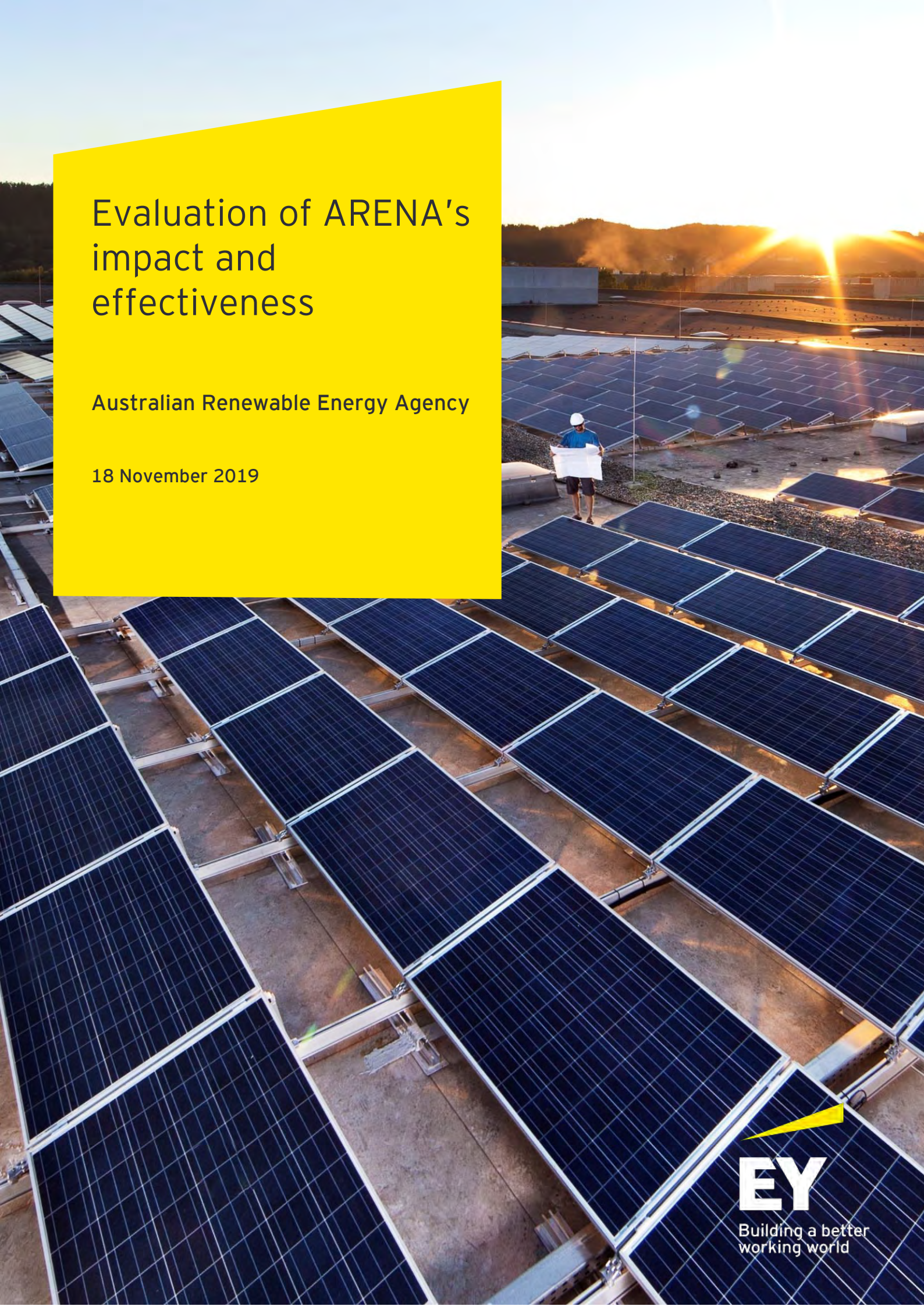
Evaluation of ARENA's impact and effectiveness

Australian Renewable Energy Agency

18 November 2019



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Ernst & Young was engaged on the instructions of the Australian Renewable Energy Agency ("ARENA" or "Client") to undertake an evaluation of ARENA's overall performance in accordance with our contract dated 6 August 2019. More specifically, it provides an analysis of whether ARENA has been effective in improving the competitiveness of renewable energy technologies and increase in the supply of renewable energy in Australia, and what impact ARENA's investments have had on the Australian renewable energy sector, energy transition and the broader Australian economy ("Project").

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Glossary

Abbreviation	Definition
AAP	ARENA Advisory Panel
ABIR	Advanced Biofuels Investment Readiness
ACAP	Australian Centre for Advanced Photovoltaics
AEMC	Australia Energy Market Commission
AEMO	Australian Energy Market Operator
ANAO	Australian National Audit Office
ANU	Australian National University
ARENA	Australian Renewable Energy Agency
ARP	Accelerating Renewables Program
ASI	Australian Solar Institute
ASTRI	Australian Solar Thermal Research Initiative
AUSIAPV	Australian and US Institute for Advanced Photovoltaics
BESS	Ballarat Energy Storage System
CEFC	Clean Energy Finance Corporation
CEIF	Clean Energy Innovation Fund
CEIH	Clean Energy Innovation Hub
CPT	Cloud Predictive Technology
CRI	Commercial Readiness Index
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CST	Concentrating Solar Thermal
DER	Distributed Energy Resources
deX	Distributed Energy Exchange
ESCRI	Energy Storage for Commercial Renewable Integration
EPC	Engineering, Procurement and Construction
EV	Electric Vehicle
EY	Ernst & Young
FCAS	Frequency Control Ancillary Services
FNR	Future Needs Review
FTE	Full Time Equivalent
GESS	Gannawarra Energy Storage System
GHG	Green House Gas
GMS	Grants Management System
KIREIP	King Island Renewable Energy Integration Project
KSP	Knowledge Sharing Plan
LSS	Large Scale Solar
MoU	Memorandum of Understanding
MW	Mega Watt
MWh	Megawatt hour
NAC	Network Aware Coordination

Abbreviation	Definition
NEM	National Electricity Market
NWIS	North West Interconnected System
PERC	Passivated Emitter and Rear Cell
PHES	Pumped Hydro Energy Storage
PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research and Development
RAR	Regional Australia's Renewables
REDP	Renewable Energy Development Program
RERT	Reliability and Emergency Reserve Trader
REVC	Renewable Energy Venture Capital
RMIT	Royal Melbourne Institute of Technology
SAPN	South Australia Power Network
SBCVC	Softbank China Venture Capital
SCRE	Southern Cross Renewable Energy
SIPS	System Integrity Protection Scheme
STC	Small-Scale Technology Certificates
STORES	Short Term Off River pumped hydro Energy Storage
SXVP	Southern Cross Venture Partners
TRL	Technology Readiness Level
UniSA	University of South Australia
UNSW	University of New South Wales
UoA	University of Adelaide
UQ	University of Queensland
UTS	University of Technology Sydney
VPP	Virtual Power Plant

Executive summary

About the evaluation

Ernst & Young (EY) has been commissioned by the Australian Renewable Energy Agency (ARENA) to undertake an evaluation of ARENA's impact and effectiveness. This report presents the findings from an evaluation of the effectiveness of ARENA in achieving its objectives under the *Australian Renewable Energy Agency Act 2011* (the Act).

To undertake this evaluation EY specifically considered:

- The effectiveness of ARENA's activities in achieving its legislated objectives of improved competitiveness of renewable energy technologies and increased supply of renewable energy[1]
- The impact of ARENA's investment on the Australian renewable energy sector, the energy transition and the broader Australian economy
- The efficiency of ARENA's processes (i.e. grants processes, project management and delivery).[2]

The evaluation has applied a 'mixed-methods' approach designed to address 22 evaluation questions[3] and to analyse the various sources of data available.[4] The evaluation has been conducted through desktop research and economic input/output modelling. It has also drawn on the findings of previous evaluations of individual ARENA programs and stakeholder research undertaken by EY Sweeney.[5]

About ARENA

ARENA was established by the Australian Government on 1 July 2012 with the objectives of improving the competitiveness of renewable energy technologies and increasing the supply of renewable energy in Australia[6].

ARENA's purpose is to accelerate Australia's shift to affordable and reliable renewable energy by:

- Providing funding to researchers, developers and business
- Building and supporting networks
- Sharing knowledge, insights and data from funded projects.

To date, ARENA has invested $1.59 billion across 528 projects with a total value of $7 billion and has achieved an average investment leverage of 1:3.4.[7]

[1] Commonwealth of Australia, 2011, 'Australian Renewable Energy Agency Act 2011' see objects and functions.

[2] The efficiency aspect of EY's evaluation was limited to a high-level summary only. We note that the ANAO is currently undertaking a performance audit of grant program management by the Australian Renewable Energy Agency. We understand from ARENA that the ANAO's performance audit is representative of an in-depth efficiency review of ARENA's processes.

[3] Evaluation questions were developed by EY and approved by ARENA, see evaluation plan in Appendix B

[4] A mixed methods approach is a methodology for conducting research and evaluation that involves collecting, analysing and integrating quantitative and qualitative data and information in a single study.

[5] EY Sweeny, 2019, 'Stakeholder Survey'

[6] ARENA website, 2019, 'About 'available at https://arena.gov.au/about/

[7] ARENA, 2019, Grants Management System data accessed 25 September

Key Findings and Recommendations

The key findings for each of the three components of our evaluation and recommendations are summarised below.

Effectiveness evaluation

ARENA's activities have contributed to the achievement of its legislated purpose. This includes improving the competitiveness of renewable energy technologies and increasing the supply of renewable energy in Australia, and better informing industry and government to navigate the energy transition. The effectiveness of ARENA's activities in achieving these outcomes is summarised below.

1. Investment in innovative research and ground-breaking technologies and projects

ARENA has helped accelerate the supply and competitiveness of Australian renewable energy technologies through investments across pre-commercial stages of the innovation chain through the following activities:

- Research and development (R&D)

  To date, ARENA has provided a total of $298 million across 198 projects at the R&D innovation stage. The majority of which has been directed towards solar PV (61%), followed by concentrated solar thermal (18%) and enabling technologies including hydrogen (18%).[8] ARENA has also financially supported the creation of two research centres – the Australian Solar Thermal Research Initiative (ASTRI) and the Australian Centre for Advanced Photovoltaics (ACAP). These initiatives have largely focused on delivering solar thermal and solar photovoltaic efficiency improvements and manufacturing cost reductions.

  The evaluation has found ARENA's R&D funding has resulted in the creation of valuable intellectual property[9], knowledge sharing and the development of important skills which has significantly improved Australia's capability in solar research and contributed to Australia maintaining a world leading position. There is a direct nexus between R&D outcomes and ARENA's legislative obligation to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy.

- Demonstration and deployment

  The primary mechanism by which ARENA funds demonstration and deployment projects is through the Advancing Renewable Program (ARP). In total, ARENA has funded 130 demonstration projects ($622.5m), 42 deployment projects ($560m) and 126 studies ($55.6m).[10]

  The evaluation has found that the ARP has been an effective funding program for ARENA to further its core objectives. Through the ARP ARENA has demonstrated the feasibility of renewable technologies to the market, reduced costs through competition and created a critical mass of vanguard technology deployment to drive market growth.

  ARENA's Large-Scale Solar (LSS) Competitive Round was found to be a particularly effective investment. The offer of grant funding stimulated investment appetite, supporting cost reduction and increased market competition in the large-scale solar sector.

[8] ARENA, 2019, Grants Management System data supplied 25 September

[9] We note that research from the Australian Centre for Advanced Photovoltaics, which is supported by ARENA funding, has been protected by more than 60 patent applications since inception. ARENA, 2016 'ACAP Centre for Advanced Photovoltaics (ACAP) ARENA Mid-Term Report.'

[10] ARENA, 2019, Grants Management System data supplied 25 September

2. Knowledge sharing activities

ARENA's knowledge sharing activities include the development of knowledge sharing reports, commissioned pieces, newsletters, workshops and forums. ARENA also publishes information about its activities, and funded projects in its Knowledge Bank, providing an open-source library of reports, studies and tools that provide guidance and learnings to benefit future renewable energy projects.

The evaluation found that ARENA's knowledge sharing activities have been extensive, effective and valued by market participants[11] to support industry development and/or knowledge dissemination. Over time, ARENA has responded to feedback from market participants to improve and tailor these activities to best meet market needs. In the future ARENA should ensure that knowledge sharing continues to be timely and continue to monitor and report on the results of knowledge sharing activities.

3. Building networks and collaborating

ARENA undertakes extensive collaboration through its funding programs, Memorandums of Understanding (MoUs) and A-Lab events. ARENA fosters collaboration through the facilitation of innovation workshops through the A-Lab program, the research activities undertaken by both ACAP and ASTRI, as well as indirectly bringing together industry and research bodies through the funding of innovative projects.

The effectiveness of ARENA's collaboration is seen through the outcomes it generates. For example, the Short Term Forecasting Round was conceived in an A-Lab session whilst the MoU with the Australian Energy Market Operator (AEMO) has seen the Demand Response Competitive Round and Reliability and Emergency Reserve Trader (RERT) trials commenced. ARENA has also collaborated with the Clean Energy Finance Corporation (CEFC) to administer 12 projects through the Clean Energy Innovation Fund (CEIF). Similarly, the Distributed Energy Integration Program (DEIP) is a collaboration of government agencies, market authorities, industry and consumer associations aimed at maximising the value of Distributed Energy Resources (DER) for all energy users.

The evaluation found that ARENA's activities in building networks and collaborating has helped to build skill and encourage dialogue across the energy sector, which helps to meet the emerging challenges of the energy sector. We recommend ARENA should continue its effective collaboration activities into the future with consideration of commercial sensitivities when partnering with industry.

Outcomes without ARENA and an international comparison of ARENA's interventions

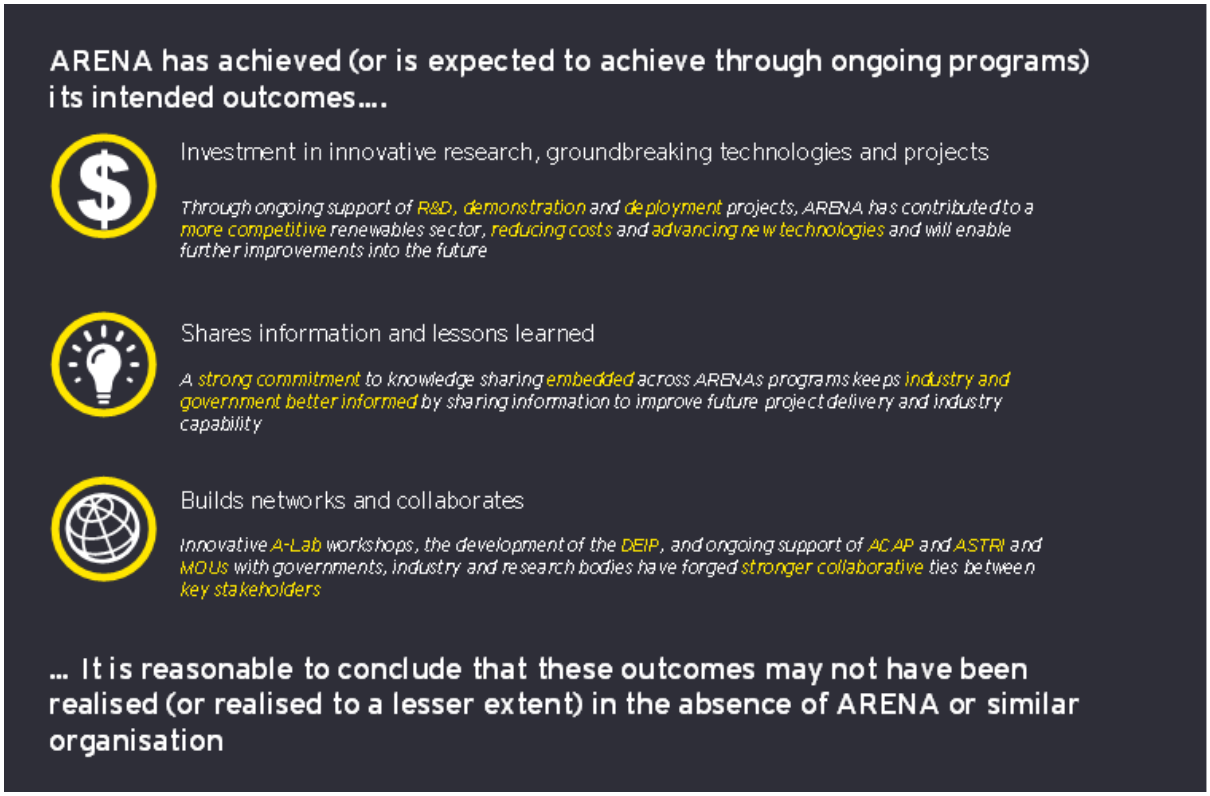
Given the findings of the stakeholder surveys, program and fund evaluations there is sufficient evidence to conclude that without ARENA's support these projects may not have been as successful and that levels of investment in renewable energy in Australia would likely have been lower.

A review of ARENA's approach to funding projects found it was broadly similar in both function and form compared to other contemporaneous grants programs nationally and internationally. This included having characteristics of a competitive multi-stage merit based application process with pre-application processes to screen for project suitability, transparent grants funding guidelines and merit criteria, and competitive evaluation processes which draw upon technical advice as required.

ARENA's 2017-18 annual budget as a proportion of GDP ranks third behind Germany and Japan's comparable clean energy innovation agencies and is among the few international agencies, along with France, Japan and the United States which support all three stages of the innovation

[11] EY Sweeney, 2019, Australian Renewable Energy Agency Stakeholder Research

pathway.[12] While it was not possible to compare outcomes across different grants programs, it is evident that ARENA is largely operating within the bounds of international examples.



Impact evaluation

ARENA supported research and development, commercialisation and deployment projects have contributed towards (or are expected to contribute towards) to seven broader impacts. These impacts are summarised below:

1. Building and enhancing technology pathways and fostering innovation

ARENA's R&D funding has significantly enhanced the technological pathway of:

- Solar PV, improving cost and performance to the point where Australian technology is expected to play an important role in the global PV market over the coming decade
- Flexible renewable energy technologies in Australia, with some technologies such as pumped hydro energy storage (PHES) and batteries expected to be more successful than others
- Enabling technologies[13] expected to enable a greater proportion of renewable energy to integrate into the grid, minimise costs, and mitigate security and reliability risks.

ARENA also identified technologies with barriers to commercialisation that suggest that they are unsuited to the Australian market.

[12] EY analysis - selection of agencies for inclusion in this comparison based on agencies identified by Future Needs Review, ARP Evaluation and the Solar RD&D Refresh as being comparable to ARENA in that they support similar stages of the innovation chain (R&D, demonstration and precommercial deployment) and that belong to OECD countries. Proportion of GDP spend based off 2017 data.

[13] Enabling technologies often take the form of demonstration projects that include distributed ledger technology (i.e. block chain); advanced metering; system modelling, forecasting and data visualisation tools; and control systems.

2. Development of industry capacity and capability building

ARENA funding has contributed to an increase in employment in the Australian renewable energy sector, particularly through large-scale solar construction activity. ABS reported annual direct employment in renewable energy activities in Australia was estimated at 17,640 jobs in 2017-18. This represented a 28 per cent increase from the previous year (2016-17) and represents the highest level of full time equivalent (FTE) employment in renewable energy activities since 2011-12.

While difficult to measure, there is also evidence to suggest ARENA has increased capability across the Australian renewable energy sector by retaining research capability and increasing the number of renewable energy companies.

3. Creating new supply chains

ARENA's deployment projects have contributed to the creation of a domestic large-scale solar and large-scale battery supply chain. A recent evaluation of ARENA's large-scale solar program found the number of developers of accredited solar PV farms increased ~2.5x times, from 12 prior to the Competitive Round to 30 post Competitive Round.[14]

ARENA is also expected to contribute towards the creation of supply chains that support renewable exports (i.e. hydrogen).

4. An electricity system with more renewable energy, reducing costs and emissions

ARENA's activities have contributed to an increase in the supply and diversity of Australia's renewable energy supply, decrease in the cost of renewable energy and reduction in electricity-related emissions. Australia has experienced a 29 per cent growth in renewable generation capacity from the period 2014 to 2018, with the largest increases in generation from solar (both rooftop and large-scale).[15]

At the same time, ARENA's renewable energy projects benefited from significant learning curves resulting in a decrease in capital costs for all renewable technologies in Australia.

Australia has also observed a steady decrease in electricity sector emissions which peaked in 2016. ARENA's recently announced investment priorities also include funding projects to reduce emissions in other emissions intensive sectors (i.e. transport and industrial process). This suggests ARENA may continue to have a future impact on emissions in these sectors.

5. Changes to market rules and frameworks

There are instances where technology is developing quicker than existing rules and market processes. As a result, learnings from ARENA funded projects (e.g. the Demand Response Round and Short Term Forecasting Round) have provided information about the technical and commercial challenges and opportunities created from innovative technologies and business models, informing and in some cases driving regulatory developments.

6. Direct and indirect economic impacts

A previous economic contributions analysis by BIS Oxford Economics found 78 of the 376 projects ARENA supported had a regional focus, which represented just over half of ARENA's total funding at the time. In addition, it found ARENA's regional program activities created 3,863 direct jobs within

[14] EY, 2019, Large-scale Solar Portfolio: Evaluation Report

[15] IRENA, 2019, 'Renewable Energy Statistics'

their local regions; the majority from utility scale solar PV projects (2659 direct jobs) in Queensland, New-South Wales and the Northern Territory.[16]

EY has also conducted its own economic contribution analysis across two case-study regions, Central and North QLD and Central West NSW, to estimate the value added and jobs created as a result of the construction of renewable energy deployment projects:

- The direct economic contribution from the construction of ARENA funded projects to the Central and North QLD economy is $272.6m. The value-added to the region's economy from this investment is estimated at $103.2m. ARENA funded projects were also expected to create 394 additional jobs (on an FTE basis) for the Central & North QLD region during construction.

- The direct economic contribution from the construction of ARENA funded projects to the Central West NSW economy is $254.6m. The value-added to the region's economy from this investment is estimated at $96.4 million. ARENA funded projects were also expected to create 339 additional jobs (on an FTE basis) for the Central West NSW region during construction.

7. Other social benefits and impacts

The monetary value of benefits associated with avoided GHG and air pollution by renewable generation in the United States was estimated to be approximately $7.4 billion in 2013, with benefits quantified in terms of climate change reduction, environmental and human health benefits.[17] The social benefits of wind and solar have been estimated to range from $USD40/MWh to as high as $USD100/MWh of generated electricity in the United States.[18]

Australia's annual renewable generation has grown steadily to reach almost 45,000GWh in 2017-18.[19] No analysis has been undertaken in Australia to estimate the social benefits associated with avoided GHG and air pollution by renewable energy. However, adopting the US estimates of the social benefits of wind and solar generation suggests that the 11,000GWh increase in Australian renewable energy generation since 2014 may yield an estimate of between $636m and $1.6 billion in additional environmental and social benefits.[20]

It is reasonable to conclude that ARENA has made an impact on increasing Australia's renewable energy generation and has contributed towards a proportion of the additional environmental and social benefits.

Attribution of intended impacts and unintended consequences

While there are multiple variables that ultimately influence the achievement of these impacts, international data on the supply and installation cost of renewable energy suggest the magnitude of change in Australia was greater than in other countries over the past decade since ARENA's inception, implying there were country specific factors in Australia that contributed. This is further supported by ARENA's investment leverage ratios, and independent stakeholder research which suggest ARENA has contributed to (or is expected to contribute to) its impacts to a large extent.

This report also considered whether ARENA's activities had caused unintended consequences. Very few instances of unintended consequences were reported, and where they were reported ARENA funded programs were not necessarily causing unintended consequences but rather exposed broader market problems that it is well placed to assist in solving.

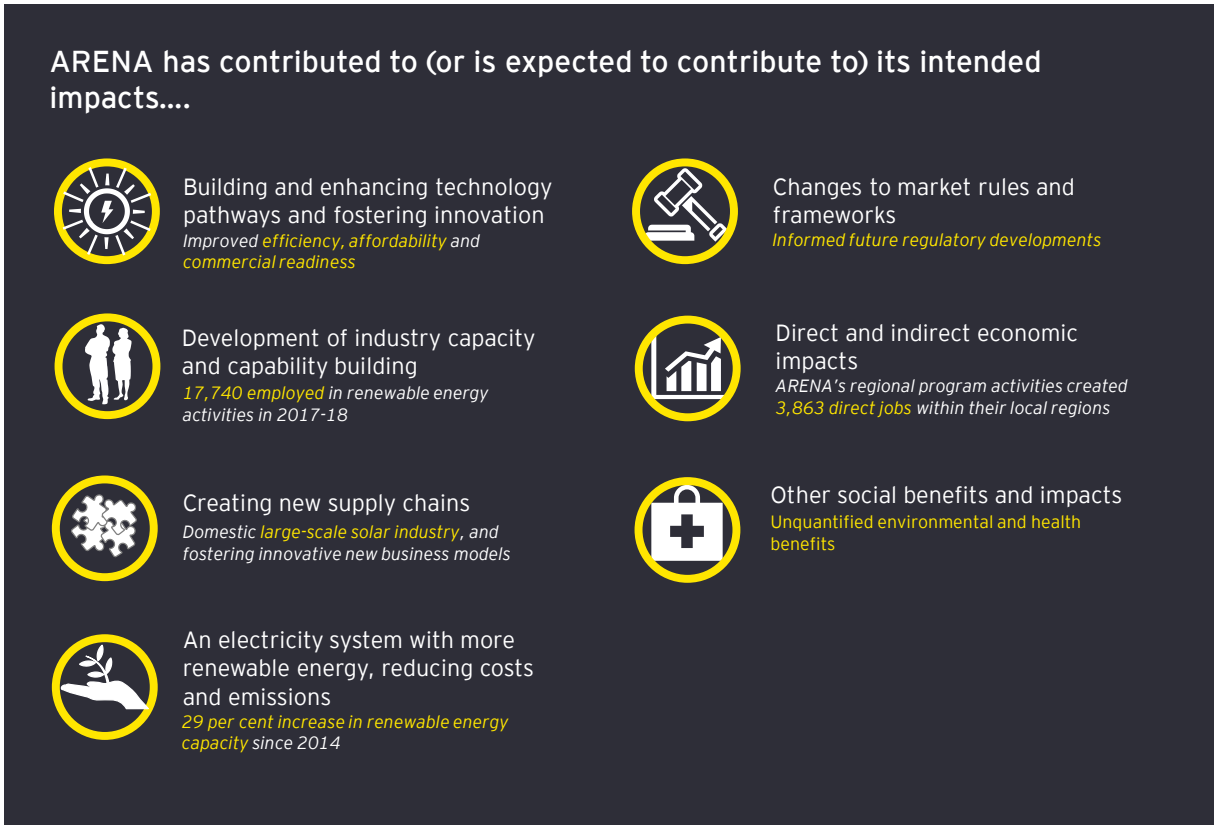
[16] BIS Oxford, 2018, ARENA Regional Contribution Analysis

[17] Barbose et al, 2016, 'A retrospective analysis of the benefits and impacts of U.S. renewable portfolio standards'

[18] Evans et al, 2013, 'Regional variations in the health, environmental, and climate benefits of wind and solar generation'

[19] Australian Energy Update, 2019, Department of the Environment and Energy, available at https://www.energy.gov.au/publications/australian-energy-update-2019

[20] Figures have been converted from $US using an exchange rate of 1.44781 (as of 3 November 2019).



Process evaluation

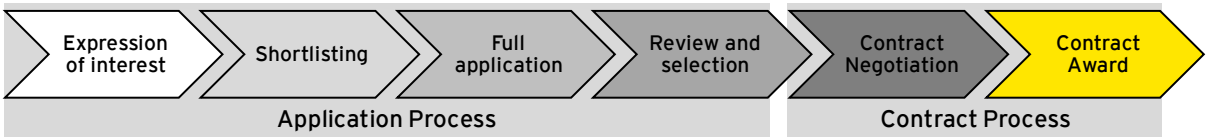
A high-level review of previous program evaluations and systematic reviews of ARENA's processes suggest ARENA's processes are appropriate and broadly efficient. ARENA's efficiency was considered in the context of three key processes essential to the delivery of its activities:

1. Grants processes

ARENA receives applications and makes available grants to proponents through competitive funding rounds, which focus on specific energy technologies (e.g. Large-Scale Solar, Demand Response and the Research and Development Program) and ongoing intakes (e.g. the Advancing Renewables Program). Both approaches generally apply a two-step application process: expression of interest and full application.

The grant application and contract award process is summarised in Figure 1.

Figure 1: High-level overview of application and contract award process



ARENA's two-stage process is consistent with government processes, filtering out low merit projects, or projects that do not meet the eligibility criteria allowing only relevant, high merit applications to move on to further assessment. It also provides a transparent mechanism to fairly assess grant submissions.

ARENA has implemented changes to improve various aspects of the application and contract negotiation process in response to recommendations from previous evaluations, and feedback from

funding recipients. For example, refreshing the standard funding agreements to be commensurate with the level of risk of projects being funded.

As a result of these challenges, we recommend that ARENA monitor changes implemented to ensure they successfully respond to feedback on the grants process.

2. Project management and delivery processes

ARENA's project management processes have improved over time, and now adopt a risk-based approach to determine the appropriate level of monitoring for projects, which has been found to be more appropriate.

Difficulties with ARENA's Grants Management System (GMS) have been acknowledged by ARENA and have been improved. ARENA has undertaken a significant update of GMS to improve data capture at concept, EOI and full application stage as well as contract details to improve overall contract and project management. We recommend ARENA continue to monitor the implementation of the updates to its GMS to assess the success of the updates.

3. Adoption of lessons learned

ARENA demonstrates good practice through its Business Improvement Steering Committee and previously through the Review Implementation Oversight Committee (RIOC)[21] to evaluate funding programs to identify opportunities for optimisation and track the implementation of recommendations using evaluation trackers. We note that there is scope to consolidate these to ensure that some recommendations are not lost.

ARENA has adopted lessons learned from previous evaluations in its grants and project management processes. This should provide confidence that it will continue to improve its processes into the future.

[21] The RIOC was tasked with the responsibility of implementing recommendations for improvements from the Future Needs Review. RIOC was closed by the Board in 2018 in recognition that all recommendations of the FNR had been implemented.

Recommendations

The evaluation identified four areas of improvement that ARENA could consider when implementing future processes:

1. Monitoring and reporting on the results of knowledge sharing activities to ensure knowledge sharing continues to be timely and effective

2. Integrating technological readiness levels reporting and commercial readiness index reporting into standard practice to consistently track the progress of ARENA funded projects across all technologies along the technology development chain

3. Continuing to apply a risk-based approach to project management which strikes the right balance between scrutiny and avoiding unnecessary burden on funding recipients in its project management and monitoring processes

4. Monitoring the implementation of updates to the Grants Management System (GMS) to assess the success of the updates in improving overall contract and project management.

1. Background

1. Background

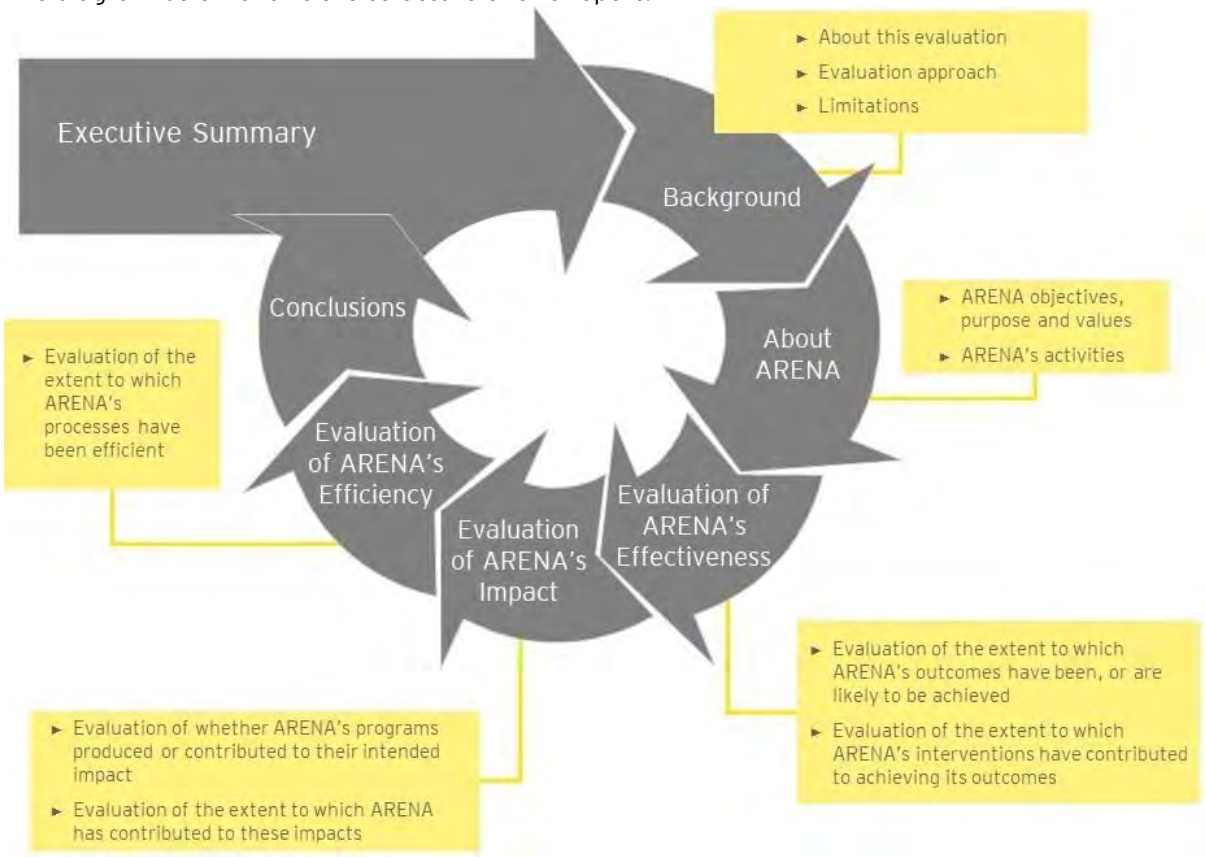
1.1 About this evaluation

The Australian Renewable Energy Agency (ARENA) has engaged Ernst & Young (EY) to undertake an evaluation of the effectiveness of ARENA in achieving its objectives under the *Australian Renewable Energy Agency Act 2011* (the ARENA Act). The evaluation will focus on three key elements identified by ARENA, namely an evaluation of:

- The effectiveness of ARENA's activities in achieving its legislated objectives of improved competitiveness of renewable energy technologies and increased supply of renewable energy, a better-informed industry and government, and better collaboration
- The impact of ARENA's investment on the Australian renewable energy sector, the energy transition and the broader Australian economy
- The efficiency of ARENA's processes (i.e. grants processes, project management and delivery).

This report presents the findings from a review of ARENA's activities based on an approach and a set of evaluation questions developed by EY in consultation with ARENA. Findings from this evaluation may potentially inform future funding rounds, performance reporting and continuous improvement for portfolio management.

The diagram below shows the structure of this report.



The evaluation has applied a 'mixed-methods' approach designed to address 22 evaluation questions and analyse the various sources of data available. A mixed methods approach is a methodology for conducting research and evaluation that involves collecting, analysing and integrating quantitative and qualitative data and information in a single study. The evaluation has

sourced information from a combination of desktop research and feedback from stakeholder interviews.

The purpose of this approach is that both qualitative and quantitative research, in combination, provide an opportunity to address evaluation questions from a number of perspectives and minimises the possibility of 'gaps' in the information and data collected.

1.2 Evaluation Plan

In consultation with key ARENA personnel, EY prepared an Evaluation Plan for the purposes of guiding the evaluation. A clear Evaluation Plan is essential for clarifying how ARENA's activities and programs are intended to work by laying out their components and the order or the steps needed to achieve the desired results. An Evaluation Plan increases the understanding of ARENA's goals and objectives and defines the relationships between factors key to the implementation of ARENA's activities and programs.

Through the development of the Evaluation Plan, the evaluation team sought to lay-out:

- ARENA's purpose and objectives, and the objectives of the evaluation
- The relationships among inputs, activities, outputs, outcomes and impacts
- The specific evaluation questions that need to be asked to examine ARENA's overall performance
- The quantitative and qualitative information required to address the evaluation questions and identification of the sources of data and information
- The evaluation risks and limitations.

1.2.1 Evaluation Program Logic Map

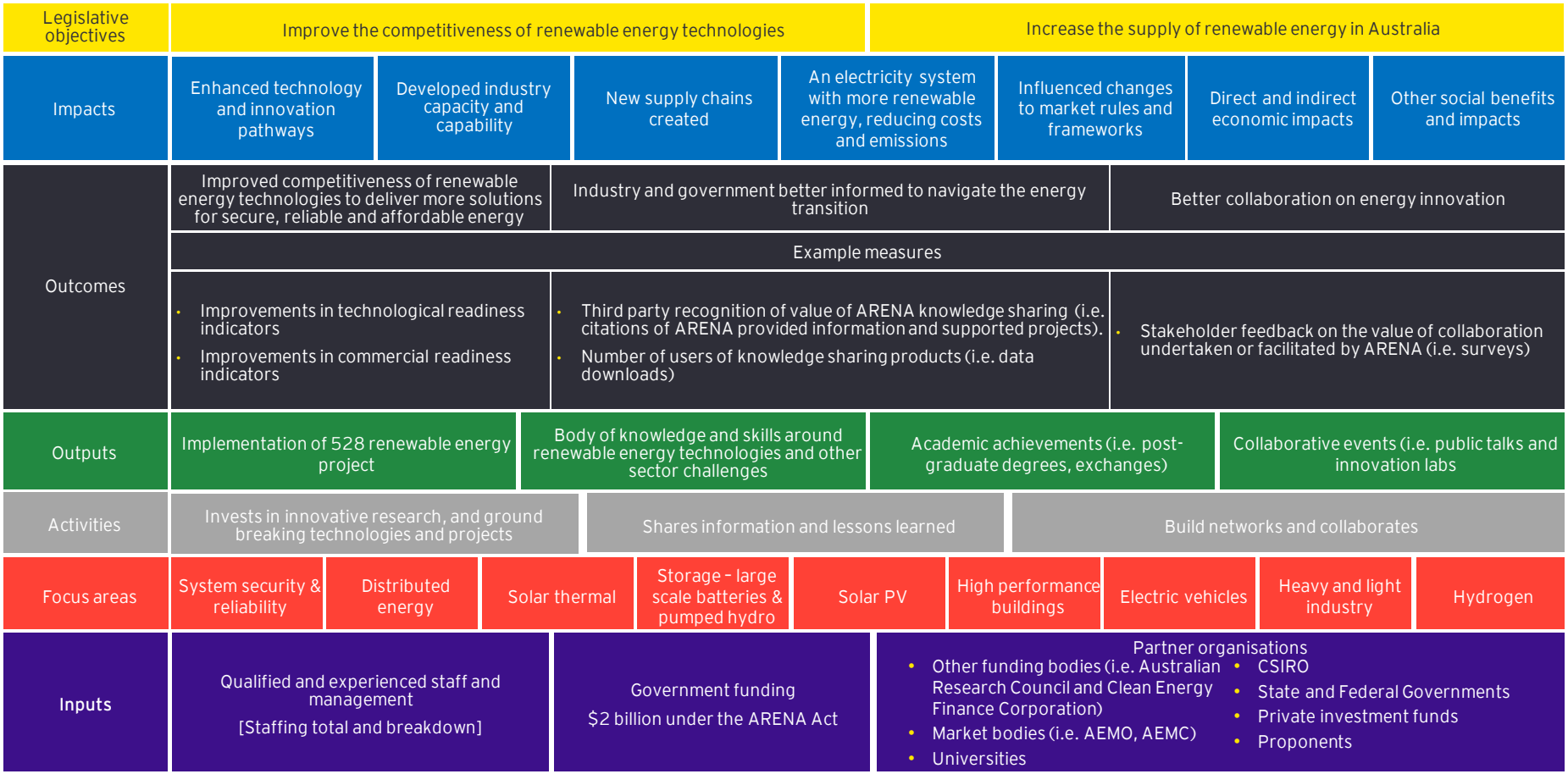
EY developed a Program Logic Map to inform the development of the evaluation approach. A program logic map is a systematic and visual way of presenting the relationships between program inputs and activities that are designed to lead to a specific set of outputs and outcomes. Logic maps are used as both a tool for program/portfolio planning and evaluation. They are intended to enable users to see if programs will lead to their desired outcome, and to make it easier to determine what evaluation questions are most appropriate.

The logic map in Figure 2 provides a high-level visual summary of the actions ARENA has undertaken since its inception, and what we consider to be its key expected outcomes based on its legislative and corporate mandate, described in section 1.

ARENA's activities, made possible by ARENA's statutory funding and staff, have enabled ARENA and/or its funding recipients to produce a range of outputs ranging from renewable energy projects to collaborative events such as innovation labs.

In delivering these outputs, ARENA has sought to achieve several short-term outcomes to change the market's knowledge, awareness and behaviour on issues such as energy innovation and the energy transition. It is has also sought to deliver on long- term outcomes and broader economic impacts.

Figure 2: ARENA Logic Map



1.2.2 Evaluation approach

As demonstrated by Figure 3 below, the evaluation questions and approach focused on three key elements:

An in-depth analysis of:

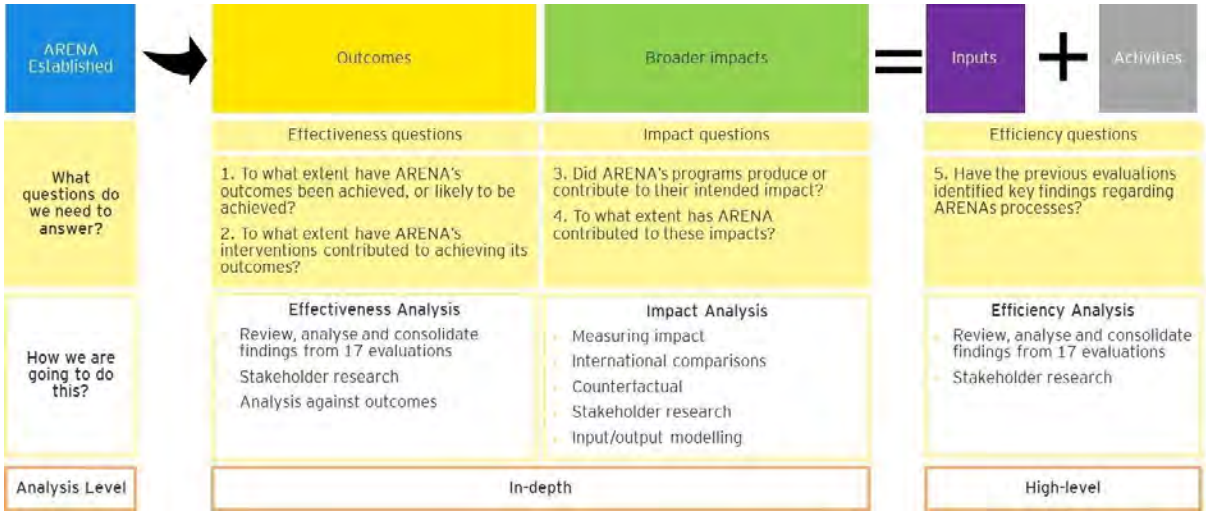
- Effectiveness – whether the interventions and activities undertaken by ARENA have been effective in delivering on its core outcomes and objectives
- Impact – identification of the broader impact of ARENA on the Australian renewable energy sector, the energy transition and the broader Australian economy.

A high-level summary of:

- Efficiency – to what extent have ARENA's processes been efficient? [22]

The evaluation approach was designed by EY based on the ARENA logic map. The detailed questions, and analytical framework is outlined in Appendix A.

Figure 3: Evaluation approach



The evaluation has been performed by desktop research of qualitative and quantitative data and economic input/output modelling (via REMPLAN). We have also drawn on the findings of individual program evaluations provided by ARENA, and the stakeholder research undertaken by EY Sweeney.

1.2.3 Limitations

Key limitations of the evaluation are detailed below. Where possible, mitigating factors have been described.

Outside of publicly available information, the analysis relies on information in independently commissioned evaluations of individual programs and portfolios, and information provided by ARENA. Where possible, source project data has been requested from ARENA to verify the analysis.

In preparing this Report we have considered and relied upon information from a range of sources believed after due enquiry to be reliable and accurate. We have no reason to believe that any

[22] The efficiency aspect of EY's evaluation is limited to a high-level summary only. We note that the ANAO is currently undertaking a performance audit of grant program management by the Australian Renewable Energy Agency. We understand from ARENA that ANAO's performance audit is representative of an in-depth efficiency review of ARENA's processes.

information supplied to us, or obtained from public sources, was false or that any material information has been withheld from us.

We do not imply, and it should not be construed that we have verified any of the information provided to us, or that our enquiries could have identified any matter that a more extensive examination might disclose. However, we have evaluated the information provided to us by ARENA as well as other parties through enquiry, analysis and review and nothing has come to our attention to indicate the information provided was materially mis-stated or would not afford reasonable grounds upon which to base our Report.

The analysis has relied on findings from previous independent evaluations of individual programs and portfolios. We have not re-interrogated results of these evaluations, except to the extent that further progress has occurred since the evaluation was undertaken. As such, the limitations of previous evaluations are also applicable to this evaluation such as:

- Specific evaluation small sample sizes, which may impact the degree to which conclusions can be extrapolated to other ARENA projects
- Departure of key project personnel, which may have resulted in the loss of information and/or project specific knowledge and experience
- Point in time of project evaluation, which may neglect to account for any improvements made by ARENA following the evaluation findings
- Reliance on information provided by ARENA may not necessarily reflect the entirety of information available
- Modelling work performed as part of our scope inherently requires assumptions about future behaviours and market interactions, which may result in forecasts that deviate from future conditions. There will usually be differences between estimated and actual results, because events and circumstances frequently do not occur as expected, and those differences may be material.

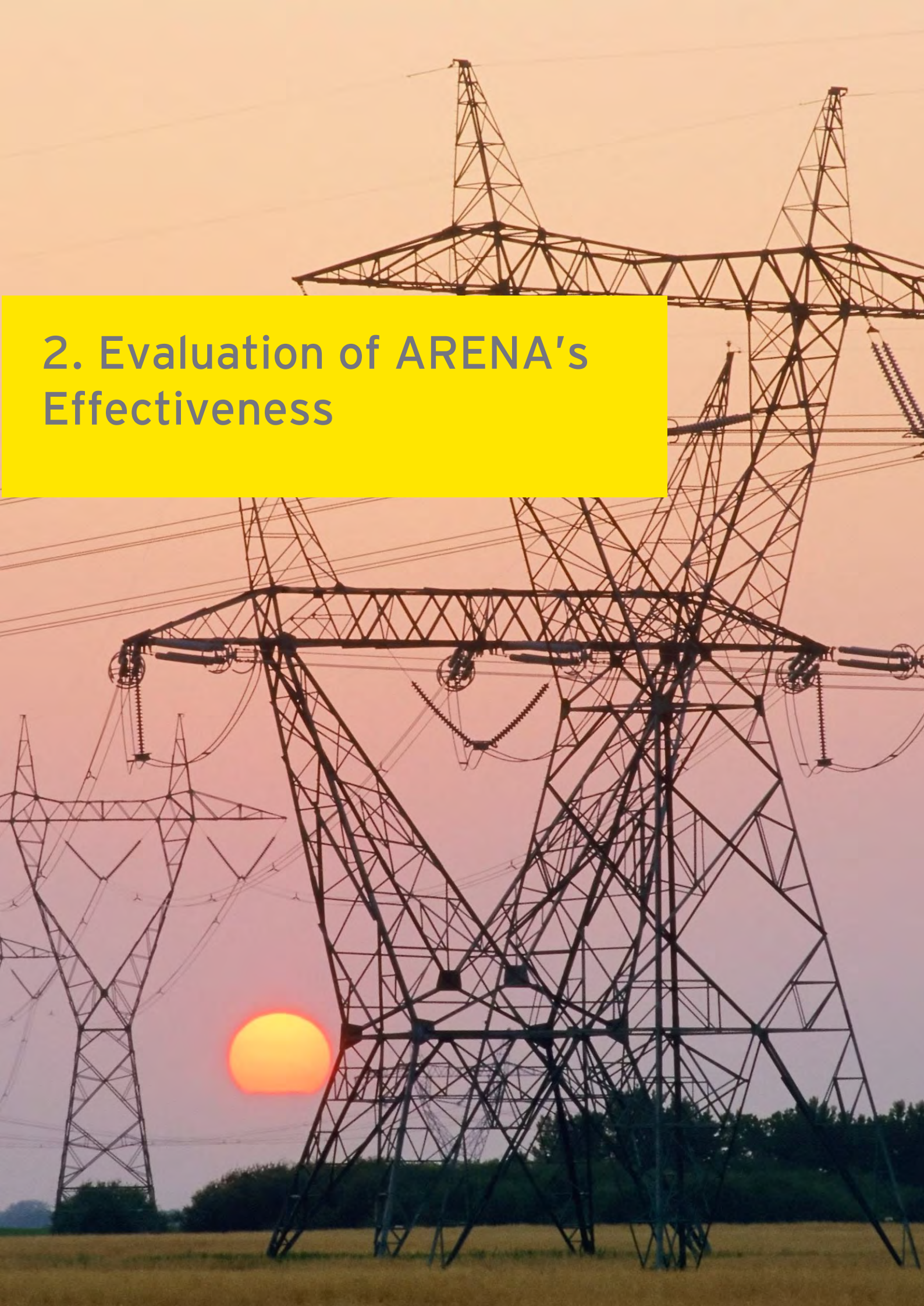
Some renewable energy technologies are at early stages in the innovation chain (e.g. hydrogen and battery storage) and therefore limited information and cost data about these technologies exist, particularly prior to ARENA's involvement in the market. As a result, multiple sources have been used to collect cost data in Australia, which limits its comparability between years due to the varying assumptions applied in calculating the figures.

The main limitation is the attribution of any outcomes or impacts to ARENA. EY is unable to control for other influences on the outcomes or impacts that ARENA has sought to make. EY has therefore conducted basic comparative analysis (i.e. a before and after comparison). Elsewhere this report also provides information on other initiatives which may have contributed to the outcomes reported here.

To minimise the impact of 'stakeholder fatigue' of key contacts, this engagement has relied on comprehensive stakeholder engagement work undertaken by EY Sweeney in parallel with this evaluation, and as gleaned from stakeholder engagement elements of individual program evaluations rather than undertaking primary stakeholder consultation.

The evaluation questions, and approach to undertake the efficiency analysis have been developed to prevent overlap with the Australian National Audit Office (ANAO) performance audit of grants management within ARENA which is occurring concurrently. As a result, the approach taken with regard to this stream of analysis is to provide a high-level summary of key findings regarding efficiency detailed in the evaluations already undertaken.

2. Evaluation of ARENA's Effectiveness



2. Evaluation of ARENA's Effectiveness

This chapter undertakes a high-level desktop assessment of the effectiveness of ARENA's core activities (funding research and development and supporting project delivery, knowledge sharing and building networks) in achieving its outcomes of improved competitiveness, a better-informed industry and government and fostering collaboration.

To complement this analysis, a qualitative counterfactual analysis was undertaken in order to determine how integral ARENA was in achieving these outcomes, whilst an assessment of other domestic and international comparators was also undertaken.

2.1 Key findings and observations

ARENA has achieved (or is expected to achieve through ongoing programs) its intended outcomes....

Investment in innovative research, groundbreaking technologies and projects

Through ongoing support of R&D, demonstration and deployment projects, ARENA has contributed to a more competitive renewables sector, reducing costs and advancing new technologies and will enable further improvements into the future

Shares information and lessons learned

A strong commitment to knowledge sharing embedded across ARENAs programs keeps industry and government better informed by sharing information to improve future project delivery and industry capability

Builds networks and collaborates

Innovative A-Lab workshops, the development of the DEIP, and ongoing support of ACAP and ASTRI and MOUs with governments, industry and research bodies have forged stronger collaborative ties between key stakeholders

... It is reasonable to conclude that these outcomes may not have been realised (or realised to a lesser extent) in the absence of ARENA or similar organisation

2.2 Effectiveness evaluation

2.2.1 Achievement of ARENA's outcomes

The following evaluation questions were considered in this section:

- Has the competitiveness of renewable energy technologies improved or likely to be improved?
- Are industry and government better informed to navigate the energy transition?
- Have ARENA's funded activities achieved their objectives, or likely to achieve their objectives?

The section below evaluates the extent to which the interventions and activities undertaken by ARENA funded activities have achieved ARENA's outcomes, and/or are likely to achieve these outcomes in the future.

2.2.1.1 Investment in innovative research, ground breaking technologies and projects

ARENA provides funding across the innovation chain; research, development, demonstration and deployment. There are two key programs through which ARENA funds early research and development and demonstration and deployment projects:

- The Research and Development Program – reaches out to the marketplace seeking projects through targeted funding rounds. Research support is available through R&D Program funding rounds and strategic research initiatives
- The Advancing Renewables Program (ARP) – funds renewable energy projects at various stages of commercialisation, from desktop feasibility studies through to later-stage demonstration and deployment projects, for activities that occur in Australia and benefit Australian renewable energy.

The following sections outline how ARENA's funded renewable energy projects in both the research and development (R&D) space as well in the demonstration and deployment of specific projects, have helped accelerate the competitiveness of Australian renewable energy technologies.

Research and Development: Programs

R&D is the first stage along the innovation chain, with ARENA providing funding that is not typically available in the commercial market to Universities, other institutions, organisations and companies undertaking research. To date, ARENA has provided a total of $298 million across 198 projects at the R&D innovation stage.[23] This includes funding provided through the following programs:

- Solar Research Excellence – since 2014 ARENA has provided $21.5 million funding for 12 cutting edge solar R&D projects, ranging from enhancing existing technologies to advancing emerging technologies in solar photovoltaics (PV), solar thermal and solar storage.[24]
- Industry and Researcher Collaboration – in 2015, $17 million was provided to promote industry and research partnerships that seek to develop and commercialise renewable energy technologies, and to provide a broader range of energy options to reduce future energy costs.[25]
- Solar Research & Development – since 2017 ARENA committed $29.2 million through a competitive funding round focussing on early stage research in solar photovoltaics.[26]
- International Engagement Program – in 2017 ARENA provided $5 million to 12 recipients to accelerate innovation in research and technology development and drive the commercialisation of Australia renewable energy technologies by linking Australian researchers with international peers.[27]
- Renewable Hydrogen for Export Program – 2018 ARENA provided $22.1 million in funding to 16 research projects dedicated to propelling innovation in exporting renewable hydrogen to the world.[28]

In addition to the direct funding of individual research and development projects, the establishment and ongoing support for the flagship strategic research institutes; the Australian Centre for

[23] ARENA, 2019, Grants Management System data supplied 25 September
[24] https://arena.gov.au/funding/solar-research-excellence/
[25] https://arena.gov.au/funding/industry-and-researcher-collaboration/
[26] https://arena.gov.au/funding/solar-research-development/
[27] https://arena.gov.au/funding/international-engagement-program/
[28] https://arena.gov.au/news/boosting-research-into-exporting-renewable-hydrogen/

Advanced Photovoltaics (ACAP) and the Australian Solar Thermal Research Institute (ASTRI) ensures that investment in innovative research continues.

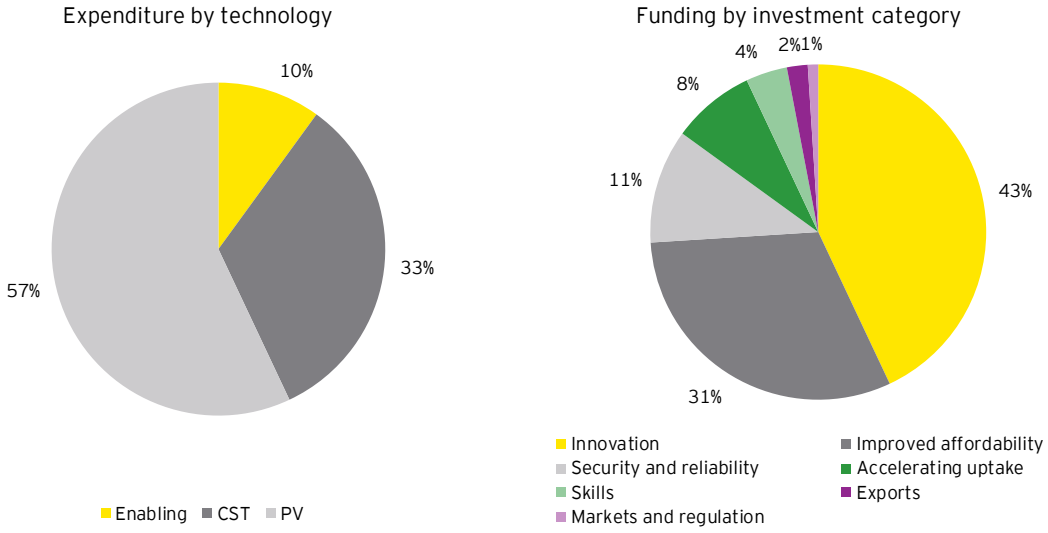
These activities assist ARENA in achieving its outcomes through:

- Targeting research and development into new renewable energy technologies, thus improving technological advances to improve competitiveness, reliability and affordability of the renewables sector through reducing technical and/or commercial risks

- Improving collaboration by participating and contributing in the development of leading research and engagement with peak research bodies, universities and industry itself.

As shown in Figure 4, the majority of ARENA's R&D funding investment to date has been directed towards solar technology. Therefore, the analysis in this section focuses on outcomes achieved in this area. Table 1 outlines the key achievements of the Solar R&D program across the three research areas; PV, Concentrating Solar Thermal (CST) and Enabling (hardware and software technologies such as resource mapping, forecasting and monitoring tools, regulatory analysis, grid integration, storage and ownership models).

Figure 4: ARENA's Solar Energy R&D funding classified by research area and investment category



Source: ARENA, 2019, 'In the Spotlight: Australian Solar Energy R&D Outcomes and achievements in a global context' page 39

Table 1 outlines some of the key findings of the Solar R&D program across the three research areas.

Table 1: Achievements of the solar R&D program

Research Area	Number of Projects	Fund Leverage	Key Achievements	Contribution to Solar Development
PV	209	1:1.67	► Solar Passivated Emitter and Rear Cell (PERC) developed with the University of New South Wales (UNSW) is expected to hold significant market share ► improved research facilities within UNSW to maintain its world leading role whilst bringing Australian National University (ANU) and CSIRO up to world class standards ► UNSW has contributed to the development of silicon defect hydrogenation process, *Power*	► Australian Researchers at UNSW and ANU have played a key role in development of the PV industry and continue to expand research into silicon-based technologies ► Helped increase the number of Australian research organisations active in the PV space ► Maintain Australia's lead in developments of PV industry which can result in higher efficiencies and lower costs being passed through to consumers.

Table 1: Achievements of the solar R&D program				
Research Area	**Number of Projects**	**Fund Leverage**	**Key Achievements**	**Contribution to Solar Development**
			Cube, high efficiency tandem or multi junction cells technologies.	
CST	67	1:1.49	► Significant increase in the capability of CST industry ► Strengthened research groups at the CSIRO and ANU, and instigated research at the University of South Australia (UniSA), University of Queensland, University of Adelaide (UoA) and Royal Melbourne Institute of Technology (RMIT) ► CSIRO has led projects including solar test towers, pilot scale solar driven air turbine, and steam receivers.	► Research has been focused on cost reduction to accelerate widespread deployment ► Research effort has mainly focussed on examining new concepts and technologies ► ASTRI to commence development of demonstration and pilot testing.
Enabling	38	1:1.43	► Development of a wide range of enabling technologies to facilitate the generation, storage and use of solar energy ► Development of the Australian Solar Energy Forecasting System.	► Performance prediction tools have contributed to significant reduction of the cost of financing large-scale PV plants, increasing deployment ► Greater diversity of energy storage option has been facilitated.

Source: In the Spotlight: Australian Solar Energy R&D Outcomes and achievements in a global context

The following case study demonstrates how ARENA's investment in research and development is leading to improvement in the competitiveness of solar by helping to reduce the cost of the technology.

Case Study: Australian Research is bringing down the cost of Solar PV

ARENA's funding has supported the development of new technologies to reduce the installed cost of PV systems, improve system reliability and develop materials for new market applications.

Efficiency improvements have a cascade effect, flowing through as per kilowatt cost savings from cells to modules, to distribution and final system costs. For every one percentage point efficiency improvement in module performance (e.g. from 20 per cent to 21 per cent), this reduces the cost of the module by approximately five per cent. This means that solar modules that were selling at 60 cents/watt can then sell at 57 cents/watt. For each one gigawatt of solar installed in Australia each year, this step change alone would deliver savings of $30 m in the cost of modules. Higher solar cell efficiencies also mean that the same electricity output can be achieved from a smaller number of modules, which also reduces balance of system costs, land costs, EPC etc. The environmental impact is therefore reduced through less material required for 'balance of system' components, such as support frames and cables and transport costs. The rapidly falling cost and increasing efficiency of PV cells and modules contributes significantly to making renewable energy technology more competitive.

Australian technology is expected to dominate the PV market over the next decade with key contributions from ARENA-funded solar research undertaken by Australian universities:

- University of New South Wales (UNSW) developed the PERC, currently used in more than 60 per cent of commercial PV cells available in the global market, achieving world record efficiencies of up to 25 per cent compared to standard solar cells (~20 per cent). An estimate made by the Australian National University (ANU) of the potential benefits of the PERC solar cell technology indicates that a five per cent relative efficiency improvement on 50 per cent of Australian PV systems installed over the ten-year period 2018 to 2028, with average annual installation rates of two gigawatts per year and average area-related costs of $1500 per kilowatt, translates to savings of $750 m. Worldwide, the savings could be 50 times larger, or more than $37 billion

- New hydrogenation technology developed by UNSW and expanded by ANU has been demonstrated to increase the performance of low-quality / low-cost solar-grade silicon wafers. This technology can be incorporated into current standard cell manufacturing lines with minimal equipment change and has 22 industry partners interested in further development prior to commercial adoption. Its deployment over the coming decade could result in global savings of some US$7.5 billion each year, with Australia to directly benefit through lower module costs and royalties feeding back into the economy.

Research into new materials and technologies, including perovskites, tandem cells and copper-zinc-tin-sulphide, will help to ensure Australian research remains at the forefront of these new technologies as they reach commercial production. This will include new, high-efficiency, low-cost, flexible and non-toxic materials which could be integrated into buildings and other new products within a decade.

ITP Renewables 'In the Spotlight' evaluation found ARENA's funding has significantly boosted Australia's solar research capability and played a critical role in keeping Australia in the forefront of the international solar industry.

Source: ARENA, 2019, 'Annual Report 2018/19'

ARENA's ongoing R&D program and R&D activities targeted at international research have contribute to developments in technology and reduced costs of PV systems resulting in improvement and expected improvements in solar competitiveness. It is expected the ARENA's R&D activities in other technology would similarly lead to further development of that technology.

Research and Development Institutions

ARENA has supported the creation of two solar research centres. Whilst the projects overseen by ASTRI and ACAP were considered as a component of the solar R&D activities detailed above, both organisations have contributed to broader R&D outcomes as outlined below:

- ASTRI is an eight-year, $87 million international research collaboration to deliver cost reductions and dispatchability improvements, as well as position Australia in CST research. ASTRI was previously developed as part of a funding agreement between the CSIRO and the Australian Solar Institute (ASI) prior to ASI's integration into ARENA. ASTRI's purpose was to provide an institutional framework for a coordinated, national approach for concentrating solar thermal power research in Australia. Key outcomes ASTRI has delivered are:
  - ASTRI represents a world class asset in CST power, having met or exceeded all the technical goals to which it was committed to under its funding agreement[29]
  - ASTRI has established itself as an international centre of excellence with its research efforts contributing at the highest levels to the development of the sector globally. [30]
- ACAP was developed by the ASI as a joint funding agreement with the UNSW. Headquartered at UNSW's School of Photovoltaic and Renewable Energy Engineering, ACAP provides the institutional framework for a coordinated national approach to PV research and supports the development of next generation photovoltaic technology, with a focus on performance improvement and cost reduction. ACAP also is the Australian partner of the joint Australian and US Institute for Advanced Photovoltaics (AUSIAPV). Key outcomes from ACAP are: [31]
  - ACAP is one of the few remaining government funded PV research organisations in existence producing world leading research[32]
  - ACAP is achieving outstanding impacts on the improvement of the competitiveness of renewable energy technologies with a direct link between the research it undertakes leading to lower manufacturing costs
  - ACAP has met or significantly exceeded each of its funding milestones and KPIs.

ARENA's investment in innovative R&D through ASTRI and ACAP has produced world class research and contributed to the development of improved solar PV technology in Australia and globally.

[29] ITP Renewables, 2018, 'In the spotlight: Australian solar energy R&D outcomes and achievements in a global context'
[30] We note that ASTRI has also taken steps to protect intellectual property generated from its research. ARENA, 2016, 'Australian Solar Thermal Research Initiative (ASTRI) Mid Term Review'
[31] ARENA, 2016, 'ACAP Centre for Advanced Photovoltaics (ACAP) ARENA Mid-Term Report'
[32] Intellectual property created from ACAP research has been protected by more than 60 patent applications since inception. For further information see the 2016 'ACAP Centre for Advanced Photovoltaics (ACAP) ARENA Mid-Term Report.'

Findings

ARENA's investment in R&D has been effective at helping accelerate the shift to more affordable and reliable renewable energy sources. R&D funding has resulted in significant knowledge creation, sharing and the development of important skills which has significantly improved Australia's capability in solar research.

The majority of funding has been allocated to projects that have delivered efficiency improvements and manufacturing cost reduction, therefore resulting in improved competitiveness and an increased supply of renewable energy.

With respect to the specific outcomes delivered by the research institutes supported by ARENA both ASTRI and ACAP have contributed to the development of research and intellectual property within the CST and PV field respectively while the ACAP programs has contributed directly to ARENA in achieving its outcome of improving the competitiveness of renewable markets through the development of world class research.

Demonstration and deployment projects

The primary mechanism by which ARENA funds demonstration and deployment projects is through the ARP. ARENA has also inherited pre-existing funding programs including the Emerging Renewables Program.

The ARP continues the commercialisation pathway post the Research and Development stages and is the primary mechanism by which ARENA funds demonstration and deployment projects.

- Demonstration projects - are those which demonstrate the feasibility of new technologies and disseminate learning to facilitate scale-up of renewable technologies.
- Deployment projects - are classified as those which improve commercial readiness through demonstrating business models and improving commercial viability of renewable technologies.

In addition to two stages of the innovation chain supported by the ARP, ARENA provides funds to feasibility and other studies that ensure demonstration and deployment projects are viable and can deliver value for money. The total number of projects and ARENA funding to the D&D stage to date is provided in Table 2.

Table 2: ARENA's total demonstration, deployment and feasibility funding to September 2019 [33]

Innovation Stage	Number of projects funded	ARENA funds contributed
Demonstration	143	$ 622.5 million
Deployment	45	$ 560.0 million
Feasibility and other studies	127	$ 111.0 million

[33] ARENA, 2019, Grants Management System data provided 25 September

The Advancing Renewables Program

The ARP provides both a continuous open acceptance mechanism for projects with high merit, as well as utilising specifically targeted competitive funding rounds such as the Large-Scale Solar Competitive Round. The objectives of the ARP and the competitive funding rounds are aligned to ARENA's legislative objectives of improving the competitiveness of renewable energy technologies to deliver more solutions for secure, reliable and affordable energy.

Outcomes delivered to date through the ARP include;[34]

- Greater understanding of the feasibility of projects
- Helping to define future targeted commercialisation of solar projects
- Stimulation of private sector investments, reducing the risk involved with projects
- Increased market confidence to invest in new technology due to ARENA's signalling around the potential of projects and technology
- Filling a crucial gap in the funding pathway, allowing projects to proceed
- Providing a 'blueprint' for other projects to follow (see Moree case study)
- Contributing to rapid growth of the PV industry since the Large Scale Solar (LSS) Competitive Round in terms of the expansion of accredited and installed capacity, an increased number of projects and a widening of market supply
- Supporting cost reductions through market developments.

The following case studies present an in-depth look at two of the deployment projects undertaken by ARENA and demonstrate the effectiveness of its grant funding to deliver on its outcomes.

Case Study: Gannawarra Energy Storage System

The Gannawarra Energy Storage System (GESS) is a 25 megawatt (MW)/50 megawatt-hour (MWh) lithium-ion battery, which is co-located with the 60 MW(DC) Gannawarra Solar Farm located west of Kerang in north western Victoria. It was developed and financed by Edify Energy in a consortium with Wirsol Energy as co-investors, Tesla as battery provider, RCR Tomlinson as EPC contractor, EnergyAustralia as long-term operator, and ARENA and the Victorian Government as providers of grant funding. ARENA provided $22.73m of the total $41.19m project cost.

This project is demonstrating how an existing solar farm can be retrofitted with battery storage. The battery will store energy at times of relatively low value and uses it at times of relatively high value. The project provides other grid services such as frequency control ancillary services (FCAS) and, should it be established under the electricity market rules, Fast Frequency Response (FFR).

The battery will help demonstrate how large-scale batteries can provide different benefits to the electricity system, including improving grid stability and power quality, and how they can help integrate more variable renewable energy into the grid. For example, the battery could assist by reducing curtailment of future renewable energy generation on what is a relatively constrained line in the Victorian electricity system hence supporting higher levels of renewables in the region by reducing or controlling peak loading on these circuits.

Source: ARENA, 2019, 'Gannawarra Energy Storage System' available at https://arena.gov.au/projects/gannawarra-energy-storage-system/

[34] Clear Horizon, 2018, 'Evaluation of the Advancing Renewable Program'

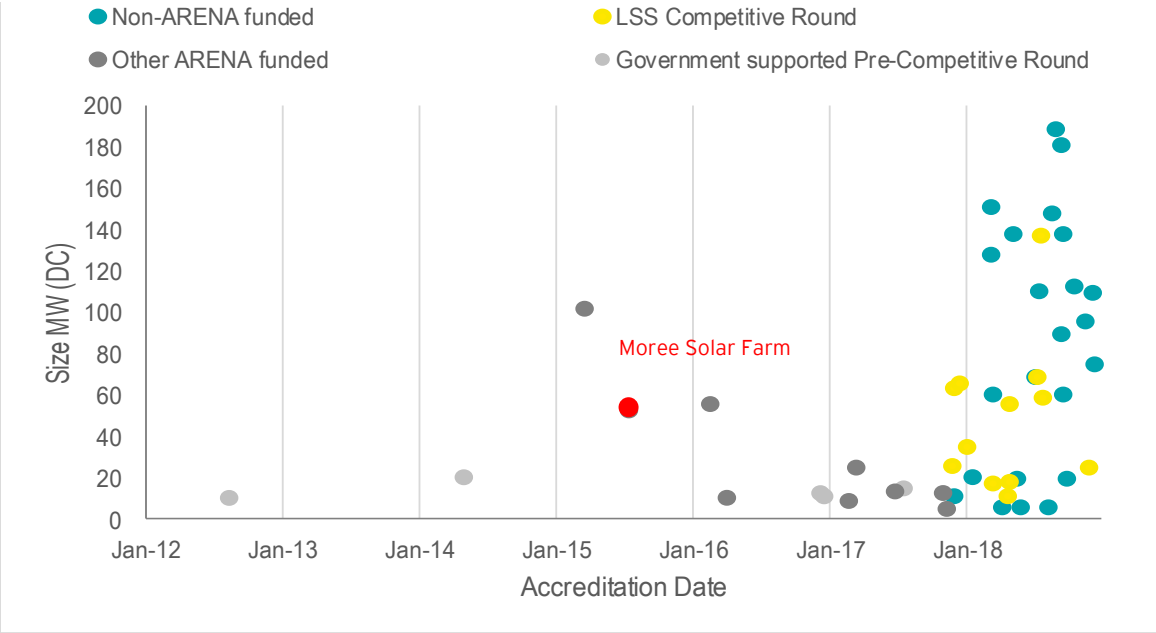
Case Study: Moree Solar PV

The 56 MW Moree Solar Farm uses solar photovoltaic-polycrystalline modules and a single-axis horizontal tracking system which allows the modules to follow the sun to maximise power output. It is connected to Essential Energy's distribution network, allowing the solar power plant to supply electricity into the National Electricity Market. The Moree location was chosen for its high-quality solar resources and proximity to the electricity network. The $201m project was completed with funding support of $101.7m provided by ARENA.

Moree is a 'landmark' project, being the first large scale solar project in Australia to use single-axis tracking system, with PV modules that track the sun's path from east to west during the day. The project was initially financed on a merchant basis, but later secured a 15-year PPA with Origin in March 2016 (during the Competitive Round process), covering 100 per cent of the output. Feedback from a participant highlighted this project as a "blueprint" for others to follow, giving other developers confidence to apply for funding initially on a merchant basis. A notable example is Swan Hill solar farm in Victoria, which was initially developed on a merchant basis and without a power purchase agreement (PPA) has secured $16.5 m in debt funding.

The funding provided to projects such as Moree removed key barriers to entry, brought in industry players (both domestically and internationally) and instilled confidence in market participants that the technology could become commercially viable and competitive among other generation sources. The creation and achievement of a large-scale solar industry in Australia is shown in the figure below where an influx of 29 non-ARENA funded projects gaining accreditation following ARENA's LSS Competitive Round.

Figure 5: Accredited Large-Scale Solar PV Projects in Australia



Source: Data from Australian PV Institute (APVI) Solar Map, funded by the Australian Renewable Energy Agency, accessed from pv-map.apvi.org.au on 25 June 2019

Findings

ARENA's funding of demonstration and deployment activities e.g. through the ARP and LSS Competitive Round have improved competitiveness of solar technology in Australia. It is expected that ARENA's demonstration and deployment investment in other technologies (e.g. batteries) will similarly contribute to the development and increased competitiveness of other renewable energy technologies.

2.2.1.2 Better informing government and industry to navigate the energy transition

Knowledge sharing activities

The objective of ARENA's knowledge sharing activities is to share technical and economic learnings with market participants and wider industry stakeholders to improve future project delivery and industry capability. ARENA's knowledge activities include:

- **Knowledge sharing plans and reports** - ARENA's funding agreements require proponents to agree to a knowledge sharing plan, setting out the requirements of knowledge sharing, as a condition of being awarded funding. ARENA may also develop technology or program level knowledge sharing reports that consolidates the knowledge learned from individual projects into a comprehensive analysis of challenges and learnings of locational or technology specific programs such as the 'New England Renewable Energy Hub Knowledge Sharing Report' and the 'Large Scale Battery Storage Knowledge Sharing Report.'

- **Workshops** – ARENA hosts workshops to bring together industry to discuss topical issues. Recent workshops have covered a range of topics including virtual power plants, demand response, short-term forecasting and large-scale battery storage.

- **Insights Forums** – ARENA facilitates 'Insights Forums' which provide an opportunity to share lessons learned from ARENA-funded projects, including current challenges and opportunities, with the broader industry. To bring international lessons to the Australian market, at its June 2019 Insights Forum, ARENA hosted an international speaker who was formerly a Commissioner with the Hawaiian Utilities Commission.

- **Policy and regulatory development** – ARENA makes submissions to regulatory reform processes which transmit information and insights from ARENA's project base and participates in policy consultation processes (such as via membership of AEMC and AEMO working groups).

- **Insights Newsletters** – Insights newsletters share reports, lessons and insights from ARENA's projects directly to industry audiences.

- **Blogs** – ARENA updates its online blog 'ARENAWire' on a weekly basis sharing the latest news about its projects to the general public whom can also subscribe to receive the updates in their inbox.

- **Knowledge Bank** – ARENA maintains an extensive, easy to navigate library of reports, studies and tools that are freely available to industry and the public.

- **Parliamentary Showcase** – ARENA hosts an annual showcase at Parliament House Canberra that brings together the Ministers for Energy and Environment and industry leaders.

- **Social media** – An ever-increasing social media presence across Facebook, Twitter and LinkedIn through which it shares knowledge.

ARENA takes a portfolio approach to knowledge sharing, using 'portfolio implementation plans' to articulate how ARENA will use data and learnings from projects to influence the behaviour of key stakeholders. About two years ago, ARENA has moved from a decentralised knowledge sharing model to the creation of a dedicated 'Knowledge Sharing Team' within the project delivery branch to coordinate knowledge sharing activities across the agency.

Over the past three years, ARENA has delivered a mix of knowledge sharing achievements, including content development, workshop and forum facilitation and delivery of specific reports and government briefings, as shown in Table 3.

Table 3: Knowledge Sharing achievements			
Activity	**2016/17**	**2017/18**	**2018/19**
Knowledge Sharing Products produced	► 8 new reports added to the Knowledge Bank ► Number of Knowledge Bank page views over 3 months from May to June 2017 was four times greater than for the same period in 2016 ► Off-grid portfolio newsletter launched ► Added ReWired podcasts and ARENAWIRE blog to the website.	► 7 new publications ► 23 new reports added to the knowledge bank ► 1182 unique downloads and more than 3700 unique Knowledge Bank page views over three months from May to June 2018 ► Monthly ARENA wire blog and podcasts obtain high engagement with audiences.	► 8 insights newsletters ► 70 public reports uploaded to the Knowledge Bank ► 20 public presentations uploaded to the Knowledge Bank ► 19 Public reports commissioned and/or prepared by ARENA and uploaded to the Knowledge Bank ► 11 Public Policy Submissions ► 15 Ministerial briefs prepared ► 84 Blog posts ► 15 videos.
Knowledge Sharing Events	► Series of presentations provided at conferences ► Site visit to the DeGrussa Solar Project.	► 11 industry events attended by more than 220 stakeholders ► Innovating Energy Summit.	► 2 insights forums ► 7 workshops and events facilitated by ARENAs knowledge sharing team
Working Group Participation	► Not reported.	► Presented at 34 industry conferences and 34 industry forums.	► ARENA participated in 8 working groups chaired by other industry bodies, including the Australian Energy Market Commission, Australian Energy Market Operator and Energy Security Board.

Source: ARENA, 2016-17 Annual Performance Statement, 2017-18 Annual Performance Statement, and '2018-19 Draft Performance Statement'

Effectiveness of ARENA's program and portfolio knowledge sharing activities

Evidence from previous evaluations suggests ARENA's knowledge sharing has been effective and improved over time. Knowledge sharing requirements in earlier funding programs were complex, and not always fit-for purpose, however, these have been refined over time to become more targeted. Similar to ARENA's collaboration activities, knowledge sharing informally brings together the private sector (e.g. developers, banks, debt and equity providers, Engineering, Procurement and Construction (EPC) and operating and maintenance businesses) to work together and deliver projects. Knowledge sharing is seen by many of ARENA's stakeholders as being both a critical and beneficial activity:

- ARENA's 2019, second quarter survey results found that 75.7 per cent of funding recipients find value in the knowledge sharing reports and in ARENA's knowledge sharing events. Further, 94.6 per cent of people feel that the Knowledge Sharing Plan and its outputs are valuable to support industry development or knowledge dissemination

- The EY Sweeny stakeholder research report found that 77 per cent of respondents considered ARENA's knowledge sharing activities effective. Further it found that ARENA's knowledge sharing is the most significant contribution made by ARENA second only to funding.[35]

Findings on the effectiveness of ARENA's knowledge sharing activities within funding programs are described in Table 4 below.

[35] EY Sweeny, 2019, 'ARENA Stakeholder research' page 35

Table 4: Findings on the effectiveness of ARENA's programs' knowledge sharing	
Extensive Knowledge Sharing has been undertaken throughout ARENA's programs	► The Advanced Biofuels Readiness Program (ABIR) shared a high level of knowledge and enabled significant and broad ranging collaboration between grant recipients, which has continued post-contract. All funding recipients produced publicly available information about the projects and there was a high level of collaboration and information sharing through the program period. ► The ACAP disseminated research findings through academic and scientific channels, and since inception has been responsible for its research being featured in 14 books and chapters, approximately 450 magazine and newspaper articles including approximately 208 publications in technical and scientific journals. ► ASTRI undertook knowledge sharing activities through publishing research in scientific and technical journals as well as participation through national and international conferences. This included impressive knowledge sharing activities undertaken by the organisation with a greater magnitude of research published and presented than would be expected from a relatively nascent research initiative.
Knowledge sharing has been effective and valued	► Formal knowledge sharing undertaken during the LSS Competitive Round was considered to benefit new market entrants, the public, regulators and other market participants more than program participants. Overall the knowledge sharing was generally effective, although there was room for improvement in the timeliness of sharing knowledge. ► Projects undertaken as part of the Regional Australia's Renewables Program (RAR) facilitated the sharing of knowledge on the provision of renewable energy to off-grid and fringe of grid areas and increased knowledge and skills in the integration, operation and maintenance of hybrid systems in fringe-of-grid and off-grid systems. Knowledge sharing was deemed to be a worthwhile and critical component of the program. Applicants appreciated the benefits they gain through having access to the knowledge generated by others in the sector. ► Proponents of the ABIR program valued the knowledge sharing aspect of their projects favourably. It enabled each to build their own knowledge-base through dialogue with others who have been made aware of the project through conference presentations, journal articles or other publicly disseminated materials. ► During the Distributed Energy Resources (DER) Integration Project ARENA actively identified the importance of knowledge sharing to drive industry capability and making project delivery more effective.[36] ► 75 per cent of respondents to ARENA's most recent quarterly knowledge sharing survey in May 2019 indicated ARENA's knowledge sharing activities were valuable to their work and 71 per cent had formed new relationships or strengthened existing relationships, demonstrating that KS activities are having a meaningful impact on industry.
There have been challenges in knowledge sharing but these have improved over time	► Issues around specific knowledge sharing requirements have been raised in earlier evaluations of ARENA's (ARP, ABIR, RAR). They made recommendations to simplify the specifics and clarify the objectives of knowledge sharing plans and tailor requirements to the market and renewable energy sector's needs. ► For example, the knowledge sharing reports as part of the DER Integration Project were not being targeted to specific audiences or industries, which may affect the ability of these activities to ensure the right information is being disseminated to right people and in the right format. ► ARENA has accepted all recommendations from earlier program and portfolio evaluations on knowledge sharing and implemented strategies to address this, such as establishing a Project Portfolio Management Committee to guide the development of program design and knowledge sharing requirements, creation of a single point of accountability (a specific Knowledge Sharing team), and simplifying knowledge sharing templates. ARENA's recent LSBS knowledge sharing report has shown that ARENA has acted to tailor knowledge sharing products to the market and sector's needs. ► The more recent LSS evaluation found knowledge and experiences from the Competitive Round have been, and continue to be, beneficial to market participants, regulators and other government agencies. ARENA should continue to produce knowledge sharing materials, while improving the timeliness of their publication and considering how best to communicate the insights.

ARENA's knowledge sharing activities undertaken as part of funding programs have been extensive, are effective and valued by market participants to support industry development and/or knowledge dissemination. ARENA has responded to feedback from market participants to improve and tailor these activities to best meet market needs.

[36] Marchment Hill Consulting, 2019, 'Distributed Energy Resources (DER) Integration Project Contribution Assessment'

Effectiveness of other knowledge sharing activities

As described above, ARENA undertakes additional knowledge sharing activities outside of funding programs to better inform industry and government of developments in the renewable energy sector. The effectiveness of these activities has been assessed through survey responses and statistical analysis of users of ARENA's knowledge sharing reports, and attendees of knowledge sharing events. Overall, these informal knowledge sharing activities are highly valued. Findings on the effectiveness of ARENA's broader knowledge sharing activities are listed Table 5 below.

Table 5: Effectiveness of ARENA's other knowledge sharing activities	
Workshops and insights forums are valued	► The LSS Competitive Round participants found informal knowledge sharing such as workshops, conferences and seminars were considered more valuable for program participants as it encouraged more open participation. ► Attendance at ARENA's Insights Forums in November 2018 and June 2019 attracted approximately 330 attendees. Feedback from the insights forums found an overall participant satisfaction level of 8.6/10 and that participants rated the value of ARENA's knowledge sharing 8.8/10 ► ARENA's May 2019 Quarterly Knowledge Sharing Survey found that most projects considered conferences were the most effective means of sharing knowledge, and 71 per cent of respondents indicated their knowledge sharing activities have resulted in new relationships formed, or strengthened existing relationships
Knowledge bank is an accessible and utilised tool	► The knowledge bank is an effective form of knowledge sharing indicated by the fact that 94 per cent of readers who visit the knowledge bank subsequently download a report, indicating that knowledge is being actively consumed by users. ► ARENA's May 2019 Quarterly Knowledge Sharing Survey found that R&D projects found published articles were the most effective and preferred method of knowledge sharing
Media and social media reach is considerable	► The ARENA insights newsletter has approximately 635 engagements per edition. Engagements indicate that readers are interested in learning more and are going on to read articles in more detail. ► ARENA's media reach is considerable, 37 project-related media releases have reached 37 million people based on media monitoring data.

ARENA's broader knowledge sharing activities are highly valued by market participants and facilitate open participation to improve future project delivery and industry capability to increase the competitiveness the supply of renewable energy.

Findings

ARENA's knowledge sharing activities are highly valued by industry, and are actively contributing to better informing industry and government to navigate the energy transition by sharing:

- Lessons learned from its funding programs and portfolios to improve future project delivery
- The latest developments in the renewable energy space to improve industry capability.

The effectiveness of ARENA's knowledge sharing activities has improved over time. Initially ARENA's knowledge sharing was facilitated primarily through contractual knowledge sharing plans. Now, ARENA's knowledge sharing activities extend to a wide range of formal and informal products and events.

ARENA has shown a commitment to improving knowledge sharing challenges highlighted in previous evaluations. Into the future ARENA should ensure that knowledge sharing continues to be timely and continue to monitor and report on the results of knowledge sharing activities.

Building networks and collaborating

ARENA facilitates the building of networks and fostering collaboration of key market participants and stakeholders to deliver on better collaboration and innovation outcomes. By encouraging collaboration across the energy sector, ARENA prompts the private sector to come together and deliver projects e.g. by bringing together debt and equity providers, EPC and O&M stakeholders.

Specifically, ARENA has undertaken collaboration through hosting A-Lab sessions, though its funding programs (with universities and the private sector), and by establishing Memorandums of Understanding (MoU) with key industry bodies and governments.

Accelerator Lab (A-Lab)

A-Lab is ARENA's innovation lab initiative which aims to create cross-sector partnerships and world first projects to transform Australia towards a clean energy future. It draws upon a network of people with a wide range of expertise and diverse experience to generate new ideas and initiatives to drive systemic change in the electricity sector.[37]

A-Lab seeks to achieve this through hosting events to drive idea generation ('Ideate' events), develop project ideas ('Incubate' Working Sessions) and support co-design of large multi stakeholder funding programs ('Accelerate' Workshops). The results delivered by the A-Lab in the past two years are summarised in Table 6 and the case study below.

Table 6: A-Lab results

Year	Events	Ideas Generated	Projects Funded by ARENA	Funding Awarded
2017 A-Lab Impact Report	11 Events since April 2016	243	14	$36.4 m
2018 A-Lab Impact report	4	300+	12 with 6 currently under review	$48.5 m

Source: ARENA A-Lab Impact Report 2017 and 2018

In 2018, 214 individuals from 147 organisations participated in the events, bringing the total A-Lab participants and organisations involved to 545 and 203 respectively.[38] Key outcomes of the A-Lab program has been the development of the Short-Term Solar Forecasting program, Demand Response pilot and Greensync's DeX program.

Stakeholders value the way in which ARENA's regular innovation labs and industry events bring different stakeholders in industry together. These views were shared in the EY Sweeney 2019 stakeholder survey where collaborative activities were seen to be critical to the collective advancement of the industry on a whole due to funding pressures.[39]

[37] ARENA, 2017, 'A-Lab Impact Report'
[38] ARENA, 2018, 'A-Lab Impact Report'
[39] EY Sweeny, 2019, 'Stakeholder Survey'

Case Study: The Distributed Energy Integration Program

An A-Lab Accelerate Workshop was attended by 60 Participants to explore options for enhancing collaboration on the challenge of integrating distributed energy resources into the grid. This event was the genesis for the Distributed Energy Integration Program (DEIP) a collaboration of key industry players working towards gaining maximum benefit for all electricity consumers from Australia's distributed energy resources.

ARENA hypothesised that improving industry collaboration could accelerate the successful deployment of DER and maximise the value this technology provides to consumers and the energy system. A-Lab was the vehicle to test this thought. The workshop had developed more than a dozen possible models for improved industry wide collaboration. These ranged from the establishment of a new peak body or agency, through to more flexible arrangements for regulatory sandboxes, where trials and technologies could be rapidly implemented within a 'safe container' to enable innovation.

Following this A-Lab session, ARENA continued to work with participants, investigating and refining potential models to build consensus around a pathway forward. It was from here that the Distributed Energy Integration Program (DEIP) was born. DEIP is a collaboration of government agencies, market authorities, industry and consumer associations aimed at maximising the value of customers' distributed energy resources for all energy users.

Source: ARENA, 2018, 'A-lab impact report' page 5

Formal funding program collaboration

ARENA's programs such as ACAP and ASTRI have played fundamental roles in strengthening national and international collaborative ties between industry and universities, particularly in PV research. For example:

- ASTRI has established a very successful concentrating solar thermal power (CSTP) research network and community, undertaking an excellent job of establishing a collaborative research program which has seen its membership grow and expand internationally.[40] The ASTRI consisted of seven key Australian Partners (CSIRO, ANU, University of Queensland, Queensland University of Technology, University of Adelaide, University of South Australia, and Flinders University) and three key US partners (Arizona State University, the National Renewable Energy Laboratory and Sandia National Laboratories)[41]

- ACAP has built strong national collaboration for PV research in Australia driving positive impact on the origination and execution of research projects and quality.[42] A key achievement is the establishment of Annual Research meetings which has brought together key Australian PV research organisations, industry and stakeholders as a key qualitative achievement.[43] ACAP's collaboration involved multiple Australian industry and research partners as well as international organisations, shown in Table 7.

[40] ARENA, 2016, 'Australian Solar Thermal Research Initiative Mid Term review' page 16
[41] https://www.astri.org.au/partners/
[42] ARENA, 2016, 'Australian Centre for Advanced Photovoltaics Review' page 17
[43] ARENA, 2016, 'Australian Centre for Advanced Photovoltaics Review' page 11

Table 7: ACAP Collaborative Partners		
Australian Scientific Partners	**Australian Industrial Partners**	**International Organisation**
UNSW ANU University of Melbourne Monash University University of Queensland CSIRO	Wuxi Suntech Power Co. Ltd. Trina Solar Ltd BlueScope Steel BT Imaging PV Lighthouse Greatcell Solar RayGen Resources Pty Ltd	National Science Foundation and Department of Energy–supported Engineering Research Centre for Quantum Energy and Sustainable Solar Technologies (QESST), based at Arizona State University The National Renewable Energy Laboratory (NREL) Sandia National Laboratories Lawrence Berkeley National Laboratory Stanford University Georgia Institute of Technology University of California, Santa Barbara

Source: ACAP Annual Report 2018

ARENA's collaboration approach aligns with the recommendations of a report undertaken in the UK by Sir Andrew Witty.[44] The report described how universities and research bodies can drive economic growth through adopting a 'third mission' to complement their education and research roles. The Witty Report noted a need for universities to identify and undertake "arrow projects". These are long-term strategic projects targeted specifically at local industries where an existing potential for international growth exists.

ARENA has facilitated economic growth in Australia through adopting the 'third mission' objective. For example, the ABIR achieved strategic partnerships between universities and industry through:

- the $5m foundation grant provided to James Cook University which facilitated collaboration between it and their commercial partner MBD Energy Ltd as well as the University of Sydney, University of Adelaide, University of Southern Queensland and with Licella Pty Ltd.
- Awarding merit based competitive grants to:
  - Licella Pty Ltd, a subsidiary of ignite Energy resources which facilitated partnerships with the world-renowned Instituto de Tecnología Química laboratory in Valencia
  - Muradel Pty Ltd who collaborated with Indian companies Aban and Chennai Petroleum Corporation, as well as with the University of Madras.[45]

While ASTRI forged close links with research bodies, it faced some difficulty in forming long term, collaborative links with industry owing to commercial difficulties experienced by its industry partners and difficulty in articulating and realising commercial pathways.

[44] The 2013 Witty Report 'Encouraging a British Invention Revolution'
[45] Clear Horizon, 2016, 'Evaluation of the Advanced Biofuels Investment Readiness Program'

Memorandums of Understanding

ARENA works with leading energy sector bodies and Australian governments to ensure that support for clean energy innovation is collaborative, efficient and effective. During 2018-19 ARENA established seven memorandums of understandings covering joint or coordinated activities.[46] Key ARENA MOU's and the effectiveness of this form of collaboration is outlined in Table 8 below.

Table 8: ARENA's established memoranda of understanding with leading energy sector bodies and governments	
Australian Energy Market Operator	▶ In 2017, ARENA and the Australian Energy Market Operator (AEMO) entered into a MOU to jointly develop 'proof of concept' projects to support the integration of renewable energy into the electricity market. ▶ Programs under the MoU include the Demand Response (DR) Competitive Round and the AGL Virtual Power Plant Trials. ▶ The effectiveness of this collaboration can be seen in the success of the Reliability and Reserve Trader (RERT) trail (described in the case study on page 77) which was undertaken as a result of the DR Competitive Round.
Australian Energy Market Commission	▶ In 2019, ARENA and the Australian Energy Market Commission signed a Memorandum of Understanding to formalise cooperation on the broad program of work currently underway to facilitate innovation in Australia's energy markets. ▶ The MoU sets out a framework for coordination and information sharing to underpin collaborative projects such as the Distributed Energy Integration Program (DEIP) which aims to maximise the value of customer investments in distributed resources.
Clean Energy Finance Corporation	▶ In 2016 the Australian Government enacted a regulation to enable ARENA to assist the Clean Energy Finance Corporation (CEFC) in the governance, management and administration of the Clean Energy Innovation Fund. ARENA and the CEFC jointly manage the Innovation Fund, which makes debt and equity investment in emerging clean energy projects and businesses, using CEFC financing. Since 2016-17, 12 projects originating from ARENA have been funded by the Clean Energy Innovation Fund (CEIF) demonstrating effective collaboration.
South Australian Government	▶ ARENA has signed a Memorandum of Understanding with the South Australian Government with a view to coordinating the assessment of projects that may be eligible for joint funding through the SA Government's Grid Scale Storage Fund (GSSF). ▶ At the time or writing, the GSSF is still receiving funding however the first funding recipient has been announced. Through ARENA's collaboration with the SA Government the GSSF will see the development of SA's first pumped hydro project.
New South Wales Government	▶ In March 2019, ARENA signed a Memorandum of Understanding with the NSW Government to work together to co-fund $75m of proposals received by the NSW Emerging Energy Program, a program designed to support the commercialisation of new large-scale dispatchable electricity capacity in NSW. The MOU will continue until the full funding amount has been allocated.

ARENA's formal and informal collaboration activities have been effective at delivering new partnerships and better informing industry and government.

Findings

ARENA undertakes extensive collaboration through its funding programs, MOUs and A-Lab events which better informs industry and government to navigate the energy transition. The effectiveness of ARENA's collaboration is seen through the outcomes it generates, for example; the Distributed Energy Integration Program was conceived in an A-Lab session whilst the MoU with AEMO has seen the Demand Response Competitive Round and RERT trials commenced.

ARENA effectively fosters collaboration through the facilitation of innovation workshops through the A-Lab program, the research activities undertaken by both ACAP and ASTRI, as well as indirectly bringing together industry and research bodies through the funding of innovative projects. ARENA should continue its effective collaboration activities into the future with consideration of commercial sensitivities when partnering with industry.

[46] ARENA, 2019, '2018-19 Annual Report' page 123

2.2.2 Achieving outcomes in the absence of ARENA

The following evaluation questions were considered in this section:

- Have ARENA's interventions contributed to achieving ARENA's objectives?
- Would these (long, medium or short term) outcomes have been achieved in the absence of ARENA?

This section assesses whether ARENA's interventions contributed to achieving ARENA's legislated objectives.

ARENA's activities are delivered in a complex, rapidly changing environment. ARENA's limited control over external factors can make it challenging to link the results of a particular activity with changes observed in the broader environment.

For this reason, we have undertaken a qualitative assessment of the counterfactual – would the same, or similar, outcomes have been achieved in the absence of ARENA.

2.2.2.1 Outcomes in the absence of ARENA

Assessing the counterfactual is complex, as it involves hypothesising what may have occurred if ARENA didn't exist.

The approach adopted has drawn on findings from research previously undertaken to identify instances where ARENA's actions have resulted in a project going ahead, that otherwise wouldn't have, or instances where the scope or scale of a project was influenced by ARENA support.

It is important to note that undertaking such analysis is not a straightforward exercise, and there are inherent limitations. For instance, many evaluations anonymised stakeholder feedback, thus it is difficult to align the feedback provided to the project in question, however where this link exists we have acknowledged it. The results of this analysis are presented below.

Evidence suggests that ARENA's activities have been effective at catalysing and supporting a number of projects going ahead. Extensive stakeholder consultation undertaken by EY Sweeney with industry stakeholders found that the majority of respondents felt that the rate of growth and acceleration of the renewables sector would have been stymied in the absence of ARENA.[47]

This is supported by analysis undertaken across previous program evaluations which found that projects:

- May not have progressed or been financially viable without ARENA funding
- Research activities may not have been successful without ARENA's involvement
- May have struggled to find alternative sources of finance in the absence of ARENA's support.

Overall it can be concluded that the outcomes ARENA has achieved (as outlined in section 2.2.1) may not have been realised, or realised to a lesser extent if not for ARENA's interventions. As such, ARENA's unique role in supporting relatively higher risk, pre-commercial technologies will have strong ongoing relevance in catalysing and accelerating Australia's response to climate change.

This section outlines specific examples of outcomes that may not have been delivered without ARENA's support.

[47] EY Sweeney, 2019, Australian Renewable Energy Agency Stakeholder Research

Previous independent evaluations undertaken of ARENA's activities have identified specific examples of outcomes that would not have been achieved without ARENA's involvement are provided below.

The review of the RAR Initiative noted that two grants recipients had identified that their projects would not have progressed without the RAR grant and would not have been financially viable without the grant funding. One recipient noted the lack of willingness of the private sector to fund projects of this nature, and another stated that if they were not able to receive the funding from ARENA, it would then be necessary to scale back projects to ensure financial viability. As such, the outcomes delivered by the RAR initiative may not have been achieved to the same extent in the absence of ARENA's funding. These outcomes included:

- The delivery of 78MW of new renewable energy generation capacity
- Attraction of new renewable energy companies to Australia
- Increasing knowledge and skills in the integration, operation and maintenance of hybrid systems in fringe-of-grid and off-grid systems.

The King Island Renewable Energy Integration project detailed that for a relatively small amount of grant funding Hydro Tasmania was able to achieve a high level of renewables in an off-grid location with new and emerging storage enabling technologies. Without ARENA it is doubtful the project would have succeeded which would have resulted in ARENA not being able to study one of the world's first renewable energy projects which combined a range of renewable energy technologies, demand management and storage systems.

Feedback from grants recipients provided to the ARP evaluation were along similar lines. The following quotes from the evaluation highlight the impact the absence of ARENA would have had on individual projects:

"Without ARENA, [the project] would not be here. It wouldn't have got off the ground. It was high risk for us because of the investment needed. Having the ARENA assessment and endorsement has been incredibly useful in getting internal sign off. It gave our Directors confidence in the technology, in an area they are not familiar with. Because [of the] the due diligence on [the project] it gave comfort to Directors. ARENA initiated the Due Diligence as part of the application. [We got] a critical source of funding – no one in the market would have provided funding. For us it offers a step change for the mining sector. Small mines don't want to commit to long term assets – they can become stranded - but short term, higher purchase cost is better for accounting purposes – new accounting obligations, people prefer to have short term higher purchase agreements."

"[The funding] enabled us to stay in Australia. Without the funding we would have been unlikely to do the activity. We would have had to go international [and that] would have been disruptive for company. ARENA helped us stay in Australia and the Region."

"We would not have proceeded with the project, but we have no immediate plans for extending the project."

"Having ARENA involved with your business. The most important thing is having the government with skin in the game (ARENA, PM and Minister interested) – this was worth more than the money. It's a lot harder if it's just ourselves as a private entity."

Further examples of how ARENA's activities and funding was vital to projects going ahead and delivering outcomes that improve the competitiveness of renewable energy technologies to deliver more solutions for secure, reliable and affordable energy are outlined in the following case studies.

Case Study: Advancing Virtual Power Plants from innovation to commercialisation

Virtual Power Plants (VPPs), are being developed with support from ARENA to better coordinate rooftop solar, batteries and other devices owned by consumers. VPPs coordinate and control thousands of residential solar PV systems, batteries and other smart energy devices so they behave like a traditional power plant. This makes it possible for VPPs to help keep the grid stable, manage peaks in electricity demand and allow participating homes and businesses to be paid for providing these services.

ARENA has been helping to develop VPPs since 2014, committing $25.2 million to projects that have increased in scale and sophistication over time. These include pilot projects that demonstrate VPPs in action as well as research projects that develop technologies and business models to help VPPs operate and earn revenue for participants.

ARENA's VPP projects include:

- **AEMO VPP demonstration program** - delivering operational data from VPPs to AEMO, and providing an evidence base to inform changes to regulatory settings or AEMO operational processes.
- **AGL's VPP - network of 1000 cloud-controlled residential premises that operates as a 5 MW VPP.**
- **Alkimos Beach** - developing, deploying and testing a new energy retail model for community-scale battery storage.
- **CONSORT** - Australian National University's project on Bruny Island that uses battery systems and Network-Aware Coordination software to support a constrained electricity network (that experiences low-quality electricity supply).
- **Ergon Retail's VPPx pilot** - demonstrated a commercial and operational model for providing grid-connected solar PV and battery storage systems for 33 systems in three Queensland towns.
- **Reposit Power's GridCredit trials** - allowed stored energy to be sold back into the grid when there is a high value in the market.
- **Simply Energy's VPPx** - 6 MW of residential energy storage, with 10 commercial businesses networked to deliver a further 2 MW of demand response capacity.

An independent evaluation of ARENA's support for DER, including VPPs, conducted in 2019 found that there was a clear progression in the scale and complexity of VPP projects funded by ARENA. The evaluation outlined clear progress towards VPPs being a viable contributor to secure, reliable and affordable electricity in the context of a high renewable electricity system.

For example, ARENA's early VPP projects, such as Reposit's GridCredits and Ergon Retail's demonstration of solar PV and batteries, made a significant contribution by demonstrating how VPPs could combine and coordinate services from numerous distributed energy resources.

The evaluation also found ARENA's funding support of these projects was vital to them going ahead and delivering these outcomes. For example, ARENA's support for Reposit's GridCredits system and Simply Energy's VPPx helped these technologies reach a commercial stage.

Source: ARENA, 2019, 'Annual Report 2018/19'

Case Study: Southern Cross Renewable Energy Fund

The Southern Cross Renewable Energy Fund (SCRE Fund) was established in 2012 under the Renewable Energy Venture Capital Fund Program (REVC Fund Program). The SCRE Fund is managed by Southern Cross Venture Partners (SXVP) with co-investment from Softbank China Venture Capital (SBCVC) and ARENA. From 2012 to 2018 the SCRE Fund has invested over $72m in 12 energy start-ups, 10 of which are still active. University of Technology Sydney (UTS) were engaged by ARENA to undertake an evaluation of the fund and concluded that:

- The SCRE Fund has contributed to an increase in the number of Australian renewable energy and enabling technology companies in Australia. There is evidence that at least some of the companies in the portfolio would either not have been established in Australia, or would have struggled to find alternative sources of finance in the absence of the SCRE Fund's support
- The SCRE Fund played a catalytic role in building industry confidence as a government backed anchor investment providing patient capital to renewable energy companies. The SCRE Fund has also provided a necessary 'local' Australian investment partner for overseas investors who would otherwise have hesitated to invest in renewable energy companies in Australia
- While the SCRE Fund has not necessarily been a critical stimulator of new flows of finance into the renewable energy sector in Australia, it has accelerated investment by others, by acting as a cornerstone investor. The SCRE Fund has also helped to improve the overall conversation about investing in renewable energy in Australia
- The commissioning of independent reviews and evaluations and the restructuring of the SCRE Fund to achieve the best possible outcomes for the SCRE Fund, demonstrates the integrity of ARENA's risk management processes and efforts to ensure the efficient use of public monies
- There is strong agreement that the SCRE Fund continues to be relevant and necessary. The evaluation has found no evidence that the REVC Fund has displaced or duplicated opportunities for alternative sources of investment for its portfolio companies.

Source: UTS, 2019, 'Renewable Energy Venture Capital Fund Evaluation'

Given the findings of the stakeholder surveys, program and fund evaluations, there is sufficient evidence to conclude that without ARENA's support many projects would not have been successful and that levels of investment in and development of renewable energy in Australia would be lower.

Findings

It is reasonable to conclude that ARENA's actions were effective at catalysing and supporting a number of projects going ahead. As a result, the outcomes that these projects achieved, may not have been realised, or realised to a lesser extent if not for ARENA's intervention.

Stakeholder consultation undertaken by EY Sweeney revealed the overwhelming majority of respondents felt that their projects would not have proceeded or been successful if not for ARENA's support. This conclusion is shared throughout several independent evaluations undertaken.

Overall, the outcomes ARENA has achieved (as outlined in section 2.2.1) may not have been realised or realised to a lesser extent if not for ARENA's involvement.

2.2.3 Comparison of alternative interventions (domestic and international)

The following evaluation questions were considered in this section:

- Are there international comparisons of alternative interventions that ARENA could have adopted?
- Would they have been more effective at achieving the outcomes?

ARENA makes use of a suite of funding mechanisms, each tailored for the circumstance to optimise the efficiency of allocating funds. ARENA programs allocate funds to recipients through two funding mechanisms:

- Ongoing intakes to ARENA initiatives (e.g. the ARP).
- Competitive funding rounds, which focus on specific energy technologies (e.g. Large-Scale Solar).

ARENA's application of the different funding mechanisms depends on the objectives of program, the maturity of the technology and the range of technologies seeking to be invested in. For both approaches, ARENA applies a two-step application process:

- Expression of interest
- Full application.

In considering whether ARENA has adopted an effective approach as an organisation and structured its activities and funding mechanisms in an effective way, we have undertaken a high-level desktop review of a selection of domestic and international examples of other organisations which have a similar purpose, form and intent, as well as the funding mechanisms that have been implemented by each. These examples are presented in Table 9 and Table 10 below, and more detail is provided in Appendix C.

There are a number of similarities across all programs considered:

- All programs adopt a competitive multi-stage merit application process, including pre-application processes that screen for project suitability and competitive evaluation processes which draw on technical advice as required.
- There is an expectation across most programs that applicants make a financial contribution or source third-party funding (degree to which varies across programs)

ARENA's funding approach is also broadly similar in both function and form compared to other grants programs internationally. International programs have a similar remit to ARENA in that they focus on the transition to a global clean energy economy and support businesses to develop and demonstrate new technologies. In particular, the programs all focus on early-stages of the commercialisation pathway, particularly the development and demonstration phase.

ARENA's 2017-18 annual budget as a proportion of GDP ranks third behind Germany and Japan's comparable clean energy innovation agencies and is among the few international agencies, along

with France, Japan and the United States which support all three stages of the innovation pathway.[48]

Outcomes of programs are not reported or evaluated consistently across the different examples. However, each program appears to have delivered on its objectives. For example, The Office of Energy Efficiency and Renewable Energy has co-funded approximately 460 projects across the US to increase the use and effectiveness of affordable renewable energy and energy efficiency technologies.

As such, it is difficult to compare whether alternative approaches would be more effective than ARENA's current approach. However, it is clear that ARENA is largely operating within the bounds of international examples of good practice.

[48] EY analysis - selection of agencies for inclusion in this comparison based on agencies identified by Future Needs Review, ARP Evaluation and the Solar RD&D Refresh as being comparable to ARENA in that they support similar stages of the innovation chain (R&D, demonstration and precommercial deployment) and that belong to OECD countries. Proportion of GDP spend based off 2017 data.

Table 9: Domestic examples of grant programs				
Program / Organisation	**Program overview**	**Funding type**	**Funding Process**	**Outcomes**
Entrepreneurs Program Overseen by the Department of Industry, Innovation and Science	Initiative to support businesses improve their competitiveness and productivity Accelerating Commercialisation provides access to expert guidance and grants to help businesses commercialise their novel products, processes and services.	Commercialisation Grants This grant provides projects up to 50% of the expenditure to a maximum of: ► $250,000 for commercialisation offices and eligible partner entities ► $1 m for all other applicants.	Applicants will go through a competitive merit application process. Applications for Accelerating Commercialisation Grants that meet eligibility will proceed to a merit assessment. AusIndustry will prepare a report on all eligible applications prior to merit assessment which includes a due diligence report, completed by a Commercialisation Adviser. This report examines the claims you have made against the merit criteria. The Programme Delegate will make the final decision.	No formal evaluation undertaken Evidence from funding recipients indicates the program has been essential in helping commercialise their products: "In Australia where there is a shortage of venture capital, the Australian Government support has been critical to us in the early stages of getting sustainable solutions to markets." Phil Hodgson, CEO, Calix.[49]
Innovation and Productivity Program Stream Overseen by Regional Development Victoria	This program stream aims to improve the productivity of regional industries and businesses to ensure the long-term sustainability of employment and business growth in regional locations.	Funding Support Applicants are expected to make a financial contribution or source third-party funding. Projects should maximise their funding support from a range of sources including commonwealth/ local government, community, private sector and regional organisations. Priority may be given to projects that are considered investment ready	Applications undergo a two-stage assessment process. The first stage involves determining the eligibility of the proposed project by assessing the project's ability to meet the core RJF and relevant program stream criteria. The first stage will also consider key risks and issues associated with the project. All applications within the RJF will be forwarded to the Back to Work Investment Committee of the Department of Economic Development Jobs, Transport and Resources (DEDJTR) for assessment prior to consideration by relevant Ministers including the Minister for Regional Development.	Outcomes not reported separately to the broader funding program

[49] https://www.business.gov.au/Assistance/Entrepreneurs-Programme/Accelerating-Commercialisation/Customer-stories/Customer-story-Calix

Table 10: International examples of Government agencies providing grant programs					
Program / Organisation	**Organisation objectives / purpose**	**Program overview**	**Funding type**	**Funding Process**	**Outcomes**
Office of Energy Efficiency and Renewable Energy (United States)	To create and sustain American leadership in the transition to a global clean energy economy. Its vision is a strong and prosperous America powered by clean, affordable, and secure energy[50]	Provides support for projects in the following key phases of the commercialisation pathway: Phase 1: Applied Research Phase 2: Development and Demonstration Phase 3: Focus on Market Barriers	Grant funding Provides grant funding to successful projects: ► Projects are required to have a least 20 % cost share ► Projects that include demonstration are required to provide at least 50% cost share during validation.	Funding opportunity announcements which encourage collaborative partnerships After this, applications undergo a rigorous peer-evaluated selection process to select projects for negotiation to receive funding. This is a two-stage process: ► Concept paper ► Full application.	Has co-funded approximately 460 projects across the US to increase the use and effectiveness of affordable renewable energy and energy efficiency technologies.
Sustainable Development Technology Canada	To support Canadian businesses to develop and demonstrate new environmental technologies that address climate change, clean air, clean water and clean soil	Fund the development and demonstration of new sustainable development technologies related to climate change, clean air, clean water and clean soil.	Grant funding Provides non-repayable contributions to successful applicants: ► On average, 33% (up to 40%) of eligible project costs ► Average contribution is $3million ► 25% of eligible costs must be funded through private sector contributions ► Funding from all levels of government must not surpass 75% of eligible costs ► At least 50% of eligible project costs must be incurred in Canada.	Competitive application process Applications for funding are accepted on a rolling basis throughout the year. Multi-step process providing checkpoints and coaching throughout the evaluation process: ► Phase 1: Application ► Phase 2: Due diligence – If the project is assessed to align with SDTC's eligibility criteria, the project proponent is invited to submit a detailed proposal. Detailed proposals will be reviewed by the Project Review Committee and presented to the SDTC Board for approval ► Phase Three: Funding Approved – if the project is approved, SDTC will assign a Project Manager to prepare a Contribution Agreement to advance the project.	By the end of March 2018, SDTC-supported projects had created 10,943 new jobs (direct and indirect) attributable to SDTC-funded projects as of March 31, 2018 and were generating $2.7 billion in annual revenues for Canadian cleantech companies. Have supported 91 projects in markets with climate change benefits at the end of 2016, with 10.1MtCO2e annual ghg emissions reductions attributable to SDTC's projects [51]

[50] https://www.energy.gov/eere/about-office-energy-efficiency-and-renewable-energy
[51] https://www.sdtc.ca/en/results/our-impact/

Table 10: International examples of Government agencies providing grant programs					
Program / Organisation	**Organisation objectives / purpose**	**Program overview**	**Funding type**	**Funding Process**	**Outcomes**
Energy Technological Development and Demonstration Program (EUDP) **(Denmark)**	Provides support for energy-policy targets for security of supply, Danish fossil fuel independence, global climate considerations and considerations for a cleaner environment and cost-effectiveness	► Co-finances the development and demonstration of new and effective energy technologies ► Primary focus on projects to develop, demonstrate and scale-up technologies in Denmark with a view to export them.	Co-finance Annual funding of DKK 170 million	A call for proposals is issues, offering opportunities to respond to an 'ordinary EUDP call' or for 'targeted action' Projects are assessed according to 11 Program criteria	Since 2007, the EUDP has supported more than 600 research, development and demonstration projects through funding of almost DKK 3 billion out of a total budget of almost DKK6 billion. Of these projects, around 400 are ongoing and have been granted a total commitment of around DKK 2 billion

Findings

ARENA's approach to funding projects, was broadly similar in both function and form comparing to other contemporaneous grants programs nationally and internationally. This included having characteristics of a competitive multi-stage merit based application process with pre-application processes to screen for project suitability, transparent grants funding guidelines and merit criteria, and competitive evaluation processes which draw upon technical advice as required.

There are broad similarities to the focus on outcomes, strategic intent and funding mechanisms undertaken by international counterparts to those approaches undertaken by ARENA. It is not possible to compare outcomes across programs, as they are not reported or evaluated consistently. However, it is clear that ARENA is largely operating within the bounds of international examples of good practice. ARENA's 2017-18 annual budget as a proportion of GDP ranks third behind Germany and Japan's comparable clean energy innovation agencies and is among the few international agencies, along with France, Japan and the United States which support all three stages of the innovation pathway.

3. Evaluation of ARENA's Impact

3. Evaluation of ARENA's Impact

The following chapter undertakes assessment of the impact of ARENA's activities on the renewable energy industry and broader economy. In addition to reviewing material provided by ARENA and conducting desktop research, an economic contribution analysis was conducted to determine ARENA's direct and indirect economic impact in terms of output ($m) and jobs in Central and North QLD and Central West NSW.

3.1 Key findings and observations

ARENA has contributed to (or is expected to contribute to) its intended impacts....

- Building and enhancing technology pathways and fostering innovation
  Improved efficiency, affordability and commercial readiness
- Changes to market rules and frameworks
  Informed future regulatory developments
- Development of industry capacity and capability building
  17,740 employed in renewable energy activities in 2017-18
- Direct and indirect economic impacts
  ARENA's regional program activities created 3,863 direct jobs within their local regions
- Creating new supply chains
  Domestic large-scale solar industry, and fostering innovative new business models
- Other social benefits and impacts
  Unquantified environmental and health benefits
- An electricity system with more renewable energy, reducing costs and emissions
  29 per cent increase in renewable energy capacity since 2014

3.2 Impact evaluation

3.2.1 Impact of ARENA's programs

The following evaluation questions were considered in this section:

- Did ARENA's programs produce or contribute to their intended impacts?
- What other broader benefits and impacts have been realised because of ARENA's programs?

ARENA's strategic planning documents (i.e. Corporate Plan) describe a range of impacts that ARENA intends to achieve. These broadly fit into seven categories:

- Building and enhancing technology pathways and fostering innovation
- Development of industry capacity and capability building
- Creating new supply chains
- An electricity system with more renewable energy, reducing costs and emissions

- Changes to market rules and frameworks
- Direct and indirect economic impacts
- Other social benefits and impacts.

Each of these impacts are discussed below.

3.2.1.1 Building and enhancing technology pathways and fostering innovation

This impact refers to ARENA's role in:

- Supporting emerging technologies to move towards commercial readiness more quickly or enable proven technologies (i.e. Solar PV) to become more efficient and affordable (i.e. R&D to demonstrations and feasibility studies)
- The development of enabling technologies and solutions to integrate renewables into the grid.
- Determining the suitability of certain technologies to the Australian market.

Each of these aspects are discussed below.

Improving solar PV cost and performance through R&D

Prior to ARENA's establishment, Australia's grid-connected solar industry was relatively small and, like many other countries, dependent on government incentives to deliver a commercial return.[52] As a result of this tight financial environment, the solar PV industry had limited incentives to make R&D investments which were typically funded through publicly funded research grants.

Since its establishment, ARENA has sought to address the solar PV industry's reliance on government incentives and lack of R&D investment by providing support to projects that substantially reduce the cost and increase the efficiency of solar power. ARENA has invested more than $266m in solar R&D,[53] making it one of ARENA's largest investments as a proportion of its overall budget.

ARENA has used multiple funding models to deliver this investment, including:

- Institutional funding - ACAP and ASTRI are long term collaborative research institutions focussed on solar PV and concentrated solar thermal respectively.
- Funding programs – led by ARENA's R&D program which supports research from early stage through to development.

Today, Australian technology is expected to dominate the global PV market over the next decade with key contributions from ARENA R&D projects undertaken by Australian universities. ARENA funded projects alone have led to 140 patents, more than 800 peer-reviewed journal articles (including >20 papers from ACAP in top 1 per cent of their field), and the demonstration in Australian research laboratories of world-leading solar resource conversion technologies. These capabilities are already underpinning the creation of new companies, jobs and export opportunities in Australia which will grow significantly over time.

ARENA has supported the commercialisation of research and facilitated the development of research-industry partnerships, for example:

[52] ARENA, "Advancing solar in Australia through RD&D investment", 2016, p.31.

[53] ARENA, 2019, Grants Management System data supplied 25 September. Data includes Solar thermal and solar PV R&D and feasibility studies

- Trina Solar – a Chinese company founded in 1997, is a partner in ACAP projects and has worked with ANU to develop high-efficiency IBC solar cells – a technology now in mass production.

- Fulcrum 3D – received ARENA support to develop 'CloudCAM' which uses remote sensors to monitor solar and cloud events. These systems have been installed in Australia as well the UK, US and other markets.

- Solar Analytics – creators of software for household energy system monitoring, was a spin-out from the solar PV research and industry. Solar Analytics provides consumer-oriented dashboard software and an associated Solar-Smart Monitor.

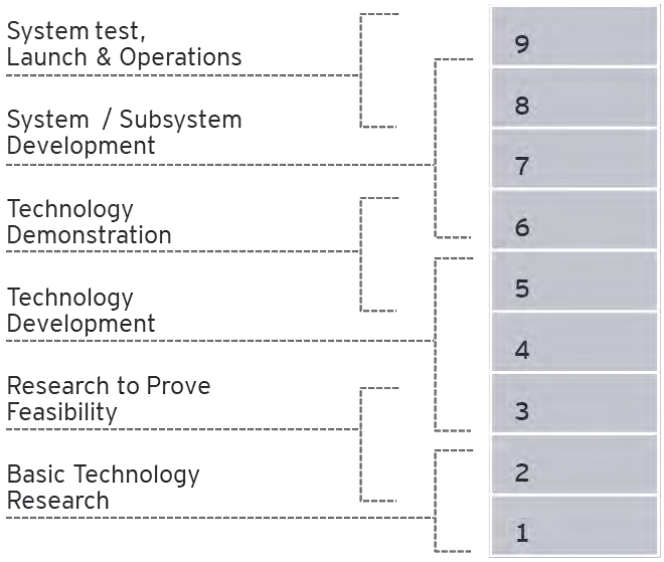
ARENA's impact in reducing solar PV cost and improving performance through R&D can be measured by looking at how solar PV R&D projects have progressed along the Technology Readiness Level (TRL) index.

The TRL index is a globally accepted benchmarking tool, measuring the development of a specific development from blue sky research (TRL1) to actual system demonstration over the full range of expected conditions (TRL9).

For the purposes of its programs, ARENA uses the scale in Figure 6 for all its renewable energy technologies.[54] A detailed description of each technological readiness level is provided in Appendix D.[55]

We note that ARENA's R&D Program has specifically targeted projects with Technology Readiness Levels between 2 to 6 i.e. basic principles through to prototype development.

Figure 6: Technology readiness level (TRL) index, as applied by ARENA



A recent evaluation of ARENA's solar R&D program reviewed ARENA's R&D solar projects' TRL. As indicated by Table 11, it found that the majority of ARENA's projects had progressed (or are expected to progress) from basic technology research (TRL 1-2) through to pre-commercial levels (TRL 5 and 6).

[54] ARENA, 2014, 'Technological Readiness Levels for Renewable Energy Sectors'

[55] ARENA has also developed a Commercial Readiness Index (CRI) as a tool to demonstrate development along the technology development chain once a technology is at the stage where research proves that it is feasible in the field (TRL2). The relationship between TRLs and CRI is also detailed in Appendix D.

Table 11: Allocation of Solar PV R&D funding by TRL at project start and anticipated at project completion[56]

TRL Start	1	2	3	4	5	6	7	8	9	Total
TRL Finish										
2	7									7
3	16	16								32
4		14	4							18
5	2	28	4	3						37
6	1	7	4	6	2					20
7		1	7	2		2				12
8		2		1	3		2			8
9					1	1		1	1	4
Total	**26**	**68**	**19**	**12**	**6**	**3**	**2**	**1**	**1**	**138**

Improving the performance of solar PV through R&D targeting areas such as solar cell efficiency means that greater energy output can be achieved from the same number of solar modules. This is expected to reduce the capital cost of solar PV, which in the long run could deliver savings to energy users.

As previously discussed in the case study 'Australian research is bringing down the cost of Solar PV', it is worth noting that solar cell efficiency improvements have a cascade effect that results in increased cost savings from cells to modules, to distribution and final system costs. For example, for every one percentage point efficiency improvement in module performance (i.e. from 20 per cent to 21 per cent), the cost of the module reduces by approximately five per cent. This means that solar modules that were selling for 60 cents/watt can then sell at 57 cents/watt. Each additional gigawatt of solar installed in Australia each year, would deliver savings of 30 million in the cost of modules.

Improvements in the performance of solar PV also mean that the same electricity output can be achieved from a smaller number of modules. This reduces the environmental impact of solar PV, as less material is required for 'balance of system' components such as support frames and cables and transport costs.

The following case studies provide further examples of ARENA's impact in improving solar PV cost and performance through one-off funding allocations for individual R&D projects.

[56] ITP Renewables, 2018, 'In the spotlight: Australian solar energy R&D outcomes and achievements in a global context'

Case Study: Advanced Silicon Solar Cells

In December 2017, ARENA contributed $1.11m to the Australian National University's three year $4m research collaboration with Jinko Solar, the world's largest PV module manufacturer, to develop new silicon solar cell technology.

The technology being developed in this project is based on thin poly silicon films which provide an alternative method to allow electrical contact to the solar cells due to their excellent electrical properties. Through a simple fabrication process, these poly silicon contacts can increase the efficiency of industrial solar cells from 22 per cent to 23 per cent without any additional costs in production.

Due to be completed in 2020, to date the project has successfully developed a range of suitable methods to create poly silicon contacts for both p-type and n-type semiconductors in the solar cells. ANU has successfully fabricated 23 per cent efficient p-type cells using a boron-doped poly silicon layer. A key focus of the remainder of the project is the transfer of these technologies to the pilot lines at Jinko Solar.

This case study demonstrates that ARENA is contributing to enabling proven technologies to become more efficient and is supporting solar PV from research and development through to introduction into pre-commercial manufacturing.

Source ARENA, 2019, 'Advanced silicon solar cells' available at https://arena.gov.au/projects/advanced-silicon-solar-cells/

Case Study: Development of stable electrodes for Pervoskite solar cells

In December 2017, ARENA contributed $936,000 to the Australian National University's five year $2.5m research collaboration with Monash University into the development of pervoskite electrodes in solar cells.

Pervoskites are a class of material that can be used to make high efficiency solar cells at low cost. The key advantage of pervoskites is they can be deposited at room temperature, have a high material quality and can be tuned to absorb light across the solar spectrum. The main limitation of pervoskite cells are their electrodes however, the project is working to develop novel multi-layered pervoskite electrodes that is expected to substantially accelerate the commercialisation the material and reduce the cost of solar energy into the future.

Source ARENA, 2019, 'Development of stable electrodes for pervoskite solar cells' available at https://arena.gov.au/projects/development-stable-electrodes-perovskite-solar-cells/

ARENA's solar PV R&D funding has significantly enhanced the technological pathway of solar PV, improving cost and performance to the point where Australian technology is expected to play an important role in the global PV market over the coming decade and contributed towards the intended impact of building and enhancing solar PV technology.

Supporting flexible renewable energy technologies towards commercial readiness through R&D, demonstrations and feasibility studies

ARENA has supported a variety of emerging technologies to advance towards commercial readiness. This includes funding R&D, feasibility studies and demonstration projects for flexible resources that support greater integration of renewable energy into the electricity network such as pumped hydro energy storage, battery storage, and concentrated solar thermal. Each is discussed below.

Pumped hydro energy storage

Hydropower currently accounts for 97 per cent of global energy storage. Australia has three pumped hydro facilities in operation (Tumut 3, Wivenhoe Dam and Shoalhaven) providing 1.34GW of generating capacity and stability support to the National Electricity Market.

ARENA has invested $57m on PHES projects, leveraging an additional $688m in private investment.[57] ARENA has invested in multiple pre-feasibility and feasibility studies through its ARP to help to demonstrate the technology's suitability in the Australian environment (i.e. the role PHES can play to underpin the renewable energy transition over the coming decade). ARENA anticipates an additional 2.8GW of new pumped hydro capacity to be in operation by 2030.[58]

The following case studies demonstrate ARENA's impact in supporting PHES towards commercial readiness. We note that ARENA has not captured how its PHES projects have improved in terms of technological readiness.

Case Study: Atlas of Pumped Hydro Energy Storage

ARENA has contributed $609,000 to the ANU's $1.21 million project to develop an Atlas of Pumped Hydro Energy Storage. The study aims to assess the potential for Short Term Off-River pumped hydro Energy Storage (STORES) to provide cost-effective storage on a large scale in Australia. STORES sites typically involve a pair of reservoirs, with one located at a higher elevation to the other.

Researchers at ANU located 22,000 potential pumped hydro sites with the potential to provide up to 67,000 gigawatt hours of energy storage. Further, ANU estimates Australia only requires 450 gigawatt hours of energy storage to support a 100 per cent renewable electricity system. The number of potential sites enables great flexibility in the location of storage sites that would best support the network and create renewable energy zones.

The abundance of sites generated significant interest including from energy companies, government and the community. The work has greatly increased confidence that a future low emissions energy system can be affordable.

ANU also produced a cost model to assist developers to obtain pre-feasibility cost estimates prior to expenditure of funds for detailed feasibility studies. This aims to substantially lower the barriers to mass deployment of pumped hydro, photovoltaics and wind.

In 2018, the project was awarded the 2018 Eureka Prize for Environmental Research.

Source: ARENA, 2019, 'Atlas of Pumped Hydro Energy Storage' available at https://arena.gov.au/projects/atlas-pumped-hydro-energy-storage/

[57] ARENA, 2019, Grants Management System data supplied 25 September

[58] ARENA website, 2019, 'Hydropower and Pumped Hydro Energy Storage'

Case Study: Kidston Hydro-Solar Project

The Kidston project developed by Genex Power, is the world's first integrated solar and pumped hydro site. ARENA has provided ongoing financial support for the project with an initial $4m grant provided for the feasibility study of the pumped hydro followed by $8.9m towards the solar PV farm and most recently in 2018, $5m to the project's pre-financial close activities.

The continued support from ARENA has enabled this world first technological innovation to come to fruition. The project is an important step to towards achieving a secure and reliable grid for Australia and increasing the value provided by renewable energy by providing dispatchable and affordable energy, including ancillary services.

Located 270km north of Townsville, the Kidston site repurposes two gold mining pits as reservoirs for water storage. The project combines 250MW of pumped hydroelectricity storage with a 270MW solar PV farm. During peak power demand, water will be released from the upper reservoir through reversible turbines to create power. During off peak periods, water will be pumped back up from the lower reservoir using electricity generated primarily by the solar farm.

By supporting Genex, ARENA is assisting in creating the world's first large-scale pumped hydro/solar project, the benefits of which go beyond Genex to the broader renewable energy industry.

Source: ARENA, 2019, 'Renewable, reliable energy from an old, abandoned mine site? That's gold' available at https://arena.gov.au/blog/kidston

Battery Storage

The use of battery storage (small-scale and large-scale) is expected to increase over the coming years. Coupling batteries with renewable energy generation allows that energy to be stored during times of low demand and released (or dispatched) at times of peak demand. Batteries can respond faster than other energy storage or generation technologies to help maintain grid stability by turning on and off in fractions of a second.

At present there is no national register of energy storage systems in Australia, making it difficult to estimate the number of energy storage systems. However:

- The Clean Energy Regulator has recorded that almost 16,000 combined battery storage and PV systems were installed in Australia between January 2016 and August 2019 – This includes all voluntary declarations of grid-connected residential and commercial combined systems, where the residents are seeking small-scale technology certificates (STCs).[59] As costs continue to fall installations have increased from around 1,500 units per annum in 2016, to more than 5,500 units per annum in 2018. Australia is expected to lead the residential storage market, with approximately one quarter of global battery installations (by capacity) to be installed in 2019[60]

- Large-scale battery storage is being developed in Australia – A number of high profile projects have recently connected to the grid including the 100MW/129MWh Hornsdale Power Reserve in South Australia which remains the world's largest battery.[61] AEMO forecasts Australia will require 15GW of utility-scale storage (i.e. across batteries, hydro etc) stage by 2040.[62]

While Australia is leading the world in terms of demonstrating the benefits of battery storage systems, early movers have found numerous commercial, technical and regulatory issues which are holding back development of the market. This includes uncertainty around the viability of certain revenue streams, demonstrating the capability of batteries to resolve technical energy system challenges (i.e. inertia, system strength, islanding), and considering the regulatory reform required to allow storage systems to be registered and dispatched.

ARENA has recognised these challenges and invested $166m to support the commercialisation of a variety of battery projects including behind the meter, in a range of off-grid and fringe-of-grid applications, and in large-scale applications in the national electricity grid (at both transmission and distribution levels). This investment has been made through its R&D, Advancing Renewables and RAR programs. ARENA has leveraged an additional $453m in private battery storage investment.[63]

ARENA's impact in progressing the development of battery storage technology is illustrated through its funding of four large-scale battery storage demonstration projects in conjunction with both the South Australian and Victorian governments. Each is outlined below:

1. Ballarat Energy Storage System (BESS) (VIC) – $2.3m grant for a 30MW (30MWh) Fluence Li-Ion battery, commissioned in Q4 2018.

2. Gannawarra Energy Storage System (GESS) (VIC) – $22.7m grant for a 30MW (50MWh) Tesla Li-Ion battery co-located with a 50 MW solar farm, commissioned in Q1 2019.

3. Electranet's Energy Storage for Commercial Renewable Integration (ESCRI) battery (SA) – $12m grant for a 30MW (8MWh) Samsung Li-Ion battery that can operate as separate micro-grid with 90 MW wind farm, commissioned in Q3 2018.

4. Infigen's Lake Bonney battery (SA) - $5m 25MW (52MWh) Tesla Li-Ion battery co-located with 279 MW wind farm, pending connection approval.

[59] The Clean Energy Regulator has previously estimated its data could represent between 33-50% of all household battery installations.

[60] Bloomberg NEF, 2019, Australia to be Largest Residential Storage Market in 2019.

[61] Clean Energy Council, information available at: www.cleanenergycouncil.org.au/resources/technologies/energy-storage

[62] AEMO, 2018, Integrated System Plan

[63] ARENA, 2019, Grants Management System data supplied 25 September, includes; battery storage, off-grid and hybrid funding

ARENA's battery storage demonstration projects sought to identify lessons and opportunities to strengthen the business case and regulatory framework for future battery storage projects. Collectively these projects have identified a range of lessons and opportunities to strengthen the business case and regulatory framework for future battery storage projects. This includes:

- Identifying the key revenue streams for energy storage going forward
- Demonstrating energy storage can provide multiple systems services
- Identifying how fit-for-purpose regulation will further support emerging projects and business models.

Some of these lessons are summarised in Table 12 below. We note that ARENA has not captured how its battery storage projects have improved in terms of technological readiness.

Table 12: Capabilities demonstrated by ARENA-funded large-scale battery storage projects[64]

Capability	Description	Contribution to energy system	Relevant demonstration projects
Wholesale energy market participation and arbitrage	Wholesale energy market participation based on energy market price signals.	Arbitrage through energy storage helps power system reliability, by discharging to the grid when supply is otherwise scarce. As one of the first large-scale grid-connected batteries ESCRI demonstrated that utility scale battery can provide both regulated and competitive energy market services. It is also the first grid-connected battery owned by a Network Service Provider.	BESS, GESS, ESCRI, Lake Bonney.
Frequency Control Ancillary Services (FCAS)	Adjusting the level of electricity export or import to re-balance supply and demand in the power system and restore system frequency to 50 Hz.	FCAS helps maintain power system security by working to keep frequency within the normal operating band, or restoring it following a contingency event. During the first three months of BESS' operation, it was dispatched to provide FCAS more than 1400 times injecting or absorbing power to compensative for excessive drops or rises in frequency. The BESS provided three per cent of raise contingency FCAS dispatched in the National Electricity Market (NEM) in Q1 2019.	BESS, GESS, ESCRI, Lake Bonney.
Fringe-of-grid islanding	Providing backup power supply to local customers following planned or unplanned outages on the transmission network.	Islanding capability can enhance reliability of supply at fringe-of-grid locations. In the case of ESCRI, grid forming and micro-grid operation capabilities allow for islanding of the local network in the event of a network outage, in conjunction with Wattle Point Wind Farm. This is expected to support improved reliability for fringe of grid applications and in the long term may provide a pathway for stand-alone power systems in isolated networks.	ESCRI
System Integrity Projection Scheme (SIPS)	A 'network loading control service', the SIPS scheme by providing fast acting power response from the batteries providing the service.	The ESCRI SIPS helps maintain power system security by protecting the Heywood Interconnector from tripping. This can allow more power flow on the interconnector, allowing more supply from renewable resources.	ESCRI

[64] ARENA, 2019, 'Large-Scale Battery Storage Knowledge Sharing Report'

[64] ARENA, 2019, 'Annual Performance Statement 2018-19'

Concentrated solar thermal (CST)

CST uptake in Australia and globally has been relatively low in comparison to solar PV and wind, due mostly to its higher installation cost.[65] However, CST power plants have attracted increased international interest due to their ability to store large amounts of energy and provide flexible dispatchable electricity supply.[66]

ARENA has invested over $144m predominantly on CST R&D (but also feasibility studies and demonstration) and leveraged an additional $281m of private investment.[67]

Funding has largely focussed on R&D to reduce the costs to accelerate widespread deployment by examining new concepts and technologies such as advanced receivers, new energy storage processes, new power cycles and solar fuels.

Overall, the impact of ARENA-administered investment in CST R&D in Australia has been a significant increase in knowledge and capability in the area. Table 13 provides a summary of ARENA's CST R&D funding in the context of technological readiness.[68] It indicates that ARENA's CST R&D funding has largely been applied and sought to progress projects from a proof of concept (TRL 3 and 4) through to the pre-commercial levels (TRL 5 and 6).[69]

Table 13: Allocation of CST funding by TRL at project start and anticipated at project completion

TRL Start	1	2	3	4	5	6	7	8	9	Total
TRL Finish										
2	7									7
3	16	16								32
4		14	4							18
5	2	28	4	3						37
6	1	7	4	6	2					20
7		1	7	2		2				12
8		2		1	3		2			8
9					1	1		1	1	4
Total	**26**	**68**	**19**	**12**	**6**	**3**	**2**	**1**	**1**	**138**

[65] If the CST sector is compared to wind and PV, it can be observed that, globally CST is currently around 2 per cent of the size of the PV sector in installed capacity and annual investment.

[66] ITP Renewables, 2018, 'Concentrating solar thermal technology status – Informing a CSP Roadmap for Australia'

[67] ARENA, 2019, Grants Management System data supplied 25 September

[68] ITP Renewables, 2018, 'In the spotlight: Australian solar energy R&D outcomes and achievements in a global context'

[69] ITP Renewables, 2018, 'In the spotlight: Australian solar energy R&D outcomes and achievements in a global context'

Despite the strong support for CST R&D over recent years in 2018 CST represented 0.02 per cent of cumulative installed capacity by fuel type in Australia.[70] Previous reviews have identified various factors that might explain why Australia has failed to complete construction of a utility-scale plant, including:

- Lack of a technology or time of generation incentives that mitigate the LCOE technology advantage of wind and solar PV
- Early mover CST project failures, resulting in an adverse perception about the role and capability of CST as a cost-effective technology in the future energy supply mix. [71]

In the absence of a clear path to deployment of CST in Australia, large international CST companies have had only a small presence here. Consequently, it has been hard for the various research groups to form meaningful commercial partnerships.

It is hard to predict the exact trajectory of the technology from individual projects as few have strongly engaged industry partners with clear commercialisation strategies. Australian CST deployment will be very much dependant on future cost reductions, which are expected to be reliant on international CSP leaders (such as Spain and the USA) driving economies of scale.[72]

ARENA funded R&D, demonstrations and feasibility studies have contributed to the intended impact of enhancing the technological pathway of flexible renewable energy technologies in Australia, with some technologies such as PHES and batteries expected to be more successful than others.

Development of enabling technologies and solutions to integrate renewables into the grid

In addition to supporting generation and storage technologies ARENA has helped develop enabling technologies and solutions that support the integration of renewables into the grid in a way that improves system reliability, maintains system security and maximises the value of distributed energy resources (DER).

ARENA has invested in projects that have contributed to developing enabling technologies and solutions across several funding programs including the R&D Program, Advancing Renewables Program and Regional Australian Renewable Community Program.

Enabling technologies often take the form of demonstration projects that include distributed ledger technology (i.e. block chain); advanced metering; system modelling, forecasting and data visualisation tools; and control systems.

ARENA's expected impacts in developing enabling technologies and solutions are:

- Supporting the electricity sector to meet or exceed its proportional share of Australia's emissions
- Helping minimise costs for electricity consumers
- Improving system security (i.e. keeping the power system within technical operational limits)
- Improving system reliability (i.e. retain sufficient generation in the system to meet consumer demand).

[70] GlobalData, 2019, 'Australia Power Market Outlook to 2030 Update 2019' page 9

[71] Ibid.

[72] Available evidence suggests that the cost of CSP systems and the energy they produce, should drop by at round 15 per cent for every doubling of global capacity, consistent with all new energy technologies.

This is supported by two recent portfolio evaluations which found:

- The vast majority of projects within ARENA's reliability portfolio (e.g. 55 of the 84 considered projects) are classified as enabling technologies and that these projects had the potential to significantly reduce the cost of electricity [73]

- A large proportion of projects within ARENA's DER portfolio (23 of 28) involved some form of enabling technology (i.e. smart controls and smart inverters), and that these projects had the potential to provide significant contributions towards understanding the risks and barriers of DER operation. For example, the use of smart inverters to manage voltage disturbances and localized solar forecasting systems to safely ramp up and down solar PV ahead of cloud cover events. [74]

The following case studies provide examples of how ARENA funded programs are helping to deliver these expected impacts. We note that ARENA has not captured how its enabling technology projects have improved in terms of technological readiness.

Case Study: Fulcrum3D CloudCAM Solar Forecasting

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 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 heavily 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 arrangement 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.

Representatives from Fulcrum3D communicated that without ARENA's $490,000 initial support, the $991,000 project would not have been undertaken. This case study is a key example of ARENA funding having a direct influence on development of an enabling technology that is benefitting consumers.

Source: HoustonKemp, 2019, 'Review of ARENA's Reliability Portfolio'

[73] Marchment Hill Consulting, 2019, 'Distributed Energy Resources (DER) Integration Project Contribution Assessment'
[74] HoustonKemp, 2019, 'Review of ARENA's Reliability Portfolio'

Case Study: Network Aware Coordination software (NAC) for Bruny Island

In 2016, ARENA contributed $2.89m to a $7.99m project lead by the Australia National University in partnership with TasNetworks, Reposit Power, University of Sydney and the University of Tasmania to trial the use of software to coordinate distributed battery storage systems on Tasmania's fringe of grid Bruny Island.

Over a three-year period, the trial successfully demonstrated that distributed energy sources can be coordinated in a way the respects network constraints and minimises the total cost of the network provider and the DER owner using NAC software. The trial was able to reduce Bruny Island's reliance on expensive diesel generation which was previously TasNetworks only means of managing network constraints by 33 per cent.

The successful demonstration paves the way for other types of DER, such as electric vehicles, to be coordinated in distribution networks. The technology is now ready for wider implementation.

Source ANU, 2019, 'Project Final Report: Network-Aware Coordination (NAC)'

Many of the generation and storage technologies that are the focus of enabling technology and investment are still moving towards commercial readiness and therefore the expected impacts of enabling technologies are still materialising.

However, based on the evidence presented above (and ARENA's decision to include enabling technologies and solutions as a key part of its 2019 investment priorities), the expected impact of developing enabling technologies could be significant.[75]

ARENA's investment in enabling technologies is expected to enable a greater proportion of renewable energy to integrate into the grid, minimise costs, and mitigate security and reliability risks and having a positive impact on building and enhancing new technology pathways.

Identifying technologies that may be unsuited to the Australian market

While ARENA has contributed to building and enhancing technological pathways and fostering innovation (as evidenced above), part of this process includes testing the viability of certain technologies in the Australian market.

Previous evaluations and ARENA project learnings have identified biofuels and geothermal energy as technologies that have significant barriers to commercialisation, indicating that they may be unsuited to the Australian market.

The following case studies provide evidence to support ARENA's impact in identifying technologies that may be unsuited to the Australian market.

[75] ARENA, 2019, ARENA's 2019 Investment Plan'

Case Study: The Advancing Biofuel Readiness Program (ABIR)

Establishment of ABIR

In 2010, an announcement was made by the Federal Government to establish an Advanced Biofuels Research Institute (ABRI). The institute was to be established with $20 m in funding so progress the commercialisation of advanced biofuels by building the investment case for significant and scalable pre-commercial demonstration projects in Australia.

In 2011, the Minster announced that the ABRI would be a virtual institute and funding would be allocated in two parts: a $5 m foundation grant to James Cook University for its High Energy Algal Fuels project, and a $15 m advanced biofuels grants program.

As part of the competitive grant program, $4.5 m was provided to for the development of a demonstration scale facility to assess the feasibility of converting microalgae to bio-crude, and $5 m to a second project to prepare a feasibility study into the large-scale construction and operation of a plan to convert low-cost, non-edible, waste biomass into a bio-crude oil. The remaining, approximately $5 m of total funding was unallocated and returned to ARENA consolidated fund.

Key findings of evaluation of ABIR

All three projects found that the process of converting biomass, such as algae, to biofuels is not commercial unless economic benefit can be realised through the creation of various co-products.

The projects have progressed the commercialisation of advanced biofuels, albeit not in the manner that was expected at program commencement. There had been a real expectation that the fuel market in Australia, and globally, was ready for the introduction of advanced biofuels and that commercialisation was achievable in the short to medium term. As it eventuated, the market changed markedly between the project commencement and its conclusion, notably the unexpected fall in the fossil crude oil prices. This had a profound effect upon the economics of the projects being pursued.

Notwithstanding the changing market, the projects have resulted in an advancement of the technology to grow and harvest one type of biomass, being algae; to convert organic biomass to bio-crude; and to convert bio-crude to biofuels. ARENA personnel suggested that each project commenced around a TRL-3 and moved to at least TRL-6. These achievements have certainly progressed the technical capacity to produce commercial quantities of advanced biofuels.

Source: Clear Horizon, 2016, 'Evaluation of the Advanced Biofuels Investment Readiness Program'

ARENA's investment has identified processes with significant barriers to commercialisation and for the ABIR program, the key barrier was the cost associated with the upgrade of biocrude to drop-in fuels.

3.2.1.2 Development of industry capacity and capability building

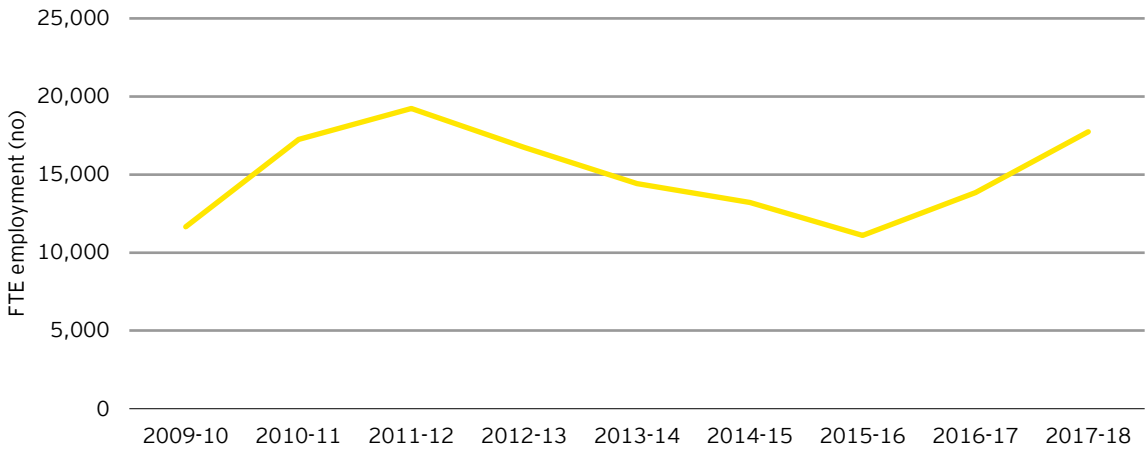
This impact refers to ARENA's role in developing industry capacity and capability. The available evidence of ARENA's impact in this space is presented below.

Employment in the Australian renewable energy sector is on the rise

The global renewable energy sector directly and indirectly employed more than 11 m people in 2018, with more countries manufacturing, trading and installing renewable energy technologies every year.[76] While most of this employment is concentrated in a handful of countries (i.e. China, Brazil, the USA and India), there is evidence to show employment in the Australia renewable energy sector is rising, and that ARENA funding has contributed to this increase.

In its most recent update, the Australian Bureau of Statistics (ABS) reported annual direct FTE employment in renewable energy activities in Australia was estimated at 17,740 jobs in 2017-18.[77] As shown by Figure 7, this is an increase of 3,890 jobs in FTE employment (28%) from the previous year (2016-17) and represents the highest level of FTE employment in renewable energy activities since 2011-12.[78] Note that the 2011-12 peak was primarily a result of feed-in-tariffs, rebates and solar credits, which increased annual small-scale solar PV and water heaters installations.[79]

Figure 7: Annual direct FTE employment in renewable energy activities in Australia, 2009-10 to 2017-18



Source: ABS, 2019, 'Employment in Renewable Energy Activities'

The increase in FTE employment in renewable energy activities between 2016-17 and 2017-18 has been driven by an increase in construction activity on large scale solar photovoltaic (PV) systems (1,950 additional FTE jobs) and roof-top solar PV (1,720 additional FTE jobs). Together, these two renewable energy types accounted for 94 per cent of this increase in FTE employment in renewable energy.

[76] ARENA, 2019, 'Renewable Energy and Jobs Annual Review'

[77] Employment in renewable energy activities refers to employment directly related to the production of renewable energy, and/or by the design, construction and/or maintenance of renewable energy infrastructure. It does not include indirect employment, which comprises all people who work in the production of intermediate inputs related to installing, operating and maintaining renewable energy infrastructure.

[78] ABS, 2019, 'Employment in Renewable Energy Activities'

[79] The Conversation, 2017, 'Three charts on: the incredible shrinking renewable energy job market'

The following section presents evidence that ARENA may have contributed to the rise in renewable energy sector employment. Figure 5 presents a historical plot of large-scale solar PV projects in Australia by accreditation date with the Clean Energy Regulator since 2012, categorised by funding source.[80] It shows that the growth in renewable energy sector employment (driven by large scale solar) reported by the ABS has occurred in the same time period as the majority of ARENA's 18 funded large-scale solar projects became accredited. This includes the 12 projects funded through a competitive process known as the LSS Competitive Round, which received $92m in aggregate grant funding in 2017 (see Figure 5).

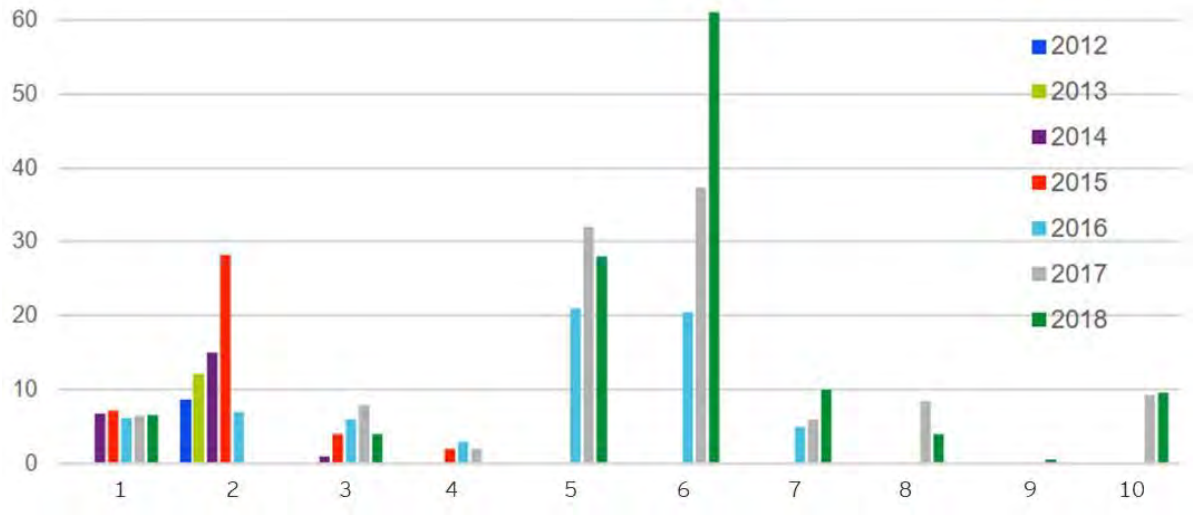
This is further supported by findings from an economic contribution study of ARENA's grant program within regional Australia completed by BIS Oxford Economics' which found that:

"ARENA's funding has been central to the successful commercialisation of large-scale solar PV technology in Australia and in underpinning the sector's current investment boom. Many of these large-scale solar projects are located within regional areas. Construction of these facilities can provide a temporary, but significant, boost to local economies."[81]

The study estimated that the total employment contribution of projects funded by ARENA to regional economies to be 3,863 direct jobs, with 2,659 of those from solar PV initiatives. It also found that only 99 of these jobs were associated with operational activities, which reflects the fact that the renewable energy sector is highly capital intensive.

ARENA's Southern Cross Renewable Energy Fund evaluation reported that the program's portfolio of renewable energy and enabling technology companies has seen an increase in employment since investment (though not all have sustained these employment levels until the present). Figure 8 below shows the number of Australian jobs (FTE) in the active portfolio companies from the financial year prior to investment by the Fund to the end of financial year 2018.[82]

Figure 8: Total number of Australian jobs (FTE) in SCRE fund portfolio of companies by year (company names removed for confidentiality)



Source: Renewable Energy Venture Capital Fund Evaluation, 2019, UTS

[80] EY, 2019, 'Large-scale Solar Portfolio: Evaluation Report'

[81] ARENA – Regional Contributions Analysis, 2019, BIS Oxford Economics

[82] Renewable Energy Venture Capital Fund Evaluation, 2019, UTS

Renewable energy sector capability building

Building the renewable energy sector's capability is a focus area for ARENA. Eight of the 13 program evaluations identified an increase in skills, capacity and knowledge relevant to renewable energy technologies as an objective of programs within the scope of its evaluation.[83]

However, there is currently no public data available that might be a measure or proxy measure of an increase in capability across the renewable energy sector i.e. number of renewable energy developers or increase in average qualifications of renewable energy sector workforce.

There are two primary ways in which ARENA programs reported building energy sector capability:

- Retaining research capability
- Increasing the number of renewable energy companies. Evidence of the nature and scale of these renewable energy sector capability building activities is provided below.

Building research capability

ARENA's investment in Solar PV R&D is a key example of ARENA's contribution to building research capability.

Australian researchers have played - and are still playing - a significant role in the development of commercially viable solar energy technologies as outlined in section 3.1.1.1. Today, Australian research is globally recognised and responsible directly and indirectly for many of the PV technologies currently in commercial production.

Australian-trained PV specialists retain key positions in all the leading PV manufacturing facilities, including Suntech, CSun, JA Solar, CSG Solar, Sunrise, Canadian Solar, REC Solar, Hanwha, Tetrasun / First Solar26.[84]

The ASI (a predecessor to ARENA) and then ARENA have directly funded 35 PhD scholarships and 48 Postdoctoral Fellowships (excluding those indirectly through the ACAP and ASTRI). Collectively, the 86 PhD and Post-Doc grants have received a total funding of $18.1 m.[85] Awards were granted for research at 15 Institutions. Efficiency increase was the most common research goal (39 per cent) with 24 per cent of researchers aiming to develop a new concept and 18 per cent aiming for manufacturing cost reductions.

Importantly, a recent evaluation of ARENA's portfolio of solar research and development found the ARENA PhD and Post-Doc grant awards have provided the key labour source for the solar research undertaken and:

"ARENA support of PhD and Post-doc positions has been instrumental in establishing a new generation of skilled personnel for both research and deployment. This group is now proactively exploring new technologies and new business opportunities. ARENA project funding has served to retain them in Australia longer than has typically been the case."[86]

[83] Multiple evaluations; Solar R&D, ACAP, ASTRI, ABIR, ARP, REVC, A-Lab, Large Scale Solar

[84] ITP Renewables, 2018, 'In the spotlight: Australian solar energy R&D outcomes and achievements in a global context' page 75

[85] PhD scholarships fell into two categories: top-up awards ranging from $20,000 to $50,000 for students in receipt of ARC or university scholarships; full scholarships ranging from $50,000 to $120,000 over 3 to 4 years.
For the Post-doctoral awards, funding provided ranged from $7,000 for short visits to international renewable energy institutions to over $400,000 for four-year research projects.

[86] ITP Renewables, 2018, 'In the spotlight: Australian solar energy R&D outcomes and achievements in a global context' page 75

As part of its assessment process, the evaluation conducted a survey[87] of scholarships and fellowships recipients which found:

- Funded research had delivered an average increase in TRL of 1.6, with 52 per cent of projects increasing by one point on the scale and 21 per cent increasing by 2 points
- A total of 406 publications were reported, the majority of which were reported as journal publications and international conference presentations
- Nine patents resulting from recipient work were reported as filed, and four granted
- 12 researchers indicated that they have been successful in receiving research grants as lead researcher since completing their ARENA funded scholarship or Fellowship.

Increase in the number of renewable energy companies

While not conclusive in nature, a number of evaluations reported increases in the number of renewable energy companies since ARENA's intervention in the market.

The most recent evaluation of ARENA's Renewable Energy Venture Capital Fund (REVC)[88] found its $72m investment had contributed to an increase in the number of Australian renewable energy and enabling technology companies in Australia. In particular:

- The REVC has been able to accept a higher level of risk than the private sector, in a space where there are few funds dedicated to early stage clean energy investment
- There was no evidence that the REVC Fund had displaced or duplicated opportunities for alternative sources of investment for its portfolio companies.

ARENA funding has contributed towards a positive impact of increasing employment and capability across the Australian renewable energy sector.

3.2.1.3 Creating new supply chains

This impact refers to ARENA's role developing new, scalable supply chains in renewable energy for both domestic and export markets. It also includes ARENA's impact in supporting the adoption of innovative business models.

Each of these sub-impacts is discussed below under the theme of creating new supply chains.

Creating new, scalable supply chains in renewable energy

ARENA's deployment projects have helped close the gap between new pre-commercial technologies and commercial competitive forms of power generation, creating new, scalable supply chains in renewable energy. A key example of ARENA's impact in this space is its investment in large-scale solar.

ARENA is also looking to utilise its renewable energy resources, export capabilities and strong relationships with key international markets to help position Australia to export renewable energy as a primary energy. The expected impact of exporting hydrogen to international markets is also explored below.

[87] The survey was sent to 80 directly funded scholarship and fellowship recipients and received 33 responses.

[88] In the 7 years since it began operating in 2012, the REVC Fund has made 12 investments, commensurate with the Investment Plan target of 9-13 companies – UTS, Renewable Energy Venture Capital Fund Evaluation, 2019

Large scale solar

In 2015, ARENA and other market participants predicted the large-scale solar industry might be cost competitive with wind in the early 2020s.[89] However, support from ARENA's Competitive Round has helped advance the commerciality of large-scale solar by five years. Consistent with Table 14 registered installed capacity increased from approximately 69MW prior to the Competitive Round to 2,011MW after the Competitive Round. While forecast capacity[90] in the National Electricity Market (NEM), has increased from 1,373 MW prior to the Competitive Round in May 2015 to 7,992MW in December 2017. As at May 2019, the forecast has increased to more than 27,530MW, with 22,530MW of capacity either committed or proposed.

Table 14: Total generation (MW) for existing and potential Solar developments in the NEM

Status	May-2015	Dec-2017	May-2019
Existing	22	632	1,933
Committed	199	1,180	2,881
Proposed	1,152	6,109	22,649
Total	**1,373**	**7,922**	**27,463**

In order to reach commercial maturity, ARENA has helped the large-scale solar industry build a new, scalable supply chain. A recent evaluation of ARENA's large-scale solar program found the number of developers of accredited solar PV farms increased ~2.5x times, from 12 prior to the Competitive Round to 30 post Competitive Round.[91] This highlighted both the growth and widening of market supply.

Interviews conducted with participating renewable energy developers reported the program enabled them to invest large-scale solar. It also enabled engineering, procurement and construction (EPC) firms to bid and construct large-scale solar projects in Australia. One company reported that industry learnings from the LSS projects are likely to enable EPC firms to complete subsequent large-scale solar projects more cheaply and efficiently.

The following case study provides an example of how the LSS Competitive Round has created scalable supply chains.

[89] ABC, 2017, 'Australia on cusp of large-scale solar boom as setup costs tumble, experts say'

[90] Forecast capacity encompasses existing, committed or proposed projects.

[91] EY, 2019, 'Large-scale Solar Portfolio: Evaluation Report'

Case study: Darling Downs Solar Farm

In 2017, ARENA contributed $20m to the $195m Darling Downs Solar Project lead by APA group in Dalby, Queensland. The 110MW solar farm project is one of twelve large scale solar PV projects supported by ARENA through its LSS competitive funding round.

The LSS competitive round aimed to build Australia's solar supply chain, increase experience in planning and building large scale solar PV, and increase the competitiveness of solar through scaling up supply chains and building capacity and capability. The LSS program is expected to triple the amount of electricity produced from utility scale solar in Australia and unlock almost $1b of commercial investment in solar technology.

Through supporting the Darling Downs Solar Farm, ARENA improved the cost trajectory of large scale solar, enabling it to become competitive with other commercial technologies. ARENA's sharing of knowledge gained from the LSS competitive round in relation to construction techniques, solar forecasting, capitals costs, operations and maintenance procedures practices and grid impacts will help to further strengthen Australia's solar supply chain.

Source: ARENA, 2019, 'Darling Downs Solar Project' available at https://arena.gov.au/projects/darling-downs-solar-project

Photo: RenewEconomy

Hydrogen

In the last few years increasing global attention has been paid to hydrogen as a fuel and energy storage medium for export. Overseas demand for hydrogen is projected to grow strongly, with countries like Japan and South Korea seeking to import renewable hydrogen to meet their long-term decarbonisation objectives. Research commissioned by ARENA calculated that global demand for hydrogen exported from Australia could be over three million tonnes each year by 2040, which could be worth up to $10 billion each year to the economy by that time.[92]

Since 2017, ARENA has spent $48m through its Advancing Renewables Program to help the renewable hydrogen industry overcome barriers to its further development such as the high cost of producing renewable hydrogen, limited regulatory frameworks for applications such as use in the natural gas network, under-developed end-use markets and insufficient demand to attract

[92] ACIL, 2018, 'Opportunities for Australia from hydrogen exports'

investment in projects. During this time, ARENA has leveraged an additional $57 m in private funding.

At this stage it is difficult to measure the potential impact of ARENA's hydrogen funding in creating new, scalable supply chain. This is acknowledged in ARENA's 2019 Investment Plan which recognises hydrogen as a current priority and that any benefits of ARENA funding will be over the long term:

The hydrogen sector is still in its infancy and while key technologies like electrolysers are available, there are few large-scale systems deployed and they are still expensive. As a result, growing this new sector will take many years and require support beyond ARENA's funding horizon. However, ARENA's support now can drive the establishment of this new industry as well as progressing R&D to unlock greater cost reductions.[93]

The following case studies provide examples of the expected impact of ARENA's hydrogen projects.

Case Study: ATCO Hydrogen Microgrid Demonstration

In July 2018, ARENA committed $1.5m towards ATCO's $3.53m hydrogen microgrid project at its Clean Energy Innovation Hub (CEIH) in Jandakot in Western Australia.

The CEIH incorporates the production, storage and use of hydrogen, as well as the commercial application of clean energy microgrid systems. The project will see green hydrogen produced from a solar powered electrolyser injected to the microgrid facility. The hub also consists of 300KW of solar panels and a 400KWh battery. The demonstration will explore some of the safety and technical challenges of hydrogen in storage applications, direct use as a fuel and blending hydrogen with natural gas.

The use of excess energy to power the electrolyser sets this project apart from other hydrogen trials currently underway in Australia. This case study demonstrates ARENA's impact towards creating new, scalable supply chains in renewable energy.

Source: ARENA, 2019, 'ATCO hydrogen microgrid' available at https://arena.gov.au/projects/atco-hydrogen-microgrid/

Case Study: Toyota Ecopark Hydrogen Demonstration

In March 2019, ARENA committed $3.07m towards Toyota Australia's $7.37m hydrogen demonstration project at its decommissioned manufacturing plant in Altona, Victoria.

The project aims to demonstrate the feasibility of producing, storing and using hydrogen generated from renewable electrolysis for both stationary energy and transport uses. The Ecopark will also contain a 'Hydrogen Education Centre' to promote hydrogen innovation and education. Toyota intends the education centre to coordinate research activities that address technology development for the safe and cost-effective generation and use of hydrogen.

The Ecopark will be Victoria's first commercial scale hydrogen refuelling station and will work to reduce the hurdles facing hydrogen infrastructure deployment and catalyse hydrogen vehicle demand. The park forms a key part of Toyota's plan to reach zero emissions from its sites and vehicles by 2050. The repurposing of the car manufacturing plant serves as an example of how industry can transition away from traditional technologies and create new supply chains in renewable technology.

Source: ARENA, 2019, 'Toyota Ecopark Hydrogen Demonstration' available at: https://arena.gov.au/projects/toyota-ecopark-hydrogen-demonstration

[93] ARENA, 2019, 'Innovating Energy ARENA's Investment Plan'

Adoption of innovative business models

It is becoming increasingly clear that the private sector requires both the right technology options and business models to deliver secure and reliable renewable energy. Innovative business models provide both policy makers and investors with the potential to unlock wider system, market, regulatory or commercial benefits to further develop Australia's renewable energy supply chain.

Since 2017, ARENA's investment in business models has sought to align with a range of renewable technologies that are at the pre-commercial deployment stage of the innovation stage. It includes projects that develop business models to:

- Support the integration of large-scale battery storage with generation technologies and as standalone investments
- Support the integration of PHES with generation technologies, and as stand-alone investments
- Demonstrate innovative approaches to maximise the value of DER to their owners, the electricity system and energy consumers, (including reducing system costs and improving system stability)
- Demonstrate electric vehicle (EV) integration in a way that minimises costs and maximises benefits for EV owners and the electricity system.

While this is only a recent investment focus for ARENA and the market more broadly, there is some evidence that ARENA's investment has contributed to the development of innovative business models that can deliver more secure and reliable renewable energy. The case studies below provide examples of the potential impact of ARENA's business model projects.

Case study: Business Renewables Centre

Launched in 2018, the Business Renewables Centre is the first Australian online resource centre and market platform aimed to make it easier for Australian corporates and local councils to purchase or procure renewable energy through corporate Power Purchase Agreements (PPAs). ARENA provided $500,000 in funding to the $1.74m which also received contributions from the Victorian and New South Wales Governments. Since 2016, corporate PPAs have supported projects with a combined capacity of nearly 3900MW, of which 3300MW accounted for new investment.

Collaborating with project partners – Climate-KIC Australia, WWF Australia, and the Institute of Sustainable Futures (UTS), the project overcame the lack of resources and awareness of corporate renewable PPAs by providing access to more than 200 companies, institutions, state and local governments, renewable energy project developers and professional services providers. It also delivered a number of other resources including templates and guides, training and industry events to support buyers and developers with negotiating and executing PPAs. The project aims to help Australian organisations procure 1GW of renewable energy by 2022 and 5GW by 2030.

This case study serves as an example of how ARENA is making the procurement of renewable energy more attractive for corporate Australia through an innovative business model and thus increase the supply of renewable energy in Australia by enabling current and future renewable projects to obtain finance.

Source:

ARENA, 2019, 'Business Renewables Centre Australia' available at https://arena.gov.au/projects/business-renewables-centre-australia

Energetics, 2019, 'Corporate renewable energy PPA deal tracker' available at https://www.energetics.com.au/insights/knowledge-centres/corporate-renewable-ppa-deal-tracker

Distributed Energy Exchange (deX) - Greensync

The deX product is a single platform that enables widespread connection of DER devices to provide greater visibility of the location, performance and technical ability of these devices for system operators. In addition, the platform contains an online marketplace for DER exchanges across a range of devices and service providers, which enables customers and communities and utilities in Australia to trade distributed energy.

The initial $405,000 of 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 benefits both in Australia and abroad. In Australia, deX has been deployed by Simply Energy in its VPPx project and utilised by South Australian Power Networks (SAPN) to increase visibility over DER exchanges. In fact, the platform is seen as a complement to other innovations rather than a competitor or inhibitor.

The service can be utilised by any VPP platform and, in conjunction with further smart-meter installations, can help unlock the true potential of household renewable assets. Representatives from GreenSync identified flexible and decentralised electricity markets as a significant future need, and see deX as the key to enhancing the democratised nature of the electricity market.

However, there are still issues to be resolved in this area. GreenSync's current focus is on identifying the rules and requirements that are likely to be an issue under the current regulatory framework. The main areas of concern are the rules regarding the rights and obligations relating to managing distributed resources to maintain system security. As a platform, deX has the capability to operate the DER market, however GreenSync stress that they are not the body to which this responsibility should fall.

Source: HoustonKemp, 2019, 'Review of ARENA's Reliability Portfolio'

ARENA's deployment projects have had a positive impact on creating new supply chains by contributing to the creation of a domestic large-scale solar supply chain, supporting the beginnings of a hydrogen economy and fostering innovative new business models. In addition, ARENA is expected to contribute towards the development of international supply chains in renewable energy exports (i.e. hydrogen).

3.2.1.4 An electricity system with more renewable energy, reducing cost and emissions

This impact refers to ARENA's role in increasing the supply of renewable energy in Australia, reducing the cost renewable energy while also reducing Australia's energy related emissions.

Increased supply of renewable energy

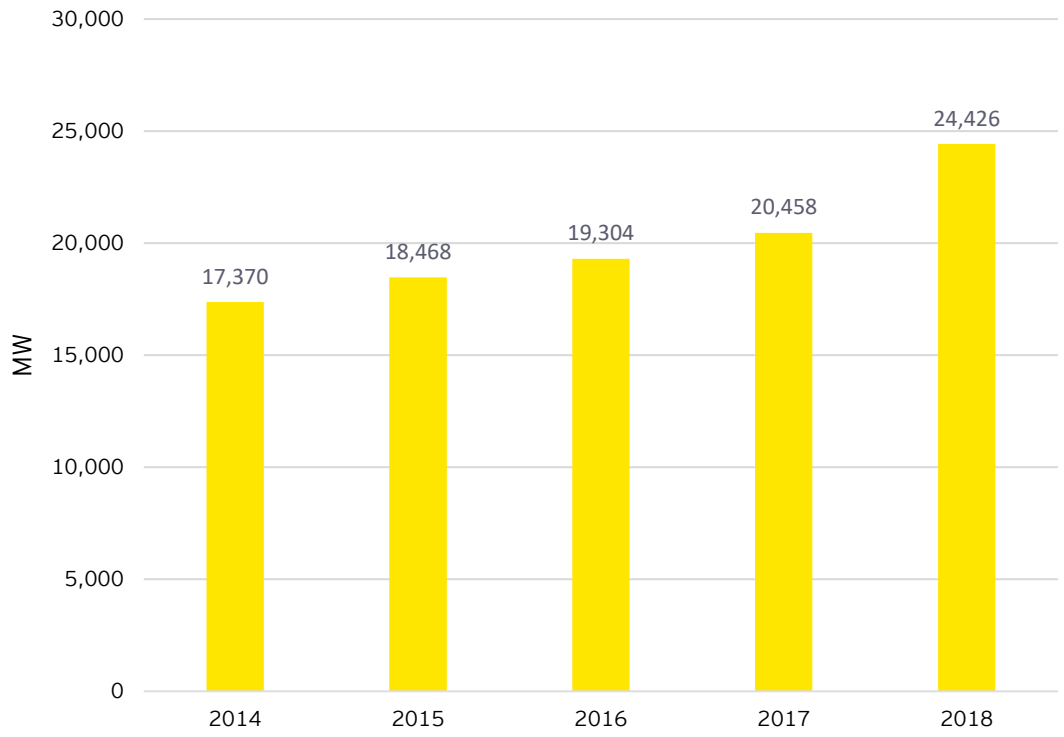
Increasing the supply of low-cost renewable energy reduces costs for residential, commercial and industrial users while also reducing emissions.

ARENA has contributed to increasing the supply and diversity of renewable energy in Australia by funding:

- The deployment of Australian first renewable energy projects (for example, the LSS contributed to cost reductions for subsequent projects, with solar overtaking wind as the cheapest source of generation in 2018)
- RD&D and feasibility studies, which improve either technology readiness or commercial readiness of renewable energy technologies, and thereby enable commercial investment beyond the specific projects funded by ARENA.

According to the International Renewable Energy Agency (IRENA) Australia has experienced a 29 per cent growth in renewable generation capacity from the period 2014 to 2018 (Figure 9).[94] A further 51.6GW of renewable generation is committed and proposed in the NEM pipeline.[95]

Figure 9: Australian renewable energy capacity



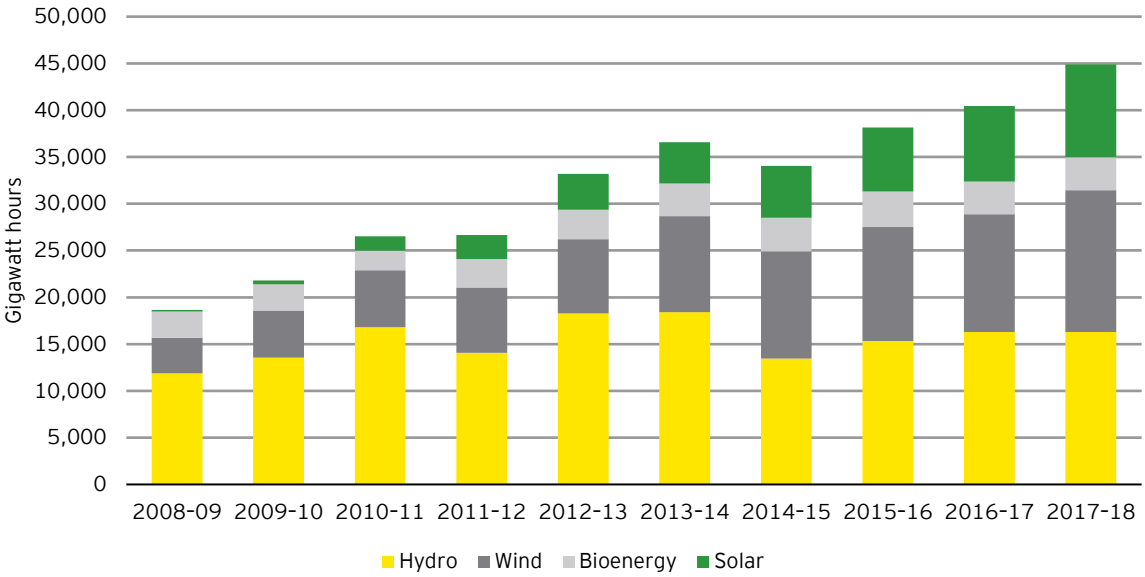
[94] Given the delay between the agency's inception, funding and commissioning of renewable energy investments, 2014 has been selected as the base year for measuring ARENA's impact in increasing the supply of renewable energy. Data sourced from IRENA Renewable Energy Statistics, 2019, available at https://www.irena.org/publications/2019/Jul/Renewable-energy-statistics-2019

[95] Calculated from AEMO NEM generation information data available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

Source: IRENA

Electricity generated from renewable sources during the same period has increased 24 per cent. The largest increase has been in generation from solar (both rooftop and large scale) which has increased 125 per cent, followed by wind which has increased by 48 per cent (Figure 10).[96]

Figure 10: Electricity generation from renewable sources



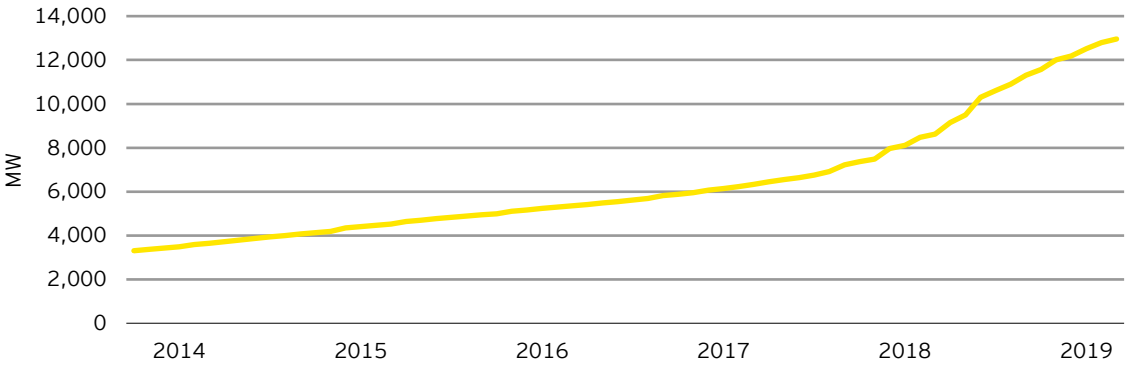
Source: Department of the Environment and Energy

The Clean Energy Regulator recently reported in May 2019, that there is 6553MW of capacity from new renewable energy projects under construction or already built, more than required to meet the 2020 Renewable Energy Target (RET) of 33,000GWh (approximately 6400MW of capacity).[97]

Rooftop solar PV

Installed capacity of rooftop solar PV has experienced a very fast rate growth, increasing from 3300MW in 2014 to more than 11,300MW in 2018 (Figure 11).

Figure 11: Growth in rooftop solar PV installed capacity



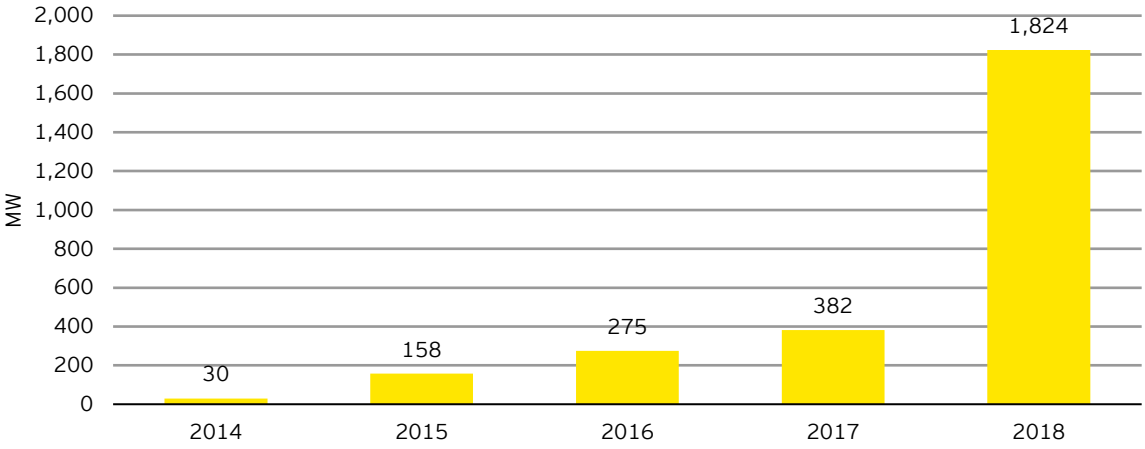
[96] Australian Energy Update, 2019, Department of the Environment and Energy, available at https://www.energy.gov.au/publications/australian-energy-update-2019
[97] Australian Energy Council, 2019, 'The RET: Mission accomplished' available at: https://www.energycouncil.com.au/analysis/the-ret-mission-accomplished/

Source: Australian PV Institute

Large scale solar

Installed large scale solar[98] capacity has grown from 30 MW in 2014 to over 1800MW in 2018 according to the Clean Energy Council (Figure 12).[99] ARENA's contribution towards this growth is identified in the LSS evaluation report (discussed below).

Figure 12: LSS cumulative installed capacity



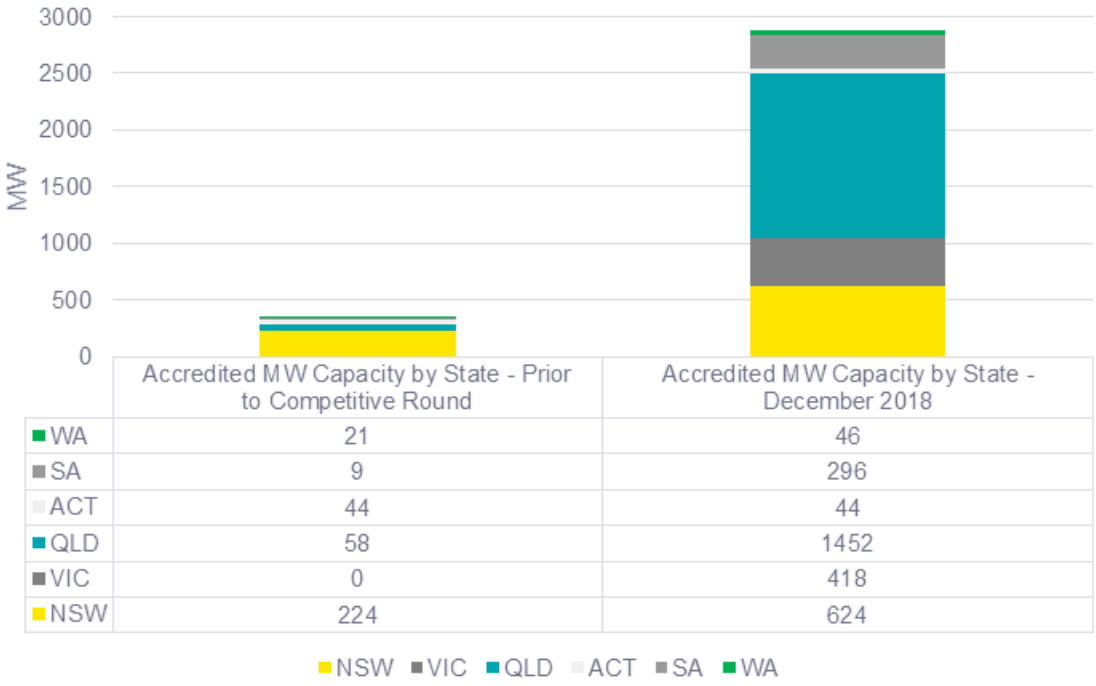
Source: Clean Energy Council

As noted in Section 3.2.1.2, ARENA provided funding for 18 large scale solar projects (beginning in 2012). ARENA's support for solar PV technology at early innovation through to deployment stages has created an investment climate that has fostered a significant amount of growth in non-ARENA funded projects.

As demonstrated in Figure 13, the accredited capacity of large scale solar in Australia increased following ARENA large scale solar program.[100] It is reasonable to conclude that ARENA had a significant impact on increasing the supply of large-scale solar projects in Australia through first mover effects.

[98] Greater than 5MW
[99] Clean Energy Australia Report, 2019, Clean Energy Council, page 70, available at https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2019.pdf
[100] EY, 2019, 'LSS Evaluation'

Figure 13: Accredited Large-Scale Solar PV Projects in Australia prior to LSS Competitive Round and post LSS Competitive Round



	Accredited MW Capacity by State - Prior to Competitive Round	Accredited MW Capacity by State - December 2018
WA	21	46
SA	9	296
ACT	44	44
QLD	58	1452
VIC	0	418
NSW	224	624

Source: EY Analysis based on accreditation data from the Clean Energy Regulator.

The following case study provides a further example of ARENA's impact in increasing the supply of renewables.

Case study: Regional Australia Renewables Initiative

While the majority of ARENA programs have been directed towards research and development stages of the innovation chain. The Regional Australia Renewables Initiative announced by ARENA in 2013 was a $400m program that aimed to demonstrate the feasibility of renewable energy solutions in regional and remote Australia. The projects funded included;

- Coober Pedy Renewable Diesel Hybrid
- DeGrussa solar project
- Lord Howe Island Hybrid Renewable Energy System
- Weipa 6.7MW solar PV farm
- Yulara solar project.

The RAR evaluation undertaken by Clear Horizon found that through the program ARENA had contributed to increase the supply of renewable energy by;

- Supporting the delivery of 78MW of new renewable energy generation capacity in fringe and off grid areas of the NEM
- Demonstrating it is possible to integrate renewable energy technologies into fringe and off-grid systems
- Improving perceptions of the reliability and viability of hybrid systems
- Increased interest within industry for hybrid energy systems and brought international energy companies to Australia.

The case study is a key example of the impact ARENA has had on increasing the supply of renewable energy in regional and remote Australia.

Source: Clear Horizon Consulting, 2018, 'Regional Australia's Renewables Initiative Evaluation Report'

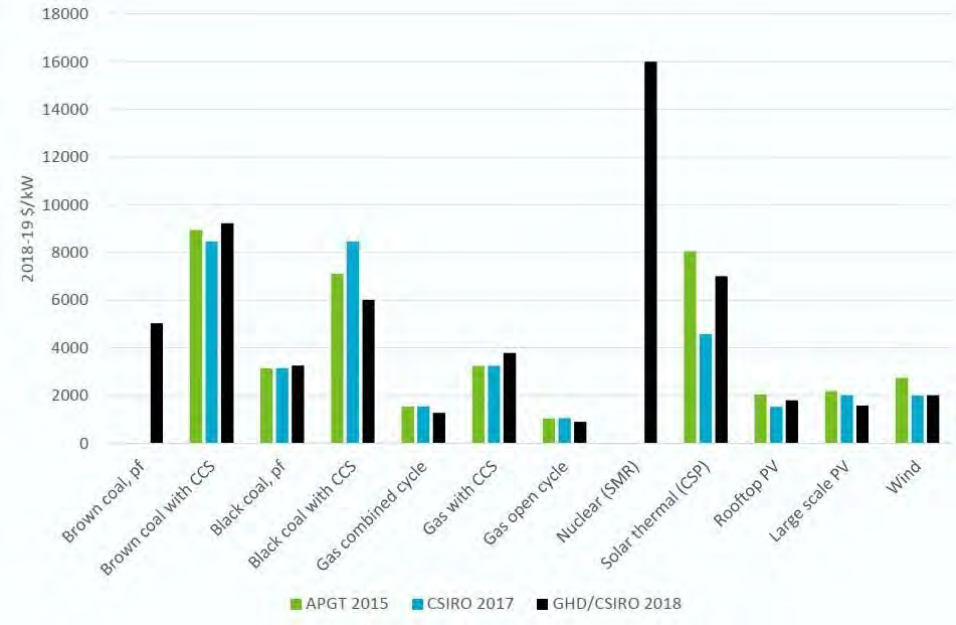
Reduced costs

ARENA has been able to influence the cost of renewable energy through direct and indirect activities:

- Directly, by funding of research and development, particularly in solar PV, to improve the efficiency of solar cell and modules
- Directly, by funding demonstration projects, ARENA enables industry and financiers to gain experience with new technologies and business models, thus reducing risk perceptions (and financing costs) for future projects
- Indirectly, by improving supply chain capability through experience on ARENA-funded deployment projects.

Globally, renewable energy projects have benefited from significant learning curves resulting in a decrease in the capital costs of components. The 2018 'GenCost' report published by the CSIRO[101] found that capital costs for all renewable technologies in Australia had decreased from 2015 levels while non-renewable technology LCOE's increased in some cases (Figure 14).

Figure 14: Comparison of capital costs of generation technologies



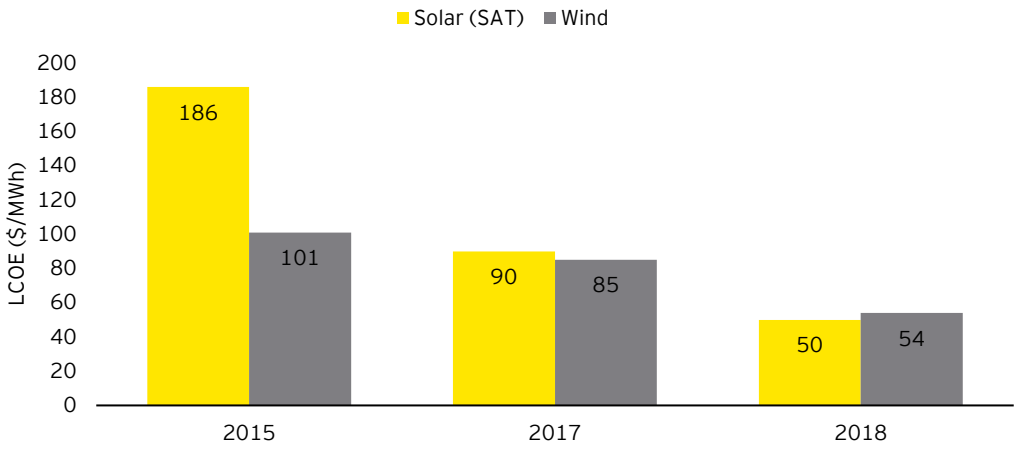
Source: CSIRO

With respect to large-scale solar costs, in the two years from 2015 to 2017, during which the ARENA LSS competitive round was taking place, the levelized cost of electricity LCOE of solar dropped more than 50% from $186/MW to $90/MW (Figure 15).[102]

[101] CSIRO, 2018, 'GenCost 2018' page 4

[102] Compiled from AEMO, 'South Australian Fuel and Technology Report', 2017, available at https://www.aemo.com.au/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2017/2017_SAFTR.pdf and Bloomberg New Energy Finance, 'New Energy Outlook 2018', available at https://bnef.turtl.co/story/neo2018

Figure 15: LCOE cost comparison



Source: 2015 and 2017 LCOE values have been sourced from AEMO's "South Australian Fuel and Technology Report" (2017), while 2018 LCOE values has been sourced from Bloomberg New Energy Finance (BNEF) "New Energy Outlook 2018" Report. Note, the trend in LCOE between years should not be extrapolated as BNEF and AEMO have different methodologies and assumptions to calculating minimum LCOE values.

Bloomberg New Energy Finance (BNEF) reported the levelised cost of electricity (LCOE)[103] of solar fell to $50/MWh in 2018, overtaking wind as the cheapest source of generation. Additionally, the evaluation of ARENA's large-scale solar program found that EPC costs decreased 43 per cent over the period 2013 to 2018, driven by decreased in both module costs and balance of system costs.[104] Critically, it found that while global utility scale solar PV costs were on the decline, the magnitude of change in Australia was greater than in other countries implying there were country specific factors in Australia that contributed to this total cost reduction.[105]

Reduced and mitigated emissions

ARENA's investment priorities have driven investment in large-scale solar PV, which represent ARENA's greatest impact on emissions reduction. In particular, ARENA's investment in RD&D, feasibility studies and Australian-first renewable energy projects has contributed to cost reduction for subsequent projects, and the increase commercialisation of renewable energy technologies. Solar is now cheaper than wind, and at a lower cost than it would have been otherwise resulting in a substantial increase in private commercial deployment. Australia has since observed a steady decrease in electricity sector emissions which peaked in 2016 (Figure 16).[106]

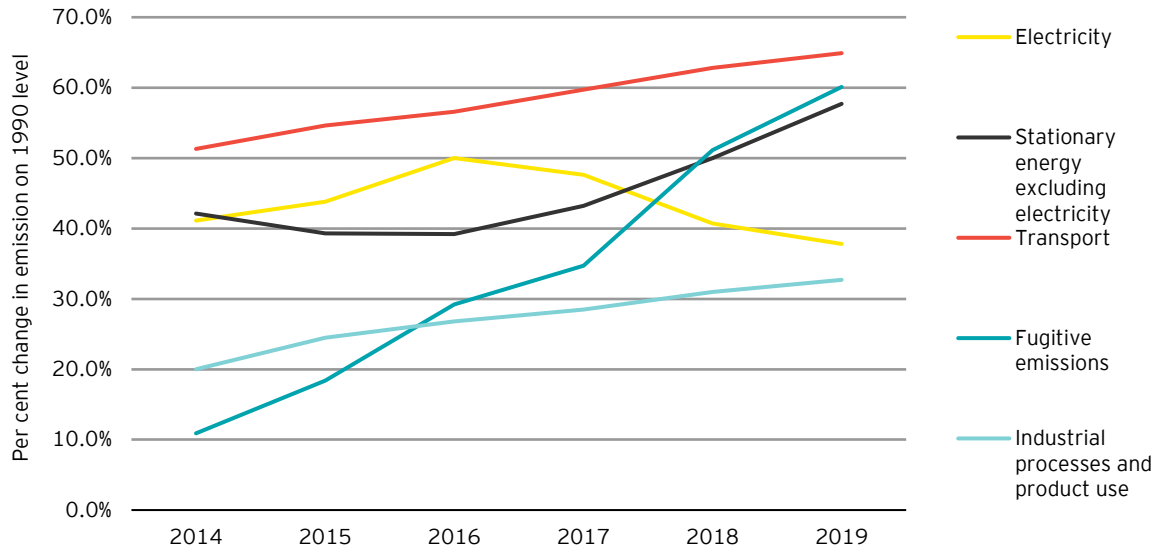
ARENA recently announced that supporting industry to reduce emissions is now an investment priority. Going forward will involve reducing electricity related emissions by supporting key technologies such as solar thermal, renewable hydrogen and renewable powered electrification technologies and processes. It also includes reducing emissions in the industrial process sector, which have both risen over the last five years, and potential for additional impact on emissions in the transport sector in the future. This investment suggests ARENA is expected to have an impact on emissions in these sectors in the future.

ARENA has estimated the direct emissions abated from its portfolio of grid connected generation, which have successfully registered on the NEM, SWIS or NWIS, or are on track towards achieving connection. At 1 October 2019, ARENA's portfolio of projects added 844MW of renewable energy capacity to their respective grids, and collectively contributed an estimated 18.1MtCO2-e of carbon

[103] LCOE values are measured on a $/MWh basis and represent the average revenue required to cover the capital costs (CAPEX) and operational costs (OPEX) in present value terms.
[104] EY, 2019, ARENA 'Large-scale Solar Portfolio: Evaluation Report'
[105] EY, 2019, ARENA 'Large-scale Solar Portfolio: Evaluation Report', page 23
[106] Department of Environment and Energy, 2019, 'Quarterly Update of Australia's National Greenhouse Gas Inventory, March 2019'

emissions abatement from Australia's electricity generation.[107] ARENA's role and funding of projects has an indirect effect of increasing emissions abatement from electricity generation by improving commercial prospects for renewable energy in the long term.

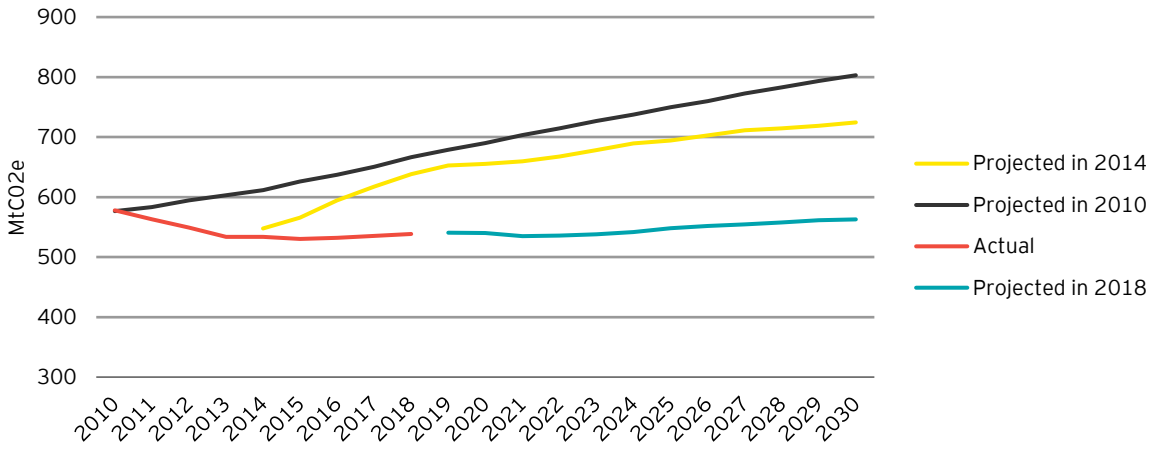
Figure 16: Change in emissions by sector



Source: Department of the Environment and Energy, Quarterly Update of Australia's National Greenhouse Gas Inventory – Figures and Tables for the March Quarter 2019

ARENA's contribution to Australia's emissions reductions can also be evidenced by observing the changes to Australia's actual emissions over time compared to previous projections. Since ARENA's establishment Australia's actual emissions have been trending significantly lower than projections made in 2010 and 2014 (Figure 17).[108]

Figure 17: Australia's total projected and actual emissions



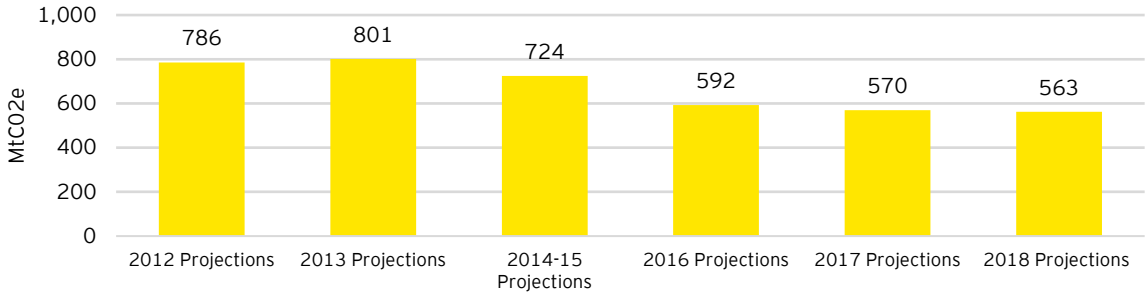
Source: Department of Environment and Energy

[107] ARENA, 2019, Emissions Abatement from ARENA's Portfolio – Projects with grid connected generation. The emissions abatement value determined is based on calculating displaced emissions of a gradually decarbonising electricity generation mix, for the life of the corresponding project. Emissions abatement is not additional to the Renewable Energy Target.

[108] EY analysis of the Department of Environment's Greenhouse gas inventories and archived emissions projections available at https://www.environment.gov.au/climate-change/climate-science-data/emissions-projections

Australia's projected emissions to 2030 have also consistently fallen over past projection years demonstrating that increases in the competitiveness and supply of renewable energy contributed to by ARENA forecast to mitigate future Australian emissions (Figure 18).

Figure 18: Updates to Australia's projected emissions to 2030



Source: Department of Environment and Energy archives

ARENA is also indirectly reducing emissions by providing financial assistance for fringe of grid and off-grid communities and mines to reduce their reliance on diesel generation. Further detail of these impacts can be found in the case studies below.

Case study: Agnew Renewable Energy Microgrid

In June 2019 ARENA contributed ARENA has contributed $13.5m to the $111.6m Agnew Renewable Energy Microgrid project in remote Western Australia. The project will see the first Australian mine be powered by a hybrid microgrid consisting of an 18 MW wind farm, 4 MW solar farm and a 13 MW (4 MWh) battery.

The Agnew microgrid will provide up to 60 per cent renewable generation to the mine, reducing its carbon emissions by 40,000 tCO2e/year. This project will provide a blueprint for the mining industry, which has traditionally relied on high emissions diesel, to transition to lower cost, lower emissions in a reliable manner.

This case study demonstrates ARENA's activities are enabling Australian first innovations and assisting industry to reduce power costs and emissions.

Source: ARENA, 2019, 'Agnew renewable energy microgrid' available at https://arena.gov.au/projects/agnew-renewable-energy-microgrid

Case study: Coober Pedy Renewable Diesel Hybrid Project

The 2014, ARENA contributed $18.41m towards Energy Developments $39m renewable diesel hybrid project in the remote mining town of Coober Pedy. The project, which began operation in 2017 combines 4MW of wind generation, 1MW of solar and a 500KWh battery with diesel backup.

The project has delivered lower cost and more stable electricity for the community at world leading penetration rates and set a global benchmark for renewables in MW scale isolated grids. The hybrid system has displaced up to 70 per cent of diesel generation and avoid approximately 6000 tonnes of CO2e emissions per annum. In August 2019, the project saw the longest continuous period of 100 per cent renewable operation since its start date at 93 hours.

This case study demonstrates ARENA's impact on reducing emissions through renewable energy and reducing costs to remote communities by reducing their reliance on volatile fuel prices.

Source: ARENA, 2019, 'Coober Pedy Renewable diesel hybrid' available at https://arena.gov.au/projects/coober-pedy-renewable-diesel-hybrid/

EDL Energy, 2019, 'Coober Pedy' available at https://edlenergy.com/project/coober-pedy/

Alternative Energy Technologies

Future ARENA initiatives will assist in off-setting emissions increasing in other sectors of the economy such as stationary energy (driven by increase gas extraction and export) and transport (driven by increased diesel emissions).

ARENA has recently updated its investment priorities to include support for new technologies that will reduce emissions non-electricity related sectors. For example, ARENA has invested $22m across five EV projects[109] which are expected to offset emissions in the transport sector and the heavy industry sector.

ARENA's primary impact in the non-electricity space has been to support the rollout of 63 intercity EV fast charging stations providing an initial backbone to support the uptake of EVs. The case study below provides an example of the expected impact of ARENA's EV projects.

Case Study: National Ultrafast EV Charging Infrastructure Network

In 2019, ARENA contributed $15m towards a $50m project lead by Evie Networks to deploy Australia's largest ultrafast charging infrastructure network of over 42 ultrafast charging sites.

The project aims to tackle one of the major barriers of electric vehicle uptake 'range anxiety' by spacing charging sites approximately 150 km apart along the major highways connecting Australia's capital cities. The charging stations will support the full range of passenger and light commercial electric vehicles currently available on the Australian market. The ultrafast chargers are capable of adding 200kms to 400kms of range in a 15-minute charge which is 15 times faster than commercially available domestic charging points.

The network will complement existing infrastructure and aims to catalyse the Australian electric vehicle industry by reducing barriers to electric vehicle uptake. This case study demonstrates ARENA's impact towards reducing emissions through alternative technologies that can decarbonise high emissions sectors of the economy.

Source: ARENA, 2019, 'National Ultrafast EV Charging Infrastructure Network' available at https://arena.gov.au/projects/national-ultrafast-ev-charging-infrastructure-network/

[109] ARENA, 2019, Projects website, accessed 12 November 2019

ARENA's activities have contributed to an increase in Australia's renewable energy supply, and a decrease in the cost of renewable energy, which has led to a reduction in electricity-related emissions. This is likely to continue to have a positive impact into the future through recently commenced initiatives.

3.2.1.5 Changes to market rules and frameworks

Learnings from ARENA-funded projects have been used to inform potential future regulatory developments. This includes providing up-to-date, relevant and accessible data and information about the technical and commercial challenges and opportunities created from innovative technologies and business models. As discussed in section 2.2.1.2, ARENA has produced knowledge sharing materials and entered into MOU's which have informed market reviews and rule change processes. ARENA maintains close communication with market bodies to identify future priorities for proof of concept demonstrations.

There are instances where technology is developing quicker than existing rules and market processes. For example, energy market bodies are continuing to refine their approach based on practical experience from battery participation in various markets. Learnings from ARENA-funded projects have informed potential future regulatory developments such as AEMO's Emerging Generation and Energy Storage (EGES) program, examination of the Generator Performance Standard (GPS) and the AEMC's Wholesale Demand Response Mechanism Rule Change.

ARENA's DER Integration Project Contribution Assessment considered its programs contribution to the development of market rules and frameworks. It found that 12 of the 28 projects assessed had been cited in ARENA's submissions published between 2017 and 2018. The following table identifies the relevant ARENA projects highlighted in each submission, and the key evidence it provided to inform regulatory developments.

Table 15: Project Contributions Toward ARENA's 2017 and 2018 Regulatory Submissions

Submission	Cited ARENA Project	Key evidence provided
ARENA Submission to the AEMC Frequency Control Frameworks Review Directions Paper - 2018	► Simply Energy Virtual Power Plant X (VPPX) – Has the technical potential to provide primary and secondary frequency control services and are identifying significant barriers in the process. ► Peak Demand Reduction Using Solar and Storage (United Energy) – Frequency response times could be reduced to around 2-5 minutes, a timeframe suitable to support frequency management should this process be fully automated.	ARENA is supporting a range of projects that are demonstrating different ways system security can be achieved in a high renewables penetration grid. This includes the potential for non-market participants to provide demand response services.
ARENA Submission to the Economics and Industry Standing Committee Inquiry into microgrids in Western Australia	► Karratha Airport Project (Karratha Solar Power) – Use of solar, storage and cloud predictive technology (CPT) to accelerate solar PV in the North West Interconnected System (NWIS). ► Rottnest Island project (Hydro Tasmania) – Use of renewable energy and smart controls to reduce diesel usage, in combination with novel demand side scheduling of desalinisation. ► Alkimos Beach (Electricity Generation and Retail Corporation) – New energy retail model to demonstrate use of enabling technologies to unlock value from rooftop PV. ► White Gum Valley (Curtin University) – Governance models for solar and storage in apartment housing.	Potential for microgrids and associated technologies to contribute to the provision of affordable, secure, reliable and sustainable energy supply in WA.

Submission	Cited ARENA Project	Key evidence provided
ARENA Submission in Response to the AEMC's Reliability Frameworks Review Issues Paper - 2018	► Karratha Airport - Use of advanced solar forecasting. ► Fulcrum 3D - Cloud prediction technology. ► AGL VPP – Use of distributed energy to improve system wide energy reliability and security. ► Facilitating local use of system charging and virtual net metering (UTS) - The use of new market designs to realise the full value of renewable energy. ► deX (GreenSync) – Demonstrating ways to improve co-ordination of resources to provide a reliable electricity supply in a market with increase renewable and DER penetrations.	ARENA funded projects relevant to the AEMC Reliability Frameworks Review. Outlining experience in DER and their interaction in maintaining secure and reliable operation of the grid.
ARENA submission to the House of Representatives inquiry into modernising Australia's electricity grid - 2017	► **Networks Renewed** (Institute for Sustainable Futures) – Improved solar voltage management through smart inverters. ► **Energy Storage Test Facility and Knowledge Bank** (University of Adelaide) – Construction of mobile energy storage test facility. ► **CSIRO VPS2 & AGL VPP** – Co-ordination of generation and storage. ► **Rottnest Island** – Advanced control integration wind, solar and desalinisation. ► **Brookfield Energy** – Exploration of commercial and regulatory barriers for residential microgrids.	Outlines ARENA's experience with projects and experience in; renewable energy generation; storage; and interactions with the electricity network and demand for electricity from consumers and industry. The submission also outlines ARENA's broader approach to enabling affordable, reliable electricity supply with a high proportion of renewable energy.
ARENA submissions to Independent Review into the Future Security of the National Electricity Market) – 2017	► **Network Opportunity Maps** (UTS) - Studies allowing for technology and cost optimisation. ► **Karratha Airport Solar Farm & Fulcrum 3D**– Use of solar forecasting cloud predictive technology. ► **AGL VPP** – Use of renewable energy storage to improve energy reliability. ► **Facilitating local use of system charging and virtual net metering** (UTS), deX (GreenSync) – Use of new market designs to realise the full value of renewables. ► **Rottnest Island** – Novel demand response mechanisms. ► **Networks Renewed** (UTS)– Use of smart inverters to improve network reliability.	Outlines ARENA's relevant experience with renewable energy generation, storage technologies, and their interaction(s) with the electricity system - both the secure and reliable operation of the grid, as well as the implications for market operations. The latter part of this submission outlines issues for market design and longer-term policy to help inform the Review's areas of focus. The submission also outlines ARENA's broader approach to enabling affordable, reliable electricity supply with a high proportion of renewable energy.
ARENA submission to the AEMC's 5 Minute Settlement Rule Change Determination - 2017	► AGL VPP, Repost Power GridCredits ► **deX (GreenSync)** – The use of aggregation to increase contributions to reliability from distributed energy sources.	Characteristics of emerging renewable energy generation technologies, storage technologies, and demand response as relevant to the rule change.
ARENA's submission to the Senate Committee into the Resilience of Electricity Infrastructure in a warming world - 2017	► Karratha Airport Solar Farm & Fulcrum 3D – Use of cloud prediction technology ► **AGL VPP** – Use of Distributed energy storage to improve system-wide reliability and security. ► **Facilitating local use of system charging and virtual net metering** (UTS) – Use of new market designs to realise the full value of renewable energy. ► **Rottnest Island** – Use of demand response as part of an overall integrated solution to enabling increased renewables.	ARENA's project portfolio and relevant experience with distributed generation, storage, and its interaction with the electricity network, and demand for electricity from consumers and industry. The submission also outlines ARENA's broader approach to enabling affordable, reliable electricity supply with a high proportion of renewable energy.

The following case study provides an example of how ARENA's is bringing about changes to market rules and frameworks

Case Study: RERT Trial

In 2017, ARENA and the Australian Energy Market Operator (AEMO) entered into a Memorandum of Understanding to jointly develop 'proof of concept' projects to support the integration of renewable energy into the electricity market.

In periods of critical peak demand, AEMO can invoke what is known as the Reliability and Emergency Reserve Trader (RERT) arrangements to provide emergency Demand Response. The program is scheduled to run for three years, from 2017 to 2020.

Through a competitive funding round, ARENA provided $28.55m to 10 selected projects to trail innovative approaches to delivering emergency demand response within either 10 or 60 minutes of a request by AEMO. To date, the trials have successful; exceeding the combined contracted capacity for Year 1 (143MW) enabling proponents to recruit and mobilise their projects in a short time-frame with positive outcomes.

ARENA's partnership with AEMO has helped to inform new program design and changes to market rules and frameworks. Year 1 of the RERT trail has been instrumental in informing the reinstatement of the long notice RERT scheme and ultimately has helped to inform the AEMC's draft determination for a Wholesale Demand Response mechanism released in July 2019.

Source: ARENA, 2019, 'Demand Response RERT Trail Year 1 Report' available at https://arena.gov.au/assets/2019/03/demand-response-rert-trial-year-1-report.pdf

Learnings from ARENA funded projects have provided information about the technical and commercial challenges and opportunities created from innovative technologies and business models, informing and in some cases driving regulatory developments which have had a positive impact on changes to market rules and frameworks consistent with ARENA's statutory objectives.

3.2.1.6 Direct and indirect economic impacts

ARENA's role in accelerating the commercialisation of large-scale renewable generation has provided a significant short to medium term economic impact to several regional economies across Australia. To determine the direct and indirect economic impacts of ARENA, an economic contribution study was undertaken on two distinct regions; Central and North QLD; and Central West NSW. These regions are case studies designed to be representative of ARENA's overall impact.

Economic impact is a measure comprising all market-related expenditure generated by a specified industry or an activity. Economic impact studies do not consider the substitution impacts to other industries (i.e. what might happen to expenditures if the specific industry or activity were lost). As such, economic contribution is a gross measure rather than a net measure.

Three common indicators used to represent the economic impact of an investment are:

- **Gross output** – Market value of goods and services produced, often measured by total expenditure. Gross output is also referred to as 'gross economic impact.'

- **Value added** – Market value of goods and services produced, after deducting the cost of goods and services used. In practice, industry value add largely comprises wages, salaries and the operating surplus of an industry (i.e. the industry's income).

- **Jobs** – Number of jobs generated by the investment.

All three measures are valuable in their own right. Industry output is a measure of production, value add is a measure of wealth generation, and arguably, employment is a measure of the distribution of income. In comparing an industry's size against others, it is generally accepted to discuss this in terms of its industry value add. This avoids the inclusion of revenues to other industries and any associated double counting.

The direct impact captures the direct expenditure increase in the region that is attributable to the construction of the ARENA funded projects in the case study regions.

The indirect impact measures the multiplier effects of the direct expenditure throughout the economy. The additional direct spending produces a second round of spending and income generation. For example, additional money spent at restaurants is allocated between the additional material inputs (such as food and drink), wages, and profits of the proprietor. Wages spent by the employees for example, on household items, circulates the money throughout a broader section of the economy creating indirect benefits.

In summary our analysis found the construction of:

- ARENA funded deployment projects have directly created $105.2m value-added to the Central & North-West QLD economy and 401 additional jobs (on a FTE basis)[110] during the construction period.

- ARENA funded deployment projects have directly created $96.4m value add to the Central West NSW economy and 339 additional jobs (on a FTE basis) during the construction period.

We note that the results in the case-study regions indicate the type of regional economic benefit that occurs from renewable energy deployment projects. EY expects that these regional economic benefits could increase further in the future as competitive renewable energy sources become an increasing part of the electricity generation mix. We also note that ARENA funded deployment projects are relatively small in the context of overall renewable energy growth.

The economic impact analysis is detailed below. In addition, consideration has been given to broader regional benefits of ARENA's projects beyond the two case-study regions.

Approach to economic contribution analysis

EY adopted an Input-Output (IO) approach to the calculation of indirect (wider) economic impacts.[111] REMPLAN[112] was engaged to develop tailored input/output multipliers that reflect the specific characteristics of the economy of the case study regions (defined below). IO modelling considers the direct and indirect contribution of the sector and is measured in terms of both employment (jobs supported) and Gross Value Added (GVA) (value of goods and services produced in the sector – which contributes to Gross State Product). The key effects captured though this modelling process include:

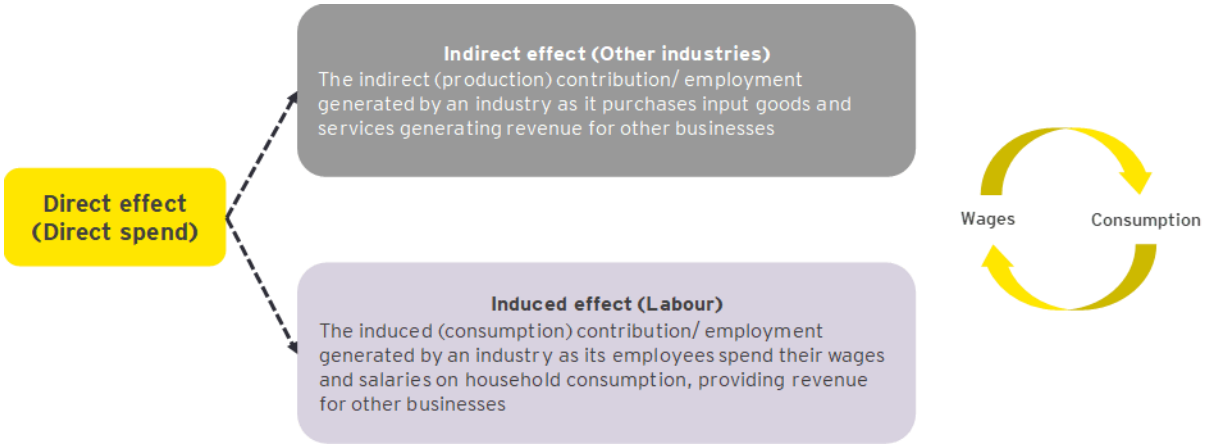
- Direct effects - measure the initial requirements for an extra dollar's worth of output of a given industry. The direct effect on the output of an industry is a one dollar change in output to meet the change of one dollar in final demand. Associated with this change, there will also be direct effects on GDP, jobs, and imports.

[110] The construction jobs presented in this report represent the total number of short-term direct jobs and longer-term indirect jobs generated as a result of the construction of the ARENA funded projects.
[111] It is important to note that input-output models do not consider capacity constraints in the economy (e.g. full employment). Such constraints can limit the extent to which economic impacts can increase in a linear fashion with changes in demand.
[112] Further information on REMPLAN can be found at Appendix E

- Production-induced effects - measure the changes due to inter-industry purchases as they respond to the new demands of the directly affected industries. This includes all the chain reaction of output up the production stream since each of the products purchased will require, in turn, the production of various inputs.

- Consumption-induced effects - measure the changes in the production of goods and services in response to consumer expenditures induced by households' incomes (i.e. wages) generated by the production of the direct and indirect requirements.

Figure 19: Economic impact measures



For further detail on the REMPLAN model and the methodology used to estimate the economic impacts of the project, please refer to Appendix E.

Construction costs were used to calculate the direct and indirect economic contribution during the construction period. EY sourced a breakdown of forecast and actual project cost information for the solar PV projects within the two defined case study regions from ARENA to the extent available.

Certain capital costs will have been spent outside the study area, for example, PV modules, inverters and single axis trackers, which are generally imported. EY adjusted the total capital costs reported for each project to exclude these costs.

Costs are not consistently reported, due to the nature of how projects contracted and developed. As a result, benchmarking was required to estimate and exclude capital costs spent outside of the region. Using the data provided by ARENA on the breakdown of capital expenditure, and supplementing this with information from EY's Renewables Database, an average proportion of costs expected to be spent outside of the case-study regions was calculated. Based on this data, approximately 60 per cent of capital costs are expected to be spent outside the case-study regions.

Annual average operating and maintenance activities were not considered.[113]

Case-regions and results

The following two case-study regions indicate the type of regional economic benefit that results from renewable energy deployment projects. EY would expected these benefits to grow in future if more competitive renewable energy sources become an increasing part of the electricity generation mix.

[113] Due to the nature of how projects are contracted and developed, there was insufficient data to determine the impact of annual average operating and maintenance activities from ARENA funded deployment projects.

Central and North QLD

This case study considered ARENA's economic impact in the Central and North QLD regions, as shown in Figure 20. The region has an estimated residential population of 235,000, with 107,292 employed largely across mining, health care and retail sectors.[114]

Since 2014, ARENA has funded eight technology deployment projects in the region, including seven large-scale solar farms and a hybrid solar PV, wind and battery storage facility. These projects have collectively received over $90m in ARENA funding largely from the ARP, but also the RAR Program.

Projects are located across the case study region collectively have a total construction cost of $682m.

The projects within the Central and North QLD case-study region are summarised in Table 13 below.

Figure 20: Central and North QLD case-study region

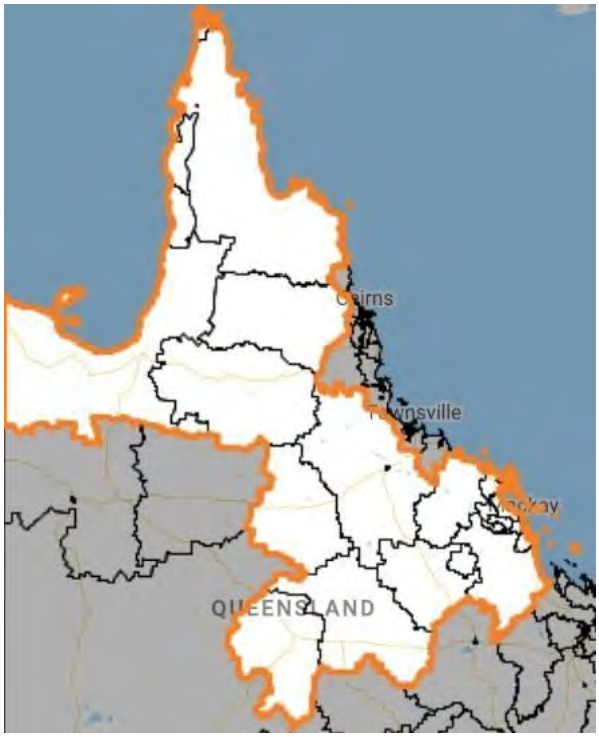


Table 16: ARENA funded projects within Central & North QLD case-study region

Project name	Size	Location	ARENA funding provided	Total project funding
Collinsville Solar Farm	42.5MW solar PV	Collinsville, QLD	$9.50m	$106.4m
Whitsunday Solar Farm	57.5MW solar PV	Collinsville, QLD	$5.35m	$124.3m
Longreach Solar Farm	$15MW solar PV	Longreach, QLD	$1.30m	$33.7m
Kidston Solar Project (Phase 1)	50MW solar PV	Kidston, QLD	$8.85m	$130.65m
Lakeland Solar and Storage Project	13.3MW solar PV 1.4MW/5.3MWh battery storage	Lakeland, QLD	$17.41m	$42.50m
Normanton Solar Farm	5MW solar PV	Normanton, QLD	$8.38m	$13.97m
Barcaldine Remote Community Solar Farm	25MW solar PV	Barcaldine, QLD	$22.8m	$70.1m
Kennedy Energy Park	15MW solar PV 43.2MW wind 2MW/4MWh battery storage	Kennedy, QLD	$18.00m	$160m
Total			$91.59	$681.62

After adjusting the construction costs to exclude capital costs we expect to be spent outside the case study region, the direct economic contribution from the construction of ARENA funded projects to the Central & North QLD economy is $272.6m. The value-added to the Central & North West QLD economy from this investment is estimated at $103.2m. ARENA funded projects were

[114] Figures derived from REMPLAN, which matches ABS data to geographic boundaries of the case-study region.

also expected to create 394 additional jobs (on an FTE basis) for the Central & North QLD region during construction.

From this direct contribution, the total indirect contribution to the Central & North QLD economy from ARENA funded projects is expected to be $192.6m. This represents an estimated increase in demand for intermediate goods and services of $124.1m (supply-chain effect) and an estimated increase in consumption of $68.5m (consumption effect) related to the creation of jobs in the economy from the increased output. The indirect effects are estimated to result in a further 598 jobs (on an FTE basis).

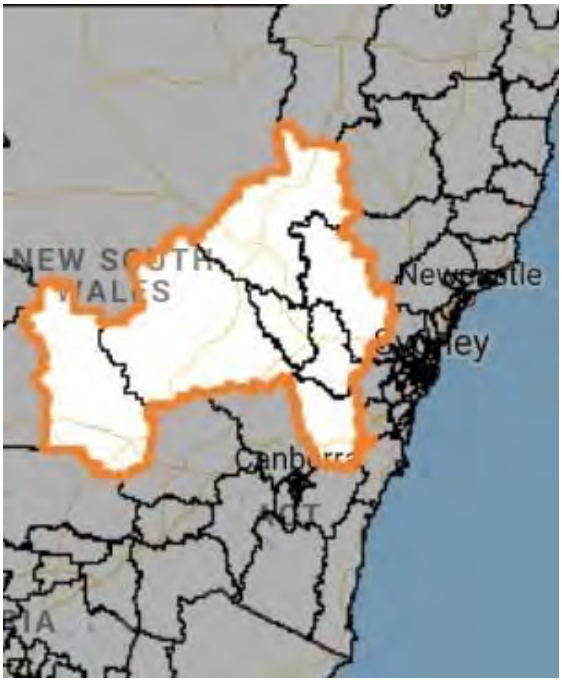
Table 17: Economic contribution to Central & North QLD region during construction

	Direct impact	Indirect impact	Total impact
Output ($m)	$272.6	$192.6	$465.2
Employment (Jobs)	394	598	992
Value-added ($m)	$103.2	$87.2	$190.4

Central West NSW

This case-study considered ARENA's economic impact in the Central West NSW region, as shown in Figure 21. The region has an estimated residential population of 372,000, with 153,989 employed largely across health care; agriculture, forestry and fishing; and retail sectors. [115]

Figure 21: Central West NSW case-study region



Since 2013, ARENA has funded eight technology deployment projects in the region, including seven large-scale solar farms and a CSP Pilot Plant. These projects have collectively received over $150m in ARENA funding all from the ARP (or its predecessor the ERP).

Projects are located across the case study region collectively have a total construction cost of $637m.

The projects within the Central and North QLD case-study region are summarised in below.

Table 18: ARENA funded projects within Central West NSW case-study region

Project name	Size	Location	ARENA funding provided	Total project funding
White Rock Solar Farm	20MW solar PV	Glen Innes, NSW	$5.40m	$41.00m
Parkes Solar Farm	55MW solar PV	Parkes, NSW	$6.75m	$114.92m
Manildra Solar Farm	$46.7MW solar PV	Manildra, NSW	$9.81m	$113.41m
Dubbo Solar Hub	25MW solar PV	Narromine, NSW	$4.95m	$51.71m
Gullen Solar Farm	10MW solar PV	Crookwell, NSW	$9.90m	$28.82m
Moree Solar Farm	56MW solar PV 1.4MW/5.3MWh battery storage	Moree, NSW	$101.70m	$200.82m

[115] Figures derived from REMPLAN, which matches ABS data to geographic boundaries of the case-study region.

Project name	Size	Location	ARENA funding provided	Total project funding
CSP Pilot Plant	1.2MW CST plant	Jemalong, NSW	$9.89m	$23.71m
Griffith Solar Farm	30MW solar PV	Griffith, NSW	$4.50m	$62.19m
Total			$152.9	$636.58

After adjusting the construction costs to exclude capital costs we expect to be spent outside the case study region, the direct economic contribution from the construction of ARENA funded projects to the Central West NSW economy is $254.6m. The value-added to the Central West NSW economy from this investment is estimated at $96.4 million. ARENA funded projects were also expected to create 339 additional jobs (on an FTE basis) for the Central West NSW region during construction.

From this direct contribution, the total indirect contribution to the Central West NSW economy from ARENA funded projects is expected to be $221.8m. This represents an estimated increase in demand for intermediate goods and services of $143.6m (supply-chain effect) and an estimated increase in consumption of $78.2m (consumption effect) related to the creation of jobs in the economy from the increased output. The indirect effects are estimated to result in a further 661 jobs (on an FTE basis).

Table 19: Economic contribution to Central West NSW region during construction

	Direct impact	Indirect impact	Total impact
Output ($m)	$254.6	$221.8	$476.4
Employment (Jobs)	339	661	1,000
Value-added ($m)	$96.4	$99.4	$195.8

Broader regional benefits

While not the focus of our economic analysis, ARENA's projects across the innovation chain are likely to have provided direct and indirect benefits to Australia's regional economies. In 2018, BIS Oxford Economics completed an economic contribution study of ARENA's grant program within regional Australia.[116] The study found:

- 78 of the 376 projects ARENA has supported had a regional focus. In addition, these 78 projects represented just over half of ARENA's total funding at the time[117]
- ARENA's regional program activities created 3,863 direct jobs within their local regions; the majority from utility scale solar PV projects (2659 direct jobs) in Queensland, New-South Wales and the Northern Territory
- For every $1m spent on ARENA funded projects in regional areas an estimated 3 jobs were created locally and regional Gross Value Added (GVA)[118] increased by $0.5m.

It also found ARENA's expected $253.2m spending on R&D from the period 2010 to 2022 will result in productivity gains (rather than short-term employment and economic output benefits). The analysis suggested that ARENA's expected $253.2m investment on R&D would raise real GDP by $526.2m or 2.1 times the initial investment over 50 years from 2010.

ARENA's funding in regional areas has also had a lasting impact beyond the immediate economic benefits of the program. Workers who are upskilled during the duration of the program can

[116] BIS Oxford, 2018, ARENA Regional Contribution Analysis, page 6

[117] BIS Oxford, 2018, ARENA Regional Contribution Analysis, page 5

[118] GVA is the value of output at basic prices minus the value of intermediate consumption at purchasers' prices. The term is used to describe gross product by industry.

continue onto more skilled careers. Local communities develop a sense of pride from playing a role in Australian first innovation and developing Australia's renewable energy legacy.

ARENA funding has been judged by regional communities as helping them achieve security or energy supply and that they were supporting important research and development efforts.[119] For example, the King Island Renewable Energy Integration Project (KIREIP), which was found to have reduced the island's reliance on diesel by 65 per cent, acted to increase the energy security of the island from imported diesel as the system is capable of running on 100 per cent renewables.

3.2.1.7 Environmental and health benefits

Wind and solar power provide health, environmental and climate benefits by displacing conventional fossil fuel generators that produce carbon dioxide, sulphur dioxide, nitrogen oxides and fine particulate matter. Renewable energy also reduces the withdrawal and consumption of water resources for thermal processes which may result in pollution.

The monetary value of benefits associated with avoided GHG and air pollution by renewable generation in the United States was estimated in as approximately $7.4 billion in 2013, with benefits quantified in terms of climate change reduction, environmental and human health benefits.[120] In another study, the estimated monetised social benefits of wind and solar range from $USD40/MWh to $USD100/MWh of generated electricity.[121]

Australia's annual renewable generation has grown steadily to reach almost 45,000GWh in 2017-18.[122] No analysis has been undertaken in Australia to estimate the social benefits associated with avoided GHG and air pollution by renewable energy. However, adopting the US estimates of the social benefits of wind and solar generation suggests that the 11,000GWh increase in Australian renewable energy generation since 2014 may yield an estimate of between $636m and $1.6 billion in additional environmental and social benefits.[123]

A future energy system with high penetration solar and other renewable energy technologies will have an enduring environmental and health benefits globally, nationally, and locally. Analysis in the United States found that a solar penetration of 27 per cent by 2050 would reduce GHG and air pollutants by 10 per cent, provided up to $789b in climate benefits and up to $298b in air quality and public health benefits. Solar power was also found to reduce water withdrawals and consumption by 4 per cent and 9 per cent respectively including in many drought prone and arid states.[124]

It is reasonable to conclude that ARENA has likely made an impact on increasing Australia's renewable energy generation and has likely contributed towards a proportion of the additional environmental and social benefits.

Findings

Evidence suggests that ARENA supported research and development, commercialisation and deployment projects, have contributed towards (or are expected to contribute towards) all seven of their intended impacts.

These range from industry specific impacts such as (i.e. building and enhancing technology pathways, developing industry capacity and creating new supply chains) to broader economic impacts (i.e. the creation of direct and indirect economic impacts).

[119] BIS Oxford, 2018, ARENA Regional Contribution Analysis, page 13

[120] Barbose et al, 2016, 'A retrospective analysis of the benefits and impacts of U.S. renewable portfolio standards'

[121] Evans et al, 2013, 'Regional variations in the health, environmental, and climate benefits of wind and solar generation'

[122] Australian Energy Update, 2019, Department of the Environment and Energy, available at https://www.energy.gov.au/publications/australian-energy-update-2019

[123] Figures have been converted from $US using an exchange rate of 1.44781 (as of 3 November 2019).

[124] Wiser et al, 2016, 'The environmental and public health benefits of achieving high penetrations of solar energy in the United States'

3.2.2 Attribution of intended impacts to ARENA

The evidence presented in Section 4.2.1 suggests that ARENA's research, development and demonstration projects have contributed to its intended impacts.

The following evaluation questions were considered in this section:

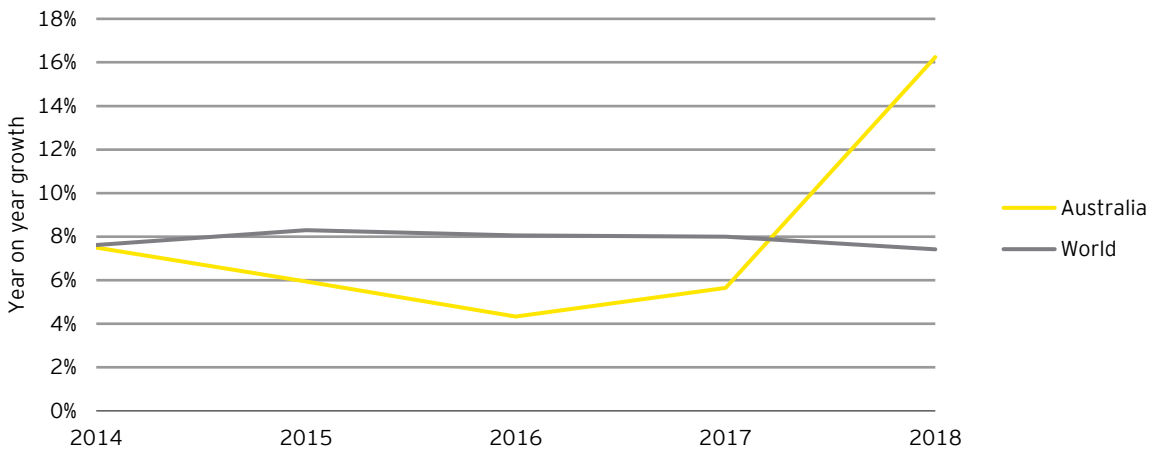
- To what extent can these impacts be attributed to activities undertaken by ARENA?
- What was the influence of other factors?

Looking across all the impacts, there are multiple variables that ultimately impact the supply and installation cost of renewable energy. This includes government initiatives (such as the Renewable Energy Target and state based reverse auctions), economic climate (nationally and internationally) and changes in global technology costs. These factors make it difficult to quantitatively attribute ARENA's activities to observed changes in the Australian energy sector.

Changes in renewable energy supply and installation cost greater in Australia than in other countries

While it may not be possible to attribute changes in supply and installation cost of renewable energy directly to ARENA, evidence suggests both have improved markedly since ARENA was formed in 2011. Figure 22, indicates that from 2014 to 2018 year on year growth in renewable capacity is significantly greater in Australia compared to the international average.[125]

Figure 22 Year on year growth in renewable generation capacity compared to the world



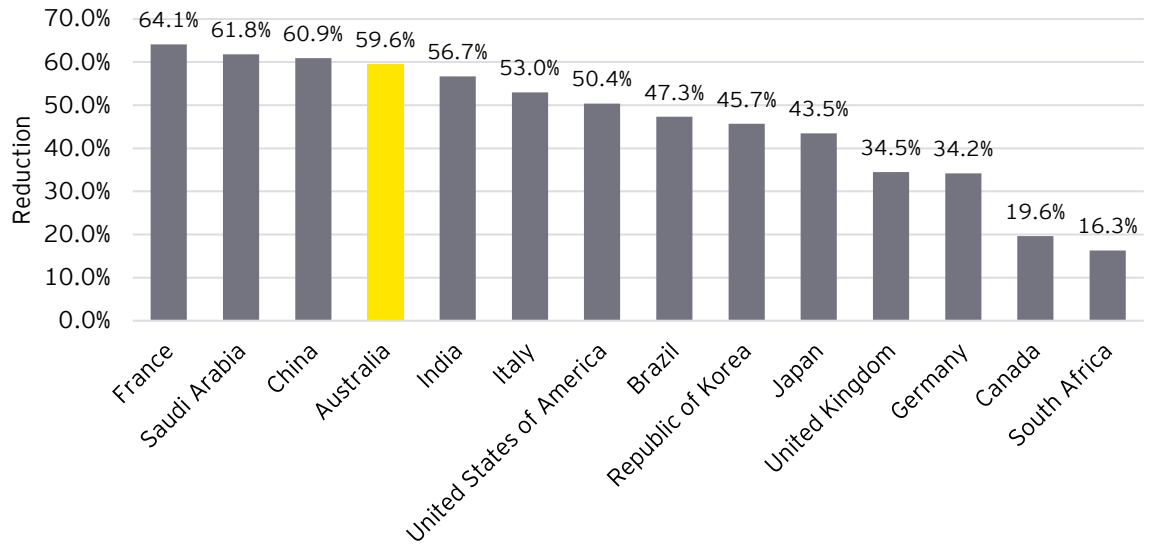
Source: IRENA

Figure 23 indicates that average market solar module prices in Australia fell by 60 per cent compared to the international average of 46 per cent from 2013 to 2018.[126]

[125] Includes 130 countries according to the United Nations 'M49' standard.

[126] IRENA, 2019, Power Generation Costs in 2018

Figure 23: Change in solar PV module prices by market 2013 to 2018



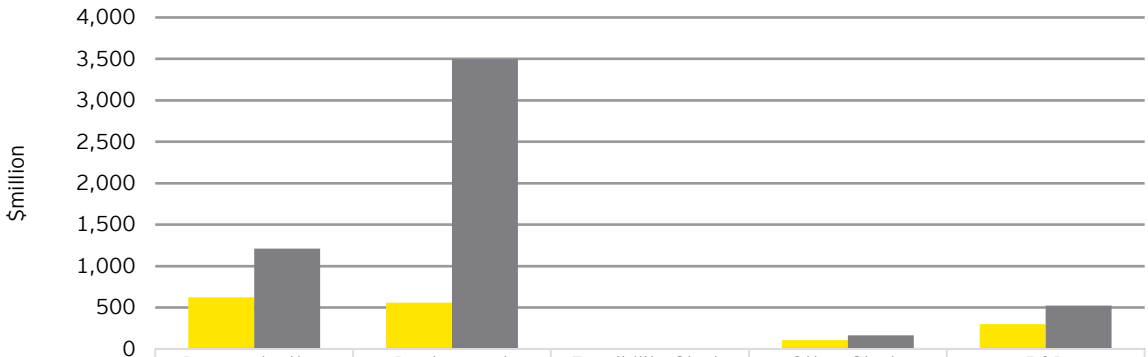
Source: IRENA

Investment leverage ratios suggest ARENA contributed to its intended impacts

ARENA's investment leverage ratios are one metric that indicates that a significant part of ARENA's intended impacts can be attributed to its activities. Overall, ARENA invested $1.59 billion delivering $7 billion of total project value – equating to an average $1:3.4 investment leverage.

Figure 24 and Figure 25 summarise ARENA's total investment leverage by innovation chain phase and technology respectively.

Figure 24: Investment leverage by innovation chain

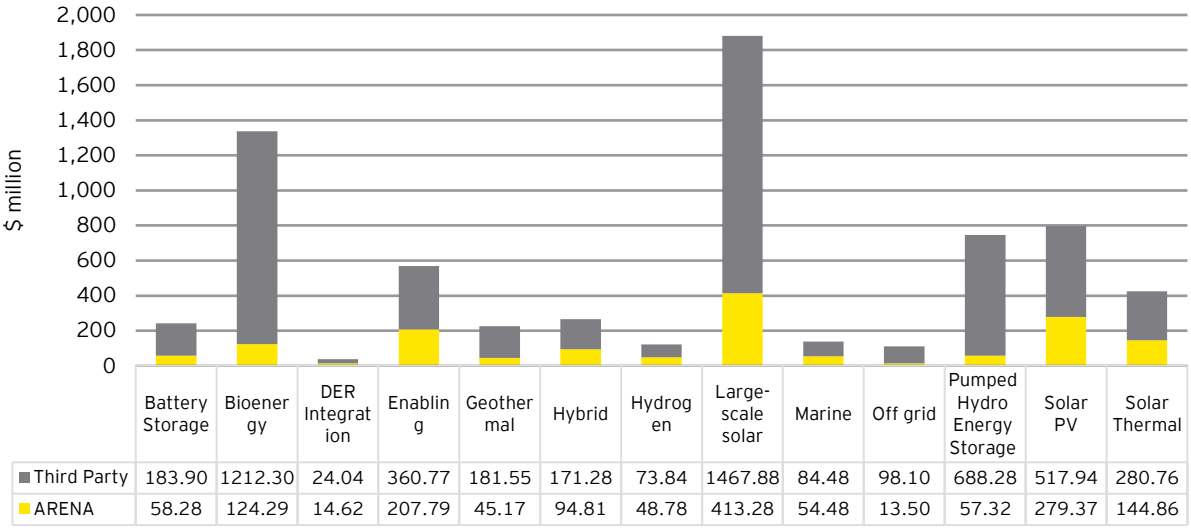


	Demonstration	Deployment	Feasibility Study	Other Study	R&D
ARENA	$622.50	$559.53	$5.07	$106.06	$297.65
Third Party	$1,210.42	$3,498.22	$11.28	$165.37	$524.80

Source: ARENA

Figure 24 suggests that ARENA's contribution to delivering its intended impacts is greater at R&D and demonstration phases, with a greater contribution from other parties (i.e. private investors) at the deployment phase.

Figure 25: Investment leverage by ARENA by technology



	Battery Storage	Bioenergy	DER Integration	Enabling	Geothermal	Hybrid	Hydrogen	Large-scale solar	Marine	Off grid	Pumped Hydro Energy Storage	Solar PV	Solar Thermal
Third Party	183.90	1212.30	24.04	360.77	181.55	171.28	73.84	1467.88	84.48	98.10	688.28	517.94	280.76
ARENA	58.28	124.29	14.62	207.79	45.17	94.81	48.78	413.28	54.48	13.50	57.32	279.37	144.86

Source: ARENA

Figure 25 suggests that ARENA's contribution to delivering its intended impacts is greater for solar PV and less proven technology categories such as DER integration, enabling technologies, hybrid, hydrogen, marine and solar thermal.

Stakeholder research suggests ARENA's involvement was key to the recipients ultimate success. Stakeholder feedback can also provide insight from the market as to whether the level of investment (and associated projects) would have gone ahead without ARENA's involvement. EY Sweeney recently conducted a stakeholder research study[127] to understand the perceptions, needs and expectations of ARENA amongst key industry stakeholders.[128]

The stakeholder research study found that ARENA plays a valued role in the Australian energy sector. Numerous stakeholders mentioned how fortunate Australia's energy sector is to have an organisation like ARENA. One survey respondent stated that ARENA's grants and funding have allowed them to build their R&D activities to a scale where they can have a real impact. Another commented on how ARENA's support helped remove technical risk that allowed financial investors to have more confidence in the business.

The stakeholder research study also found ARENA's involvement in projects is having a strong impact on their ultimate success. Around two in three stakeholders confirm ARENA contributed to the successful outcome of their work in the energy sector via management of grants (68 per cent) and/or delivery of programs (64 per cent). 76 per cent of stakeholders agreed that ARENA was effective in building investor confidence in renewable energy projects.

Most importantly, 73 per cent of funding recipients do not believe their initiative would have been successful without ARENA's involvement. This finding is most evident for stakeholders from scientific research organisations with 82 per cent indicating their initiative would not have been successful without ARENA's involvement. Stakeholders from energy supply/generation organisations are more likely to predict project success without ARENA's involvement (19 per cent).

[127] Included 23 in-depth interviews across funding applicants, government, industry, NGOs and academics; as well as a quantitative survey completed by 173 participants.
[128] EY, 2019, 'ARENA Stakeholder Research Report'

Findings

While there are multiple variables that ultimately impact the supply and installation cost of renewable energy, international data on the supply and installation cost of renewable energy suggest the magnitude of change in Australia was greater than in other countries implying there were country specific factors in Australia that contributed.

ARENA's investment leverage ratios by innovation chain and technology, and independent stakeholder research suggest ARENA has contributed to (or is expected to contribute to) these intended market impacts to a large extent.

3.2.3 Unintended consequences

The following evaluation questions were considered in this section:

- What unintended consequences (positive or negative) were produced? How has ARENA's role contributed to these unintended consequences? Did ARENA's existence mitigate any of these unintended consequences?

A significant part of ARENA's funding has been in R&D, study and demonstration which are unlikely to have broader system impacts, and therefore no unintended consequences. Our analysis therefore considered whether any unintended consequences were produced as a result of its deployment projects, which could have been exposed to broader system impacts.

Looking across the 17 evaluations, there were very few instances where unintended impacts were reported. Where they were reported, ARENA funded programs were not necessarily causing unintended consequences but rather exposed broader market issues.

ARENA's large-scale solar program is a key example of an ARENA supported program exposing broader market issues. In particular, the large-scale solar program's Competitive Round identified issues related to grid connections and declines marginal loss factors (MLFs). Each of these issues are summarised in Table 20 below.

Table 20: Broader market issues identified through ARENA's large-scale solar program

Broader market issue	Description
Backlog of approvals and commissioning	The Competitive Round saw 12 large scale projects being progressed at the same time, resulting in a backlog of approvals and commissioning. 11 of 12 LSS projects failed to meet expected timeframes and were on average 8.5 months behind schedule in terms of reaching commercial operation.[129] Further to this, the Clean Energy Regulator recognised grid connection and network access as the biggest problem facing new solar projects (as well as wind and storage projects) in 2018.[130]
Complicated connections process and rigorous modelling requirements	The connection process and modelling requirements were found to be more demanding than comparable markets overseas and another factor causing delay. Contributing to this complicated process is the connections requirements for projects in the pipeline being impacted by each approval of a new generator, which can cause many iterations of revised modelling. Additionally, AEMO have proposed more detailed modelling requirements and more thorough inspections to the review process in response to the South Australian blackout in September 2016. [131]

[129] Ekistica, Topic 7.2: Policies and Scenarios for Renewables, Societal and Global Challenges, Lessons from utility-scale PV in Australia: Experience from ARENA's LSS portfolio

[130] Clean Energy Council, "Clean Energy Outlook Confidence Index 2018," 2018. [Online]. Available: https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-outlook/Executive-confidence-index-2018-A4.pdf. [Accessed 6 Jun. 2019]

[131] Ekistica, Topic 7.2: Policies and Scenarios for Renewables, Societal and Global Challenges, Lessons from utility-scale PV in Australia: Experience from ARENA's LSS portfolio

Table 20: Broader market issues identified through ARENA's large-scale solar program	
Broader market issue	**Description**
Predictability of MLFs	There have been notable challenges to proponents in predicting MLFs, specifically the extent to which new generators will connect proximally, and the timing of their construction. This is evidenced by an overestimated MLF in 10 of 12 LSS Competitive Round projects resulting in average yield deficit of 6 per cent in first year of operations.[132]

As an entity that shares knowledge and collaborates with industry, ARENA has demonstrated that it is well placed to mitigate some of the effects of broader market issues (or unintended consequences should they emerge in the future). In the case of the large-scale solar program, the co-ordinated nature of the Competitive Round helped facilitate the identification of solutions earlier through the knowledge sharing organised by ARENA.

Further information about ARENA's knowledge sharing activities is presented in Section 3.

Findings

There are very few instances where ARENA has been reported as causing unintended consequences. Where they were reported, ARENA funded programs were not necessarily causing unintended consequences but rather exposed broader market issues.

As a knowledge sharing entity that collaborates with industry, ARENA is well placed to assist in mitigating the impacts of broader market issues (or unintended consequences should they emerge in the future).

[132] Ibid

4. Evaluation of ARENA's Efficiency

4. Evaluation of ARENA's efficiency

The section below seeks to identify the extent to which processes in ARENA led interventions have been efficient. A high level analysis has been taken for this analysis to minimise overlap with the ANAO audit, being undertaken concurrently.

The analysis relies heavily on the outputs of previous evaluations and other agency wide evaluations as provided by ARENA. Internal discussions with ARENA staff have supplemented these resources.

4.1 Key findings and observations

4.2 Efficiency evaluation

4.2.1 Grant application processes

The following evaluation question was considered in this section:

- Has ARENA provided and managed grants processes in an appropriate manner?

ARENA receives and makes available grants to proponents through two primary avenues:

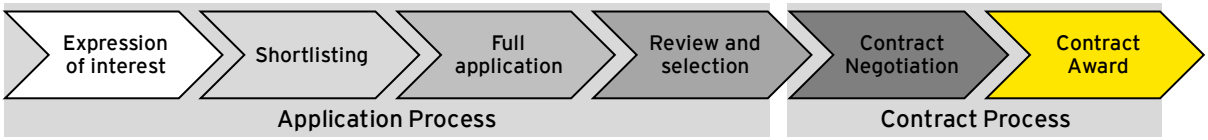
- Competitive funding rounds, which focus on specific energy technologies (e.g. Large-Scale Solar, Demand Response)
- Ongoing intakes (e.g. the Research and Development Program, Advancing Renewables Program).

For both approaches, ARENA applies a two-step application process:

- Expression of interest
- Full application.

Following selection of successful proponents, they are sent a formal Letter of Offer to negotiate contracts before contracts are finally awarded. The grant application and contract award process is summarised in Figure 26.

Figure 26: High-level overview of application and contract award process



4.2.1.1 Application process

The formal application process consists of two primary phases, each with reviews and assessment appropriate to the level of time invested by the applicant. Prior to the submission of the EOI it is common for ARENA staff to have some informal engagement with potential applicants.

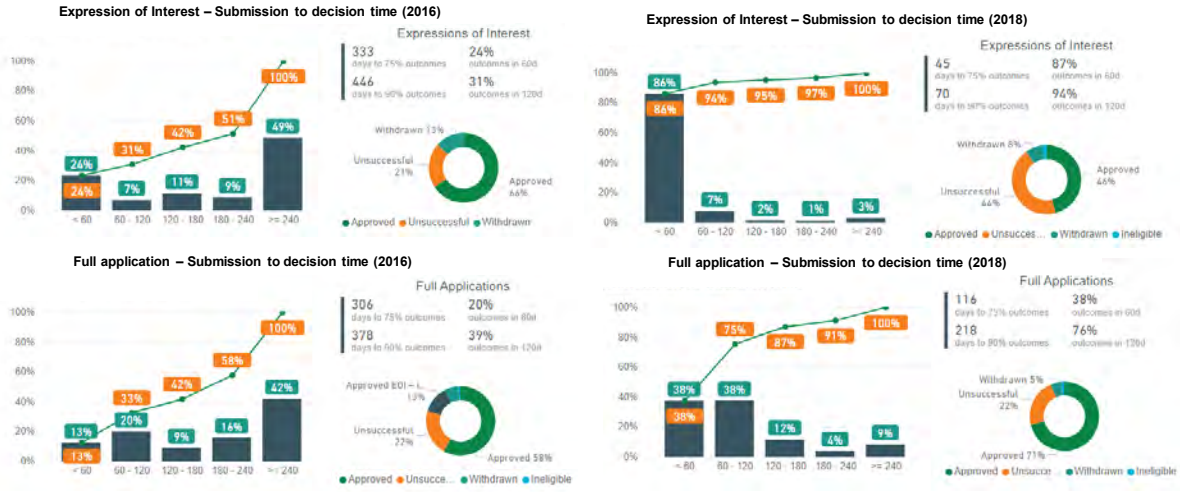
EOIs undergo a screening process by evaluation teams against eligibility and merit criteria defined in the individual programs. Criteria include TRL, funding leverage and knowledge sharing potential.[133]

ARENA's in-house assessment team performs initial screenings and prepares summaries of EOIs which are then sent to the business development manager. Low merit proposals are removed from consideration once approval is obtained from the CFO.

For the full applications, applicants are required to submit more detailed information including a proposed Knowledge Sharing Plan (KSP). ARENA performs technical and financial due diligence assessments which are used by the ARENA Advisory Panel[134] (AAP) in the project selection process. As part of the full application, applicants are invited to present to the AAP. Unsuccessful applicants are sent feedback letters explaining the rationale for rejection with an offer to reapply.

Over time, ARENA has improved the time taken to process both expressions of interest and full applications. As shown in Figure 27, ARENA significantly reduced its decision time from 2016 to 2018.

Figure 27: Expression of Interest and Full Application decision time, 2016 and 2018



Source: ARENA

Key findings on the efficiency and appropriateness of the application process are detailed in Table 21 below.

[133] EOI's are not required in circumstances where the funding relates to studies, reports, data collection, collaboration activities and analysis, new business models or when the amount sought is less than $500,000.
[134] The ARENA Advisory Panel assesses program funding applications and provides specialist advice as required

Table 21: Findings on key elements of the application process	

The eligibility and merit criteria are fit for purpose	► The eligibility criteria and merit criteria provide the right balance between being broad enough to allow for a range of ideas to be presented and flexible enough to enable the filtering of proposals that do not meet ARENA's mandate.
	► ARENA has frequently sought to waive EOI requirements in cases where:
	  ► timeframes for applications are constrained to avoid propagating delays at later stages of the grants process
	  ► where applicants have previously been awarded grants, or for well advanced proposals, to streamline the application process and reduce duplication of already completed work.
	► The TRL criterion is international best practice, helps to streamline the assessment of projects' suitability for the funding program and ensures alignment with the program objectives and innovation stage. The usefulness of the TRL was demonstrated in a 2018 review of the solar R&D program as it achieved a good spread of investment across all TRLs (from level 2 to level 6).
	► Program criteria in some earlier funding programs, e.g. ABIR program, were found to have been somewhat restrictive, resulting in projects being omitted that may otherwise have achieved the overarching objective of the program. In response to recommendations in evaluations on these programs, ARENA has since aligned eligibility criteria with their Performance Framework to include the consideration of co-production benefits.
	► Instances of the return of unallocated funds to ARENA demonstrates a robust and outcomes focused approval process and evidences that meeting the eligibility and merit criteria takes precedence over allocation of funds.

ARENA's due diligence is high quality and valued	► Undergoing financial and technical due diligence as part of the full application assessment has been highly valued by applicants and AAP decisions makers. ► Advice given to applicants throughout the process helped to refine and reshape project plans to give the best chances of success. ► Evaluations of prior funding programs found the assessment process was rigorous. For example, applicants in the LSS were asked detailed questions, in relation to their tax structuring and technologies used as part of the assessment process.[135] ► In addition to giving participants confidence in the process, investing the time for technical and financial due diligence in the application process reduces the risk to the project management and delivery.
Application selection processes are appropriate and broadly efficient	► The AAP process adds weight to the weight funding allocation decisions and to the projects themselves and assists in identifying projects aligned to ARENA' s objectives. ► ARENA's experienced client managers in the BD&T team are able to discourage applications that are misaligned with ARENA's objectives and identify early on where further improvements in proposals are needed. ► The mid-term review of the ACAP program found 'sound decisions' were made in relation to project origination and selection, supported by 'good process'. ► EY Sweeny's stakeholder survey found 'overall satisfaction with ARENA's funding process is high' with only 8 per cent dissatisfied with the process to any degree. The survey acknowledged ARENA's continued efforts to streamline this process.
Engagement is resource intensive but highly valued	► ARENA staff take significant time to engage with applicants both pre-application and during the application process. ► There is a 'heavy resource load' due to the high levels of support provided at early stages in the grants process. The ARP evaluation questioned whether the high-level support provided to applicants by ARENA is justified given the cost incurred in person hours. ► The ThinkPlace study recommended that ARENA introduce higher barriers to entry while making more resources available for applicants to better self-assess in order to ensure efficient allocation of ARENA's support staff towards more advanced applications. This recommendation was supported by the ARP review. ► The RAR Initiative evaluation found client managers were regarded as helpful and pragmatic. ► The ARP evaluation found engagement with client managers and applicants has been seen as crucial to the success of applications. ► ARENA should continue with its current standard of engagement post EOI stage while increasing the resources available to applicants to reduce resources devoted to early engagement. ► We note that ARENA has recently introduced a self-assessment alignment tool to assist applicants in determining proposal alignment with ARENA objectives.

[135] EY, 2019, Large Scale Solar Portfolio Evaluation Report' page 65

Table 21: Findings on key elements of the application process	
Improvements in the application process should continue to be monitored	► Some dissatisfaction has been reported within this process by previous evaluations. ► At the time of the Future Needs Review (FNR) ARENA did not have a process for the review of unsuccessful applications, leaving the formal complaints channel as the only means of contesting decisions. This is likely why some rejected applicants have approached the ARENA Board and Chairman directly.[136] ARENA has since reviewed and implemented recommendations for unsuccessful applicants through the Review Implementation Oversight Committee (RIOC). ► The FNR also recommended that ARENA introduce an application review process to ensure the complaints process is reserved for legitimate complaints only and not a means of relitigating decisions. ARENA has since revised and implemented recommendations from the FNR. The potential for this process to increase resource burden should be considered further.

4.2.1.2 Contract negotiation process

Following the selection of successful applications, ARENA extends an 'Offer to Negotiate' in relation to the contract. During the contract negotiation phase, details of the KSP and funding mechanism are confirmed.

Key findings on the contract negotiation process are detailed in Table 18 below.

Table 22: Findings on key elements of the contract negotiation process	
Contract negotiation has been challenging	► The contract negotiation process has generally been found to be the most common source of frustration in the grant process. ► The ARP evaluation noted that for some recipients the difficulties experienced in negotiating contracts were cause for reconsidering 'whether they should invest the time in the process'. ► Negotiations with the CEFC and commercial banks in relation to some project financing areas were challenging and protracted. In the LSS program, the tripartite deed was the most contested aspect of project documentation. These arrangements could be potentially streamlined in the future through arrangements prior to the documents being released to participants.[137] ► Participants considered that upfront market engagement would likely have ensured the commercial position ultimately presented to the market was acceptable, streamlined negotiations and increased process efficiency.[138]
Knowledge sharing remains challenging	► The ambiguity of knowledge sharing requirements and timeliness of agreement of KSPs have been an ongoing cause of delays and highlighted in multiple evaluations; ARP, RAR and LSS. ► The FNR reiterated that the time taken in negotiating the knowledge sharing element of the funding agreement was regarded as 'excessive'. Recipients complained of overly complex requirements, especially for universities where there already exists a strong culture of publishing research findings. ► As the FNR highlighted and ARP evaluation reiterated, attempting to define required knowledge sharing at the contract negotiation phase may be a misplaced allocation of resources. ► KSPs were 'difficult to get right' and greater clarity was needed in regard to the type of information that would be shared to reduce the time taken negotiating contracts.[139] ► ARENA has since simplified the knowledge sharing plan template to make knowledge sharing plans proportionate to the project. ► ARENA should leverage lessons learned from other ARENA programs that have performed well in defining knowledge sharing requirements e.g. ARENA's battery storage program.
Contracts are inflexible	► Evaluations of earlier programs, including the RAR and ABIR found that the process for varying contacts for anything other than minor variations is lengthy due to a lack of flexibility.[140] ► ARENA has responded to recommendations from these evaluations, and refreshed its standard funding agreements in 2017. They are now risk-based and commensurate with the level of risk of projects, and a more complex standard funding agreement exists for high risk projects.

[136] Harris, 2017, 'Future Needs of the Australian Renewable Energy Agency' page 45
[137] EY, 2019, 'Large Scale Solar Portfolio Evaluation Report' page 66
[138] EY, 2019, 'Large Scale Solar Portfolio Evaluation Report' page 66
[139] Clear Horizon, 2018, 'Regional Australia's Renewables Initiative Evaluation Report' page xiii
[140] Clear Horizon, 2018, 'Regional Australia's Renewables Initiative Evaluation Report' page 29

Table 22: Findings on key elements of the contract negotiation process	
Timeliness concerns	► The FNR reiterated that 'applicants large and small were concerned about the long times taken after acceptance of the application in the negotiation of the agreement required'. For example, the LSS contract template is over 200 pages long and seen as overly complex and conservative. ► Setting targets and tracking times for completing negotiation and ensuring there are adequate legal and commercial contracting resources available is recommended to manage future increased volumes of contracts.[141] ► Participants in the LSS reported they incurred significant rework because of ARENA's late preparation and delayed amendments of the documents necessary to support the agreed contracting framework.[142]

Findings

The two-stage process is consistent with government processes, filtering out low merit projects or projects that do not meet the eligibility criteria allowing only relevant, high merit applications to move on to further assessment, and ensuring it provides a transparent mechanism to fairly assess grant submissions.

ARENA has implemented changes to improve the application and contract negotiation process in response to recommendations from evaluations, and feedback from funding recipients. For example, refreshing the standard funding agreements to be commensurate with the level of risk of projects being funded.

4.2.2 Project management and delivery

The following evaluation question was considered in this section:

► Has ARENA applied appropriate project management practices (e.g. taken a risk-based approach)?

Once contracts are signed, the management of projects is handed from the BD&T team to the Project Delivery team. The Project Delivery team has established a Project Portfolio Management Committee (PPMC) that works to review the performance of ARENA-funded projects, ensure that projects are governed in a manner that is consistent with Australian Government expectations in relation to governance, compliance and risk management, monitor project performance and maximise knowledge sharing outcomes.[143]

ARENA has also developed Standard Operating Procedures which describe how to negotiate and manage funding agreements, including KSP's.

Multiple evaluations have found ARENA's consultation and engagement throughout the application and delivery process to be consistently of a high standard, examples of which are listed in Table 23 below.

[141] Harris, 2017, 'Future Needs of the Australian Renewable Energy Agency' page 74
[142] Harris, 2017, 'Future Needs of the Australian Renewable Energy Agency' page 45
[143] ARENA, 2018, 'Enhancing our business processes' available at https://arena.gov.au/assets/2018/10/enhancing-business-processes.pdf

Table 23: Key findings on ARENA's project management process	
Project management has improved over time, and now adopts a risk based approach	► ARENA's project management of early funding programs was onerous and inefficient due to a one-size-fits all approach. For example: ► The ABIR program evaluation found the monitoring of the program was assisted by a 'stringent process' of milestone-based reporting which was sometimes onerous for funding participants. ► The Future Needs Review found that monitoring performance has been regarded as 'cumbersome and inefficient' due to ARENA's one-size-fits all approach and that more cost-efficient approaches used by other grant makers are not being utilised. It also cautioned that the onerous nature of the milestone reviews can cause delays in payment that can impact cash flow and possibly threaten the survival of start-ups. ► The RAR review found that assessments can take time, which meant it could be a number on months between a milestone being reported and the applicant receiving the next instalment of funds. ► ARENA has responded to recommendations from these evaluations and implemented a risk-based approach to determine the appropriate level of monitoring for projects. ARENA now uses an adaptive and risk-based approach to monitoring which is largely achieved through milestone reports provided by project proponents. The task of monitoring and reporting is overseen by the Project Portfolio Management Committee (PPMC). ► ARENA payments are made following completion of milestones as agreed during the contract negotiation phase. This management practice presents a 'low risk profile' and ensures funding does not continue to be supplied if the project is encountering difficulties as milestone deliverables are incorporated into program funding agreements. ► Evaluations of more recent funding programs and portfolios have found this risk-based approach to be efficient. ► ABIR evaluation found that ARENA's ongoing project management is efficient and encountered no major issues. ► The ASTRI mid-term review concluded that ARENA's program management has been largely successful.[144] ► The ACAP evaluation concluded that the overall strategic direction and management of the program was made in a 'collegial fashion' and that the research program was well managed by a cohesive leadership team. Strategic decision-making was centralised to a management committee with outcomes and resource allocation reviewed annually and consistent with ARC Centres of Excellence governance.[145] ► The recent LSS evaluation found that monitoring and reporting requirements were not overly burdensome and have improved from previous evaluations. Furthermore, ARENA's assurance and governance processes were consistently applied.[146] ► ARENA should ensure that it continues to strike the right balance between scrutiny and avoiding unnecessary burdens in reporting.
ARENA has improved its management of staff turnover	► ARENA's earlier programs found high turnover had resulted in a lack of continuity and consistency in the management of some projects, as found in the RAR Initiative evaluation. ► The handover process has previously caused inefficiencies when project history and relationship continuity is lost and is subsequently required to be rebuilt between managers.[147] ► The subsequent evaluation of client management in the LSS portfolio noted that transition from the outgoing ARENA manager to the incoming managers was smooth, which indicates ARENA has addressed this earlier feedback.

[144] ARENA, 2016, 'Australian Solar Thermal Research Initiative Mid-term Review' page 4
[145] ARENA, 2016, 'Australian Centre for Advanced Photovoltaics Mid-term review' page 24
[146] EY, 2019, 'Large Scale Solar Portfolio Evaluation Report' page 61
[147] Clear Horizon, 2018, 'Evaluation of the Advancing Renewables Program' page vi

Table 23: Key findings on ARENA's project management process	
ARENA has implemented additional functionality to its Grants Management System in response to feedback	► ARENA's Grants Management System (GMS) is used from the acceptance of EOIs and full applications, through to project assessments and the management of project milestone. ► The GMS has caused some dissatisfaction among funding recipients in the past. Experienced grants system users have reported that ARENANet is 'clunky and unfriendly' compared to other GMS systems, and primarily used only up to the end of the selection process unlike end-to-end systems used by other comparable organisations such as the ARC and NHMRC.[148] ► The GMS system has limitations in supporting the end to end process. The FNR recommended that any updates to the GMS include portfolio management functionality and potentially outsource its use to existing systems such as at the Department of Industry (DoI). This was subsequently considered and discounted by the ARENA Review Implementation Oversight Committee due to its misalignment with the Board governance model, increased budget, staffing pressures and potential to weaken the knowledge sharing mandate.[149] ► However, ARENA has undertaken a significant update of GMS to improve data capture at concept, EOI and full application stage as well as contract details to improve overall contract and project management. This includes implementing 'Power BI' is used for some enhanced financial reporting and high-level financials, while the 'Technology One' utility is used to manage payment and financial reporting. ► ARENA should continue to monitor the implementation of the updates to GMS to assess the success of the updates

Risk management

ARENA has demonstrated good risk management practice in cases where issues have been identified with project delivery. While management of some projects has be resource intensive, it has enabled the maintenance of good relationships.[150]

Examples of ARENA's appropriate risk management in key risk areas are outlined in Table 24 below.

Table 24: ARENA's demonstrated risk management in key areas	
Financial Risk	► ARENA makes use of a suite of funding mechanisms to mitigate risk. For example, of the 30 projects underway at the time of the ARP evaluation, 14 received non-recoupable grants and 16 were funded through a range of other financial recoupment mechanisms. ► The LSS also incorporated provisions for ongoing financial capacity of the recipient and its ability to deliver the relevant funded project, such as multiple conditions precedents and monitoring and reporting provisions e.g. Funding Conditions Precedent, Initial Conditions Precedent and General Conditions Precedent.[151] ► The use of recoupable grants reduces ARENA's financial risk.[152] ► The use of bid bonds in the LSS program was viewed favourably because it engaged serious bidders and excluded incapable parties and was particularly useful when timeframes were compressed for achieving financial closure and ensuring projects would proceed.
Reputational Risk and conflicts of interest	► The ARP evaluation considered the use of recoupable grants also reduces ARENA's reputational risk. For example, the risk to ARENA's reputation from projects that fail or perform worse than expected is somewhat lessened as the funding can be recouped. Also, non-recoupable grants may present a reputational risk in that projects that go onto achieve success and sell at a premium may be seen as using public monies to enable a private firm to achieve a substantial monetary return.[153] ► The ARP evaluation considered that the use of debt-equity funding may create conflicts of interest regarding the protection of intellectual property and jeopardise ARENA's knowledge sharing mandate. ► ARENA has recently removed debt/equity rights from its suite of funding mechanisms to reduce complexity for the applicant, administrative burden for ARENA and to acknowledge the role of the CEFC in providing debt and equity.

[148] Harris, 2017, 'Future Needs of the Australian Renewable Energy Agency' page 49
[149] ARENA, 2018, "8th Review Implementation Outsourcing Oversight Committee Meeting'
[150] Clear Horizon, 2016, Evaluation of the Advanced Biofuels Investment Readiness Program' page iii
[151] EY, 2019, Large Scale Solar Portfolio Evaluation Report' fig 11
[152] Clear Horizon, 2018, 'Evaluation of the Advancing Renewables Program' page 40
[153] Clear Horizon, 2018, 'Evaluation of the Advancing Renewables Program' page 40

Table 24: ARENA's demonstrated risk management in key areas	
Contract Risk	► ARENA used a risk management approach to contract assessment including close scrutiny of the financial and position of the recipients. For example, when a grant recipient was identified as having a high financial risk, ARENA took steps to mitigate the risk through the inclusion of additional review points. ► A Contract Management Services (CMS) team is responsible for the day to day management of funding agreements. Any projects encountering troubles are transferred to a Project Solutions team for more intense monitoring. As of June 2019, there have been no projects transferred demonstrating risk management has been effective.
Delivery Risk	► Milestone deliverables are incorporated into program funding agreements. For example, ACAP's work programs were designed to accord with milestone deliverables under the Funding Agreement and each encompassed an agreed project scope and budget. ► ARENA established the Project Portfolio Management Committee in 2018 to review the performance of ARENA funded projects, ensure that projects are governed in a manner consistent with Australian Government expectations in relation to governance, compliance, and risk management, monitor project performance and maximise knowledge sharing outcomes.

The following case study provides an example of ARENA's due diligence in managing risk in relation to its funding recipients.

Case Study: Evolution of the R&D program

ARENA has provided approximately $300 million in funding towards renewable energy projects at the research and development stage in the innovation chain. Drawing on its long-standing history of managing contracts with research institutions ARENA has recognised the lower level of risk associated with early stage innovation projects undertaken by universities, research institutions and their associated industry partners. Over time, ARENA has refined its contracting and reporting requirements for recipients in the R&D program to ensure processes and obligations are efficient and proportional to the lower level of risk inherent in projects at the R&D stage.

ARENA's R&D project portfolio generally funds research institutions and universities that are large, long-standing organisations with robust governance, reporting and risk management structures in place to effectively manage ARENA's funding commitment and deliver outcomes related to that funding. These projects therefore present a reduced financial, work health and safety and environmental risk.

Recognising that, ARENA has made a number of efficiency improvements in relation to selection and ongoing management of the R&D program including streamlining the funding agreement template to reduce the administrative overhead without compromising compliance or project outcomes.

The evolution of the R&D program demonstrates ARENA is continually improving its approach to risk management.

Source: EY consultation with ARENA staff

Findings

ARENA's project management processes have improved over time, and now adopt a risk based approach to determine the appropriate level of monitoring for projects, which has been found to be appropriate.

ARENA has implemented changes to improve its project management processes in response to recommendations from evaluations, and feedback from funding recipients. For example, ARENA has implemented additional functionality to its Grants Management System in response to feedback to improve data capture at concept, EOI and full application stage as well as contract details to improve overall contract and project management.

ARENA has demonstrated good risk management practice in cases where issues have been identified with project delivery. While management of some projects has been resource intensive, it has enabled the maintenance of good relationships.

4.2.3 Adopted lessons learned

The following evaluation question was considered in this section:

- Have lessons learned been adopted by ARENA to optimise future investments?

The Review Implementation Oversight Committee (RIOC) was established by ARENA in response to recommendations made by the FNR and tasked with the responsibility of implementing recommendations for improvements. In addition, ARENA's Business Improvement Steering Committee is a business as usual processes which works to identify opportunities for optimisation and reviews the recommendations of previous evaluations.[154]

RIOC was closed by the Board in 2018[155] in recognition that all recommendations of the FNR had been implemented. Evidence of the awareness, consideration and implementation of recommendations is evident from the previous sections, and in ARENA's internal 'evaluation trackers' (Table 25). The evaluation tracker consolidates and lists the recommendations of several previous reviews of; the ABIR, RAR Initiative, ARP, and DER programs.

Table 25: Summary of evaluation tracker

Evaluation	Accepted Recommendations	Status
ABIR Evaluation	5/8	Completed
RAR Evaluation	9/9	Completed
ARP Evaluation	7/8	Completed
DER program	13/13	Underway
FNR	29/29	Completed

Findings

ARENA demonstrates good practice through its Business Improvement Steering Committee and Project Portfolio Management Committee to evaluate funding programs and organisational reviews to identify opportunities for optimisation and track the implementation of recommendations through the use of evaluation trackers.

ARENA has adopted lessons learned from previous evaluations in its grants and project management processes.

[154] Harris, 2017, 'Future Needs of the Australian Renewable Energy Agency' page 50
[155] ARENA, 2019, 'Annual Report 2018-19' page 64

5. Conclusions

5. Conclusions

This evaluation sought to determine the extent to which ARENA's activities have contributed to ARENA's legislative objective of increasing the competitiveness and supply of renewable energy in Australia and the likelihood of it continuing to do so into the future. It found that ARENA's funding support for renewable technologies across the research and development, demonstration, and deployment stages of the innovation chain, has been critical to achieving the agency's mandated objectives, intended outcomes and led to broader impacts on the Australian energy sector and broader economy. ARENA has been able to, and will continue to, achieve these outcomes by providing financial support, stimulating private sector investment, supporting industry to grow and building its capacity, and reduce the costs of renewable energy technologies.

The assessment framework used in this evaluation was built upon ARENA's logic map. The logic map describes ARENA's intended outcomes and impacts on Australia's renewable energy landscape, in addition to its legislated objectives. The approach taken by EY ensured that the scope of the evaluation remained closely aligned to ARENA's objectives, impacts and outcomes by directing analysis through three lenses; effectiveness, impact and efficiency.

ARENA has previously commissioned multiple evaluations of individual funding program but to date, had not undertaken an agency wide evaluation to determine the agency's performance as a whole. This evaluation has consolidated and analysed the findings of over 17 previous individual funding program evaluations, the results of funding recipient surveys, internal ARENA's documents and additional desktop research, including input/output analysis and international comparisons to reach the conclusions below.

ARENA has helped accelerate the supply and competitiveness of Australian renewable energy technologies through investments across pre-commercial stages of the innovation chain. This includes providing funding to 198 R&D projects, which has resulted in significant knowledge creation, sharing and the development of important skills and enabled Australia to maintain its world leading position in solar PV. It also includes supporting projects which demonstrate the feasibility of renewable technologies to the market, reduced costs through competition and created a critical mass of vanguard technology deployment to drive market growth.

ARENA's knowledge sharing activities undertaken as part of funding programs have been extensive and are effective and valued by market participants to support industry development and/or knowledge dissemination. In addition, ARENA effectively fosters collaboration through the facilitation of innovation workshops through the A-Lab program, the research activities undertaken by both ACAP and ASTRI, as well as indirectly bringing together industry and research bodies through the funding of innovative projects. We recommend ARENA continue to monitor and report on the implementation of existing knowledge sharing recommendations from previous evaluations. This could include liaising with stakeholders to determine whether the improvements have addressed the issues and taking corrective action where necessary.

Given the findings of the stakeholder surveys, program and funding evaluations there is sufficient evidence to conclude that without ARENA's support these projects would not have been successful and that levels of investment in renewable energy in Australia would be lower. Further ARENA's approach to funding projects has been found to be broadly similar in both function and form compared to other contemporaneous grants programs nationally and internationally. While it was not possible to compare outcomes across different grants programs, ARENA is operating within the bounds of international examples of good practice.

ARENA supported research and development, commercialisation and deployment projects, have contributed towards (or are expected to contribute towards) seven impacts. ARENA's R&D investment has significantly improved the cost and performance of solar PV. Its demonstrations and feasibility study projects have supported emerging technologies to move towards commercial readiness more quickly and develop enabling technologies that will support renewables to integrate into the grid in a way that improves reliability and maintains system security. Critically, ARENA has

contributed to reducing the cost of renewable energy, supporting an increase in the supply of renewable energy and a reduction in energy related emissions. In addition, there were very few instances where ARENA's activities were reported as causing unintended consequences. Where they were reported, ARENA funded programs were not necessarily causing unintended consequences but rather exposed broader market issues that it is well placed to mitigate due to its knowledge sharing activities. We recommend ARENA integrate the use of the technology readiness level (TRL) index reporting and commercial readiness index (CRI) reporting into their BAU practice to consistently track the progress of projects across all technologies along the technology development chain.

ARENA's processes have been broadly efficient and appropriate as determined through analysis of previous program evaluations and systematic reviews. The two stage grants process has enabled the efficient allocation of resources and initial difficulties with the contract negotiation process have been acknowledged and actioned by ARENA and there is evidence that it has improved over time. The use of varying funding mechanisms has shown ARENA considers multiple factors in relation to the broader economic climate, capacity of recipient and level of commercialisation and used competitive funding rounds to drive efficient outcomes with impressive results. A high standard of project management and a risk-based approach has been able to identify issues and resolve them without impact on program delivery.

Lastly, ARENA's demonstrated ability to consider and action recommendations should provide confidence that it will continue to improve its processes into the future.

5.1 Key findings

The following Table 26 provides a summary of the key findings from the program analysis performed.

Table 26: Findings on ARENA's impact and effectiveness

Investment in innovative research and ground-breaking technologies	► ARENA has effectively supported innovative and ground-breaking research through its large R&D program and other targeted funding programs. Through supporting R&D, demonstration and deployment ARENA has been effective at increasing the competitiveness of renewable energy in Australia and has enabled improvements into the future. ► R&D funding has resulted in significant knowledge creation, sharing and development of important skills and creation of world class research while the ARP and the LSS have proven to be effective grants funding mechanisms to support demonstration and deployment projects. ► The majority of ARENA's research funding has been allocated to projects related to efficiency improvement and manufacturing cost reduction, thus drawing a nexus between R&D outcomes and ARENA's legislative remit to improve competitiveness and increase supply of renewables. The creation of the ASTRI and ACAP has enabled further research to continue outside of ARENA's remit, improved solar research facilities and helped maintain Australia's world leading research role. ► Both ASTRI and ACAP have contributed significantly to the development of research within the CST and PV field respectively. ACAP, specifically, has contributed directly to ARENA in achieving its outcome to improve the competitiveness of renewable energy technology through the development of world class research. ► The ARP grants programs have effectively demonstrated the feasibility of new technologies, reduced costs and created momentum and a critical mass of vanguard technological deployment to drive market growth.
Better informing government and industry to navigate the energy transition	► ARENA undertakes extensive knowledge sharing activities, actively contributing to delivering the outcome of driving industry and government to be better informed to navigate the energy transition. ► ARENA has taken on board recommendations and implemented strategies to improve knowledge sharing functions. ARENA's significant improvement in informal knowledge sharing over time is now ensuring the knowledge is targeted and tailored. ► There is clear evidence of ARENA effectively achieving better collaboration on energy innovation. ARENA fosters collaboration through the facilitation of innovation workshops through the A-Lab program, the research activities undertaken by both ACAP and ASTRI, MoU's as well as indirectly bringing together industry and research bodies through the funding of innovative projects.

Table 26: Findings on ARENA's impact and effectiveness	
Achieving outcomes in the absence of ARENA	► ARENA's interventions have contributed to achieving innovation in renewable energy, knowledge sharing and collaboration. In the absence of ARENA many of the renewable energy projects that received support would not have proceeded or been able to adopt the scale and ambition without the support provided by ARENA. ► It is reasonable to conclude that ARENA's actions are effective at catalysing and supporting a number of these projects going ahead. As a result, the outcomes that these projects achieved, may not have been realised, or realised to a lesser extent if not for ARENA's intervention. ► If is unlikely such knowledge sharing activities would have been undertaken in the absence of ARENA.
Comparison of alternative interventions	► The main ARENA grants program, the ARP, was broadly similar in function and form comparing to other contemporaneous grants programs nationally. ► This included having characteristics of providing pre-application processes to screen for project suitability, transparent grants funding guidelines and merit criteria, and competitive evaluation processes which draw upon technical advice as required. ► There are broad similarities to the focus on outcomes, strategic intent and funding mechanisms undertaken by international counterparts to those approaches undertaken by ARENA. ► It would suggest that ARENA is largely operating within the bounds of international examples of better practice.

Impact of ARENA's programs	► Evidence suggests that ARENA supported research and development, commercialisation and deployment projects, have contributed towards (or are expected to contribute towards) all seven of their intended impacts. These range from industry specific impacts such as (i.e. building and enhancing technology pathways, developing industry capacity and creating new supply chains) to broader economic impacts (i.e. the creation of direct and indirect economic impacts).
	► In particular, ARENA funding has:
	  ► significantly enhanced the technological pathway of solar PV, flexible renewable energy technologies and enabling technologies
	  ► contributed to an increase in employment in the renewable energy sector, largely through large-scale solar construction activity
	  ► contributed to the creating of a domestic large-scale solar supply chain
	  ► increased the supply and diversity of Australia's renewable energy supply, and contributed to the reduction in the cost of renewable energy
	  ► influenced changes to market rules and frameworks.

Attribution of intended impacts to ARENA	► While there are multiple variables that ultimately impact the supply and installation cost of renewable energy, international data on the supply and installation cost of renewable energy suggest the magnitude of change in Australia was greater than in other countries implying there were country specific factors in Australia that contributed. ► ARENA's Investment leverage ratios, and independent stakeholder research suggest ARENA has contributed to (or is expected to contribute to) its intended market impacts to a large extent.
Unintended consequences	► There were very few instances where ARENA has been reported as causing unintended consequences. Where they were reported, ARENA funded programs were not necessarily causing unintended consequences but rather exposed broader market issues. ► As a knowledge sharing entity that collaborates with industry, ARENA is well placed to mitigate the impacts of broader market issues (or unintended consequences should they emerge in the future).
Grants process	► The two-stage process is consistent with government processes, filtering out low merit projects that do not meet the eligibility criteria allowing only high merit applications to move on to further assessment, and ensuring it provides a transparent mechanism to fairly assess grant submissions. ► ARENA is aware of the difficulties and delays experienced in the contract negotiation process and has since extended 'streamlined' contracts as utilised in the R&D programs to be extended across all ARENA's programs. It is expected that this will address areas identified as causing delays.
Project management and delivery	► ARENA demonstrates high quality but resource intensive project management. ► Difficulties with the Grants Management System have been acknowledged by ARENA and have been improved. ► ARENA has demonstrated good risk management practices in key risk areas.

Table 26: Findings on ARENA's impact and effectiveness	
Adopted lessons learned	► The establishment of the Review Implementation Oversight Committee (RIOC) to implement the recommendations of the Future Needs Review, since completed, is an example of how ARENA has adopted lessons learned. ► ARENA demonstrates good practice through the tracking of program evaluations in multiple 'trackers'. There is scope to consolidate these to ensure that some recommendations are not lost. ► ARENA has adopted lessons learned from previous evaluations.

5.2 Recommendations

This evaluation has identified four areas of improvement that ARENA could consider when implementing future processes. Each are outlined in Table 27 below.

Table 27: Recommendations	
Monitor and report on implementation of existing knowledge sharing recommendations	► A number of evaluations (i.e. ARP, ABIR, RAR) noted recommendations with a focus on knowledge sharing. For example, simplifying the specifics and clarifying the objectives of knowledge sharing plans (KSP's), tailoring knowledge sharing requirements to the market and renewable energy sector's needs. ► ARENA has since accepted all knowledge sharing recommendations from these evaluations and is implementing strategies to address this. ► We recommend ARENA continue to monitor and report on the implementation of existing knowledge sharing recommendations from previous evaluations. This could include liaising with stakeholders to determine whether the improvements have addressed the issues and taking corrective action where necessary.
Integrating technological readiness levels reporting into standard practice	► Our evaluation of ARENA's impact found ARENA's TRL index and CRI as useful quantitative methods to evidence the extent to which ARENA-funded projects have built and enhanced technological pathways. ► At present TRL index has been used to measure the progress of solar PV and CST R&D projects only. TRL and CRI information is not available for other emerging technologies that ARENA has invested in (i.e. Large-Scale Battery Storage). ► We recommend ARENA integrate TRL index reporting and CRI reporting into its BAU practice to consistently track the progress of projects across all technologies along the technology development chain.
Continue to apply a risk based approach to project management	► ARENA's project management of early funding programs was onerous and inefficient due to a one-size-fits all approach. ► ARENA responded to recommendations from the ABIR, RAR, ARP and DER evaluations and implemented a risk-based approach to determine the appropriate level of monitoring for projects. ARENA now uses an adaptive and risk-based approach to monitoring which is largely achieved through milestone reports provided by project proponents. ► Evaluations of more recent funding programs and portfolios found this risk-based approach to be efficient. ► We recommend ARENA continue to strike the right balance between scrutiny and avoiding unnecessary burden on funding recipients in its project management and monitoring processes.
Monitoring the implementation of GMS updates	► ARENA's Grants Management System (GMS) has caused some dissatisfaction among funding recipients in the past. Experienced grants system users have reported that ARENANet is 'clunky and unfriendly' compared to other GMS systems. The GMS system also has limitations in supporting end to end processes. ► ARENA has undertaken a significant update of GMS to improve data capture at concept, EOI and full application stage as well as contract details to improve overall contract and project management. ► We recommend ARENA continue to monitor the implementation of the updates to its GMS to assess the success of the updates.

Appendices

Appendix A About ARENA

ARENA was established by the Australian Government on 1 July 2012, through the passing of the ARENA Act with the objectives of improving the competitiveness of renewable energy technologies and increasing the supply of renewable energy in Australia.[156]

ARENA assumed some of the roles of its predecessor, the Australian Centre for Renewable Energy (ACRE) which was established in 2009 to promote the development, commercialisation and deployment of renewable energy and enabling technologies and improve their competitiveness in Australia. As an independent statutory authority, ARENA is subject to legislation, regulations and standards that apply to corporate Commonwealth entities.

ARENA's purpose is to accelerate Australia's shift to affordable and reliable renewable energy by:

- Providing funding to researchers, developers and business
- Building and supporting networks
- Sharing knowledge, insights and data from funded projects.

A key role ARENA plays is to find and support the building blocks of Australia's future energy system, helping to accelerate the transition to renewable energy.

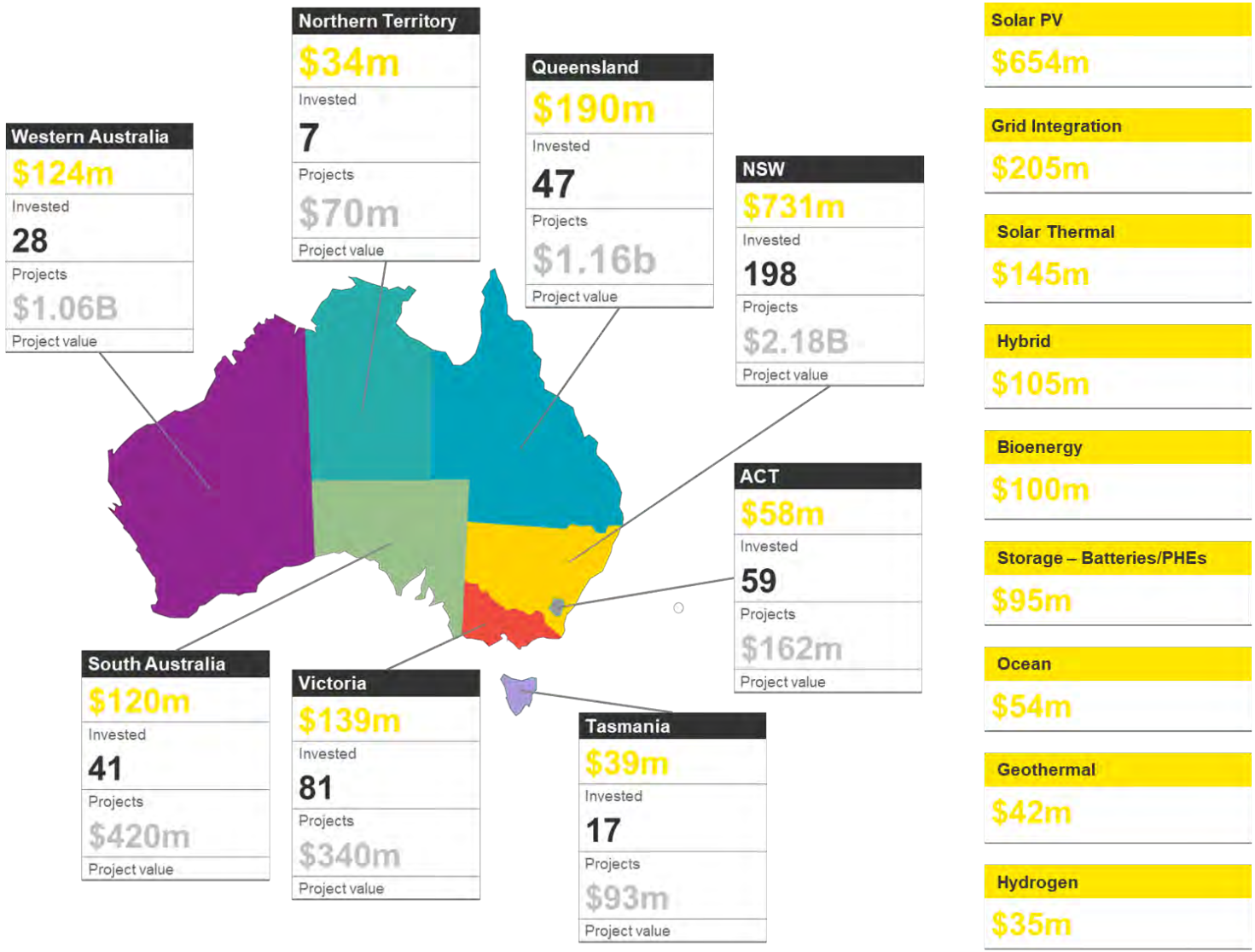
ARENA seek to enable more renewables and lower emissions by driving innovation and commercialisation of renewable energy technology. By funding projects and sharing knowledge, ARENA aims to improve the competitiveness of renewable energy and support the transformation of Australia's energy mix, benefiting the Australian economy, industry and wider community.

To date, ARENA has invested $1.59 billion across 528 projects with a total value of $7 billion and has achieved an average investment leverage of 1:3.4.[157] Figure 28 summarises the scale of ARENA's investment across technology type, and in each state since 2012.

[156] Commonwealth of Australia, 2011, 'Australian Renewable Energy Agency Act 2011'

[157] ARENA, 2019, Grants Management System data accessed 25 September

Figure 28: ARENA's investments at a glance – Funding commitment to projects 2012-19

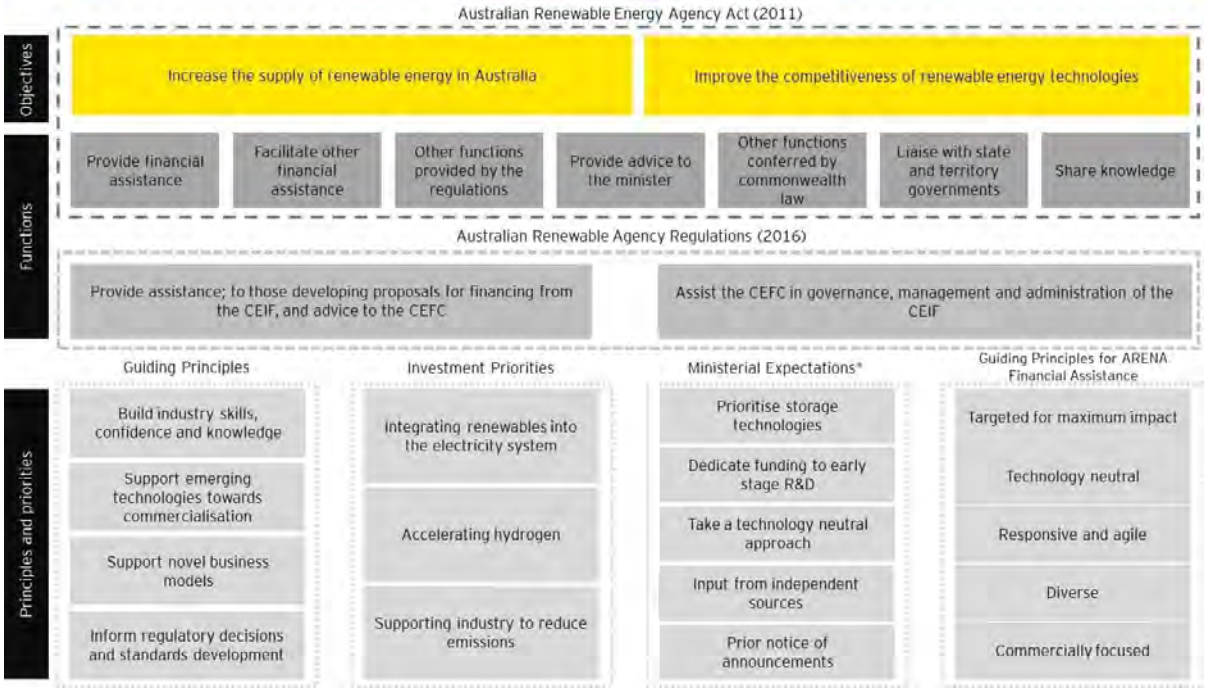


Source: Adapted from ARENA, Annual Report 2018-19, Figure 2: ARENA at a glance – Funding Commitment to projects 2012-19

Stated objectives, purpose and values

The *Australian Renewable Energy Agency Act (2011)* and *Australian Renewable Energy Agency Regulation* 2016 form ARENA's statutory requirements. In addition to these primary legislative requirements, ARENA has outlined additional priorities, activities and public service values in its annual reports, performance frameworks and corporate plans. An overview of this material and other relevant documentation is detailed in Figure 29 below.

Figure 29: Overview ARENA's key objectives, functions and priorities from legislative and corporate documents



**Ministerial expectations are outlined in a letter from the former Minister for Environment Josh Frydenberg dated 23 November 2016. The current minister has not issued a letter of expectations to ARENA.*

Legislation

The Australian Renewable Energy Agency Act (2011)

Section 3 of the *Australian Renewable Energy Agency Act (2011)* states the main objective of ARENA is to:

- Improve the competitiveness of renewable energy technologies
- Increase the supply of renewable energy in Australia.

The Act also stipulates the functions available to ARENA to achieve its primary objectives:

a. Providing financial assistance for renewable energy, research, development, demonstration, commercialisation, deployment and knowledge sharing

b. Enter into agreements for the purpose of providing financial assistance as per (a)

c. Collecting, analysing, interpreting and disseminating information and knowledge related to renewable energy technologies

d. Providing advice to the Minister for Environment and Energy in relation to improving the competitiveness, supply, development of skills in the renewable energy sector and use of renewable energy technologies

e. Liaising with State and Territory governments and other authorities for the purposes of facilitating renewable energy projects

f. Any other functions provided by the regulations

g. Any other functions conferred on ARENA by the Act or any other commonwealth law

h. To do anything incidental to, or conducive to, the performance of the above functions.

In addition to the two primary objectives and functions, other legislative documents outline the expectations that ARENA is expected to meet. These additional legislative documents are outlined below.

The Australian Renewable Energy Agency Regulations 2016

The *Australian Renewable Energy Agency Regulation 2016* prescribes the additional functions of:

- Assisting the Clean Energy Finance Corporation (CEFC) in relation to the governance, management and administration of the Clean Energy Innovation Fund (CEIF)
- Providing assistance to persons developing project proposals for financing from the CEIF and advice to the CEFC in relation to such proposals.

The Australian Renewable Energy Agency (General Funding Strategy) Determination 2019

The *Australian Renewable Energy Agency (General Funding Strategy) Determination 2019* (the GFS) provides guiding principles for how ARENA provides financial assistance to eligible activities. ARENA applies the GFS principles to set its investment priorities, which are detailed in its Investment Plan. The GFS reflects how ARENA intends to achieve its objectives and takes account of the Government's priorities reflected in the Minister's Statement of Expectations. The GFS is reviewed each year and updated if necessary.[158]

The GFS specifies that ARENA's financial assistance is expected to deliver changes beyond the funded project such as to:

- Build industry skills, confidence and knowledge, reducing risk for future similar activities
- Support emerging technologies to move along a pathway to commercialisation
- Support novel business models
- Inform regulatory decisions and standards development by other agencies.

Additionally, the GFS describes five principles which ARENA must consider when developing and delivering its investment priorities. These principles are intended to be balanced against each other and target financial assistance to areas of maximum impact while allowing for a degree in diversity in investment. They are as follows:

- **Investments be targeted for maximum impact** - Investments with high impacts are those with the highest contribution to ARENA's objective, particularly where there is potential for ARENA to progress technologies along the innovation chain faster than would occur without ARENA's support.
- **Technology neutral** – This principle allows for a full range of renewable energy and related energy technologies to be explored, increasing the chances of the lowest cost and most effective solutions being available in the long term.
- **Responsive and agile** – Investments should be made in response to market conditions and industry needs as they arise.
- **Diverse** – To reduce portfolio risk, investments should be diversified to include activities at different stages of development in the commercialisation pathway.

[158] Note the 2019 GFS is the most recent version and is currently in force.

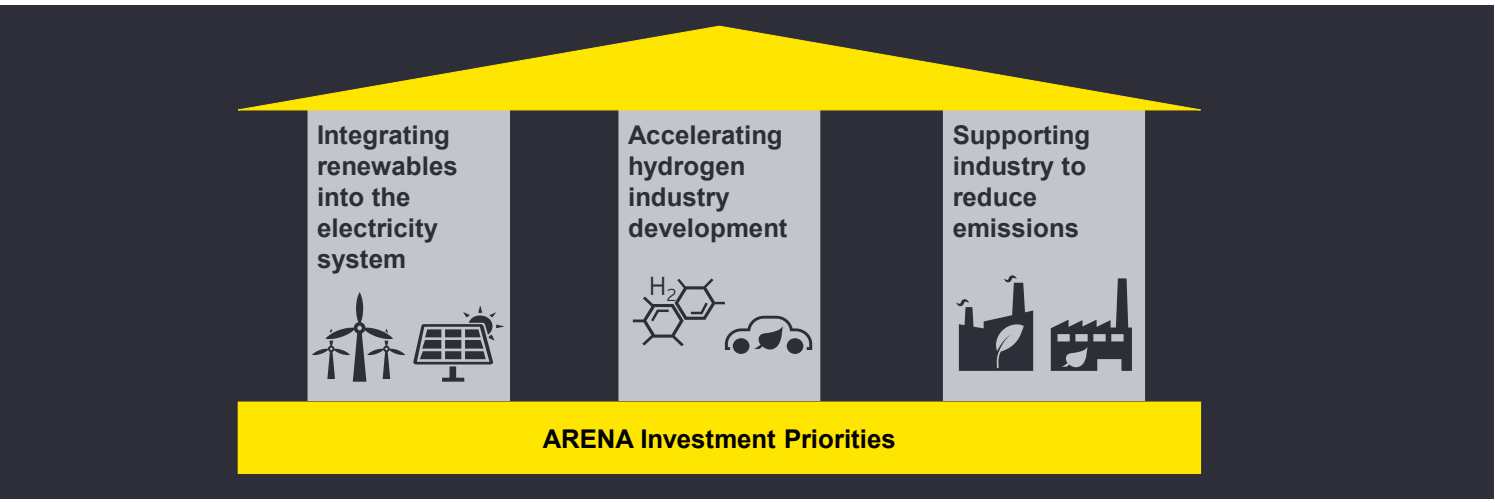
- **Commercially focused** – To invest in the advancement of technologies towards commercial readiness.

Lastly, as an entity of the Commonwealth and in receipt of public resources, ARENA is also subject to the requirements of the *Public Governance, Performance and Accountability Act 2013*.

Corporate Plan

ARENA's 2019/20 – 2022/23 Corporate Plan describes ARENA's priorities as shown in Figure 30 below. These priorities align ARENA's activities and investment decisions with the long-term objectives of the Act.

Figure 30: ARENA's investment priorities



Source: Adapted from ARENA, Innovating Energy – ARENA's Investment Plan, 2019, p. 7.

The Corporate Plan also describes ARENA's performance framework which describes the outcomes ARENA aims to achieve, the activates undertaken to achieve these outcomes, and various performance measures ARENA will use to measure performance.

Annual Report

ARENA describes its purpose as being to accelerate Australia's shift to affordable and reliable renewable energy.[159] According to its most recent annual report the agency's core activities undertaken in 2017-18 to achieve this purpose fell into three categories:

- Supporting world-leading Australian research and development
- Fast tracking commercialisation technologies and business models
- Building knowledge and evidence to inform decision making.

These activities were undertaken in conjunction as part of the investment.

Ministerial Expectations

The *Australian Renewable Energy Agency Act (2011)* sets out additional expectations as required by the Minister which are listed below. There are further non-legislative expectations that have been outlined by the Minister in official letters to the Agency.

The Act requires that ARENA:

- Consider any request by the Minister to provide funds for a particular project.

[159] ARENA, 2018, 'Annual Report' and 2019/20 – 2022/23 Corporate Plan

- Obtain written approval from the Minister to provide grants totalling more than $50 m.

In a letter of expectations, the Minister for Environment and Energy[160] outlined personal expectations that ARENA should:

- Dedicate substantial funding to early stage research and development with a line of sight to commercial outcomes and not to provide assistance to commercially viable technologies
- Prioritise funding of storage technologies that support grid security and stability.
- Take a technology neutral approach to developing investment priorities
- Revise and set funding priorities according to input from independent expert sources including the CSIRO
- Provide a written report to the Minister within 10 days of each board meeting and prior notice to the Department of significant announcements, events, or intentions to participate in public discussions.

It should be noted that the current minister, who was appointed in 2019 after the last Federal election, has not issued a letter of expectations to ARENA.

Performance Framework

ARENA's internal performance management is assessed through yearly performance reporting. A balanced and complete performance measurement and reporting system provides both financial and non-financial information that allows judgements to be made on the public benefit generated by agencies spending public funds.[161]

ARENA's performance measurement and reporting system comprises a set of concepts, business processes, roles and responsibilities whose design has been informed by the *ARENA Act 2011*, the Portfolio Budget Statements, and ARENA's corporate plan.

The performance framework outlines the key activities, outcomes and impacts that ARENA will measure performance against, as shown in Table 28 below. It also indicates how ARENA will measure its performance in relation to the outcomes and activities.

Table 28: ARENA Performance Framework[162]

ACTIVITIES: **What ARENA does to achieve its purpose and how effectively it does this**	OUTCOMES: **The results that ARENA's activities will produce**	IMPACT: **The enduring, positive change that ARENA will contribute to**
Investing in innovative research and ground-breaking renewable energy technologies and projects Funding provided via ARENA programs FY19-20 to FY21-22 Jointly manage Innovation Fund with the CEFC	Energy users, producers and market bodies benefit from improved competitiveness of renewable energy technologies	Increase in supply of renewable energy Secure, reliable and affordable electricity system with a significantly higher share of renewable energy Commercial scale value chains in renewable hydrogen established Industry captures new opportunities and reduces emissions via renewable energy

[160] Hon. Josh Frydenberg, Minister for Environment and Energy, 2016, 'Statement of Expectations'.
[161] ARENA, 2019, '2019-20 Performance framework guide' page 2
[162] Adapted from ARENA 2019-20 Corporate Plan

Table 28: ARENA Performance Framework[162]		
Sharing knowledge and lessons learnt to improve understanding, remove barriers and inform decision making	Industry and government better informed to navigate the energy transition	
Building networks and collaborating across the energy sector to build skills, encourage dialogue and help meet emerging challenges	Energy users, producers and market bodies benefit from better collaboration on energy innovation	

ARENA's activities

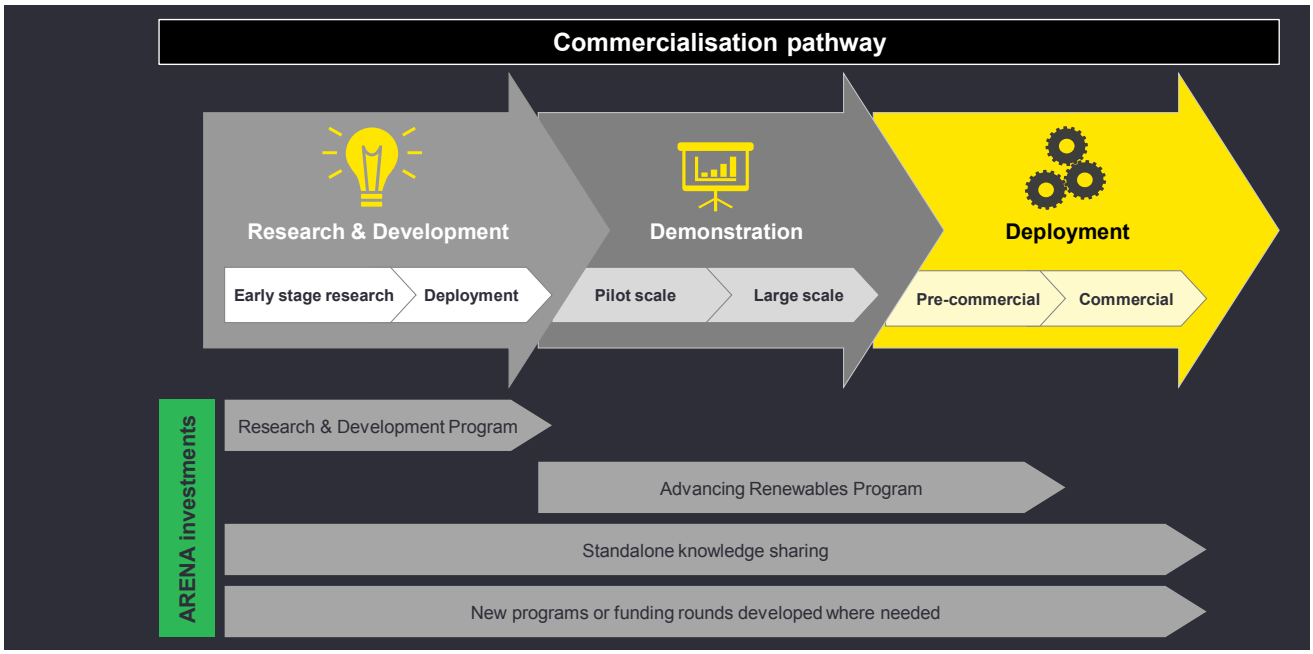
ARENA undertakes a diverse and varied range of activities in order to meet its stated objectives to accelerate Australia's shift to affordable and reliable renewable energy. These activities fall under three broad categories:

- Provision of financial assistance
- Sharing of information and knowledge
- Collaboration with and between organisations and governments.

Provision of financial assistance

ARENA invests in projects spanning the entire innovation chain, from research and development to deployment, as shown in Figure 31. The key focus of ARENA's investment and funding programs is to find and demonstrate first-of-a-kind renewable energy technologies and business models that can grow Australia's renewable energy supply, knowledge and expertise.

Figure 31: ARENA supports innovation and commercialisation of technologies across the innovation chain



Source: Adapted from ARENA, 2019, 'Innovating Energy – ARENA's Investment Plan' page 14

ARENA has undertaken a number of funding programs to support renewable energy projects at various stages, from desktop studies through to later-stage innovation and commercialisation projects, led by Australian start-ups and businesses. These funding programs include both:

- Continuous funding programs, for example the Advancing Renewables Program, which is continuously open for applications

- Targeted funding rounds, which are time-limited and seek specific types of projects.

ARENA's current and past funding programs are summarised in Table 29.

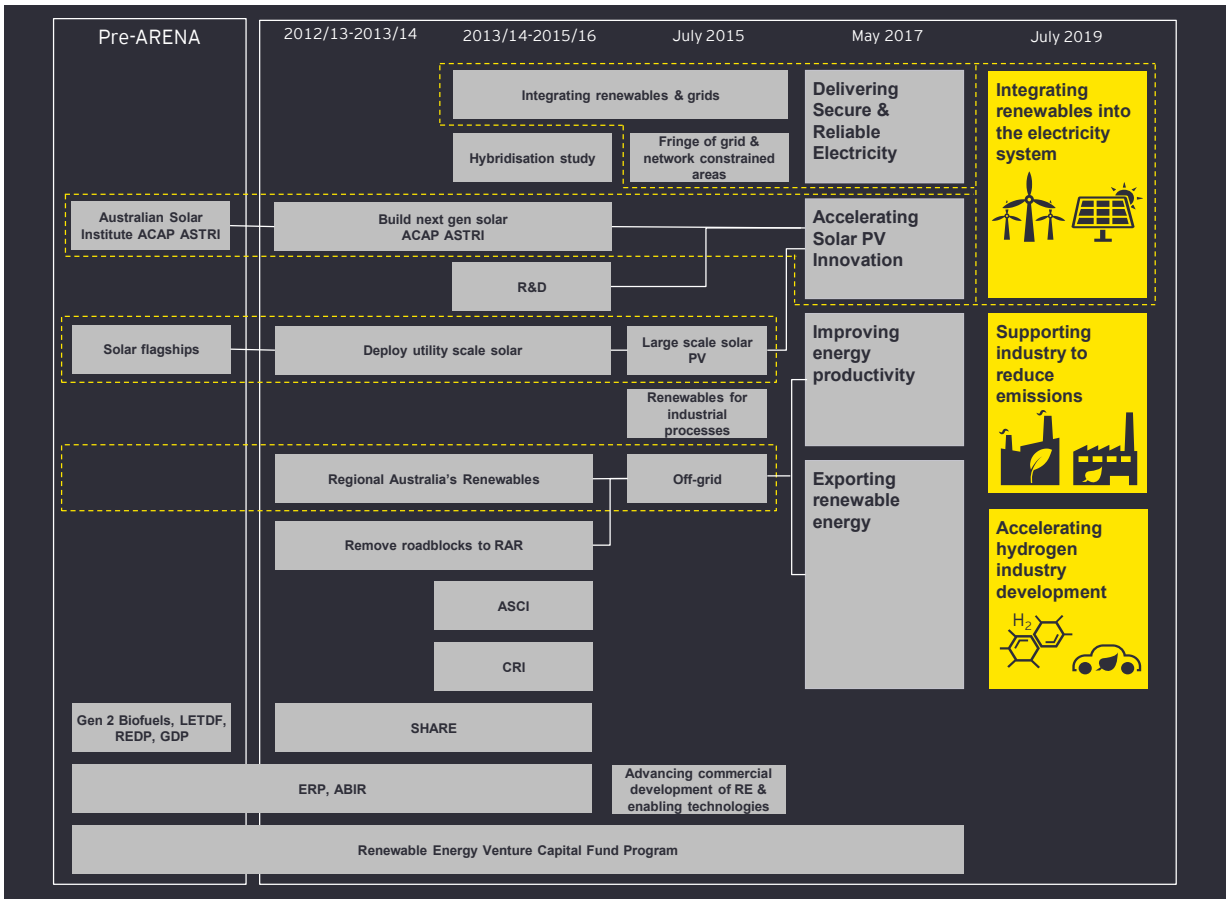
Table 29: ARENA's current, closed and past funding rounds[163]	
Funding program	**Description**
Currently ongoing or subject to availability	
Advancing Renewables Program	Development, demonstration and pre-commercial deployment projects
Research and Development	Renewable energy technologies that will increase commercial deployment within Australia
Renewable Energy Venture Capital Fund (REVC)	REVC provides management expertise and makes equity investments in early-stage renewable energy companies to help them overcome capital constraints, develop technologies, increase skills and forge international connections.
Innovation Fund	Emerging Australian technologies & businesses that can accelerate Australia's transition to a renewable energy economy.
Closed	
System Security	ARENA is allocating up to $7 m of funding towards activities focused on the provision of power system security and strength services from innovative methods or technologies that are non-traditional sources of those services.
Commercialisation of R&D Funding Initiative Pilot	Australian Renewable Energy Agency (ARENA) will fund a pilot funding initiative to help progress early stage research and development (R&D) along the commercialisation pathway. This initiative has been designed to be delivered in conjunction with the CSIRO's ON Prime program
Past	
Short Term Forecasting Funding Round	Activities focused on 5-min ahead self-forecasting for wind and solar farms operating in the NEM
Distributed Energy Resources	Pilot projects and studies to integrate distributed energy resources into the electricity system
Demand response	Managing electricity supply during extreme peaks
Large-Scale Solar	Supporting further cost reduction in large-scale solar PV
Renewable hydrogen for Export	Developing potential renewable energy export supply chain
Solar Research & Development	Reducing the cost and improving the efficiency of solar PV
Solar Research Excellence	Promoting excellence in solar research and build on Australia's reputation for delivering world-leading photovoltaic and concentrating solar thermal technologies
Emerging Renewables Program	Supporting a broad range of development, demonstration and early stage deployment projects to lower the cost and increase the use of renewable energy technologies in Australia.
Regional Australia's Renewables	Supporting trials of renewable energy solutions, including hybrid systems, in regional and remote locations with the aim of increasing the use of these technologies for power generation once they become affordable
Accelerated Step Change Initiative (ASCI)	Supporting exceptional, breakthrough projects that were not otherwise eligible under existing ARENA funding programs.
The Australian Centre for Renewable Energy (ACRE)	ACRE was established in 2009 to promote the development, commercialisation and deployment of renewable energy and enabling technologies and improve their competitiveness in Australia
Department of Resources Energy and Tourism	ARENA assumed responsibility for projects under the following programs managed by the former Department of Resources, Energy and Tourism: Second Generation Biofuels Research and Development (Gen 2) Program: A competitive grants program that supported the research, development and demonstration of new biofuel

[163] Information on ARENA's funding opportunities has been sourced from ARENA's website, accessible here: https://arena.gov.au/funding/

Table 29: ARENA's current, closed and past funding rounds[163]	
Funding program	**Description**
	technologies and feedstocks to address the sustainable development of a biofuels industry in Australia. Solar Flagships Program: The Solar Flagships Program was established in December 2009 to support the construction and demonstration of large-scale, grid-connected solar power stations in Australia. The program supported solar power playing a significant role in Australia's electricity supply and operating within a competitive electricity market.
Australian Solar Institute	The Australian Solar Institute operated from August 2009 before being merged into ARENA on 31 December 2012. ASI developed a portfolio approaching $450 m in value from the initial $150 m, supporting over 350 solar researchers across more than 120 projects.

As illustrated by Figure 32 projects have evolved over time to align with ARENA's investment priorities.

Figure 32: Evolution of ARENA's projects to align with investment priorities[164]



ASCI: Australian Step Change Initiative **SHARE**: Supporting high-value Australian Renewable Energy Knowledge Initiative **CRI**: Commercialisation Readiness Index **ERP**: Emerging Renewables Program **ABIR**: Advanced Biofuels Investment Readiness Program **GEN 2 Biofuels**: Second Generation Biofuels Program **REDP**: Renewable Energy Development Program **GDP**: Geothermal Drilling Program **LETDF**: Low Emissions Technology Demonstration Fund **RAR**: Regional Australia's Renewables **RE**: Renewable Energy

Sharing of information and knowledge

Another key component of ARENA's activities is sharing of information and knowledge, undertaking research, informing policy decisions, and bringing together people from across the energy sector, government, start-ups, and universities to collaborate with one another and share their knowledge.[165]

[164] Adapted from ARENA 2018-19 Corporate Plan
[165] See section 2.2.1.2

ARENA also publishes information on their activities, and funded projects in its Knowledge Bank, providing an open-source library of reports, studies and tools that provide guidance and learnings to benefit future renewable energy projects. It also shares information through its monthly ARENA Insights newsletter and ARENA Insights Forums. Sharing knowledge from early-mover projects can:[166]

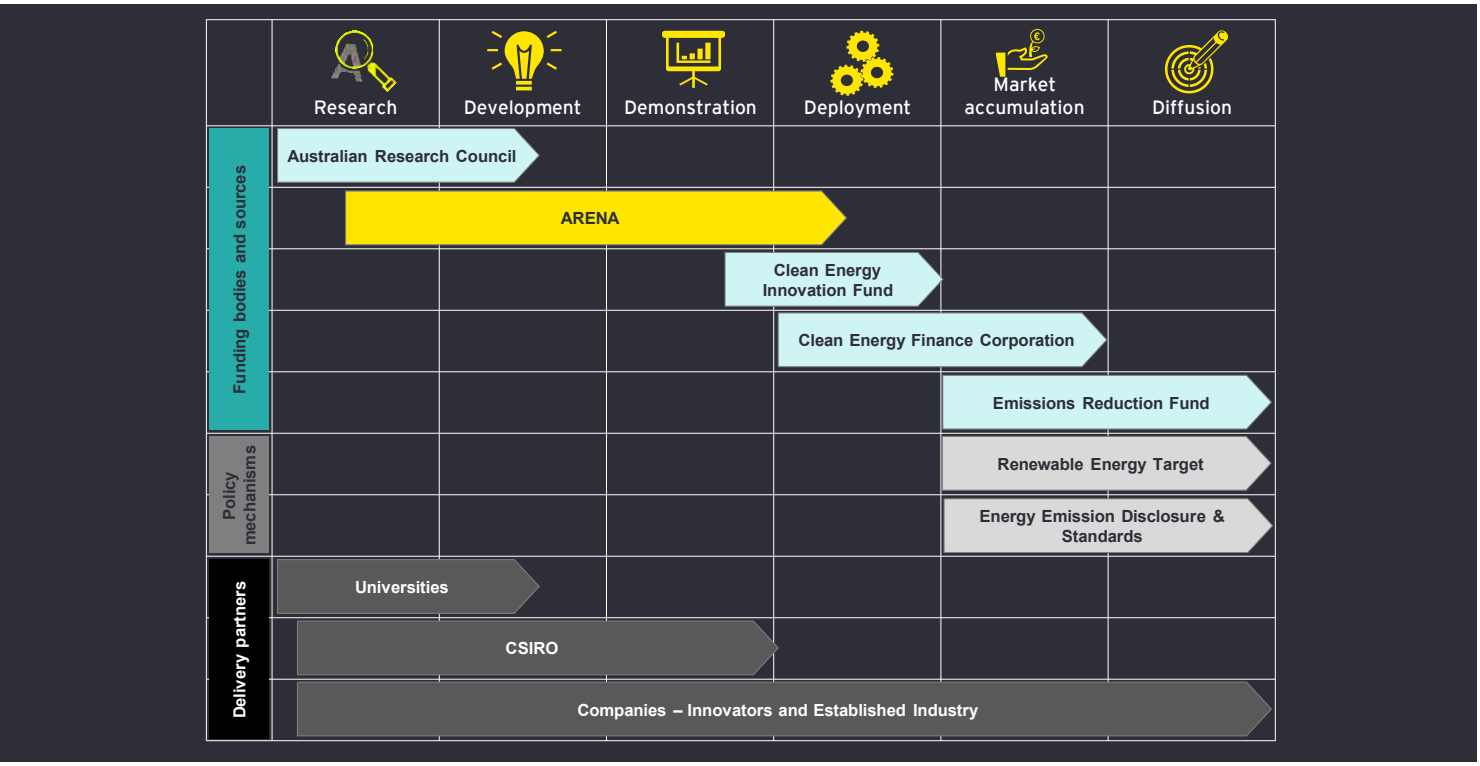
- De-risk or lower the risk for follow-on projects and prepare industries for scaling up to commercial size
- Accelerate deployment of safe and commercially viable technologies
- Increase public understanding and confidence in new technologies
- Support capacity and capability development
- Inform future policy making.

Collaboration between organisations and governments

ARENA works closely with other leading energy sector bodies and governments (both state and federal) to ensure that support for clean energy innovation is as collaborative, efficient and effective as practicable.[167] ARENA's funding programs (described in Table 29) are intended to work alongside other government policies and programs, such as the Climate Solutions Fund, Regional and Remote Communities Reliability Fund and the Renewable Energy Target.

Figure 33 shows how ARENA interacts with partners, and other government policies and programs across the innovation chain.

Figure 33: Partnerships across the innovation chain



Source: Adapted from ARENA, Innovating Energy – ARENA's Investment Plan, 2019, p. 15.

[166] ARENA, 2019, 'Annual Performance Statement 2018-19' page 93
[167] ARENA, 2019, 'Corporate Plan 2019/20 – 2022/23' page 19

ARENA's works with organisations like CSIRO, CEFC, energy sector peak bodies, consumer groups, universities, major energy companies and start-up businesses to assist with Australia's transition to cleaner and cheaper energy. Examples of some of the collaborative projects ARENA has undertaken are shown in Table 30.

Table 30: Examples of Collaboration projects[168]

Programs Projects and Initiatives	Description
Industry and Researcher collaboration	Supporting collaboration between industry and the research sector focused on innovative renewable energy technologies that integrate renewable energy into networks, buildings and industrial processes.
International Engagement Program	Supporting Australian representation and access to global forums, which are dedicated to creating and sharing knowledge on renewable energy research, deployment, markets, policies and regulations
A-LAB	ARENA's innovation lab that looks to create cross-sector partnerships and world-first projects to transition Australia to clean energy. A-Lab brings together a diverse network of people with the expertise and passion to drive systemic change in the electricity sector. Together this network works to define solutions to the most complex challenges facing the energy sector by combining the respective strengths of participants in order to build momentum for change.
Australian Centre for Advanced Photovoltaics (ACAP)	ARENA supports ACAP in undertaking Australian research and development in solar photovoltaic to help solar power become cost competitive with other energy sources. ACAP, the Australian partners of the Australia-US Institute for Advanced Photovoltaics (AUSIAPV), is developing the next generations of photovoltaic technology, providing a pipeline of opportunities for performance increase and cost reduction. Headquartered at UNSW's School of Photovoltaic and Renewable Energy Engineering, the Centre includes research groups at CSIRO, Australian National University, University of Melbourne, University of Queensland and Monash University. AUSIAPV links ACAP with NSF/DOE Energy Research Centre for Quantum Energy and Sustainable Technologies (QESST), based at Arizona State University, the National Renewable Energy Laboratory, Sandia National Laboratories, The Molecular Foundry at Lawrence Berkeley National Laboratories, Stanford University, Georgia Institute of Technology and University of California – Santa Barbara. These national and international research collaborations provide a pathway for highly visible, structured photovoltaic research collaboration between Australian and American researchers, research institutes and agencies, with significant joint programs based on the clear synergies between participating bodies. [169]
The Australian Solar Thermal Research Initiative (ASTRI)	ARENA supports ASTRI in undertaking Australian research and developing to deliver cost reductions and dispatchability improvements to Concentrating Solar Thermal (CST) Power in Australia and position Australia in CST technologies. ASTRI was designed to provide an institutional framework for a coordinated, national approach to CST research in Australia, and also encouraged international collaboration with the USA. As a consortium, ASTRI incorporates researchers from the following seven institutions: CSIRO, Australian National University Flinders University Queensland University of Technology University of Adelaide University of Queensland University of South Australia.[170]
Distributed Energy Integration Program	The Distributed Energy Integration Program (DEIP) is a collaboration of government agencies, market authorities, industry and consumer associations aimed at maximising the value of customers' distributed energy resources for all energy users. Led by a steering group, the forum is driven by the premise that information exchange and collaboration on DER issues will enable more efficient identification of knowledge gaps and priorities and accelerate reforms in the interest of customers.[171]
Australian Alliance for Energy Productivity (A2EP)	The Australian Alliance for Energy Productivity (A2EP) is an independent, not-for-profit coalition of research, business and government leaders. With an emphasis on collaboration, A2EP aims to advance and support the widespread introduction of world's best practices and technologies in energy productivity.

[168] Information on ARENA's funding opportunities has been sourced from ARENA's website (accessible here: https://arena.gov.au/funding/) and
[169] ACAP, http://www.acap.net.au/
[170] ASTRI, 2017, Annual Report
[171] ARENA, Distributed Energy Integration Program, https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/

Table 30: Examples of Collaboration projects[168]	
Programs Projects and Initiatives	**Description**
	ARENA recently supported A2EP with $460,500 of grant funding to investigate opportunities for using renewables in process heat manufacturing. The project aligns with ARENA's new investment priority to help industry reduce emissions by supply case studies which can be replicated more widely.[172]
Cities Power Partnership	The Cities Power Partnership (CPP) is the largest local government climate program, with 100 councils representing almost 11 million Australians. Created by the Climate Council, this free national program aims to accelerate the pollution reduction and clean energy successes of Australia's towns and cities. ARENA support will enable the Climate Council to scale up the program, expanding its membership and increasing program resources.[173]
Australian Renewable Energy Mapping Infrastructure (AREMI) Project	AREMI provide a 'one stop shop' for all open geospatial data relevant to the energy sector stakeholders from government, industry and research. ARENA support has enabled AREMI to better inform energy supply and infrastructure investment decisions; reduce the time and costs associated with early stage project planning; and create opportunities for value adding analytical work within the public and private sectors.[174]

[172] ARENA, https://www.aemo.com.au/media/Files/Other/planning/0409-0005%20pdf.pdf

[173] ARENA, https://arena.gov.au/projects/cities-power-partnership/

[174] ARENA, https://arena.gov.au/projects/aremi-project/

Appendix B Evaluation plan: evaluation questions and analytical framework

Effectiveness Evaluation

The effectiveness evaluation focused on determining whether ARENA's activities achieved their legislative objectives. For example, evidence around the extent to which the supply of renewable energy has increased, and competitiveness of renewable energy technologies has improved in Australia since ARENA commenced.

The following evaluation questions were developed by EY in consultation with ARENA, and used to evaluate ARENA's effectiveness.

Table 31: Effectiveness evaluation questions

Primary questions	Sub-questions
1. To what extent have ARENA's outcomes been achieved, or likely to be achieved?	► Has the supply of renewable energy in Australia increased, or likely to increase? ► Has the competitiveness of renewable energy technologies improved or is likely to be improved? ► Are industry and government better informed to navigate the energy transition? ► Have more solutions for delivering secure, reliable and affordable energy been found? ► Has there been better collaboration on energy innovation? ► Have ARENA's funded projects achieved their objectives, or are likely to achieve their objectives? ► Have there been any unanticipated outcomes (positive and negative)? How has ARENA role contributed to these unanticipated outcomes? Did ARENA's existence mitigate any of these unanticipated outcomes?
2. To what extent have ARENA's interventions contributed to achieving its outcomes?	► Have ARENA's interventions contributed to achieving ARENA's objectives? ► Would these (long, medium or short term) outcomes have been achieved in the absence of ARENA? ► Are there international comparisons of alternative interventions that ARENA could have adopted? Would they have been more effective at achieving the outcomes?

Analytical Framework/Approach

The following analytical approach was undertaken by EY to answer the evaluation questions outlined above:

- Undertook a review of the 17 evaluations in order to develop critical summaries were referred to throughout the evaluation. The summaries:
  - Established a consolidated list of program outcomes that ARENA has sought to achieve, as well as any unintended outcomes
  - Analysed the findings of the 17 evaluations and built an early view of the progress that had been made towards the outcomes. Key limitations of the evaluations were highlighted in order to assess the extent to which they should be relied upon.
- Undertook desktop research around the extent to which ARENA's outcomes have been achieved or are likely to be achieved. This desktop research built on evidence from credible sources and EY analysis of the findings of the 17 evaluations
- Undertook desktop research and consulted with ARENA staff to identify, develop and analyse a series of case studies to understand the extent to which outcomes can be attributed to activities undertaken by ARENA. We also undertook an assessment of International comparators of cost trends

- Identified and developed a series of case studies that were used to analyse whether and how ARENA's interventions have contributed to achieving its objectives. The case studies developed selected were reflective of the variety of activities conducted by ARENA and enabled an assessment of the counterfactual

- Undertook desktop research of other government grant programs within Australia and internationally. This enabled EY to identify and define a list of alternative interventions that could have been used to achieve ARENA's outcomes

- Undertook analysis to determine whether alternative interventions taken by other domestic and international bodies would have been more effective at achieving the outcomes. Consideration was given to the extent to which these interventions would have been suitable in an Australian context i.e. market comparability.

- In order to review whether outcomes would have been achieved in the absence of ARENA (i.e. the degree of change that may have been achieved otherwise), we:

    - Identified and developed additional case studies of other comparable markets (i.e. international jurisdictions of a similar profile to Australia) that considered differences in outcomes through various measurable factors (i.e. cost trends).

Impact Evaluation

The impact evaluation focused on determining the impact of ARENA's activities on the renewable energy industry and broader economy. This included the potential economic contribution in terms of direct and indirect economic output ($m) and jobs at a state and national level.

EY developed the following evaluation questions to evaluate ARENA's impact.

Table 32: Impact evaluation questions

Primary questions	Sub-questions
3. Did ARENA's programs produce or contribute to their intended impact?	► Did ARENA's programs produce or contribute to their intended impacts (as set out in the program logic)? ► What other broader benefits and impacts have been realised because of ARENA's programs? ► What unintended impacts (positive or negative) were produced?
4. To what extent has ARENA contributed to these impacts?	► To what extent can these impacts be attributed to activities undertaken by ARENA? ► What was the influence of other factors?

Analytical Framework/Approach

The following approach was undertaken by EY to answer the evaluation questions outlined above:

- Analyse ARENA's 17 evaluations in order to establish a consolidated list of impacts that ARENA intended to produce or contribute towards

- Undertake desktop research to assess the impact that ARENA has facilitated in the following key areas

- Building and enhancing technology pathways and fostering industry innovation (such as examining the number and types of companies funded by the Clean Energy Innovation Fund)

- Development of industry capacity and capability building (such as analysing third party recognition of the value of ARENA's knowledge sharing)

- Cost reduction and efficiency gains of relevant renewable energy supply chains (such as examining movements in ARENA's technological and commercial readiness indicators)
- Reducing electricity system costs and emissions through increased uptake of renewable energy
- Changes to market rules and frameworks (such as examining how ARENA's activities have influenced decisions by the Australian Energy Market Commission)
- Direct and indirect economic impacts such as value added, job creation and GDP growth, and other social benefits and impacts
- Conduct input/output modelling drawing on information about the size and location of funding invested through ARENA's activities. Note the input/output modelling is intended to provide information about the expected economic contribution of ARENA's programs (i.e. indirect and direct economic output and jobs)
- Input/output modelling will be conducted through REMPLAN economic analysis software. REMPLAN is essentially an input-output (IO) model of the Australian economy and regional economies. Input output models trace the revenue and expenditure flows that link industries and workers within and outside economic regions. is an optional item
- Where possible, EY will compare the results of the input/output modelling to the intended short, medium and long term impacts of ARENA's programs. If the intended impacts are unclear, conclusions will be made around the magnitude of impact based on the input/output modelling alone
- Undertake desktop research and review EY Sweeney's Stakeholder Engagement Report to identify, develop and analyse a series of case studies to understand the extent to which impacts can be attributed to activities undertaken by ARENA. ARENA staff may be consulted if necessary
    - Undertake 'case study assessments' of ARENA's key focus areas (i.e. solar PV). This work will enable EY to see how the market has changed over time and consider the influence of 'other factors' other than ARENA's activities (both positive and negative (i.e. technological advances, market forces).

Efficiency Evaluation

The process evaluation considered:

- Whether the previous evaluations have identified key findings with relation to processes in ARENA led interventions.

EY developed following evaluation questions which were used to evaluate ARENA's processes. It is important to note that these questions were selected to prevent overlap with the ANAO performance audit of grants management within ARENA occurring concurrently. The audit criteria focuses on the following key areas:

- Does grant project selection support the achievement of ARENA's objectives?
- Are grant funding agreements managed effectively?
- Does evaluation of grant programs indicate that ARENA is achieving its outcomes?[175]

Noting the ANAO work that is already underway, and to minimise potential duplication of effort between this engagement and the ANAO performance audit, the scope of this analysis has been

[175] https://www.anao.gov.au/work/performance-audit/grant-program-management-the-australian-renewable-energy-agency

limited to developing a high-level summary of key findings for processes that have developed through the previous 17 evaluations.

Table 33: Process evaluation questions	
Primary questions	**Sub-questions**
5. Have the previous evaluations identified key findings regarding ARENAs processes?	► Has ARENA provided and managed grants processes in an appropriate manner? ► Has ARENA achieved the maximum leverage possible from other funding sources (private sector, universities)? ► Was there sufficient collaboration and consultation with other organisations (i.e. CEFC, universities, State and Territory governments)? ► Have knowledge sharing processes performed as required? ► Was the choice of funding process the most appropriate for the circumstances? (e.g. procurement mechanisms; competitive round vs individual application?)

Analytical Framework/Approach

The following analytical approach was undertaken by EY to answer the evaluation questions outlined above.

Note that EY intends to take a high level approach to its analytical approach; relying heavily on the ANAO report and the outputs of the other 17 evaluations. Internal discussions with ARENA staff supplemented these resources to answer specific questions.

- Reviewed whether ARENA provided and managed grants processes in an appropriate manner, drawing on findings in the 17 evaluations, including the approval process, contract management and process for awarding funds

- Reviewed whether there was sufficient collaboration and consultation with other organisations and knowledge sharing processes were performed as required, drawing on the findings in the 17 evaluations. This work considered the collaboration and consultation undertaken during the design of programs, information and data captured by ARENA, and the timing and frequency of information and data provided to and from funding recipients

- Conducted a desktop comparison of the appropriateness of various funding mechanisms, drawing on the 17 evaluations findings.

Data Gathering Methodology

Overview

To assess the evaluation questions, EY collated and analysed quantitative and qualitative data, and developed the evidence base with regard to each question. This was achieved via a combination of desktop research, economic input/output modelling and previous stakeholder consultations.

Desktop Research

We utilised desktop research to inform the impact evaluation. Specifically, this involved undertaking the following:

- Reviewing[176] the available data and documentation of the 17 previous ARENA evaluations (Appendix B) with regards to the evaluation questions outlined in Section 2 above

[176] This review will not entail a re-interrogation of the outcomes of the evaluations themselves but will simply involve a desktop review of the results of each evaluation.

- Mapping data and information requirements and developing data and information gathering tools and templates
- Reviewing ARENA analysis and knowledge sharing reports
- Assessing ARENA strategic documents including, legislation, corporate/annual/investment plans
- Reviewing other relevant documentation (including broader energy market information) as required.

Input/output Modelling

As detailed in our response, we undertook a measurement of the broader economic contribution/impact of ARENA's services on the renewable energy sector, energy-dependent sectors and economy in terms of impact on labour markets (job creation) and industry output by utilising an economic input/output model known as REMPLAN.

REMPLAN is an economic analysis software package designed for use by economic development practitioners. REMPLAN provides detailed economic data for single or combinations of local government areas and also incorporates a dynamic economic modelling capability to allow the analysis of 'what if' scenarios. EY owns a licence to use this software.

REMPLAN is an input-output (IO) model of the Australian economy and regional economies. Input output models trace the revenue and expenditure flows that link industries and workers within and outside economic regions. For instance, an increase in output in one industry (the "direct impact") would give rise to demand for inputs from other industries (industrial effect) as well as labour (consumption effect). In turn, these support industries would demand further inputs and labour, and so on. REMPLAN's core data set is based on the latest Australian Bureau of Statistics national accounts figures of the Australian economy, coupled with the latest Census data. There is a cost involved in determining the dataset with which the analysis is undertaken, and we confirmed with ARENA the key datasets required (whether regional specific, state level or Australia-wide).

In order to undertake this analysis, we developed, alongside ARENA, an estimate of the total capital injection into the renewable energy markets, and then evaluated the REMPLAN results.

Appendix C Examples of alternative interventions

The examples below further detail both domestic and international examples of alternative interventions taken by other organisations with a similar purpose as ARENA as referred to in section 2.2.3.

Domestic Example – the Entrepreneurs Programme

Overseen by the Department of Industry, Innovation and Science, the Entrepreneurs' Programme is the Australian Government's on-going flagship initiative for business competitiveness and productivity. The programme offers support to businesses through four elements: [177]

- Accelerating Commercialisation — helps small and medium businesses, entrepreneurs and researchers to commercialise novel products, services and processes.
- Business Management — provides access to a national network of experienced business advisers and facilitators to assist you to improve your business practices, become more competitive, and take advantage of growth and collaboration opportunities in order to increase your business's capability to trade in Australian markets and/or markets in other countries.
- Incubator Support — assists new and existing incubators to improve the prospects of Australian start-ups achieving commercial success in international markets, through helping them to develop their business capabilities.
- Innovation Connections — experienced Innovation Facilitators work with your business to identify knowledge gaps that are preventing your business growth. The outcome is an Innovation Facilitation Report.[178]

The accelerating Commercialisation element is most closely aligned to that of the ARP, and the key aspects of it are detailed in the following table.

Table 34: Entrepreneurs Programme – Accelerating Commercialisation

Aspect	Characteristic
Overview	► Accelerating Commercialisation provides access to expert guidance and grants to help businesses commercialise their novel products, processes and services. ► Accelerating Commercialisation offers Commercialisation Guidance, Accelerating Commercialisation Grants and Portfolio Services to successful applicants.
Commercialisation Grants	This grant provides projects up to 50% of the expenditure to a maximum of: ► $250,000 for commercialisation offices and eligible partner entities ► $1 m for all other applicants.
Eligibility Criteria	Applicants must be one of the following to apply: ► a for-profit company registered and operating in Australia ► a commercialisation office or Eligible Partner Entities ► individuals, partnerships or trustees who agree to form a for-profit company.
Merit Criteria	All of the merit criteria, except for "Need for Funding" (Criterion 1), are equally weighted. ► Merit Criterion 1 - Need for Funding

[177] https://www.business.gov.au/assistance/entrepreneurs-programme
[178] https://www.business.gov.au/assistance/entrepreneurs-programme

Table 34: Entrepreneurs Programme – Accelerating Commercialisation	
Aspect	**Characteristic**
	► Merit Criterion 2 - Market Opportunity ► Merit Criterion 3 - Value Proposition ► Merit Criterion 4 - Execution Plan ► Merit Criterion 5 - Management Capability ► Merit Criterion 6 - National Benefits
Assessment Process	Applicants will go through a competitive merit application process. Applications for Accelerating Commercialisation Grants that meet eligibility will proceed to a merit assessment. AusIndustry will prepare a report on all eligible applications prior to merit assessment which includes a due diligence report, completed by a Commercialisation Adviser. This report examines the claims you have made against the merit criteria. The Programme Delegate will make the final decision.

Source: https://www.business.gov.au/Assistance/Entrepreneurs-Programme/Accelerating-Commercialisation

Like the ARP applicants go through a two-stage process, with feedback provided on an initial expression of interest by an AusIndustry Customer Service Manager. This advice is intended to guide applicants in determining whether to proceed with the application. If an applicant does proceed, and their application is successful, a funding agreement is provided outlining the payment milestones and requirements to meet them.

Domestic Example – the Innovation and Productivity Program Stream

Overseen by Regional Development Victoria, the Innovation and Productivity Stream[179] is intended to support activities linked to business innovation or technological commercialisation and provide support for collaboration between industry clusters and research centres that strengthen competitiveness. It is a stream within the larger Regional Jobs Fund which aims to facilitate job creation and retain existing jobs. It is targeted at assisting regional businesses to grow their workforce, expand markets and create jobs of the future.

The objectives of the innovation stream will focus on areas of regional competitive advantage and give preference to those proposals which seek to create jobs in emerging sectors including but not limited to:

- Food and fibre
- Professional services
- New energy technology
- Medical technology, life sciences and healthcare
- Transport, defence and construction technology
- International education
- The visitor economy.[180]

As a component of the Regional Job Funds, the components of the innovation stream fall under the guidelines of the entire program, an overview which is presented below.

[179] The stream is part of the Victorian Government Regional Jobs fund
[180] http://www.rdv.vic.gov.au/grants-and-programs/regional-jobs-fund/innovation-and-productivity

Table 35: Innovation and Productivity Program Stream	
Aspect	**Characteristic**
Overview	This program stream aims to improve the productivity of regional industries and businesses to ensure the long-term sustainability of employment and business growth in regional locations.
Funding Support	Applicants are expected to make a financial contribution or source third-party funding. Projects should **maximise their funding support from a range of sources including commonwealth/ local government, community, private sector and regional organisations.** **Priority may be given to projects that are considered investment ready**
Eligibility Criteria	Applications will be considered from: ► Private sector businesses and agencies ► Business and industry groups including: ► Chambers of commerce and business associations ► Industry peak bodies ► Business and industry clusters and networks ► Local government authorities ► Government agencies ► Not-for-profit organisations and community groups that: ► Are an incorporated body, cooperative or association ► Have an Australian Business Number (ABN) or can provide written advice from the Australian Tax Office that no withholding tax is required from the grant payment ► Higher education and private training institutions ► Regional organisations e.g. regional strategic planning alliances.
Merit Criteria	The primary aim is to facilitate job creation and therefore assessment criteria are weighted towards quantifiable economic development benefits. In preparing the application, applicants will be asked to provide relevant supporting documents to demonstrate the project's ability to address each of the following criteria: ► Direct economic development benefits ► Additional economic development benefits ► Social and environmental benefits ► Alignment with state and regional priorities and demonstrated project need ► Demonstrated project feasibility and delivery ► Financial viability ► Maximising value to the state.
Assessment Process	Applications will undergo a two-stage assessment process. The first stage involves determining the eligibility of the proposed project by assessing the project's ability to meet the core RJF and relevant program stream criteria. The first stage will also consider key risks and issues associated with the project. All applications within the RJF will be forwarded to the Back to Work Investment Committee of the Department of Economic Development Jobs, Transport and Resources (DEDJTR) for assessment prior to consideration by relevant Ministers including the Minister for Regional Development.

Source: Regional Jobs Fund Application Guidelines

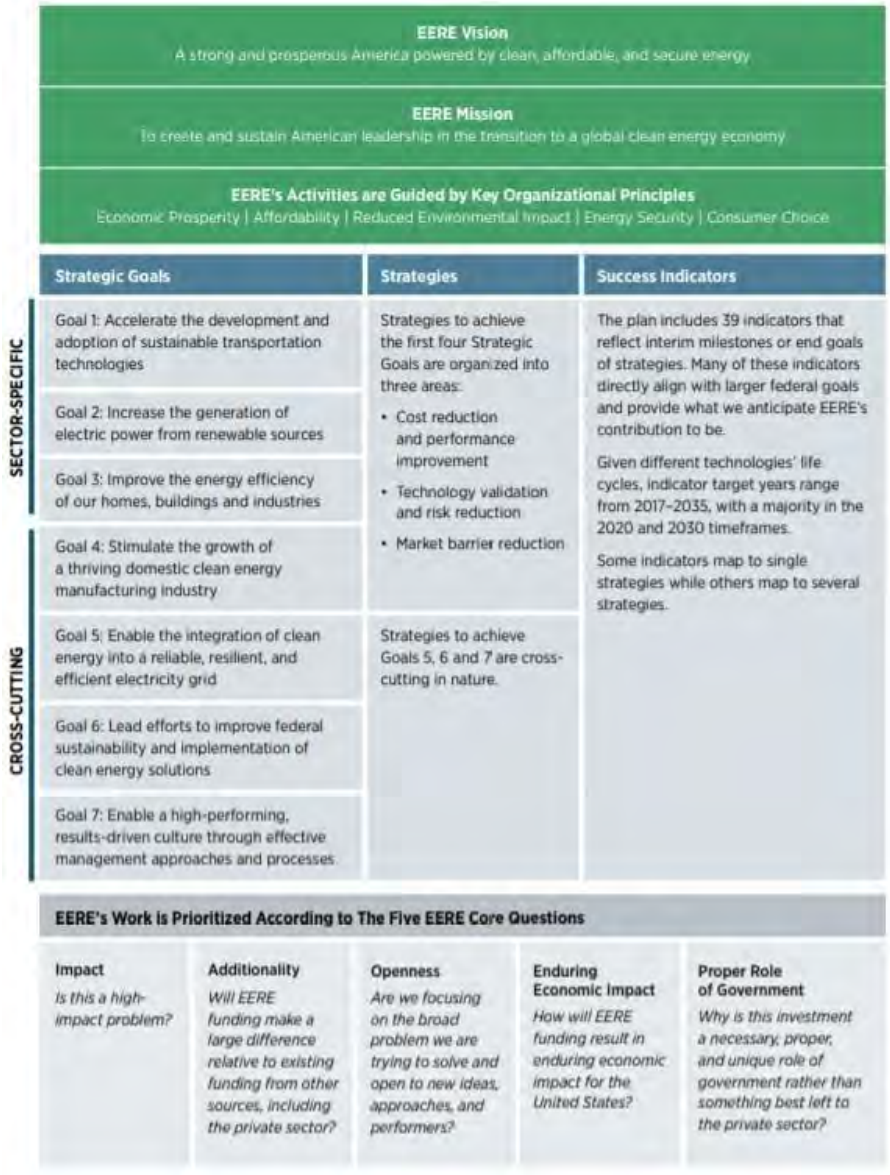
Applicants are encouraged to reach out to Regional Development Victoria officers whose aim is to work with the applicant to determine the project's potential suitability, before an application form is completed, in broadly the same approach undertaken by the ARP and other ARENA grants funding mechanisms.

International Example – The Office of Energy Efficiency and Renewable Energy United States

Established in 1973 crisis and ongoing to present day, was created in response the energy the Office of Energy Efficiency and Renewable Energy (EERE) is an office within the United States Department of Energy whose mission is to create and sustain American leadership in the transition to a global clean energy economy. Its vision is a strong and prosperous America powered by clean, affordable, and secure energy and remains active to date.[181]

Like ARENA, the EERE has a focus on improving competitiveness and supply of renewable energy through achieving the following overarching objective – to create and sustain American leadership in the transition to a global clean energy economy.[182]

Figure 34: EERE Strategic Plan



Source: United States Department of Energy Office of Energy Efficiency and Renewable Energy 2016–2020 Strategic Plan and Implementing Framework

[181] https://www.energy.gov/eere/about-office-energy-efficiency-and-renewable-energy
[182] *United States Department of Energy Office of Energy Efficiency and Renewable Energy 2016–2020 Strategic Plan and Implementing Framework*

EERE is divided into three specific technological sectors, transportation, renewable energy and energy efficiency sectors. Like ARENA, ERRE focuses on the initial stages of the commercialisation pathway. ERRE's investment approach provides supports for projects in the following key phases:

- **Phase 1: Applied Research** - In this phase, EERE invests heavily through the national laboratories and universities, as well as industry. Detailed analysis is performed to identify if a technology may be able to achieve market competitiveness and fundamentally lower costs to society.

- **Phase 2: Development and Demonstration** - EERE's investments during this phase focus on testing and validating performance, reliability, and costs through full-scale technology demonstration and analyses of the technology's market competitiveness. EERE may also fund small or limited scale demonstrations, with technologies integrated into full systems, to catalyse and leverage additional private sector investment. Aided by these EERE investments, the barriers to private investment are decreased, opening up development of business models and supply chains and further reducing cost.

- **Phase 3: Focus on Market Barriers** – EERE focuses on activities that overcome barriers that cost-effective technologies may face to high volume adoption due to "Soft" or "Perceived Costs" by the market.[183]

International Example – Sustainable Development Technology Canada

Sustainable Development Technology Canada (SDTC) was established by the Government of Canada to support Canadian businesses to develop and demonstrate new environmental technologies that address climate change, clean air, clean water and clean soil. SDTC's mission is to be a catalyst and convenor for Canada's cleantech ecosystem by helping Canadian entrepreneurs accelerate the development and deployment of globally competitive clean technology solutions and remains active to date. To realise this mission, SDTC seeks to:

- Fund the development and demonstration of new sustainable development technologies related to climate change, clean air, clean water and clean soil.

- Foster and encourage innovative collaboration and partnering amongst the private sector, academia, not-for-profit and other like-mandated organisations to develop and demonstrate environmental technologies with respect to climate change, clean air, clean water and clean soil.

- Promote timely diffusion of new sustainable development technologies across key economic sectors in Canada.[184]

There is a close alignment between these outcomes, and those established by ARENA to improve competitiveness through funding projects, promoting and disseminating knowledge and foster and facilitate collaborative partnerships. The requirements to access this funding is detailed in the table below.

Table 36: Sustainable Development Technology Canada	
Aspect	Characteristic
Overview	SDTC's mandate is to fund projects that support Canadian small- and medium-sized enterprises (SMEs) advancing innovative technologies that are pre-commercial and have the potential to demonstrate significant and quantifiable environmental and economic benefits in one or more of the following areas: climate change, clean air, clean water and clean soil.

[183] United States Department of Energy Office of Energy Efficiency and Renewable Energy 2016–2020 Strategic Plan and Implementing Framework
[184] https://www.sdtc.ca/en/about/about-us/

Table 36: Sustainable Development Technology Canada	
Funding Support	The funding is a non-repayable contribution. SDTC typically provides: ► Funding of up to 33% of eligible projects costs (up to 40%). ► An average contribution of $2 m to $4 m, with funds disbursed over the life of the project up to a five-year period. To be funded by SDTC, a project: ► Must obtain a private-sector contribution of at least 25% of eligible project costs. ► Cannot include funding from other government entities that in its totality is greater than 75% of eligible project costs. ► Must incur at least 50% of its eligible project costs within Canada.
Eligibility Criteria	To be eligible for funding, applicants must: ► Be a Canadian company developing a new and novel technology with significant and quantifiable environmental benefits that will provide a significant retained Canadian benefit following execution of the project. ► Have a defined project and be looking to demonstrate a pre-commercial technology. ► Have a strong end-user, value proposition and be able to validate the market and commercialization potential of the technology. Form a consortium that includes at least one other partner (recommended that applicants seek partners who are either end users or able to validate the need and market for the technology).
Merit Criteria	The following criteria are used to evaluate projects: ► Environmental benefits ► Strength of technology innovation ► Technology Readiness Level (TRL) ► Management capability ► Business plan and path to market ► Financial strength.
Assessment Process	The assessment process commences with an applicant reviewing SDTC's eligibility and evaluation criteria prior to applying. Once an application is submitted a team of internal SDTC experts will review the application to determine eligibility. If an initial review shows that the project may meet SDTC criteria, an applicant may be invited to make a presentation and to submit a detailed proposal via our online portal. The SDTC Project Review Committee will then review your project and all recommended projects are presented to the SDTC Board for approval.

Source: https://www.sdtc.ca/en/apply/faqs/

Appendix D ARENA Technology Readiness Levels

There are various TRL rating scales that may be applicable to various technologies. For the purposes of its programs, ARENA uses the following scale for renewable energy technologies.

Figure 35: Technological Readiness Levels[185]

Level	Summary
1	**Basic principles observed and reported:** Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
2	**Technology concept and/or application formulated:** Applied research. Theory and scientific principles are focused on a specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
3	**Analytical and experimental critical function and/or characteristic proof of concept:** Proof of concept validation. Active research and development is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.
4	**Component/subsystem validation in laboratory environment:** Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
5	**System/subsystem/component validation in relevant environment:** Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
6	**System/subsystem model or prototyping demonstration in a relevant end-to-end environment**: Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
7	**System prototyping demonstration in an operational environment:** System prototyping demonstration in operational environment. System is at or near scale of the operational system with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
8	**Actual system completed and qualified through test and demonstration in an operational environment:** End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
9	**Actual system proven through successful operations:** Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

ARENA has also developed a Commercial Readiness Index (CRI) as a tool to demonstrate development along the technology development chain once a technology is at the stage where research proves that it is feasible in the field (TRL2). The relationship between TRLs and CRI is outlined in Figure 36 and Figure 37.[186]

[185] ARENA, 2014, 'Technological Readiness Levels for Renewable Energy Sectors'
[186] ARENA, 2014, 'Commercial Readiness Index for Renewable Energy Sectors'

Figure 36: TRL and CRI

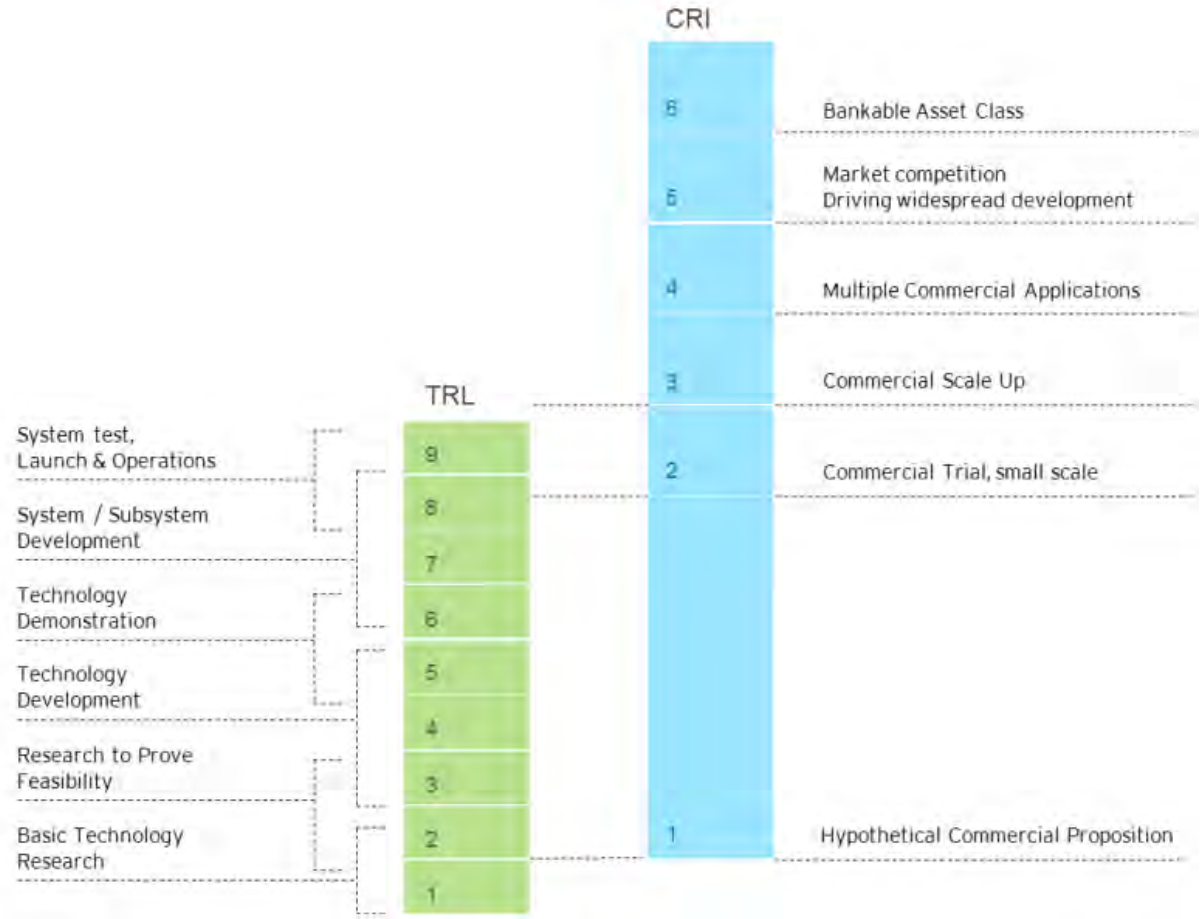
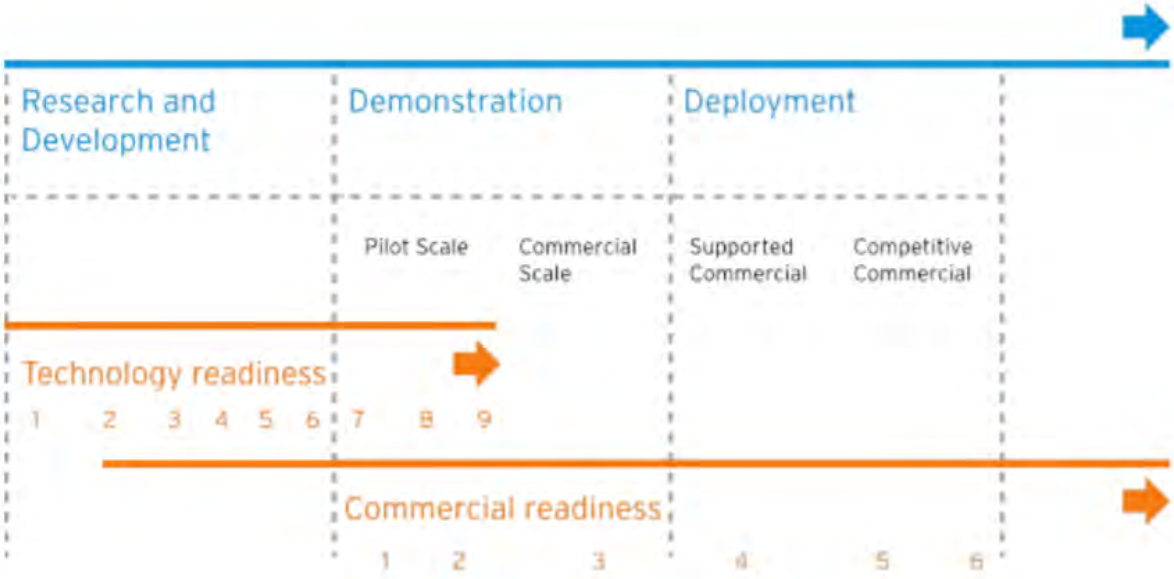


Figure 37: TRL and CRI mapped to the technology development chain



Appendix E REMPLAN

The economic analysis has been undertaken using REMPLAN software that estimates direct and indirect impacts of infrastructure developments or policy changes. REMPLAN is an economic analysis software package designed for use by economic development practitioners. REMPLAN provides detailed economic data for single or combinations of local government areas and also incorporates a dynamic economic modelling capability to allow the analysis of 'what if' scenarios. REMPLAN is an input-output model of the Australian economy and regional economies. Input-output models trace the revenue and expenditure flows that link industries and workers within and outside economic regions.

REMPLAN's core data set is based on the latest Australian Bureau of Statistics (ABS) national accounts figures of the Australian economy, coupled with the latest Census data. REMPLAN's key advantage over other input-output models or "off-the shelf multipliers" is that it can be regional specific. For instance, in the past, economic practitioners have used national multipliers produced by the ABS. It should be noted that the ABS has not published national input-output multipliers since 1998-99 and does not plan to compile and reissue this table because of concerns over the abuse of them in economic assessments.

The region chosen to analyse were Central and North Queensland and Central West New South Wales. To assess contribution to local economies, two "sub-regions" were chosen and its data sets created with REMPLAN software. For these smaller regions, multipliers tend to be smaller than national multipliers since their inter–industry linkages are normally relatively shallow. Inter–industry linkages tend to be shallow in small regions since they usually don't have the capacity to produce the wide range of goods used for inputs and consumption, instead importing a large proportion of these goods from other regions. The REMPLAN model accounts for 'leakage' of direct expenditure from the economy in its multipliers. However, it may still be possible for the economic contribution presented to be realised in places other than the regions identified above.

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