CO-LOCATION OF LARGE SCALE WIND AND SOLAR FARMS

Learnings from Gullen Solar Farm Development and Construction

This report was prepared by
BJCE Australia for Gullen Solar Pty Ltd

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BJCE

GULLEN SOLAR FARM

This report has been prepared by BJCE Australia for the Australian Renewable Energy Agency (ARENA).

Selected text has been redacted for distribution to the public due to it being commercially sensitive.

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[SOME TABLES AND FIGURES HAVE BEEN REDACTED FROM PUBLIC VERSION]

*Location plan extracted from NGH prepared Statement of Environmental Effects

1 *Definitions*

- AEMO – Australian Energy Market Operator
- ARENA – Australian Renewable Energy Agency
- ASEFS – Australian Solar Energy Forecasting System
- AWEFS – Australian Wind Energy Forecasting System
- DA - Development Application
- DBJV – Decmil Balance Joint Venture (the EPC Contractor)
- DPIE – NSW Department of Planning, Industry and Environment
- EPC – Engineer Procure Construct
- GHI – Global Horizontal Incident Irradiation
- GPS – Generator Performance Standards
- GRWF – Gullen Range Wind Farm
- GSF – Gullen Solar Farm
- ULSC – Upper Lachlan Shire Council
- JRPP – Joint Regional Planning Panel, Southern Region
- MLF – Marginal Loss Factor
- NER – National Electricity Rules
- NGRWF – New Gullen Range Wind Farm Pty Ltd, the owners of Gullen Range Wind Farm
- NSP – Network Service Provider
- OEM – Original Equipment Manufacturer
- PLC – Programmable Logic Controller
- PPA – Power Purchase Agreement
- WOM – Warranty, Operations and Maintenance

2 Executive Summary

Gullen Solar Farm (GSF) is a 10MW AC (13.154 MW DC) solar farm, co-located with the Gullen Range Wind Farm (GRWF) in the Southern Highlands of NSW. GRWF was constructed from 2013 to 2014. GSF connects to the electricity grid through the GRWF 33/330kV substation. Both GSF and GRWF are owned by Beijing Jingneng Clean Energy (Australia) Pty Ltd (BJCE Australia). BJCE Australia purchased GSF from Goldwind Capital (Australia) Pty Ltd in 2016. The project was developed to the point in time where Development Approval was obtained by Goldwind Australia, after which development was managed by BJCE Australia.

GSF was identified for a $9.9 million grant from the Australian Renewable Energy Agency (ARENA) in 2014. The grant was provided to assist in demonstrating the benefits of co-locating large scale solar generation with existing wind farms, particularly utilising existing wind farm infrastructure, connection to the electricity network and stakeholder relationships to reduce construction and operational costs. ARENA Financial Close was achieved in July 2016.

The GSF has been operational since September 2018. Operation was initially at a reduced capacity of 9.17MW, due to AEMO concerns with National Electricity Rules (NER) compliance of the project's solar inverters. Operation at 10MW was achieved in August 2018.

A Development Application (DA) for the GSF was submitted on 17th December 2015 to the Upper Lachlan Shire Council (ULSC) under Part 4 of the Environment Planning and Assessment (EP&A) Act 1979 (ref 7/2016). The development application was determined by the Joint Regional Planning Panel – Southern Region (JRPP). A lesson was learnt that the JRPP requires more detailed project design information in comparison to a State Significant Development determined by the NSW Department of Planning, Industry and Environment (DPIE). This requirement has consequences including a reduced ability to find efficiencies in design and difficulties with design and construct contracting.

The project was constructed under an EPC design and construct contract by Decmil Balance Joint Venture. First generation was within the schedule required by ARENA, but two weeks later than specified in the EPC contract, due to delays with AEMO registration. First generation was achieved on 1st September 2017.

Lessons learnt during construction regarding co-location of large-scale renewable technologies included:

- It can be difficult to arrange revenue metering for co-located sites, where two generators sit behind one Network Service Provider (NSP) connection point.
- AEMO is currently not able to send separate dispatch limits to co-located plant, that is, at Gullen Range, separate solar farm and wind farm dispatch limits cannot be provided. This has implications for compliance with Generator Performance Standards (GPS) and requires consideration when designing plant control systems.
- There are cost savings associated with modifying existing plant SCADA systems to monitor and control the solar farm. However, these are non-standard modifications which can be complicated to arrange.
- Attention needs to be given to interfaces between the EPC and operations and maintenance contracts for existing plant, and how they will be affected by construction and operation of the new plant to be co-located.
- AEMO requires individual generating units to be NER compliant, meaning that each co-located technology cannot be used to compensate for deficiencies in the other technology. This reduces some of the potential cost advantages of co-location.

Debt for the project was financed using the free cash flows of the existing GRWF as a guarantee. The use of common financiers across the co-located plant and the existing plant is recommended, as existing project financiers will be risk averse to the co-located plant if they are not benefiting.

High level analysis on interaction between solar farm and wind farm generation was undertaken. Further analysis will be performed in the subsequent Knowledge Sharing report before conclusions can be made regarding the solar farm's influence on the existing wind farm's generation intermittency.

[TEXT REDACTED FROM PUBLIC REPORT VERSION]

The average settlement price has exceeded that forecast at ARENA Financial Close, but has been predominantly below the Average Regional Reference Price (RRP) published by AEMO for NSW.

Community consultation was undertaken regarding the location of the solar farm. This resulted in the solar farm being relocated prior to a Development Application being submitted, with certain environmental and archaeological assessments having to be repeated. However, this empowerment of the local community was a large factor in the project being well supported by the community throughout construction and operation. Ongoing engagement includes free tours of the solar farm undertaken in coordination with the ULSC.

Co-location of the GSF with the existing GRWF resulted in grid connection cost savings of approximately $4.5 million.

3 Introduction and Background

Gullen Solar Farm (GSF) is a 10MW AC (13.154 MW DC) solar farm, co-located with the Gullen Range Wind Farm (GRWF) in the Southern Highlands of NSW.

GRWF is owned by New Gullen Range Wind Farm Pty Ltd (NGRWF). Beijing Jingneng Clean Energy (Australia) Pty Ltd (BJCE Australia) has been the majority shareholder of NGRWF since 2014.

GSF is owned by Gullen Solar Farm Pty Ltd. During the development phase Gullen Solar Farm Pty Ltd was owned by Goldwind Capital (Australia) Pty Ltd and Goldwind Australia developed the project up until the point in time where a Development Approval had been granted. Soon after that date, Gullen Solar Farm Pty Ltd was sold to BJCE Australia. BJCE Australia is therefore the controlling shareholder of GRWF and GSF. This Knowledge Sharing Report has been prepared by BCJE Australia for Gullen Solar Pty Ltd and ARENA.

GSF was identified for funding from the Australian Renewable Energy Agency (ARENA) under the Advancing Renewables Program in 2014. ARENA provided $9.9 million of grant funding to the project under this program. The grant was provided to assist in demonstrating the benefits of co-locating large scale solar generation with existing wind farms, particularly utilising existing wind farm infrastructure, connection to the electricity network and stakeholder relationships to reduce construction and operational costs. Financial Close under the Arena Funding Agreement was achieved on 15th July 2016.

The project was constructed under an Engineer Procure Construct (EPC) contract by Decmil Balance Joint Venture. The contract was executed in September 2016. On-site works began in December 2016 and the plant was commissioned in August 2017 with first energy exported on September 1st 2017 at a reduced peak capacity of 9.17MW AC. The capacity was reduced initially while discussions occurred with AEMO regarding performance of the project's solar inverters and their compliance with the National Electricity Rules (NER). The plant's output was increased to 10MW in August 2018 after minor retrofits to the inverters had occurred.

GSF is located on land owned by Gullen Solar Farm Pty Ltd. Access from the public road is via a Crown Road. A location plan is attached in Appendix A. The solar farm connects to the electricity grid via the existing substation at GRWF. A single underground 33kV circuit is connected to an existing set of switchgear on the wind farm's 33kV switchboard. It shares the wind farm Operations and Maintenance building, including staff welfare facilities.

4 Development Approval Process

4.1 Overview of the Process

A Scoping Document for the GSF was compiled in 2014 and amongst other things, considered the potential assessment and approval pathways for the project. On the basis of a project capital cost of $25 to $30 million the Scoping Document stated that the proposal could be constructed and operated under Part 4 of the EP&A Act 1979 (EP&A Act). Furthermore, it stated that being private infrastructure with a capital cost of over $5 million, it would be deemed Regional Development under the provisions of Part 4 Clause 20 of the State Environmental Planning Policy (State and Regional Development) 2011. While it would have been possible to marginally increase the scale of the project and associated capital value to have the project determined by the NSW Department of Planning and Environment (now NSW Department of Planning, Industry and Environment) (DPIE), Goldwind Australia considered that determination by local government gave the opportunity for a local decision rather than the possibility of what could be regarded by local stakeholders as a State imposed decision. Nevertheless, in making that choice, it was recognised that local decisions may not place the same weight on National and State targets for sustainable energy development as would a decision by DPIE.

Based on the provisions of the EP&A Act and strategic considerations for local government decision making, it was identified that a development application would be required to be submitted to Upper Lachlan Shire Council and the final determination of the application would be made by the Joint Regional Planning Panel – Southern Region (JRPP). That process resulted in approval being granted in June 2016.

The initial GSF site that was referenced by the Scoping Document was subject to comprehensive environmental assessment and community consultation. The program of community consultation identified community concerns with the initial site selection and alternative locations were subsequently considered. An alternative site was identified with reduced community concerns. It was then subject to further design studies, site assessments and community consultation. The outcomes of these investigations formed the basis of a development application for the preferred site. The change in site location resulted in delays to submission of the application, but this was offset by greater community support.

A development application (DA) in respect of the alternative site was subsequently submitted on 17th December 2015 to the Upper Lachlan Shire Council (ULSC) under Part 4 of the Environment Planning and Assessment (EP&A) Act 1979 (ref 7/2016). The DA was advertised and referred to specific government agencies for comment.

As part of the DA review process by ULSC, supplementary information was provided to ULSC in response to their specific requests, some relating to agency requests.

Council referred the DA to the JRPP on 28th January 2016. Upper Lachlan Council prepared an assessment report which was published on 31st March 2016. The report recommended the development application was approved, subject to conditions of consent.

An initial meeting of the JRPP on 12th April 2016 deferred the decision on determination of the DA and requested Goldwind Australia prepare further detailed information regarding the proposed development, such as the exact, size, location and layout of the PV panels.

Goldwind Australia had been in the process of tendering the EPC design and construct contract for the project at this time. A preferred tenderer had been selected and they had performed a greater than normal level of design work in comparison to market norms for a project that had not yet received

development approval. This was fortuitous and meant the increased detail requested by the JRPP could be quickly provided to ULSC and the JRPP. On the basis of the additional information submitted, a supplementary assessment report was prepared by ULSC. It was published on 9th June 2016 and again recommended approval subject to conditions. A subsequent meeting of the JRPP was arranged for 22nd June 2016 and the development application was granted approval at that meeting.

4.2 Summary of Factors Impacting Efficiency, Risk and Cost

Although GSF did not trigger criteria to be State Significant, it was quite different in comparison to those previously determined by the JRPP. It was evident in the determination process that whilst experienced in determining development applications, the JRPP did not have experience with development applications for large-scale renewable energy projects. Goldwind Australia utilised a reputable consultant to prepare the development application for the project. The application was prepared to a similar level of detail as required for State Significant projects being determined by the DPIE. However, it became apparent during the determination of GSF that the JRPP had a greater requirement for detailed design information than required by the DPIE. In the case of GSF, this design information was available and could be provided, however, this approach had subsequent effects for the project and has repercussions for other similar sized projects in NSW.

In Australia, it is generally agreed that the most efficient way to deliver a project is through large design and construct contracts. The contractors who win such contracts are generally experts in their field, moving from construction of one solar farm to another. They are able to integrate their knowledge from construction into the design process for a solar farm. They can holistically consider available technology, available materials, available plant and equipment and site-specific conditions to come up with the most efficient design for a particular solar farm. However, in order for this approach to work, the contractor needs to have freedom to iterate the design to find the efficiencies.

These contracts are normally a lump sum construction cost. A typical tendering process involves inviting three or four of these expert companies to provide their lump sum cost, a construction program and a predicted electrical output for the solar farm. They are given six to eight weeks to tender. Tendering costs are high. The tenderer needs to visit the site and complete a high level of design work, in order to be able to determine the lump sum cost and predicted output of the plant. If they win the tender, they will be bound to the cost and the performance of the plant through the terms of the contract, so they need to do a thorough job at tender stage.

In a busy renewable energy market, these companies need to be sure they are tendering on projects that will be built. It does not make good business sense to spend significant time and money on tendering for a project that may not go ahead. One of the key risks to a project going ahead is whether it has been granted a Development Approval or not.

The high level of design information requested by the JRPP prevents efficient design and construct contracting and is therefore likely to increase the cost of delivering renewable energy projects. Developers are forced to fix most elements of the design, potentially before an EPC tender has been undertaken, leaving these expert construction companies with less ability to find efficiencies. Developers are also forced to engage expensive designers to prepare these designs. It is difficult for developers to fund such designs ahead of a Development Approval, as risk in the project is high and therefore the cost of borrowing money to undertake this work is also high. A good design requires extensive intrusive geological survey work. This is expensive and it is also illogical to perform such intrusive work (digging trial pits and drilling boreholes) when a Development Approval has not been granted.

GSF was in a slightly different position to that described above, because an EPC tender had been undertaken. This was due to timescales for ARENA Financial Close required for securing the grant funding. It was possible because the renewable energy construction market was not as busy in 2016 as it is now and there were more companies willing to put time into tendering.

Goldwind Australia provided the design of the preferred tenderer to the JRPP. Although this ultimately satisfied the JRPP, it led to further risks in procurement. When granted, the Development Approval only allowed one tenderers design to be built. A developer cannot easily sign an EPC Contract with no development approval, the risk of the project proceeding is too high. However, with only one tenderer's design approved and little flexibility to modify the development approval, there is a substantial loss in contractual leverage, both between the developer and the EPC Contractor and the EPC Contractor and its subcontractors. This can lead to a higher project cost, either due to increased margins or because there are legitimate price increases with no flexibility to adjust the design to avoid them.

Solar farms are particularly susceptible to this issue due to the extent that the different elements of a solar farm interact. For instance, the choice of solar panel and the way the panels interact with the inverters changes the layout of the blocks of solar panels in the array. If the layout of the blocks has been specified, it may not be possible to change the panel type or the inverter.

In contrast to determination of a State Significant Development by the DPIE, the JRPP process is a more detached process. The DPIE remains in close contact with applicants for developments it is determining. In that way, they ensure that the information being provided by applicants includes the information they need to be able to determine the application and that conditions applied to the development approval achieve the goal they are designed to with the least impact possible to the project. The JRPP did not use such an iterative approach when determining GSF. They could not be approached to discuss information submitted and what might be necessary in the future. Conditions of consent were provided by local council and they were modified by the JRPP with very limited consultation. Changes to the conditions were briefly placed on a projector screen at the JRPP's public meeting and the developer was asked if there were any comments. Additionally, because the JRPP only sits on occasion, it is problematic to modify a Development Approval granted by JRPP, a factor compounded by the conditions of consent being quite prescriptive, those conditions being prepared with a comparatively lower level of consultation and a high level of design detail being annexed.

An example of this is the route of the export cable between the solar farm and the wind farm. A portion of the route passes down a steep rocky section. Trenching cables in rock is expensive, slower and noisier than in soil. Cables installed in steep terrain often have issues with water flows, potentially washing out bedding sand and causing premature cable failure. With the EPC Contract signed and a higher level of resource available from the contractor, it was apparent that minor micro-siting could avoid this steep section, within the bounds of areas previously subject to ecological survey. Unfortunately, ULSC (who administered the consent once approved) could not allow this micro-siting without a modification to the Development Approval by the JRPP, so the cable was installed over the steep rocky terrain. This is an example of inflexible planning conditions preventing the minimisation of impacts.

4.3 Opportunities for Improvement

While the JRPP certainly had reasons for requesting an elevated level of design detail, the industry and government needs to consider the most efficient way of constructing solar farms. The following points are provided for discussion:

1. Is the pathway through the JRPP the most appropriate one for renewable energy developments of the same scale as GSF?
2. Why does the JRPP need a greater level of design detail than that required by the DPIE for larger developments?
3. What is the information required to assess whether a development has acceptable impact and should be approved or declined? What is the correct balance between the information required at DA determination stage compared to the freedom allowed to designers to find efficiencies after a development approval has been granted?

From a Developer's perspective, one should carefully consider before committing to a development pathway involving the JRPP, allow additional time for the determination process, err on the side of providing more detail rather than less detail in the planning submission, attempt to engage with the JRPP throughout the submission and determination period and design a procurement process where an increased level of design detail is available for submission, even if that means a higher total project cost. Additional CAPEX should be allowed during modelling to allow for inflexible planning conditions.

5 Overview of the Construction Process

5.1 Summary

The project was constructed predominantly under an Engineer Procure Construct contract by Decmil Balance Joint Venture. The award of this contract was subsequent to a comprehensive tendering process. The contracted value of the EPC package was $19.2M. It was compulsory for tenderers to offer a Warranty, Operations and Maintenance (WOM) contract. The EPC contract was on normal market terms for renewable energy projects.

The project was constructed on budget within allowed contingencies. At financial close, a project contingency of 3.4% was allowed and at completion of construction 1.4% of this had been expended. First generation was achieved two weeks later than expected under the EPC Contract, due to complications during AEMO registration.

There were no lost time injuries.

5.2 Contract Structure

The conditions of the development consent included the requirement for significant public road works, being the widening and sealing of approximately 1.3km of existing unsealed public road. This work was to be completed prior to commencement of construction. In order to expedite the construction program, the work was contracted directly to Gullen Solar Pty Ltd, rather than through the EPC contract. This allowed the work to be commenced quickly, while final negotiations regarding the EPC contract terms could be completed. A reputable local contractor was utilised, which assisted with quickly obtaining council approvals, as that contractor was well versed with the ULSC's procedures. Interfaces between the public road work and the EPC contractor's work were carefully defined. The public road work was contracted under a modified Australian Standards Design and Construct contract (A4902), with the contractor ultimately responsible for satisfying the requirements of the relevant Development Approval Conditions of Consent.

Gullen Solar Pty Ltd also has a contract with New Gullen Range Wind Farm Pty Ltd for provision of a connection to the electricity grid. As the two companies have the same ultimate ownership, and the two projects are subject to finance from the same banks, this contract was straightforward.

Gullen Solar Pty Ltd contracted AECOM as an Owners Engineer for the project. In the spirit of finding efficiencies, AECOM's role was combined with the Independent Certifier role for ARENA. There was no separate banks engineer for the project, but the financiers were provided with the Owners Engineer's reporting. This was possible due to the financing methodology. The Owner's Engineer role was limited predominantly to design reviews, with site visits once during construction and at EPC practical completion.

Gullen Solar Pty Ltd contracted an Owner's Site Representative separately from the Owner's Engineer contract. This role was fulfilled by a specialist, who had performed the role on behalf of the owners of many wind farms and one previous solar farm. Having a full-time presence aided in filling gaps in the EPC Contractor's knowledge, particularly at Gullen Solar where the EPC contractor did not have large-scale solar experience. Although the Owner's Representative has very limited powers to direct the EPC Contractor, having an experienced person in this role to make suggestions for the EPC Contractor to consider is still invaluable.

5.3 EPC Contract Tendering

Tendering was conducted by Goldwind Australia prior to BJCE Australia's ownership. A scope of works for the EPC package was prepared by Aurecon and a form of contract by Norton Rose Fulbright. The

form of EPC contract was market standard for solar farms in 2016. Expressions of interest for the tender were made to ten contractors, with detailed bids requests from five of these. Goldwind Australia evaluated the bids and developed a shortlist of two potential contractors. One of these tenderers had built several solar farms in Australia, while the other was new to the large-scale solar market. There were several rounds of clarification before a preferred tenderer was announced. The preferred tenderer's design for the project was submitted to the JRPP in response to their request for further information whilst determining the project's Development Approval application (as described in detail in Section 4.2 of this report).

The request for tender allowed maximum flexibility to the tenderer to design within the site's constraints. An area of land of approximately 95 ha was made available to the tenderer, but it was the tender's responsibility to avoid constraints, such as archaeology, native vegetation and hollow bearing trees. A maximum AC installed capacity was specified, and the tenderer was responsible for ensuring the existing 33/330kV transformer that the electricity would pass through at GRWF would not be overloaded. Preliminary geotechnical information was provided, consisting of six trial pits, electrical and thermal resistivity testing, pile load testing and topographic survey information. Tenderers were encouraged to find the lowest cost of energy within the constraints. A major constraint to the layout was the Transgrid 330kV overhead connection line which traversed the site, roughly from South West to North East.

The two shortlisted tenderers found different ways of achieving this goal, although both proposed fixed panel systems rather than tracking, due to the terrain undulations. One tenderer used as much of the land as possible to install the maximum AC capacity with the largest possible distance between the panel rows. Panels were to be installed on both sides of the 330kV connection line. The other tenderer (Decmil Balance Joint Venture), achieved the lowest cost of energy by utilising the section of the site on one side of the connection line, which had a steeper north facing slope. The north facing slope allowed the spacing between the panel rows to be reduced. Only an AC capacity of 10MW was achieved, but the significantly smaller footprint and reduced complexity from not having the solar farm area split by the 330kV overhead line allowed a lower cost of energy to be achieved.

Goldwind Australia appointed Decmil Balance Joint Venture (DBJV) as the preferred tenderer. Gullen Solar Pty Ltd was purchased by NGRWF before the contract was executed. BJCE Australia completed contractual negotiations with DBJV and an EPC and WOM contract was executed 23rd September 2016.

5.4 EPC Construction Phase

Public roadworks were commenced in late September 2016 and were completed to the satisfaction of Council in December, which was approximately two weeks behind schedule.

Notice to Proceed was granted to the EPC Contractor 11th October 2016. On-site works began in late December 2016 and the plant was commissioned in August 2017 with first energy exported on September 1st 2017 at a reduced peak capacity of 9.17MW AC.

5.4.1 Construction Schedule and Delays

As required under the EPC Contract, DBJV provided an updated program soon after Notice to Proceed had been achieved.

DBJV underestimated the time required to obtain approvals from council in order to commence works, particularly in relation to Conditions of Consent requiring documentation to be reviewed or approved by the Office of Environmental Heritage and Water NSW. These conditions were DBJV's responsibility under the EPC Contract. Another of the Conditions of Consent required Gullen Solar to have an easement for the underground cable registered by NSW Land Registry Services prior to construction.

Registration is a lengthy process and issues with the plan of the easement delayed the process. This condition was Gullen Solar's responsibility. DBJV and Gullen Solar were successful in agreeing with council that some enabling works could be performed while the final conditions were discharged, which successfully mitigated these delays.

By March 2017 DBJV's reporting showed a 7% lag in progress on site. Delays to shipment of the PV modules and time spent finding efficiencies in the piling process contributed to this delay. However, by June 2017 this had been reduced to 3%. Mechanical and electrical completion sufficient to enable commissioning was subsequently achieved by the end of July, which was on schedule for a mid-August completion date.

Commissioning of the project was delayed due to delays in obtaining AEMO registration for the modified plant. As GSF is connected behind the meter to the GRWF, registration involved modifying the existing registration for the wind farm to include the solar farm. Although registrations have been updated when new plant is augmented (such as Capital solar farm), this was not a straightforward process for AEMO to navigate and took considerable time. Issues encountered included compliance with S5.2.5.4 of the NER, dispatch limit control of the co-located wind and solar farm and solar farm metering, which are all discussed further in Section 5.6 of this report.

Agreement was reached with AEMO to register the solar farm at a reduced capacity of 9.17MW AC in August 2017. First electricity export from the solar farm was achieved on 1st September 2017, with all inverters online and generating by 2nd September. This was two weeks later than the expected generation date under the EPC contract, but within the timescales expected for EPC completion in the ARENA Funding Agreement. The financial model expected generation to be in Q2 2017 although this was a modelling error, as the associated EPC payment for achieving generation was not modelled as payable until August 2017, consistent with the EPC contract.

Agreement with AEMO to lift the export capacity to 10MW was not reached until August 2018, with the plant first exporting at 10MW on 28th August. EPC completion was not possible until this had been achieved and it was subsequently awarded. The 9.17MW restriction to peak output equated to a theoretical reduction in annual generation of approximately 3%.

R2 testing was performed with negligible lost generation from the wind farm or solar farm. This was possible due to the solar farm's installed capacity being small in comparison to the wind farm's. No hold point testing was required of either the wind farm or the solar farm during commissioning.

5.5 Comparison of Actual and Forecast CAPEX

The project was delivered within budget, with approximately $510,795 of $850,000 allowed contingency remaining once all construction costs had been allowed for. The total project cost was $24,810,470 compared to a forecast without contingency of $24,471,367.

The major variations are as described below:

- Communications and commissioning – Additional server for the solar farm, when it was realised having a shared server between the solar farm and wind farm would not be manageable in terms of permissions. Provision of 4G communications to the solar farm meter which had not been adequately scoped in the EPC Contract.
- Insurance during construction – The construction period was longer than allowed for in the financial model and the initial cost of insurance was higher than modelled.
- Grid Connection and SCADA – With the benefit of hindsight, this item was not well estimated in the original Financial Model. Goldwind SCADA integration fees, while reasonable, were double this value. However, the Financial Model made no allowance for AEMO and Transgrid due diligence during registration and no allowance for the wind farm operations and maintenance contractor's time during connection and commissioning works.

5.6 *Complications arising from Co-location*

There were several observations made regarding the complications of installing the solar farm co-located with the wind farm. These are discussed in turn below.

5.6.1 *Revenue M*etering

Revenue metering of co-located facilities in the National Electricity Market (NEM) presents issues under the National Electricity Rules. Prior to BJCE Australia's purchase of the GSF, Goldwind Australia consulted with AEMO with regard to the principles of co-location.

Goldwind proposed to meter the solar farm at 33kV. That 33kV meter would be 'on-market', meaning it would be registered in the NEM. It is shown at location 1 in Figure 1.

It was important to ensure the two plants were accurately metered for revenue settlement. This was particularly important as the wind farm's output is subject to a power purchase agreement, while the solar farm trades its electricity on a merchant basis.

The wind farm's connection point is at 330kV. Behind that connection point there are two 90MVA 33/330kV transformers. The wind farm's seven 33kV feeders are split between these two transformers. The solar farm connects to one of those 33/330kv transformers through a spare set of 33kV switchgear on one of the wind farm's 33kV switchboards.

For revenue settlement purposes, the electricity generated by the solar farm at 33kV would need to be adjusted for losses between the 33kV meter and the 330kV connection point. During initial discussions with AEMO by Goldwind, AEMO were agreeable to the 33kV meter being NEM registered and the losses algorithm being applied as part of an 'on market' solution. Goldwind Australia commissioned a consultant to prepare a losses algorithm. Calculation of the losses was not straightforward, as the energy lost across the 33/330kV transformer is dependent on the load on that transformer, which relates to the output of the wind farm and the solar farm. Goldwind Australia wanted to avoid having to install a 330kV meter on the transformer (location 3 in Figure 1), as such a meter would be costly and difficult to install and would require wind farm downtime.

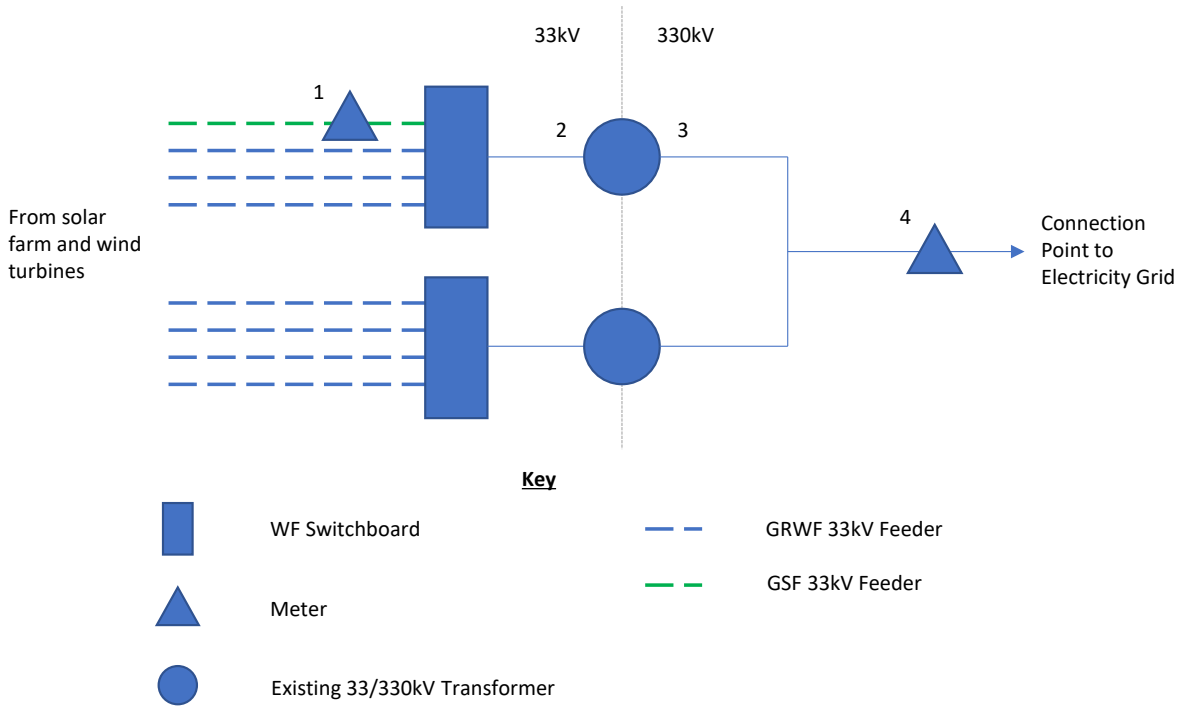

Figure 1 – Arrangement of Metering

During registration, it became apparent that AEMO was no longer supportive of this approach because it was not acceptable under the National Electricity Rules (NER). AEMO noted concerns with the complexity of the algorithm. AEMO concluded they would not register the solar farm meter 'on-market' within the NEM. At this point an alternate approach was taken to pursue an 'off-market' settlement approach for the solar farm meter. Plus ES (formerly Ausgrid) was engaged as the Meter Data Provider to design and implement a generation segregation algorithm between the wind farm and the solar farm, using the 33kV meter on the solar farm feeder.

The co-located plant is metered in the NEM as a hybrid plant at the 330kV connection point for the purposes of on-market settlement. Plus ES calculates the split of generation at the 330kV meter between the solar farm and the wind farm. An 'off-market' settlement is performed by New Gullen Range Wind Farm Pty Ltd and the solar farm revenue is transferred from the wind farm to the solar farm on a weekly basis.

Such an arrangement requires buy-in from any PPA providers. It was also possible in this instance as both GSF and GRWF have the same financiers, and GSF is not strictly project financed. If both the solar farm and wind farm were project financed by separate financiers, then there would be concerns regarding the revenue of the solar farm flowing to Gullen Solar Pty Ltd through NGRWF.

The issue of metering therefore needs to be carefully thought through at feasibility stage. A larger solar farm could have supported its own 33/330kV transformer and been metered at 330kV, however, this 330kV meter still may not be NEM registerable by AEMO without it being subject to a standalone Connection Agreement with the NSP. If AEMO require a separate connection point to the electricity network for each project meter, then the largest savings from co-location will not be realised.

5.6.2 Generator Dispatch

AEMO's internal systems are not currently capable of issuing combined dispatch limits for a co-located generator behind a shared connection point.

Discussions with AEMO by Goldwind Australia at feasibility stage and then during the registration process by BJCE Australia did not identify this constraint. Given both plants operate under one combined GPS at the connection point, it was expected that the co-located plant would be dispatched together with one set of combined dispatch points. Extensive negotiation with AEMO regarding the GPS had already occurred. However, late in the registration process, in May 2017, AEMO advised that they intended to send two separate sets of power dispatch signals to the co-located plant, one set to the solar farm, and one set to the wind farm. AEMO was resource constrained at the time, and separate teams were responsible for due diligence of the GPS compared to those responsible for the dispatch limits. Separate dispatch limits were an issue for the solar farm control, as the modifications being made to the wind farm's Power Plant Controller, in order to connect the solar farm, did not allow for the wind farm controller to accept two sets of dispatch points and pass one on to the solar farm.

Meetings were held with AEMO during June 2017 to discuss this issue. AEMO could not facilitate a combined dispatch limit for a combined wind and solar farm as their systems were not compatible. AEMO noted this was due to AWEFS (Australian Wind Energy Forecasting System) and ASEFS (Australian Solar Energy Forecasting System) being separate systems and the dispatch engine was incompatible with issuing a combined hybrid dispatch point. Co-location of different generation technologies was not envisaged when that software was developed. AEMO identified the need to improve their software, but acknowledged that this would take considerable time to achieve. A

solution was developed where the dispatch signals for the solar farm and the wind farm are managed using the wind farm control system. It will be possible for the plant to revert to the original single-dispatch design if AEMO's dispatch systems are updated with the required capability in future.

5.6.3 Generator Registration

The negotiations with TransGrid and AEMO to modify the wind farm's connection in order to add the solar farm were relatively straightforward from a co-location perspective. The GPS performance requirements were predominantly unchanged. It is important to note, however, that this modification was seen as relatively low risk given that the solar farm's installed capacity was small relative to the existing wind farm. It would be expected that this modification process would be more exhaustive if the additional plant had a larger capacity and was expected to have a greater impact on the existing connection. AEMO's due diligence requirements have also become more onerous since 2017.

The AEMO registration process required considerably more time than originally programmed. AEMO was very busy with the number of registration requests occurring. AEMO due diligence timeframes and work by their Onboarding team contributed to the longer than expected timeframes.

From a technical perspective, the largest project impact was not due to co-location, but rather the solar farm's ability to meet GPS clause s5.2.5.4 as discussed below.

If brownfield co-located generation facilities are to be attractive to developers, it is important that the existing facility is not exposed to risk during the registration and R2 testing process of the combined plant. Existing projects are a source of revenue and often limited by the requirements of project financiers. It is non-sensical that a generator, that is already exporting unrestricted to the electricity grid, would be constrained due to the incorporation of a co-located generator. If the combined plant or the co-located generator are found not to be NER or GPS compliant, it would seem an appropriate rectification measure to return to the situation where only the original generator was online, that is constrain the new plant being installed. To a certain extent on this co-located project, this situation was achieved, as there were no restrictive hold points applied to GRWF during R2 testing.

5.6.4 SCADA integration and control

In order to facilitate the addition of the solar farm, the existing wind farm SCADA and control systems were augmented.

One of the cost saving benefits of co-location is that the additional plant can share the existing control infrastructure rather than implement its own. The solar farm does not have its own bespoke power plant controller, but rather a simple PLC that is incorporated into the existing wind farm's control systems. This reduces the implementation costs, however it does create new interfaces that need to be managed.

A lesson learnt on the project is to put more focus on the SCADA and control systems augmentation in the development phase of the project to better forecast integration complexity, time and costs.

Although a standalone solar farm SCADA system was avoided, this approach required Goldwind to prepare bespoke functionality to the wind farm SCADA system. This functionality required coding by Goldwind in Beijing. This arrangement was already proposed by Goldwind Australia when BJCE Australia purchased the GSF, and Goldwind delivered on their commitment to provide this functionality. However, it would ordinarily be difficult and expensive to contract a wind turbine OEM, who has no financial interest in a solar farm to be co-located nearby to a wind farm they construct and maintain, to modify their SCADA system. It is important to think through this interface at feasibility stage. It may be a better compromise between risk and cost to install a stand-alone SCADA system for

the solar farm. Another solution would be to contract the wind turbine OEM to build the co-located solar farm, but this may limit competitiveness during tendering and is only possible if that OEM has the necessary capability in the area of solar farms.

There was only minor augmentation required to the existing SCADA for the substation. This SCADA system sits between Transgrid's SCADA system and the wind farm's SCADA system. It was adjusted to pass additional signals relating to the solar farm through to Transgrid.

5.6.5 Interfaces with existing operating plant

In the case of GSF, the EPC contractor (DBJV) on the solar farm construction was a different party to the Operations and Maintenance (WOM) contractor (Goldwind Australia) on the existing wind farm. This is likely to be the same for most co-located projects of this type. This creates operating interfaces that need to be closely managed.

The predominant interface between the two parties was regarding the grid connection of the solar farm into the existing wind farm substation. The construction activities within the solar farm project area were largely independent of the existing wind farm operations and did not raise interface issues, although design interface of the earthing grids between the two facilities did require careful consideration.

The existing substation is an operational facility for the wind farm and is subject to strict Goldwind Australia management procedures. Any works that DBJV proposed on the connection of the solar farm into the substation needed to be discussed, approved and permitted by Goldwind Australia. The main interface works included:

- trenching the solar farm cable close to existing wind farm cables,
- isolating the switchboard to allow connection of the solar farm cables, and
- arranging the switching program to safely energise the solar farm when ready.

It is important to clearly define these interfaces in the development phase and address them in the EPC contract. This should include:

- minimum time periods to request outages
- qualification and induction requirements to work within the substation, and
- requirements for regular interface meetings between both parties.

Co-location also requires careful consideration of interactions between the construction and operation and maintenance contracts for the new plant and the existing plant. For Gullen Solar, this means the interaction of the EPC design and construct, and the WOM contracts with the existing WOM contract at the wind farm. To avoid risk exposure, it is likely that the existing plant's WOM contract will need to be varied.

The following are examples of contractual interactions that may need to be considered:

1. Shared use of facilities, such as sharing office space. Who is responsible for increased costs such as maintenance and cleaning? Is the existing plant WOM contractor entitled to use all of the existing facility?
2. Ensuring definition around availability warranties is clear. For instance, what if the solar farm causes an outage of the wind farm?
3. In the case of Gullen Solar, the switchgear at the wind farm was pre-existing (and subject to a Defect Liability Period under the wind farm construction contract), but was used by the

solar farm EPC to connect the solar farm feeder. Who is responsible for maintenance and operation of that switch gear? What if it is not operated correctly?

4. Are warranties on existing major components affected. For instance, the solar farm transmits the electricity it generates through an existing 33/330kV transformer at GRWF. That transformer is more heavily loaded now than when it was procured.

Modification of the WOM contract for the existing plant may be difficult if the existing WOM contractor does not stand to benefit from the new co-located plant. If the new plant is subject to project finance then it's first two years of operation will likely be with the EPC contractor moving into the WOM contractor role, so there is no immediate opportunity for the existing plant WOM contractor to move into that role. Project financiers will also take a keen interest in any modifications to the existing plant WOM contract, especially if they are not standing to gain from the new plant being installed.

The importance of managing these interfaces was highlighted during connection of the new 33kV solar farm export cable to the existing GRWF switchboard. The GRWF has two 33kV switchboards. The seven windfarm 33kV feeders are split between these two switchboards. The solar farm connects to a spare 33kV set of switchgear on one of these two 33kV switchboard. During connection of the cable, this 33kV switchboard was disconnected from the 33/330kV transformer, by operating another set of switchgear. After the solar farm cable was connected and the wind farm was being restarted, that set of switchgear malfunctioned. The wind farm was unable to return to service. Due to the malfunction, specialist switching plans needed to be written. Approximately half of the wind farm was able to be returned to service at lunchtime the next day, with the remaining half energised the following morning. In total, 2249 of wind turbine outage hours was incurred, split across the wind farm's 73 turbines.

5.7 Other Construction Phase Lessons Learnt

5.7.1 Solar farm compliance with GPS clause s5.2.5.4

In the late stages of AEMO's review of the project's grid studies prior to registration approval, AEMO raised a concern with the solar farm's ability to comply with s5.2.5.4 of the GPS. This concern was specific to the solar farm, and not related to the wind farm.

Clause s5.2.5.4 requires that each individual generating unit making up a plant does not lose active power in response to a voltage disturbance at the connection point up to 10%, known as *continuous uninterrupted operation* under the NER's. GSF has four inverter stations, each classified as a separate generating unit by AEMO. Solar inverters operate such that they require an immediate current increase in response to a voltage drop in order to maintain active power. This effectively means that in order to meet this clause strictly, solar inverters must have extra 'headroom' in their capacity of up to 10%.

At the time that AEMO raised this concern, the solar farm construction was almost complete. The inverters were installed on site and ready for energisation which was expected within weeks. A decision was made, in consultation with AEMO, to register the solar component of the plant at a reduced capacity of 9.17MWac in order to energise and commence generating while a suitable solution could be found.

In consultation with TransGrid, AEMO, and SMA (inverter manufacturer) over the ensuing 12 months, a solution was found which involved retrofitting some components in the SMA inverters on site to increase the required headroom of the inverter. The plant was commissioned and tested again, and the plant was subsequently registered at its original designed capacity of 10MWac.

The NER's require that individual generating units must be NER compliant, as well as the entire plant behind the connection point. Therefore, co-location is not a way of using one renewable energy technology to compensate for deficiencies in another technology. Given that AEMO is sending separate dispatch limits to the solar farm and the wind farm (as discussed in Section 0 of this report), this makes some sense. It is at AEMO's discretion whether the wind farm is 'off' and the solar farm 'on', meaning that the solar farm must achieve NER compliance without the aid of the wind farm. However, it could be considered whether this is the most efficient way to build a robust electricity system.

Furthermore, as each individual solar inverter on a solar farm needs to meet clause s5.2.5.4A of the NER's, it was not possible to use an additional piece of plant, such as a battery or capacitor bank to meet this requirement. Retrofitting of the existing inverters, replacement of the inverters or installation of a fifth inverter (which would involve extensive re-cabling) were the only NER compliant rectification options to meet the headroom requirement. Replacement of the existing inverters, which were installed but not commissioned, would have had a considerable cost implication, but an even more significant impact on timeframes for commissioning due to the lead time on new inverters. It was fortunate SMA was able to find a retrofitting option that was workable.

5.7.2 PV panel specification

DBJV indicated in the early construction phase that Yingli (panel supplier) will supply a slightly different panel than originally specified at tender. Manufacturing of the panels commenced in early January 2017. The project commissioned an independent QA assessment on the panels in China at the manufacturing facility. This independent analysis assessed the panels are sufficient for the lifetime of the project. However, they were of slightly lower durability than that proposed during tender stage due to a reduced panel glass thickness.

These panels were supplied and installed. One of the technical completion tests included the assessment of microcracking. As the panel glass is slightly thinner than originally proposed, particular attention was paid to ensuring microcracking had not developed during installation. The tests passed without issue.

5.7.3 Damage to pile heads during installation

GSF was designed using a driven pile solution. Approximately 90% of piles were driven successfully, with 10% reaching refusal before design depth was achieved. Additional testing and design work was completed to ascertain whether sufficient pull-out resistance had been achieved at this design depth. In the majority of cases, sufficient pull-out resistance was achieved, but a small proportion of piles needed to be drilled and concreted. Where sufficient pull-out resistance was achieved, these piles were cut-off using a rotating saw. Piles that were cut-off were corrosion protected in the field using galvanised paint. The EPC contractor and their framing subcontractor, Schletter, confirmed that warranties were not affected, including the corrosion guarantee on the framing. AECOM, as the Owner's Engineer reviewed each stage of the process.

6 Financing

Gullen Range Solar Farm does not have a Power Purchase Agreement. Electricity generated is sold on a merchant basis.

In 2016, when Gullen Solar was being financed, trading on a market basis was seen as unacceptable for project finance, or if possible, not at an interest rate and gearing ratio that would allow the project to be viable. The co-location of GSF with GRWF presented the opportunity to extend the project finance debt facility already in place for GRWF to finance the solar farm.

Gullen Solar Pty Ltd and NGRWF belong to the same holding company. GSF was financed using the free cash flows of NGRWF as a guarantee. This reduced due diligence requirements for the solar project and allowed a lower interest rate to be negotiated. It also meant that the usual market requirements for a share and asset mortgage in relation to the solar farm could be waived.

This approach was made possible due to the co-location of the solar farm with the wind farm. It could be extended to other co-located projects, but common ownership, financier participation and healthy existing plant cashflows are required. The approach would become more difficult as the size of the solar farm relative to the wind farm increased.

7 Plant Operational Performance

7.1 Solar Farm Performance

GSF has performed well against its predicted output, as presented in the financial model at Arena Financial Close.

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Figure 2 and Figure 3 examine Global Horizontal Irradiation (GHI), against that modelled in the Financial Model. The Financial Model used irradiation figures derived from an onsite pyranometer (installed July 2014) and long-term satellite-derived data. The analysis was performed by DNV-GL in October 2015. Total GHI from Q4 2017 to Q4 2019 was 4170 kWh/m^2 compared to a modelled value of 4285 kWh/m^2, a deviation of 2.7%. This deviation is within the uncertainty estimations predicted by DNV-GL.

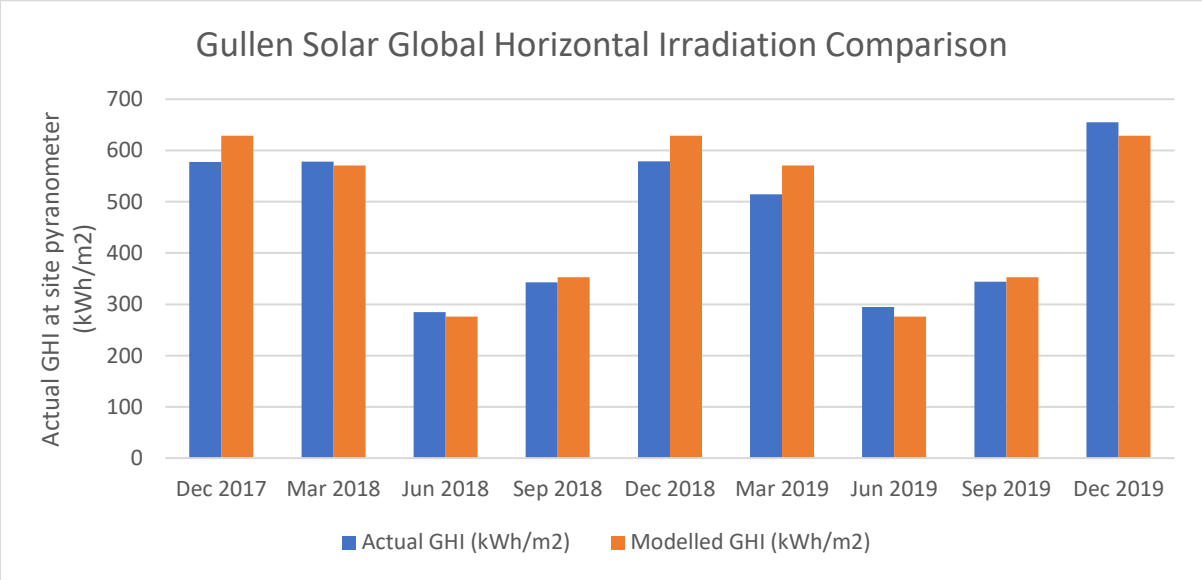

Figure 2 - Comparison of Gullen Solar Actual and Predicted GHI by Month

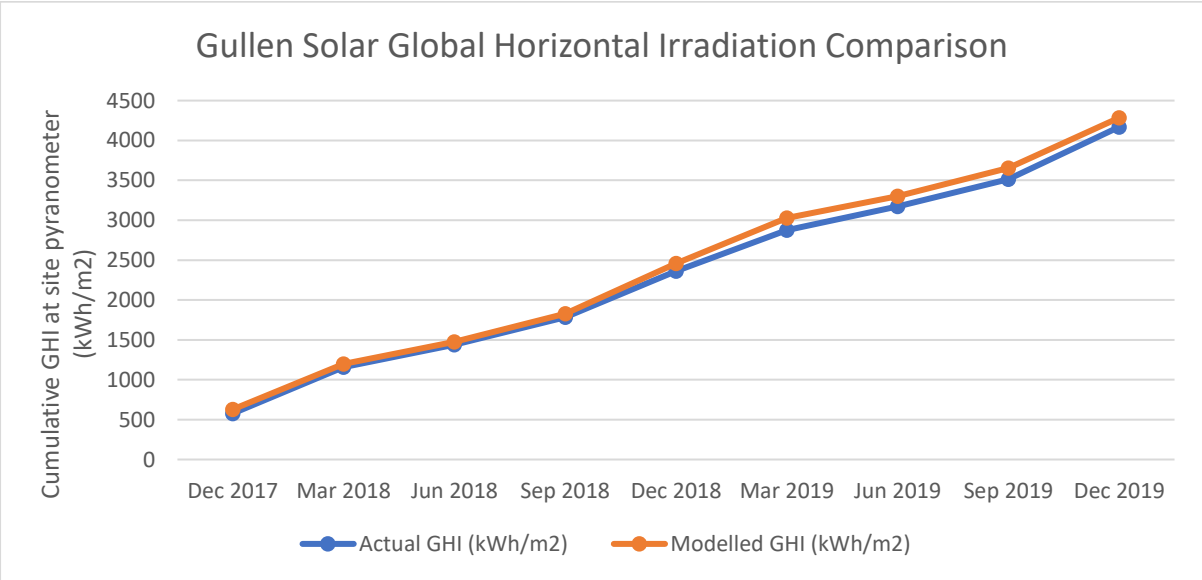

Figure 3 - Comparison of Gullen Solar Actual and Predicted Cumulative GHI

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Table 1 below separately reports on actual vs modelled MLF factors. Fluctuation of MLF from predicted factors has been an industry problem for large scale solar in recent years, but Gullen Solar has been unaffected. In the second quarter of 2019, the actual MLF fell below the modelled MLF for the first time since the solar farm was commissioned.

Quarter	MLF Model	Actual MLF
Jun 2017	0.9909	0.9909
Sep 2017	0.9909	1.001
Dec 2017	0.98	1.001
Mar 2018	0.98	1.001
Jun 2018	0.98	1.001
Sep 2018	0.98	0.9959
Dec 2018	0.9697	0.9959
Mar 2019	0.9697	0.9959
Jun 2019	0.9697	0.9959
Sep 2019	0.9697	0.9694
Dec 2019	0.9698	0.9694

Table 1 – MLF Factors

7.2 Analysis of Combined Wind and Solar Farm Output

One of the objectives of the GSF is to examine how co-located wind and solar could assist with reducing the perceived resource intermittency of renewable energy.

The below analysis is an update on that presented by Goldwind Australia at the Clean Energy Council's Wind Forum in 2016. Further analysis will occur in the next GSF knowledge sharing report.

Goldwind Australia presented graphical data, examining the interaction of wind and solar at Gullen Range on a month by month and diurnal basis. These graphs are reproduced below as Figure 4 and Figure 5, using actual wind and solar farm data from January 2017 to December 2019.

When analysed across the two-year sample period, GRWF has a very consistent output on a diurnal basis. The maximum deviation between the wind farm electricity output across the day and the average output of the wind farm during the sample period was only 3.4MW, at 8am. The addition of the 10MW solar farm assists with the deviation at 8am, but across the daytime period it causes a greater deviation from the average then was evident before the solar farm was installed.

This is a simplistic analysis, using data averaged across a two-year period. Further analysis needs to be conducted on the days where GRWF has its greatest intermittency.

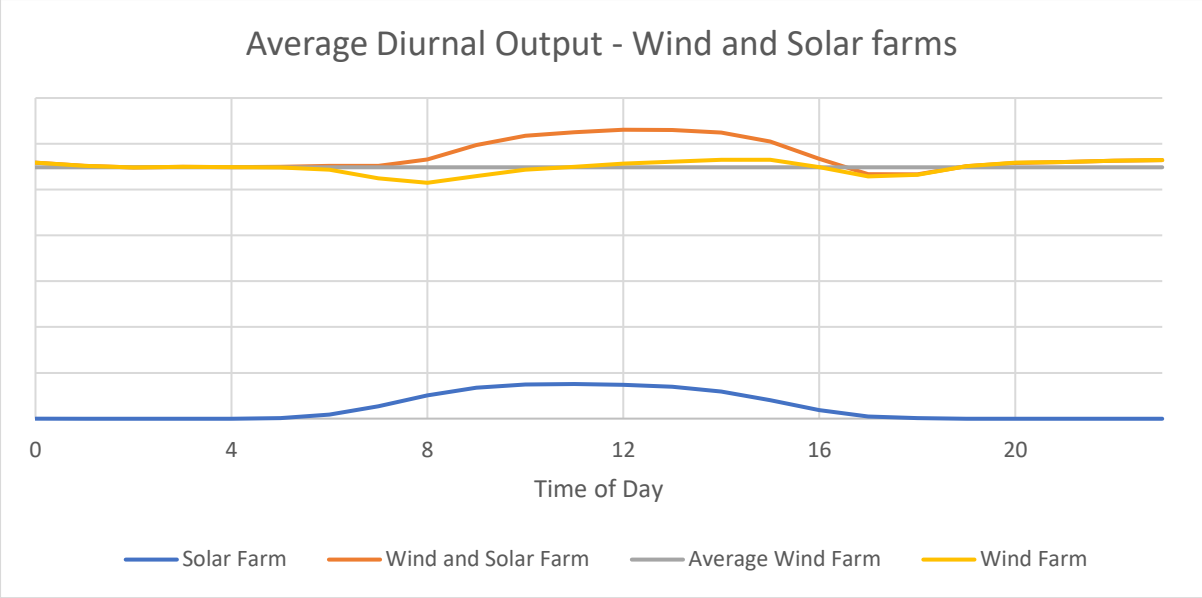


Figure 4 – Average Diurnal Output of GSF and GRWF

When analysed on a monthly basis, the solar farm generation and wind farm generation are complementary, but a much larger solar farm would be required to address wind farm month by month intermittency. Figure 5 illustrates that the months where the wind farm has its lowest output correspond to those where the solar farm's output is at its highest.

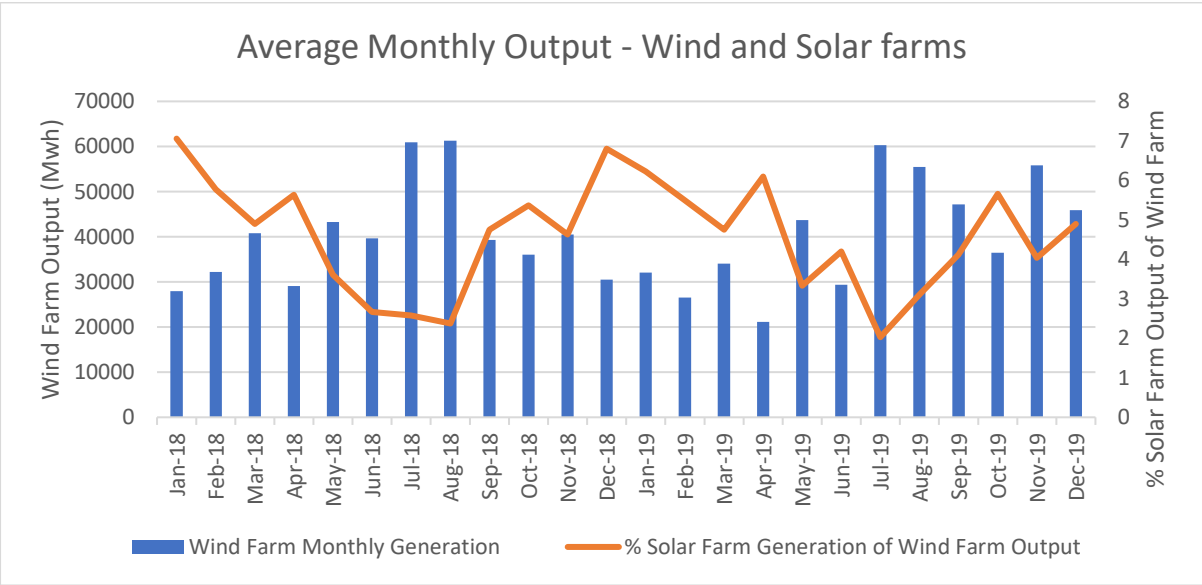


Figure 5 – Comparison of Solar and Wind Farm Output by Month

However, as can be seen from Figure 6, the installed capacity of the solar farm would need to be considerably larger.

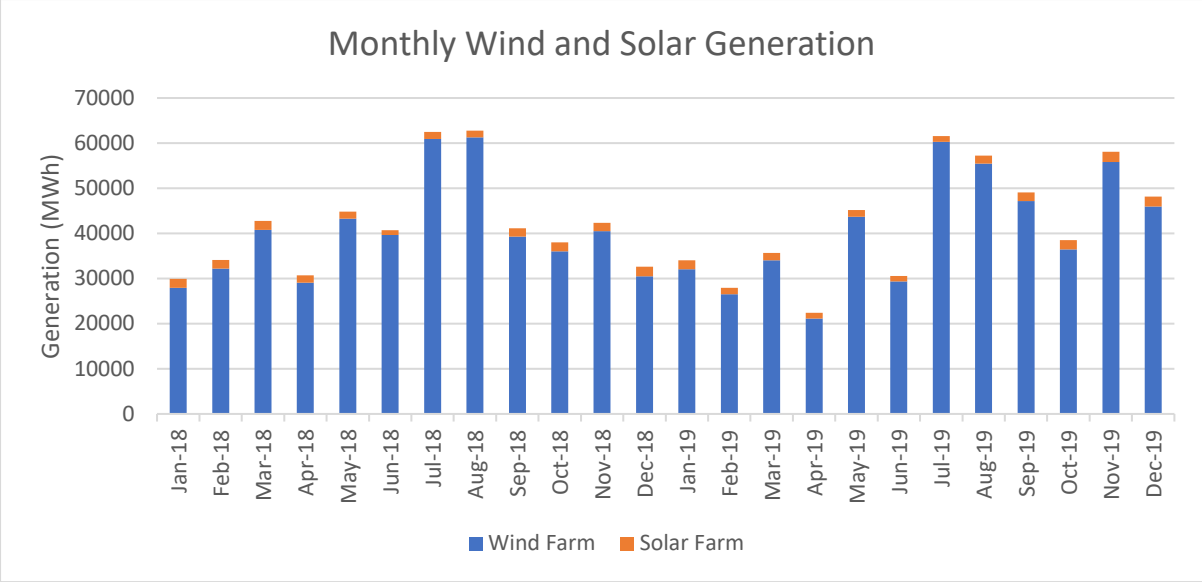


Figure 6 - Average Monthly Output of Wind and Solar Farms

In Figure 7, the solar farm output has been multiplied by a factor of ten, in order to offer a simplistic view of overall output if a 100MW solar farm was co-located, rather than a 10MW one. Although deviation from the average annual generation is reduced in the Figure, there is still considerable deviation in the month by month output of the combined plant.

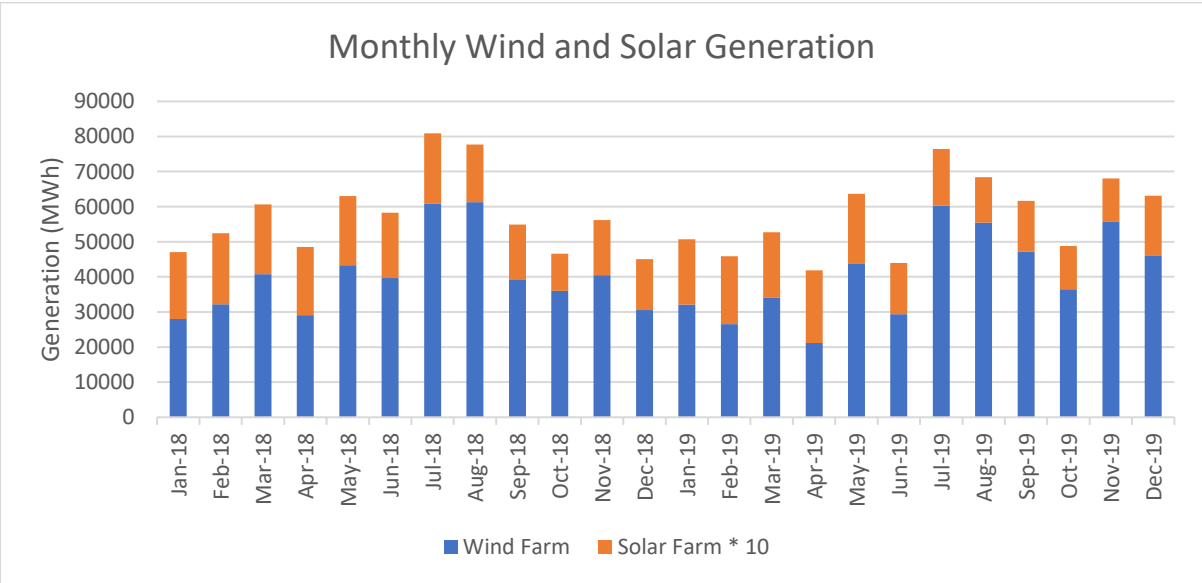


Figure 7 – Comparison of Wind and Solar Generation with 100MW Solar Farm

As discussed elsewhere in this report, GSF offered numerous benefits as a site for co-location. However, improvement of intermittency was not the strongest of these benefits, as the existing wind farm already had relatively consistent output. Further analysis on days of highest wind farm intermittency will be undertaken and reported on in the next Knowledge Sharing report.

During the feasibility stage of the GSF, there were concerns that the existing GRWF 33/330kV transformer that the solar farm electricity generation would pass through would be overloaded, requiring curtailment. Careful analysis of transformer performance and effect on design life were undertaken. To date, no curtailment of the transformer has been required.

8 Merchant Power Price Uncertainty

The electricity generated by GSF is traded on a merchant basis. There was considerable uncertainty when forecasting the predicted merchant price at feasibility stage. A forecast from a reputable analyst was used. The merchant power price is affected by many factors.

The following Figures illustrate the average GSF settlement price by month for the solar farm in the period from January 2018 to December 2019. The settlement price is compared to the average NSW Regional Reference Price (RRP), as published by AEMO and the forecast GSF settlement price at financial close.

In Figure 8 and Figure 9 below, it can be seen that the solar farm traded above the predicted price used in the financial model, but always equal to or below the RRP, indicative of the 'duck curve' associated with solar generation as a greater quantity of it is present on the electricity grid.

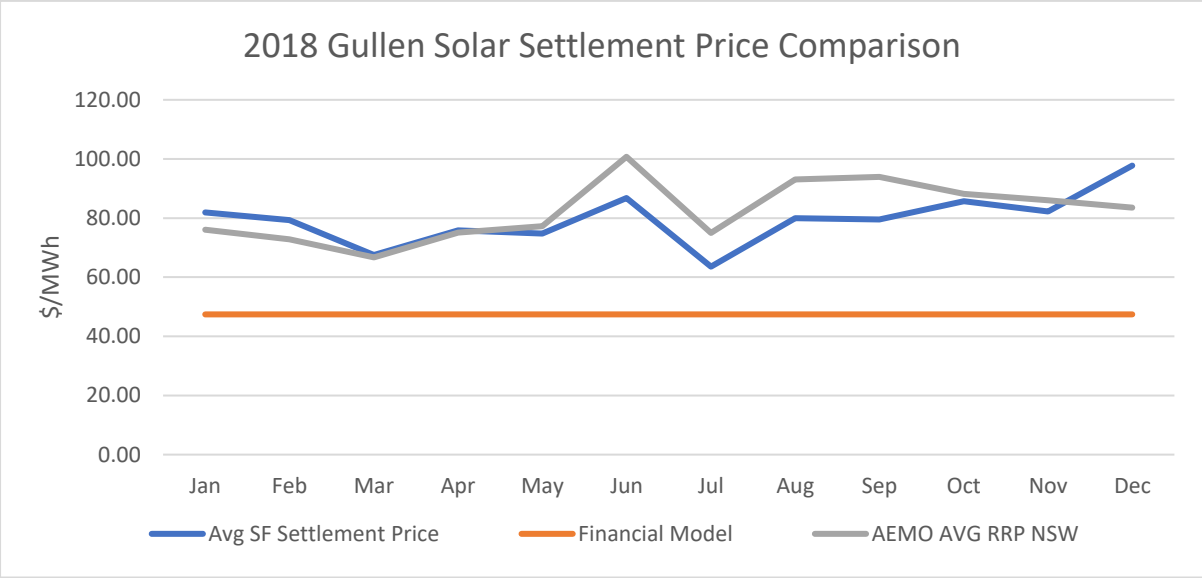


Figure 8 – 2018 Gullen Solar Settlement Price Analysis

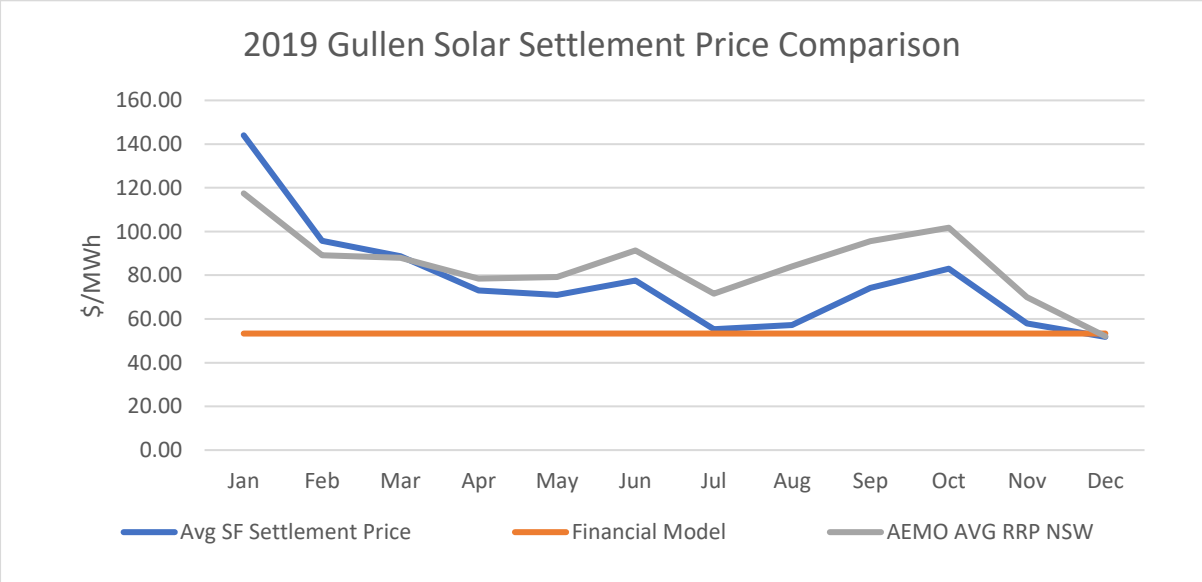


Figure 9 - 2019 Gullen Solar Settlement Price Analysis

Comparison of GSF settlement prices in 2018 to those in 2019, in Figure 10, illustrates that the average price across these two years was almost identical, although both prices are nominal, indicating a decline in the real price obtained in 2019.

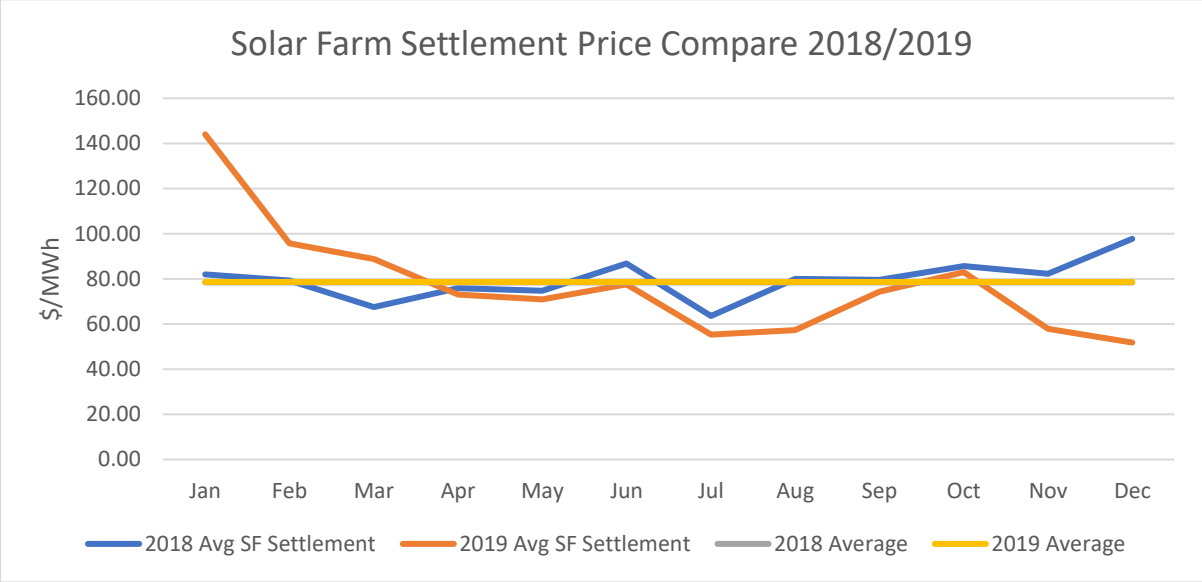


Figure 10 – Comparison of Settlement Prices from 2018 and 2019

9 Community Consultation and Community Issues

A comprehensive Community Consultation Plan was prepared by Goldwind Australia with feedback from ARENA.

'Neighbour agreements' were offered to three nearby landowners. One of these involved an arrangement to access the GRWF substation for the purposes of the solar farm and included rights for the solar farm land to be used for grazing of the landowner's stock. It was not industry standard to offer neighbour agreements for large-scale solar projects at this time.

As has been discussed in previous knowledge sharing deliverables, Goldwind Australia consulted heavily with the near neighbours before deciding on a location for the solar farm. The original preferred location was discarded in favour of the final location, which was much more acceptable to those near neighbours. Moving the solar farm site delayed the project and increased the development costs, as environmental and archaeological studies had already been undertaken at the original site. Ideally, the community consultation regarding the site location would have arrived at the point where a decision was made to relocate earlier. However, timeframes around such consultation is always difficult. Earlier consultation may have resulted in site locations that were not feasible being discussed with the community, as the required survey work to assess early feasibility would not have been conducted yet.

This heavy early consultation resulted in positive construction and operational phases. These benefits were substantial. The delay and costs mentioned in the previous paragraph need to be considered in the light of these benefits.

Part of the challenge in early consultation is determining who to consult with and how to effectively consult. The benefits of co-location were evident here, with Goldwind Australia having a good knowledge of the various stakeholders through their knowledge as the constructor of the GRWF.

Monthly notices were sent to nearby landowners regarding planned construction activities during the construction phase. Face to face meetings were conducted where required.

The highest impact works during construction were the public road upgrades, required by ULSC and the JRPP as a condition of the Development Approval. A section of approximately 2km in length was widened and sealed. These works affected users of the road. A reputable contractor (not local, but based near Goulburn) was used for the works. They had a good knowledge of local issues and stakeholders and were key to this portion of the works being delivered with no complaints received.

Two primary concerns raised during the Development Approval determination period were noise from the solar farm piling rig and visual impact of the panels. No complaints were received regarding either of these issues.

A complaints register is maintained for the project. Two complaints have been received from the commencement of construction through to the date of this report. Both of these complaints related to traffic during construction, with two complainants concerned trucks were travelling too fast to and from the solar farm. The first was in February 2017 and the second in May 2017. In both cases site staff were reminded about the importance of driving slowly and the complainants were directly contacted to discuss their concerns.

A toll-free information line is in place for the project and a project website is regularly updated with latest news.

The GSF is open for approximately six free public tours per year. Bookings are managed collaboratively with ULSC and tours include a visit to the GRWF. Tours depart from a local hotel in Crookwell, with free refreshments provided. The tour is by mini-bus and they have generally been booked out. The tour has proved a good way to engage with the broader community during the operational phase.

Several school groups each year visit the solar farm as a part of the Science in Schools Program run by Regional Development Australia Southern Inland Division. In 2018 a joint event with University of New South Wales was undertaken where the university brought their solar racing car to the solar farm in order that local high school students could see two examples of solar power at the same time.

10 Financial Benefits to Co-location

Goldwind Australia reported on the potential cost benefits of co-located solar in a report prepared for ARENA in 2015 (ref REP-E14012-R005_V0). The report concluded the majority of savings were related to grid connection. Table 2 discusses those three items in the context of GSF:

Item	Savings reported by Goldwind Australia	Comments in relation to GSF
Avoided transmission connection costs	$2.1M	The total cost of the 33kV electricity cable from GSF to GRWF substation, together with costs of modifications to the substation was $460,320.
Lower substation costs	$1.3M	
Avoided reactive plant requirements	$1M	There was no reactive plant required. However, it is not a valid assumption to presume co-location will result in cost savings on reactive plant, as the NER requires individual generating units to be NER compliant on a standalone basis (as discussed in Section 5.7.1 of this report)

Table 2 – Discussion on Predicted Cost Savings from Co-location

A further analysis of the costs of the grid connection for the GSF during AEMO construction and registration are presented in Table 3.

Item	Cost	
33kV electrical	$460,320	EPC cost including 33kV cable from solar farm to wind farm existing switchgear, modifications to existing substation (limited to trenching of 33kV cable)
Other grid connection	$302,993	Transgrid costs, AEMO costs, Grid Studies, R2 testing, wind farm WOM contractor supervision during commissioning and modification to wind farm SCADA
Communications and Commissioning	$272,582	Fibre optic to wind farm and communications hardware connecting solar farm to existing wind farm hardware
Total	**$1,035,895**	

Table 3 – Actual CAPEX attributable to Grid Connection

Goldwind Australia's report for ARENA estimates a total connection cost of $5,515,000 for a 66kV connected solar farm (without indexation), excluding $500,000 allowed in that analysis for reactive plant. The total connection cost of $1,035,895 therefore represents an approximate saving of $4,479,105, not including an allowance for wind farm generation forgone when the solar farm was connected. This is without considering the benefits of Gullen Solar being connected at 330kV. It is generally accepted that projects connected to stronger grid infrastructure suffer less from network curtailment. It would not be possible to connect a 10MW project at 330kV due to the high connection costs and if the above cost saving was calculated on this basis it would considerably greater.

Appendix A – Location and Site Plan

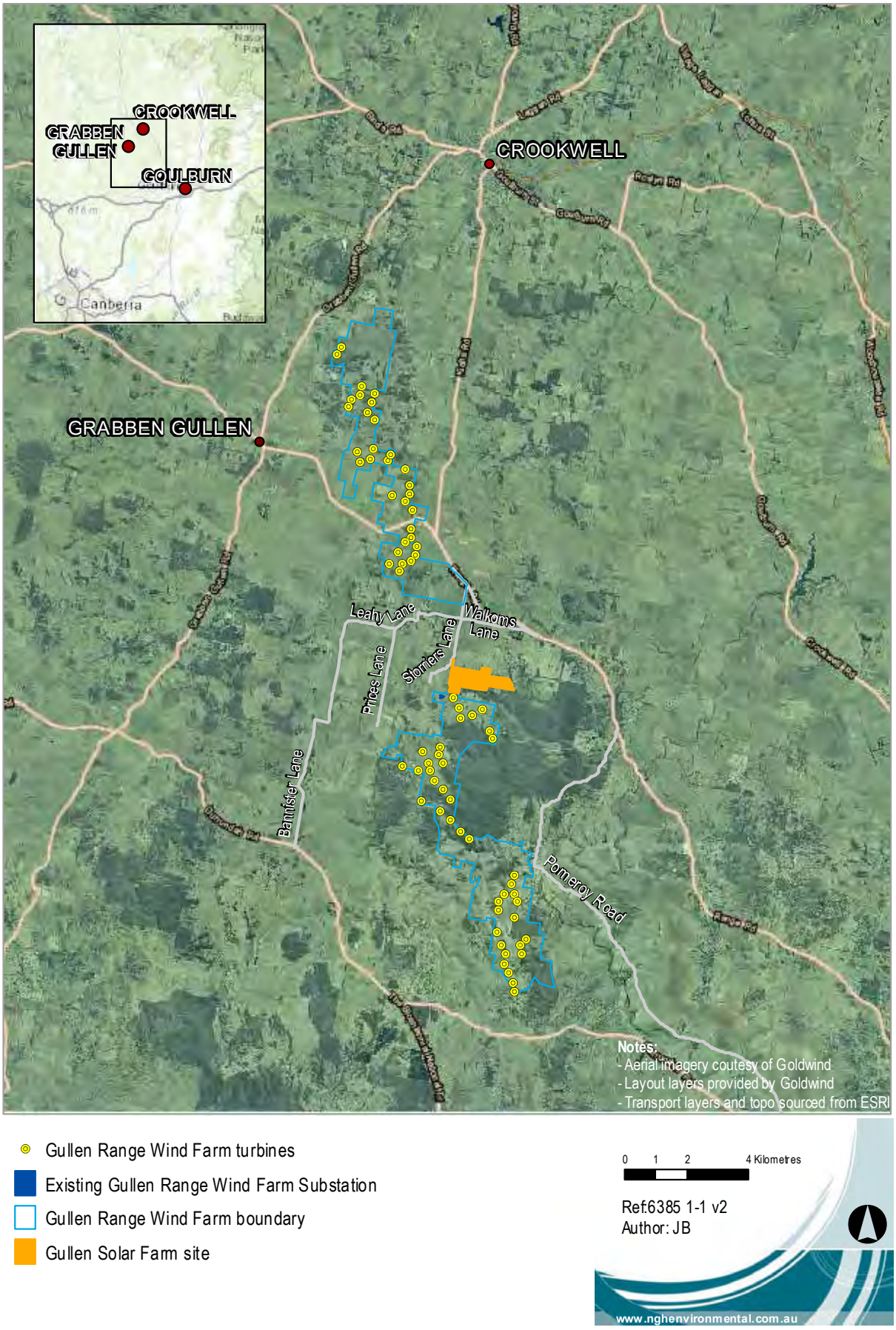
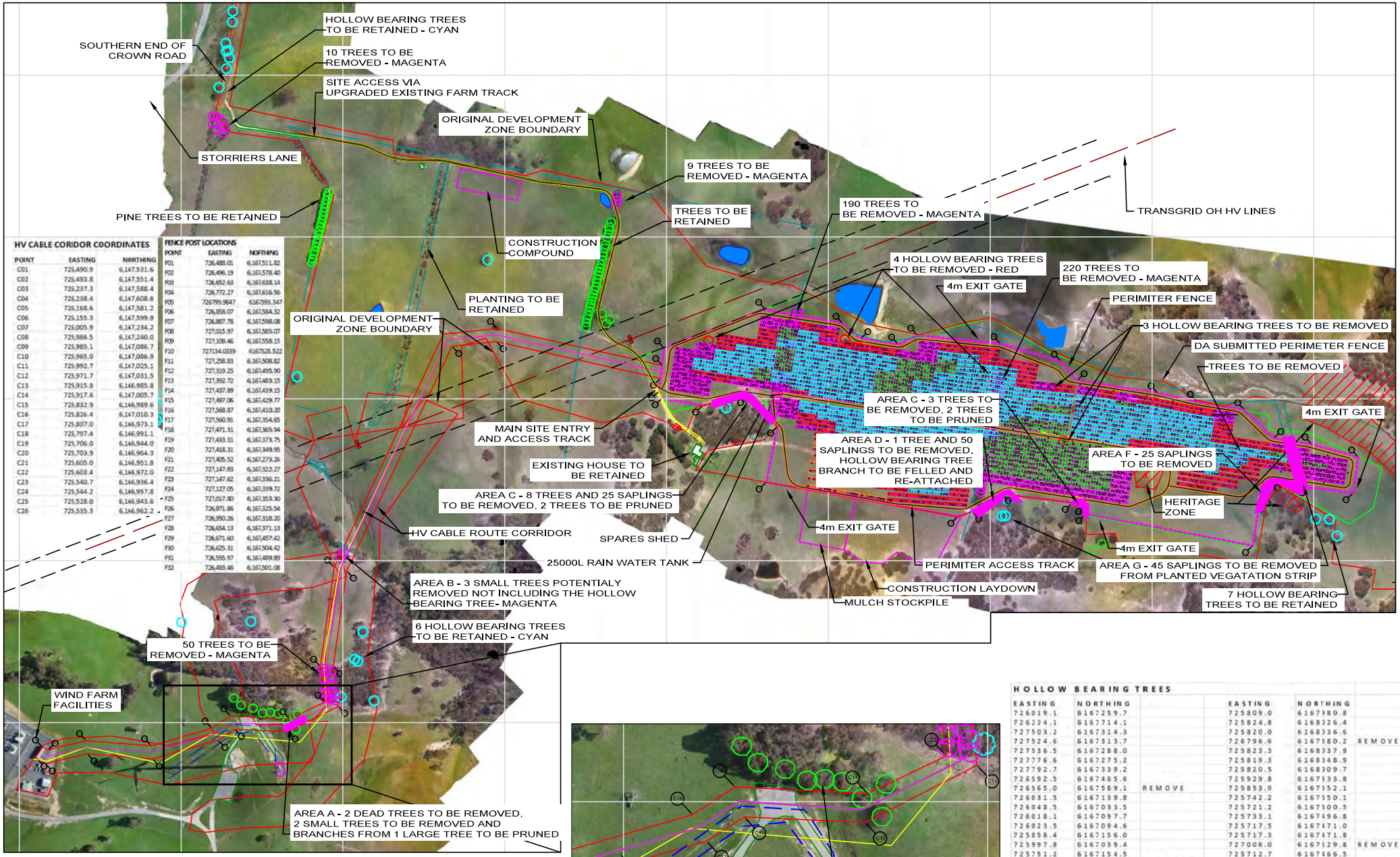


Figure 1-1 Regional location of the proposal.

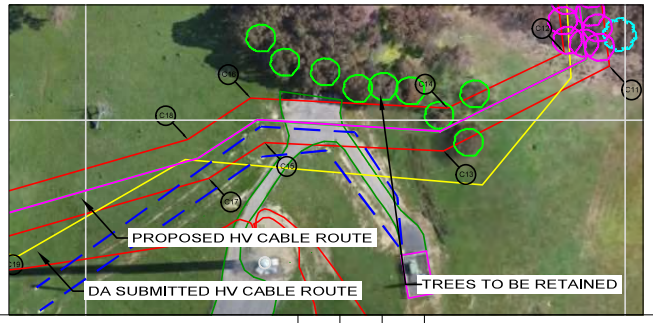


HV CABLE CORIDOR COORDINATES

POINT	EASTING	NORTHING
C01	725,490.9	6,147,531.6
C02	725,493.8	6,147,551.4
C03	725,237.3	6,147,588.4
C04	725,238.4	6,147,608.6
C05	725,168.6	6,147,581.2
C06	725,155.3	6,147,599.9
C07	725,005.9	6,147,234.2
C08	725,986.5	6,147,240.0
C09	725,985.1	6,147,086.7
C10	725,965.0	6,147,086.9
C11	725,992.7	6,147,025.1
C12	725,971.7	6,147,031.5
C13	725,915.9	6,146,985.8
C14	725,917.6	6,147,005.7
C15	725,832.9	6,146,989.6
C16	725,826.4	6,147,010.3
C17	725,807.0	6,146,973.1
C18	725,797.4	6,146,991.1
C19	725,706.0	6,146,944.0
C20	725,703.9	6,146,964.3
C21	725,605.0	6,146,951.8
C22	725,603.4	6,146,972.0
C23	725,540.7	6,146,936.4
C24	725,544.2	6,146,957.8
C25	725,528.0	6,146,943.6
C26	725,535.3	6,146,962.2

FENCE POST LOCATIONS

POINT	EASTING	NORTHING
F01	726,488.01	6,167,511.82
F02	726,496.19	6,167,578.40
F03	726,652.63	6,167,638.14
F04	726,772.27	6,167,616.56
F05	726799.9647	6167593.347
F06	726,858.07	6,167,584.32
F07	726,887.78	6,167,598.08
F08	727,015.97	6,167,585.07
F09	727,109.46	6,167,558.15
F10	727134.0339	6167528.522
F11	727,258.83	6,167,508.82
F12	727,319.25	6,167,495.90
F13	727,392.72	6,167,483.15
F14	727,437.89	6,167,439.15
F15	727,497.06	6,167,429.77
F16	727,568.87	6,167,410.20
F17	727,560.91	6,167,354.65
F18	727,471.31	6,167,365.94
F19	727,433.31	6,167,373.75
F20	727,418.31	6,167,349.95
F21	727,405.52	6,167,273.26
F22	727,147.93	6,167,322.27
F23	727,147.62	6,167,336.21
F24	727,127.05	6,167,339.72
F25	727,017.80	6,167,353.30
F26	726,971.86	6,167,325.54
F27	726,950.26	6,167,318.20
F28	726,654.13	6,167,371.13
F29	726,671.60	6,167,457.42
F30	726,625.31	6,167,504.42
F31	726,555.97	6,167,489.89
F32	726,493.46	6,167,501.08



HOLLOW BEARING TREES

EASTING	NORTHING		EASTING	NORTHING	
726019.1	6167259.7		725809.0	6167380.8	
726224.1	6167714.1		725824.8	6168326.4	
727503.2	6167314.3		725820.0	6168336.6	
727524.6	6167313.7		726796.6	6167580.2	REMOVE
727536.5	6167288.0		725823.3	6168337.9	
727776.6	6167275.2		725819.3	6168348.9	
727792.7	6167339.2		725820.5	6168309.7	
726592.5	6167485.6		725929.8	6167533.8	
726565.0	6167589.1	REMOVE	725853.9	6167552.1	
726031.5	6167139.8		725742.2	6167550.1	
726048.5	6167033.5		725721.2	6167500.5	
726018.1	6167097.7		725733.1	6167496.8	
726023.5	6167094.6		725717.5	6167471.0	
725858.4	6167156.0		725717.3	6167471.8	
725997.8	6167039.4		727006.0	6167529.8	REMOVE
725751.2	6167154.5		725712.7	6167166.5	
726776.0	6167591.2	REMOVE	725862.8	6167168.6	
725834.8	6168135.3		725893.7	6167167.5	
725831.5	6168119.5		725766.6	6167527.0	
725830.2	6168098.4		727018.4	6167318.5	
725829.5	6168081.9		727023.9	6167319.2	
727095.6	6167513.1	REMOVE	727027.5	6167344.6	
727136.2	6167481.6	REMOVE	727057.8	6167305.6	
727113.6	6167434.8	REMOVE			

DECMIL Balance UTILITY SOLUTIONS

REFERENCES

REVISIONS

REV	DATE	DESCRIPTION	DRWN.	CHKD.	APPR.
1	2017.08.23	AS-BUILT	MS	MT	MSD
K	2017.07.02	ADDED TREE REMOVAL AREAS	DW	AH	AH

GULLEN Solar Farm

TITLE
GULLEN SOLAR PTY LTD
GULLEN SOLAR FARM
GENERAL ARRANGEMENT
OVERALL SITE LAYOUT

DWG No. 10191-G-GAD-01B

SCALE NTS

REV. 1

SHEET SIZE A1

Appendix B – Construction Phase Photographs

Appendix B – Construction Photographs

Crown Road re-construction

Formation of new Site Entry

Commencement of Site Compound

Site entry looking East

Site offices

Pine tree removal in solar

Mulching of pine trees east shelter belt

Formation of access track near site entry

Delivery of PV structures commences

PV structures unloaded in Site Compound yard

Piling rig in position for installation of first pile

Temporary stormwater detention basin

Purlins delivered to site in 12m containers

Single core DC Cable drums on-site

Solar Farm looking east from entry access track 04 February

Solar Farm looking east from entry access track 28 February

Pile structural field testing

Frame assembly Power Block 3

PV Frame assembly Power Block 1 & 2

First PV Modules arrive and unloaded from container

Quality inspection on-site

Inspection of sub-station HV cable access

DC cables in laydown yard

First PV module unpacked

Solar Farm looking South toward Wind Farm

Solar Farm looking east from entry access track 9 March

Quality testing

Cable jinker with DC cables ready for laying

PV Frame assembly Power Block 2 & 3

First prototype PV tables

Pile drilling where driven piles were refused

DC cable trenching in progress

Solar Farm looking east (early April)

33kV Electrical trench (inside Solar Farm)

Rejected driven pile (damaged encountering rock)

Interconnecting 33kV cable (Solar Farm to Wind Farm)

PV modules commencing from western end

DC (1500v) cable installation

Interconnecting 33kV cable trench progressing

PV module installation progress (late April)

33kV Cable alignment south of Wind Farm boundary

Testing driven pile pull-out and deflection resistance

Investigation of 33kV cable entry at Wind Farm SS

Concrete encased pile

33kV trench uphill of creek crossing

Preparation for PCB support piers

PV structures looking east from CB39 (approx.)

Quality checking Plane of Array

PCB structural supports

PV installation looking from north-east corner

PCB preparation for perimeter Earth Ring

Combiner Box – DC cabling terminated

PCB in final position

Final section of perimeter security fence completed

PCB with cable mechanical protection shroud

Inspecting PV structures

Preparing 33kV cable termination at PCB1

Meteorological Station

Storage shed construction commenced

Preparing Solar Farm cables in Wind Farm switchyard