Insights From the First Wave of Large-Scale Solar Projects in Australia

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Australian Government
Australian Renewable Energy Agency

ARENA

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INTRODUCTION

In 2016 the Australian Renewable Energy Agency (ARENA) ran a $100 million competitive grant funding round with the aim of driving down the cost of delivering large-scale solar photovoltaic (PV) projects in Australia. Under the Large-Scale Solar (LSS) Funding Round, ARENA funded 12 projects. Two additional projects that did not receive funding signed up to ARENA's knowledge sharing obligations. This brought the portfolio to 14 projects totalling 603 MW (the LSS Round Projects).

The Clean Energy Finance Corporation (CEFC) offered a long-term debt product alongside ARENA's grant funding to 10 of the LSS projects. This was to provide finance certainty irrespective of whether projects had a guaranteed revenue stream from a power purchase agreement (PPA) prior to ARENA grant allocation and financial close.

Following the LSS Round, in 2017 and 2018, the CEFC provided finance to eight projects that did not require ARENA grant funding (the Post-LSS Round Projects).

ARENA's LSS Funding Round played an important role in the development of the large-scale solar industry in Australia by helping to drive down the cost of large-scale solar development, construction and finance. The round also attracted international engineering, procurement and construction (EPC) providers to Australia, which further improved the cost competitiveness of the local EPCs. Today, the building, owning and operation of large-scale solar farms in Australia no longer requires grant funding.

The project proponents were obliged to share knowledge, insights and data from their funded projects. This information and interviews with key personnel from the LSS Round Projects was aggregated, anonymised[1] and then analysed by ARENA with the assistance of technical advisory firm, Ekistica.

This report presents the key insights and trends that project proponents learnt from reaching financial close, construction, grid connection, and ramping up to full generation. The trends are illustrated in a series of charts, where the CEFC has also provided commentary on the experience of the Post-LSS Round Projects.

The LSS Round Projects have overcome many challenges to reach first generation. Information and knowledge collected from the projects provides crucial insights for the energy industry and regulators about the nature of renewable projects amid the energy transition.

We also acknowledge the significant role other projects have played, particularly those built prior to the LSS Funding Round. They helped develop the industry by achieving their intended outcomes, with those projects helping to establish a "blueprint" for those that followed.

The findings can help developers, investors and electricity grid authorities to better understand the Australian large-scale solar market and the potential risks of and mitigants for investments in this space.

1 Note that to maintain confidentiality for individual projects the order of projects is different across the figures in this report

ACHIEVEMENTS

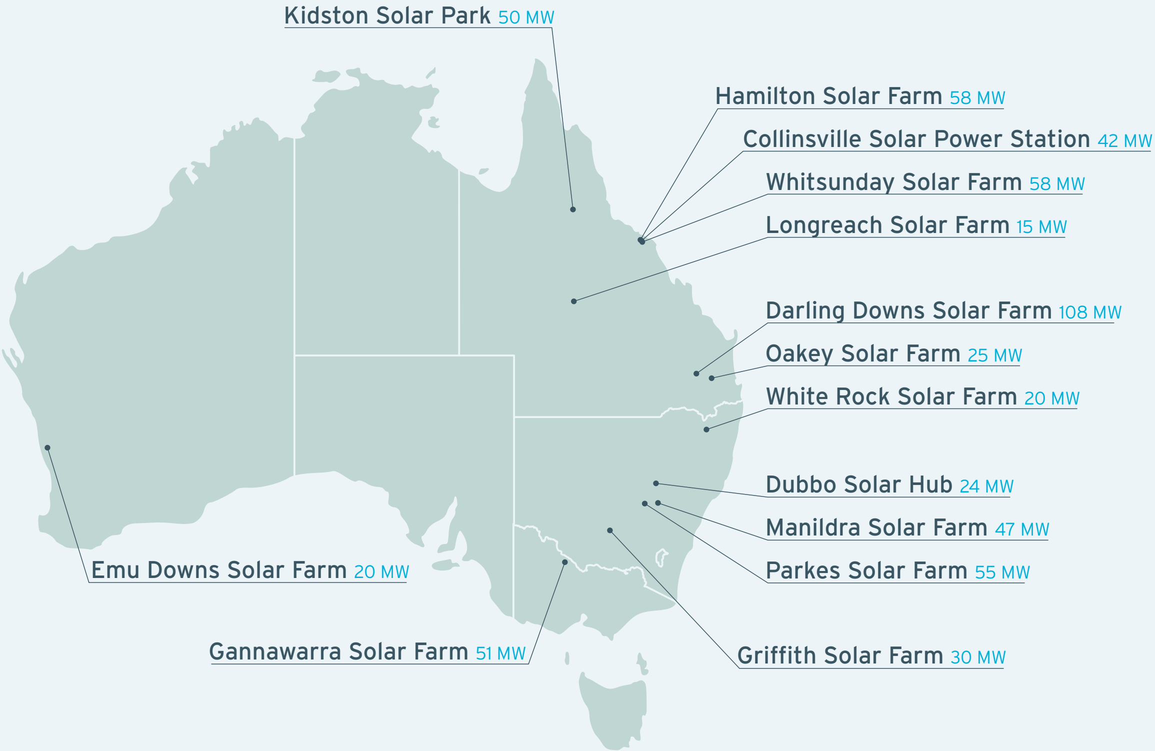

Figure 1. This map plots the location and nameplate capacity of the projects from the LSS Funding Round.

The LSS Funding Round received 77 expressions of interest, of which 22 were shortlisted and invited to submit full applications. Of those that submitted full applications, 12 received ARENA funding and an additional two projects that did not receive funding signed up to ARENA's standard knowledge sharing obligations for the LSS Funding Round. This brought the portfolio to 14 projects totalling 603 MW (the LSS Round Projects).

The LSS Round Projects received almost $90 million of ARENA grant funding, which unlocked almost $1 billion of commercial investment in the projects. Across New South Wales, Queensland and Western Australia, these projects created jobs and provided direct and indirect economic benefit to the rural and remote communities in which they operate.

The projects have also helped to reduce the emissions of Australia's electricity grid. The 12 projects which received ARENA funding under the LSS Funding Round have an emissions abatement impact of 11.6 million tonnes of carbon dioxide equivalent.

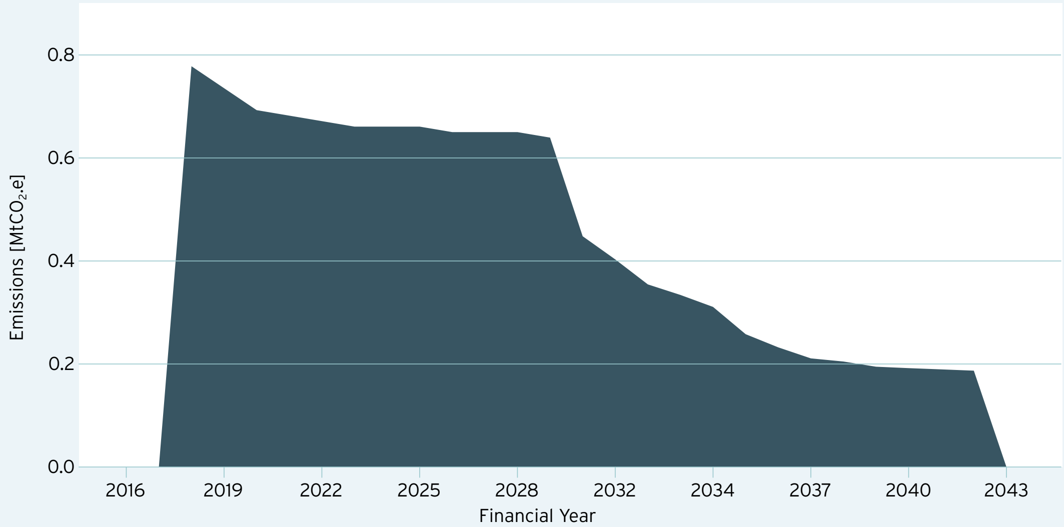

Figure 2. Emissions abated from the 12 ARENA-funded LSS projects, which started generating in 2017, 2018 and 2019

Since the LSS Funding Round, Australia's large-scale solar sector has undergone a remarkable transformation. With the introduction of more efficient technologies and more experienced operators, construction and operational costs declined and, in turn, the large-scale solar industry became able to build projects on the basis of expected electricity revenue streams, rather than being supported by grant funding.

ARENA and the CEFC's efforts played a major role in increasing Australia's medium to large-scale (>100 kW) solar capacity by helping to unlock gigawatts (GW) of new developments in Australia. Figure 3 shows that over 4 GW of medium to large-scale solar is currently installed in Australia. Data from the Clean Energy Regulator (CER) indicates that over 2 GW of large-scale solar was accredited in 2018, which is up more than 870 per cent from 2017. This equates to, on average, over 27 medium to large-scale solar farms being accredited each month in 2018[2].

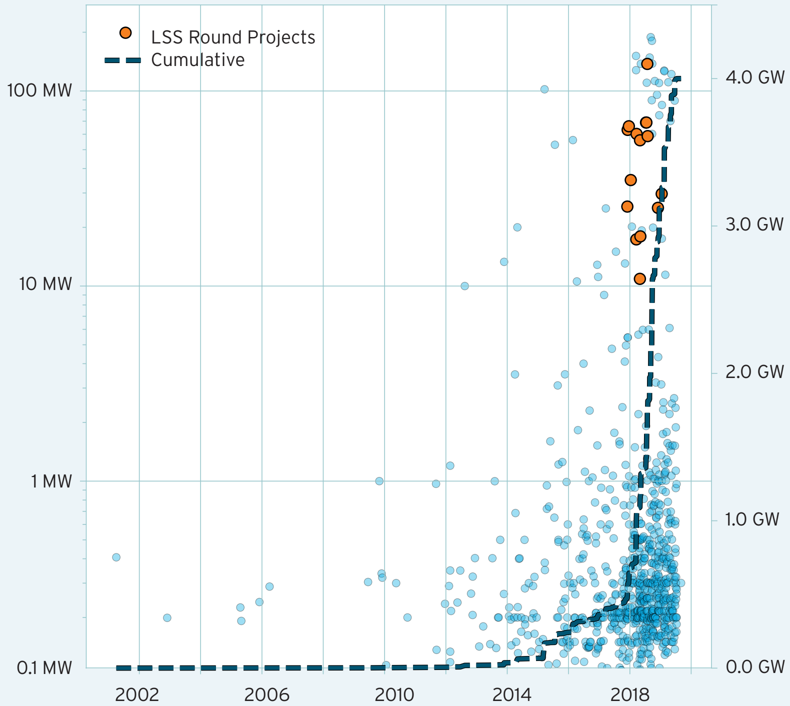

Figure 3. Solar PV systems greater than 100 kW accredited by the CER in Australia. Ekistica analysis of data from the Australian Photovoltaic Institute[3]

2 "Large-Scale PV Systems," Australian PV Institute, accessed 12 December 2019 http://pv-map.apvi.org.au/power-stations.

3 Ibid, p.3

The support of ARENA and the CEFC has helped to close the cost gap that existed between large-scale solar and other commercially competitive forms of power generation – contributing to large-scale solar becoming cost competitive with wind energy and cheaper than new build coal and gas[4].

The cost of large-scale solar (tracking) has fallen from $135 per megawatt hour (MWh) in 2015 to $28-68/MWh in 2019[5]. This was driven by both local and international cost reductions, with reductions expected to continue[6]. Local costs include the cost of finance and construction, and international cost drivers include the cost of manufacturing.

This combination of factors means that today, less than three years after the first of the LSS Funding Round projects reached financial close, Australia is deploying renewable energy generation at one of the highest per capita rates in the world[7].

INSIGHTS

The proponents of the LSS Round Projects were asked to identify the risks associated with their projects. The key challenges were identified as:

1. lower operational revenue from adverse changes in Marginal Loss Factors (MLF) than that originally assumed by developers during project development
2. connection delays and cost overruns due to requirements in Generator Performance Standards (GPS) and commissioning (including R2 validation testing[8]) taking longer than originally assumed by project developers and EPC contractors
3. delays caused by poor weather experienced during construction and commissioning
4. close monitoring by proponents of progress and standards under the EPC agreements.

4 PV tracking $28-68/MWh; coal $90-138/MWh; and closed cycle gas turbine $70-101/MWh, sourced from "Current LCOE range ($/MWh, nominal) - Australia, 2019 H2" BloombergNEF, accessed 16 December 2019.

5 Ibid.

6 "Forecast LCOE range ($/MWh, real 2018) - Australia, PV tracking" BloombergNEF, accessed 16 December 2019.

7 A. Blakers, M. Stocks and B. Lu, "Australia: the renewable energy superstar", Australian National University, Canberra, 2019.

8 R2 validation testing involves the verification that the project's grid models are representative of the installed system.

Figure 4 shows the main construction and commissioning risks identified by the project proponents.

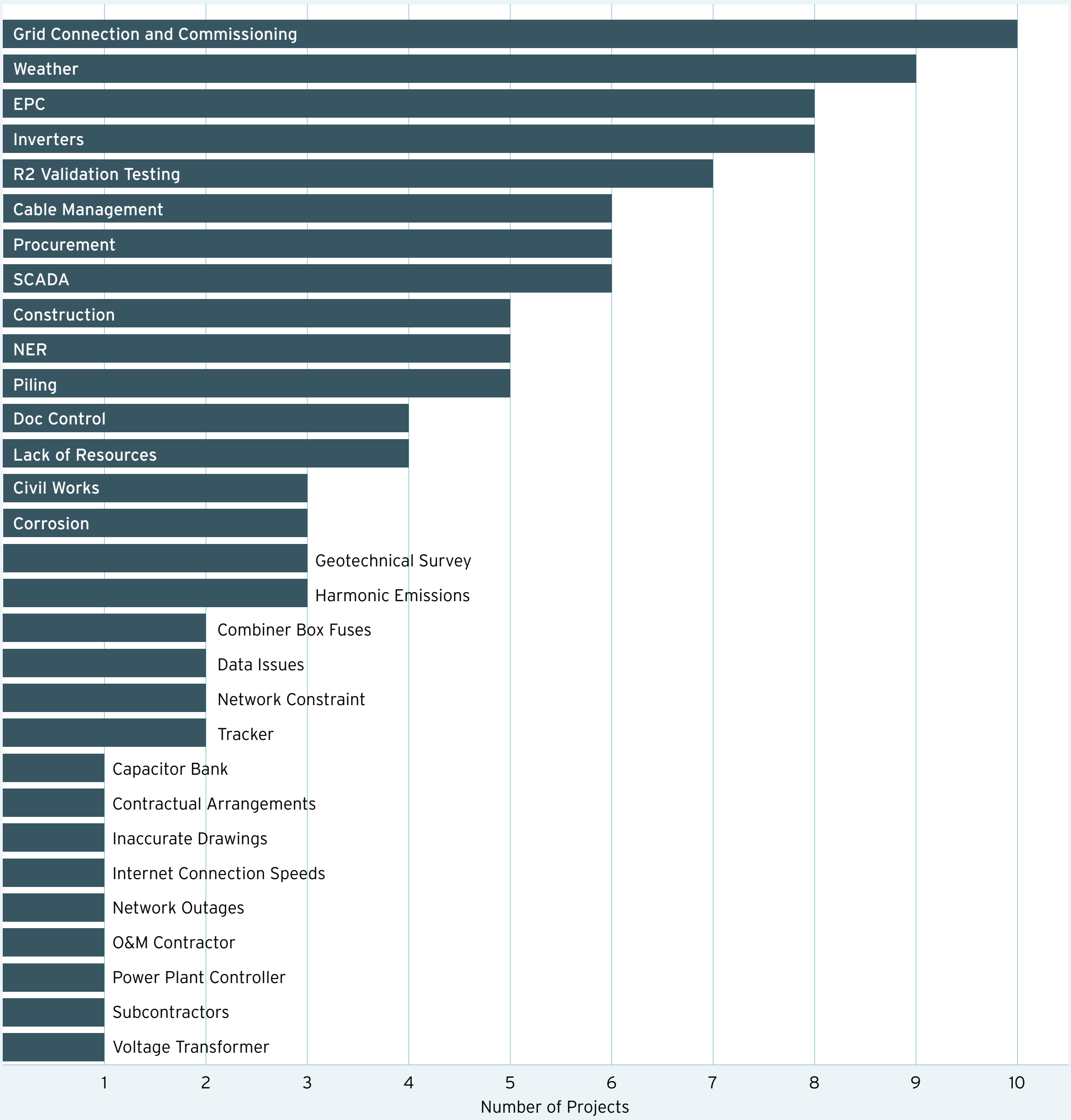

Figure 4. Project challenges, as identified by individual project proponents

TIMEFRAMES

Delays in practical completion and achieving maximum generation were common across the entire portfolio of LSS Round Projects, primarily due to the challenges described above. The analysis below comments on the scope of, and perceived reasons for the delays.

Practical completion

On average, the LSS Round Projects reached practical completion 38 weeks after the original date forecast at financial close. On 2 October 2019, Merrill Lynch released a report, 'The National Electricity Market (NEM): The capacity bomb is still coming', which showed that projects across the large-scale renewables sector continue to be delayed, demonstrating that the LSS Round Projects are not outliers. Collated data shows the current average delay on large-scale projects in Australia is 7.5 months (approximately 32 weeks)[9].

9 B. Low, M. Yang, "Australian Utilities The National Electricity Market (NEM): The capacity bomb is still coming" Bank of America Merrill Lynch, Australian Utilities Equity Research, 2 October 2019

Figure 5 below demonstrates the delays encountered for the LSS Round Projects, where major delays occurred during construction and commissioning (ensuring GPS compliance and ramping up to maximum generation). On average across the LSS Round Projects, the construction and initial connection processes were responsible for more than 15 weeks' delay, while the stages between first generation and practical completion (i.e. going through hold point testing) were responsible for approximately 10 weeks' delay.

Some of the main causes for delay during these periods were:

- difficulty meeting the GPS
- poor weather during both construction and hold point testing
- issues associated with the EPC and/or the EPC entering voluntary administration
- harmonic compliance
- inaccurate or inadequate geotechnical survey conducted
- reactive power fluctuations
- issues with the Power Plant Controller settings.

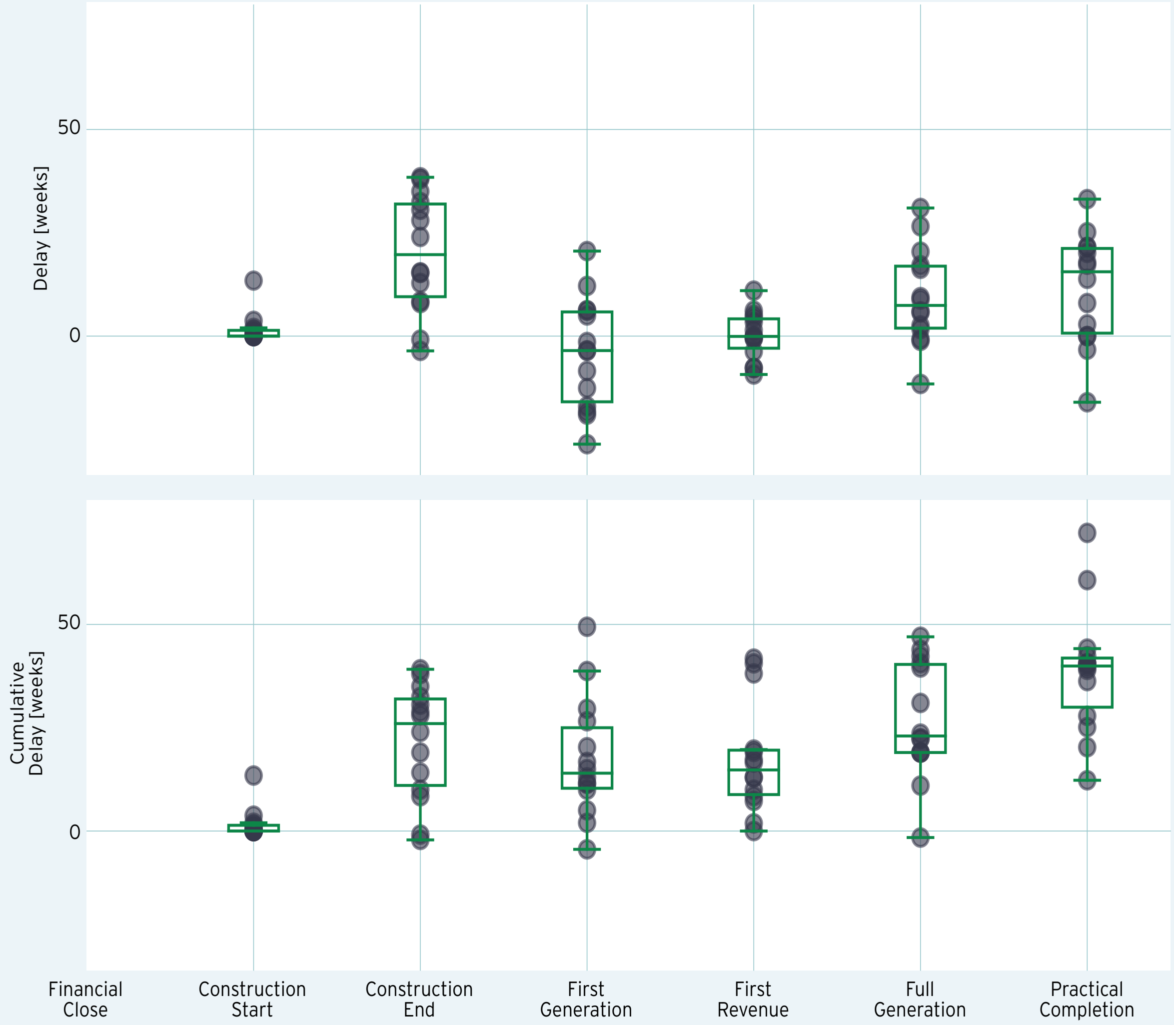

Figure 5. Project delays when compared to forecasts at financial close

For the Post-LSS Round Projects, the CEFC observed similar delays in completing the project milestones, even after adjusting for projects that were affected by the administration of their EPC.

It is likely that the EPC contracts across the LSS Round Projects defined practical completion in slightly different ways. As such, the delays in practical completion would have affected each project's generation profile and revenue stream differently. For instance, some projects were able to generate at full capacity prior to reaching practical completion and others did not reach full capacity until after practical completion was achieved.

The large variance in delay in time to reach practical completion may also be due to different incentive structures under each project's PPA. It is possible that some sponsors were incentivised to reach practical completion quickly (and, for example, be more flexible on punch-list items under the EPC contract) to ensure that PPA sunset dates were met (reducing the risk of liquidated damages). Other sponsors may have been happy to reach practical completion more slowly and collect high merchant and large-scale generation certificate (LGC) revenues before beginning delivery under the PPA. These dynamics are specific to individual project arrangements and have not been analysed in detail as part of this report.

Maximum Generation

Many LSS Round Projects forecast maximum generation to coincide with first generation. However, the Australian Energy Market Operator's (AEMO) public dispatch data for these projects demonstrates that, on average, maximum generation was achieved approximately 28 weeks after first generation occurred. These delays were primarily due to issues encountered during commissioning and R2 validation testing.

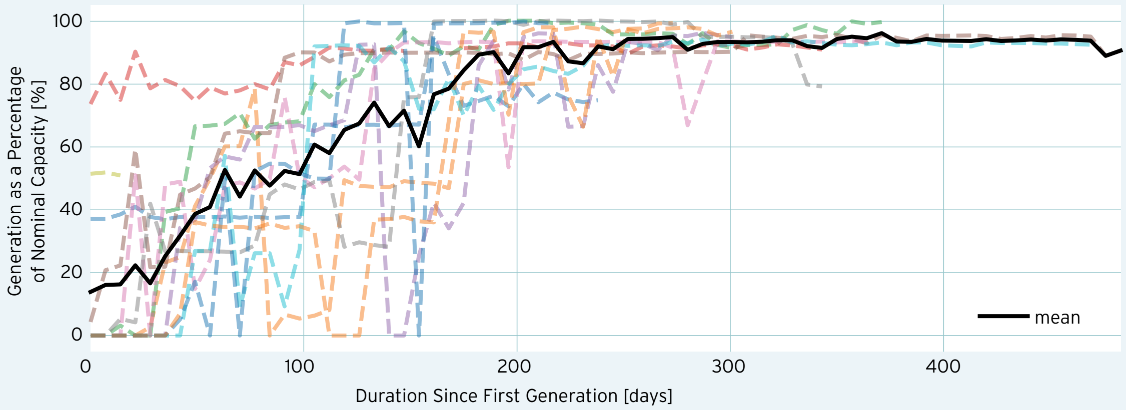

Figure 6. LSS Round Projects ramping up generation over time, where each line represents a different project. Note that each data point represents the power system's maximum dispatched power each week and has not been seasonally adjusted.

The CEFC has observed that, for the Post-LSS Round Projects, the mean period between first generation and full generation was not significantly different to the LSS Round Projects, even after adjusting for those projects which were delayed by the administration of their EPC.

REVENUE

Most of the LSS Round Projects secured PPAs that cover 100 per cent of generation and surrender of LGCs. Figure 7 shows the PPA and merchant split across the LSS Round Projects. While two projects are exposed to significantly high levels of merchant risk, it is likely they are a part of a larger portfolio of projects that, overall, achieves a desired level of merchant risk for its investors.

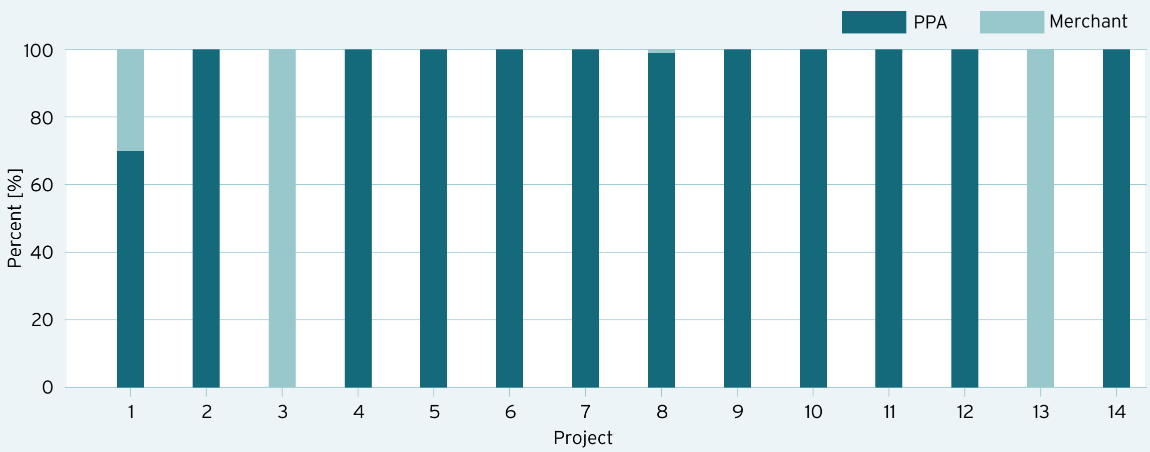

Figure 7. PPA and merchant split across the LSS Round Projects

COSTS

Of the 14 LSS Round Projects, 11 submitted EPC[10] and non-EPC[11] cost data. Figure 8 below demonstrates the actual (A) non-EPC and EPC costs compared to what was forecast (F) at financial close. The actual costs experienced on five projects were significantly different to what was originally forecast. Several projects reported actual cost data to be equal to the forecast and the data appears to reflect what the developer paid as opposed to the true costs outlaid by the EPC.

Total project costs (non-EPC and EPC) across the portfolio varied from 16 per cent under budget to 25 per cent over budget. On average, the 11 projects were approximately 2 per cent over budget (i.e. the total costs paid by the sponsors to deliver the project were 2 per cent above expectations). These costs exclude liquidated damages and operational expenditure (OPEX).

Figure 8 shows the average non-EPC cost was 28 per cent over budget, with one project almost doubling its expected non-EPC costs. On average, non-EPC costs made up approximately 12 per cent of the total project cost, with a range between 3 per cent to 21 per cent. For the EPC costs, there is a large spread in variation between actual and forecast costs, with the average EPC cost close to budget. One project's EPC costs came out 16 per cent under budget and another being 18 per cent over budget.

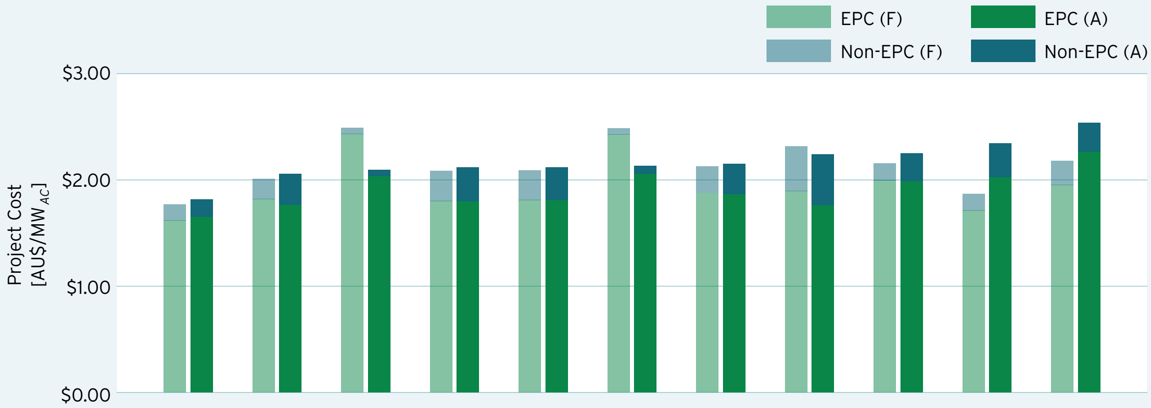

Figure 8. The actual EPC and non-EPC costs compared to what was forecasted at financial close for the LSS Round Projects. These costs exclude liquidated damages and operational expenditure.

10 EPC costs have been defined as Modules, Inverters, Frames, Trackers, Grid Connection, Substation, Civil Works, Electrical Works, Labour, Other.

11 Non-EPC costs have been defined as Development, Owner's Engineer, Management, Financing, Legal, Insurance, Other.

Figure 9 shows each project's forecast annual OPEX was consistently between $10k – 40k per MW_{AC}. The variation in the forecast OPEX is partly due to the fixed versus tracking system types and the large range in project sizes. The actual OPEX for the projects have not been reported here due to the limited data to date.

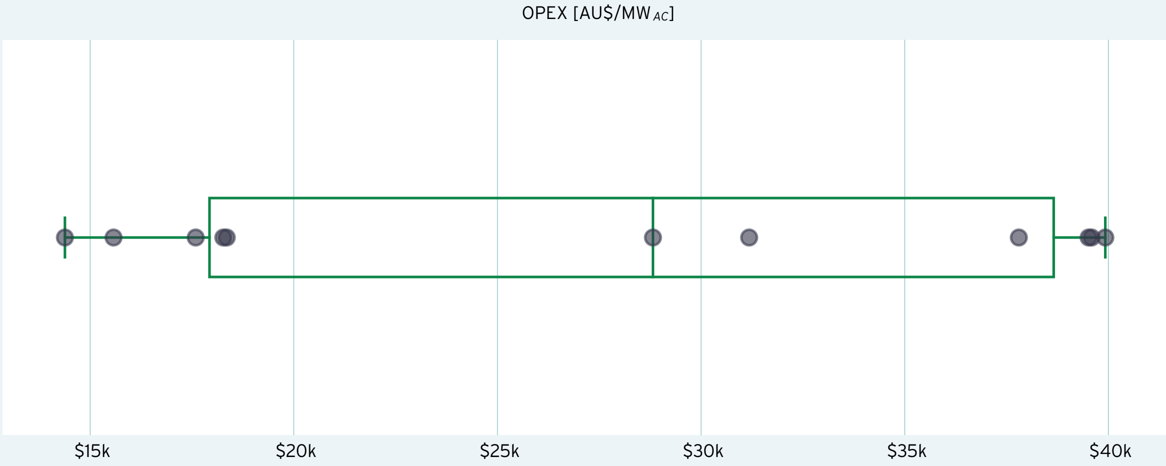

Figure 9. Forecast annual OPEX for 10 of the 14 LSS Round Projects

Some projects did not report liquidated damages received by the project under the EPC contract. For the 10 LSS Round Projects that did, Figure 10 shows that the average amount of liquidated damages was $4.2 million, with one case rising to $9.7 million. These liquidated damages were generally caused by delays under the EPC contracts as described above.

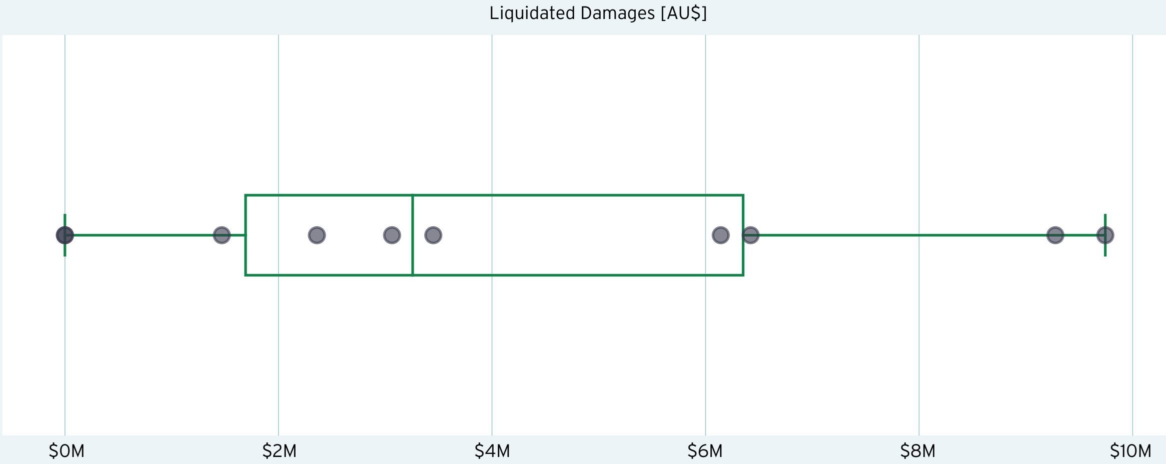

Figure 10. Actual exposure to liquidated damages for 10 of the 14 LSS Round Projects[12]

MARGINAL LOSS FACTORS

The MLF is a yield-scaling factor, assigned every financial year by AEMO to each load centre and generator on the NEM, representing the marginal change in loss between a connection point and the regional reference node (RRN) due to an increase in load. For example, an MLF of 1.05 results in a 5 per cent equivalent energy yield increase for a generator, while a load at that location must pay as if it consumed 5 per cent extra energy.

12 The data in Figure 9 and Figure 10 is represented using a boxplot, where the vertical green lines highlight the minimum, first quartile, median, third quartile, and maximum.

As a result, variations in MLF over time will affect project revenues, unless the off-taker has borne the MLF risk. The MLF also affects how generators participate in the bid stack, as the bid price is divided by the MLF: a bid for AU$90/MWh with an MLF of 0.90 is treated as if the bid was AU$100/MWh; this further adds to the merchant risk of a project. MLFs set by AEMO are essentially a prediction for the state of the network in the forward financial year.

Key drivers of MLF are:

1. **distance from load** (which can change over time as local supply/demand balances change)
2. **quality and length of the transmission** line to which the generator is connected
3. **other projects with a similar generation profile nearby,** or in between the generation and the load.

For example, as solar projects have a similar time-of-day generation profile, incremental neighbouring solar projects can have more immediate impacts on MLF than neighbouring wind projects, which may have different generation profiles from each other.

AEMO assigns an MLF for each generator and load centre once per year. A solar project receives payments from AEMO and (generally) the electricity off-taker based on the volume of generation multiplied by the MLF. The volume of LGCs a project can create is also adjusted by the MLF. As a result, variations in the MLF over time will affect the revenue of a project, unless the off-taker has borne the MLF risk.

As earlier noted, ARENA's LSS Funding Round received 77 expressions of interest, of which 22 were shortlisted and 12 received ARENA funding. Figure 11 below shows the MLF forecast for the shortlisted and LSS Funding Round projects. While some project proponents forecast varying MLFs, the vast majority assumed little or no change to the MLF over the expected operational lifespan.

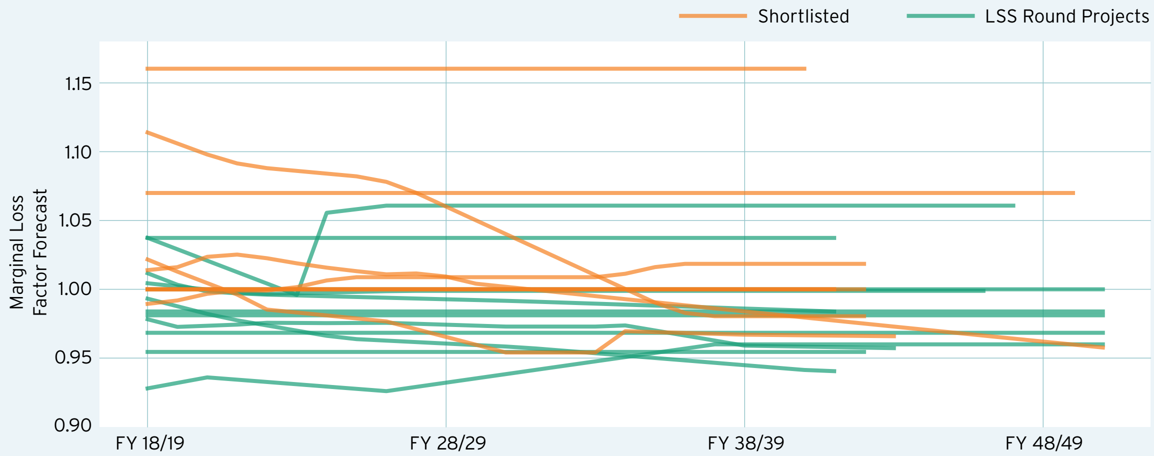

Figure 11. MLF forecasts for projects that were shortlisted in ARENA's LSS Funding Round

Figure 12 below shows the difference between the forecast and actual MLF for the LSS Round Projects, along with those that were not successful in receiving ARENA funding, but were built nonetheless. The MLF forecast error is shown for the two most recent financial years – 2018/19 and 2019/20. Figure 12 shows that the actual MLF for both financial years was (generally) lower than forecast by the project proponents. The lower MLFs will result in (all other things being equal) lower revenues than originally forecast.

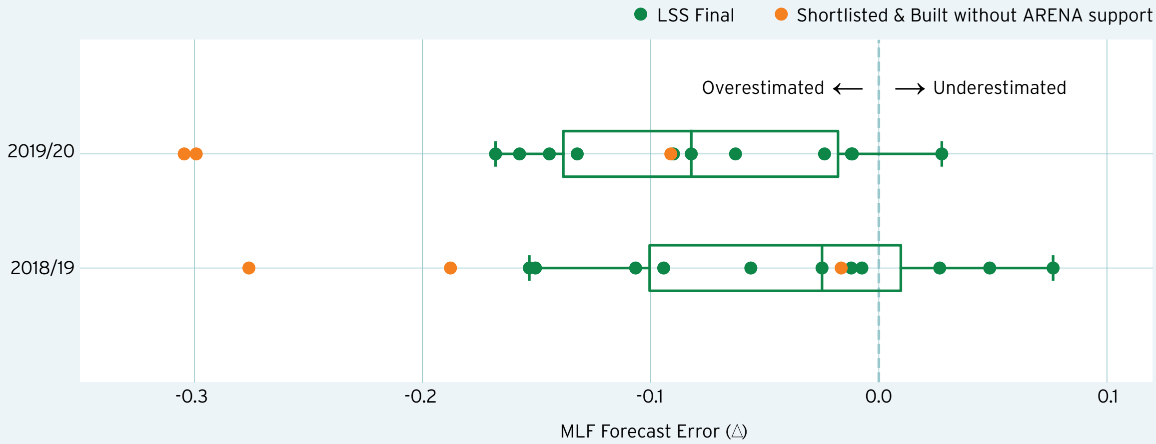

Figure 12. The difference between the forecast and actual MLF values for shortlisted projects in ARENA's LSS Funding Round

Figure 13 highlights how MLFs have changed over the last two financial years in the National Electricity Market (NEM), using AEMO's published data. Regions of the NEM are coloured according to the nearest connection point associated with an MLF load centre, while generators are shown as points. The shaded colour indicates the MLF, the shape of the icon indicates the generator technology, and the size of the icon is proportional to the registered megawatt capacity. The maps demonstrate the rapid change in MLF over the last two years. The complexity of power flows in the NEM means generators can impact the MLF in regions well beyond their immediate neighbourhood.

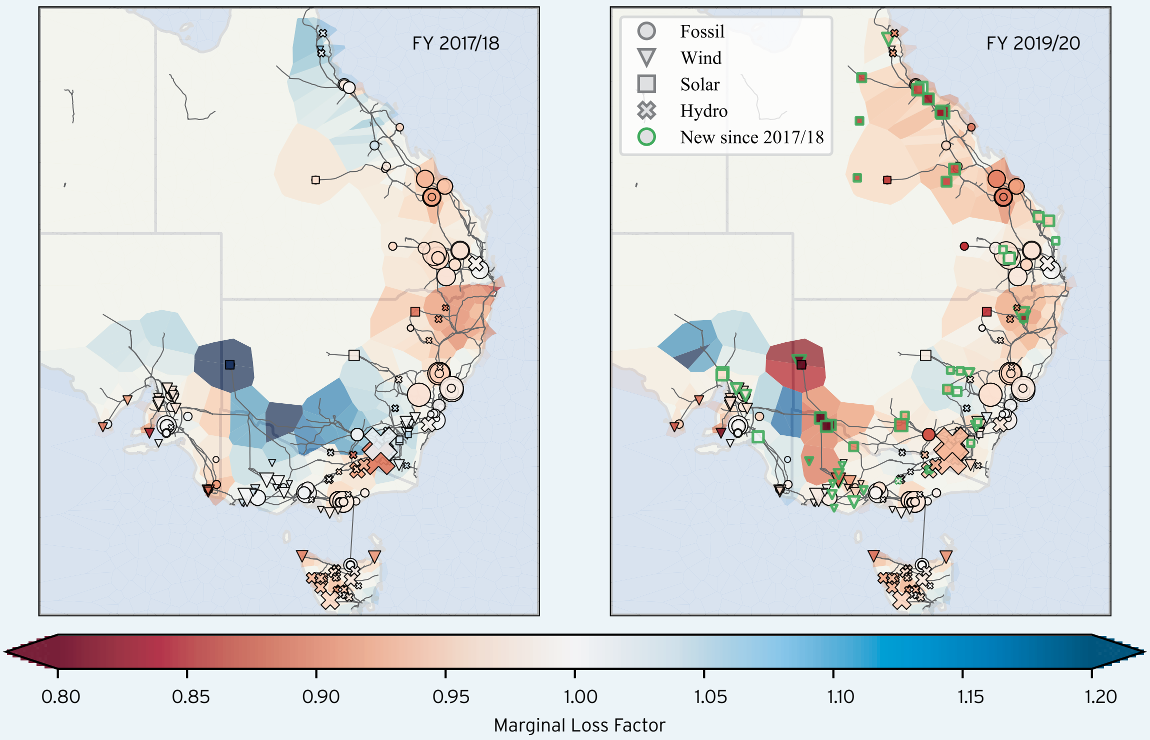

Figure 13. AEMO publishes MLFs for both generators and load centres, both of which are depicted in the maps above. Regions of the NEM are coloured according to the nearest connection point associated with an MLF load centre. Generators are shown as points, with the shaded colour indicating the MLF, the shape indicating the generator technology and the size indicating the registered megawatt capacity. Generators outlined in green were installed in the displayed financial year.

Figure 14 below shows the annual weighted average MLF across different technologies in the NEM since financial year 2008/09 (weighted by nameplate capacity and not total generation). It shows a drop of 0.114 for solar across two years, from 1.017 in 2017/18 to 0.904 in 2019/20.

Solar proponents are better able to take advantage of regions with higher MLFs compared to wind proponents as wind resources are more constrained than solar. This, combined with the weighted average impact, is likely why there has been such a large drop in the MLF of solar generators (i.e. high irradiation and high MLFs justified the build of initial projects, with subsequent projects in those same regions adversely impacting the incumbent projects).

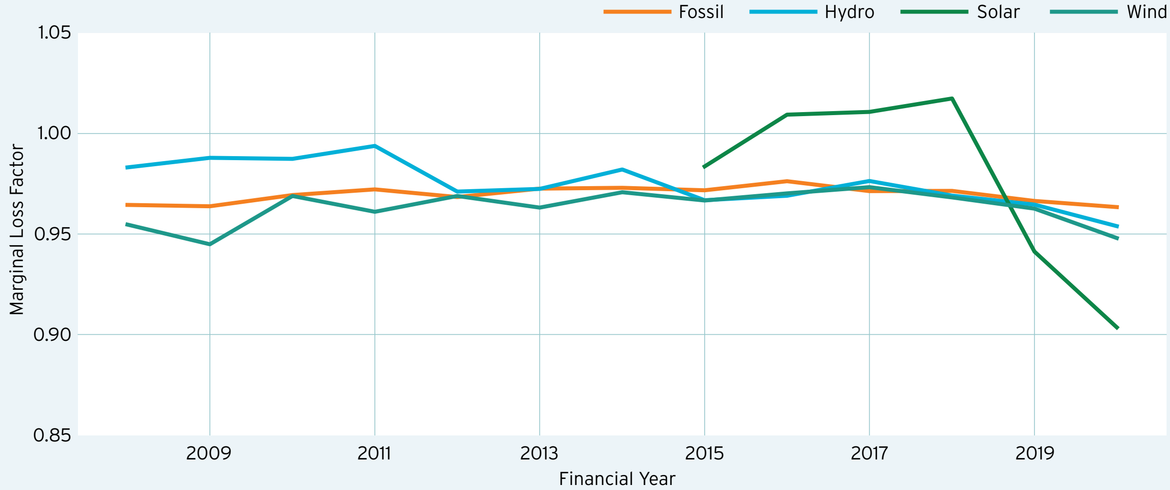

Figure 14. The weighted average (weighted by nameplate capacity) MLF for generator technologies on the NEM (according to current records from AEMO for all generators greater than 5 MW)

In many circumstances, the reduced MLF for those projects will be impacting early year returns, and are likely to impact future year returns. The MLFs for both the LSS Round Projects and Post-LSS Round Projects are expected to continue to vary over time, depending on the rate of development of new projects, changes in load, grid enhancements and the development of storage projects. Observing the historical trends in MLF for different regions will assist investors to more accurately forecast future project MLFs under different scenarios.

WHAT COMES NEXT?

Leveraging the support of ARENA and the CEFC, the large-scale solar industry has experienced a boom over the last three years. The industry has weathered the challenges facing any new sector as it has sought to achieve a lower cost of production and build a proliferation of projects. The work of the project proponents and knowledge sharing partners has paved the way for other projects to flourish in their wake. Using data from the CER, Figure 15 below demonstrates that there are currently 891 medium to large-scale solar systems accredited in Australia[13].

13 "Australian PV market since April 2001," Australian PV Institute, accessed 10 September 2019 https://pv-map.apvi.org.au/analyses.

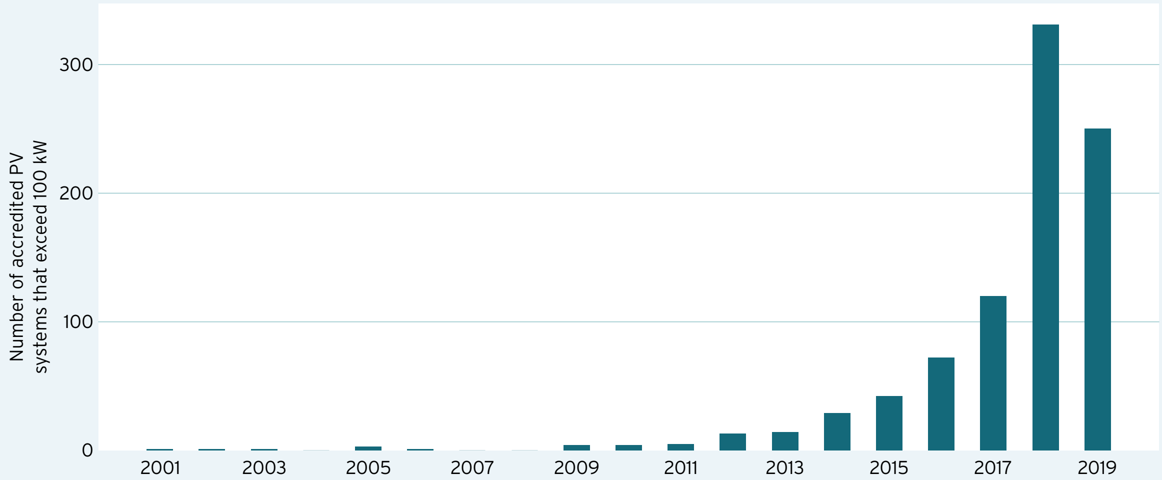

Figure 15. The number of medium to large-scale (>100 kW) solar systems accredited each year by the Clean Energy Regulator since 2001 (data up to 2 October 2019)

Today, investors in these projects are entering the asset management phase. Being capital intensive renewable energy projects, a large share of the project costs have already been spent; however, there will be ongoing opportunities to optimise the performance of the projects and minimise costs and curtailment over the 30 year asset lifetimes. The cost efficiencies of this stage will most likely improve with the entry of specialist operations and maintenance providers along with asset management firms which should increase competition for these services.

CONCLUSION

The LSS Round Projects, and the projects that followed, have contributed to the transformation of Australia's energy mix and have been a critical factor in reducing the emissions intensity of the Australian electricity grid. These projects also created billions of dollars of investment opportunities, significant economic activity and employment in rural and remote communities.

The analysis in this report shows that this success has not been without risk for individual project investors. Key insights drawn from this funding round include the fact that the best data and studies of trends available for MLF forecasts and strategic site connection points were unable to factor in the unprecedented and rapid integration of large-scale solar. This 'unknown' meant investment decisions were made for the LSS Round Projects that were unable to accurately consider or model the future NEM.

Additionally, the exponential growth in solar projects under development placed significant resource constraints upon industry professionals and network authorities including EPC providers, technical experts, transmission authorities and AEMO. This meant the industry was suddenly facing the challenge of establishing and managing a growing industry that was attempting to integrate new technologies in a system designed for large, thermal generators.

In sharing the insights from the LSS Round Projects and Post-LSS Round Projects, the findings can assist key players to better understand the history of the Australian large-scale solar sector and the prospective risks and mitigants for investments in this space.

ARENA and the CEFC would like to thank the project proponents for their participation in this knowledge sharing activity.