LESSONS LEARNED IN THE DEVELOPMENT OF MOREE SOLAR FARM

1. INTRODUCTION

The Moree Solar Farm project is a photovoltaic (PV) ground-mounted generating facility located in Moree, which is in North-Western New South Wales (NSW). The project has a nominal installed capacity of 56MWac.

The project is being developed by Fotowatio Renewable Ventures (FRV), a European company focused on developing utility-scale PV plants with an active presence in Australia, South Africa, Latin-America, Middle-East and Europe. The project has received finance from the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC).

2. PROJECT LOCATION

FRV selected the project site near Moree, NSW, as the most suitable site for the following reasons:

- Moree has one of the highest solar irradiance profiles in NSW.
- Moree has an electricity grid capable of 56MWac of solar power injection.
- Moree was supportive of the project – see the section on Community and Stakeholders
- The land is highly suitable for PV installations: it is flat and mostly cleared of vegetation, providing a relatively smooth planning consent process and mitigating environmental offsetting.
- There are minimal visual amenity issues affecting neighbouring properties/stakeholders.

The project site is located approximately 10km south of the Moree township. It was finally selected after confirmation from the Transmission and Distribution Network Service Providers, TransGrid and Essential Energy, of the technical feasibility of connecting the entire 56MWac facility at the Moree Zone Substation.

Key lessons learned:

- Move early to secure land options in the preferred location, as competition for ideal project sites is likely to be high in response to specific support programs.
- Competent site selection and due diligence allows trouble free permitting with reduced ongoing compliance requirements.
- Engage early with the network service providers and competent consultants to understand the suitability of the site from a connection point of view.

3. COMMUNITY AND STAKEHOLDERS

Moree Solar Farm has had a positive history of engagement with the community since the project's inception in 2010, with strong support from local government and the broader community. This is due to a number of factors, including:

- *A progressive local government*. As was identified early on during the site selection process when considering Moree as an option, the local government authorities showed a high level of interest in the project. Moree Plains Shire Council, its Councillors, Mayor and officers are all great supporters of the project. Moree Plains Shire Council is progressive relative to others, supporting suitable development within the Shire that will bring benefit to the local economy and community.

- *Provision of accurate and timely information about the project*. Active community involvement and dissemination of accurate project information has ensured that the community is both aware of the real facts about the project and its impact on and benefit to the community. It is critically important that actual facts about a project are available to the community and that misinformation is not allowed to be disseminated within the community uncontested. This is best achieved via a transparent engagement with the community in a timely manner.
- *Effective community engagement*. Engagement with the community has been achieved through listening to the broader community and neighbours through local stakeholder meetings, special interest working groups and community representatives / advocates from within the community.
- *Fit-for-purpose consultation*. Consultation has progressed in "waves" of activity, depending on project status and stage of development. As a result, at times of lower activity this has led to some confusion within the community as to whether the project is progressing. Conversely, at some stages of regular and intense engagement with the community the level of interest has waned and participation numbers have fallen.

Key lessons learned:
- *Progressive communities* - Select localities supportive of development determined through early engagement with local government and community.
- *Engage early and openly* - Even if project information is not popular you will be respected for transparency.
- *Effective community engagement* - Listen rather than promote and engage with issues that are important to the community rather than what the project owner thinks should be important to the community.
- *Fit-for-purpose consultation* - Don't over consult, but provide regular status updates to ensure that misconceptions regarding the project do not emerge.

The importance of project advocates

Complicated development projects don't proceed when all the stakeholders just "do their job". Development and financing of a large infrastructure project such as MSF is complicated and challenging and often requires individuals to go beyond what is normally required of them. This can mean either personally becoming an advocate for the project or pushing others within their organisation to do something outside "normal practices". For example, for the grid connection of the project, the grid operator's project sponsor / manager was able to accelerate its internal processes which would normally take place over a longer timeframe. As a developer it is very easy to forget that your own project is highly important to you but less so to many other stakeholders. Their efforts must be genuinely appreciated rather than expected. Identification and engagement with project advocates within stakeholder organisations is paramount to project success.

4. TECHNICAL

The main system components of the Moree Solar Farm include the PV modules, the horizontal tracking system and the inverters.

The expected output of the project is around 150,000MWh of electricity per annum or roughly enough to power 15,000 average NSW homes.

PV modules

All the PV modules to be installed in the solar farm are of the polycrystalline silicon type. This is the most mature and proven of the commercially available PV module technologies.

The facility uses PV modules from a top tier module manufacturer. As part of the selection process, potential module suppliers were required to demonstrate a long-term, robust history and experience in manufacturing high quality PV modules backed by a product warranty that meets typical standards in the industry. Other factors such as average degradation rates and quality control systems at manufacturing facilities were also considered. It was also necessary for companies to demonstrate their financial standing and production capability.

Key lessons learned:

- *Quality control* - when selecting a PV module manufacturer it is important to understand the quality control measures being utilised at each of the manufacturer's production lines used for the project.
- *PV module certification* - there are a number of IEC testing standards being utilised in the market, which demonstrate compliance with safety requirements (IEC 61730), construction standards (IEC 61730), performance standards (IEC 61853) and reliability and durability standards (IEC 61215). It is important to consider what certification a PV module manufacturer has in place when selecting a product.
- *Power degradation and warranties* – PV module output generally decreases over time due to degradation of module encapsulation materials, delamination, degradation of interconnections, moisture intrusion and semiconductor device degradation. In particular, Light Induced Degradation (LID) is becoming better understood in the industry and it is important that PV module suppliers provide testing records for module degradation.

Tracker

Moree Solar Farm uses horizontal single-axis solar trackers to continually follow the sun and increase the energy yield compared to fixed structures. This is the first large-scale solar farm to use this type of solar tracking system in Australia.

This decision to utilise single-axis trackers was made because:

- The particular split between diffuse and direct irradiation in Australia maximises the efficiency of the tracking systems.
- The use of tracking systems matches the grid energy load profile much better than fixed tilt systems and therefore maximizes the value of the plant in terms of the stability of grid and the value to any potential offtaker.

There are various types of tracking systems on the market. Two varieties are single-axis and dual-axis tracking. With dual-axis tracking, the system always maintains an optimum alignment to the sun. However, dual-axis tracking tends to be more technically complicated compared to single-axis tracking. Single-axis tracking simplifies the mechanical design whilst maintaining proportionally high energy gains. However, it is important to understand the tracking supplier's drive system and control functions to assess the likelihood that tracking components will fail and reduce the solar farm's energy yield. The single-axis trackers used at Moree Solar Farm track the sun's daily path from east to west.

An onsite meteorological (weather) station was installed on the Moree Solar Farm site, which included the following equipment:

- Pyranometer for measuring global horizontal irradiation (GHI) and/or diffuse horizontal radiation (DHI) conforming to ISO Secondary Standard class.
- Pyrheliometer and solar tracker for measuring direct normal irradiance (DNI) conforming to ISO First Class standard.
- Calibrated reference cell for measuring irradiation from a fixed plane.
- Anemometer and wind vane for measuring the wind direction and speed.
- Temperature and humidity sensor.
- Precipitation gauge for measuring rainfall.

Dataloggers at the weather station record the maximum, minimum and average values at 1 minute intervals. These recorded measurements were then correlated against a mix of spatially derived long-term datasets (including the Australian Bureau of Meteorology and Geomodel Solar) to allow a credible production assessment to be calculated for the solar farm.

Key lessons learned:

- *Meteorological data* – longer-term site data, that has a high level of accuracy as determined under the ISO Class standard, is critical for understanding the available solar resource, particularly for solar tracking applications. In addition, reference datasets for correlating site data need to have good temporal coverage as well as spatial resolution. Ultimately a high level of confidence is required to correlate site derived data with longer-term meteorological data.
- *Ongoing costs* – tracking systems are more complex to build than fixed structures and involve higher ongoing costs due to maintenance and replacement of components.
- *Site inclination* – tracking systems require much flatter sites than fixed structures (generally < 5° slope). It is important to bear this in mind when selecting a site for a solar farm project considering the use of tracking. In addition, the mounting structure for the tracking system needs to be suitably elevated if the project site is prone to flooding, as is the case for Moree.

Inverter

One of the most critical parts of the solar farm is the inverter. Inverters are power electronic devices that are directly connected to the PV array (on the DC side) and to the electrical grid (on the AC side).

Inverter efficiency and power quality (e.g. harmonic current distortion and power factor) play an important part in determining the maximum allowable transfer of capacity to the grid. Compared to Europe and the United States, Australia's vast size and low population density means that locations with good solar resource tend to be on the end of long, skinny electricity lines, or in a location on the electricity network that has a high impedance (or resistance / reactance). This means that harmonic current distortion, created in the DC-AC conversions of inverters, can be amplified in rural location compared to stronger networks.

Inverters also play an important role in protecting both the solar farm and the grid from electrical faults and network instability. As Moree Solar Farm covers an area nearly 300 hectares in size, AC power is normally stepped up from around 400V to a medium voltage (e.g. 11kV, 22kV, 33kV, etc.) using step-up transformers to minimise the losses through electrical conductors. Moree Solar Farm uses a number of power blocks that integrate the inverter, step-up transformer and power protection in the same enclosure.

Key lessons learned:

- *Harmonic current distortion* – It is important to analyse and design the solar farm such that the level of harmonic current distortion does not exceed relevant standards or the requirements of the network service provider.
- *Integrating inverters with transformers* – Utilising a number of power blocks that integrate the inverter, step-up transformer and power protection in the same enclosure allows for components to be factory assembled and provide for quicker installation and better quality control.

5. GRID-CONNECTION

Moree Solar Farm will connect to the 66kV Moree distribution network approximately 12km south of the Moree township. The grid-connection activities fall into two main categories:

- The physical connection arrangement and construction of electrical infrastructure.
- The grid-connection studies demonstrating that the solar farm will not have an adverse impact on the network stability or system security.

Physical connection arrangement

Moree Solar Farm will connect to the Moree distribution network by cutting into and extending an existing 66kV sub-transmission line by approximately 4km to connect the solar farm (otherwise known as a 'loop-in' connection). This requires a new switching station to be constructed within the boundaries of the Moree Solar Farm, which will be operated and maintained by the Distribution Network Service Provider, Essential Energy.

The existing 66kV sub-transmission line will have to be upgraded to allow for the additional capacity of the solar farm, between the cut-in point and the existing Moree substation.

Aside from the chosen option, an earlier option that was considered involved the construction of a new 132kV line from the solar farm site to the Moree substation. This option was originally considered when the project was conceptualised as a much larger (150MWac) facility, prior to finally selecting the optimal size of 56MWac.

Key lessons learned:

- *Extending existing infrastructure* - utilising existing electricity infrastructure saves in the amount of new infrastructure that needs to be constructed and reduces the environmental and visual impacts of these works.

Grid-connection studies

Owing to the large capacity of the solar farm to generate power within the Moree distribution network, numerous grid-connection studies were carried out in accordance with the National Electricity Rules to evaluate whether the solar farm would have an adverse impact on network stability and system security.

A critical component of the grid-connection study was the development of a reactive power control strategy (or voltage control strategy) that ensured that the network was not stressed by intermittent solar generation (e.g. fast moving cloud cover). This was particularly pertinent in a distribution network that stretched large distances with long, skinny (high impedance) distribution lines.

Moree Solar Farm will be one of the first solar farms to be connected to the Australian Solar Energy Forecasting System (ASEFS) being developed by the Australian Energy Market Operator (AEMO) with support from ARENA. The system will allow AEMO to forecast generation from large-scale solar farms with timeframes ranging from 5 minutes to 2 years.

Moree Solar Farm engaged with the Network Service Provider early to develop the reactive power control strategy and met frequently to determine the best reactive power control strategy for both the solar farm and the network.

Key lessons learned:

- *Reactive power control strategy* – understanding the electricity network being used to connect the solar farm is crucial to understanding the challenges associated with grid-connection.
- Grid-connection studies should be undertaken early to look at the performance of the network with and without the generator to determine the pre-existing network characteristics and help develop strategies for the solar farm.

Regulatory Framework for connection of Generators

The current regulatory framework for connection of Generators provides little incentive or penalty for Network Service Providers to complete the connection process in a timely manner or with any consideration of the project program. Time is critical in many projects, as has been the case for the Moree Solar Farm. As a result of the positive engagement with the NSW Government and in support from its Renewable Energy Advocate and the NSP's Connection Manager, the Moree Solar Farm has been able to meet deadlines for the project's success in most areas. In other areas, such as design and costing of NSP non-contestable works, Moree Solar Farm has been forced to take risk which has resulted in financiers needing to make otherwise avoidable contingency allowances.

Embedded Generators, such as solar farms, have the potential to provide support to the grid, particularly in remote areas where the grid is susceptible to fluctuations. However, the regulatory framework for providing grid-support can be lengthy and give little certainty to solar farms regarding availability of revenue that can be attributed to the project for these services. For this reason, many generators are reluctant to engage in the grid-support process while developing projects. However, once projects are committed, grid-support mechanisms can then be pursued.

It should be noted that whilst NSPs have an obligation to explore options other than network augmentation, their requests for proposals are done at points in time determined by them, are very specific on the amount, timing, and duration of the support required and to date NSPs have been reluctant to consider non-compliant proposals. Regulatory reform in this area could be used to encourage network operators to be more innovative in this area.

Key lessons learned:

- Improvements within Chapter 5 of the National Electricity Rules to include mandatory times for Generator Connection steps, including costing of non-contestable works, would provide greater certainty to project financiers and accelerate project development, thus allowing faster deployment of renewable energy.

6. MARGINAL LOSS FACTOR (MLF) AND DISTRIBUTION LOSS FACTOR (DLF)

One of the most important parts of the early development stages of the project was to choose the ideal project size given the location and the point of connection where the project was to be connected. The objective was to ensure that electrical losses within the electricity network were balanced against having a project size with attractive economies of scale.

Losses within the National Electricity Market (NEM) comprise the Marginal Loss Factor (MLF) and the Distribution Loss Factor (DLF), which are largely dependent on the following aspects:

- Magnitude and time during the day that power is produced by the solar farm.
- Coincidence of loads and energy consumed within the network.
- Coincidence of power produced by other generators within the network.
- Proximity of loads and other generators to the solar farm and efficiency of the grid to transfer power flows.

The MLF and DLF have a direct impact on the energy that the solar farm will be able to sell in the NEM and therefore influence the project's revenues.

For this project, Moree Solar Farm chose a top tier consulting firm to undertake a detailed analysis of these factors and assess the potential MLF and DLF for different PV plant sizes. The outcome of the study was that the optimal size of the PV plant should be 56MWac.

The original 150MW project size was selected to meet the specific requirement of the Solar Flagships program, which required a minimum project size of 150MW. At the time of Solar Flagships, various State governments were also offering funding support to projects participating in the Solar Flagships program. NSW in particular indicated support for projects of 150MW within NSW and decreased support smaller projects. This pushed the original project development leader to propose a 150MW project within NSW. Unfortunately, sites with sufficient capacity within the grid were limited. The original consultant that was engaged to provide a MLF assessment of the 150MW project indicated lower losses than were eventually identified by another consultant for the 150MW project, providing significant but not insurmountable commercial pressures on the project economics. Once the project was no longer constrained by a minimum project size, its size could be optimised. MLF and DLF need to be calculated and reviewed each year to take into account variations in loads, generation and other changes within the NEM. It is important to take into account load forecasts and other expected changes within the NEM when considering the financial performance of the solar farm through its project life.

Key lessons learned:

- It is important to engage a top tier consultant that specialises in assessing MLF and DLF in the early stages of the project in order to choose the right project size for the solar farm.
- When undertaking load forecasts and analysing other expected changes in the National Electricity Market it is important to perform a sensitivity analysis to ensure future project revenues can be reasonably assured.

7. PROJECT FINANCE

An innovative aspect of the Moree Solar Farm is that it will be the one of the first renewable energy projects in Australia that will sell the energy and green certificates generated by the project on the wholesale "spot" market. This is otherwise known as a "merchant" arrangement. Most renewable energy projects in Australia operate under a Power Purchasing Agreement (PPA), which is where a buyer (typically an electricity retailer or large user) pays a guaranteed price for the energy and/or green certificates for a defined period of time.

Compared with the merchant arrangement, the PPA model provides greater certainty to project proponents that expected project revenues can be achieved, since those revenues are not exposed to variability in market prices. However, obtaining a long term PPA proved to be challenging in the current market environment. Added to the relative lack of experience in Australia with the financing of utility-scale PV plants in general, financing the project on a merchant basis was an added challenge for the commercial debt market. The commercial debt market's appetite for funding "non-standard" projects of this type is low – both domestically and internationally. Therefore, the support provided by public funding through an ARENA grant and public financing through a loan from the Clean Energy Finance Corporation (CEFC) has been fundamental for the successful development of the Moree Solar Farm.

This highlights the potential for project developers to identify and execute more innovative project structures. Originally, the Solar Flagships program and subsequent ARENA program required a PPA in order to be eligible for government funding. However, ultimately, a flexible solution was found for this project and the project was able to proceed on a merchant basis.

ARENA's long term support and commitment to the project has been the key facilitator to assist the sponsors in attracting other sources of funding for its development. ARENA's support has served several functions:

- Providing a foundation for the development of an appropriate overall financing structure for the asset.
- Providing flexibility to adapt in accordance with the changing market and regulatory environment.
- Providing flexibility over time to actively consider the requirements of potential commercial lenders and from the perspective of the CEFC.

The existence of open and fluid channels of communication between MSF and ARENA, accompanied by ARENA's knowledge of the project, has made this process possible. An open attitude towards the many challenges associated with the development and financing of an asset of this nature, and a constructive and creative approach to finding solutions to overcome those challenges has been a key element to the success of Moree Solar Farm from a financing point of view.

The experience in financing the Moree Solar Farm has proven that despite the challenges identified, the associated risks can be dealt with by introducing innovative debt structuring mechanisms and the efficient allocation of those risks among project stakeholders. In a nutshell, any risk affecting the project that can be adequately and objectively assessed and measured can also be allocated, managed and priced.

Further, it is expected that as the local commercial debt market becomes more familiar with solar PV technology and the construction and operations risk profile of large-scale solar PV assets that the financing conditions and volume of available commercial funding will improve.

During the due diligence process, lenders rely on their specialist technical advisors to provide expert advice on the appropriateness of various project assumptions – for example, solar irradiation levels. While there are no specific requirements on which those specialist advisors base their assessment, and each case is somewhat unique, in most cases great similarities exist across projects. For example, while there is no fixed minimum resource data period for solar irradiation, it is the quality of data collected and available to be verified from other sources that is important. The more data provided for review by the technical advisor, the better the correlation that can be made between the data collected on the project site and the long term data available from other sources.

Key lessons learned:

- Public funding support from ARENA has been critical to underpinning the financing of Moree Solar Farm in a challenging market environment
- Despite the fact that Moree Solar Farm is being financed as a merchant asset, government backed debt financing has still been achievable through innovative debt structuring and risk allocation
- As the commercial debt market gains experience with solar PV technology and local contractors gain experience in delivering large scale PV plants, the appetite for financing such projects will increase and the associated costs of finance will fall

Electricity market modelling

Given that MSF is selling the electricity and green certificates (Large-scale Generation Certificates, or LGCs) on a merchant basis, a detailed analysis of electricity and LGC prices was required in order to understand the revenue outlook for the project. For this purpose, a leading Australian consultancy firm was chosen to undertake the energy sector modelling, as part of the package of advice provided to the financiers and sponsors of the project.

In the current market environment, it was challenging to select the right combination of assumptions to underpin the scenarios under which the modelling exercise was to be conducted. The challenges included:

- The change in Government at the end of 2013 and potential change in energy policy.
- The Renewable Energy Target (RET) review that was subsequently announced.
- The need for projecting energy demand and price forecasts out 30 years (for the life of the project).

The financiers and the sponsors took a view around what the base case for the modelling exercise should be and also performed certain sensitivities around this. As part of this analysis, it was shown that the project could break even with a conservative minimum electricity price which would allow the project to repay its debt, even when assuming no revenues from the sale of green certificates (LGCs).

Key lessons learned:

- Choose a top tier advisor to perform the market analysis.
- Working with the financiers and the advisor, carefully choose appropriate assumptions for the modelling exercise.
- Perform a sensitivity analysis including a ‘break even’ price test to see whether the electricity + LGC price needed to repay the debt is at a reasonable level.

8. SELECTION OF AN EPC CONTRACTOR

Moree Solar Farm conducted a Request for Proposal (RFP) process for the engineering, procurement and construction (EPC) contract under which the project will be built, inviting suitably qualified local and international parties to submit bids based on a detailed tender specification and basic design. These bids were assessed and a small number of bidders shortlisted for detailed analysis and tender clarification, based on a broad assessment of the capability and track record of the bidder or consortium as well as the economics of the proposal. The bidders’ performance history in terms of health and safety and community aspects was also a key consideration.

A preferred bidder was eventually appointed and MSF worked closely with this bidder to negotiate and document detailed EPC contract terms, agree timeframes and provide the information necessary for due diligence processes.

A number of the bidders were consortiums of experienced international PV contractors in partnership with local subcontractors for civil and electrical works. A key consideration in the assessment of these bids was the interface between the various parties in the consortium as well as their individual experience and capabilities. An understanding of the local labour market, local regulation and construction practices was deemed essential for a consortium, alongside experience in delivery of plants of similar technology.

Early engagement with the lender's technical due diligence advisor proved valuable. By keeping the advisor informed of developments, equipment suppliers under consideration and areas of concern the advisor was able to undertake background work and ensure they received the information they needed to provide firm recommendations to lenders on a timely basis.

A similar approach was taken to final selection of equipment suppliers. EPC contractors are generally only to obtain optimum pricing and terms of suppliers once they have a committed project. Given that dynamic, the documents and due diligence processes were structured to allow final selection of suppliers (from an approved short list) to take place at a relatively late stage in the process. This ensured that the short-listed contractor was able to obtain good commercial terms and certainty of delivery schedule for key components. This was important for keeping down the overall project costs, because the key technology components make up roughly 50% of the total costs as per the following rough breakdown:

- PV modules: around 30% of the total EPC price
- Inverters: around 10% of the total EPC price
- Tracking system: around 10% of the total EPC price

As project funding was provided by both ARENA and the CEFC, there are federal OHS accreditation requirements that have to be met before either of those financiers can fund works. Early engagement and constructive discussion between ARENA, the CEFC, the developer of Moree Solar Farm and the shortlisted contractor ensured that all parties' expectations and approach to meeting the legislative requirement were clear and agreed.

Large capital value projects, particularly those supported by government or debt providers are very mindful to ensure risks are allocated away from the project, this generally means that "turn-key" construction contracts must be entered into, with that turn-key contractor left to optimise equipment on contractor sub-contracts.

The experience in developing the Moree Solar Farm confirms that retaining flexibility in the selection of the technology provider and the construction company until relatively late in the process helps to reduce project costs. Often, government programs can require or assess more favourably the inclusion of a specific technology provider and / or construction company as part of the initial project proposal, as was the case for the Solar Flagships program. While the intended outcome of this approach is to further de-risk the project, this can result in less efficient outcomes as developers are unable to utilise competitive tension in the selection of providers. The flexibility ultimately allowed by ARENA in this respect helped to minimise the overall project costs for Moree Solar Farm.

Key lessons learned:

- Ensure that the contractor or consortium has an appropriate mix of local knowledge and PV-specific experience.
- Involve the technical due diligence adviser early in the process to address any queries or concerns upfront.
- Build flexibility into project documentation and due diligence arrangements to assist the contractor with their supplier negotiations.
- Ensure all parties are clear on any legislative requirements relating to project stakeholders that need to be met.
- Allowing project proponents and contractors the flexibility to deliver the project in an efficient and competitive way can result in a better result for all project stakeholders (for example, via less restrictive funding requirements relating to pre-selection of providers).