Identifying risks, costs, and lessons from ARENA-funded off-grid renewable energy projects in regional Australia

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Abstract
The Australian Renewable Energy Agency (ARENA) has provided grant funding to 18 off-grid and fringe-of-grid renewable energy projects under the Regional Australia’s Renewables (RAR) program since 2013. This program was designed to address real and perceived risks associated with early stage, precommercial renewable energy development and provide a foundation of demonstration projects to enable the development of a competitive renewable energy sector. These projects range from low to high renewable energy fractions at megawatt scale in remote regions of Australia and encompass a variety of sectors, such as mining, tourism, and remote communities. All projects use photovoltaic as a key technology, often supplemented by additional technologies. The experience from these projects shows that land acquisition, technical integration, stakeholder engagement, and access to finance are among the main reasons for project delivery delays. A qualitative assessment for the remoteness premium is given, based on a comparison of ARENA-funded on-grid and off-grid projects. This indicates that the structural barriers of governance, supply chains, and finance need to be tackled further to lower soft costs. One of the key enablers for future lower renewable energy costs is ARENA’s Knowledge Sharing model, through which the funding agency is recompensed by data and information that is provided to the market and increases the impact of ARENA funding.

KEYWORDS
knowledge sharing, off-grid, remoteness premium, risks, structural barriers

1 INTRODUCTION

Globally, estimates for the number of people with limited or no access to reliable (on-grid) electricity are more than 1.2 billion.1,2 Predominantly, these people live in high-insolation areas, such as sub-Saharan Africa and India.2 In this context, the potential exists for a rapid cost-effective electrification with low(er) carbon dioxide emissions using photovoltaic (PV) power as the key low-emission generating technology.

The sustained cost declines observed worldwide for grid-connected PV and reported on using learning curves,3-6 together with high fossil fuel-powered generation costs in remote and regional Australia, have resulted in revived interest in the use of renewable technologies for electric power supply in these areas: Approximately 2% of Australia’s population lives in remote and regional Australia as classified by the Australian Statistical Geography Standard,7 yet are in locations with some of the highest renewable energy resource potential—in particular solar power.

The people and businesses in remote and regional Australia account for circa 6% of the country’s annual electricity use, with a 5:1 ratio of energy use of mining to remote communities.8 Diesel and natural gas-powered generators dominate the Australian off-grid electric power supply, with limited renewable power capacity, particularly within larger mines and communities. The gap between what is then identified on paper as potential for PV applications and what is installed in practice remains large. It was within this context of rapidly improving economics of solar and wind, and the expectation that these technologies were now cost competitive in many parts of regional Australia, that the Australian Renewable Energy Agency (ARENA) launched the Regional Australia’s Renewables (RAR) program in 2013.

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The RAR program was developed to stimulate renewable energy uptake in remote areas with 2 streams: one focused on industry such as mines and tourism facilities and another focused on remote communities and islands. The industry-focused stream included funding for fringe-of-grid projects, which are connected to a centralised grid, but are located in weak areas of the network, such as at the end of very long transmission lines, where diesel backup is often required to maintain power supply. Grant funding under the RAR program was designed to cover a part of the total project cost (the remainder being funded by equity and/or debt by the proponent) and was aimed at bridging the (perceived or apparent) risk gap and/or improve the financial viability of the project. A critical difference of the RAR program to similar funding in other countries is ARENA’s Knowledge Sharing requirement, which obliges project proponents to provide ARENA with information. This includes:

- Standard project information (system size, technologies used, application purpose, expected renewable energy penetration and/or fossil fuel displacement, ...).
- Financial models, including the impact of the ARENA grant on project finances.
- Operational data post completion for a period of up to 3 years.
- Lessons learnt (Knowledge Sharing) reports for external distribution to the market.

Through this, ARENA receives a wealth of objective and verified information on projects that is otherwise difficult to obtain, which can help to answer key questions relating to the uptake of renewables in the off-grid and fringe-of-grid space: “What is the cost premium for remote locations (the ‘remoteness premium’) when compared to on-grid projects?”; “What is the risk appetite by key stakeholders (users and financiers) for such projects?”; and “How do first-mover costs and integration challenges evolve over time?”. Furthermore, the data provided allows ARENA to benchmark future investments, to ensure that its funding continues to stimulate innovation throughout the value chain. The intended goal of ARENA’s Knowledge Sharing on RAR-funded projects is to accelerate the impact of its funding and increase awareness in stakeholders, so that future costs can be reduced over time and that risks can be identified, quantified, and, where possible, managed or reduced.

The terms renewable energy fraction (REFperiod) and renewable power fraction (RPF) are used in this article instead of renewable penetration, as they allow better clarity for communication regarding how renewable power and energy serve the load and how both the generation and the load must be considered when designing, or discussing, power systems where a renewable generator is included. Ambiguity around the term renewable penetration is removed by describing characteristics using both the REF and the RPF metrics.

\[
\text{REF}_{\text{period}} = \frac{E_{\text{Ren}}}{E_{\text{load}}} \times 100\% \quad (1)
\]

\[
\text{RPF} = \frac{P_{\text{Ren}}}{P_{\text{load}}} \times 100\% \quad (2)
\]

In both Equations 1 and 2, the subscript Ren is for renewable energy or power, respectively, where the load is the consumption of electricity by the end-user. Conversely, the FPF and FEF can be defined as the fossil-powered equivalents of the RPF and REF, respectively. The period for the REF is often clear from the context, although misunderstandings may arise by conflating daily with annual REF values, and not considering either the load or the generation’s seasonality—a communication and lexicon issue that has appeared repeatedly with the projects in the RAR portfolio.

This article discusses the RAR program as a potential template for other funding bodies such as governments, multilateral development banks, or nongovernmental organisations (NGOs). Some of the key risks encountered throughout the RAR program and its funded projects will be discussed, together with lessons learnt by ARENA, the funding recipients, and stakeholders. The costs and project delivery models of the RAR-funded projects are used to illustrate the structural barriers encountered in supplying renewable power in remote locations, such as remote and regional Australia. Lastly, the RAR program serves as a “sandbox” in which components of the structural barriers can be tackled or elucidated, to achieve high renewable energy fractions on the grid (isolated or not), of which certain aspects will increasingly manifest themselves in the coming years.

2 | REGIONAL AUSTRALIA’S RENEWABLES PROGRAM OVERVIEW

2.1 | Historical context in Australia

ARENA became active on 1 July 2012 with the mandate to increase the uptake of renewable energy in Australia, systematically lower its costs, and support and stimulate innovation throughout the value chain, from early research to initial commercial deployment.

From the outset, the off-grid sector represented an opportunity to rapidly progress the commercial competitiveness of renewable energy in a niche market. The 2 years leading up to the launch of the RAR program in 2013 saw the price of crude oil climb to over US$100/barrel and hold steady. In 2012/2013, remote and regional areas of Australia had (and continue to have) some of the highest marginal costs of generation anywhere in Australia, because of reliance on diesel-powered and gas-powered generation. These combined cost fundamentals underpinned the assumption that renewable energy would likely be competitive with diesel on a pure cost basis, once derisked via demonstration projects.

Photovoltaic module costs in Australia dropped up to 80% between 2008 and 2012. While on-grid residential PV boomed in Australia in response to favourable government support schemes, uptake of PV in the off-grid market was sluggish, suggesting that PV costs were not the only driver for off-grid deployment. Figure 1 shows the magnitude of the PV capacity additions supported by ARENA under the RAR program compared to previous years and suggests that while small compared to the on-grid market (by the end of 2016, more than 5 GW of on-grid residential PV had been installed in Australia), the off-grid renewable power sector is emerging after a long period of limited growth.

The growing need for off-grid mines, communities, and tourist facilities to reduce their cost of power supply offered the promise that renewable energy solutions, once proven, would have room to replicate. ARENA estimates in 2012 placed the share of off-grid power demand at 6% to 10% of Australia’s total power demand, with off-grid power
and security. By building a suite of projects across community and financial support, expected savings could be realised without sacrificing power quality, reliability, or security. To provide a basic service to remote areas at a cost comparable to urban customers, state and federal governments provide subsidies for power supply to utilities and independent power producers. The expectation of continued fuel subsidies further reinforced the idea for government entities that finding renewable powered solutions for remote communities would deliver long-term benefits.

The vastness of Australia is well known. Supply chains are drawn out over long distances and difficult terrain, complicating delivery of fuel and spares, and access to technical expertise. Moreover, large swathes of the country are regularly subject to the vagaries of the harsh weather conditions that can strongly constrain access, and impose severe strain on infrastructure. Australia has a country-specific definition for remoteness, which is based on distance from roads and population centres. This Remoteness Area classification is defined in, based on work by. The off-grid projects in ARENA’s RAR portfolio are in either Remote or Very Remote Australia (the highest on the remoteness scale). For context, reaching locations in Very Remote Australia often entails costly boat or air transport or land travel from major Australian cities exceeding 500 km and up to 2000 km.

Attempting to answering a shared need of mines and remote communities for reliable and less volatile costs for power supply, it was expected that a self-sustaining remote power supply market could develop, if renewable energy projects funded by ARENA’s RAR program could shine a light on and tackle the structural barriers of governance, supply chains, and access to finance, through pilot projects serving mining and off-grid communities.

2.2 Regional Australia’s Renewables program design

The fundamental premise of the design of the RAR program, and off-grid investment for ARENA, was that project economics, subsidy reduction potential, and strong forecast power demand growth constituted a powerful “cost pull,” but that an additional “technology push” was needed to demonstrate to end-users that those theoretical cost savings could be realised without sacrificing power quality, reliability, and security. By building a suite of projects across community and industrial energy use, ARENA could retire risk perceptions surrounding the technology and provide evidence of cost savings. The more forgiving cost environment of off-grid power supply meant that renewable energy (particularly solar PV) could be built and derisked, at a time when utility-scale PV was struggling to gain momentum on the Australian grid. Furthermore, by stimulating high renewable energy fraction projects on isolated grids, it was (and is) possible to test renewable energy integration solutions in the off-grid “sandbox,” with the findings then available for translation back on the main grid when needed.

The RAR program was designed to provide a total funding of up to AU$400 million (US$384M) for both off-grid projects and fringe-of-grid projects, with 2 separate funding streams focused on renewable energy supply for remote and regional communities (Community and Regional Renewable Energy) and an industry funding stream, aimed at mining and tourism (RAR-Industry). The size of the RAR program, funding to ARENA’s total funding for projects at the time (AU$3200M; US$3072M) was designed to approximate the ratio of the remote and off-grid power demand to the total power demand in Australia.

To address the structural barriers to the commercial competitiveness of off-grid and fringe-of-grid renewable energy, the RAR program sought to tackle first mover costs and risks, and perceptions of the high cost and unreliability of renewable energy by funding a portfolio of demonstration projects. The program aimed to build 150 MW of total renewable energy capacity, including at least 2 utility-scale plants of ≥10 MW each, and to ensure that projects would be utilised for at least 5 years following commissioning. Sharing of project data and lessons learnt was added to the program, and included in the contractual obligations for successful applicants. By funding a suite of demonstration projects, ARENA also hoped to address strategic “roadblocks,” such as risks associated with the integration and management of renewable energy in a hybrid system, and increase skills and capacity associated with renewable hybrid systems in remote areas.

Australian Renewable Energy Agency’s funding for the RAR program followed a stage-gate process that is still ongoing:

1. Expression of interest: Applicants were invited to submit a preliminary project proposal.
2. Full application: Following assessment of expression of interests, short-listed projects submitted a full project proposal to ARENA. This entailed a lengthier and more in-depth assessment process that involved external expert due diligence studies.
3. Funding agreement: Once project proposals were agreed to, ARENA and the project proponents entered into funding negotiations, involving settling contractual obligations surrounding the funding amount to be paid to the proponent, project outcomes, and Knowledge Sharing.

4. Funds are disbursed to proponents upon successful completion of the agreed-upon milestones, subject to technical, legal, and financial due diligence.

To better enable communication among stakeholders and to tackle the lack of data capture standardisation, ARENA’s RAR Data Specification was developed. While the projects in the RAR portfolio will provide performance data and information to ARENA for subsequent distribution to the market, many more project configurations exist which are not yet captured in the RAR portfolio, and for which additional data will be beneficial.

3 | REGIONAL AUSTRALIA’S RENEWABLES PROGRAM: APPLICATIONS, APPROVALS, AND RESULTS

Australian Renewable Energy Agency received 72 applications for RAR funding in the initial application period (June–December 2013), indicating a high level of interest from off-grid and remote area consumers of electricity, and project developers. Of the 72 applications, 18 projects were approved for funding. Four of the approved projects (22%) are no longer active, with the funding made available by ARENA, but not disbursed. Figure 2 shows where the RAR-funded projects are located around Australia.

A description of the portfolio of active projects and the technologies used is given in Table 1. PV is the shared generating technology within the portfolio, although it generally needs to be supplemented by other technologies such as wind power or battery storage to achieve the design high annual Renewable Energy Fractions.

3.1 | Costs and timing of Regional Australia’s Renewables projects

To date, most active projects have been within 10% of their agreed-upon cost budgets. Figure 3 illustrates the scaled project costs, the design annual renewable energy fraction, and the number of renewable technologies used to reach the design annual REF values. The scaled project cost is determined as

\[
P_c = \frac{\text{Total project cost (AU$)}}{\text{Total RE net generating capacity (Wdc)}}
\]

where net renewable capacity is the DC (or DC equivalent) name-plate net generating (ie, solar and wind) capacity, and excludes storage.

As can be observed from Figure 3, costs for projects vary strongly, with projects that aim for higher annual REF values generally showing higher (net renewable generating) costs. Similarly, more remote projects (particularly from a supply chain perspective) also are expected to have higher (transport) costs and a desire for higher REF values. Moreover, the associated technical complexity with integrating multiple technologies to reach high REF values (in general, more technologies are needed to reach higher annual REF values) also results in higher costs. Further cost differences relate to the timing of the projects: Later projects were able to capture some benefits from lower global PV, wind, and battery storage CAPEX costs.

Given the above, a more detailed look at the projects can give an indication as to what constitutes a "remote premium."

3.2 | Remoteness premium

With the data from the RAR projects’ financial models at the time of funding by ARENA available, the PV-specific costs were extracted and compared to the ARENA-funded Large-Scale Solar (LSS) projects, which were granted funding in August 2016. The LSS projects are utility-scale, PV-only projects connected to either the National Electricity Market or the South-Western Interconnected System, and are in

![FIGURE 2 Locations of the ARENA-funded RAR projects around Australia. According to, much of the northern territory is classified as very remote Australia, with the locations of the SETuP-supported communities displayed in a different colour for easier identification [Colour figure can be viewed at wileyonlinelibrary.com]](image-url)
significantly less remote areas of Australia than the RAR-funded projects—more details about the LSS program can be found in. 20

Figure 4 shows the cost comparison of the RAR versus the LSS projects (AC system ratings used for both), which bring to light a few cost implications.

The effects of remoteness (transport costs, supply chain issues) are evident, with the highest PV-specific costs for the most remote locations. System-scale impacts project costs to a similar extent, and this effect may reinforce or counteract the remoteness of the site. The projects with a later investment date were able to capture cost declines and industry learning, which lead to lower costs. The specifics, however, vary for each project and location.

For example, Degrussa, Coober Pedy, and Yulara have similar PV-specific ($/W_{ac}$) costs, yet have widely differing characteristics and system sizes. Degrussa is a remote mine with a single-axis tracking 10.56 MWp system, while Yulara at 1.83 MWp has multiple fixed-orientation arrays distributed on ground and rooftop, and Coober Pedy has 1 large 1.34 MWp fixed-orientation array, with the site's location having high integration costs. In the case of the islands in the RAR portfolio (Rottnest, Flinders, and Lord Howe), the submegawatt size

| TABLE 1 Portfolio of ARENA RAR-supported projects and technologies used |
|--------------------------|-----------------|-----------------|--------------------------|
| Project                  | Application     | PV (MWp) | Wind (MW) | Battery (MW/MWh) | Comment/Additional Renewable Technologies Used |
| Barcaldine               | Fringe of grid  | 25       | –         | –              | Stimulating utility-scale PV in remote region |
| Coober Pedy              | Off-grid mining | 1.34     | 4.1       | 1/0.5          | 2 × 0.85 MVA flywheel on fast-start diesel, 3 MW dynamic resistor for stability, integrating control system |
| DeGrussa                 | Off-grid mine   | 10.56    | –         | 3.2/1.81       | PV 1-axis tracking, battery-aided high REF, battery peak output 6 MW |
| Degrussa                 | Off-grid community | 0.264 + 1 | – | – | Increase of renewable energy fraction by expanding PV on grid |
| Flinders Island          | Off-grid community | 0.25 | 0.9 | 0.75/0.3 | 0.85 MVA flywheel on fast-start diesel and 1.5 MW dynamic resistor for stability, integrating control system |
| Karratha airport         | Fringe of grid  | 1.02     | –         | 0.47/0.32      | Solar PV, batteries, and cloud predictive technology for forecasting and ramp rate control, as per network operator requirements |
| Lakeland                 | Fringe of grid  | 13       | –         | 1.4/5.3        | Battery for grid support and/or stand-alone operation (islanding distribution line from grid) |
| Lord Howe Island         | Off-grid community | 0.45 | 0.55a | 0.4/0.4 | Physical space limited for renewable energy technologies (small island, conservation, and tourism measures) |
| In preparation           | Off-grid community | 0.51 | – | 3.75/1.5 | System upgrades to achieve high REF |
| Normanton                | Fringe of grid  | 5.17     | –         | –              | Demonstrator project: PV to aid network stability at the end of a very long (1000 km+) transmission line. |
| NT SETuP                 | Off-grid community | 10   | –         | 0.8/1.6        | 30 communities, integrating PV with existing diesel. 1 site: high REF system, 1 MWp PV, and battery (diesel off possible), business transformation |
| Rottnest Island          | Off-grid community | 0.63 | 0.6 | – | Demand management, efficiency measures, integrating control system for high renewable energy fraction |
| Weipa                    | Off-grid mine   | 1.71     | –         | –              | Demonstrator project: solar PV used as diesel offset for mine |
| Yulara                   | Off-grid community | 1.83 | – | – | Distributed solar PV to mitigate variability in isolated grid¹ |

*Lord Howe Island’s application for wind turbine approvals has recently been denied, and the project proponents and ARENA are evaluating which changes are necessary for the project to continue.*
of the arrays and the remoteness work hand in hand to give PV-specific project costs that were significantly higher than Degrussa, Yulara, or Coober Pedy.

Similarly, the fringe-of-grid systems of Normanton, Barcaldine, and Lakeland have the benefit of scale over Karratha and are less remote than the remainder of the RAR-funded off-grid projects, with commensurate lower costs. Lakeland has the lowest costs of the portfolio and the fringe-of-grid projects, because of its less remote location, and having the project refined several times prior to the final investment decision, thus enabling the project to capture improvements in the PV supply chain. Similar cost improvements are expected for the LSS projects for the final steps prior to construction: The values in Figure 4 were the basis for funding by ARENA to the projects, and for the projects to proceed to securing financing, and signing engineering, procurement, and construction contracts. Nevertheless, contrasting the LSS projects to the RAR project portfolio, a scale and remoteness premium is clear. Given the many variables involved for the different projects, further study will be required to fully quantify the remoteness premium.

On the timing side, projects have—with few exceptions—not been able to complete within the planned, or expected, timeframe. The project duration is calculated from full application to commercial operation. For the projects yet to be completed, the expected completion date is calculated assuming that the project delivery plan is executed as planned with no knock-on delays. Figure 5 illustrates this and shows that when compared to the initially proposed timelines, all projects are on average 10 to 12 months late, and the shortest project completion is 20 months for the PV-only projects. On average, projects with more technologies to integrate take longer to complete.

However, the increased complexity of projects, evidenced by the number of technologies involved, has not led to the longest delays experienced in the portfolio, which are found among the PV-only projects. The main causes for delays in all projects were in obtaining financing, land use agreements, legal approvals, and, to a minor extent, project execution delays.

These longer-than-expected project delivery schedules have a variety of causes, not all of which are a priori controllable or knowable, yet there are lessons learnt, and some risks bear further emphasis. Land acquisition (or legal use thereof) for the project is vital, yet most, if not all, of the projects in the RAR portfolio did not have the luxury of first selecting and acquiring suitable land to then develop a project. The physical space around a remote location that is technically and economically feasible for renewable capacity additions to the existing electricity infrastructure is limited. This increases negotiation risks, as few alternative locations or counterparties exist, and many projects suffered significant delays.

The importance of stakeholder engagement and consultation is also higher in isolated grids, as there are limited to no opportunities to find more amenable counterparties if the project on the selected location is to proceed. In several projects, the need to educate co-decision makers, including local power station engineers who have had to change their operational paradigm, to board-level executives who had limited exposure to, and understanding of, the technologies proposed, caused delays beyond what had been anticipated.

While efforts such as those used at Yulara (geographically distributing PV around a location to reduce variability on the grid) can be used to allow higher RPF and REF values on the grid with the same amount of spinning reserves, the nature of stand-alone grids is that they often are concentrating in operation: Wind turbines and PV arrays can be dispersed.
only so far from the local load centre while remaining within economical limits, which thus lead to higher enabling technology needs and costs.

With extended project development timeframes, personnel change becomes a larger risk for all stakeholders. Similarly, significant electricity infrastructure upgrades tend to be few and far between, which carries the risk that the institutional memory of the local stakeholders may lapse. The experience of the RAR portfolio shows that the significant changes to the electricity infrastructure that these projects entail can and do take longer than the continued presence of decision-makers who changed throughout the course of the projects, causing a loss of the context of the project, the decision-making process, and the incentives that drove these. This is compounded by the general lack of experience with renewables integration by local decision-makers, and the large variety in relevant regulations which often hamper the approvals and project delivery process. In some cases, project developers in the RAR portfolio needed to restate the business case for a project to a new set of decision-makers, after having already committed to it. While this type of risk is common among many infrastructure projects, the long project lead times and relative unfamiliarity of stakeholders and decision-makers with renewable energy means that this risk is magnified for off-grid renewables.

The prolonged negotiations involved in the projects have also resulted in the risk of more stakeholders being involved, each with its own agenda and incentives. In one case, a project started with 4 main stakeholders. One of these, the state-owned electricity utility, was unbundled from a vertically integrated power company to 3 separate entities covering generation, distribution, and retail. This brought a new set of split incentives to the project. Where previously the loss of fossil fuel generation revenue because of the addition of end-user-owned, distributed PV could be compensated for internally by lower utility operations and maintenance costs, unbundling of the utility unrationed the potential for internal transfer of cost savings. Including the financing aspects of the project, several more stakeholders were added between awarding the project funding by ARENA under the RAR program and project completion, bringing about negotiations which ballooned from 4 to more than 10 stakeholders at the same time, which pushed back the financial close of the project.

The need to adapt the project to local circumstances, such as for example educating the renewable energy project developers in mining safety regulations (which are additional to standard country-wide regulations), as well as educating the end-user about the technical capabilities of the renewable technology, has also caused delays in completing the project within the anticipated timeframe. On a broader scale, equipment imported from overseas into Australia has occasionally failed to meet the local regulations, because of a lack of awareness or attention by foreign suppliers to the (slight) differences between Australian and international standards. The rectification work to achieve factory or site acceptance test certification then adds cost and often creates knock-on delays for the project.

3.3 Lessons from the Regional Australia's Renewables portfolio

The key lesson (or rule) which is often forgotten, overlooked, or underestimated by stakeholders for (renewable) electricity supply in remote locations, be they regulators, funding agencies, private sector participants, or end-users of electricity, is that place, people, and communication matter.

Place: Communities, mining operations, and tourist facilities are often in remote locations, far removed from supply of labour, spares, and institutional knowledge. Even if PV and other renewable hardware were to experience more aggressive cost declines than previously observed, this equipment still needs to be transported over long distances, installed with labour subject to remoteness or hardship premiums, to reach a location that is, by definition, difficult or costly to reach.

People: The expectations of the different stakeholders, some of which do not live in the remote environments discussed, need to be managed carefully, to ensure durable results for the end-users. For example, stakeholders sometimes expect that capital cost declines observed in other (often less remote) locations can be fully translated and passed on to the remote locations under study, while overlooking the integration and stakeholder engagement aspects.

Communication: Even if the stakeholders (eg. ARENA and project proponents) have a solid understanding of the place and the people involved, there is still the need to communicate the concepts properly and, where needed, to spend time actively educating stakeholders to ensure that the magnitude and probability of risks are put into the appropriate context. Mitigating risk associated with end-user and stakeholder acceptance of the project is predicated upon good design and execution.

The risk appetite for a new technology to be added for power generation is often very low. The potential impact of a loss of revenue because of the risk of poor, or incomplete, integration of a renewable technology on the operations of a mine or a tourist resort is a multiple of the operational expenditure for the power and energy. While the absolute risk of failure in a remote site may not be materially different from an urban location with similar climatic conditions, the relative impact of such a failure on the local operations is much more severe, which then needs more operational guarantees to convince the local end-users to sign on for such changes. From feedback provided to ARENA, many developers of renewable power projects underestimate the risk aversion that is present, overestimate the capabilities of the technology being proposed, lack awareness of the technical limitations of the generation on-site, or are unable to fully articulate the relationship of risks to benefits, to convince the end-user to invest in the new technology.

The involvement of ARENA and other government departments also have led to higher due diligence, reporting, and compliance requirements, which in some cases caused project delays. For some projects, the key performance indicators to be reported on to satisfy ARENA’s Knowledge Sharing requirements brought about prolonged negotiations. Further, as Knowledge Sharing was developed within ARENA during the RAR program's initial phase, some projects signed on to Knowledge Sharing requirements to answer questions that were no longer relevant by the project’s commercial operation, which point to historically rigid requirements in the funding agreements. As the RAR program was among the first programs undertaken by ARENA, learnings such as these have since been incorporated into subsequent funding design, for example, for the LSS funding round.\textsuperscript{20}
While PV and similar renewable energy technologies have improved significantly in the past years, see,\textsuperscript{22-25} they often lack all the characteristics that the traditional fossil-powered generators offer in 1 package or technology, such as dispatchability, (mechanical) inertia, rapid deployment, and all of these under the umbrella of financial viability. Various renewable and enabling technologies must be combined to achieve the same perception of reliability and control. For off-grid power supply, there are few cases where renewable technologies such as PV are accepted as a drop-in replacement or plug-and-play add-on to the incumbent technology. These situations are where enabling technologies ranging from low-load diesel generators to flywheels and batteries to improved power station management and operation software can play a larger role for increased uptake of renewable power for isolated grids.

4 | CONCLUSIONS

The continued experience and lessons from the projects funded by ARENA’s RAR program point to issues for the integration of renewables which will increasingly manifest themselves in the coming years, for both on-grid and off-grid situations. A number of these issues are technical, and advances from either the on-grid or off-grid spheres can migrate to the other. On the other hand, with capital costs for renewable technologies decreasing over time, the relative importance of the structural barriers grows, as the ease of access to finance, the governance structures in place, and the available supply chains will play an increasing larger role in project execution.

While the magnitude of the remoteness premium has not been quantified, it has been illustrated by comparing ARENA’s RAR-funded projects to the LSS utility-scale projects in Australia. By definition, the remoteness premium is context-specific and dependent on a range of discrete variables such as scale, location, and quality of existing infrastructure, both electrical and transport. The impact of project scale and remoteness (or difficulty of access) have the potential to compound or counteract each other, depending on the project and locational configuration: Large capacity additions in very remote locations may have similar specific costs to smaller systems in less remote areas, whereas lowest costs (approximating on-grid system costs) are achieved for large system sizes in less remote locations.

From the RAR portfolio project experience, attempting to reach higher RPF and annual REF is costlier and, on average, requires more time to complete, yet the longest project delays were experienced among projects that aimed for less ambitious annual REF values. From a technical perspective, once projects secured legal and financial approvals, project executions have been close to the contractual plans in time and expenses. The location-specific and project-specific delays experienced by the RAR projects point to areas where time and cost improvements can be achieved. The development and execution of the projects is contingent upon ensuring that stakeholder engagement and the particulars of the place are not forgotten.

Australian Renewable Energy Agency’s Knowledge Sharing requirements allow the RAR projects to be benchmarks for the future within Australia and the world. The Knowledge Sharing model—if properly designed and implemented prior to providing funding to projects—can significantly increase the impact of funding by governments, multilateral development banks, and nongovernmental organisations and lower costs for future renewable energy projects.

ACKNOWLEDGEMENTS

The authors wish to thank Lachlan McLeod and George Dickeson for the graphical inputs, the projects team at ARENA for the insights and fact-checking of data, and the project proponents for actively participating in Knowledge Sharing. Ekistica is ARENA’s Knowledge Sharing partner and data handler under Work Order CEAP-WO-14/15-003.

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How to cite this article: Herteleer B, Dobb A, Boyd O, Rodgers S, Frearson L. Identifying risks, costs, and lessons from ARENA-funded off-grid renewable energy projects in regional Australia. Prog Photovolt Res Appl. 2018;26:642-650. https://doi.org/10.1002/pip.3004