if it achieves its potential based on three affordability impact metrics, ie, magnitude, likelihood and timing; and
- the realised group performance – an indication of the extent to which the project group has delivered on the potential affordability impact, taking into account outcomes from specific projects.

In summary, our analysis of affordability impacts finds that:

- ARENA has dedicated the largest share of funding to technological coordination projects which aligns with our view that projects in this category have had, and will continue to have, the most significant overall affordability impact;
- projects focused on coordination of large scale generation and the commercial and social aspects of distributed energy resources have large potential impacts on affordability going forward but projects in these

[3] We refer to these in the body of the report as Phase 3 needs. See section 2.1.3 for an explanation of the phases of reliability needs.

categories have faced regulatory, commercial and technical challenges that have hindered their contribution to date;

- projects that make a broad contribution to the sector as a whole (ie, ‘sector contribution’ projects) are estimated to have the smallest impact on affordability, mainly due to the small magnitudes of impact. However, the funding dedicated to these initiatives is substantially lower than for other aspects of the portfolio;

Figure E 1: Comparison of potential affordability impact and realised group performance

** Realised group performance is scaled by the potential affordability impact to provide a measure in absolute terms.*

- battery storage is likely to have the nearest term affordability impact of the technological contribution projects owing to the immediate needs met by short-duration storage – experience with the current battery storage projects indicates that further development of the body of knowledge is required in this area; and

- reducing barriers to pumped hydro storage will contribute to improving affordability in the long term – currently, significant uncertainty around future revenue streams for system security services and future treatment of losses, in addition to broader uncertainty regarding energy market and arbitrage revenues, are barriers to establishing positive pumped hydro business cases.

Barriers exist to progressing learnings in key areas

Our evaluation finds that a number of barriers exist to ARENA, and the broader sector, progressing the body of knowledge in relation to some key aspects of the reliability portfolio. These principally include:

- a current lack of markets or clear revenue streams for provision of system security and short-term regulating services;
- lack of regulations that specify the rights and responsibilities of DER owners and DNSPs relating to managing the impact of the installation of DER on the grid and real-time control of the resources;
- lack of regulations relating to information sharing and coordination amongst parties relating to satisfying requirements for grid connections;
- lack of standards to govern interactions with DNSPs when negotiating competitively procured connections; and
- challenges in establishing business cases for pumped hydro storage, solar thermal and battery storage owing to uncertainty regarding future revenue streams for provision of frequency control and system strength support, in addition to broader uncertainty regarding energy market and arbitrage revenues.

These barriers are a primary driver of gaps we have identified in our evaluation of the reliability portfolio. We identify two potential approaches from ARENA in response to these barriers, namely:

- where barriers are well understood and restrict projects from delivering meaningful outcomes, we recommend that ARENA should consider whether directing further funding to these areas is appropriate and whether funding should be deferred until the barriers have been addressed; or
- where uncertainty exists regarding the extent and nature of the barriers, ARENA funding can assist the sector in gaining further understanding of the barriers, to better enable the development of appropriate solutions to address them.

We suggest that ARENA should be cognisant of the nature of the barriers that may impact on a potential future project when making funding decisions.

The portfolio should have a continued focus on future technological developments

Through our evaluation we have identified potential future gaps in the portfolio relating to the contributions of future technologies to ARENA reliability outcomes.

Hydrogen production is an evolving area which has the potential to have very significant implications for the means by which supply reliability is provided and managed. Future reliability portfolio projects in this area may relate to: [4]

- the potential reliability contribution of hydrogen as a form of energy storage;
- the use of hydrogen as a potential fuel source for domestic dispatchable power; and
- the potential for demand smoothing through hydrogen production.

Such projects would contribute towards meeting reliability needs that are most pressing in the medium-to-long term (ie, Phase 3 needs) and so ARENA has scope to investigate more innovative approaches. We suggest that ARENA only provide limited funding to investigate these reliability-related aspects of hydrogen until more certainty exists with regards to the technological, policy and regulatory context for hydrogen production.

We also consider that alongside the development of hydrogen production, bioenergy, including biomass in electricity generation, may also see an increased role as a dispatchable source of electricity generation. We recommend that ARENA continue to consider potential opportunities in bioenergy, while also recognising that its cost profile and the challenges in producing and sourcing fuel sources on a large scale may place limits on its future uptake.

These recommendations do not relate to ARENA funding directed towards these technologies for the purpose of contributing to ARENA outcomes, other than reliability.

The portfolio should continue to support areas where further capacity building is required

The current funding under the reliability portfolio has delivered significant improvements in the knowledge base and capacity across numerous areas, however, there are areas where we consider future funding would be beneficial to continue to develop capacity in the sector.

We recommend that ARENA continue to support enabling technologies for distributed energy to help facilitate the efficient integration of distributed energy into the energy system. We find that further funding would likely continue to deliver positive affordability impacts.

In addition, we recommend that ARENA should consider funding capacity building in the pumped hydro sector. The sector is expected to experience

[4] We acknowledge that ARENA has supported the development of bioenergy and hydrogen outside of the portfolio that have a focus that is not directly related to reliability.

significant growth over coming years and so is likely to encounter capacity constraints with regards to key areas of expertise, such as community engagement.

Trials based on alternative market arrangements will help inform future market design

A final gap we have identified is in undertaking trials, particularly for large scale technologies, that are subject to pricing and market rules that would apply under an alternative market design. Such projects would examine how technologies could more effectively operate and coordinate under different system and market conditions, principally to support system security. ARENA funding could help incentivise market participants to engage in these trials by ensuring that the costs to market participants (including potential foregone revenues) are recovered. Such approaches to funding would be similar to those applied for demand response projects funded through the 2017 funding round.

1. Introduction

The Australian Renewable Energy Agency (ARENA) promotes the uptake of renewable energy through providing funding to projects that seek to improve the sector's capabilities and knowledge of renewable energy technologies and integration issues.

HoustonKemp has been commissioned by ARENA to conduct a review of the agency's Reliability Portfolio (the portfolio) of projects.[5] The portfolio comprises 118 projects that are principally funded under the 'delivering secure and reliable electricity' investment priority, or were funded for other reasons but could expected to make a contribution to ARENA's impact in this area.[6]

The purpose of the review is to assess the portfolio against two ARENA objectives, namely:

- ARENA's Reliability Focus Area Outcome, ie:

  > Innovative technologies and approaches demonstrated for operating the electricity system reliably and affordably with high shares of renewable energy

- ARENA's Performance Framework impact measure, ie:

  > Secure, reliable and affordable electricity system with a significantly higher share of renewable energy

In light of the above objectives, our evaluation assesses the portfolio based on performance across four dimensions, namely:

- technology coverage – the extent to which the portfolio covers an appropriate range of technologies;
- innovation phase coverage – the extent to which the portfolio covers an appropriate range of innovation phases that are aligned with the timing of future reliability needs;
- reliability needs coverage – the extent to which the portfolio appropriately addresses the future reliability needs of the sector; and
- affordability impacts – the extent to which the portfolio maximises its potential contribution to improving affordability.

In assessing these dimensions, the evaluation aims to:

- assess the appropriateness of the past allocation of funding across the above dimensions;
- identify gaps in the past allocation of funding; and
- make recommendations for the future allocation of funding in light of the gaps identified.

We acknowledge that ARENA is currently funded until 2022. The recommendations we make are equally applicable to another body that may exist beyond that date which performs the current functions of ARENA.

To undertake our analysis, we allocate each of the projects within the portfolio to one of 16 project groups. These groups classify the projects based on the mechanism by which they contribute to the reliability needs of the sector.

The report is structured as follows:

- section two describes the framework we apply in evaluating the portfolio;
- section three outlines the findings of our project group evaluations;
- section four outlines the findings of our portfolio evaluation; and

[5] Our evaluation is based on ARENA funded projects as at 10 July 2019.

[6] 15 projects were excluded from the evaluation. See appendix A1.18 for a list of these projects.

- section five provides a summary of the implications of our findings for ARENA’s future funding strategy.

In addition, appendix A1 provides additional detail on the underlying project group evaluations. Appendix A2 provides a comparison of the project groups and the taxonomy used by ARENA.

2. Evaluation framework

This section describes the framework we apply in evaluating ARENA's Reliability Portfolio of projects. First, we describe the key concepts relied upon in our evaluation framework. This is followed by a description of the components of the evaluation framework.

2.1 Key concepts

Our framework for evaluating the portfolio draws on a number of underlying concepts relating to technological development and innovation, reliability needs and affordability of electricity in the sector.

Based on ARENA's Reliability Objectives, we have identified four dimensions over which we assess the portfolio. These dimensions are:

- technology coverage – the extent to which the portfolio covers an appropriate range of technologies;
- innovation phase coverage – the extent to which the portfolio covers an appropriate range of innovation phases that are aligned with the timing of future reliability needs;
- reliability needs coverage – the extent to which the portfolio appropriately addresses the future reliability needs of the sector; and
- affordability impacts – the extent to which the portfolio maximises its potential contribution to improving affordability.

We describe each of these dimensions and the key concepts relating to each of these dimensions below.

2.1.1 Technology coverage

For the purposes of this report we define **fundamental technologies** as the underlying generation or storage technologies. We distinguish these from **enabling technologies** which enable the integration or coordination of, potentially multiple, fundamental technologies into the grid.

Both types of technologies work in unison to contribute to the reliability of an electricity network with a high share of renewable energy. The underlying fundamental technologies target firmed renewable generation, storage development and dispatchable renewable generation while innovation in enabling technologies will facilitate the use of these fundamental technologies to achieve a higher share of renewable energy sources.

Within the 'delivering secure and reliable electricity' strategy, ARENA articulates a desire for:[7]

> New flexible capacity and grid stability technologies (and associated business models) that could balance the electricity system with higher shares of renewable energy, ensuring electricity is available where and when it is needed.

This quote highlights ARENA's intent to develop a range of fundamental and enabling technologies that contribute to increasing the role of renewable generation in the network and to providing this high share of renewables reliably.

The extent to which ARENA has achieved this goal is determined in the technology coverage evaluation. This dimension evaluates how ARENA has distributed funds across technology types in the past and how payments

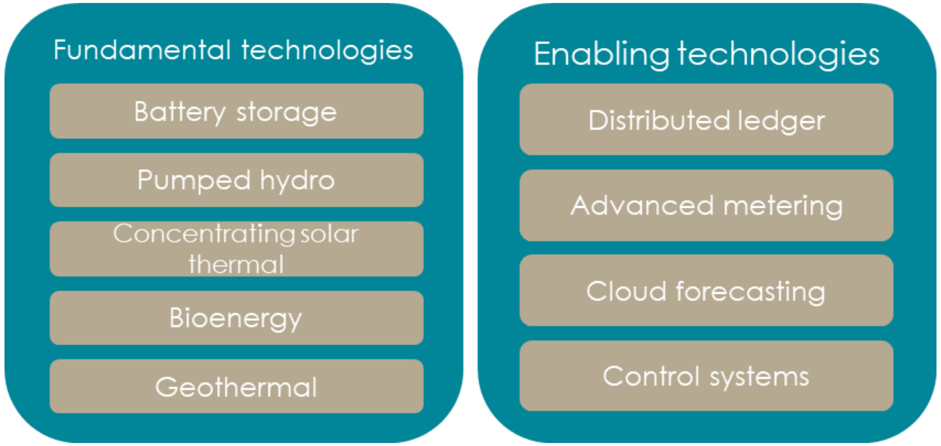
[7] ARENA, *Investment plan*, 2017, p 11.

associated with current contracts are expected to be distributed across technology types in the future. The outcome of this process is the identification of existing and emerging technologies that ARENA has under-emphasised, or potentially over-emphasised, in constructing the portfolio.

There are a wide range of fundamental and enabling technologies covered in the portfolio and that are assessed in the technology coverage evaluation, as shown in figure 2.1. Included in this assessment are considerations regarding:

- the allocation of funds across technologies;
- the role of each technology in the future of the electricity sector;
- the ability for each technology to contribute to reliability; and
- any technologies that could provide similar results but have not been included in the portfolio.

Figure 2.1: Technology types in ARENA's Reliability Portfolio



In approaching the technology coverage of the portfolio, we acknowledge that ARENA has two approaches it could adopt:

- react to funding requests and technology developments; or
- undertake proactive internal analysis to identify the technologies in which to invest.

We consider ARENA's ability to identify and encourage new technologies within this evaluation, as well as whether this approach has been successful.

2.1.2 Innovation phases and readiness for deployment

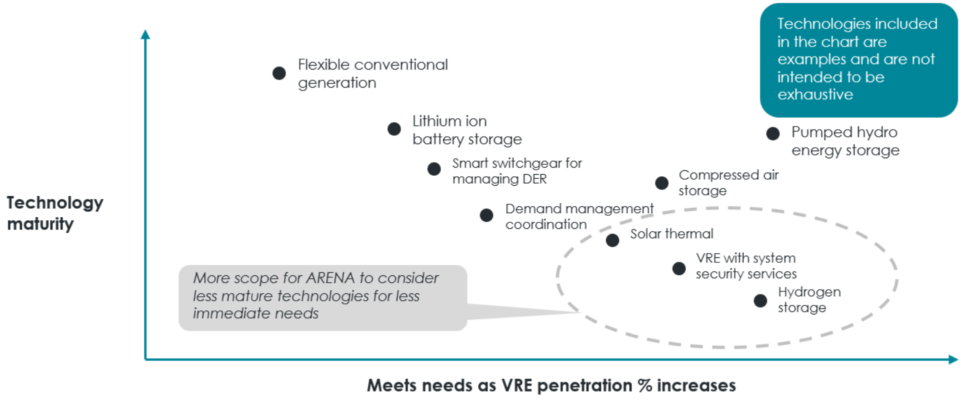
The projects in the portfolio lie across a spectrum of innovation phases, technology maturity and the extent of regulatory or commercial barriers. This gives rise to varying extents of readiness for deployment across technologies. The purpose of the innovation phase evaluation is to assess how the projects are distributed across these different maturity and innovation stages. This provides insight into whether ARENA is adequately encouraging new approaches as well as refining more mature technologies.

The electricity network experiences different issues at different levels of variable renewable energy (VRE) penetration in the network. As a result, different technologies are required at different points in time as the network supports an increasing share of renewable output.

As an example, different storage technologies remedy network issues associated with different penetration levels of VRE. Short-duration battery storage tends to be needed at lower levels of VRE penetration relative to pumped hydro energy storage which provides long term storage and dispatchable power which tends to be required at higher shares of renewable generation.

Figure 2.2 shows an illustrative example of how a particular technology solves a market need at differing shares of VRE penetration. In addition to the indicative VRE share, the figure shows the relative technology maturity of some key renewable energy technologies. A more mature technology is undergoing large-scale demonstration and deployments or even be at a full commercial stage, while less mature technologies are at the research stage or be undertaking early pilots.

Figure 2.2: Technology maturity and needs as VRE penetration grows



As in the technology coverage analysis, we make a distinction between the underlying fundamental technology and the enabling technology. In many situations an immature enabling technology or project is utilising or facilitating the coordination of multiple mature underlying technologies. In these cases, we set out this relationship in the innovation phase evaluation.

Since there is an inherent link between the type of technology and the stage at which the technology would be needed, there is scope for ARENA to explore a variety of different innovation phases within the portfolio. The innovation phase dimension is vital in understanding the temporal aspect of the portfolio evaluation and how ARENA should consider funding across the different innovation phases.

2.1.3 Reliability needs

As explained in section 2.1.2, different shares of VRE generation will give rise to different issues in the electricity market. Quite often these issues must be solved sequentially and issues that arise at lower VRE shares will inhibit the transition of the network to a higher level of VRE penetration until they have been solved.

The reliability needs evaluation identifies the issues that specifically relate to system reliability. We assume that reliability principally relates to medium-to-long term electricity adequacy, and so excludes short term, period-by-period, system security requirements.

Figure 2.3 shows the variety of reliability needs expected as the indicative share of VRE grows. We note that the exact level of VRE penetration when system conditions emerge depends on a range of factors, eg, the technology mix in the system, transmission infrastructure and resource quality.

Figure 2.3: Reliability needs as the share of VRE grows

	Phase 1	Phase 2	Phase 3
System conditions	VRE has minor to moderate impact on system operation	VRE generation determines the operation pattern of the system	VRE makes up almost all generation during some periods
Indicative average VRE %	5 - 20 per cent	20 - 60 per cent	60 + per cent
Reliability needs	• Adjustments to conventional generators to increase flexibility • Managing connection of non-synchronous generation • Testing commercial models • Adjustments to regulatory frameworks • Development of toolkits and models	• Improved forecasting ability • Resource identification and coordination • Firming of VRE output • Integrated demand response • Establishing stand-alone power systems with high renewable shares • Shorter duration storage integration	• Dispatchable renewable generation • Capacity to provide frequency control and system strength support • Supply adequacy during periods of extended low VRE output
Application to the NEM	Areas close to loads with substantial conventional generation, eg, East coast between Brisbane and Melbourne.	Areas with moderate to high penetrations of VRE and limited connection to the rest of the network, eg, South Australia, western Victoria.	Areas where high penetrations of VRE and limited connection to the rest of the network, South Australia when Heywood interconnector is down.

Our approach simplifies the sequential phases approach seen in recent publications by the International Energy Agency (IEA).[8] If the reliability needs in Phase 1 are not adequately satisfied, then incorporating further renewable generation to progress to Phase 2 will give to rise to additional costs and pose additional risks for the system.

As an example, the issues associated with connecting non-synchronous generation and intermittent energy sources to the grid should ideally be addressed at a low level of VRE penetration otherwise further integration of renewables will pose increasing system security risks.

Once these connection issues have been resolved and the share of VRE grows, the reliability needs shift towards Phase 2 needs, such as developing appropriate demand response capacity to help supports higher levels of renewable generation. Once the reliability needs from Phase 2 have been met and the penetration of VRE grows, eg, past approximately 60 per cent, renewable energy sources will have an increasing role in the providing reliability services, such as dispatchable power, that are currently served by existing conventional plants, ie, a Phase 3 need.

To undertake the reliability needs evaluation, we identify 14 distinct reliability needs we have identified as being most important as the share of VRE grows. This list of reliability needs has been developed with input from ARENA. Collectively, the identified needs are intended to cover all of the reliability issues that are currently facing the system or are likely to develop as the system integrates larger shares of renewable energy.

[8] IEA, *Getting wind and sun into the grid: A manual for policy makers*, 2017.

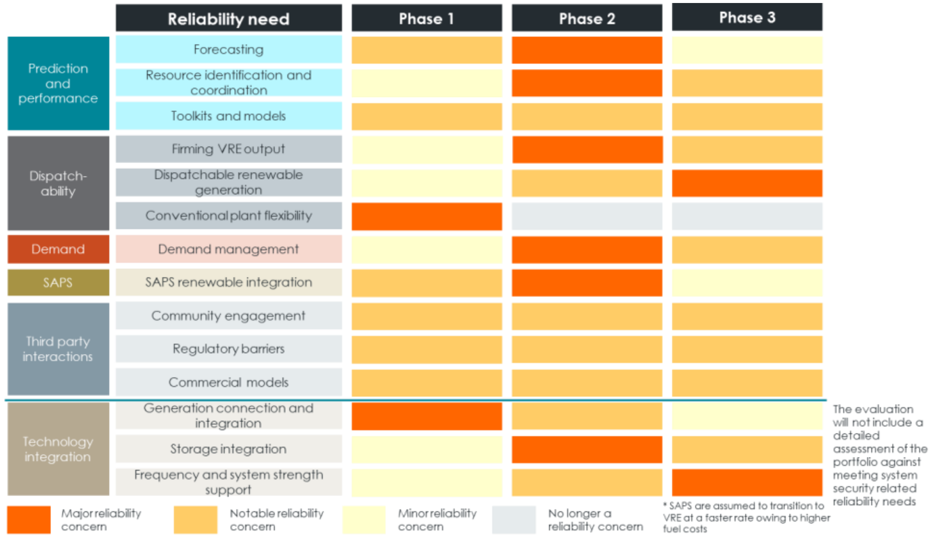
These 14 reliability needs fall into one of six broad categories:

- prediction and performance, ie, the need for improved use of information and tools to improve performance of the technologies and the system;
- dispatchability, ie, the need to understand and incorporate technologies that can provide dispatchable generation;
- demand, ie, the need to manage demand and participation of variable loads in the market;
- stand-alone power systems (SAPS), ie, the need to operate standalone power systems with higher penetrations of renewable energy;
- third party interactions, ie, the need to efficiently and effective incorporate considerations from all stakeholders in the development of the system whether they be commercial partners, regulatory bodies, or community members impacted by changes to the system, eg, through prices or development; and
- technology integration, ie, the need to manage the integration of new technologies into the system.[9]

Figure 2.4 presents the expected reliability needs that manifest as the system transitions to higher VRE penetration and the phase at which this reliability need is expected to be most pressing to the system.

[9] The evaluation does not include a detailed assessment of the portfolio against system security related needs.

Figure 2.4: Reliability needs across renewables integration phases



As figure 2.4 indicates, there are specific reliability needs associated with each category that we identify as more importance in a particular phase. By defining the reliability needs in this way, we capture the changes in reliability needs that occur as the level of VRE penetration increases.

Our reliability needs coverage evaluation is complementary to our innovation stages coverage, insofar as both evaluation approaches include a relationship with the degree of VRE penetration in the network. The results of this evaluation are then checked against the results of its technology coverage to assess whether ARENA has appropriately allocated their resources towards projects that are most likely to be needed by the electricity system.

There is a degree of diversity within the portfolio across the total amount of funding for each project. For example, the demonstration of a SAPS or microgrid requires a vastly different funding amount compared to the feasibility study of pumped hydro sites or the development of system coordination software. Ignoring this distinction between project types gives greater weight to expensive demonstration and deployment projects and lesser weight to smaller projects, such as desktop studies.

In order to capture this distinction, we group the projects into one of two types:

- demonstration and deployment; and
- other studies and R&D.

Within these two groups we then divide the projects into three tiers relative to their funding size within the group. The breakdown of this allocation is provided in table 2.1.

Projects classified as demonstration and deployment have average funding equal to $6.7 million while other studies and R&D have an average funding equal to $1.8 million.[10]

Table 2.1: Allocation of projects by type and funding

	Demonstration and deployment		Other studies and R&D		Weight
	Range	Number of projects	Range	Number of projects	
Low project value	*< $1.75m*	*16*	*< $445k*	*19*	*1*
Medium project value	*> $1.75m < $5.5m*	*16*	*> $445k < $1m*	*20*	*2*
High project value	*> $5.5m*	*15*	*> $1m*	*18*	*3*

Source: HoustonKemp analysis of ARENA data.

In evaluating the reliability needs coverage, we assign each project a weight due to its type and level of funding, as per table 2.1.

[10] The mean amount of funding is considerably larger than the median amount for both groups - $3.3m for demonstration and deployment, and $538k for other studies and R&D.

We use these adjusted project contributions to form a weighted contribution towards each reliability need. The total weighted contribution towards a reliability need is the sum of the contributions from all projects that map to that particular reliability need. This methodology is further explained in section 4.3.

2.1.4 Affordability impacts

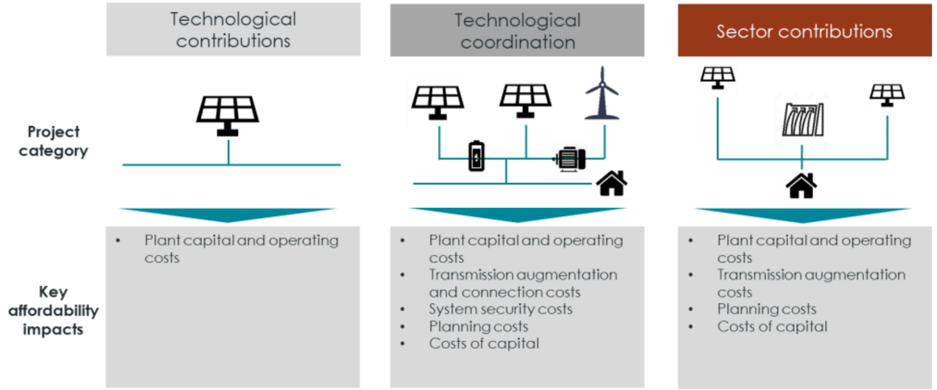
Affordability is a key aspect of ARENA's Reliability Objectives. The affordability impacts dimension of our framework involves assessing whether the portfolio as a whole will result in a significant reduction of costs associated with the generation, transmission and consumption of electricity.

We identify three main categories of projects that have a distinct impact on the affordability of electricity. These three categories are:

- technological contributions;
- technological coordination; and
- sector contributions.

Figure 2.5 describes potential affordability impacts across each of these three categories.

Figure 2.5: Affordability impacts of different project categories



Projects within the technological contributions category tend to have the impact of lowering capital and operating costs of individual plants. This is because these projects are focused on a single fundamental technology type. The expected affordability impacts from fundamental technologies result in more efficient or less costly renewable energy generation, which can directly reduce operating or capital costs respectively.

Projects within the technological coordination category tend to have a broader scope of potential impacts on affordability since these are typically hybrid, coordination or enabling technologies. Enhanced coordination results in more appropriate system planning, more efficient renewable energy connections, and greater system security.

The affordability impacts of projects within the sector contributions category tend to have a less clear impact on affordability owing to the indirect nature through which they influence specific technologies and their cost drivers. The impacts from these types of projects are very similar to those for the other categories, however they tend to be more indirect in their effects.

The use of the affordability impact dimension does not imply that the portfolio exists purely to seek affordability improvements. Rather, the dimension is utilised to explore the possibility that the cost of reliable energy provision falls due to the projects within the portfolio. Further, a quantification of any affordability impacts determines whether these cost improvements are significant or insignificant.

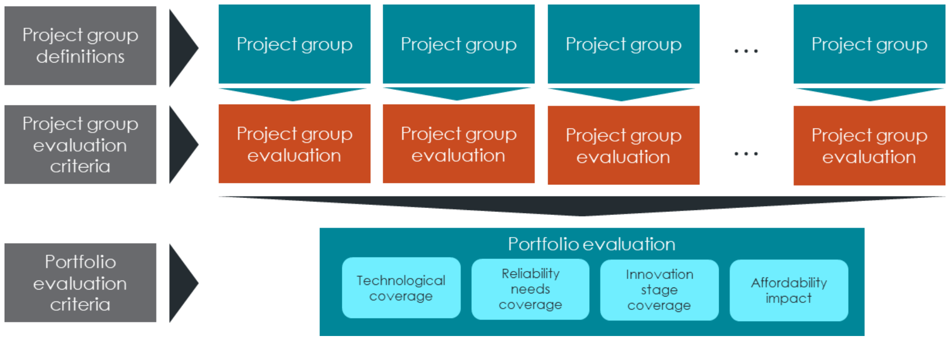
Similarly, the affordability impact dimension does not specifically place weight on the commercialisation of a project or technology as in our view, ARENA need not focus on commercialisation as a metric of success nor as an indicator for funding need. Contributions to the wider body of knowledge, adjustments to the regulatory framework or the demonstration that a commercial model is infeasible are all alternate project outcomes to commercialisation that would have positive affordability impacts.

2.2 Description of the evaluation framework

Figure 2.6 below provides a summary of the evaluation framework. The evaluation framework comprises three principal elements, namely:

- project group definitions;
- project group evaluation; and
- portfolio evaluation.

Figure 2.6: Overview of the evaluation framework



The project group definitions are a means of classifying the projects within the portfolio according to the mechanism by which they contribute to reliability needs.

The project group definitions are similar to the classification of projects applied in ARENA's internal project taxonomy. The principal difference between the two approaches is that additional sub-categorises have been added under our project definitions. See Appendix A2 for a comparison of the project groups and the classification of projects under ARENA's taxonomy.

The project group evaluation comprises a quantitative and qualitative assessment of the projects based on the characteristics, project performance, contributions to reliability needs and expected affordability impacts. The project group evaluations are undertaken by applying the project group evaluation criteria as described in section 2.2.2.

The final element of the framework is the portfolio evaluation. This entails taking the information from the evaluations of each of the project groups and considering the contributions of the group of projects as a whole. As discussed in section 2.1, we evaluate the portfolio across four dimensions, namely:

- technology coverage.
- innovation phase coverage;
- reliability needs coverage; and
- affordability impacts.

In the evaluation of each of these dimensions, we analyse both the historical and potential future contributions of the portfolio. Our analysis focuses on the identification of portfolio gaps within each of these dimensions by comparing the expected timing of reliability needs with the expected realisation of the portfolio benefits.

In the remainder of this section we provide the relevant explanatory material for the framework, including:

- the project group definitions;
- project group evaluation criteria; and
- the portfolio evaluation framework.

2.2.1 Project group definitions

In this section, we detail the approach used to develop the project groups. Figure 2.7 provides a summary of the project group definitions. We have separated the project groups into the three categories from section 2.1.4, namely:

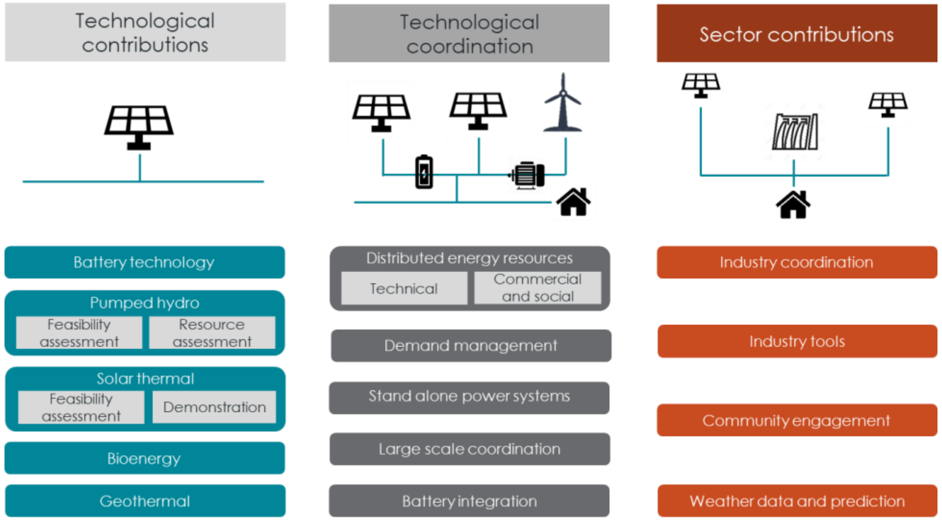
- technological contributions;
- technological coordination; and
- sector contributions.

Technological contribution projects are those that contribute to the body of knowledge relating to a specific generation or storage technology. Examples include projects that contribute to the understanding of pumped hydro resources or the feasibility of specific solar thermal projects.

Technological coordination projects are those that contribute to the body of knowledge relating to the coordination and integration of a range of technologies operating in the same system. For example, distributed energy resources, demand management and stand-alone power systems.

Sector contribution projects are those that contribute to the body of knowledge that applies to the sector as a whole. For example, financial modelling tools, frameworks for community engagement or weather prediction technologies.

Figure 2.7: Project group definitions

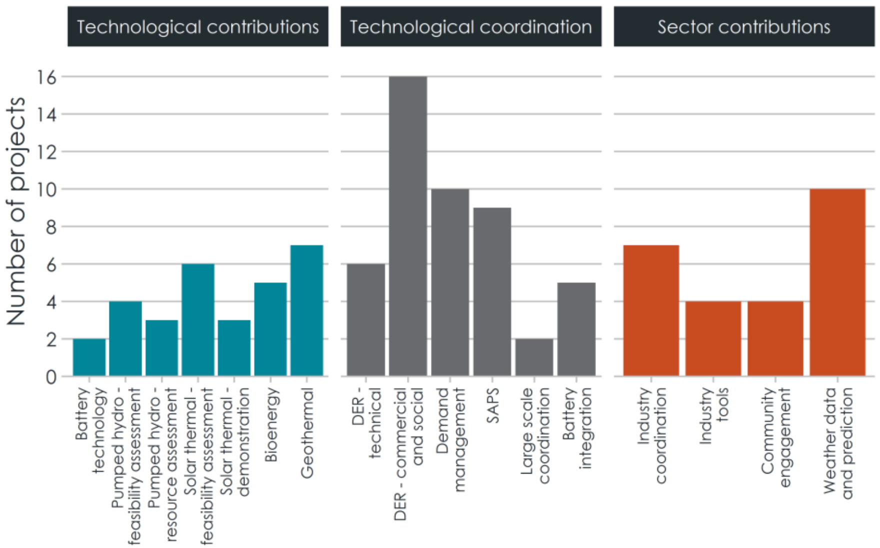


The purpose of allocating projects to project groups is twofold, ie:

- to provide a means of assessing and discussing the contribution of projects to project groups; and
- to enable the clearer consideration of the body of knowledge associated with a specific area from a more holistic perspective.

Figure 2.8 maps the classification of the portfolio into our project groups. There are 118 projects in total, of which we classify 34 projects in the technological contributions type, 43 projects in the technological coordination type, 26 projects in the sector contributions type and exclude 15 projects. See appendix A1 for full details on the projects allocated to each project group.

Figure 2.8: Portfolio breakdown by project group



Source: HoustonKemp analysis of ARENA data.

The portfolio breakdown indicates that the reliability portfolio has targeted considerably more projects with a coordination focus rather than technological or sector contributions.

2.2.2 Project group evaluation

For each of the project groups, we apply a set of quantitative and qualitative criteria to establish a view of the contribution of the project group to the reliability needs of the sector and the potential impact on affordability of the projects.

Figure 2.9 provides an overview of the project group evaluation criteria. We separate the project group evaluation criteria into four dimensions, namely:

- project description;
- technological aspects of the project;
- reliability needs contributions; and
- affordability impacts.

Figure 2.9: Overview of project group evaluation criteria

	Field	Format
Overview	High level description of group	Free text
	Current project group performance	1-5 rating + free text
Technology	What underlying technologies do the projects relate to?	Categorical (Technologies)
	Are the underlying technologies base technologies or enabling technologies?	Categorical (Base/Enabling/NA)
	What are the innovation phases of the underlying technologies?	Categorical (Innovation phase/NA)
Reliability needs	What are the key reliability needs met by the projects?	Categorical (Reliability needs)
	How do the projects contribute to meeting each reliability need?	Free text
	How well aligned are the projects innovation phases with the timing of reliability needs?	1-5 rating + free text
Affordability impact	What aspects of affordability will the projects potentially impact on?	Free text
	To what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	Free text
	What is the likelihood that the projects will impact on affordability?	1-5 rating + free text
	What is the potential magnitude of the impact on affordability?	1-5 rating + free text
	What is the timing of the potential impact on affordability?	1-5 rating + free text

The overview criteria include a high-level description of the project group and a quantitative evaluation of the current performance of the group. The current group performance is based on our view of the extent to which the project within the portfolio have achieved their potential. Projects may fall short of their potential where issues have been encountered, principally relating to regulatory or commercial barriers or project specific issues. We define the current group performance metric for each project group based on aggregation of the performance of individual projects in a group in achieving their own particular project objectives.

The technology criteria includes a classification of the project based on underlying technologies within the project group, whether the projects are fundamental technologies, ie, electricity generation or storage, or enabling technologies, ie, technologies that enable the deployment of the fundamental technologies, and the innovation phases applicable for the underlying technologies.

The reliability needs criteria of the project group includes a description of the reliability needs that the project group principally contributes to and the mechanism by which this contribution occurs. The reliability needs used in the project group evaluation are the same as those set out in section 2.1.3.

The reliability needs criteria include a quantitative rating of the extent of alignment between the project innovation phases and the timing of the reliability needs that the project contributes to. A high value for this rating reflects an alignment between the innovation phase and the timing of the reliability need. This may mean, for example:

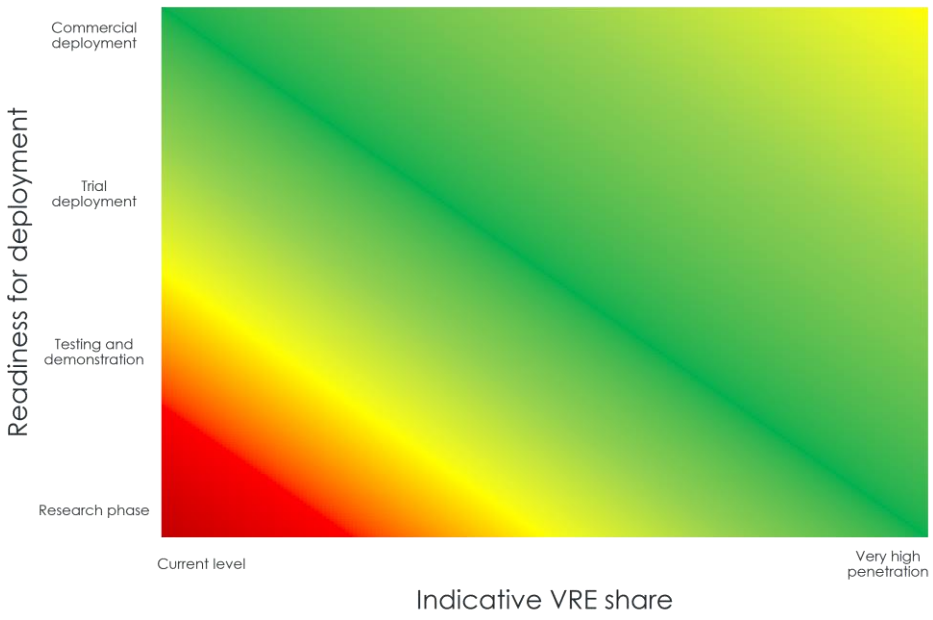
- projects that are at an early innovation phase that contribute towards reliability needs that are not pressing until the share of VRE is very high (providing time for the technology to develop); or
- projects that are at a later innovation phase that contribute towards reliability needs that are pressing in the more immediate future.

The alignment of reliability need and innovation phase indicates whether the benefits from the project group are likely to be realised at the optimal time.

Figure 2.10 below provides an illustration of this relationship. As the point of optimal implementation moves further into a future with a higher share of VRE, the maturity requirement of the technology is lessened. This is represented by the diagonal green band sloping downwards across the illustration. The red areas of figure 2.10 indicate a misalignment of the timing of the need of the technology and the innovation stage.

The dark red area towards the bottom left represents technologies for which there is an immediate need for implementation, however the technology requires significant development to be ready from commercial deployment. This implies that the technology will not be able to optimally resolve the reliability needs it is designed to satisfy.

Figure 2.10: Illustration of relationship between the share of VRE in the electricity sector, the maturity of the technology and rating of alignment



We assess the affordability impacts of the project group through the application of three quantitative evaluation criteria, namely:

- the likelihood that the project will have an impact on affordability
- the potential magnitude of the impact on affordability; and
- the timing of the potential impact on affordability.

Each criterion of the affordability impact is applied to the individual projects in the portfolio. The details of these criteria are explained below, with a description of the specific values in Box 1.

The likelihood that the project will have an impact on affordability is determined based on an assessment of:

- the expected likelihood that the reliability needs that the project contributes to will be present in the future;
- the expected likelihood that the reliability needs that the project contributes to will be not met by alternative technologies; and
- the expected likelihood of related policy initiatives, alternative funding mechanisms or market forces leading to the technology or solutions being developed without ARENA involvement.

It follows that the likelihood estimate is a measure of the *marginal* impact of ARENA's funding and not a measure of the *absolute* likelihood of the project impacting on affordability. In this sense, we identify the additional likelihood of an affordability impact as a direct result of ARENA's funding. In doing so, we consider related initiatives that will influence the impact of ARENA's funding both in terms of alternatives sources of funding and alternative technologies that may contribute to the same reliability needs.

The potential magnitude of the impact on affordability is determined based on an assessment of:

- the categories of system costs that the projects are expected to contribute to;
- the expected proportion of market participants impacted by the affordability change;
- the expected magnitude of the categories of system costs that the projects are expected to contribute to; and
- the potential change in each category of system costs that the project may have.

The timing of the potential impact is determined based on our assessment of the timeframe over which the affordability impact will be delivered. This is influenced by, for example:

- the timing for when investment in a technology that a project contributes to is expected to occur; and
- the timeframe over which the technology would need to mature before the technology could be implemented widely.

There is a general correlation between the timing of the potential impact and phases of VRE penetration. For example, projects that have an immediate timing impact would generally be targeting Phase 1 reliability needs, while projects with an impact in the longer term would generally target Phase 3 needs.

In assessing each project group, we consider each affordability impact in isolation. That is, the magnitude of impact does not take into account the likelihood or timing impacts, eg, we assess the magnitude of the affordability impact assuming that the impact has materialised at a particular point in time. In this sense, the affordability criteria are independent of each other and measure distinct aspects of the portfolio.

Box 1: Description of quantitative evaluation criteria

The project group evaluation criteria include a number of quantitative measures of the expected contribution of the projects in the groups. These quantitative measures include:

- current project group performance;
- extent of alignment of project innovation phases with timing of reliability needs;
- the likelihood that the project will have an impact on affordability;
- the potential magnitude of the impact on affordability; and
- the timing of the potential impact on affordability.

The table below provide guidance on the interpretation for the 5-point ratings assigned to each of the quantitative measures.

Measures	Ratings	Description
Current project group performance	5	The project group has achieved or is on track to achieve all project milestones or is otherwise maximising development of the body of knowledge
	4	The project group has achieved or is on track to achieve key milestones or is otherwise making a significant contribution to the body of knowledge
	3	The project group has not been able to deliver as intended on its key milestones but has made some contribution to the body of knowledge.
	2	Barriers or other impediments have had a significant impact on the contribution of the project

		group to the body of knowledge.
	1	Barriers or other impediments have prevented the project group from making any meaningful contribution to the body of knowledge.
Alignment between project innovation phases and timing of reliability needs	5	The technology will be at a mature stage and the commercial deployment will be understood when the reliability needs becomes most pressing.
	4	The technology will be approaching the stage of commercial deployment when the reliability needs becomes most pressing.
	3	There is a degree of misalignment between the innovation phase and reliability need timing, this could be due to a technology maturing too late due to delayed innovation or due to funding being directed to a technology well before the need it meets materialises.[11]
	2	The technology will be approaching full maturity yet will not have addressed the issues of commercial deployment when the reliability needs become most pressing.
	1	The technology will be under-developed, and an understanding of the commercial deployment will not be displayed when the reliability needs becomes most pressing.
Likelihood of impact on affordability	5	Projects have demonstrated positive affordability impacts in a commercial or pilot deployment due directly to involvement by ARENA. In addition, there is little to no support from other sources in

[11] ARENA has finite resources and so over-investing in a technology that solves a distant need may not be a preferable outcome where alternative projects that meet shorter term needs exist.

		this area.
	4	Projects have demonstrated positive affordability impacts in a specific or tailored deployment or trial due directly to involvement by ARENA. In addition, there is little support from other sources in this area.
	3	A degree of uncertainty exists surrounding the commercial viability despite involvement by ARENA, however new avenues and models are being developed. In addition, there is a degree of support from other sources in this area.
	2	Projects are facing significant technical issues or barriers to commercial deployment that causes reasonable doubt over the likelihood of success despite involvement by ARENA. Alternatively, there could be external support from other sources.
	1	Projects have shown an inability to impact positively on affordability during commercial deployment despite involvement by ARENA with few new avenues available. Alternatively, there could be considerable external support from other sources driving this area.
Magnitude of impact on affordability	5	The affordability impact is both large in value and relevant to a significant proportion of electricity consumers.
	4	The affordability impact is either large in value but not relevant to the majority of electricity consumers or applies a significant proportion of the network but is less significant in size.
	3	The affordability impact is less significant and does

		not apply to the majority of electricity consumers.
	2	The affordability impact is either modest in size or insignificant on a network-wide scale.
	1	The affordability impact is both modest or negligible in size and only relevant to a specific region of the network or type of electricity consumer.
Timing of impact on affordability	5	The affordability impacts are expected to be delivered immediately.
	4	The affordability impacts are expected to be delivered in the next two years.
	3	The affordability impacts are expected to be delivered in the next two to five years.
	2	The affordability impacts are expected to be delivered in the next five to ten years.
	1	The affordability impacts are expected to be delivered in over ten years' time.

2.2.3 Portfolio evaluation

The portfolio evaluation looks at the historical and future contributions of projects to establish a view of the extent to which the portfolio delivers on ARENA's reliability objectives.

The portfolio evaluation assesses the portfolio on its performance across the four evaluation dimensions, namely:

- technology coverage;
- innovation phase coverage;
- reliability needs coverage; and
- affordability impacts.

The assessment of technology coverage assesses the extent to which the portfolio covers an appropriate range of technologies. This includes considering:

- the appropriateness of the distribution of funding across technology types within the portfolio;
- the extent to which ARENA has not, to date, included technologies within the portfolio that may contribute to future reliability needs and could benefit from ARENA funding;
- the relative importance of different technology types for meeting reliability needs in the future, eg, based on expected future take-up and applicability across the sector.

The assessment of reliability needs coverage considers the appropriateness of the distribution of funding in the portfolio across reliability needs. This includes considering:

- the appropriateness of the relative levels of funding dedicated to meeting each of the reliability needs; and

- whether the distribution of funding is proportional to their relative importance of reliability needs, eg, the expected costs of meeting the reliability need.

The assessment of innovation phase coverage considers the extent to which the portfolio covers an appropriate range of innovation phases that are aligned with the timing of future reliability needs. This includes considering the degree to which:

- funding from ARENA focuses on projects that are at an appropriate innovation phase such that they will be ready for deployment when the reliability needs that they contribute to are pressing; and
- the distribution of funding covers technologies at different innovation stages to ensure a pipeline of technologies that will assist in meeting future reliability needs.

The assessment of affordability impacts considers the extent to which the portfolio maximises its potential contribution to improving affordability. This includes considering:

- the distribution of ratings of likelihood, magnitude and timing for each project group;
- how the distribution of historical funding relates to the to the opportunities for affordability impact; and
- ways in which ARENA funding could be directed to maximise the impact on affordability impacts in the future.

We undertake this assessment by developing two measures, namely:

- the potential affordability impact – a measure of the hypothetical contribution of the project group under the best-case scenario based on the three affordability impact metrics, ie, magnitude, likelihood and timing;[12] and
- the realised group performance – an indication of whether the group is expected to achieve specific goals and if these goals will be achieved at the optimal time.

Realised group performance is measured by combining the alignment of reliability need and innovation phase measure with the current group performance measure. It represents the degree to which the potential affordability impact has been achieved.

The potential affordability impact and the realised group performance should be viewed comparatively. For example:

- a project group with high potential affordability impact and low realised group performance indicates a high value area where ARENA could potential have a positive influence;
- a project group with low potential affordability impact and low realised group performance indicates an area where ARENA does not have considerable influence;
- a project group with high potential affordability impact and high realised group performance indicates a successful area of the portfolio; and
- a project group with low potential affordability impact and high realised group performance indicates a low value area where the portfolio has been successful.

Comparing these two metrics provides a quantitative assessment of the key gaps that may exist in the portfolio with regards to maximising the impact of the portfolio on affordability.

[12] The potential affordability impact is constructed irrespective of the contribution of ARENA funded projects.

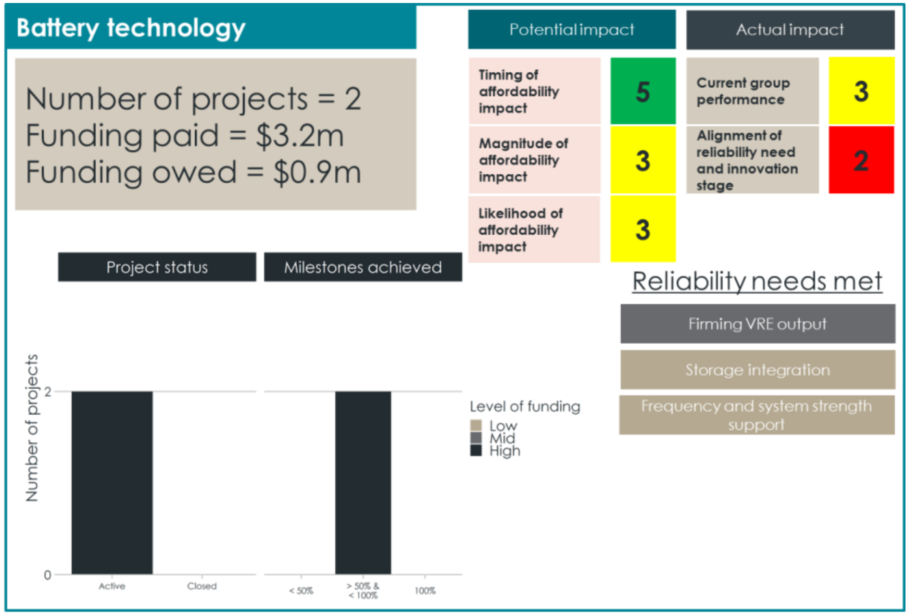
3. Project group evaluations

In this section we present a summary of the findings of the project group evaluations. We provide additional detail on the evaluations in appendix A1.

3.1 Technological contribution

3.1.1 Battery technology[13]

Figure 3.1: Summary of battery technology project group evaluation



This group contains projects aimed at improving the body of knowledge relating to battery storage technologies. Projects within this group contribute towards firming VRE output, storage integration and frequency and system strength support through improving the performance of particular battery technologies in terms of both cost effectiveness and operational performance. There are two projects within this group, both of which remain active. We anticipate that further learnings will eventuate from this group in the near term.

The results for the quantitative evaluation criteria are presented in figure 3.1. The magnitude of the potential affordability impact is not highly significant due to:

- the limited applicability of short-term duration storage technologies that are captured within this project group; and
- the uncertainty relating to the potential of these projects to impact battery technology development, which is typically sourced globally.

Battery technology has both small scale and large scale deployment options which increases the likelihood of an affordability impact. Furthermore, these affordability impacts would be felt immediately. Both large and small-scale batteries are being implemented while the technology is still improving, and the reliability need is pressing. As such, the alignment of need and innovation stage receives a low rating. This group is currently delivering a range learnings regarding the implementation and operation of new battery technologies.

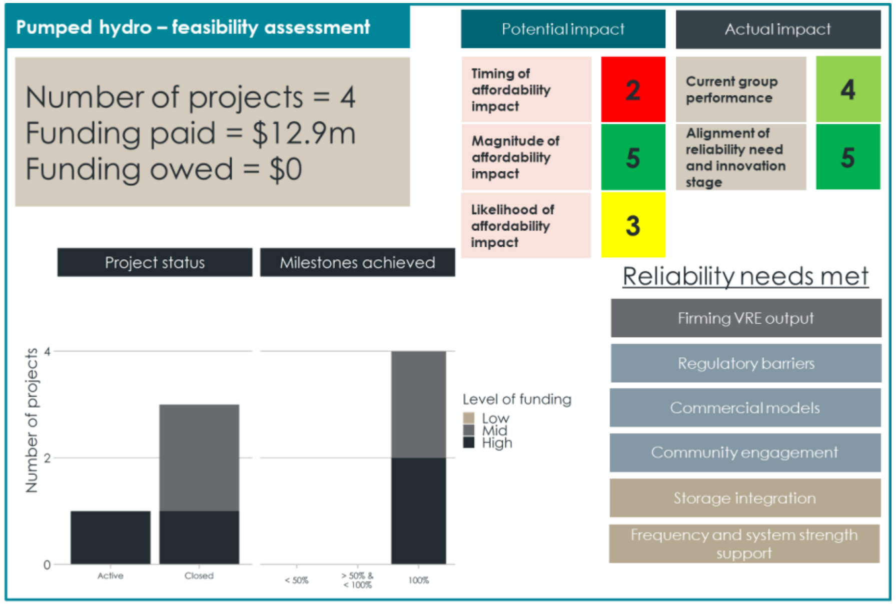
The first project involves a trial of sodium ion batteries at the Bondi sewage treatment plant. These batteries are less expensive to manufacture as sodium is more abundant than lithium, however the performance of these sodium batteries remains to be tested. The second project is the University of

[13] We included those battery storage-related projects focused on the coordination of battery storage with other technologies in Section 3.2.6.

Adelaide's mobile energy storage test facility, which has provided learnings on how new battery technology perform in behind the meter demand management tests, voltage support and peak shaving on distribution networks and in microgrids.[14]

3.1.2 Pumped hydro – feasibility assessment

Figure 3.2: Summary of pumped hydro feasibility assessment project group evaluation



This group aims to contribute to the body of knowledge surrounding the commercialisation and implementation of pumped hydro facilities. Pumped hydro is currently considered the cheapest, most mature technology to provide bulk storage,[15] however knowledge relating to the implementation and deployment of these facilities, particularly relating to social and environment concerns is relatively underdeveloped. Pumped hydro provides a viable source of long-term storage, which will firm VRE output and is able to meet the need for frequency and system strength support. These specific feasibility assessments also explore the third-party interactions associated with the commercial deployment of pumped hydro facilities.

The four projects in this group have all completed 100 per cent of their milestones, indicating that the learnings from this group have been largely established. The total funding for this group is relatively large for a group of feasibility studies. This high level of funding is being driven by the Snowy 2.0 and Kidston mine projects receiving significant funding compared to other feasibility studies in the portfolio.

The results for the quantitative evaluation criteria are presented in Figure 3.2 Pumped hydro storage will not be required until there is significant coal-fired retirement which is not expected to occur within the next 10 years.[16] Government have also committed substantial funds towards pumped hydro, which reduces the expected incremental impact that ARENA funding has on the likelihood of the affordability impact occurring.[17]

We view the magnitude of the affordability impacts as being spread across the entire network since there is no clear substitute for pumped hydro to provide long term storage, over 24 hours in duration, at this stage. There is a strong alignment of need and innovation phase since the need is pressing in the medium-to-long term and the projects are undergoing feasibility assessments which must occur well before deployment. Considering the ability for pumped hydro to provide the required long-term storage forecast by AEMO in the

[14] The University of Adelaide, *Australian Energy Storage Knowledge Bank*, (available at https://www.adelaide.edu.au/energy-storage/capabilities/, accessed 9 September 2019).

[15] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

[16] AEMO, *Integrated System Plan*, July 2018, p 7.

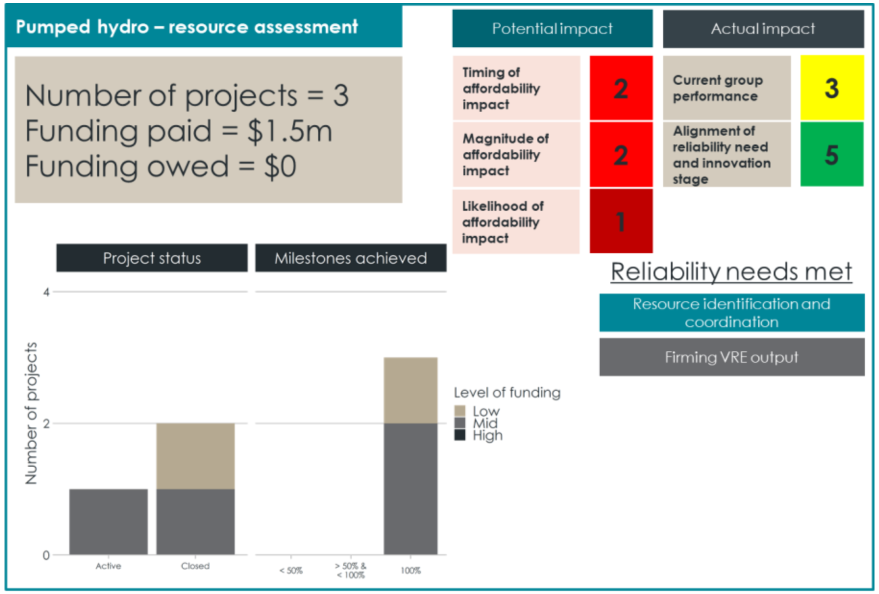
[17] See: Appendix A1.2.

future,[18] we believe that this project group could be contributing slightly more towards a highly valuable body of knowledge.

The two highest value projects in this group are the Kidston mine transformation and Snowy 2.0 feasibility studies. The learnings from the Kidston mine transformation project could be applied to a multitude of other disused mines in Queensland which could result in significant impacts across the entire state.[19] The feasibility study of Snowy 2.0 produced positive results and the project has been progressed by the NSW and Commonwealth governments. Hydro Tasmania has undertaken a series of feasibility studies, which are described in the Hydro Tasmania case studies in box 2.

3.1.3 Pumped hydro - resource assessment

Figure 3.3: Summary of pumped hydro – resource assessment project group evaluation



This project group contributes to the wider knowledge base regarding pumped hydro technology. In particular, the group focuses on identifying pumped hydro resources and the issues that may arise during pumped hydro deployment. This group focuses on the identification of pumped hydro resources and contributing to the broader knowledge base. In addition, the contribution to the body of knowledge surrounding pumped hydro from this group will aid the firming of VRE output.

All projects in this group have achieved 100 per cent of their milestones and there is no future funding allocated to this group. This implies that the learnings from this group have largely been realised and there are minimal

[18] AEMO, *Integrated System Plan*, July 2018, p 33.

[19] Genex Power Limited, *Kidston pumped storage hydro project: Knowledge sharing - ARENA*, December 2018, pp 5-6.

future developments expected in this group. Engagement with stakeholders indicated that the principle areas where ARENA could benefit the sector is through supporting capacity building around the social, environmental and technical issues relating to the development of pumped hydro facilities.

The results for the quantitative evaluation criteria are presented in figure 3.3. The rationale for the alignment and timing criteria is explained in section 3.1.2. These projects have expanded the way that pumped hydro has been viewed in Australia, however there is minimal technical or economic analysis undertaken in this group nor are the site-specific issues relating to social, environment and technical factors addressed by these projects. As such, the magnitude and likelihood of the affordability impacts are rated as low. Similarly, these projects do not directly address the principal environmental, social and economic issues with pumped hydro deployment and so receive a lower performance rating.

The two main projects are an Australia-wide resource assessment by the ANU and a Tasmanian specific assessment by Hydro Tasmania. The Australia wide atlas project identified around 2000 PHES sites in Tasmania,[20] a number which was corroborated in the Hydro Tasmania report.[21] A more detailed discussion of the Hydro Tasmania projects for PHES is provided in box 2.

Box 2: Pumped hydro energy storage – Hydro Tasmania

Hydro Tasmania identified around 2000 potential sites for pumped hydro in Tasmania through their concept study project. Hydro Tasmania has subsequently refined this list through the 'Augmenting the Tasmanian hydropower system' project and are expected to produce a list of six sites to proceed to feasibility assessment in the next phase of this project. These six sites are expected to provide an additional 3000MW of long-term storage.

The motivation for this work is twofold:

- the integration of the Tasmania system into Victoria through additional interconnector construction increases the demand for long term storage from Tasmania; and
- the pre-existing hydro energy generators in Tasmania can be easily connected to provide pumped hydro energy storage.

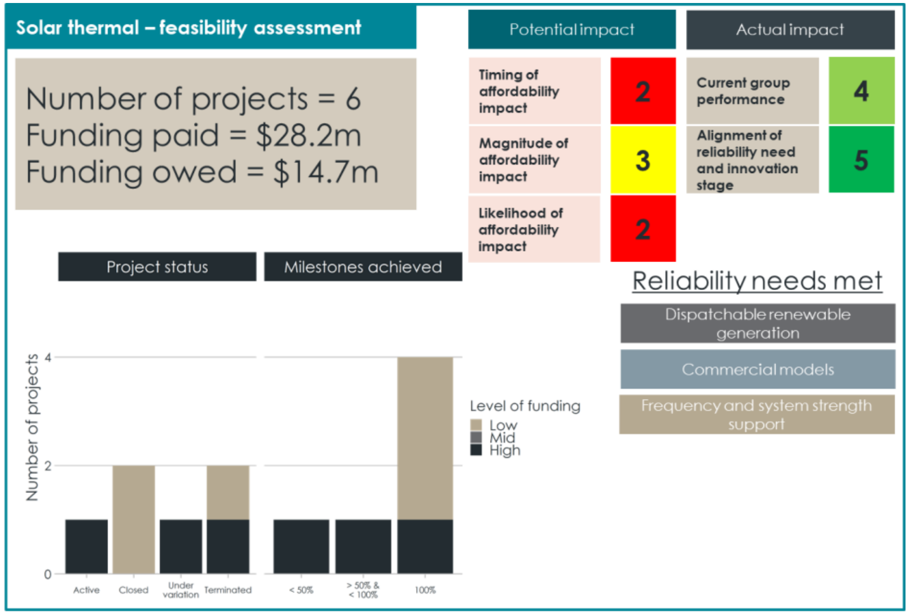
We expect that ARENA's current support of feasibility studies and knowledge sharing will aid the overcoming of barrier in site selection and the development of projects from a social and environmental standpoint. We expect ARENA to play a significant role in the future of pumped hydro energy storage.

[20] The Australian National University, *An atlas of pumped hydro resources*, September 2017, p 4.

[21] Hydro Tasmania, *Tasmanian pumped hydro in Australia's future electricity market: Concept study knowledge sharing report*, April 2018, p 23.

3.1.4 Solar thermal – feasibility assessments

Figure 3.4: Summary of solar thermal – feasibility assessment project group evaluation



Projects in this group primarily focus on assessing the feasibility of solar thermal plants at specific locations. In addition to feasibility studies and R&D, this group explores the role for solar thermal for providing a renewable energy source for high heat energy dependent industries such as mining and material processing. Concentrating Solar Thermal Power (CSTP) plants generate high temperatures and use molten salt as a heat transfer fluid, which can be used to create steam to power generators which provides a form of dispatchable renewable energy generation. The solar thermal projects in the portfolio are all aiming to improve the commercial viability of the technology.

All feasibility studies in this group have been completed, while the alumina processing project is currently under variation. The remaining funds are aimed at the Australian Solar Thermal Research Institute (ASTRI), which is focused towards the R&D side of the technology. In July 2016, a Review Panel was selected by ARENA to perform a mid-term review of ASTRI. This review recommended that attention be turned to "projects that move CSTP technology through scale-up demonstrations to deployment"[22] which aligns with other stakeholder views that the most significant learnings regarding solar thermal are likely to be obtained from the demonstration group. Since this report was released, ARENA has not commenced funding any solar thermal projects within the reliability portfolio.

The results for the quantitative evaluation criteria are presented in figure 3.4.[23] Solar thermal receives a low affordability timing rating since the technology will principally be required in the long term to provide dispatchable renewable generation. Solar thermal energy faces competition from pumped hydro energy storage and bioenergy which affects the likelihood of solar thermal having a significant impact in the future.[24] The solar thermal industry widely acknowledges the need for deep cost reductions before the technology becomes economically viable,[25] and that these cost reductions will only be achieved through "a disruptive approach to all of the components in the system".[26] Solar thermal will continue to have a low likelihood of affordability impact until these cost reductions are realised.

We understand that solar thermal will be unlikely to be viable at all points across the NEM and will be most viable for dispatchable generation in fringe-

[22] ASTRI, *ARENA Mid-term review: Review panel report*, 31 July 2016, p 4.

[23] Solar thermal has applications that extend beyond electricity generation however only the affordability impacts relating the reliability of renewable energy are considered in this evaluation.

[24] While there are other technologies that may provide dispatchable renewable generation, solar thermal has an advantage in its ability to be more scalable due to a modular plant design.

[25] ASTRI, *ASTRI Milestone 12 Report*, June 2017, p 22; and ASTRI, *Public Dissemination Report*, June 2019, p 3.

[26] ASTRI, *Public Dissemination Report*, June 2019, p 24.

of-grid locations where solar resources are of higher quality.[27] In addition, solar thermal has the greatest value in storage duration of less than 20 hours which does not provide adequate support during extended solar droughts.[28]

There is a strong alignment of need and timing since the technology is relatively immature and the reliability needs it meets are not pressing until Phase 3. Despite the termination of some projects in this group, the feasibility assessments have all provided significant learnings that improve the understanding of the role of, and market need for, solar thermal which was identified as a key issue in the ASTRI mid-term review.[29]

ASTRI recommended exploiting deployment opportunities in a limited number of fringe-of-grid or remote markets[30] however ARENA has not funded any new solar thermal projects within the reliability portfolio since this review was completed. Prior to this review, two of the location specific feasibility assessments were deemed to not be commercially viable and were terminated.[31] These terminated projects added to the technical understanding of solar thermal but proved that certain implementations of solar thermal are too risky and expensive to be commercially viable.[32] The difficulties with developing a commercial model for solar thermal in Australia arise from the limited reduction in deployment costs to date.[33] With this in mind, we acknowledge ASTRI's suggestion to explore near term opportunities for solar thermal at fringe-of-grid locations.[34] These types of projects represent "low-hanging fruit for the scalable concentrating solar thermal technology".[35] A more detailed explanation of the demonstration of solar thermal is explored in box 3.

[27] IT Power, *Inquiry into the Government's Direct Action Plan: Submission 76 – Attachment 1*, May 2012, p 154; Jeanes Holland and Associates, *Australian Concentrating Solar Thermal Roadmap*, August 2018, p 9; and ASTRI, *Public Dissemination Report*, June 2019, p 3.

[28] ITP, *Comparison of dispatchable renewable electricity options*, October 2018, p xi.

[29] ASTRI, *ARENA Mid-term review: Review panel report*, 31 July 2016, p 4.

[30] ASTRI, *ASTRI Milestone 12 Report*, June 2017, p 9; and ASTRI, *Public Dissemination Report*, June 2019, p 3.

[31] ARENA, *Port Augusta Solar Thermal Feasibility Study*, (available at https://arena.gov.au/projects/port-augusta-solar-thermal-feasibility-study/, accessed 28 May 2019); and ARENA, *Conversion of Coal to Hybrid Solar Thermal/Gas*, (available at https://arena.gov.au/projects/feasibility-study-into-conversion-of-collinsville-power-station-from-coal-to-hybrid-solar-thermalgas/, accessed 28 May 2019).

[32] These conclusions were reached in the current market context, given the degree of technology maturity. We acknowledge that the feasibility of these projects may improve in the future.

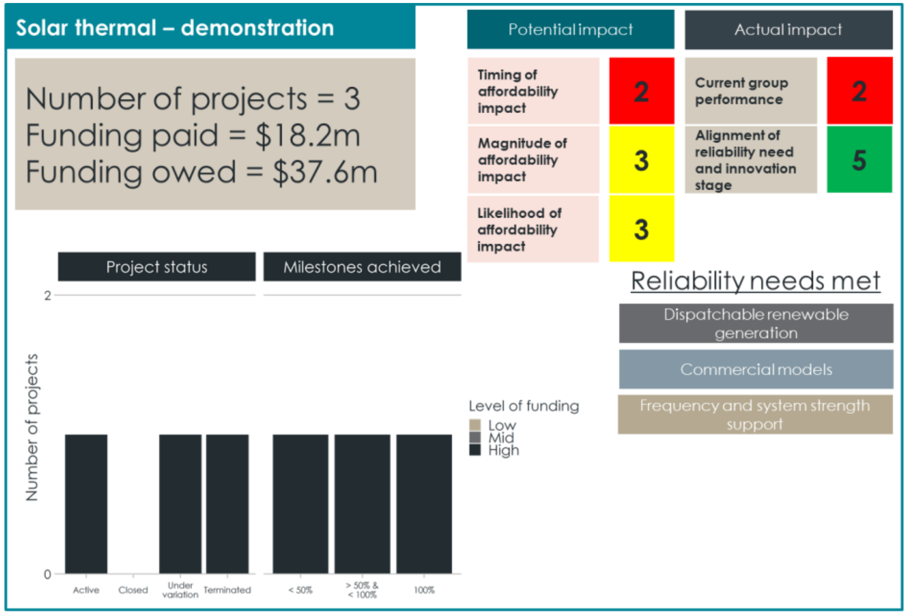
[33] ASTRI, *ASTRI Milestone 12 Report*, June 2017, p 9; and ASTRI, *Public Dissemination Report*, June 2019, p 3.

[34] ASTRI, *Public Dissemination Report*, June 2019, p 3.

[35] ASTRI, *ASTRI Milestone 12 Report*, June 2017, p 13.

3.1.5 Solar thermal – demonstration

Figure 3.5: Summary of solar thermal - demonstration project group evaluation



This group assesses the readiness for commercialisation of solar thermal technology through demonstrations of the technology. A key part of this assessment is an understanding of the financing requirements and regulatory barriers associated with the deployment of solar thermal.

This group contains two active projects, both with significant levels of funding. These projects are intended to be run sequentially. Internal conversations with ARENA have revealed a significant delay in the first project, which has not completed all milestones and remains active. Since this project has not been completed, the second project is under variation by ARENA to incorporate the updated findings and learnings from the initial project. Given the relatively early stages of both projects, we see a significant unrealised contribution to the body of knowledge from this project group. The third project in the group was terminated in March 2016 as "the solar thermal addition could not be commercially deployed without substantial further financial investment – and there was no prospect of ever getting a positive return on that investment".[36]

The results of the quantitative evaluation criteria for this group is presented in figure 3.5. The progression of the active projects indicates that there is a degree of growth in the commerciality of the technology and is reflected in the higher affordability likelihood criterion result. The development of a functioning pilot concentrating solar thermal plant has experienced significant issues and delays. It follows that the group performance is low.

The active projects in this group are both run by Vast Solar who are developing a unique, modular approach to concentrating solar thermal plants in an attempt to keep costs down and improve the commerciality of the solar thermal model. An in-depth study of these solar thermal projects is presented in box 3.

Box 3: Concentrating solar thermal power plants – Vast Solar

Solar thermal technology has been deployed commercially overseas, however, to date it has not been successfully deployed in Australia. A typical concentrating solar thermal plant consists of a formation of heliostats to direct sunlight to a receiver containing a heat transfer material that can retain high temperatures which can then be used to create steam to power generators for dispatchable energy.

The portfolio contains nine solar thermal projects, of which three have been terminated and another two are currently under variation. The key findings from the feasibility studies is that concentrating solar thermal plants face

[36] CS Energy, *Solar Boost Project*, September 2016, p 16.

excessive capital costs and costs of deployment. Vast Solar's approach has been to develop a much smaller plant to reduce the costs and risks associated with the larger designs.

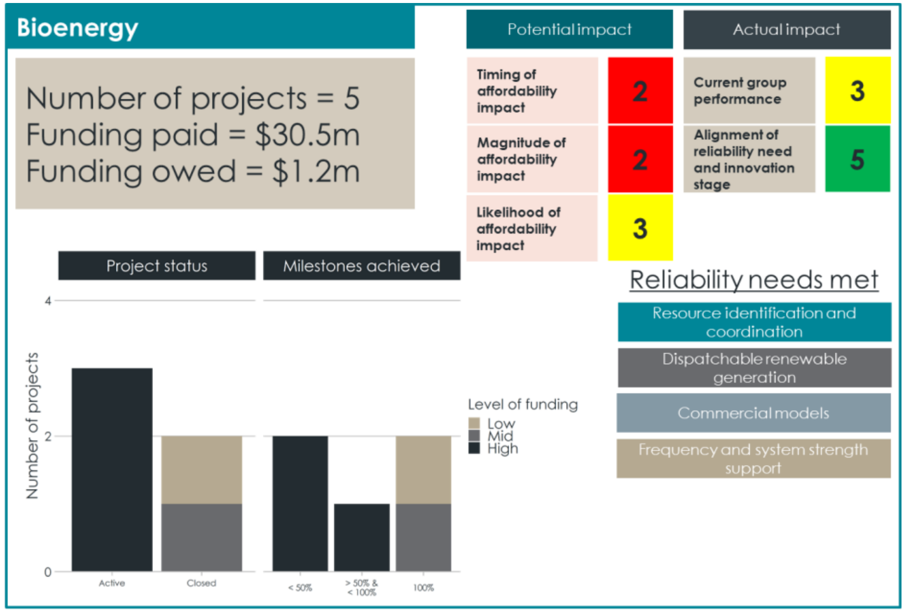
Vast Solar's approach contains two innovative dimensions: a new sodium heat transfer fluid and a flexible, modular plant design. The Vast Solar pilot concentrating solar thermal plant project contains five small plants that can be scaled up into a larger system once the technology has been proven on the small scale. This provides a more attractive approach for potential investors as the costs are lower due to the smaller size and the risks are mitigated to an extent by the reduced complexity of the system and the replicability of the modular plant.

The two demonstration projects were designed in sequence by Vast Solar. The 30MW plant at Jemalong required the successful deployment of the pilot plant, which is only recently operational after a delay of several years, before it could commence. The learnings from the delay to the pilot plant are directly applicable to the design and implementation of the larger commercial deployment. This has led to a re-scoping and re-evaluation of the initial project considering the advancements in the market since its inception.

Solar thermal can provide dispatchable renewable energy as well as a storage service. The appeal of providing dispatchable energy via concentrating solar thermal plants is due to the decrease in expected peaking revenue during daytime peaks from widespread solar PV integration. Concentrating solar thermal plants could store energy during the day and then dispatch at night, targeting the evening and morning peaks.. If Vast Solar's upcoming deployment is successful, there is potential for solar thermal to play a role in the electricity sector in the next ten years – however, the required cost improvements are significant. Even if Vast Solar is ultimately unsuccessful, the learnings from solar thermal developments overseas could be transferred here at some point in the future.

3.1.6 Bioenergy

Figure 3.6: Summary of bioenergy project group evaluation



This broad category contains projects that are quite distinct. One project compiles a central and national database of biomass resources, while another project contributed technical knowledge towards building the first full scale biomass gasifier. The three remaining projects are focused on waste to energy projects. We understand that bioenergy has a wide range of applications across the energy sector, however the projects in this group contribute to meeting specific reliability needs. The biomass gasification technology can be used to create biofuels that can be used on demand to generate dispatchable renewable energy and provide frequency and system strength support.[37] This particular project is seeking to develop a suitable commercial model for this technology. The waste-to-energy projects are also focused on providing a renewable source of dispatchable energy. The database of potential bioenergy resources contributes to the coordination and identification of Australia's bioenergy resources.

The biomass gasification project was completed in 2018, while the database project has completed just over 50 per cent of its milestones and anticipates a conclusion date in 2020. The database project has been allocated over $3m of funding, making it one of the largest desktop studies in the portfolio. Furthermore, the two active waste to energy projects have both completed less than one quarter of their milestones. Due to the infancy of the database and waste to energy projects and the plans to commercialise the completed biomass gasification technology, we anticipate significant future learnings to be generated from this group.

The results for the quantitative evaluation criteria are presented in figure 3.6. The biomass gasification and waste to energy projects specifically targets base load energy generation and frequency control, which are solving reliability needs that are not immediate. We do not assess the affordability impacts to be likely due to the issues associated with commercialising these specific technologies. Further, bioenergy may be applicable only in specific rural areas or on a smaller modular scale which results in a low magnitude of affordability impact.[38] However, since the technology is not yet commercially viable, and the need is not immediately pressing this group receives a high alignment rating. We assess that the current bioenergy group performance to be moderate, since the viability of bioenergy technology has been demonstrated, yet ARENA has not expanded this group.[39]

In addition to the Kwinana and Mt Piper projects we have evaluated, ARENA has also supported an additional 19 projects exploring waste to energy options as a source of biofuels. These projects have a combined $50 million worth of committed ARENA funds and can be expected to have contributed towards meeting the reliability needs linked to this group as seen in Figure 3.6.

The biomass gasification project is attempting to enable better links between biomass suppliers and end users. Discussions with members of the Australian bioenergy sector indicate that the Australian bioenergy industry is poorly coordinated. The bioenergy assessment project will seek to solve this issue. Further discussion of coordination issues in the bioenergy industry is contained in box 4.

Box 4 : Biomass gasification – Renergi

This project developed an advanced biomass gasification technology that converts biomass, such as agricultural waste crops, into a clean gaseous fuel that can be used to generate electricity. This project was successfully completed in 2018 and has since been attempting to commercialise the technology.

The main advantage of biomass technology is that it can be used to produce dispatchable renewable energy, whereas other renewable technologies produce on a variable basis. This highlights the opportunity for bioenergy to contribute to dispatchable generation requirements in the future.

This project has demonstrated the viability of an innovative bioenergy

[37] ARENA, *An advanced biomass gasification technology: Project results*, p 4.

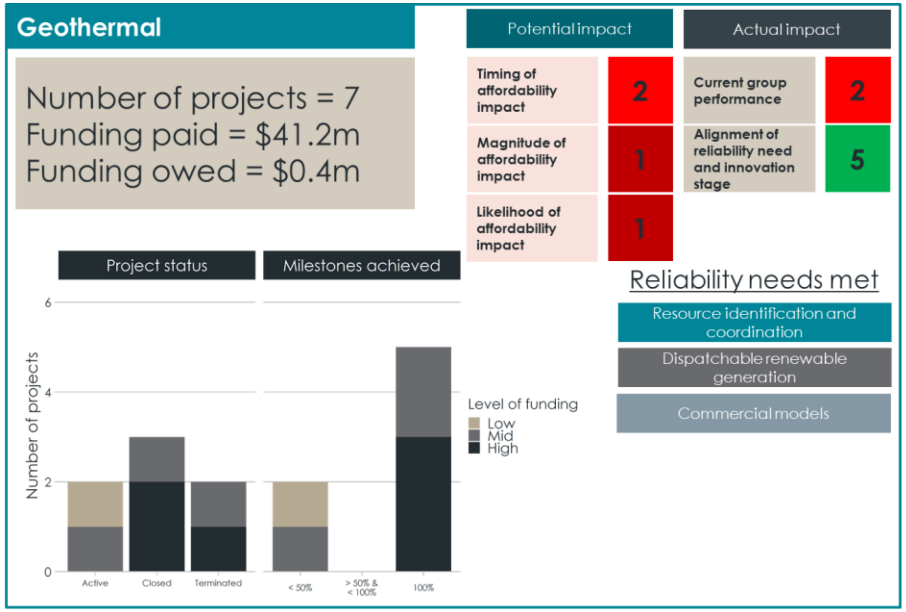
[38] The waste to energy projects have not progressed to deliver significant learnings, however positive learnings from Kwinana and Mt Piper could have a major influence on the magnitude of affordability impacts.

[39] Our analysis has not included an explicit analysis ARENA's bioenergy projects that fall outside the reliability portfolio as currently defined. See section 4.1 for more details on bioenergy projects outside of the portfolio.

technology that could be commercialised in the near future. The underlying technology is most likely to make a contribution to the generation of dispatchable renewable energy generation in rural locations.

3.1.7 Geothermal

Figure 3.7: Summary of geothermal project group



This group focuses on the identification and extraction of geothermal resources in Australia. This has occurred through large scale demonstrations, small scale commercial projects and research and development studies.

This group contains two active projects, with a small amount of funding remaining to be paid. These projects are principally focused on small scale commercial and residential applications. One project focuses on using geothermal for heating and cooling systems in new greenfield developments while the other project uses geothermal as part of a net zero energy facility. Two projects in this group were terminated by mutual agreement of the proponents after the lack of financial benefit became evident. These terminated projects have contributed to the knowledge of the challenges surrounding geothermal technology. These challenges principally include identifying suitable resources, extracting the geothermal resources and overcoming capital and transmission costs. The key findings from this group have revolved around the approach to resource identification prior to drilling,[40] which suggests that geothermal technology is a long way from test and pilot demonstrations.

The results of the quantitative evaluation criteria for this group is presented in figure 3.7. Geothermal receives a low affordability timing rating since the technology will only be required in the long term to provide dispatchable renewable generation. There has been a distinct lack of successful trials and deployment of geothermal technology and a relatively modest understanding of the market need for geothermal contribute to a low likelihood of impact.

We predict that geothermal may not be viable at all points across the NEM due to the transmission costs required for the remote generation location,[41] which reduces the magnitude of the affordability impact.

There is a strong alignment of need and timing since the technology is immature, yet the reliability needs it meets are not pressing until Phase 3.

Despite some promising active projects, there have been multiple terminations of large scale projects in this group. In addition, the learnings of successfully completed projects have been targeted at the exploration of resources prior to drilling. As a result, we assign a low current group performance result.

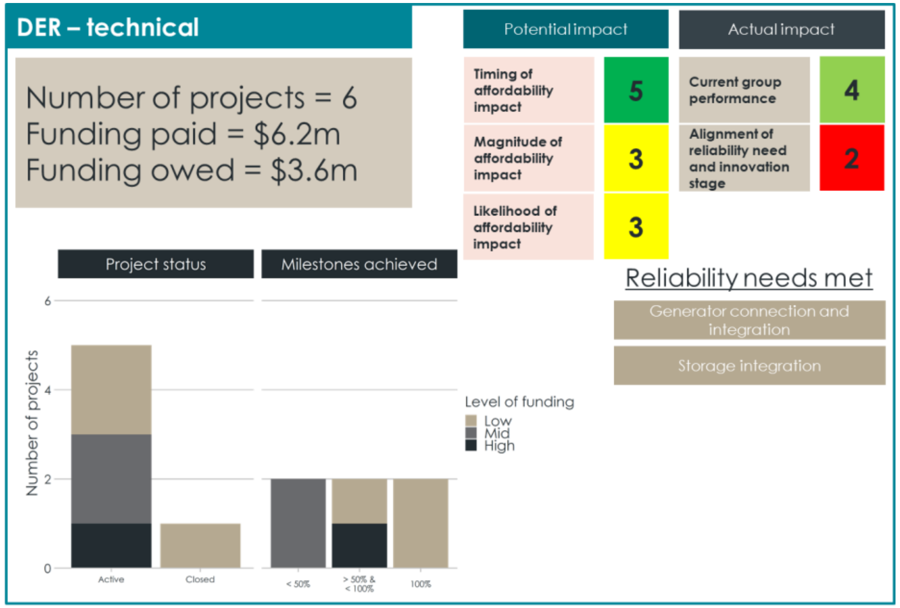
[40] NICTA, *Data fusion and machine learning for geothermal target exploration and characterisation*, June 2014, p 5; Institute for Mineral and Energy Resources, *ARENA Measure: Reservoir quality in sedimentary geothermal resources*, December 2014, p 2; and ARENA, *ARENA structural permeability map project: project results and lessons learnt*, March 2018, p 6

[41] There are two active projects that may make the technology more viable in residential and commercial areas, but they have not provided any learnings as of yet.

3.2 Technological coordination

3.2.1 DER – technical

Figure 3.8: Summary of DER - technical project group evaluation



These projects focus on the technical development of new distributed energy resources (DER), which are behind the meter technologies such as solar PV and batteries. The technical side of DER is focused on integrating small scale generators and storage devices into the wider grid, as well as developing devices for monitoring and controlling other consumer assets. As such, this project group meets the reliability needs associated with generator connection and integration and storage integration.

This project group has two clear groupings: early active projects with relatively larger allocated funds, and projects at or nearing closure with significantly less funding. This indicates recent growth in this area of the portfolio. We anticipate a substantial amount of future learnings to come from this group which will build upon the current body of knowledge in this area.

The results for the quantitative evaluation criteria are presented in figure 3.8. The recent increase in rooftop solar and household batteries has led to an immediate need for DER. Given that there are other DER projects already at the stage of commercial deployment, the marginal increase in likelihood due to ARENA's funding is lower than seen for those commercial deployment projects. In the DER space, the affordability benefits associated with overcoming technical issues are not as significant as those associated with overcoming the coordination and commerciality issues. Considering there is a large proportion of active projects in this area the learnings from these projects are current being realised. We believe that the adjustments and improvements from these learnings should ideally be implemented in the current market. As such, this group is slightly delayed in alleviating the immediate reliability needs it aims to solve. Further, given the limitations of this group, the relative success of these new technologies indicates that the current performance is reasonably high.

The key projects in this group contribute to new technology developments in the DER space. For example, this group provides the demonstration of smart inverters and switchgear technology and a network analysis computer program that increases network visibility. These projects have focused on the technical advancement of DER rather than addressing the regulatory barriers or commercial models relating to these technologies. The United Energy residential solar and storage project indicates that DER technology can have significant impacts on reducing network augmentation costs.[42] Box 6 presents a discussion of the NOJA intelligent switchgear technology developed within the portfolio.

Box 5: Intelligent Switchgear – NOJA Power

The technology being developed in this project is a smart switchgear device that monitors energy flows and captures high resolution, real time network data. A total of 100 units will be provided to two local DNSPs. This data is shared with ARENA, AEMO, DNSPs and university partners to provide higher network visibility and provide better network management. Due to the range of potential beneficiaries of the data produced by this device the project is a unique collaboration between a variety of stakeholders.

This technology will impact reliability by allowing system operators to observe real time fluctuations in the output of renewable energy generators and assess the risk from accepting power from a particular generator. A recent American study has shown that implementing switchgear technology of this type can enable the network operator to reduce up to 10 per cent of reliability problems. This results in a significant decrease in customer outage rates. Ultimately, the device will reduce the connection costs of renewable energy generators and facilitate further integration of intermittent renewable energy generation into the grid.

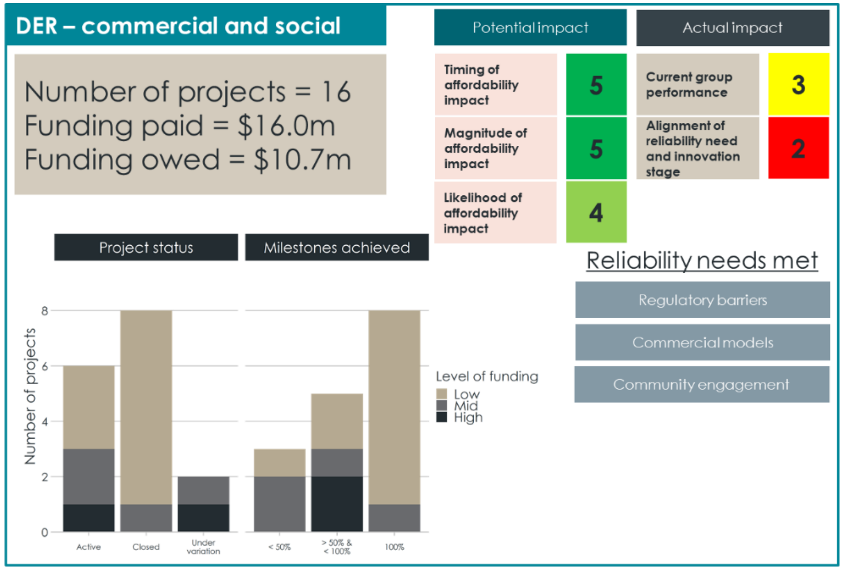
Representatives from NOJA Power feel that the project has been a success thus far, however there are concerns about possible delays in the installation phase due to storms and bushfires. NOJA cite the lack of a standard regulatory approach across the states as a key inhibitor to the connection of mid-scale renewables energy generators to the grid.

The switchgear device is not replacing a substantial gap in the system, it is improving on existing approaches in the DER realm. NOJA Power launched this project in response to a request from ARENA for improved technology to address connectivity issues facing renewables. We view this project as a successful example of ARENA's ability to identify the technologies and needs in which to invest.

[42] United Energy, *ARENA Knowledge Sharing Plan – Residential Solar and Storage Program Interim Report*, February 2018, p 12.

3.2.2 DER – commercial and social

Figure 3.9: Summary of DER – commercial and social project group evaluation



Projects in this group do not focus on developing new DER technologies, but rather on how these established technologies can be appropriately integrated into the network. As such, this group contains a number of trials and deployments that attempt to resolve the issues surrounding third party interactions of DER technology implementation.

A large number of projects in this group have completed 100 per cent of their milestones, however the projects that remain active have a significant amount of funding still to be received. The projects that are yet to be completed include virtual power plant (VPP) trials by AGL and Simply Energy, which we believe can contribute substantially to the learnings around DER implementation. As a result, the potential learnings from this group are expected to be significant in the near future.

The results for the quantitative evaluation criteria are presented in figure 3.9. We view ARENA's contribution in this area as having a significant impact on the likelihood of DER having a positive affordability impact. However, there are still considerable regulatory barriers to the commercial deployment of these resources that may be out of ARENA's control. In particular, there is immediate need for distribution networks to handle the increasing amount of two-way interactions from consumers on the grid. We see little evidence to suggest that existing projects in this group have met the current needs for DER, which drives our assignment of a relatively poor alignment rating. We view the 'DER – commercial and social' group as having had a relatively weak performance against the potential impacts on account of the regulatory issues surrounding the rights and obligations of DER market participants that have prohibited the successful commercialisation of these projects.

Key areas of this group involve embedded networks, smart-grids and peer-to-peer trading. The results from Enwave embedded network suggest that a hybrid cooperative/investor model known as a multi-user local ownership model is a viable approach in this scenario.[43] The Alkimos Beach smart-grid has provided cost savings for almost all users of their community battery.[44] The trial deployment of automated DER control on Bruny Island saw a reduction of diesel requirements by one third over the trial period.[45] The deX project developed an online platform for peer-to-peer (P2P) trading that is reaching commercial viability while AGL's P2P trial indicated that P2P trading has economic benefits for consumers and prosumers.[46] Box 6 and box 7 present in-depth discussions of key DER projects.

[43] Brookfield, *Delivering higher renewable penetration in new land and housing developments through edge-of-grid microgrids*, May 2016, p 13.

[44] Synergy, *Alkimos Beach energy trial*, (available at https://www.synergy.net.au/Our-energy/Future-energy/Alkimos-Beach-Energy-Storage-Trial, accessed 28 May 2019).

[45] CONSORT, *Project Final Report: Network-Aware Coordination (NAC)*, April 2019, p3.

[46] AGL, *Peer-to-peer distributed ledger technology assessment*, October 2017, p 9.

Box 6: Distributed energy exchange – deX and GreenSync

deX is a digital platform that enables widespread connection of DER to provide system and network operators greater visibility of the location, performance and technical ability of these devices on the low voltage network, then provides tools to adjust DER behaviour or contract them for services at critical times.

In addition, the exchange allows new marketplaces for energy services to operate. It's not designed as a market itself, rather it provides the tools and software platform on which new markets for DER energy services can operate.

The initial project funding by ARENA was vital in propelling the project from an idea to a commercial product. Without this funding, deX would not be a globally competitive platform with demonstrated application benefits both in Australia and abroad. In Australia, deX has been deployed by Simply Energy in its VPPx project and utilised by SAPN to increase visibility over DER exchanges. The platform is designed as, a complement to other innovations and technologies, rather than a competitor or inhibitor.

The immediate focus and application for deX in Australia is two-fold; it stops DER exacerbate problems with grid reliability, and at the same time provides a pathway for DER (customer and business owned) to contribute to the solution.

The exchange can be utilised in conjunction with VPPs or other aggregation platforms and can help unlock the full potential of household renewable assets - both for the grid operators and end customers. Representatives from GreenSync identified flexible and decentralised electricity markets as a significant future need and see deX as a key component to achieve a reliable, affordable two-way transactive electricity market.

While there are still issues to be resolved in this area given current regulatory frameworks, GreenSync is providing a unique and immediate solution that supports the industry to navigate them in the context of maintaining reliability, market competition and customer choice..

Box 7: Alkimos Beach - Synergy

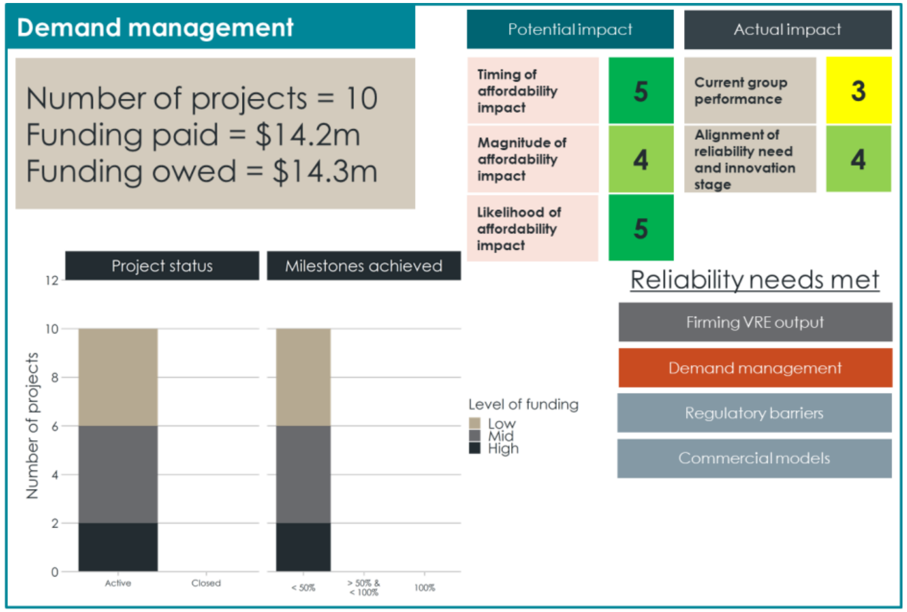
The Alkimos Beach project was designed to develop, deploy and test multiple new energy retail models. The project is based at a new residential development site that combines a community scale battery storage device, high penetration rooftop solar PV and energy management devices. The battery device was commissioned in 2016, and since this date Synergy have reported very little roadblocks in this project.

The aims of this project were to develop a new retail model around a time-of-use pricing approach, explore the network issues around large scale battery connection and to generate data to further develop other retail models. Representatives from Synergy expressed a belief that these objectives have been met.

Moving forward, Synergy are considering alternate uses of the community battery in line with the original objectives of the trial, optimising value to Synergy and its customers, property developers and network infrastructure. The learnings from Alkimos Beach are being used by Synergy in the Meadow Springs PowerBank trial.

3.2.3 Demand management

Figure 3.10: Summary of demand management project group evaluation



The demand management group is focused on the development of new and innovative technologies to provide demand response options for consumers and prosumers. This enables more penetration of renewables, ie, firms VRE output, by adapting demand management systems to new solar PV connections and output. There is also an emphasis on developing approaches and models to ensuring effective demand response across the grid.

This group consists entirely of early active projects that are slightly higher than average in terms of the amount of funding from ARENA. Less than half of the allocated funds have been paid and since all projects have achieved less than 50 per cent of the milestones, we expect considerable and sustained learnings to be produced from this group in future years.

The results for the quantitative evaluation criteria are presented in figure 3.10. Addressing peak demand reduction is a reliability need that is currently an issue, so any affordability impacts would be immediate. The demand response group has already demonstrated an ability to control peak demand and hence will have an affordability impact.[47] Since demand response technology is only utilised during rare peak events these affordability impacts are not realised on a regular basis which reduces the magnitude of the affordability impact.

Despite the demonstration of positive results, these projects are not sufficiently refined in order to appropriately meet the immediate reliability need which impacts our judgement of the alignment criterion. The projects in this group are currently quite early in their development, meaning that there are few indicators to accurately measure the performance of this group. With this in mind, we assess that the demand management group has historically performed well, despite the considerable amount of work that remains to be performed in this group.

The demand response group contains a range of approaches to address peak demand issues. Some of these projects have already demonstrated substantial demand response capability: including 12 MW from United Energy;[48] 5MW from Flow Power;[49] and 10 MW from Intercast and Forge.[50] There are also multiple projects that increase the reach of AEMO's reliability and reserve trader (RERT) system to large and small scale consumers.

[47] See: Appendix A1.10.

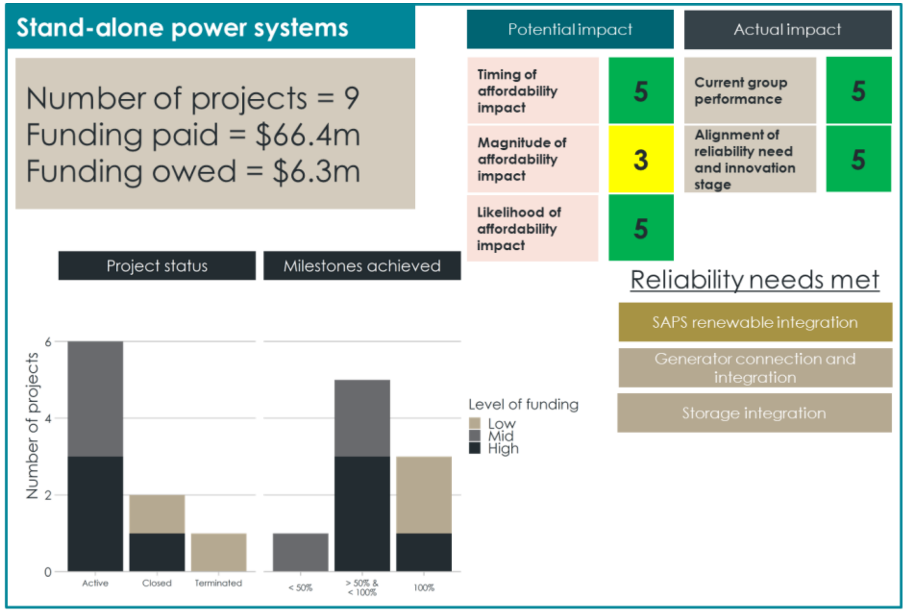
[48] United Energy, *Demand response project performance report – Milestone 3*, June 2018, p 5.

[49] Flow Power, *Project performance report – Energy under control*, November 2018, p 4.

[50] Australian Financial Review, *Powershop, United Energy, metal foundry sign up for demand response trial*, 11 October 2017 (available at https://www.afr.com/business/energy/electricity/powershop-united-energy-metal-foundry-sign-up-for-demand-response-trial-20171011-gyydxu, accessed 28 May 2019).

3.2.4 Stand-alone power systems

Figure 3.11: Summary of stand-alone power systems project group evaluation



Stand-alone power systems (SAPS) utilise and combine multiple well-established renewable energy sources with innovative hybrid, storage and enabling technologies. SAPS enable increased renewable contribution whilst maintaining the same level of renewable penetration by shifting the load to be in line with the renewable output, which requires adequate storage integration. In this sense, the SAPS project group meets the growing need for generator connection and integration and storage integration as these systems increase their renewables share.

This group has received a considerable amount of funding and the majority of projects in the group are active and have achieved over 50 per cent of their milestones. This indicates that the learnings from the group are relatively well documented and these demonstrative projects are advanced compared to other groups.

It is important to note that one of the closed projects is the King Island hybrid system by Hydro Tasmania was a significant project in this field and has provided a repeatable template for further SAPS deployments. The King Island project has provided a wealth of knowledge and we expect the remaining SAPS projects to use this knowledge in their specific applications rather than contribute to a body of knowledge that may be applicable to the wider grid. As such, we view limited ability for the SAPS group to provide tangible benefits to a wide range of network participants.

The results for the quantitative evaluation criteria are presented in figure 3.11. The reliability needs surrounding SAPS are currently of importance and the affordability impacts will be experienced in specific locations immediately. However, benefits will only be realised by individuals in fringe-of-grid locations,[51] which is a relatively small proportion of the network. There are a number of projects which have been successfully implemented, indicating that the likelihood of affordability impacts is high. Considering the immediacy of the needs and the advanced stages of deployment of certain projects we consider there to be a strong alignment of reliability need and affordability timing. Further, the number of projects, their level of funding and amount of tangible learnings from this group indicate a strong performance towards meeting reliability needs.

A key outcome of many projects in this group is the reduced dependence on diesel generation in fringe-of-grid locations.[52] Hydro Tasmania has led many projects in the SAPS area, including the highly successful King Island project. The King Island hybrid system is able to run solely on renewables when

[51] ARENA, *Stand-alone power systems review issues paper*, October 2018, p 2.

[52] ARENA, *Stand-alone power systems review issues paper*, October 2018, p 2.

weather conditions permit, and this approach has been repeated by Hydro Tasmania in their Rottnest Island and Flinders Island hybrid systems. Some of the more innovative hybrid systems are incorporating water desalination as a use for excess renewable energy generation. Carnegie energy is also attempting to harness wave energy in the Garden Island hybrid system.

Box 8: Stand-alone power systems – Hydro Tasmania

Hydro Tasmania has undertaken a number of projects that have accelerated the development of SAPS that operate with high shares of renewable energy generation. ARENA has supported projects on King Island, Flinders Island and Rottnest Island as part of its reliability portfolio and has produced a variety of commercial, social and technical learnings with regard to renewable generation in off-grid environments.

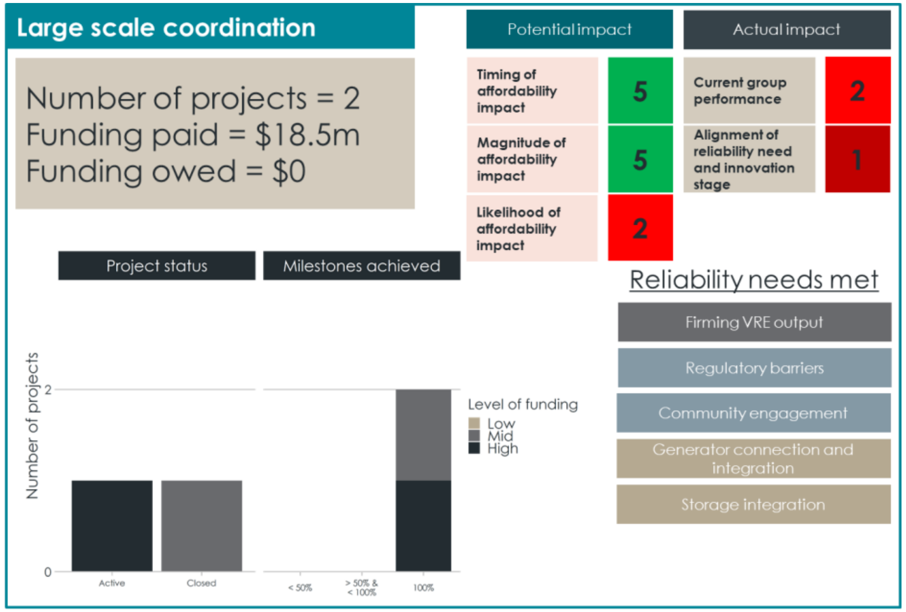
The key learnings from these projects have related to:

- models for community battery ownership;
- coordinating high penetration solar system;
- microgrid distributed control; and demand response of individual assets.

Hydro Tasmania have introduced new and innovative techniques to enhance the coordination of these systems. The advantage of initially implementing these techniques in a SAPS is that the proponent is able to see trends much more quickly in a SAPS setting than in the rest of the grid. In this sense, Hydro Tasmania's work on SAPS may have some application to the wider NEM as the indicative share of VRE in the network grows.

3.2.5 Large scale coordination

Figure 3.12: Summary of large scale coordination project group evaluation



We define projects in this group to be those concerned with the coordination of multiple renewable energy generators in the form of renewable energy hubs. These hubs focus on the connection issues of renewable generators and storage as well as the regulatory issues surrounding the way in which this grid connection occurs.

The two projects in this group have both completed 100 per cent of their milestones. The Kennedy Energy Park project remains active as the proponents have not managed to settle on an agreement with the local network service provider to power the park. Kennedy Energy Park is one of the largest projects in the portfolio by funding size, with a total of $18m paid by ARENA.

The results for the quantitative evaluation criteria are presented in figure 3.12. Efficient connection and management of large scale renewable generation has the potential to have an immediate, significant and likely impact on the affordability of the transition to renewable energy. The lessons learned from these renewable energy hubs indicate significant regulatory hurdles outside of ARENA's control are restricting the deployment of these projects. [53] Until these projects begin to operate, there is limited ability to obtain learnings about the practical operation of renewable energy hubs. This severely hinders the likelihood of realizing affordability benefits. These barriers are a material hinderance to the performance of this group and result in a very low rating. Since the reliability needs are pressing now and there are barriers to successful deployment, this group scores poorly on the alignment criterion.

The two projects in this group highlighted the regulatory issues preventing the widespread deployment of renewable energy hubs. While there have been positive steps taken regarding the ideal mix of renewable generation and integration of storage options at potential hubs, the issues of negotiating an agreement regarding the grid connection of these hubs remain. An in-depth look at the issues facing the Kennedy Energy Park is provided in box 9.

Box 9: Kennedy Energy Park - WindLab

Kennedy Energy Park is a renewable energy hub in North Queensland that combines wind, solar and large scale storage. A key feature of this project is that the two intermittent generation sources (wind and solar) are strongly negatively correlated, ie, solar energy is generated during the day and wind energy is generated during the night. This results in low curtailment and a less volatile output profile.

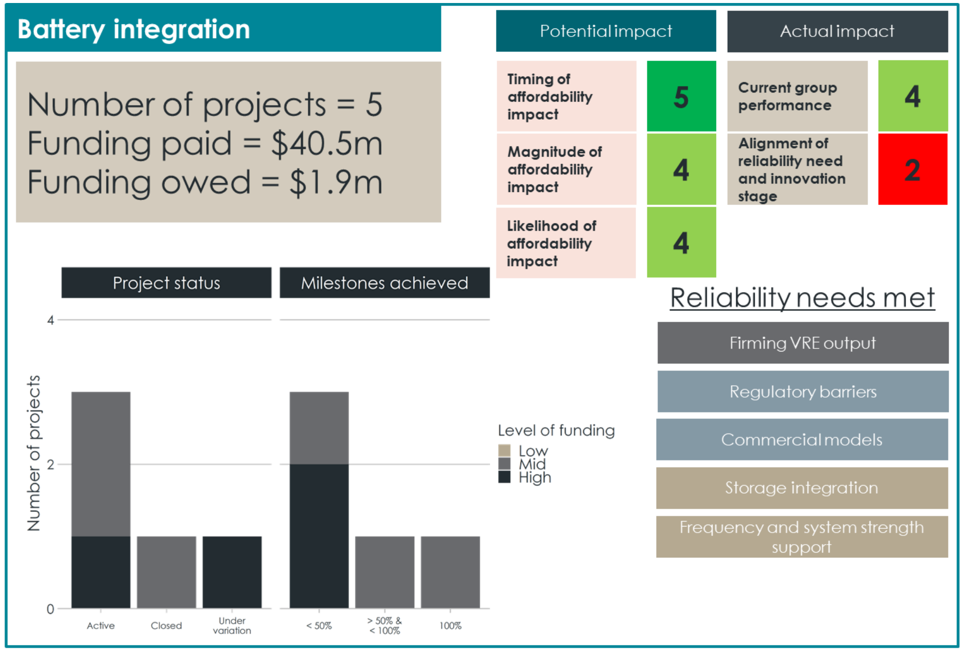
The project reached financial close in October 2017 and was expected to be operational in October 2018. During the construction of the project there has been significant delays in the grid connection. The park is constructed and mechanically complete, however, has not been able to connect to the grid as at July 2019. Until this issue is resolved, and the park becomes commercially operational, no demonstrative learnings can be drawn from this project. This hold-up exemplifies some of the issues facing these renewable energy hubs.

Many of the issues experienced by Windlab are outside of the direct influence of ARENA and the project proponents and may not be completely solved by the projects currently in this portfolio alone. Until these barriers are removed, there may be little impact from this section of the portfolio.

[53] TransGrid, *Renewable energy hub knowledge sharing report*, June 2016, p 3.

3.2.6 Battery integration

Figure 3.13: Summary of battery integration project group evaluation



This group contains projects that examine the role of medium-to-large scale battery storage as more renewable energy is integrated into the electricity network. Storage integration will contribute towards firming VRE output, provide variable load benefits and can provide ancillary services and, to an extent, other system security services. These projects are particularly focused on developing a commercial model for large scale batteries. In particular, projects in this group are developing technology with the ability to supply fast frequency response and FCAS services as well as black start and islanding capabilities.[54]

There are six projects in this group, which includes four individual demonstrations of large scale battery storage facilities. As at July 2019, three of these batteries were operational.[55] Furthermore, all four of these demonstrations remain active, with three projects yet to complete the majority of their milestones. This suggests that there are still considerable learnings to be drawn from this group – particularly in relation to the commercial deployment and future revenue streams of a large scale battery.

The results for the quantitative evaluation criteria are presented in figure 3.13. The magnitude of the potential affordability impact is significant in reducing system costs through reducing curtailment of VRE generators, relieving network constraints and providing ancillary services. The downside of battery storage is the short duration of the storage which reduces the possible magnitude of the affordability impact. Unlike other, larger storage options, batteries can be placed at specific locations to target specific issues which implies a high likelihood of an affordability impact.

Furthermore, these affordability impacts would be felt immediately. In reality there are regulatory barriers that restrict the integration of battery storage, indicating that further development of the body of knowledge would assist in realising these affordability impacts.[56] These barriers reduce the current group performance result. There is a significant current need for short-duration storage devices, yet there remain barriers that have prevented the extraction of the full value of these devices. As such, there is a low alignment of need and project innovation since these batteries would ideally be commercially viable already yet are not quite at the commercial deployment stage.

[54] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 12-17.; and ElectraNet, *ESCRI-SA project summary report*, May 2018, p 35-38.

[55] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 5.

[56] See: Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, pp 29-30; and ElectraNet, *ESCRI-SA project summary report*, May 2018, pp 16-20.

The lack of knowledge in the application of batteries to the electricity sector provided the motivation to progress ESCRI to demonstration despite a poor business case.[57] These battery storage projects highlight the value of supporting large scale storage integration, as the market grows in capability and regulatory precedents are defined with each new project.[58] Learnings from these projects indicate that there is a need for clear energy policy and strategy at a state level to provide certainty around the valuation of the range of services potentially provided by large scale battery projects.[59] This certainty would need to extend over the lifetime of the battery, which is typically 10 years. The understanding of the implementation of large scale battery storage would benefit from further development within this group.

[57] ElectraNet, *ESCRI-SA: Phase 1 – General project report*, December 2015, p 71.

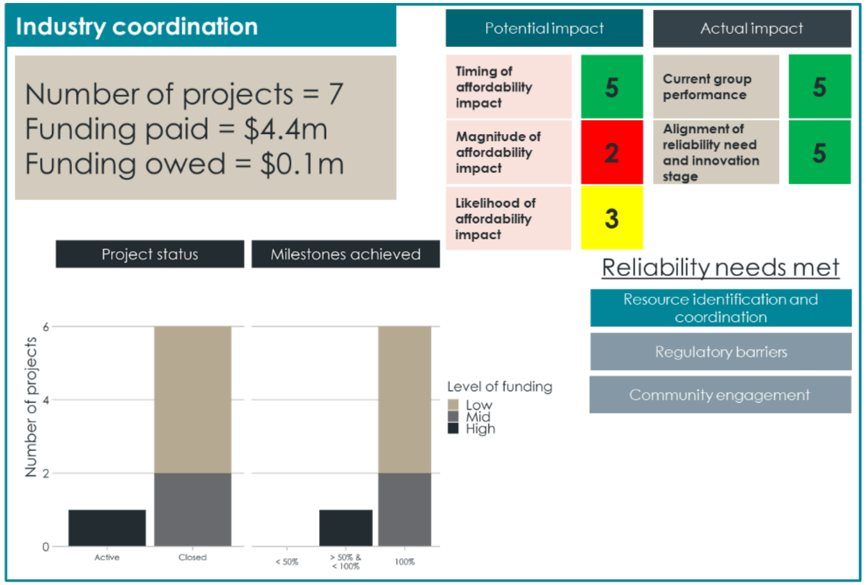
[58] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 1.

[59] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 33.

3.3 Sector contribution

3.3.1 Industry coordination

Figure 3.14: Summary of industry coordination project group evaluation



This group contains non-specific projects focusing on knowledge creation and sharing to assist the transition towards a more sophisticated, high renewables grid. A major affordability impact of this group was to assess the potential for renewable generation to defer network augmentation. This project group is primarily focused on resource identification and coordination, as well as knowledge sharing to develop successful projects. Only one project in this group remain active and very little funds are allocated in the future.

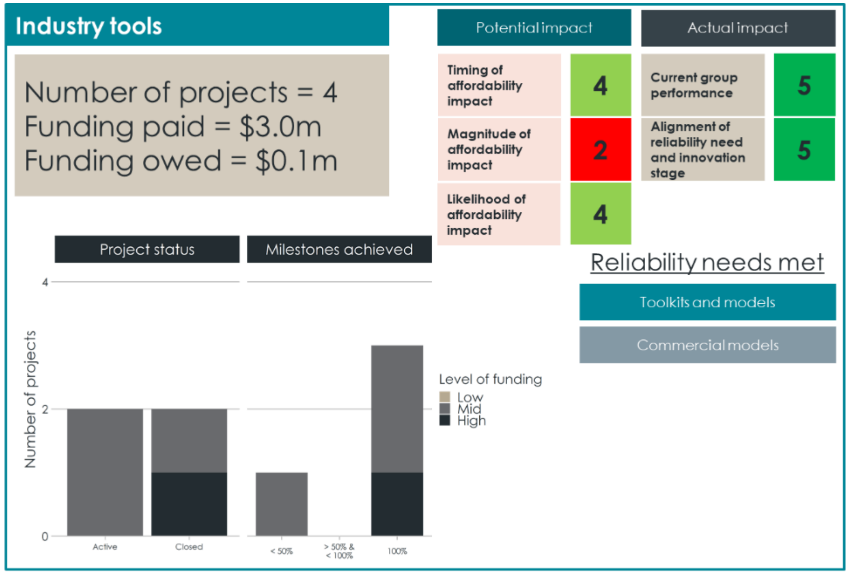
The results for the quantitative evaluation criteria are presented in figure 3.14. Industry coordination can solve immediate issues and hence has immediate benefits.[60] While these projects are likely to have direct impacts on sector wide coordination, whether these materialise into affordability impacts remains to be seen, and if these benefits do materialise, they are likely to only be indirectly impacting affordability. Since the group has produced learnings and these learnings are able to be implemented now, we assign high ratings for the performance and alignment criteria. For example, the Clean Energy Council's future proofing report calls for an improvement of battery regulation, which can deliver immediate effects to the sector if implemented successfully.[61]

[60] Examples include Adelaide University's energy storage test facility that is helping to improve battery technology and the Australian Renewable Energy Mapping Infrastructure (AREMI) ability to share mapping data and information across the renewable energy industry.

[61] Clean Energy Council, *Energy storage safety: Responsible installation, use and disposal of domestic and small commercial systems*, November 2015, p 65.

3.3.2 Industry tools

Figure 3.15: Summary of industry tools project group evaluation



This group contains projects that address industry coordination and commerciality issues through the development of specific toolkits which are publicly available. This group seeks to provide engaged stakeholders with the ability to further develop the level of public knowledge regarding renewable energy in the NEM. This group has received relatively little funding and with only one project yet to complete all milestones we do not anticipate significant future learnings.

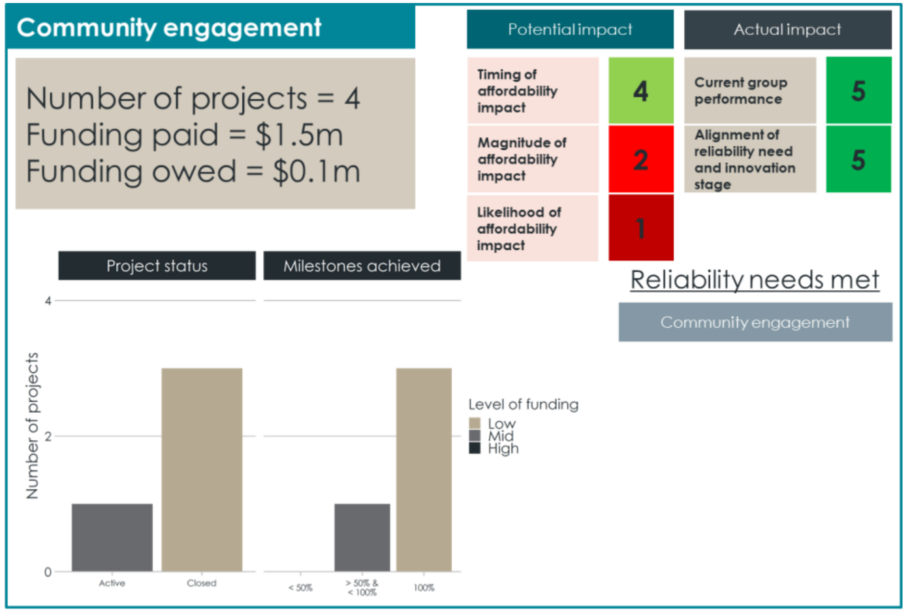
The results for the quantitative evaluation criteria are presented in figure 3.15. These industry tools could be applied in the short term to achieve affordability impacts. Without a direct impact on fundamental or enabling technologies, these projects will likely only have indirect coordination impacts, which would result in minimal affordability impacts. Since these projects are specifically tailored at improving sector wide synergy and coordination, we anticipate a high likelihood of achieving positive affordability impacts. Since the group has produced learnings and these learnings are able to be implemented now, we assign high ratings for the performance and alignment criteria. In particular, The University of Melbourne's cost-effective abatement modelling project found that the uptake of DER is only optimal when network augmentation costs are high.[62] The phase change energy storage project from The University of South Australia can be expanded to coordinating solar PV in DER systems and for demand management purposes.[63] This group has therefore contributed to better coordination of DER, which our findings suggest plays a pivotal role in the delivery of a reliable electricity system.

[62] ARENA, *Achieving cost-effective abatement from Australian electricity generation: Project results and lessons learnt*, March 2017, p 3.

[63] University of South Australia, *Maximising solar PV with phase change thermal energy storage: Project results and lessons learnt*, February 2019, p 7.

3.3.3 Community engagement

Figure 3.16: Summary of community engagement project group evaluation



This group contains projects that produced tangible knowledge with the clear aim of increasing community engagement surrounding renewable energy integration. Increased community engagement would allow for more coordinated approaches to higher shares of renewable energy generation. ARENA allocated very little funding to projects in this group, and there is minimal future funding committed to this group.

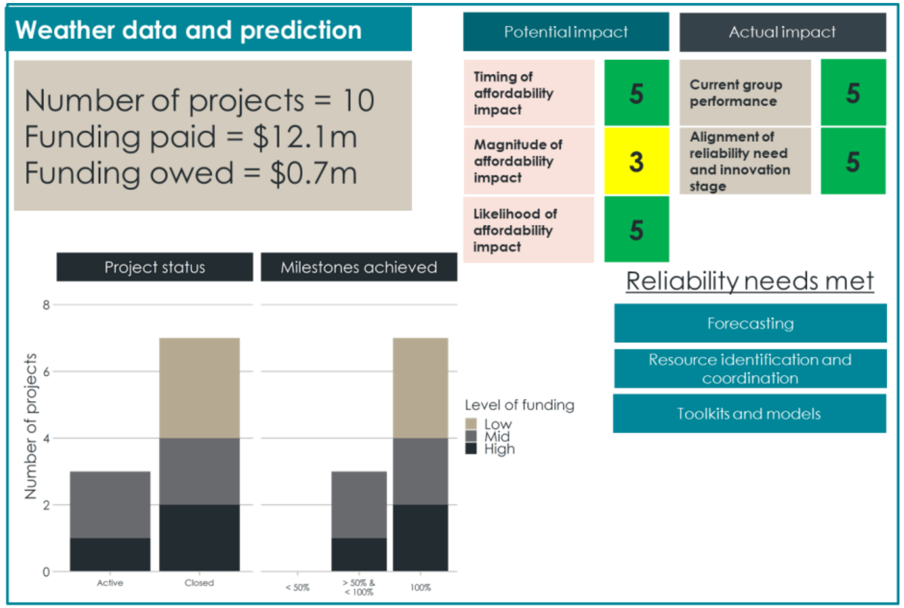
The results for the quantitative evaluation criteria are presented in figure 3.16. Enhanced community engagement will have an affordability impact as the share of VRE increases in the short term.[64] That being said, we do not predict significant or wide-spread affordability impacts. This view is primarily driven by the lack of demonstrable learnings from this group.[65] ARENA also faces an inability to increase the likelihood of an affordability impact through increased activity in this space. Since the group has produced learnings and these learnings are able to be implemented now, we assign high ratings for the performance and alignment criteria.

[64] Effective communication of social and environmental issues to stakeholders is a key barrier to the development of renewable energy generation infrastructure. See: box 2.

[65] The models for community owned solar and strata asset ownership developed in this group require further testing, so more work will be required in order to provide significant demonstrable learnings. This results in a low likelihood of affordability impact currently from this group. See: Appendix A1.16.

3.3.4 Weather data and prediction

Figure 3.17: Summary of weather data and prediction project group evaluation



This group addresses the integration of solar power into the grid by providing centralised databases, resources, prediction technology and solar radiation mapping as well as an exploration of geographic dispersion of solar resources. The findings of this group are of particular relevance to the improved performance of solar thermal plants. These projects contribute to the coordination of solar PV resources, the forecasting of VRE output, the development of toolkits for better weather forecasting and one project on optimizing wave energy design. The demonstration of these technologies, such as the Australian Solar Energy Forecasting System (ASEFS), by AEMO have facilitated better operation of the network with increased solar PV penetration.[66] Most projects in this group are closed, however the projects that remain active may contribute further to the learnings of this group.

The results for the quantitative evaluation criteria are presented in figure 3.17. With the rapid increase in rooftop solar, there is a need to make accurate predictions about the volatility of intermittent generation to ensure a reliable electricity system. As such, weather prediction technology would have an immediate impact on affordability. Some projects in this group have already demonstrated benefits through increased forecasting capacity. This is evidenced by the successful, commercial third-party sales and installation of the "CloudCAM" system from this project group,[67] which is explored further in box 10. It follows that the likelihood of an affordability impact is high. Benefits from these projects are concentrated in a specific area of the network, ie, solar generation, so the affordability impact is only moderate in size. Since the group has produced learnings and these learnings are able to be implemented immediately, we assign high ratings for the performance and alignment criteria.

Box 10: Predicting cloud movements – Fulcrum3D

Fulcrum3D have developed the "CloudCAM" technology to provide accurate short term forecasts of cloud movements. This technology is used by solar plants to provide more accurate forecasts of their energy output. "CloudCAM" was initially designed for fringe-of-grid locations, however the successful deployment of the technology has led Fulcrum3D to believe that the product has commercial value for utility scale solar generation.

In the fringe-of-grid context, "CloudCAM" predicts short term decreases in solar output and gradually decreases the output from the plant into the system. This curtailment allows other generators, typically diesel plants, to

[66] ARENA, *Australian Solar Energy Forecasting System: Final report: project results and lessons learnt*, May 2016, p 6.

[67] ARENA, *Cloud detection and prediction for maximising solar PV utilisation in off-grid hybrid power systems: Final report: project results and lessons learnt*, November 2016, p 3.

see an increase in load and gradually ramp up their generation. This decreases the risk of diesel generators stalling as they attempt to increase their output rapidly during times of sudden change in load.

Fulcrum3D predict that the technology has the potential to have a material impact of system costs, particularly in fringe-of-grid applications. For example, Fulcrum3D estimates that the installation of CloudCAM on the Ti-Tree and Kalkarindji power stations reduced battery usage by approximately 30 per cent and increased the average yield of solar power by 4-5 per cent.

The CloudCAM business model and commercial viability is dependent upon market arrangements. A solar PV farm would not have an incentive to reduce its output through the use of CloudCAM if not for arrangements that penalise generators for rapid changes in their output. In the case of the NEM, this occurs through the causer pays FCAS arrangements. It follows that changes in market arrangement that place stricter limits on compliance with short term output forecasts will increase the value of short term weather forecasting technologies such as CloudCAM.

This project is an example of ARENA funding having a direct influence on development of a technology that is benefitting consumers and creating an export opportunity for Australia. This insight has influenced our view of the performance of the weather forecasting project group.

4. Portfolio evaluation

In this section we outline the results of our evaluation of the portfolio against ARENA's reliability outcomes. We outline the results of assessing the portfolio across four dimensions:

- technology coverage;
- innovation phase coverage;
- reliability needs coverage; and
- affordability impacts.

4.1 Technology coverage

Key findings

- Overall, our findings indicate that ARENA's past funding has demonstrated a comprehensive coverage across a suitable range of technology types.
- Funding from ARENA has led to significant progress in the body of knowledge relating to distributed energy resources (DER), particularly with regards to managing the impact of the connection of large quantities of distributed solar PV and battery storage. We view the impact of the portfolio in this domain as its most significant contribution.
- A high proportion of ARENA funding has been focused on stand-alone power systems (SAPS) – while many of these projects have delivered direct affordability benefits and helped establish a substantial body of knowledge relating to SAPS with high penetrations of renewable energy, generalising learning from SAPS to the wider grid presents challenges. We suggest that ARENA consider the extent to which funding is directed towards SAPS in the future for contributing towards reliability outcomes.
- ARENA has committed limited funding towards the *reliability aspects* of emerging generation and fuel technologies, for example, hydrogen.[68] We consider there to be benefits in gaining further understanding of the reliability aspects of hydrogen technology, with the level of funding dedicated by ARENA commensurate with the expected likelihood of future commercial viability, taking into account future policy direction regarding hydrogen. We consider the past level of funding in this area to be appropriate but consider this an area for future funding opportunities
- ARENA's recent funding round aimed at demand response has filled a previous gap in the portfolio and the broader sector in this area – we suggest that further funding in this area should be deferred until the findings of the current funded projects are established to inform the future direction in this aspect of the portfolio.
- Funding of solar thermal demonstration projects has represented a substantial proportion of the portfolio - results of solar thermal projects have indicated economic and practical challenges with the technology. We suggest that limited further investigation be dedicated to solar thermal projects above those committed to ASTRI and to Vast Solar until findings from these projects have been established that indicate a means of overcoming the economic and practical challenges.
- Based on our assessment of technology coverage, we conclude that ARENA should consider future funding in the following areas:
  - reliability implications of hydrogen technologies through storage, dispatchable electricity and demand management options, should

[68] Our analysis has not included an explicit analysis of ARENA's hydrogen research and development projects to date as these fall outside the reliability portfolio.

policy changes indicate a reasonable likelihood of hydrogen production reaching commercial viability;

  - opportunities for bioenergy to contribute to dispatchable generation in the future;
  - testing of VRE generators providing system security services, either through integration battery storage or overload capabilities;
  - continued support of enabling technologies for distributed energy; and
  - capacity building in the hydroelectric sector to underpin growth in the sector over time.

The reliability portfolio covers a range of technologies, each with different roles in facilitating the delivery of renewable electricity supply. This section presents our findings with regards to the technological coverage of the portfolio. In assessing the current and future level of funding across technology groups. We assume that the portfolio should ideally:

- incorporate a reasonable range of both fundamental and enabling technologies that are expected to contribute to reliability in the future; and
- have a distribution of funding that is broadly commensurate with the likely value that the technology is likely to add to the sector in terms of affordability impact.

First, we consider the current funding across technology groups. This is followed a discussion of levels of funding over time. Finally, we make suggestions regarding the potential future direction of the portfolio with regards to technological coverage.

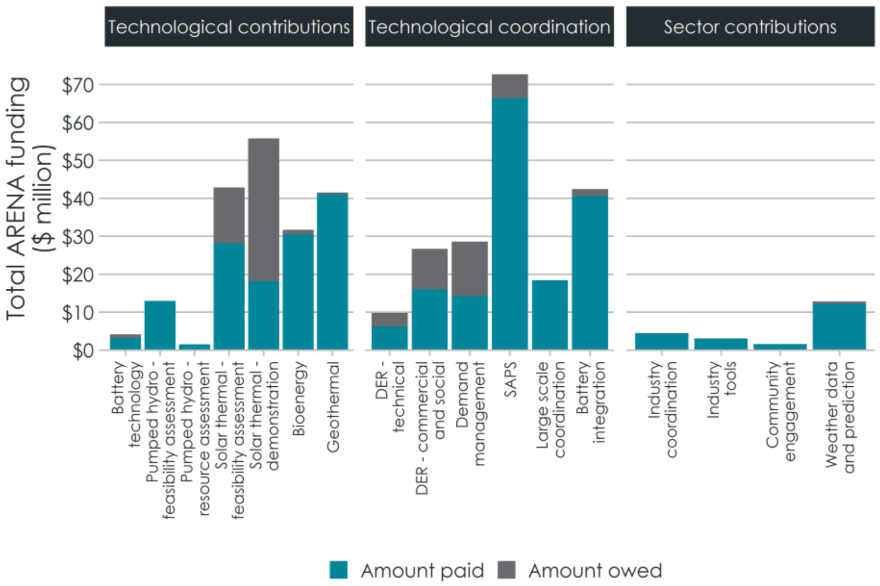
4.1.1 Current funding across technology groups

Figure 4.1 shows the distribution of funding from ARENA for each project group. This chart shows:

- the majority of funding has been dedicated towards stand-alone power systems and solar thermal demonstration projects - in the case of solar thermal this reflects the substantial level of funding to the Vast Solar demonstration project while the SAPS project group contains a large number of smaller projects;
- the majority of funding goes towards technological coordination projects, ie, those focused on coordinating existing underlying generation and storage technologies in a more efficient manner;
- the level of funding for sector contribution projects is low – this reflects that these projects are typically desktop studies or research as opposed to demonstration projects; and
- that the amount owed to current projects is relatively small compared to past spending for all groups with the exception of solar thermal demonstration and demand management.

We view the level of funding that has been directed at technological coordination and the technologies to enable this coordination as well aligned with the reliability needs of the sector at this stage. In many cases, the fundamental generation and storage technologies exist to meet technical needs but further development of technologies to utilise these resources in an efficient manner and in the unique contexts across the grid is required.

Figure 4.1: Total ARENA funding by project group



Source: HoustonKemp analysis of ARENA data.

The significant amount of funding owed to the demand response projects is due to the recent round of ARENA funding specifically focused on demand response projects. In October 2017, ARENA committed $28.6 million in total to fund set-up and operational costs for 10 pilot projects under the demand response initiative.[69] This round of targeted funding is a major contributor to the $39.1 million dollars of ARENA funding allocated to this group.

The demand response funding round has filled a previous gap in the portfolio in this area. We suggest that further funding in this area should be deferred until the findings of the current funded projects are established to inform the future direction in this aspect of the portfolio. This reflects the fact that at this stage the key barriers and gaps in the body of knowledge relating to demand response will evolve as these projects progress.

For instance, the EnerNOC demand response projects have attempted to recruit partners from a variety of industries to reduce their consumption during peak demand periods. The proponents have found that industries with high levels of compliance requirements, such as water services, face considerable difficulties to provide demand response at certain times.[70] As these projects continue to explore this space, we anticipate that demand response initiatives will be able to be implemented across a wider range of industries than is currently possible.

The significant remaining payments for solar thermal demonstration projects are entirely for Vast Solar's 30MW concentrating solar thermal power plant in Jemalong, NSW. This project follows directly from another pilot plant demonstration also run by Vast Solar. There were significant delays in the first pilot plant that have delayed the commencement of the second project, giving rise to the remaining payments.

More broadly, the results of solar thermal feasibility assessment projects have indicated economic and practical challenges with solar thermal technology and so we suggest that limited additional funds be dedicated to solar thermal projects above the committed to the Vast Solar project until findings from this project have been established.

The material funding levels dedicated to large scale coordination is principally driven by the $18 million of funding provided to the Kennedy Energy Park project.

[69] ARENA, *AEMO and ARENA demand response trial to provide 200 megawatts of emergency reserves for extreme peaks*, (available at https://arena.gov.au/news/aemo-arena-demand-response/, accessed 27 May 2019).

[70] EnerNOC, *ARENA Demand Response Trial: Knowledge Sharing Project performance report*, December 2018, p 13.

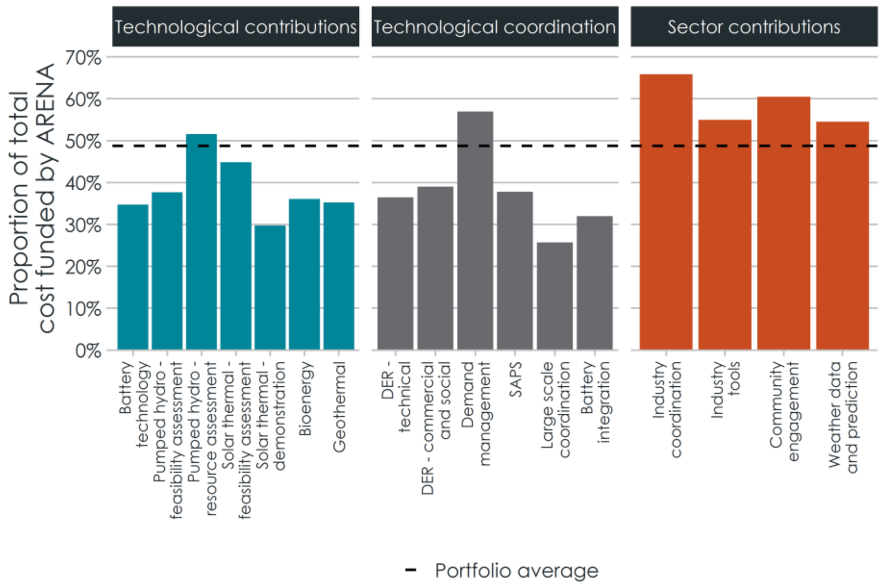
The remaining funding to be paid out to distributed energy projects principally relate to the NOJA switchgear project, from a technical perspective, and both the Simply Energy and AGL VPP trials from a commercial perspective. Our view is that the previous funding from ARENA has led to significant progress in the body of knowledge relating to distributed energy resources, particularly, with regards to managing the impact of the connection of large quantities of distributed solar PV and battery storage.

Figure 4.2 shows the proportion of total project costs funded by ARENA. This is a measure of the extent to which ARENA funding is critical and to which ARENA funding is being leveraged to deliver outcomes.

We typically see high average ratios in those project groups where studies tend to be research or other desktop studies. This reflects that these projects tend to have lower total costs in general and do not give rise to other revenue streams which can contribute to covering project costs. This is a principal reason why sector contribution projects tend to have a higher proportion of total costs funded by ARENA.

In contrast, technological coordination projects tend to have a lower proportion as these projects often give rise to other revenue streams, eg, through market revenues. For example, large scale coordination has a low value owing to the relative low proportion of total funds provided by ARENA for the $160 million Kennedy Energy Park project.

Figure 4.2: Proportion of total project costs funded by ARENA



Source: HoustonKemp analysis of ARENA data.

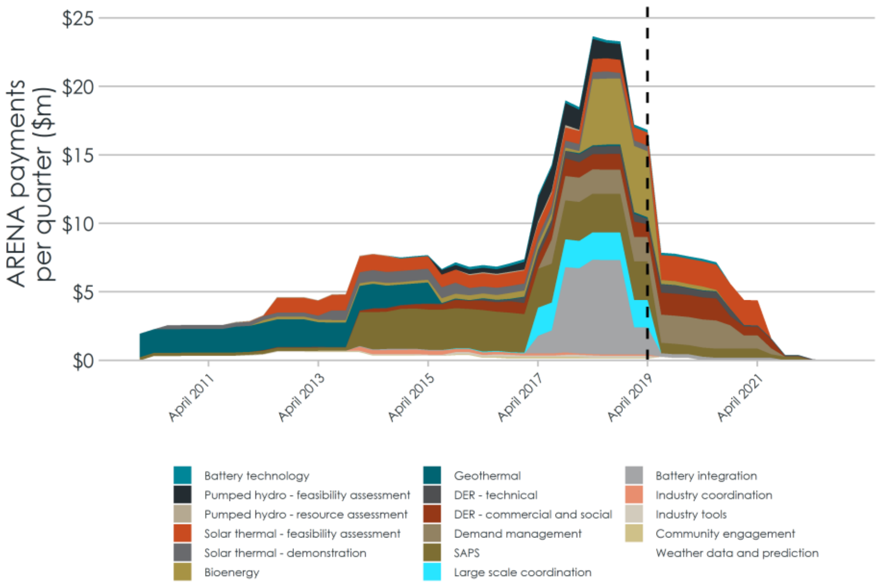
4.1.2 Current technology funding over time

Figure 4.3 provides an illustration of the profile of funding from ARENA by technology type over time.

ARENA provided a detailed list of information on every project in the portfolio. By combining information on project commencement and conclusion dates and the funding arrangement for each project, we are able to create an approximation to the profile of ARENA's funding since the first project in the portfolio commenced in February 2010.

In approximating the profile of past spending, we allocate all of the prior spending on a project evenly between the commencement and conclusion dates, or if the project is still active, between the commencement date and April 2019.[71] The profile of future spending is approximated by allocating any owed funds evenly between April 2019 and the conclusion date of the project.

Figure 4.3: Allocation of ARENA funding by project group



Source: HoustonKemp analysis of ARENA data. Note: this analysis removes Vast Solar's project at Jemalong that is currently under variation by ARENA.

This indicative funding profile shows:

- ARENA has provided substantial funds for stand-alone power systems for a number of years,
- That recent spending has been allocated towards battery storage, demand management and distributed energy resources and large scale coordination;
- a significant decrease in future spending within the reliability portfolio compared to ARENA's recent spending in this area, most significantly in the areas of:
  - battery storage;
  - pumped hydro resource assessments and feasibility assessments; and
  - large scale coordination; and
- that funding towards weather data and prediction was significant in early years but has reduced in the last two years.

4.1.3 Future direction for technological coverage funding

The assessment of technological coverage highlights a number of areas where ARENA could consider adjusting its funding strategy going forward to have a more complete coverage of technologies.

Currently, the scope of fundamental generation or storage technologies in the portfolio is relatively low, with limited funding outside of Vast Solar's projects. We note that ARENA may fund projects aimed at developing fundamental technologies outside of its reliability portfolio. We do not explicitly consider ARENA's funding plans outside of the reliability portfolio.

Key technologies that we identify as potential inclusion in the reliability portfolio include:

- hydrogen technologies, with a focus on the reliability impacts of hydrogen – we recommend that significant funding on projects focused on reliability issues be considered when policy developments or findings from other

[71] The data on project expenditure is accurate to April 2019.

ARENA studies indicate that the underlying technology will likely reach sufficient scale to be commercially viable in the future;[72]

- projects focused on integration of large scale VRE and storage; and
- bioenergy technologies.

Hydrogen is an emerging technology that may provide a flexible form of storage and dispatchable generation. We understand that ARENA has committed around $37 million across 23 projects towards the development of hydrogen since 2018. The majority of these projects are in the research and development stage and are focusing on accelerating the development of a hydrogen energy export supply chain. Some hydrogen projects are also in the early demonstration phase, such as the ATCO Gas and Jemena projects. This funding towards hydrogen technologies has fallen outside of the portfolio however the learnings and developments have potential to impact on reliability needs in the future.

The role for hydrogen in the Australian electricity sector remains unclear at this early stage of its development, particularly surrounding the competitiveness of hydrogen generation in providing dispatchable renewable energy. Our view is that there is scope for hydrogen-fuelled electricity generation to be developed where a broader hydrogen production, transmission and export system in established.

We suggest that ARENA consider whether studies that focus on the reliability contribution of domestic hydrogen production should be targeted for future funding in the portfolio. These types of studies could include:[73]

- the potential reliability contribution of hydrogen as a form of energy storage;
- the use of hydrogen as a potential fuel source for domestic dispatchable power; and
- the potential for demand smoothing through hydrogen production.

We suggest that ARENA also consider funding trials, particularly for large scale technologies, that are not subject to pricing and market rules that apply under the current market design. Such projects would examine how technologies could more effectively operate and coordinate under different system and market conditions, principally to support system security.

In particular, understanding how VRE technologies assets may operate in the context of the market arrangements that may exist in the future, eg, a strong emphasis of revenue from regulating services and more volatile prices, will be an important dimension to potential projects in this area. To achieve this understanding, ARENA may be required to establish funding arrangements that provide appropriate price signals. ARENA may then be required to fund a larger proportion of total project costs to account for the risks that such a regime poses for project proponents. Alternatively, in a manner that is more consistent with current funding approaches, ARENA funding could help incentivise market participants to engage in these trials by ensuring that the costs to market participants (including potential foregone revenues) are recovered.

We note that the Kennedy Energy Park project has encountered material problems with regards to establishing grid connection. Therefore, there may be merit in ARENA deferring substantial demonstration projects until connection arrangements have improved. We note that the AEMC is currently considering a rule change to address these issues.[74]

[72] We note that hydrogen-related research and development projects are not included within the reliability portfolio and so have not been explicitly considered in this evaluation.

[73] ARENA has previously covered this area at a high level, however this exploration was not performed under the portfolio. See: ARENA, *Comparison of dispatchable renewable electricity options*, (available at https://arena.gov.au/projects/dispatchable-renewable-electricity-options/, accessed 25 June 2019).

[74] The transparency of new projects rule change seeks to enhance publicly available information about new generation projects. See: AEMC, *Transparency of new projects – Rule Change*,

To date, the portfolio has focused on enabling technologies to assist in the deployment of proven storage technologies with limited consideration for the reliability contribution of alternative storage technologies. Key exceptions within the portfolio are the use of pumped seawater hydro storage near Port Augusta by Energy Australia[75] and the construction of a solar thermal plant with storage in the Western Australian mining region by Spanish renewables firm Abengoa.[76] We suggest that ARENA consider whether further funding oriented towards applying more innovative storage technologies in the Australian context may be appropriate.

Studies funded within the current reliability portfolio have demonstrated the viability of innovative bioenergy technologies and the scope of biomass resources that are available. While the future role of bioenergy in electricity production remains uncertain, the funding dedicated to this area of the portfolio is relatively low. We consider that there is scope for ARENA to consider whether additional funding be directed towards bioenergy to assess its potential role in providing dispatchable renewable generation.

We understand that ARENA has committed over $124 million across 38 projects towards bioenergy development with the aim of improving energy productivity. The five projects included in our bioenergy project group are part of this wider collection of projects. In addition to the Kwinana and Mt. Piper projects in the reliability portfolio, there are several projects that explore the use of municipal solid waste as a viable source of biofuel. These projects, amongst others in this bioenergy collection, will have a wide range of potential impacts towards meeting the reliability needs of the sector.

More broadly, we consider that ARENA should continue to identify opportunities for enabling technologies to support the deployment of more mature technologies. We have not identified any specific gaps in enabling technologies but recognise that some key technologies that enable metering and control of distributed energy resource require further development to be deployed across the network. We discuss potential areas for directing funding to maximise impact on affordability further in section 4.4.

2019 (available at https://www.aemc.gov.au/rule-changes/transparency-new-projects, accessed 28 May 2019).

[75] This project belongs to the pumped hydro – feasibility assessment group.

[76] This project belongs to the solar thermal – feasibility assessment group.

4.2 Innovation phase coverage

Key findings

- Further development of enabling technologies is required to maximise the affordability impacts of existing and emerging generation and storage (termed 'fundamental') technologies. It follows that these fundamental technologies are relatively more aligned with the timing of the needs than enabling technologies. We find that further work is most required in the integration of distributed energy resources and battery storage technologies.
- The focus within the portfolio on projects relating to enabling DER, both technically and commercially, reflects a good alignment between innovation phase and the timing of reliability needs – projects within these project groups target reliability needs that are pressing at current levels of renewable energy deployment.
- ARENA's funding has made a meaningful contribution to the body of knowledge around the barriers to implementing pumped hydro storage. The underlying technology is mature yet barriers to deployment of pumped hydro storage still exist, principally relating to uncertainty around revenues for system security services and the impact of losses. While ARENA may influence the sector's understanding of the barriers, these require changes in the market rules to be fully addressed. There are also notable community engagement barriers associated with pumped hydro energy storage which ARENA has an ability to influence.
- Large scale coordination projects face significant regulatory and commercial barriers that have inhibited the progression of the body of knowledge and so the technologies and processes that enable large scale coordination are lagging behind the timing of need. Without changes in the regulatory environment to address these challenges further funding from ARENA may not lead to material improvement in the body of knowledge in this area. We note that the AEMC is progressing rule changes relating to these barriers.[77]
- Solar thermal is not meeting immediate reliability needs and so time can be taken to understand the technology - we see scope within the portfolio for solar thermal to be explored at earlier innovation phases, such as feasibility assessments and pilots, owing to the nascent state of the underlying technology.

The project innovation phase, or maturity of a technology, describes the readiness of the technology to be deployed in the electricity system. A technology would ideally be at the commercial deployment stage when the reliability need is most pressing. As the timing of the reliability need moves further into the future, the required current level of readiness of the technology moves towards earlier innovation phases and less technology maturity. It follows that ARENA has more flexibility with regards to the technologies or approaches that can be considered for projects that seek to address needs that are pressing at higher levels of renewable penetration.

4.2.1 Current funding and readiness for deployment

In section 2, we presented the underlying rationale for the assessment of projects groups on the basis of innovation phase coverage. To summarise, we consider that the portfolio has an appropriate coverage of innovation phases coverage where:

- funding from ARENA focus on projects that are at an appropriate innovation phase such that they will be ready for deployment when the reliability needs that they contribute to are pressing; and
- the distribution of funding covers technologies at different innovation stages to ensure a pipeline of technologies that will assist in meeting future reliability needs.

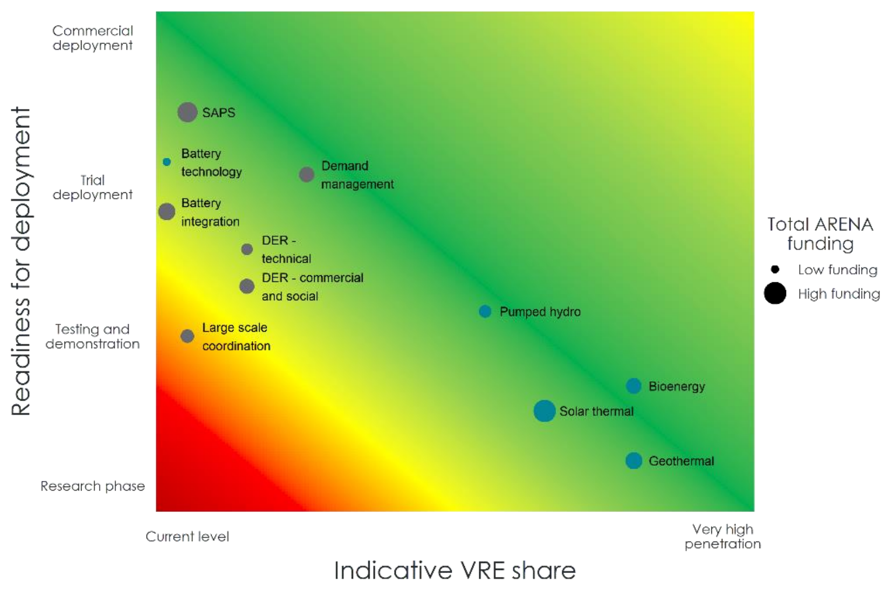
[77] AEMC, *Transparency of new projects – Rule Change*, 2019 (available at https://www.aemc.gov.au/rule-changes/transparency-new-projects, accessed 28 May 2019).

Figure 4.4 plots each of the project groups based on the relationship between their technological maturity and level of VRE penetration at which ideal implementation will occur. The coloured region in which each project group lies reflects the rating of this criterion in the project group evaluation. The ratings are based on a holistic assessment of the state of technological development and body of knowledge of the projects within the project groups. In practice, there is typically underlying variation in the technologies within each project group.

The level of VRE penetration at which ideal implementation will occur for each project group corresponds to the score given to each project group under the timing of affordability impact criterion which we discuss further in section 4.4. That is, the issues associated with the current share of VRE corresponds to the group targeting reliability needs in the short term (or Phase 1 needs). On the other hand, the issues associated with very high penetration of VRE corresponds to distant reliability needs (Phase 3) being satisfied by this group.

The readiness of technology refers to underlying technologies whether this is a fundamental technology, ie, generation or storage, or an enabling technology. In particular, for technological coordination projects, the readiness of technology rating reflects the state of enabling technologies and the associated body of knowledge that facilitate the utilisation of a number of fundamental technologies. For example, a SAPS project may use a number of mature technologies such as wind, solar PV and battery storage, however the technologies for coordinating the different technologies and demand response may be relatively less mature.

Figure 4.4: Readiness for deployment against indicative share of VRE



Source: HoustonKemp analysis of ARENA data.

Figure 4.4 also shows the amount of funding ARENA has allocated each project group. Larger circles indicate a larger amount of funding. Our analysis indicates that ARENA has funded projects that are broadly aligned with regards to the readiness for deployment and the timing of the reliability needs, as indicated by the distribution of project groups across the green band in figure 4.4.

An important feature of these results is that project groups that demonstrate a lower degree of alignment between readiness for deployment and the timing reliability needs tend to have a lower level of funding from ARENA. This suggests that funding has not been overly dedicated to areas where value is not maximised.

However, the location of DER, large scale coordination and battery storage projects towards the red area indicates our view that these technologies would ideally be more advanced in terms of their readiness for deployment to meet needs that a currently pressing for the sector.

These views are based on the following:

- battery storage is increasingly becoming economic to be installed to manage losses and spillage associated with new VRE connections. However, the battery storage projects have identified the following regulatory issues that will impact future battery storage projects:
  - the allocation of operating expenditure of the battery under the owner's cost allocation methodology;
  - any payments to be made under the Transmission Use of System (TUOS) rules;
  - the connection to the transmission system;
  - hybrid registration of assets as a generator and a load; and
  - lack of long term certainty for marginal loss factors (MLFs);
- the large scale coordination projects (ie, Kennedy Energy Park and New England Renewable Energy Hub study) have identified a number of barriers both for commercial reasons and due to the current rules for:
  - meeting connection requirement specified by DNSPs, including modelling system security impacts in the context of multiple connections; and
  - coordinating multiple parties to utilise connection assets more effectively; and
- the penetration of distributed energy resources in parts of distribution networks is posing challenges for the operation of the network – while technical solutions exist for managing these issues, regulatory arrangements and commercial models, enabled by communication technologies, need to develop to enable these resources to be utilised in the most efficient manner.

The principle barriers to these technologies being progressed further lies in barriers relating to the National Electricity Rules and the current market design. In particular, rules relating to:

- the obligation on parties and standards associated with large scale generation and storage connection;
- the rules regarding the rights and obligations relating to managing distributed resources to maintain system security – eg, the extent to which distribution network operators can control output from household resources and under what condition this is allowed.

We consider demand management to be an important contributor to meeting reliability needs for the sector in the medium term as VRE penetration levels increase to higher penetration levels across the country's electricity systems. We consider the recent round of funding of demand management projects to be timely as demand management will increasingly play an important role in contributing to the management of higher penetrations of VRE. We view the timing of this round of funding as being well aligned with the timing of need.

In addition, we find that the focus on pumped hydro storage across the sector in recent years means that the technology will be ready for deployment ahead of when the reliability needs the technology meet will be pressing. In particular, ARENA's funding has made a meaningful contribution to the body of knowledge around the barriers to implementing pumped hydro storage and the resources available to be utilised. It follows that we consider this funding to be well-aligned with the timing of need.

A key remaining barrier to establishing business cases for pumped hydro storage relates to the level of uncertainty relating to revenues for system security services and measuring the benefits associated with reductions in losses which are well captured under the existing marginal loss factor calculation methodology. ARENA has an indirect ability to influence these factors through funding projects that help develop the sector's understanding of how these issues are best resolved but changes to the National Electricity Rules will be required to more fully address these issues. On the other hand, another key remaining barrier for pumped hydro storage is related to community engagement and information sharing with stakeholders. This is a barrier that further ARENA involvement can assist in helping resolve.

4.2.2 Future funding across innovation phases

Our analysis of the current portfolio concludes that future funding opportunities for ARENA that reflect a coverage of innovation phases include:

- Hydrogen technologies – hydrogen storage and hydrogen powered generation could contribute to Phase 3 reliability needs and so ARENA has significant scope for developing the body of knowledge prior to these needs becoming pressing. As discussed in section 4.1.3, we suggest that some funding be directed towards the reliability components of hydrogen development, even at the early stages of development, but that significant funding on projects be considered when policy developments or findings from other ARENA projects indicate that the underlying technology will likely reach sufficient scale to be commercially viable in the future;[78]
- Integration of DER and battery storage – we suggest that ARENA continues to look for opportunities to support the integration of battery and DER as these technologies are associated with pressing reliability needs and further development of the body of knowledge relating to these technologies is required;
- Solar thermal – solar thermal is not required at current VRE to meet reliability needs and so time can be taken to understand the performance of the technology through small scale pilots and testing rather than larger-scale projects. In this sense, we view scope for solar thermal to be explored at an earlier innovation phase than other fundamental dispatchable generation technologies, such as pumped hydro. This sentiment is shared by ASTRI, who are aiming to make solar thermal economically competitive with other renewable energy options over the next four years.[79] There may also be an opportunity to take advantage of progress made in other international jurisdictions before significant additional funds should be dedicated; and
- Coordination of large scale generation – the development of the body of knowledge and enabling technologies regarding the coordination of large scale generation and storage assets has been hindered by regulatory barriers. Until these barriers are overcome, there is more limited value in increased funding towards large scale coordination by ARENA. We suggest that ARENA delay funding in this area until these regulatory barriers are overcome.

[78] We acknowledge that ARENA already has a separate funding stream that contributes to the development of hydrogen technologies, rather than the reliability implications of hydrogen.

[79] ASTRI, *Public Dissemination Report*, June 2019, p 24.

4.3 Reliability needs coverage

Key findings

- The portfolio covers all the key reliability needs we have identified with the exception of conventional plant flexibility, as this falls outside of ARENA's mandate to promote renewable energy resources.
- Reliability needs that have received the most coverage within the portfolio are:
    - interactions with third parties (eg, regulators, the financial sector and community members), including commercial models, regulatory barriers and community engagement;
    - firming VRE output, ie, projects focused on technologies or coordination of technologies to assist in managing variation in VRE output;
    - storage integration; ie, projects focused on implementing the required storage capacity as the share of intermittent generation grows; and
    - frequency and system strength support, ie, projects focusing on providing services related to system security.
- The high proportion of projects that contribute to third party interactions is consistent with our finding that ARENA's most significant contribution to meeting future reliability needs relates to coordination amongst stakeholders in the sector.
- Projects that contribute to demand management and SAPS renewable integration maintain the current level of contribution into 2021, whereas all other needs see a considerable decrease in contributions in 2019 – suggesting that funding that contributes to the majority of reliability needs will drop significantly over the coming year.
- The portfolio has a lower relative contribution in the portfolio towards Phase 3[80] needs, such as dispatchable renewable generation and inertia and system strength support in the future. While these reliability needs can be met with existing technologies, we expect there is potential scope for further efficiencies in the deployment of the technologies that contribute to meeting these needs through ARENA funding that targets technological innovation and building of the body of knowledge.

Each project within the reliability portfolio aims to contribute to one or more reliability needs for the sector. Figure 4.5 provides a summary of our view of the sector's reliability needs that are met by the reliability portfolio.

To quantify the impact of the portfolio across these reliability needs, we identify links between each project group and the reliability needs that it meets. The links between each project group and the reliability needs that it meets is presented within each project group evaluation in section 3.

To quantify the coverage of reliability needs, we use the weights developed in section 2.1.3. The total weighted contribution towards a reliability need is the aggregation of all the contributions from project groups that map to that particular reliability need.

4.3.1 Overall portfolio contribution to reliability needs

Figure 4.6 presents the weighted contribution to reliability needs. This measure is relative rather than absolute. It follows that the relative size of the contributions from project groups is useful for drawing insights rather than the magnitude of each individual contribution.

[80] See section 2.1.3 for an explanation of the phases of reliability needs.

Figure 4.5: Summary of reliability needs

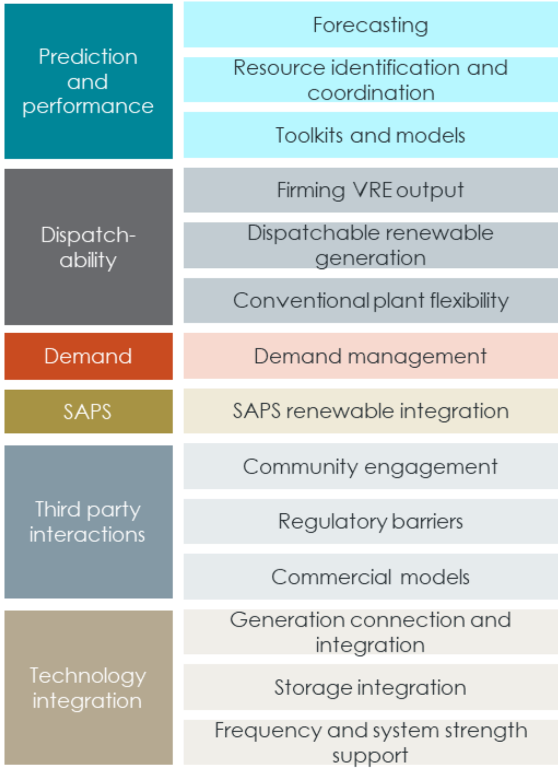
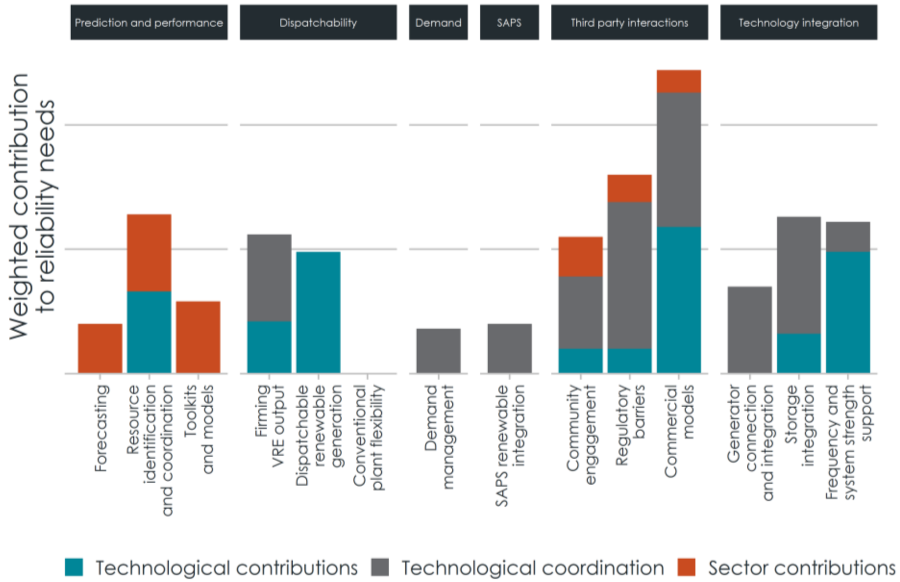


Figure 4.6: Weighted contribution of portfolio to reliability needs



Source: HoustonKemp analysis of ARENA data.

To provide context for our assessment of reliability needs and the contribution of project groups, we have developed a set of key issues in the sector related to reliability needs based on our discussions with project proponents and the Australian Energy Market Operator (AEMO). These include:

- uncertainty regarding future commercial models and revenue streams for technologies that provide system security and regulating services;[81]
- uncertainty regarding appropriate responsibilities for managing weather driven volatility in energy supply, eg, to what extent should individual participants be responsible for managing the volatility and impact on the system of their output;
- uncertainty regarding rights and responsibilities of DER owners and DNSPs relating to managing the impact of the installation of DER on the grid and real-time control of the resources;
- challenges in information sharing and coordination amongst parties relating to satisfying requirements for grid connections – in particular, modelling the impact of a projects grid impacts without appropriate information from other new projects;
- challenges in interacting with DNSPs when negotiating competitively procured connections;
- lack of standardized regulatory approaches across jurisdictions with regards to metering and connections which impacts the ability to develop standardized approaches; and
- lack of scale and policy support for advancing the application of bioenergy in the Australian context.

Our analysis of reliability needs finds that third-party interactions, such as commercial models and regulatory barriers, receive the largest contribution from the portfolio. This is consistent with the key concerns of stakeholders mentioned above which principally relate to commercial models and regulatory barriers as key areas where further development is required.

[81] This concern is also expressed in Aurecon, *Large scale battery storage knowledge sharing report*, July 2019.

Technical aspects of reliability needs have also seen substantial funding within the portfolio, ie, generation connection and integration, storage integration and frequency and system strength support. This is principally driven by the fact that most technological contribution and DER technical projects are focused on addressing the technical issues associated with operating the system with increasing levels of renewables.

We estimate the portfolio contribution towards forecasting as low relative to other reliability needs.[82] This reflects that the projects that contribute to this need are principally smaller research or pilot projects with low requirements for assets to be purchased by project proponents. We view the relatively low funding as appropriate given the relatively advanced level of technology in this space.

The results also show that demand management and SAPS renewable integration receive some of the lowest contributions from the portfolio. This highlights the specific nature of these reliability needs. The recent round of demand management funding was timely, as prior to this funding round there was a lack of projects that met this reliability need.

4.3.2 Funding towards reliability needs over time

We also analysed the funding that maps to each reliability need over time. In order to provide greater flexibility than the weights employed above, we apply a transformation to the funding of each project so that demonstration and deployment projects are comparable to other studies.

We created an indexed funding measure by transforming the total ARENA funding allocated to each demonstration and deployment project to the same scale as the other studies. To do this we divide the funding for demonstration and deployment projects by the average funding for that group and multiply by the average funding for the other studies and R&D group.[83] The result is a

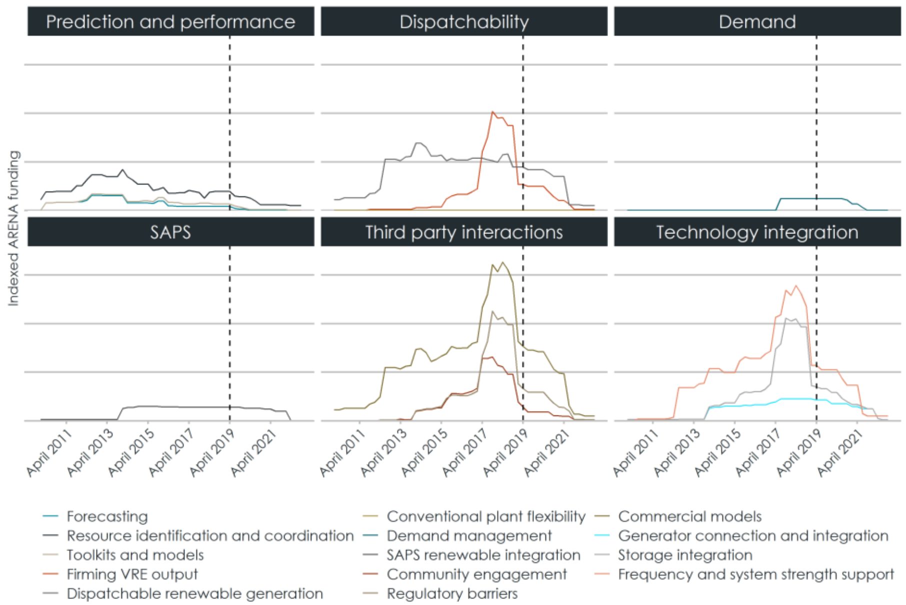
[82] Our evaluation does not include an analysis of additional short term forecasting projects that have been supported by ARENA outside of the reliability portfolio as currently defined.

[83] Mathematically, the transformation is:

measure of funding that has the same average across the two groups, which allows for more appropriate comparisons between different project types and account for the differences in the different capital requirement across the groups.

Figure 4.7 maps the past and future expenditure from ARENA that will impact on each reliability need. Again, this is a relative measure rather than an absolute measure. The relative height of each line determines the relative coverage of the reliability need within the portfolio.

Figure 4.7: Indexed ARENA funding allocated to reliability needs



Source: HoustonKemp analysis of ARENA data.

$$funding_{index,demonstration} = \frac{funding_{demonstration}}{average\ demonstration\ funding} \times average\ other\ study\ funding$$

We find that prediction and performance, dispatchability, third party interactions and technology integration have all been experiencing a decline in funding since 2017 that is expected to continue without additional project funding. Despite this, there is still considerable future contributions towards third party interactions, dispatchability and technology integration.

Contributions towards SAPS renewable integration and demand management in the future remain comparable to their current levels owing to substantial funding commitments for projects that meet these needs.

Over the past two years, ARENA has contributed most significantly towards five reliability needs as presented in table 4.1.

Table 4.1: Reliability needs with the largest funding between 2017 and 2019

Reliability need	Phase when need most pressing
Commercial models	All phases
Frequency and system strength support	Phase 3
Regulatory barriers	All phases
Storage integration	Phase 2
Firming VRE output	Phase 2

We find that the emphasis on funding directed towards third party interactions over recent years to be an appropriate use of ARENA resources. Third party interactions are important at all phases and our analysis has indicated that the learnings from these interactions are pivotal to solving the key issues currently facing the sector.

As table 4.1 illustrates, we find that reliability needs that are most important during Phase 1, such as generation connection and integration, have received less funding in recent years relative to other reliability needs.

We view the significant funding towards frequency and system strength support as less aligned with immediate needs of the sector, however, the contribution towards this need has often been a secondary benefit from projects that had other more pressing reliability needs as their central focus.[84] This indicates that ARENA's recent expenditure could have been better aligned with reliability needs that are more pressing, such as storage integration.

The reliability needs with the largest committed future funding, and the phase in which they are most pressing, are presented in table 4.2. The reliability needs on this list are likely to be pressing in the near future and so we view this funding as a sensible use of immediate funds due to the short time frame in which these needs are expected to be pressing.

Table 4.2: Reliability needs with the largest future committed funding

Reliability need	Phase when need most pressing
Commercial models	All phases
Frequency and system strength support	Phase 3
Dispatchable renewable generation	Phase 3
Storage integration	Phase 2
Regulatory barriers	All phases

The reliability needs with the lowest committed future funding, and the phase in which they are most pressing, are presented in table 4.3. The majority of reliability needs that have received low levels of funding are in areas that do not require significant funding to deliver meaningful insights. In general, in these areas meaningful insights can be more readily obtained from desktop studies which require lower funding relative to pilots or demonstration projects. We view this distribution of funding as broadly appropriate.

[84] For example, despite the fact that VRE generators are currently installing network support equipment in order to meet requirements of connection, we view the need for frequency and system strength support services to be provided by VRE generators to be of most importance in Phase 3.

Table 4.3: Reliability needs with the lowest future committed funding

Reliability need	Phase when need most pressing
Forecasting	Phase 2
Toolkits and models	All phases
Community engagement	All phases
Resource identification and coordination	Phase 2

4.4 Affordability impacts

Key findings

- ARENA has allocated resources effectively within the portfolio to achieve the greatest possible affordability impacts.
- ARENA has dedicated the largest share of funding to technological coordination projects. This aligns with our view that technological coordination projects have had, and will continue to have, a significant overall affordability impact, more so than technological contribution or sector contribution projects. This is largely owing to the nearer term requirements for reliability needs met by technological coordination projects.
- Sector contribution projects are estimated to have the smallest impact on affordability, mainly due to the small magnitude of the impacts. However, the funding dedicated to these initiatives is substantially lower than for other aspects of the portfolio.
- Battery storage is likely to have the nearest term affordability impact of the technological contribution projects covered in the portfolio owing to the immediate needs met by short-duration storage and the potential magnitude of impact – experience with the current battery storage projects indicates that further development of the body of knowledge is required in this area.
- 'Large scale coordination' and 'DER – commercial and social' have the largest potential for impacting on affordability, as we see these as the major impediment to more efficient utilisation of large scale and distributed renewable energy generation respectively.
- Reducing barriers to pumped hydro storage will contribute to improving affordability in the long term – currently, significant uncertainty around future revenue streams for system security services and future treatment of losses, in additional to broader uncertainty regarding energy market and arbitrage revenues, are barriers to establishing positive pumped hydro business cases. ARENA has an indirect ability to influence these factors through funding projects that help develop the sector's understanding of how these factors can be captured in project business cases. However, changes to the National Electricity Rules and policy changes will be required to more fully address these uncertainties

A key driver of the whether the reliability portfolio satisfies the objectives of ARENA is whether it is delivering affordability impacts to the sector, ie, it is lowering the costs to consumers of transitioning towards a high penetrations renewable energy future. In this section, we outline our assessment of the reliability portfolio based on the extent to which it is delivering affordability impacts.

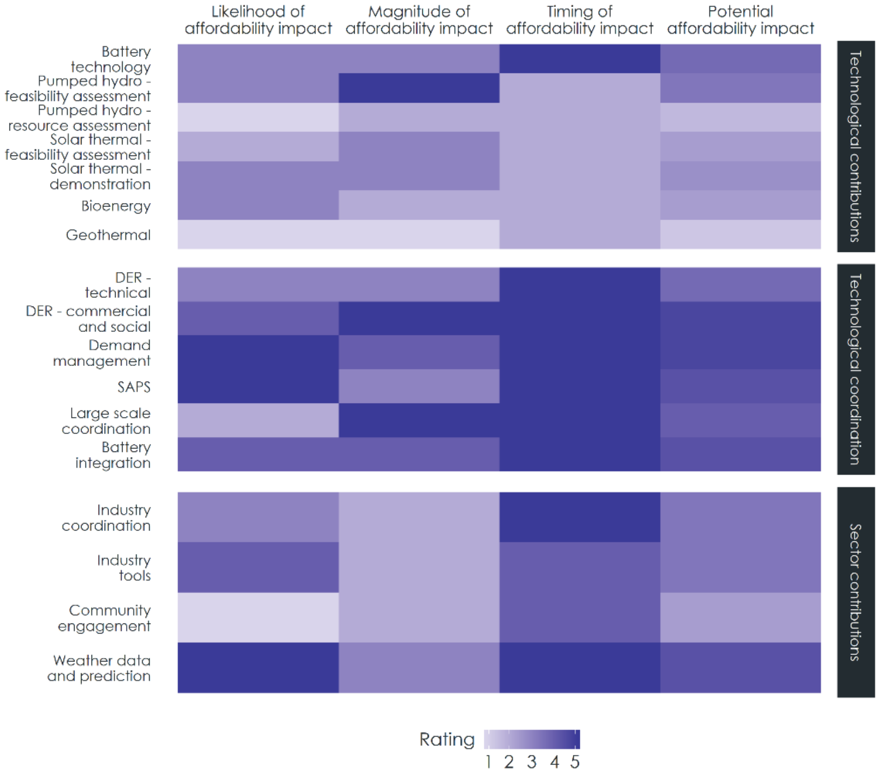
4.4.1 Potential affordability impacts

Figure 4.8 presents the assessment for each affordability criterion for all project groups. The likelihood, magnitude and timing impacts referenced in this figure are presented in each project group evaluation in section 3. The potential affordability impact reflects the aggregation across these three criteria. It is a measure for the overall potential affordability impact of each project group.

With regards to the likelihood measure, technological contribution projects have the lowest ratings. A number of the fundamental technologies are not yet at the deployment stages and hence uncertainty regarding their likelihood of having a material affordability impact in the future remain. Sector contribution projects are primarily closed projects with demonstrated results - this is the principal drivers of their stronger likelihood scores. Similarly, many technological coordination projects are at the commercial deployment stage and so we have assigned a higher likelihood measure.

Technological contribution and technological coordination projects score higher than sector contribution projects on the magnitude measure. Technological contributions have a more direct affordability impact than sector contribution projects. Similarly, technological coordination projects are larger in magnitude as their potential benefits tend to be more broadly applicable across the sector.

Figure 4.8: Potential affordability impacts



Technological coordination projects score well on the timing measure while almost all technological contributions score very poorly for timing. This is due to the difference in expected implementation timeframes for the fundamental and enabling technologies that comprise the portfolio. That is, there is a need to implement the enabling technologies immediately, whereas the need to implement the fundamental technologies tends to be further into the future.

Figure 4.9 provides a comparison of the total funds committed by ARENA and the potential affordability impact we have assigned to each project group. Under our evaluation framework, ARENA would ideally allocate the most significant amount of funding towards project groups that have the highest potential affordability impacts.

In general, we do see a trend in the portfolio, whereby ARENA's funding has targeted high potential value-for-money areas. We consider that technological coordination to have the highest potential affordability impacts, and ARENA has appropriately allocated considerable funds towards these areas. Similarly, some of the technological contributions groups, such as pumped hydro and solar thermal, have relatively low potential affordability impacts and have received more limited levels of funding.

One exception is solar thermal demonstration, to which ARENA has committed a large amount of future funding through the Jemalong solar demonstration which is currently under variation by ARENA. This indicates an area where ARENA funding may not have been allocated to maximise affordability impacts. However, if the modular approach to solar thermal explored in this project delivers positive outcomes, then the potential affordability impact of this group would likely increase.

Figure 4.9: Comparison of potential affordability impact and the amount of funds committed by project group

Source: HoustonKemp analysis of ARENA data.

In the remainder of this section we discuss each of the categories of projects in additional detail.

Technological contribution project groups

Within the technological contribution category, we find that the majority of funds have been dedicated to demonstration and pilot projects across solar thermal, bioenergy and geothermal. We have rated these project groups as having a lower likely affordability impact. While this suggests that the funding is not making a tangible near-term impact on affordability, the funding is assisting in improving the sector's understanding of the meeting important future reliability needs.

For example, a number of solar thermal projects funded by ARENA have encountered challenges related to economic case for the technology. Two feasibility studies and one demonstration included in the portfolio were terminated when the proponents concluded that the underlying projects would not be financially viable. It follows that while the projects are improving the understanding of the future role of solar thermal, the affordability impacts of the project groups are expected to be low.

Our findings suggest that the most immediate affordability impacts will most likely come from battery technology. We find that projects funded in this space from ARENA are making a material contribution to the body of knowledge relating to the technical capabilities of emerging battery technology.

We also find that pumped hydro storage technology has amongst the highest potential impact on affordability, principally in the medium to long term, as this is a mature technology with relative certainty that it will play a material role in the sector in the future. ARENA has dedicated significant funding to supporting improvements in the understanding of pumped hydro storage, principally associated with the Snowy 2.0 project and the Tasmania Battery of the Nation Plan and Marinus Link interconnector project.[85]

[85] Funding from ARENA for the Marinus Link project does not form part of the Reliability Portfolio.

Technological coordination project groups

The project groups within the technological coordination category exhibit higher potential affordability impacts than those in the other categories. This is driven primarily by these projects providing benefits to the sector that can be realised immediately, as reflected in the high timing of reliability impacts across the project groups in this category.

The two groups that we view as having the highest potential affordability impacts are 'DER – commercial and social' and 'demand management'. We view ARENA's funding towards 'DER – commercial and social' projects as having a particularly high magnitude of affordability, while we see the ARENA funding as having a particularly high likelihood of affordability impact. Both of these group receive a substantial amount of funding which we view as an appropriate use of ARENA's funds and suggests that ARENA's historical spending in this space has been well allocated.

We find that the majority of funds across technological coordination projects have been dedicated to SAPS and battery integration. This is owing to the relatively large size of these types of demonstration and deployment projects. We have rated these project groups as having a strong affordability impact.

Within the technological coordination category, we find that the potential magnitude of affordability impact is likely to be greatest in 'large scale coordination' and 'DER – commercial and social'.

We estimate that 'DER – commercial and social' projects that ARENA has funded, and could fund in the future, have a high potential magnitude of impact on affordability. This is principally because:

- commercial models for integration of DER will increase the efficiency of the deployment of distributed resources; and
- models for coordinating distributed energy will reduce system costs through maximizing the value of these assets for the network and market.

To illustrate the potential impact of removing barriers to establishing commercial models for DER we estimate the expected benefit of more efficient utilisation of DER. We estimate that the order of magnitude of the impact of ARENA's funding on the affordability through its actions on distributed energy resources to be approximately $140 million in NPV terms. This is based on:

- total projected output from distributed energy resources;[86]
- a change in efficiency due to removing barriers to successful commercial models in distributed energy resources of 5 per cent;
- an estimate of ARENA's contribution to changes in the 20 per cent; and
- a value of $50 per MWh to each unit of energy.

The projected efficiency changes are principally attributable to establishing an effective platform for the coordination of distributed energy technologies, eg, deX platform, and the underlying technical capabilities to enable commercial models that are aligned with the needs of distribution networks and consumers to thrive.

We estimate improvement in large scale coordination has the potential to have substantial impacts on systems costs and affordability. This is principally because:

- more efficient coordination of connections within the same geographic areas will enable reductions in the total capital costs of connection assets; and
- better coordination of VRE plants and storage assets has the potential to reduce losses in the system and reduce spillage of VRE output.

To illustrate the potential impact of improvements in the coordination of large scale generation assets we estimate the potential order of magnitude of the

[86] AEMO, *ESOO Demand Forecasts*, February 2019, (available at forecasting.aemo.com.au, accessed 28 May 2019).

reduction of connection costs in the sector. We estimate that the potential impact on connection costs from ARENA funding be in the order of $25-30 million in NPV terms. This is based on:

- the net present value of connection costs is calculated based on the estimates of new wind and solar generation and storage construction based on projections from AEMO's ISP;
- estimate potential saving due to rule changes and increases in body of knowledge as 10 per cent of the net present value of connection costs; and
- estimate impact of ARENA funding calculated as 10 per cent of the potential savings.

The estimated affordability impacts arising from the large scale coordination group are lower relative to 'DER - commercial and social', largely owing to the lower proportion of savings that can be attributable to the funding from ARENA. This is consistent with the lower ratings for likelihood of affordability impact, relative to 'DER - commercial and social', for the large scale coordination group.

Sector coordination project groups

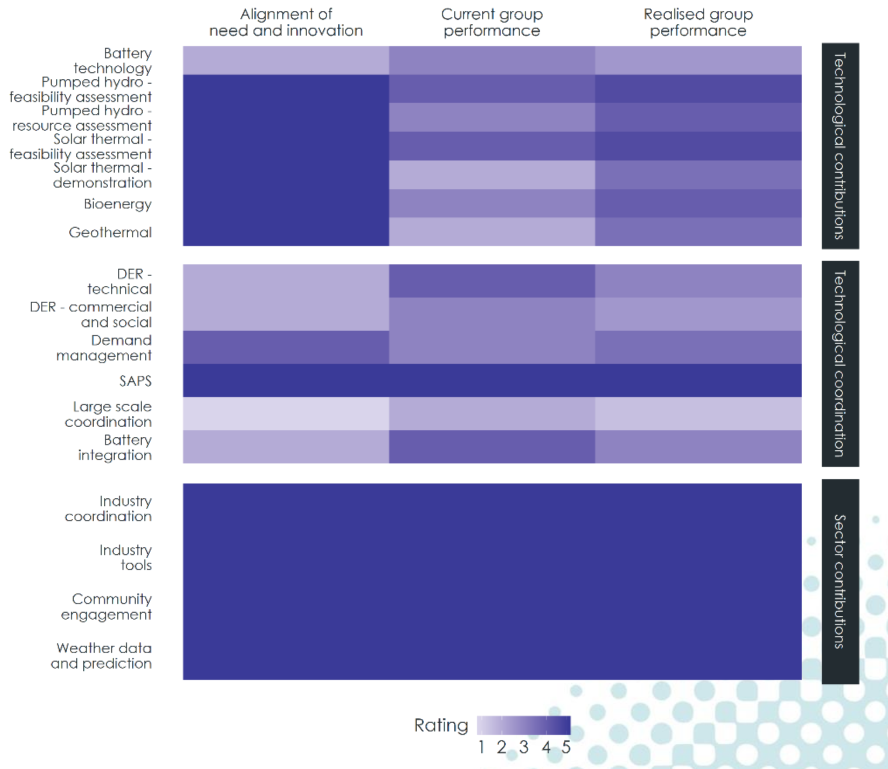
With regards to sector contribution projects, we find that weather and data prediction has the highest ratings owing to the role that the technologies are playing in improving the performance of existing systems, eg, the use of CloudCam by solar PV plants to optimise their operations. We assign lower ratings to industry tools, industry coordination and community engagement as these project groups have a less direct impact on the costs to the sector.

4.4.2 Realised group performance

The realised group performance represents the degree to which the potential affordability impact has been achieved. It reflects how well the project group is delivering key learnings at an appropriate point in time. Realised group performance is measured by combining the measures that captures the alignment of reliability need and innovation phase with the current group performance measure. These quantitative assessments are presented in each project group evaluation in section 3.

Figure 4.10 shows the results of our assessment of the realised performance for each project group. The realised group performance measure reflects the aggregation across the alignment of reliability need and innovation phase measure and the current group performance measure.

Figure 4.10: Realised group performance



The realisation of group performance for the sector contributions group is consistent across all project groups and is very strong due to:

- the immediate contribution of the learnings to alleviate system issues resulting in an ideal alignment of need and innovation; and
- the coordination of an ever-growing body of knowledge that would otherwise not exist resulting in a strong group performance.

We discuss the technological contributions and technological coordination groups in further detail below.

Technological contribution project groups

Within the technological contribution category, we see that pumped hydro, solar thermal and bioenergy display a strong alignment of reliability need and innovation phase. These technologies are yet to reach commercial deployment but are targeting distant reliability needs. On the other hand, wide-spread battery technology would ideally be implemented immediately, and this project group is developing technology that could be commercially viable in the short term.

Battery and pumped hydro storage projects have provided key learnings directly dealing with the barriers that face the implementation of these technologies. For example, battery storage projects are being progressed to deployment with the intention of informing a new regulatory framework. The resource and feasibility assessments of pumped hydro are contributing to the understanding of the social and environmental impacts of pumped hydro implementation. As such, the current performance of these projects groups is reasonably high.

Similarly, the feasibility assessments of solar thermal sites are deepening the understanding of the viability, or lack thereof, of this technology given the current market conditions and technology maturity. In addition, the bioenergy group is contributing to the coordination of the sector, which is a key barrier to the growth of the bioenergy industry. As such, these groups have a degree of success in meeting their key aims despite a lack of demonstrable outcomes.

The demonstration of solar thermal has faced significant delays and is yet to provide any sound learnings. It follows that the current performance of these demonstrations is lower than other groups in this category.

Technological coordination project groups

The alignment of reliability needs and innovation phase displays a large degree of variation across the technological contribution groups. The reliability needs associated with this set of project groups tend to be pressing in the short term, however not all enabling technologies and approaches from these groups are at the deployment stage. SAPS and demand management are relatively more developed in the commercial sense than DER and large scale coordination which explains the difference between these projects in the alignment criterion.

Within the technological coordination category, we find that the SAPS project group has performed the strongest due to the successful deployment of the technology, eg, King Island, and the current attempts to improve the technology, eg, using desalination and wave energy on Garden Island.

Both the technical and commercial and social groups of DER have performed well, however there are still improvements to be made in this area. For instance, the development of further commercial models is required to resolve the trade-off associated with having the system operator or DNSPs controlling DER and utilising them to provide system services and allowing customers to maintain control of their DER assets.

The weakest performing group is large scale coordination which has not provided the constructive learnings that were expected at this stage. The Kennedy Energy Park project is completely constructed but is not operational. This has delayed the realisation of the learnings which are pivotal to the development and implementation of other projects in this area. Currently, this group has only contributed to the identification of barriers to implementation and has made no contribution to the demonstrative learnings of large scale coordination. It is for this reason that the large scale coordination group is the weakest performing group in the portfolio.

4.4.3 Maximising the future impact on affordability

To identify those areas where we expect that efforts from ARENA will have the most significant impact on the affordability of electricity, we compare the potential affordability impact with the realized group performance measure.

Figure 4.11 shows the comparison of these two measures. We note that the realised group performance represents how close each group has come to achieving the full potential of the affordability impact. A relatively larger shade difference between the two measures indicates that the current impact of the project group is much lower than it potentially could be. If the two measures have the same shade, then this indicates that the project group is performing as well as we could expect.

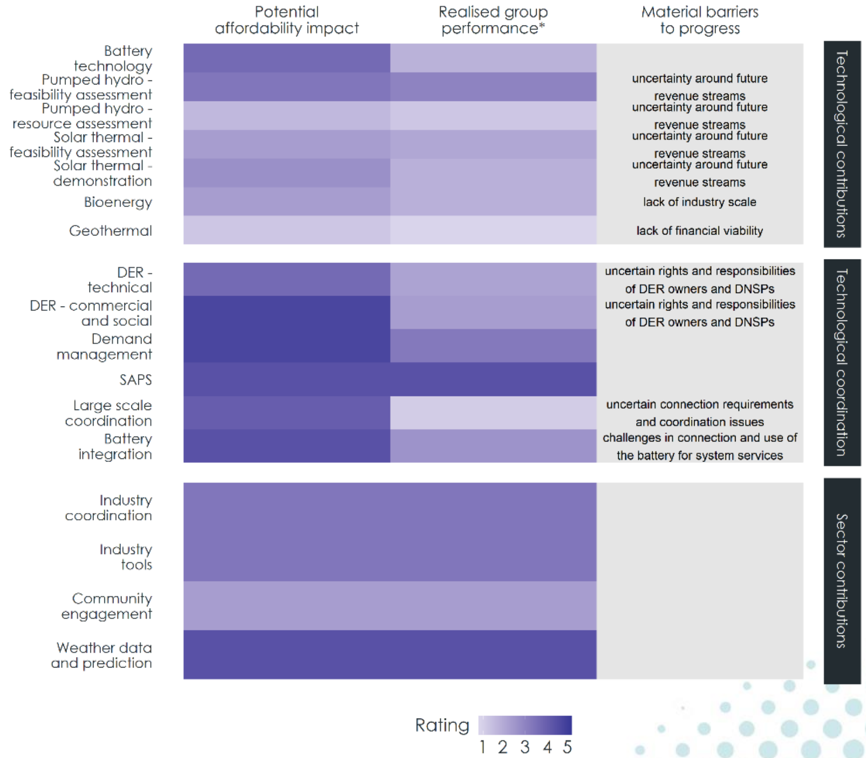
If the current impact is significantly lower than the potential impact, then this indicates an area in which ARENA has potential to have a more pronounced impact on the affordability of electricity.

The technological contributions groups are performing reasonably close to potential, with the exception of battery technology. This gap is driven by a relatively poor alignment of reliability need and innovation as battery technology is required at present VRE levels, yet the technology still has some unresolved issues in its widespread application.

In the technological coordination groups, we see a range of performance results. SAPS and demand management are currently operating at, or very close to, their potential, while DER and large scale coordination are not performing as well.

The sector contributions are performing strongly. This is because any contribution from these groups can be used to meet reliability needs immediately and by simply funding these types of projects, ARENA has successfully achieved the desired outcomes of these groups.

Figure 4.11: Comparison of potential affordability impact and realised group performance



* Realised group performance is scaled by the potential affordability impact to provide a measure in absolute terms.

5. Implications for future funding

Table 5.1 presents a summary of the full list of our recommendations. These recommendations are elaborated further in the text that follows below. The recommendations below only relate to funding aimed at contributing towards ARENA's reliability outcomes. The recommendations do not directly address ARENA funding aimed at meeting other ARENA outcomes.

Table 5.1: Summary of implications for future funding

	Finding	Suggestion
Barriers to progressing the body of knowledge in relation to some key aspects of the reliability portfolio	Lack of regulations that specify the rights and responsibilities of DER owners and DNSPs.	ARENA's involvement can assist the sector in gaining clarity with regards to the barriers to better enable the development of appropriate solutions to address the barriers. ARENA should be cognizant of funding projects for which these barriers may present insurmountable challenges or impede the insights that can be gained from them.
	Lack of markets or clear revenue streams for provision of system security and short term regulating services	
	Lack of regulations relating to information sharing and coordination amongst parties relating to satisfying requirements for grid connections	
	Lack of standards to govern interactions with DNSPs when negotiating competitively procured connections	
	Challenges in establishing business cases for pumped hydro storage, solar thermal and battery storage owing to uncertainty regarding future revenue streams for provision of market services	
Future technological developments	Hydrogen production is an evolving area with potentially significant implications for the means by which reliability of electricity supply is managed	ARENA should consider exploring the following areas related to hydrogen production to contribute towards meeting reliability needs that are most pressing in the medium-to-long term: • the potential reliability contribution of hydrogen as a form of energy storage; • the use of hydrogen as a potential fuel source for domestic dispatchable power; and • the potential for demand smoothing through hydrogen production.

	The contribution of waste and biomass resources to the need for dispatchable renewable energy sources.	ARENA should continue to consider potential opportunities in bioenergy, while also recognising that its cost profile and the challenges in producing and sourcing fuel on a large scale may limits its uptake in the future.
Technology priorities	Translating insights from standalone power systems to the broader grid.	We suggest that ARENA consider the extent to which future funding is directed towards SAPS for contributing to ARENA reliability outcomes as generalising learnings from SAPS to the wider grid presents challenges.
	Approach to future funding of solar thermal projects.	We suggest that limited further funding be dedicated to solar thermal projects above those committed to ASTRI and Vast Solar until findings from these projects have been established that indicate a means of overcoming the economic and practical challenges with solar thermal technologies. Further, we suggest that funding that is deployed should focus on early innovation stages, eg, up to demonstration, rather than large-scale projects.
	Alleviating constraints on the development of pumped hydro energy storage.	We suggest that ARENA consider supporting projects to alleviate potential future capacity constraints in relation to key areas of pumped hydro energy storage expertise, such as community engagement.
Undertaking trials in alternative market structures	The reliability portfolio would benefit from projects that operate large scale generation and storage projects subject to alternative pricing approaches under an alternative market design.	We suggest that ARENA consider funding trials, particularly for large scale technologies, that are not subject to pricing and market rules that apply under the current market design. Such projects would examine how technologies could more effectively operate and coordinate under different system and market conditions, principally to support system security.

In this section, we provide a summary of the findings of our evaluation and consider the implications of our findings for potential reliability needs gaps and exploratory avenues in the future. In particular, we consider:

- potential approaches to guiding the sector in implementing the strategy;
- implications of our findings for the potential timing of future funding.

The following discussion elaborates on the findings and suggestions presented in table 5.1.

A number of barriers exist to progressing the body of knowledge in relation to some key aspects of the reliability portfolio. These principally include:

- lack of markets or clear revenue streams for provision of system security and short term regulating services;
- lack of regulations that specify the rights and responsibilities of DER owners and DNSPs relating to managing the impact of the installation of DER on the grid and real-time control of the resources;
- lack of regulations relating to information sharing and coordination amongst parties relating to satisfying requirements for grid connections – in particular, modelling a project's grid impacts without appropriate information from other new projects;
- lack of standards to govern interactions with DNSPs when negotiating competitively procured connections; and
- challenges in establishing business cases for pumped hydro storage, solar thermal and battery storage owing to uncertainty regarding future revenue streams for provision of frequency control and system strength support, in addition to broader uncertainty regarding energy market and arbitrage revenues.

These barriers are a primary driver of gaps we have identified in our evaluation of the reliability portfolio. However, the appropriate approach from ARENA in response to these barriers varies. In particular, barriers have two principal potential implications for how projects dealing with these issues may be handled in the future, namely:

- where barriers are well defined and restrict projects from delivering meaningful outcomes, ARENA should consider whether directing further attention to this area is appropriate and whether investigation should be deferred until the barriers have been removed; and
- where uncertainty exists regarding the extent and nature of barriers, then involvement can assist the sector in gaining clarity with regards to the barriers to better enable the development of appropriate solutions to address the barriers.

The former case can be considered to apply in the area of large scale coordination, where, for example, connection issues are materially impacting on the ability for Kennedy Energy Park to maximise its contribution to the body of knowledge. The latter case can be considered to apply in DER where work on integrating distributed resources is helping the sector clarify the nature of the barriers that are faced in this area.

ARENA should be cognizant of the nature of the barriers that may impact on the learnings in a potential future area when considering whether to pursue an individual project.

We envisage that industry will continue to provide a source of project ideas in these areas owing to the current progress that is being made in these areas by project proponents and the fact that many stakeholders in the sector are working on addressing these issues.

Future technological developments are another source of gaps we have identified in the reliability portfolio. For example, hydrogen production is an evolving area which has the potential to have very significant implications for the means by which reliability of electricity supply is supplied and managed. At present there is a high degree of uncertainty regarding how hydrogen might be integrated into the Australian electricity sector. Future projects in this area may relate to:[87]

- the potential reliability contribution of hydrogen as a form of energy storage;
- the use of hydrogen as a potential fuel source for domestic dispatchable power; and
- the potential for demand smoothing through hydrogen production.

Such projects would contribute towards meeting reliability needs that are most pressing in the medium-to-long term (ie, Phase 3 needs) and so there is scope to investigate more innovative approaches in this space. Substantial investment in exploring the reliability implications of hydrogen production may be deferred until more certainty exists with regards to the technological, policy and regulatory context for hydrogen production.

We also consider that alongside the development of hydrogen production, bioenergy, including biomass in electricity generation, may also see an increased role in contributing to dispatchability requirements for electricity generation.[88] We consider that ARENA should continue to consider potential opportunities in bioenergy, while also recognising that its cost profile and the challenges in producing and sourcing fuel sources on a large scale may place limits on its future uptake.[89]

Our analysis of the distribution of ARENA funding across technologies indicated that a high proportion of funding has been focused on SAPS – while many of these projects have delivered direct affordability benefits and helped

[87] Our analysis has not included an explicit analysis of ARENA's hydrogen projects that fall outside the reliability portfolio as currently defined. See section 4.1 for more details on hydrogen projects outside of the portfolio.

[88] We acknowledge that ARENA has supported the development of bioenergy and hydrogen outside of the portfolio.

[89] Our analysis has not included an explicit analysis of ARENA's bioenergy projects that fall outside the reliability portfolio as currently defined. See section 4.1 for more details on bioenergy projects outside of the portfolio.

establish a substantial body of knowledge relating to SAPS with high penetrations of renewable energy, generalising learning from SAPS to the wider grid presents challenges. We suggest that ARENA consider the extent to which funding is directed towards SAPS in the future.

Further, we find that funding of solar thermal demonstration projects has represented a substantial proportion of the portfolio. Results of solar thermal projects have indicated current economic and practical challenges with the technology. We suggest that limited further funding be dedicated to solar thermal projects above those committed to ASTRI and to Vast Solar until findings from these projects have been established that indicate a means of overcoming the economic and practical challenges. Further, we suggest that funding that is deployed should focus on early innovation stages, eg, up to demonstration, rather than large-scale projects.

We suggest taking a more proactive approach to supporting projects to meet technological developments. Relative to those projects that aim to address gaps arising due to external barriers, we expect that sourcing project proponents may be more challenging in this area.

A final gap we have identified is in undertaking trials, particularly for large scale technologies, that are not subject to pricing and market rules that apply under the current market design. Such projects would examine how technologies could more effectively operate and coordinate under different system and market conditions, principally to support system security. ARENA funding could help incentivise market participants to engage in these trials by ensuring that the costs to market participants (including potential foregone revenues) are recovered.

This represents a departure from the typical project funding arrangements that have been historically applied across the reliability portfolio. The recent demand response trials reflect funding arrangements that are more aligned with this approach.

A1. Detailed project group evaluations

A1.1 Battery technology

Table A1.1: Details of projects in the battery technology group

Organisation	Description	Status	Total funding	Progress
University of Wollongong	The Smart Sodium Storage System for Renewable Energy Storage	Active	$2,678,307	71.43%
Adelaide University	Energy storage test facility and knowledge bank	Active	$1,441,811	87.50%

Table A1.2: Portfolio group evaluation for the battery technology group

Overview	Project group summary	This group contains projects aimed at improving the body of knowledge relating to battery storage technologies. In particular, these projects aim to improve the performance of particular battery technologies in terms of both cost effectiveness and operational performance of different technologies.	
	Key project group outcomes	• establish an online database for Australian energy storage devices; • developing new storage technology that could be more cost effective than lithium ion technology; and • create a functional mobile energy storage test facility.	
	Current group performance	3	This group has unearthed learnings on the performance of new storage devices prior to implementation. Adelaide University's mobile energy storage test facility is currently assessing the potential for new and innovative batteries to be successfully

			deployed in the Australian energy market. The facility is providing learnings on how new battery technology perform in applications such as:[90] • behind the meter demand management tests; • voltage support and peak shaving on distribution networks; • islanding of LV feeders on the distribution network; and • simulated operation on a microgrid.
Technology	What underlying technologies do the projects relate to?	Battery storage.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental technology.	
	What are the innovation phases of the underlying technologies?	Mature.	
Reliability needs	What are the key reliability needs met by the projects?	Firming VRE output, storage integration and frequency and system strength support.	
	How do the projects contribute to meeting each reliability need?	Improvements in the underlying battery technology will lead to higher penetrations of renewable generation through increased storage capacity. Once this storage capacity has been integrated, batteries can provide frequency and system strength support.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	2	Effective battery storage is necessary to manage the increasing quantities of VRE generation being installed. There is considerable need for widespread battery integration across the NEM, however there are some aspects of battery technology that are still being developed to perform optimally.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced capital costs for large and small scale battery owners; • reduced operating costs for large and small scale battery owners; and	

[90] The University of Adelaide, *Australian Energy Storage Knowledge Bank*, (available at https://www.adelaide.edu.au/energy-storage/capabilities/, accessed 9 September 2019).

			• reduced transmission augmentation costs in remote locations.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		There are various other energy storage technologies that will likely have a similar impact on affordability. Any developments in these technologies may diminish the need and/or impact of battery storage. These technologies include:[91] • pumped hydro; • flywheels; • compressed air; • flow battery energy storage; • (super)capacitors; and • superconducting magnetic energy storage (SMES). In addition, the NSW and SA governments have established funding programs to incentivise the deployment of additional energy storage technologies.[92]
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	3	The underlying battery technology can be utilised on both the small and large scale.
	Magnitude – what is the potential magnitude of the impact on affordability?	3	The impact on affordability is not highly significant since battery storage only has limited impact owing to its short storage duration. Furthermore, the main driving force behind the affordability impact is due to the successful integration into the network rather than the underlying technology.
	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

[91] ElectraNet, *ESCRI-SA Milestone 3: Energy storage systems*, June 2015, p 12.

[92] NSW Government, NSW Emerging Energy Program Guidelines, February 2019, p 5; and Department for Energy and Mining, Grid Scale Storage Fund: Investment Guidelines, (available at http://www.energymining.sa.gov.au/clean_energy_transition/grid_scale_storage_fund, accessed 27 June 2019).

A1.2 Pumped hydro – feasibility assessment

Table A1.3: Details of projects in the pumped hydro – feasibility assessment group

Organisation	Description	Status	Total funding	Progress
SnowyHydro	Snowy 2.0 feasibility study	Closed	$8,000,000	100.00%
Genex Power Limited	Kidston pumped storage project	Active	$3,996,211	100.00%
Hydro Tasmania	Augmenting the Tasmanian hydropower system	Closed	$500,000	100.00%
EnergyAustralia	SA PHES feasibility study	Closed	$453,000	100.00%

Table A1.4: Portfolio group evaluation for the pumped hydro – feasibility assessment group

Overview	Project group summary		Projects that undertake feasibility assessments of specific potential pumped hydro sites across Australia, including Snowy 2.0, a mine transformation in Queensland and dam re-developments in Tasmania. The technology associated with pumped hydro facilities is mature, however the implementation and deployment of these facilities is relatively less well known. Pumped hydro is currently the cheapest, most mature technology to provide bulk storage.[93] These projects are aimed at learning more about how specific pumped hydro facilities could be integrated into the network.
	Key project group outcomes		• understanding the technical and commercial feasibility of pumped hydro facilities; and • contribute to the body of knowledge surrounding the development of pumped hydro facilities.
	Current group performance	4	Projects within the group have delivered meaningful outcomes that have resulted in development of the body of knowledge relating to pumped hydro storage. Considering the ability for pumped hydro to make a significant contribution to long term storage needs, for example, as indicated by AEMO,[94] we believe that there is scope for this project group to make additional contributions to the body of knowledge.

[93] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

[94] AEMO, *Integrated System Plan*, July 2018, p 33.

Technology	What underlying technologies do the projects relate to?	Pumped hydro storage.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental technologies.	
	What are the innovation phases of the underlying technologies?	Mature.	
Reliability needs	What are the key reliability needs met by the projects?	Firming VRE output, community engagement, regulatory barriers, commercial models, storage integration and frequency and system strength support.	
	How do the projects contribute to meeting each reliability need?	Pumped hydro provides a viable source of long term storage, which will firm VRE output as the share of VRE in the network increases. Pumped hydro is a particularly important part of the generation mix as the penetration of VRE increases owing to the need for long term storage in such a system. Pumped hydro integration also contributes to storage integration, and will be liable for TUOS charges in the same manner as battery storage.[95] Pumped hydro facilities are able to meet the need for frequency and system strength support and so these assessments indirectly contribute to reducing the future costs of these reliability needs.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Maintaining reliability of a system with VRE through pumped hydro facilities meets reliability needs that are primarily pressing at higher levels of VRE penetration. It follows that the knowledge created by these studies is important for identifying future avenues for further development. Underlying pumped hydro technology is mature, and the knowledge that requires expansions principally relates to understanding the commercial models, planning and environmental barriers and the regulatory framework. The sector does not require immediate impacts from pumped hydro technology to meet near term reliability needs. For example, the AEMO integrated system plan does not project material storage requirements until the early 2030s when coal plants retirements are substantial.[96]
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced costs of frequency control and system strength support through additional	

[95] ARUP, *Cultana Pumped Hydro Project: Knowledge Sharing Report*, September 2017, p 28.

[96] AEMO, *Integrated System Plan*, July 2018, p 7,; AEMO, *Building power system resilience with pumped hydro energy storage*, July 2019, p. 7.

			technological options for provision of these services; • reduced capital and operating costs for pumped hydro facilities; and • reduced costs of capital for pumped hydro projects owing to lower uncertainty for investors in pumped hydro projects.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		Pumped hydro project have also received funding from other government sources. In particular, the federal government is supporting the development of Snowy 2.0 through an equity investment of up to $1.38 billion and has provided a further $56 million to the Battery of the Nation project in Tasmania.[97] In addition, the Tasmanian government contributed to an initial feasibility study of the Marinus Link project through TasNetworks alongside ARENA. The Australian Government established the Underwriting New Generation Investments program to support lower prices for reliable electricity. In 2019, 6 pumped hydro projects received funding through this scheme.[98] The NSW and SA governments have established funding programs to incentivise the deployment of additional energy storage technologies.[99] Funding directed towards other storage technologies may diminish the impact of pumped hydro storage however, currently there are no clear alternative technologies that are direct substitutes for pumped hydro storage.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	3	The existence of related initiatives reduces the likelihood of success directly attributable to ARENA's funding. Furthermore, these projects are feasibility studies that may never reach commercial deployment.
	Magnitude – what is the potential magnitude of the impact on affordability?	5	Pumped hydro deployment has the potential to have a significant affordability impact through efficient long term storage and firmed VRE output. There is no clear technological substitute for pumped hydro storage for providing long term storage[100] at this stage and so the potential of pumped hydro in general is substantial. The feasibility studies funded by ARENA are on the most significant pumped hydro

[97] Office of the Prime Minister of Australia, *Historic Snowy 2.0 Plan Approved*, Media Release, 26 Feb 2019 (available at https://www.pm.gov.au/media/historic-snowy-20-plan-approved, accessed 28 May 2019).

[98] Department of the Environment and Energy, Underwriting New Generation Investments program (available at https://www.energy.gov.au/government-priorities/energy-supply/underwriting-new-generation-investments-program, accessed 27 June 2019).

[99] NSW Government, *NSW Emerging Energy Program Guidelines*, February 2019, p 5; and Department for Energy and Mining, *Grid Scale Storage Fund: Investment Guidelines*, (available at http://www.energymining.sa.gov.au/clean_energy_transition/grid_scale_storage_fund, accessed 27 June 2019).

[100] We define long term storage as being over 24 hours in duration. This view has been influenced through engagement with key stakeholders in the pumped hydro space.

			projects in the country.
	Timing – what is the timing of the potential impact on affordability?	2	Pumped hydro storage will not be a required on a significant scale until there is a material amount of retirement of coal-fired generation which is expected to occur over the late 2020s and early 2030s.[101] However, long lead times for these developments mean that initial planning is required in the short term.

A1.3 Pumped hydro - resource assessment

Table A1.5: Details of projects in the pumped hydro – resource assessment group

Organisation	Description	Status	Total funding	Progress
Waratah Power	Impact of small scale hydropower technologies on Australian native fish species	Closed	$613,377	100.00%
The Australian National University	An atlas of Pumped Hydro Energy Storage	Active	$609,000	100.00%
Hydro Tasmania	Battery of the Nation - A concept study of Tasmanian pumped hydro options	Closed	$300,000	100.00%

Table A1.6: Portfolio group evaluation for the pumped hydro – resource assessment group

Overview	Project group summary	Projects that do not provide a technical feasibility assessment of any specific pumped hydro facilities yet do contribute to the wider knowledge base surrounding the deployment. In particular, projects focus on identifying pumped hydro resources and the issues that may arise from pumped hydro deployment. Pumped hydro is currently the cheapest, most mature technology to provide bulk storage.[102]
	Key project group outcomes	• identification of potential pumped hydro sites; and • assessment of potential quality of pumped hydro resources.

[101] AEMO, *Integrated System Plan*, July 2018, p 7.

[102] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

	Current group performance	3	This project group could contribute more towards the body of knowledge surrounding pumped hydro energy storage. The lack of technical, social or economic analysis in this group drives this relatively low performance score.
Technology	What underlying technologies do the projects relate to?		Pumped hydro storage.
	Are the underlying technologies fundamental technologies or enabling technologies?		Fundamental technologies.
	What are the innovation phases of the underlying technologies?		Mature.
Reliability needs	What are the key reliability needs met by the projects?		Resource identification and coordination and firming VRE output.
	How do the projects contribute to meeting each reliability need?		Projects that identify and coordinate the potential sites for pumped hydro facilities, and lead to the eventual selection of the most viable sites will ensure that the deployment of this technology will be optimised.
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	See explanation for the pumped hydro – feasibility assessment group.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?		The principal affordability impacts are expected to be: • reduced capital and operating costs for pumped hydro facilities; • reduced costs of alternative investment owing to more efficient selection of resources; and • reduced costs of capital owing to lower uncertainty for investors in pumped hydro technology.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		See explanation for the pumped hydro – feasibility assessment group.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	1	These resource assessments do not provide technical or economic analysis which reduces the likelihood of a direct affordability impact.

	Magnitude – what is the potential magnitude of the impact on affordability?	2	these projects do not engage with the coordination or feasibility issues so would have a minimal affordability impact.
	Timing – what is the timing of the potential impact on affordability?	2	See explanation for the pumped hydro – feasibility assessment group.

A1.4 Solar thermal - feasibility assessment

Table A1.7: Details of projects in the solar thermal – feasibility assessment group

Organisation	Description	Status	Total funding	Progress
CSIRO	Australian Solar Thermal Research Initiative (ASTRI)	Active	$35,208,747	64.00%
Adelaide University	Integrating Concentrating Solar Thermal Energy into the Bayer Alumina Process	Under variation	$4,490,752	42.86%
RATCH - Australia Corporation Limited	Feasibility study into conversion of Collinsville power station	Terminated	$2,150,000	100.00%
Abengoa Solar Power Australia Pty Ltd	Perenjori solar tower feasibility study	Closed	$436,144	100.00%
Alinta Holdings	Port Augusta solar thermal feasibility study	Terminated	$408,100	100.00%
Australian Solar Thermal Energy Association Ltd	Potential network benefits of solar thermal in the NEM	Closed	$179,965	100.00%

Table A1.8: Portfolio group evaluation for the solar thermal – feasibility assessment group

Overview	Project group summary	Projects focused on assessing the commercial and technical viability of specific solar thermal projects and locations. Two out of three specific locations were deemed to be not commercially viable. Another project in this group explored the network benefits associated with locating concentrating solar thermal plants at constrained network locations. The Adelaide University project has attempted to advance the use of solar thermal for industrial energy generation.

	Key project group outcomes		• understanding the technical and commercial feasibility of solar thermal plants and how these plants may provide niche services in high energy use industries such as mining and mineral processing; and • contribute to the body of knowledge surrounding the implementation of solar thermal plants.
	Current group performance	4	These feasibility assessments have all provided significant learnings that shape the understanding of the role of solar thermal in the future electricity sector. In addition, the Australian Solar Thermal Research Initiative (ASTRI) has historically met and exceeded milestone deliverables in relation to their research impact.[103] The alumina processing project has successfully developed a use for solar thermal in the material processing sector.[104]
Technology	What underlying technologies do the projects relate to?	Solar energy.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental technologies.	
	What are the innovation phases of the underlying technologies?	Immature.	
Reliability needs	What are the key reliability needs met by the projects?	Dispatchable renewable generation, commercial models and frequency and system strength.	
	How do the projects contribute to meeting each reliability need?	Solar thermal plants generate high temperatures that can be utilised with molten-salt storage technology. As this technology becomes more efficient, storage costs will decrease, and hence solar thermal would become a more viable dispatchable renewable energy option. Concentrating solar thermal plants aid in the provision of energy with low cost storage.[105] These plants may operate as an intermediate or peaking source of generation.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Dispatchable renewable generation and frequency and system strength support are less immediate needs, so there is relatively more time to understand the integration of solar thermal into the grid.

[103] ASTRI, *ARENA Mid-term review: Review panel report*, July 2016, p 3.

[104] The University of Adelaide, *Solar thermal in the Bayer alumina process*, 20 June 2019 (available at https://www.adelaide.edu.au/cet/solar-alumina/, accessed 17 August 2019);

[105] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced operating costs for solar thermal facilities (or heat energy intense industries); • reduced system security costs; • reduced costs of capital owing to lower uncertainty for investors in solar thermal technology; and • reduced transmission augmentation costs.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	The South Australian government supported the Aurora Solar Thermal project. This project has subsequently failed to reach financial close.[106] Australia's most significant effort to introduce utility scale solar thermal came via the Solar Flagships program by the Australian Government in May 2009. One solar thermal project was chosen, and the Australian Government committed $464 million to the project that ultimately did not reach financial close. [107] Currently, solar thermal faces competition from pumped hydro energy storage and bioenergy in meeting future requirement for dispatchable renewable generation. These technologies are more mature and at this point, appear likely to be more cost effective technologies capable of providing similar services. This could reduce the incentive for proponents to explore solar thermal as an option for dispatchable renewable generation. The NSW and SA governments have established funding programs to incentivise the deployment of additional energy storage technologies.[108] The Queensland government provided $7 million from the Queensland Renewable Energy Fund for the Cloncurry Solar Thermal Project.[109]	
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	2	More rapid cost reduction pathways must be demonstrated for solar thermal to become more broadly adopted as a mainstream energy generation technology.[110] The solar thermal industry does not demonstrate sufficient knowledge on the market

[106] ABC News, *Port Augusta solar thermal power plant scrapped after failing to secure finance*, 5 April 2019 (available at https://www.abc.net.au/news/2019-04-05/solar-thermal-plant-will-not-go-ahead-in-port-augusta/10973948, accessed 6 June 2019); and Jeanes Holland and Associates, *Australian Concentrating Solar Thermal Roadmap*, August 2018, p 17.

[107] Jeanes Holland and Associates, *Australian Concentrating Solar Thermal Roadmap*, August 2018, p 22.

[108] NSW Government, *NSW Emerging Energy Program Guidelines*, February 2019, p 5; and Department for Energy and Mining, *Grid Scale Storage Fund: Investment Guidelines*, (available at http://www.energymining.sa.gov.au/clean_energy_transition/grid_scale_storage_fund, accessed 27 June 2019).

[109] Queensland Government, *The Queensland Renewable Energy Plan*, June 2009, p 13.

[110] ASTRI, *ASTRI Milestone 12 Report*, June 2017, pp 9 and 22; and ASTRI, *Public Dissemination Report*, June 2019, pp 3 and 24.

			need for solar thermal – a problem which is exacerbated by the commercial failure of multiple demonstration projects.[111]
	Magnitude – what is the potential magnitude of the impact on affordability?	3	Solar thermal does have a role to play in providing dispatchable energy, however we view this to be in fringe-of-grid locations and for medium term storage. Furthermore, the positive results from the alumina project are confined to a specific industry and are unlikely to be present across the entire network. Solar thermal could avoid augmentation costs of the network in areas with strong solar resources. The greatest value of solar thermal energy is providing dispatchable energy in fringe-of-grid areas, which represents a small segment of the network.[112] In addition, there are other technologies within the portfolio that are more mature and cost effective that can provide these services. Solar thermal is likely to only be competitive in the market storage of less than 20 hours.[113] This storage duration is helpful in load-shifting scenarios, however this technology experiences a diminished ability to provide dispatchable generation in the event of a prolonged solar drought. We view the ability to provide storage beyond 24 hours as valuable for effective dispatchable generation in the future and since solar thermal cannot provide this duration, we view the potential magnitude of the affordability impact to be marginally lower than other technology options such as pumped hydro.
	Timing – what is the timing of the potential impact on affordability?	2	Long term.

A1.5 Solar thermal – demonstration

Table A1.9: Details of projects in the solar thermal – demonstration group

Organisation	Description	Status	Total funding	Progress

[111] ASTRI, *ARENA Mid-term review: Review panel report*, 31 July 2016, p 4.

[112] IT Power, *Inquiry into the Government's Direct Action Plan: Submission 76 – Attachment 1*, May 2012, p 154; and ASTRI, *ASTRI Milestone 12 Report*, June 2017, p 9.

[113] ITP, *Comparison of dispatchable renewable electricity options*, October 2018, p xi.

Jemalong Pty Ltd (Vast Solar)	Jemalong demonstration	Under variation	$39,500,000	30.00%
Vast Solar	Concentrating solar thermal pilot plant	Active	$9,896,960	94.74%
CS Energy Ltd	Kogan Creek	Terminated	$6,403,000	100.00%

Table A1.10: Portfolio group evaluation for the solar thermal – demonstration group

Overview	Project group summary	Projects addressing the issues associated with implementing commercial scale solar thermal generation and connecting these plants to the grid.	
	Key project group outcomes	Assess the readiness and commercialisation for solar thermal technology; understand financing requirements of solar thermal; and improve public and regulatory body understanding and awareness of solar thermal.	
	Current group performance	2	Significant technical issues have resulted in significant delays to the pilot plant project. In addition, the Kogan Creek project was terminated due to technical and contractual difficulties and the resultant negative impact on the project's commercial prospects.[114] This results in a low performance rating. The mid-term review of ASTRI in 2016 recommend that priority be given to "projects that move CSTP technology through scale-up demonstrations to deployment",[115] a suggestion that has been attempted but ultimately unsuccessful to date.
Technology	What underlying technologies do the projects relate to?	Solar energy.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental technologies.	
	What are the innovation phases of the underlying technologies?	Immature.	
Reliability needs	What are the key reliability needs met by the projects?	Dispatchable renewable generation, commercial models and frequency and system strength support.	
	How do the projects contribute to meeting each reliability need?	See explanation for the solar thermal – feasibility assessment group.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	See explanation for the solar thermal – feasibility assessment group.

[114] CS Energy, *Solar Boost Project*, September 2016, p 16.

[115] ASTRI, *ARENA Mid-term review: Review panel report*, July 2016, p 4.

Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?		See explanation for the solar thermal – feasibility assessment group.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		See explanation for the solar thermal – feasibility assessment group.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	3	There is a lot of uncertainty surrounding the commercial feasibility of solar thermal, however these demonstrations are moving towards resolving this. It is for this reason that we view solar thermal demonstration projects to be more likely to have an affordability impact than solar thermal feasibility assessments.
	Magnitude – what is the potential magnitude of the impact on affordability?	3	See explanation for the solar thermal – feasibility assessment group.
	Timing – what is the timing of the potential impact on affordability?	2	See explanation for the solar thermal – feasibility assessment group.

A1.6 Bioenergy

Table A1.11: Details of projects in the bioenergy group

Organisation	Description	Status	Total funding	Progress
Macquarie Capital (Australia) Limited	Kwinana Waste to Energy	Active	$23,000,000	16.67%
Renergi Pty Ltd	Advanced biomass gasification technology	Closed	$4,160,542	100.00%
Rural Industries Research & Development Corporation	The Australian biomass for bioenergy assessment project	Active	$3,160,669	53.85%
Re.Group Pty Ltd	Mt Piper Hybrid W2E Project - Financial Investment Decision Study	Active	$1,000,000	25.00%
Re.Group Pty Ltd	Mt Piper Hybrid W2E Project – Feasibility Study	Closed	$400,000	100.00%

Table A1.12: Portfolio group evaluation for the bioenergy group

Overview	Project group summary	This broad category contains projects that are quite distinct. One project compiles a central and national database of biomass resources, while another project contributed technical knowledge towards building the first full scale biomass gasifier. The three remaining projects are focused

			on waste to energy projects.
	Key project group outcomes		• demonstrate an ability to convert waste resources to provide energy; • identify potential biomass resources across Australia; and • demonstration of technical knowledge that contributes to the use of bioenergy facilities.
	Current group performance	3	The viability of bioenergy technology has been demonstrated, yet ARENA has not attempted to explore how this technology can be expanded further. The waste to energy projects are currently too early in the deployment phase for any significant learnings to have been realised. The feasibility study at Mt Piper has been completed, however the second phase has only completed one quarter of its milestones, while the Kwinana project has completed less than one fifth of its milestones.
Technology	What underlying technologies do the projects relate to?		Biomass gasification.
	Are the underlying technologies fundamental technologies or enabling technologies?		Fundamental technologies.
	What are the innovation phases of the underlying technologies?		The technology for producing biofuels is relatively immature, however the technology for burning fuels is relatively more mature.
Reliability needs	What are the key reliability needs met by the projects?		Dispatchable renewable generation, resource identification and coordination, commercial models and frequency and system strength support.
	How do the projects contribute to meeting each reliability need?		Bioenergy is ideal for small scale applications due to its compact design; it provides an option for dispatchable renewable generation and is already in use in remote areas.[116] Waste to energy can provide renewable baseload energy generation through an augmentation of existing power stations or through stand-alone facilities. The use of waste to energy facilities reduces the risks associated with the price and supply of coal to conventional coal fired generators by providing a reliable, dispatchable renewable energy source.[117]

[116] ARENA, *An advanced biomass gasification technology: Project results*, p 4; and Clean Energy Council, *Australian bioenergy roadmap*, September 2008, p 21.

[117] Energy Australia, *Mt Piper Energy Recovery Project: Knowledge Sharing Report*, March 2018, p 6.

	How well aligned are the projects innovation phases with the timing of reliability needs?	5	The biomass gasification technology is relatively immature at the commercial scale and meets reliability needs that are less immediate needs. Similarly, Kwinana waste to energy is expected to be opened in 2021, which may result in commercial maturity in the next 5 to 10 years, when the need for dispatchable renewable generation will be most pressing.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?		The principal affordability impacts are expected to be: • reduced operating costs for biomass generation facilities; and • reduced transmission augmentation costs in remote locations.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		The NSW and SA governments have established funding programs to incentivise the deployment of additional energy storage technologies.[118] Certain bioenergy projects may be eligible for these programs. Pumped hydro energy storage and solar thermal plants can provide dispatchable renewable energy to compete with bioenergy.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	3	Biomass and waste to energy technology must be shown to be effective and affordable before it can be used at a commercial level.
	Magnitude – what is the potential magnitude of the impact on affordability?	2	We view bioenergy as being most applicable in rural and fringe-of-grid areas that are proximal to biomass resources which reduces the potential for widespread affordability impacts. However, this may not be the case if the widespread use of waste to energy is proven to be viable through the projects at Kwinana and Mt Piper We are aware that many international reports claim that bioenergy is the "overlooked giant of renewables".[119] We find little Australian policy evidence to suggest that bioenergy will be widely adopted in the NEM.
	Timing – what is the timing of the potential impact on affordability?	2	Long term.

[118] NSW Government, *NSW Emerging Energy Program Guidelines*, February 2019, p 5; and Department for Energy and Mining, *Grid Scale Storage Fund: Investment Guidelines*, (available at http://www.energymining.sa.gov.au/clean_energy_transition/grid_scale_storage_fund, accessed 27 June 2019).

[119] International Energy Agency, *Renewables analysis and forecasts 2018 to 2023*, October 2018, p 13.

A1.7 Geothermal

Table A1.13: Details of projects in the geothermal group

Organisation	Description	Status	Total funding	Progress
Geodynamics Limited	Cooper Basin Enhanced Geothermal Systems Heat and Power Development	Terminated	$32,750,000	100.00%
Petratherm Ltd	Demonstration of geothermal heat exchanger in hot sedimentary rocks	Terminated	$4,200,000	100.00%
National ICT Australia Limited	Data fusion and machine learning for geothermal target exploration and characterisation	Closed	$1,878,210	100.00%
Adelaide University	Reservoir quality in sedimentary geothermal resources	Closed	$1,250,000	100.00%
Climate KIC Australia	Residential Heat Pump Study	Active	$500,000	25.00%
PICAC	Narre Warren - Net Zero Energy Facility	Active	$500,000	33.33%
Adelaide University	Geothermal structural permeability map	Closed	$450,000	100.00%

Table A1.14: Portfolio group evaluation for the geothermal group

Overview	Project group summary	Projects focused on improving the procedure by which geothermal resources are identified and explored, the development of geothermal technology and how these innovative technologic advancements may become commercially viable.	
	Key project group outcomes	• demonstration of a commercial scale thermal energy ground source heat pump (GSHP) to provide heating and cooling in residential developments; • national database and map of critical Australian basins to better exploit geothermal resources; and • development of information and software that can be used to improve exploration, discovery and characterisation of geothermal resources.	
	Current group performance	2	While there are some potential future learnings from current projects, the past learnings from this group suggest that producing geothermal electricity is not financially viable in Australia. In addition, the two currently active projects in this group have not sufficiently progressed for key learnings to be obtained. The lack of commerciality is due to three main factors:

			• identifying suitable resources; • producing flows of hot fluid from reservoirs at a high rate; and • overcoming significant up-front capital costs and the cost of transmission from remote locations. The completed projects that were not terminated have learnings that are focused on the exploration and extraction of geothermal resources. The data fusion project aimed "to fundamentally alter the approach to geothermal exploration",[120] the reservoir quality project sought "to develop a workflow for assessing geothermal reservoir quality ahead of drilling"[121] and then was able "to refine the process of detecting fracture and fault populations".[122]
Technology	What underlying technologies do the projects relate to?	Geothermal.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental technologies.	
	What are the innovation phases of the underlying technologies?	Immature.	
Reliability needs	What are the key reliability needs met by the projects?	Resource identification and coordination, dispatchable renewable generation, and commercial models.	
	How do the projects contribute to meeting each reliability need?	Geothermal energy generation extracts high temperature fluids from the Earth whose extreme heat allows for a diverse range of potential energy uses. Geothermal energy production uses this renewable source of heat to generate dispatchable energy. As the better resources are identified and the extraction of these fluids becomes more efficient and effective, geothermal would become a more viable dispatchable renewable energy option.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Dispatchable renewable is a less immediate reliability need, so there is relatively more time to understand the role for geothermal in the electricity network. However, the distinct lack of progressive learnings suggests that geothermal may

[120] NICTA, *Data fusion and machine learning for geothermal target exploration and characterisation*, June 2014, p 5.

[121] Institute for Mineral and Energy Resources, *ARENA Measure: Reservoir quality in sedimentary geothermal resources*, December 2014, p 2.

[122] ARENA, *ARENA structural permeability map project: project results and lessons learnt*, March 2018, p 6.

			never mature as a technology.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced operating costs for geothermal facilities; • reduced costs of capital owing to lower uncertainty for investors in geothermal technology; and • reduced transmission augmentation costs.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	Currently, geothermal faces competition from pumped hydro energy storage, solar thermal and bioenergy to provide dispatchable renewable energy, which are more mature and cost effective technologies. This could reduce the incentive for proponents to explore geothermal as an option for dispatchable renewable generation	
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	1	Geothermal technology must prove itself as an economic option for renewable dispatchable generation. Given that completed projects have only limited learnings regarding the first step of the geothermal production process, there is little evidence to suggest that geothermal will ever become commercially viable in Australia.
	Magnitude – what is the potential magnitude of the impact on affordability?	1	In addition to the capital costs of a geothermal plant, there must also be substantial investment in transmission infrastructure to the remote locations at which these plants can be located. This implies that any affordability impact would be negated by these additional transmission costs. However, the two currently active projects – residential heat pumps and the net zero energy facility – are focused on residential applications which would have the ability to provide larger affordability impacts. As stated above, it is too early in these projects to determine how the learnings will impact the affordability impact of geothermal.
	Timing – what is the timing of the potential impact on affordability?	2	Long term.

A1.8 DER - technical

Table A1.15: Details of projects in the DER - technical group

Organisation	Description	Status	Total funding	Progress
NOJA Power	NOJA switchgear	Active	$5,000,000	36.36%
UTS	Networks renewed	Active	$1,599,340	100.00%
The University of Queensland	Increasing visibility of distribution networks to maximise PV penetration levels	Active	$1,190,000	75.00%
University of New South Wales	Addressing barriers to efficient renewable integration	Active	$982,000	16.67%
Ecoult	UltraBattery distributed PV support and remote area power supply	Closed	$583,780	100.00%
United Energy	Peak demand reduction using solar and storage	Active	$450,000	83.33%

Table A1.16: Portfolio group evaluation for the DER - technical group

Overview	Project group summary	Projects that focus on the connection of renewables – particularly storage and solar PV – to the network by the use of new technologies such as smart inverters. Effective integration of DER into wholesale markets could unlock potential for broader suite of participants to provide energy services, increasing the supply of low-emission energy.[123]	
	Key project group outcomes	• address frequency control issues; • advance new dynamic response technologies; and • ability to use of real-time monitoring data to control consumer devices.	
	Current group performance	4	The successful development and testing of these new technologies indicate that the current performance is reasonably high.
Technology	What underlying technologies do the projects relate to?	Solar PV, batteries, smart inverters.	
	Are the underlying technologies fundamental technologies	Enabling technologies.	

[123] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

	or enabling technologies?		
	What are the innovation phases of the underlying technologies?		Immature coordination approaches of mature technologies.
Reliability needs	What are the key reliability needs met by the projects?		Generator connection and integration and storage integration.
	How do the projects contribute to meeting each reliability need?		DER technical projects are focused on small scale renewable technologies (mainly solar and storage), which both firms VRE output and integrates storage. Furthermore, DER technology contributes to frequency control solutions and system security knowledge. In particular, this group could add to the knowledge of optimising dynamic system response, synchronous condensers and batteries.
	How well aligned are the projects innovation phases with the timing of reliability needs?	2	These reliability needs are reasonably immediate, and these technical projects are currently active. The results and findings may not be reached quickly enough in order to meet the needs at the appropriate time.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?		The principal affordability impacts are expected to be: • reduced system security costs; • reduced connection costs of solar PV and batteries; • reduced operating costs; and • reduced substation augmentation costs (reduced capex). Results from this group indicate that reduced network augmentation costs are the most significant expected affordability impacts.[124]
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		The Demand Management Incentive Scheme (DMIS) and Demand Management Innovation Allowance (DMIA) are alternative and potentially complementary sources of funding for projects aimed at demand management, including management of DER to reduce peak demand.[125] The DMIA provides funding for DNSPs to undertake research and development for the purpose of developing ideas that could form projects under the DMIS. Projects undertaken under the DMIA have requirements for reporting to share project learnings with the sector.

[124] United Energy, *ARENA Knowledge Sharing Plan – Residential Solar and Storage Program Interim Report*, February 2018, p 12.

[125] AER, *Final decision: Demand management incentive scheme and innovation allowance – Fact sheet*, 14 December 2017.

	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	3	These projects are focused on resolving technical issues and advancing the technical side of DER rather than the commercial viability. As such, these projects do not contribute to the largest barrier to widespread DER adoption. The DMIA is an alternative source of funding for similar projects undertaken by DNSPs.
	Magnitude – what is the potential magnitude of the impact on affordability?	3	The affordability benefits in the DER space lie in resolving commerciality issues rather than technical issues. There are still some material benefits from technical advancement.
	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

A1.9 DER - commercial and social

Table A1.17: Details of projects in the DER - commercial and social group

Organisation	Description	Status	Total funding	Progress
Simply Energy Solutions	Simply Energy Virtual Power Plant (VPPX) Project	Under variation	$7,700,000	50.00%
AGL Energy Ltd	AGL Virtual Power Plant	Under variation	$5,000,000	40.00%
Electricity Generation and Retail Corporation	Solar and storage trial at Alkimos Beach residential development	Active	$3,310,000	70.00%
The Australian National University	Consumer Energy Systems Providing Cost-Effective Grid Support	Active	$2,895,951	83.33%
Horizon Power	Horizon Power Business Model Pilot Project - Phase 1	Active	$1,920,000	42.86%
NEV POWER Pty Ltd	Narara Ecovillage Smart Grid	Active	$1,158,660	66.67%
SAPN	Advanced VPP grid integration	Active	$1,032,000	25.00%
CSIRO	Virtual Power Station 2	Closed	$850,000	100.00%
GreenSync	Decentralised Energy Exchange (deX)	Closed	$450,000	100.00%
Reposit Power	Intelligent storage for Australia's grid	Closed	$445,666	100.00%
ENWAVE Energy Pty Ltd	Delivering higher renewable penetration in new land and housing developments through off grid microgrids	Closed	$442,400	100.00%

The University of technology Sydney	Facilitating local use of system charging and virtual net metering	Closed	$402,760	100.00%
Ergon Energy Queensland Pty Ltd	Trialling a new residential solar PV and battery model	Closed	$400,000	100.00%
LO3 Energy Pty Ltd	Latrobe Valley Microgrid - Feasibility Assessment	Active	$370,000	50.00%
Australian PV Institute	A Distributed Energy Market: Consumer and Utility Interest, and the Regulatory Requirements	Closed	$173,550	100.00%
AGL	AGL Virtual Trial of Peer-to-Peer Energy Trading	Closed	$120,000	100.00%

Table A1.18: Portfolio group evaluation for the DER - commercial and social group

Overview	Project group summary	Projects that test the commercial viability of delivering high penetration distributed renewable energy. Projects in this group are demonstrating new applications and coordination of distributed energy resources (DER). Increased uptake of DER options is driving the need for more fundamental regulatory changes. Effective integration of DER into wholesale markets could unlock potential for a broader suite of participants to provide energy services, increasing the supply of low-emission energy.[126] Successful projects from this group will demonstrate an ability to coordinate multiple parties, such as DNSPs, retailers, consumers and intermediaries to utilise the DER technology to its full potential.	
	Key project group outcomes	• resolve the technical and cost barriers of distributed energy systems; • develop avenues to provide incentives for dispatchable generators to operate at peak times; • understanding of the optimal sizing and operation of distributed generators; • establish markets for the trading of available energy (P2P); • the regulatory environment is a key barrier to the emergence of these technologies; and • demonstrate the role of VPP in enabling higher penetration of renewables.	
	Current group performance	3	The regulatory issues surrounding the rights and obligations of DER market participants have prohibited the successful commercialisation of many of these projects. This has negatively impacted the performance of this group.
Technology	What underlying technologies do the projects relate to?	Solar PV, batteries, micro-grids, embedded networks, internet of things, inverters, P2P trading,	

[126] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

		VPP.
	Are the underlying technologies fundamental technologies or enabling technologies?	Enabling technologies.
	What are the innovation phases of the underlying technologies?	Immature coordination approaches of mature technologies.
Reliability needs	What are the key reliability needs met by the projects?	Commercial models, regulatory barriers and community engagement.
	How do the projects contribute to meeting each reliability need?	These commercial and business models focus on increasing the value of DER technology to the user, which results in an increase in the value of renewable generation. This will firm VRE output and enable better coordination of VRE devices and a smoothing out of intermittent energy generation. In addition, this group explores the capability for VPPs to provide FCAS and other network services.[127]
	How well aligned are the projects innovation phases with the timing of reliability needs?	2 — These reliability needs are reasonably immediate however the findings of the projects suggest that the benefits of DER are unlikely to be met under current market conditions. P2P trading needs to move from virtual to real-world trials before regulatory changes can be recommended. Many projects reported positive results but cited regulatory barriers that would need to be addressed before the benefits could be realised.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • avoided duplication of infrastructure; • reduced system security costs; • reduced cost of capital; • reduced operating costs; and • reduced planning costs.
	Related initiatives – to what extent are other initiatives in	The Demand Management Incentive Scheme (DMIS) and Demand Management Innovation

[127] Simply Energy, *VPPx: ARENA Stage 1 Knowledge Sharing Report*, February 2019, p 5.

	the electricity sector likely to deliver similar affordability impacts?	Allowance (DMIA) are alternative and potentially complementary sources of funding for projects aimed at demand management, including management of DER to reduce peak demand.[128] The DMIA provides funding for DNSPs to undertake research and development for the purpose of developing ideas that could form projects under the DMIS. Projects undertaken under the DMIA have requirements for reporting to share project learnings with the sector.	
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	4	There have been calls to change the regulatory framework for DER since 2013.[129] This is an ongoing issue in the uptake of solar PV that reduces the likelihood of maximum affordability impacts. The closed projects have provided the foundation for the wide range of active projects. For instance, the CSIRO's VPS2 project commenced in 2014 and concluded that "smart deployment of hardware and software to effectively control devices enabling greater deployment of solar power" is a viable alternative to network augmentation.[130] This early work has provided a launching board for the exploration of these innovative new enabling technologies.
	Magnitude – what is the potential magnitude of the impact on affordability?	5	AGL's findings into peer-to-peer trading has demonstrated that there are financial benefits for both consumers and prosumers.[131] In the Alkimos Beach project, significant affordability impacts have been documented for participating consumers.[132] The trial deployment of automated DER control on Bruny Island saw a reduction of diesel requirements by one third over the trial period.[133] We expect that the magnitude of affordability impacts will increase with the increasing uptake of small scale battery and solar PV systems driven by a reduction in their costs.
	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

[128] AER*, Final decision: Demand management incentive scheme and innovation allowance – Fact sheet*, 14 December 2017.

[129] Australian PV Institute, *A distributed energy market: Consumer and utility interest and the regulatory requirements*, August 2013.

[130] CSIRO, Virtual Power Station 2.0: Project results and lessons learnt, January 2018, p 14.

[131] AGL, *Peer-to-peer distributed ledger technology assessment*, October 2017, p 9.

[132] Synergy, *Alkimos Beach energy trial*, (available at https://www.synergy.net.au/Our-energy/Future-energy/Alkimos-Beach-Energy-Storage-Trial, accessed 28 May 2019).

[133] CONSORT, *Project Final Report: Network-Aware Coordination (NAC)*, April 2019, p3.

A1.10 Demand management

Table A1.19: Details of projects in the demand management group

Organisation	Description	Status	Total funding	Progress
EnergyAustralia	Energy Australia Demand Response (VIC and SA)	Active	$6,929,000	42.86%
United Energy	United Energy Distribution Demand Response	Active	$5,762,000	42.86%
EnerNOC	EnerNOC Demand Response (VIC)	Active	$5,400,000	42.86%
AGL Energy	AGL Energy Application for Demand Response in (NSW)	Active	$2,624,019	42.86%
Planet Innovation	ZenHQ Virtual Power Plant 2013 delivering rapid distributed demand response and accelerating renewables integration through automated HVAC control	Active	$1,878,404	42.86%
EnerNOC	EnerNOC Demand Response (NSW)	Active	$1,800,000	42.86%
EnergyAustralia	Energy Australia Demand Response (NSW)	Active	$1,435,500	42.86%
Flow Power	Flow Power's Energy Under Control Demand Response	Active	$1,318,250	42.86%
Powershop Australia	Behavioural demand response program (Powershop DR Program)	Active	$1,113,269	31.25%
Intercast & Forge	Intercast and Forge Demand Response	Active	$323,654	42.86%

Table A1.20: Portfolio group evaluation for the demand management group

Overview	Project group summary	The demand management group is focused on the development of new and innovative technologies to provide demand response options for consumers and prosumers. This enables more penetration of renewables, ie, firms VRE output, by adapting demand management systems to new solar PV connections and output. There is also an emphasis on developing approaches and models to ensure effective demand response across the grid. Demand response allows demand with the highest value to be supplied with high reliability and encourages participation in AEMO's Reliability and Emergency Reserve Trader (RERT) scheme.

	Key project group outcomes		• use of new and innovative technologies to provide demand response options for consumers and prosumers; • enable more penetration of renewables by adapting demand management systems to new solar PV connections and output; and • increase the reach of AEMO's RERT system to large and small scale consumers.
	Current group performance	3	This group has performed well. We anticipate a significant amount of progress that remains to be achieved in this group.
Technology	What underlying technologies do the projects relate to?		Demand management, DER.
	Are the underlying technologies fundamental technologies or enabling technologies?		Enabling technologies.
	What are the innovation phases of the underlying technologies?		Mid-maturity.
Reliability needs	What are the key reliability needs met by the projects?		Firming VRE output, demand management, commercial models and regulatory barriers.
	How do the projects contribute to meeting each reliability need?		Demand management devices capture real time network data and provide protection, control and monitoring solutions to facilitate the connection of renewables to the grid.
	How well aligned are the projects innovation phases with the timing of reliability needs?	4	These reliability needs will become pressing in the medium term, and these projects are in the deployment stage. These types of projects do not seem to be facing the same type of regulatory issues that other DER technologies are facing.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?		The principal affordability impacts are expected to be: • reduced costs of connection; • reduced system security costs; • reduced transmission augmentation costs; and • reduced planning costs.
	Related initiatives – to what extent are other initiatives in		The Demand Management Incentive Scheme (DMIS) and Demand Management Innovation

	the electricity sector likely to deliver similar affordability impacts?		Allowance (DMIA) are alternative and potentially complementary sources of funding for projects aimed at demand management, including management of DER to reduce peak demand.[134] The DMIA provides funding for DNSPs to undertake research and development for the purpose of developing ideas that could form projects under the DMIS. Projects undertaken under the DMIA have requirements for reporting to share project learnings with the sector.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	5	Projects have already demonstrated substantial demand response capability: • 12 MW from United Energy;[135] • exceeded the planned 5 MW in Year 1 from Flow Power;[136] and • 10 MW from Intercast and Forge, as well as $600,000 in consumption savings over a three month period.[137]
	Magnitude – what is the potential magnitude of the impact on affordability?	4	Large potential benefit, however, since the technology is only utilised during rare peak events these affordability impacts are not realised on a regular basis.
	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

A1.11 SAPS

Table A1.21: Details of projects in the SAPS group

Organisation	Description	Status	Total funding	Progress
Indigenous Essential Services	Northern Territory solar energy transformation program	Active	$31,500,000	76.47%
EDL Group Operations	Coober Pedy renewable diesel hybrid	Active	$18,410,879	53.33%

[134] AER, *Final decision: Demand management incentive scheme and innovation allowance – Fact sheet*, 14 December 2017.

[135] United Energy, *Demand response project performance report – Milestone 3*, June 2018, p 5.

[136] Flow Power, *Project performance report – Energy under control*, November 2018, p 4.

[137] Australian Financial Review, *Powershop, United Energy, metal foundry sign up for demand response trial*, 11 October 2017 (available at https://www.afr.com/business/energy/electricity/powershop-united-energy-metal-foundry-sign-up-for-demand-response-trial-20171011-gyydxu, accessed 28 May 2019).

Hydro Electric Corporation	King Island renewable energy integration project	Closed	$5,950,450	100.00%
Hydro Tasmania	Flinders Island hybrid energy hub	Active	$5,500,000	75.00%
Lord Howe Island Board	Lord Howe Island hybrid renewable energy system	Active	$4,500,000	46.15%
Hydro Tasmania	Rottnest Island Water and Renewable Energy Nexus (WREN) project	Active	$3,758,010	87.50%
Carnegie Wave Energy	Garden Island Microgrid Project	Active	$2,500,000	50.00%
Laing O'Rourke Australia	Re-deployable Hybrid Power (Sunshift)	Closed	$451,986	100.00%
Ergon Energy	Doomadgee Solar Project	Terminated	$145,084	100.00%

Table A1.22: Portfolio group evaluation for the SAPS group

Overview	Project group summary	SAPS utilise and combine multiple well established renewable energy sources with innovative hybrid, storage and enabling technologies. SAPS enable increased renewable contribution whilst maintaining the same level of renewable penetration by shifting the load in line with the renewable output, which requires adequate storage integration.	
	Key project group outcomes	• innovative enabling, storage and coordination of mature renewable technologies; • demonstration of significant diesel replacement in fringe-of-grid locations; • demonstration of > 60 per cent renewable energy share on island locations; • utilising desalination plants as a viable use of surplus VRE output; and • addressing the knowledge gap surrounding system stabilisation in a low inertia/high renewables scenario.	
	Current group performance	5	The number of projects, their level of funding and amount of tangible learnings from this group indicate a strong performance towards meeting reliability needs.
Technology	What underlying technologies do the projects relate to?	Hybrid control system, diesel, biodiesel, wind, solar, battery, dynamic resistor, flywheel, switchgear, demand management.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Enabling technologies.	

	What are the innovation phases of the underlying technologies?	Mature.	
Reliability needs	What are the key reliability needs met by the projects?	SAPS renewable integration, generator connection and integration and storage integration.	
	How do the projects contribute to meeting each reliability need?	Projects contribute directly to the growing knowledge surrounding SAPS through targeted demonstration projects that will become large scale commercial deployments. A functioning SAPS will require efficient integration of generators (diesel back-up) and storage options (batteries).	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	These are primarily Phase 2 needs, although in some fringe-of-grid locations these are immediate needs. These projects are focused on addressing issues in these fringe-of-grid of locations.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced plant capital costs; • reduced plant operating costs; • avoided transmission augmentation and connection costs; • reduced planning costs; and • reduced costs of capital.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	The AEMC's recent review of the regulatory frameworks for SAPS will reduce the barriers for the rollout of SAPS by DNSPs in specific areas of the NEM.[138] However, we believe that there is still scope for ARENA to promote renewables integration in SAPS.	
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	5	Success of completed projects such as SunShift and King Island suggest that further rollout of these systems is likely.
	Magnitude – what is the potential magnitude of the impact on affordability?	3	Significant impact for fringe-of-grid and remote locations but these represent a small proportion of total costs in the sector.[139]

[138] AEMC, *Review of the Regulatory Framework for Stand-alone Power Systems – Priority 1 – Final Report*, 30 May 2019.

[139] ARENA, *Stand-alone power systems review issues paper*, October 2018, p 2.

	Timing – what is the timing of the potential impact on affordability?	5	The affordability impacts are likely to be in the next 2-10 years.

A1.12 Large scale coordination

Table A1.23: Details of projects in the large scale coordination group

Organisation	Description	Status	Total funding	Progress
Kennedy Energy Park	Kennedy Energy Park	Active	$18,000,000	100.00%
The Trustee for the NSW Electricity Networks Operations Trust & TransGrid	TransGrid New England Renewable Hub (REHub) Feasibility Study	Closed	$450,000	100.00%

Table A1.24: Portfolio group evaluation for the large scale coordination group

Overview	Project group summary		Projects that focus on testing solutions for coordinating co-located transmission-connected variable renewable generation, storage, loads and other technologies to enable efficient connection and management of renewable generation.
	Key project group outcomes		• understanding of the technical, regulatory and commercial barriers to establishing and operating renewable energy hubs; and • contributing to a body of knowledge likely to lead to avoidance of connection costs of new generation and transmission infrastructure.
	Current group performance	2	The group is experiencing extensive barriers to deployment that are a material hinderance to the performance of this group.
Technology	What underlying technologies do the projects relate to?		Battery storage, wind, solar PV.
	Are the underlying technologies fundamental technologies or enabling technologies?		Fundamental technologies.

	What are the innovation phases of the underlying technologies?	Mature.	
Reliability needs	What are the key reliability needs met by the projects?	Firming VRE output, regulatory barriers, community engagement, generator connection and integration and storage integration.	
	How do the projects contribute to meeting each reliability need?	Projects that investigate the coordination of generation and storage through renewable energy hubs contribute to the sector's understanding of integration of storage with VRE technologies to produce firmed VRE output and the islanding of parts of the grid with high penetrations of VRE. In addition, the projects contribute to the understanding of regulatory barriers to and commercial models for establishing and operating renewable energy hubs.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	1	Coordination of large scale generation, storage and load through renewable energy hubs meets reliability needs that are primarily pressing at moderate levels of VRE penetration. It follows that the knowledge created by these studies is important currently and will be increasingly so in the near future. The sector would likely benefit from additional understanding around coordination of large scale assets and load.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced connection costs for new generation; • avoided transmission augmentation costs; • reduced costs of capital owing to lower uncertainty for investors in large scale generation; and • reduced losses through more efficient integration with load and storage.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	The AEMC COGATI review may also contribute to the sectors understanding of renewable energy hubs. In addition, state government funding and policies, eg, NSW transmission strategy, may encourage the establishment of renewable energy hubs and so further contribute to the body of knowledge. Understanding of the coordination of large scale assets has been hindered by regulatory barriers that the COGATI review will hopefully address. We note that the initial COGATI publication refers to Kennedy Energy Park as a project that may encounter connection issues.[140]	

[140] AEMC, *Coordination of generation and transmission investment*, Final report, December 2018, table 8.1, pp 106-107.

	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	2	The issues with renewable energy hubs are primarily commercial in nature,[141] which ARENA may not be able to help resolve.
	Magnitude – what is the potential magnitude of the impact on affordability?	5	Efficient connection and management of large scale renewable generation has the potential to have significant impact on the affordability of the transition to renewable energy.
	Timing – what is the timing of the potential impact on affordability?	5	The affordability impacts are likely to be in the next 2-10 years.

A1.13 Battery integration

Table A1.25: Details of projects in the battery integration group

Organisation	Description	Status	Total funding	Progress
GESS Devco Pty Ltd	Gannawarra Energy Storage System	Active	$22,735,000	45.45%
ElectraNet	ESCRI Phase 2	Under variation	$12,000,000	42.86%
Lake Bonney BESS Pty Ltd	Lake Bonney BESS	Active	$5,000,000	36.36%
Spotless Sustainability Services	Ballarat Terminal Station BESS	Active	$2,265,000	75.00%
AGL	ESCRI Phase 1	Closed	$445,846	100.00%

Table A1.26: Portfolio group evaluation for the battery integration group

Overview	Project group summary	Battery storage is a mature technology; however, there is limited practical experience with the application of grid scale storage devices. The need for knowledge surrounding the application of large batteries is evidenced by the progression of the ESCRI project to demonstration despite poor business case results. The need for large scale storage integration is now,

[141] TransGrid, *Renewable energy hub knowledge sharing report*, June 2016, p 3.

		however the understanding of the implementation has not sufficiently progressed. Large scale battery storage has a wide range of applicable uses for reliability, including:[142] • stand-alone large scale operation and participation in wholesale energy markets; • paired operation with a large scale generator to smooth generation; • managing voltage over long power lines; and • operation embedded in network infrastructure.

	Key project group outcomes	• improved understanding of technical issues of battery integration, ie, devices must meet generator performance standards and implement islanding capability if required;
		• seeking to address barriers for accessing emerging battery revenue streams such as:[143]
		  ○ reducing the Causer Pays factor (CPF) and curtailment of co-located generators;
		  ○ networking loading control;
		  ○ synthetic inertia;
		  ○ Fast Frequency Response; and
		  ○ adhering to the South Australian Government's System Integrity Protection Scheme (SIPS).
		• identifying regulatory issues, ie, many of the regulatory issues remain unsolved such as:[144]
		  ○ hybrid registration of assets as a generator and a load;
		  ○ lack of long term certainty for Marginal Loss Factors (MLFs);
		  ○ augmentation of existing markets to enable services provided by batteries to be monetised;
		  ○ the allocation of operating expenditure of the battery under the owner's cost allocation methodology;
		  ○ any payments to be made under the Transmission Use of System (TUOS) rules; and
		  ○ the connection to the transmission system and the transparency of proposed

[142] ARENA, *Reliability focus area strategy – Overview: Attachment A*, February 2018, slide 11.

[143] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, pp 7, 10 & 16.

[144] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, pp 29-30; and ElectraNet, *ESCRI-SA project summary report*, May 2018, pp 16-20.

			grid connected projects.
	Current group performance	4	The ESCRI, Ballarat and Gannawarra systems are all currently operational, with the Lake Bonney system awaiting connection approval.[145] The difficulties with the connection approval has delayed the Lake Bonney project by over 6 months.[146] The regulatory barriers that restrict the integration of battery storage are significant, indicating that further development of the body of knowledge would assist in realising any affordability impacts. It is noted that the regulation of ESCRI will not set a precedence for future projects. The AER has stated that ESCRI will not set a precedent for:[147] • cost allocation; • registration; and • TUOS charges. However, the Ballarat Energy Storage System did establish an important precedent for stand-alone battery-based energy storage assets.[148] Large scale battery storage projects have demonstrated an ability to harness the following revenue streams:[149] • FCAS; • FFR; and • fringe-of-grid islanding (ESCRI only).[150] These initial projects in the large scale battery storage space have encountered commercial, technical and regulatory issues that have restricted the development of

[145] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 5.

[146] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 10.

[147] ElectraNet, *ESCRI-SA project summary report*, May 2018, pp 16-20.

[148] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 6.

[149] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 12-17.

[150] ElectraNet, *ESCRI-SA project summary report*, May 2018, p 35-36.

			the market to its full potential.[151]
Technology	What underlying technologies do the projects relate to?	Battery storage.	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental technology.	
	What are the innovation phases of the underlying technologies?	Mature.	
Reliability needs	What are the key reliability needs met by the projects?	Firming VRE output, storage integration, regulatory barriers, commercial models and frequency and system strength support.	
	How do the projects contribute to meeting each reliability need?	Projects that investigate the role of medium-to-large scale energy storage contribute to the sector's ability to integrate further renewable energy generation through firming VRE output and providing frequency management services. These projects also investigate the regulatory barriers to and commercial models for large scale battery use in the electricity network with the aim of identifying ways in which these barriers could be overcome.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	2	The integration of battery storage is a pressing reliability need in parts of the NEM. However, the knowledge surrounding proper large scale storage has not sufficiently progressed to meet these needs. The learnings from ESCRI indicate that there is general support towards gaining real world experience with the application of a transmission level battery.[152] However, regulation in the NEM needs to evolve to allow further development in this area.[153]
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	Improved understanding of the integration of battery storage and the technical performance of the technology improves affordability of delivering reliable electricity through: • reduced energy costs through energy arbitrage; • reduced operating costs for energy storage through improved technical performance; • lower cost supply of frequency control ancillary services;	

[151] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 33.
[152] ElectraNet, *ESCRI-SA: Phase 1 – General project report*, December 2015, p 15.
[153] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 33.

			• more efficient utilisation of renewable energy through reducing spillage of energy; • reduced unserved energy through enabling islanding; and • reduced costs of capital owing to lower uncertainty for investors in battery technology. A large scale battery may potentially utilise the following revenue streams:[154] • taking advantage of energy arbitrage opportunities; • providing system ancillary services; • synthetic inertia; • providing load for co-located generators; and • providing network support services.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		A number of sources of funding other than ARENA for battery storage projects currently exist. These include: • South Australia Grid Scale Storage Fund; and • Victorian government (who also contributed to the Ballarat Energy Storage System) It follows that the body of knowledge regarding battery storage may develop in the absence of additional funding from ARENA.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	4	Unlike larger storage options, batteries can be placed at specific locations to target specific issues which implies a high likelihood of an affordability impact.
	Magnitude – what is the potential magnitude of the impact on affordability?	4	Efficient storage can unlock more affordable large scale renewable generation. However, the impact on affordability is not highly significant since battery storage only has limited impact owing to its short storage duration.
	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

[154] Aurecon, *Large scale battery storage knowledge sharing report*, July 2019, p 7; and ElectraNet, *ESCRI-SA Milestone 1: Regulatory overview,* November 2014, p 5.

A1.14 Industry coordination

Table A1.27: Details of projects in the industry coordination group

Organisation	Description	Status	Total funding	Progress
National ICT Australia	AREMI	Active	$2,197,150	92.31%
University of Technology Sydney	Mapping network opportunities for renewable energy	Closed	$538,240	100.00%
Regional Development Australia	Establishing a SERREE Industry Cluster	Closed	$488,870	100.00%
Clean Energy Council	Future proofing in Australia's Electricity Distribution Industry	Closed	$426,498	100.00%
Clean Energy Council	Analysis of the value of commercial scale embedded generation and storage to distributed networks	Closed	$408,377	100.00%
MEMSI	Pathways to Deep Decarbonisation in 2050	Closed	$305,893	100.00%
Clean Energy Council	Clean Energy Australia: Annual Renewable Energy Industry Analysis	Closed	$112,441	100.00%

Table A1.28: Portfolio group evaluation for the industry coordination group

Overview	Project group summary	Projects in this group do not align with a particular fundamental or enabling technology, but rather focus on the sector wide coordination of renewables integration in the electricity network. This project group is primarily focused on resource identification and coordination, as well as knowledge sharing and developing areas of expertise. This group ranges from market reports to data mapping programs and pathway reports.	
	Key project group outcomes	• knowledge creation and sharing to assist the transition towards a more sophisticated grid; and • assess the potential for renewable generation to defer network augmentation.	
	Current group performance	5	These projects contribute to a growing body of knowledge that would otherwise not exist.
Technology	What underlying technologies do the projects relate to?	Coordination of renewables across the sector.	

	Are the underlying technologies fundamental technologies or enabling technologies?	Enabling.	
	What are the innovation phases of the underlying technologies?	N/A	
Reliability needs	What are the key reliability needs met by the projects?	Resource identification and coordination, regulatory barriers and community engagement.	
	How do the projects contribute to meeting each reliability need?	This project group focuses on knowledge sharing and collaboration which results in increased sector wide coordination and enhances the knowledge around regulatory issues and community engagement. For example, the Clean Energy Council's future proofing report calls for improved access to information on battery energy storage technologies and an improvement of regulatory codes relevant to batteries.[155]	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Coordination issues are currently of concern and the learnings from these projects can be implemented immediately.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced planning costs; and • reduced transmission augmentation costs.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	We are currently unaware of any related initiatives in this space.	
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	3	These projects are likely to have direct impacts on sector wide coordination, however whether these materialise into affordability impacts remains to be seen.
	Magnitude – what is the potential magnitude of the impact on affordability?	2	Any affordability impacts would likely be indirect and therefore smaller in magnitude. For instance, reports such as the Deep Decarbonisation Pathways by MEMSI outline the transition towards a high share VRE system yet do not implement strategies or technologies that directly contribute to attaining the associated benefits.

[155] Clean Energy Council, *Energy storage safety: Responsible installation, use and disposal of domestic and small commercial systems*, November 2015, p 65.

	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

A1.15 Industry tools

Table A1.29: Details of projects in the industry tools group

Organisation	Description	Status	Total funding	Progress
University of Melbourne	Achieving cost-effective abatement from Australian electricity generation	Closed	$1,030,069	100.00%
The University of South Australia	Maximising solar PV with phase change thermal energy storage.	Active	$995,290	100.00%
IT Power Australia	Open source grid integration model for the NEM	Active	$624,940	45.45%
Frontier Carbon	Toolkit for community renewable energy funding and financing	Closed	$467,717	100.00%

Table A1.30: Portfolio group evaluation for the industry tools group

Overview	Project group summary		This group contains projects that address industry coordination and commerciality issues through the development of specific toolkits which are publicly available. This group seeks to provide engaged stakeholders with the ability to further develop the level of public knowledge regarding renewable energy in the NEM.
	Key project group outcomes		• development of dynamic tools focusing on analysing the network with higher renewable shares; • demonstrate the capacity for thermal storage technology to become commercially viable in demand management and solar PV settings; • easy to understand financial models for groups looking to invest in renewables; and • understand of pathway towards a low carbon NEM.
	Current group performance	5	These projects contribute to a growing body of knowledge that would otherwise not

			exist.
Technology	What underlying technologies do the projects relate to?	N/A	
	Are the underlying technologies fundamental technologies or enabling technologies?	N/A	
	What are the innovation phases of the underlying technologies?	N/A	
Reliability needs	What are the key reliability needs met by the projects?	Toolkits and models, commercial models.	
	How do the projects contribute to meeting each reliability need?	Provides sector wide models of community financing, higher renewable share pathways and grid integration which leads to sector wide contributions and coordination.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Learnings from these projects are currently being realised and can be implemented immediately.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced planning costs; and • reduced transmission augmentation costs.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	We are currently unaware of any related initiatives in this space.	
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	4	Commercial and financial modelling will likely have an impact on affordability.
	Magnitude – what is the potential magnitude of the impact on affordability?	2	Without a direct impact on fundamental or enabling technologies, these projects will likely only have indirect coordination impacts, which would be small. For instance, The University of South Australia's thermal storage project could be deployed with up to 23 per cent of the energy used in the NEM,[156] but would then need further DER

[156] University of South Australia, *Maximising solar PV with phase change thermal energy storage: Project results and lessons learnt*, February 2019, p 7.

			coordination or demand management systems to unlock the potential of the affordability impacts. The University of Melbourne's cost-effective abatement modelling project found that the uptake of DER is only optimal when network augmentation costs are high.[157] Modelling capabilities such as this are useful from a coordination standpoint, however, do not directly impact the magnitude of the affordability impact.
	Timing – what is the timing of the potential impact on affordability?	4	Short term.

A1.16 Community engagement

Table A1.31: Details of projects in the community engagement group

Organisation	Description	Status	Total funding	Progress
Curtin University	White Gum Valley: Increasing the uptake of solar PV, using energy storage, monitoring and grid-connected micro-grids within strata.	Active	$900,375	77.78%
MEMSI	Monash University and ClimateWorks low carbon study	Closed	$390,000	100.00%
University of Technology Sydney	National Community Energy Strategy: Catalysing community renewables in Australia	Closed	$330,280	100.00%
Monica Oliphant Research	Model for community-owned solar	Closed	$15,000	100.00%

Table A1.32: Portfolio group evaluation for the community engagement group

Overview	Project group summary	This group contains projects which produced tangible knowledge with the clear aim of increasing community engagement surrounding renewable energy integration. Increased community engagement would allow for more coordinated approaches to medium scale renewable energy generation.

[157] ARENA, *Achieving cost-effective abatement from Australian electricity generation: Project results and lessons learnt*, March 2017, p 3.

	Key project group outcomes	• unlocking the benefits of solar PV and battery storage in residential developments; • development of the national Community Energy Strategy; and • creation of a replicable, successful community owned solar model.	
	Current group performance	5	These projects contribute to a growing body of knowledge that would otherwise not exist.
Technology	What underlying technologies do the projects relate to?	N/A	
	Are the underlying technologies fundamental technologies or enabling technologies?	N/A	
	What are the innovation phases of the underlying technologies?	N/A	
Reliability needs	What are the key reliability needs met by the projects?	Community engagement.	
	How do the projects contribute to meeting each reliability need?	Enhance the communication and sharing of information and experience necessary to build the ability of industry and the community to support rapid development and integration of renewable energy at the community level.	
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Learnings from these projects are currently being realised and can be implemented immediately.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?	The principal affordability impacts are expected to be: • reduced planning costs; and • reduced transmission augmentation costs.	
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?	We are currently unaware of any related initiatives in this space.	

	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	1	The model for community owned solar developed in this group requires further testing and the White Gum Valley model for strata asset ownership has only been tested over four developments within one location.[158] As such, further work will be required in order to provide significant demonstrable learnings. This results in a low likelihood of affordability impact.
	Magnitude – what is the potential magnitude of the impact on affordability?	2	Indirect impacts only.
	Timing – what is the timing of the potential impact on affordability?	4	Short term.

A1.17 Weather and data prediction

Table A1.33: Details of projects in the weather and data prediction group

Organisation	Description	Status	Total funding	Progress
Geoscience Australia	Solar resource mapping project	Closed	$4,976,364	100.00%
CSIRO	Australian Solar Energy Forecasting System (ASEFS) - Phase 1	Closed	$3,089,000	100.00%
The Australian National University	Real-time Operational Distributed PV Simulations for DNSPs	Active	$1,198,359	66.67%
The University of Western Australia	Cost reduction through location and configuration optimization of wave energy	Active	$994,198	54.55%
CSIRO	Integrated solar radiation data sources over Australia	Closed	$678,551	100.00%
The Australian National University	A Robotic Vision System for Automatic Inspection and Evaluation of Solar Plant Infrastructure	Active	$596,183	57.14%
Fulcrum3D Pty Ltd	Predicting cloud movements to maximise solar PV use	Closed	$545,559	100.00%
University of New South Wales	Forecasting and Characterising Grid Connected Solar Energy and Developing Synergies with Wind	Closed	$470,284	100.00%
Centre for Appropriate Technologies Projects	Analysis of variations in instantaneous weather effects	Closed	$242,625	100.00%

[158] Monica Oliphant Research, *Lessons Learnt Report: Community Owned Solar (Stage 2)*, June 2013, pp 1-2; and Curtin University, *Citizen Utilities: Unlocking Australian Strata Developments to the benefits of solar and battery storage innovations*, October 2018, p 9.

Australian Solar Thermal Energy Association Ltd	Improving the accessibility of the System Advisor Model for Australian concentrating solar power	Closed	$73,500	100.00%

Table A1.34: Portfolio group evaluation for the weather and data prediction group

Overview	Project group summary	The overall aim of these projects is to provide sufficient accuracy in solar pattern forecasting to enable power generation control systems to respond adequately ahead of time to the variability of energy generation.	
	Key project group outcomes	• use of robotic technology to monitor dust collection at solar plants; • forecasting wave energy output and optimizing the design of wave energy plants; • improved data resources to enhance the understanding of the uncertainty surrounding solar power output variability; • development of the solar irradiation database; • creation of the Australian Solar Energy Forecasting System (ASEFS); • creation of the Australian Solar Energy Information System (ASEIS); and • commercial use of a cloud prediction technology at solar plants.	
	Current group performance	5	These projects contribute to a growing body of knowledge that would otherwise not exist.
Technology	What underlying technologies do the projects relate to?	Solar	
	Are the underlying technologies fundamental technologies or enabling technologies?	Fundamental	
	What are the innovation phases of the underlying technologies?	N/A	
Reliability needs	What are the key reliability needs met by the projects?	Forecasting, resource identification and coordination and toolkits and models.	
	How do the projects contribute to meeting each reliability	Reduces the lack of understanding about the variability of renewable energy sources, which is	

	need?		a key barrier to commercial development of large scale renewable technology.
	How well aligned are the projects innovation phases with the timing of reliability needs?	5	Weather prediction is currently a concern and the learnings from these projects can be implemented immediately.
Affordability impacts	**Mechanism** – what aspects of affordability will the projects potentially impact on?		The principal affordability impacts are expected to be: • reduced plant capital and operating costs; • reduced cost of capital; • reduced planning costs; and • reduced transmission augmentation costs.
	Related initiatives – to what extent are other initiatives in the electricity sector likely to deliver similar affordability impacts?		We are currently unaware of any related initiatives in this space.
	Likelihood – what is the likelihood that ARENA's involvement will influence the impact on affordability?	5	There have been successful, commercial third-party sales and installation of the CloudCAM system from this project group.[159] In addition, the Australian Solar Energy Forecasting System (ASEFS) was successfully developed and implemented at AEMO.[160] The characterisation of grid connected solar developed methods that have been modified to perform distributed forecasting within the ASEFS.[161]
	Magnitude – what is the potential magnitude of the impact on affordability?	3	Impacts will only be felt in the solar industry, or the wave industry, and the benefit will be through a marginal improvement in forecasting.
	Timing – what is the timing of the potential impact on affordability?	5	Immediate.

[159] ARENA, *Cloud detection and prediction for maximising solar PV utilisation in off-grid hybrid power systems: Final report: project results and lessons learnt*, November 2016, p 3.

[160] ARENA, *Australian Solar Energy Forecasting System: Final report: project results and lessons learnt*, May 2016, p 39.

[161] ARENA, *Forecasting and Characterising Grid Connected Solar Energy and Developing Synergies with Wind: Project results and lessons learnt*, p 22.

A1.18 Excluded projects

Table A1.35: Details of excluded projects

Organisation	Description	Status	Total funding	Progress
Goldwind Australia Pty Ltd	Demonstration of a high penetration renewable microgrid on an operating mine in WA	Pending	$13,500,000	0.00%
Local Government Association of Queensland	Bore drilling programme for Geothermal energy projects in regional Queensland	Approved	$3,641,000	0.00%
PGWF Pty Ltd	Fringe of Grid Battery Microgrid for Port Gregory Wind & Solar Farm	Under variation	$3,000,000	0.00%
Indigenous Essential Services Pty Ltd	Daly River Solar Research Project	Closed	$462,358	100.00%
CSIRO	Development of an off-grid renewable energy island solution to reduce diesel dependency using mine dewatering	Under variation	$432,000	0.00%
Laing O'Rourke Australia Pty Ltd	Re-deployable Hybrid Power Feasibility Study	Closed	$410,309	100.00%
C2K Pty Ltd	Development of an off-grid renewable energy island solution to reduce diesel dependency using mine dewatering	Closed	$300,000	100.00%
CSIRO	Mission Innovation Smart Grids Innovation Challenge	Active	$113,750	25.00%
Australian Solar Energy Society Ltd	Australian Energy Storage Council Research and Report	Closed	$45,000	100.00%
South Australian Govt DMITRE	Solar Storage Diesel Hybrid System at Marree	Terminated	$0	0.00%
SPARK Infrastructure SA (No 1) Pty Limited	SAPN Fort Largs Community Microgrid	Terminated	$0	0.00%
Balfour Beatty	Project Harvest	Terminated	$0	100.00%
Geodynamics Limited	Hunter Valley Geothermal Project	Terminated	$0	0.00%
Petratherm Ltd	Construction of a 7 MW EGS hot fractured rock demonstration plant	Terminated	$0	0.00%
Petratherm Ltd	Paralana Engineered geothermal Systems Project	Terminated	$0	0.00%

A2. Comparison of project group definitions and ARENA taxonomy

In this appendix we present the results of our comparison of our project group definitions and the classification of projects under ARENA's taxonomy.

Figure A2.1 shows the distribution of projects within the reliability portfolio based on their ARENA project type classification. The figure shows that the majority of projects are classified as 'Other study'. The remainder of the portfolio comprises of 'Demonstration', 'Research and development' or 'Deployment' projects, with no projects classified as 'Feasibility study'.

Figure A2.1: Distribution of ARENA project types for reliability portfolio projects

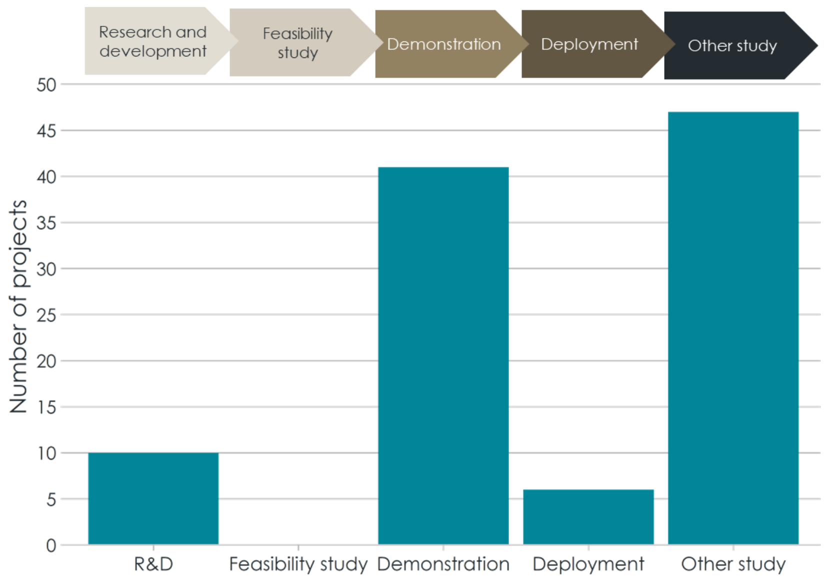


Figure A2.2 shows the distribution of projects within the reliability portfolio by ARENA technology categories. The vast majority of projects are classified as 'Enabling', ie, relate to technologies that are enabling or otherwise contribute to knowledge relating to enabling other technologies. The remainder of projects are distributed across 'Bioenergy', 'Geothermal', 'Hybrid, 'Solar' and 'Storage' categories.

Figure A2.2: Distribution of ARENA technology categories for reliability portfolio projects

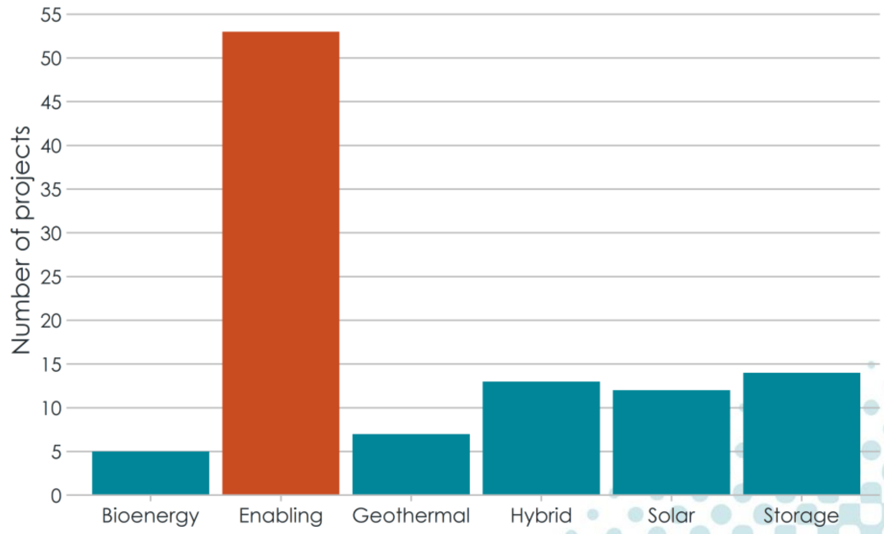
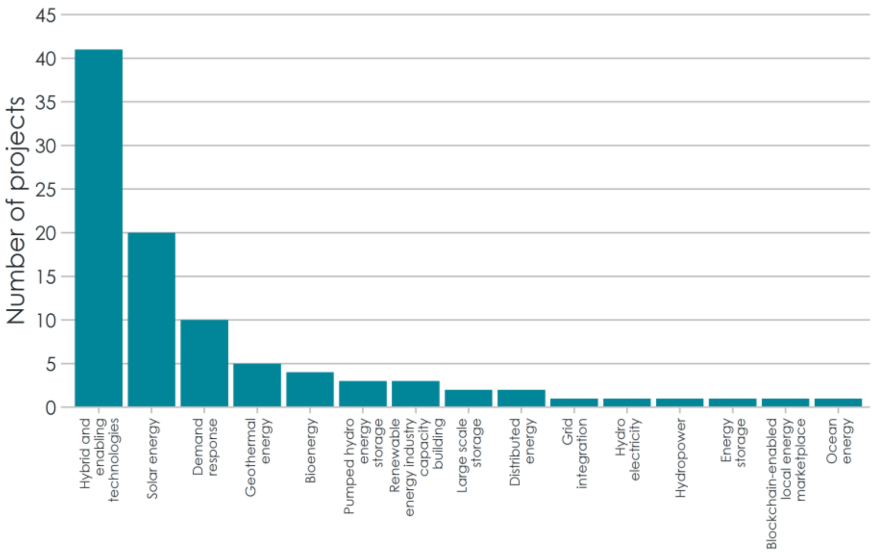


Figure A2.3 shows the distribution of projects across the ARENA technology tags applied on the ARENA website. Under this classification, the majority of projects are classified as ‘Hybrid and enabling technologies’. We note that pumped hydro projects are distributed across three categories, namely ‘Pumped hydro energy storage’, ‘Hydro electricity’ and ‘Hydropower’.

Figure A2.3: Distribution of ARENA technology groups for reliability portfolio projects

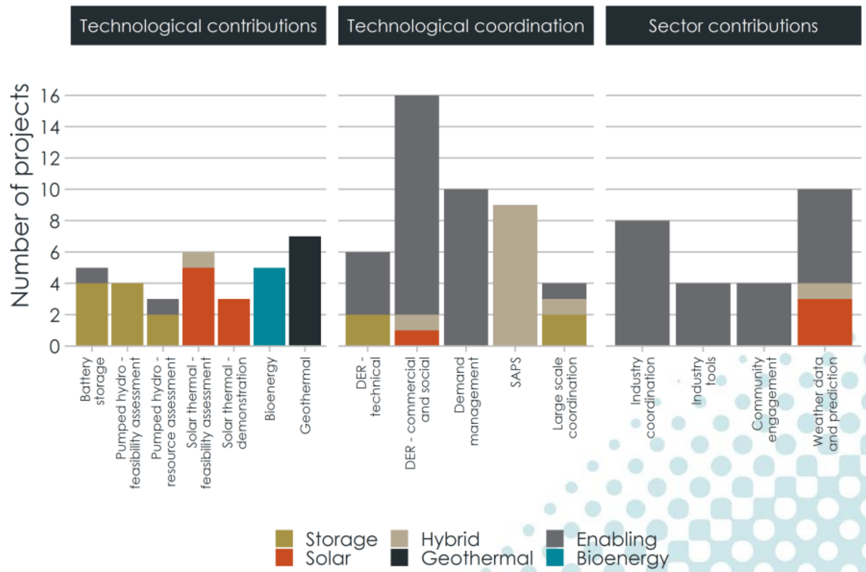


Note: 8 projects were not allocated a category.

Figure A2.4 shows the mapping of the project groups developed for the purpose of this analysis and the ARENA technology categories referenced in Figure A2.2. We make the following observations:

- the projects in the ‘Sector contributions’ category are predominately ’Enabling’ projects;
- the projects in the ‘Technological coordination’ category are a mix of ‘Enabling’ and ‘Hybrid’, with four projects classified as ‘Storage’ and one project classified as ‘Solar’; and
- the projects in the ‘Technological contributions’ category are principally a mix technology specific projects, ie, ‘Bioenergy’, ‘Geothermal’, ‘Solar’ and ‘Storage’, with one ‘Hybrid’ and two ‘Enabling’ projects.

Figure A2.4: Distribution of projects across project groups and ARENA technology categories



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