EPC Technologies
ARENA Feasibility Study - Public

G.James Glass and Aluminium - A demonstration of how medium-scale solar on industrial roof-tops can be effectively integrated into the distribution network

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EPC Technologies Pty Ltd
ABN: 64 612 341 849
http://www.epctechnologies.com.au

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1 Executive Summary

EPC Technologies Pty Ltd (EPCT) was provided grant funding by the Australian Renewable Energy Agency toward the 'Demonstration of how Medium Scale Solar on Industrial Roof-Tops can be Effectively Integrated into the Distribution Network', Project (the Project) under the Advancing Renewable Program Funding Agreement number G00911 ("the Funding Agreement"). Under the Funding Agreement EPCT has certain reporting and knowledge sharing obligations in return for receiving funding from ARENA. This report covers the requirement to provide a feasibility study for public release.

At the initiation of the Project, solar installations on industrial roof tops were generally limited in scale by the local network owner requiring a zero-export device to be installed. This limited the scale of systems that could be constructed on large industrial roof-spaces to approximately the peak energy load on that site. This limit on export is largely driven by the network's requirement of maintaining stability of the system across the year and therefore is driven by a limited number of low demand days.

To enable medium-scale solar to be installed, the Project addressed the technical, regulatory and commercial issues that currently prevent solar installations that exceed the expected capacity of the incumbent load.

This project has successfully demonstrated a pathway through the technical and regulatory challenges. From a technical perspective, EPCT has demonstrated how existing technologies can be used to allow material quantities of solar energy to be exported back into the local network. For the demonstration project, approvals were received for over 5MW of export capacity onto the two distribution feeders in Eagle Farm, using approximately 12MW of solar. The demonstration project has the potential to fundamentally change the way industrial and commercial customers consider distributed generation and storage, and how local network companies develop and manage distribution feeders.

Through this project, EPCT demonstrated the regulatory pathway for a new entrant in the development of distributed energy and storage. We have secured all the necessary regulatory approvals, market registrations and licencing exemptions needed to develop distributed generation and storage in Queensland.

Our case study also demonstrates the commercial outcome of medium-scale solar energy. For the chosen sites in the industrial suburb of Eagle Farm, Brisbane, the project was unable to compete with current costs for grid supplied electricity (including market, green and network charges.

2 Introduction and Purpose

2.1 Introduction and purpose

In late 2016 solar installations on commercial and industrial roof-tops in Australia were limited by network requirements requiring either a dedicated electrical feeder or (in most cases) and export limiting device. As a consequence, the size of the commercial solar market was muted, with few installations typically of limited size, designed to directly address the load under the available roof-top. Very little electricity generated from renewable sources was exported from commercial and industrial sites.

EPCT identified that available technologies such as static synchronous compensators (STATCOM's), Battery Energy Storage Systems (BESS's), protection and communication equipment could be used to allow solar energy to be injected into distribution feeders. Further, this equipment could be used to enhance the system security and reliability of electricity supply for all users on the feeder. We considered that it was technically feasible to install medium-scale solar generators in an industrial setting, and have this solar energy integrated into the distribution feeder. In this context, we believed the technical limit for solar in the commercial/industrial setting should be linked to the capacity of local transformers and the size of the available roof-top. This would require overcoming the limits placed on solar installations by the local network companies.

In addition to overcoming the technical challenges, the installation of medium-scale solar on commercial roof-tops requires regulatory approval. In a manner consistent with many solar installers, EPCT anticipated seeking a retail licence or retail licence exemption for the sale of solar power directly to an industrial load. We also anticipated the need for a distribution licence (or distribution licence exemption) to install equipment directly within the local distribution network. Energy sales into the electricity grid would require National Electricity Market participation. While this could be addressed commercially through a third party, direct market participation would require registration as a Small Generator Aggregator with each connection point representing a non-scheduled generator.

If the technical and regulatory barriers could be overcome, the feasibility study needed to also prove that the conceptual approach would be commercially viable. Ultimately, a project needed to be identified and pursued such that it could be developed commercially. EPCT secured an exclusive agreement with G.James Australia Pty Ltd (G.James) to pursue the feasibility study. G.James own a series of buildings in the Brisbane industrial suburb of Eagle Farm each of which could support several hundred kilowatts (kW) of solar, and with several buildings that could support megawatt (MW) scale facilities. G.James also owns building elsewhere in Brisbane and around Australia.

In assessing the technical, regulatory and commercial feasibility, the project sought to enable increased penetration of distributed solar directly within the areas where the demand for energy is most needed. In doing so it sought to remove barriers to increased renewable energy uptake.

2.2 Physical project description

2.2.1 Summary

Although all of the sites are unique from a load and solar design perspective, there were a number of lessons learnt that could be applied across many or all of the sites.

2.2.2 Narangba location

G.James owns and operate a separate facility with four roof-tops in the northern Brisbane suburb of Narangba. EPCT was able to pursue a medium-scale export-enabled solar solution for the Narangba site in addition to the Eagle Farm sites. This location allowed us to test and implement technical and regulatory solutions in advance of the Eagle Farm rollout.

Figure 1 - Narangba site and proposed installation

EPCT has installed 2,778 solar panels at this site with a total capacity of 0.730MW, producing an expected 1,129MWh of electricity annually.

The peak load at this site is over 1.5MVA and annual consumption exceeds 3,000MWh. Over eighty percent of the solar energy produced will be consumed on site. This site therefore reflects a more traditional opportunity for roof-top solar, yet EPCT was able to secure a connection agreement with 200kW of export capacity.

2.2.3 Eagle Farm locations

In the suburb of Eagle Farm, a total 20 roof-tops across 13 sites have been identified for solar installations. Of these, only three will qualify for Small-scale Generation Certificates.

The Eagle Farm sites are located on feeders originating at Ergon 33/11kV Zone Substations at Whinstanes (WSS) and Hamilton Lands (HTL). Both of these substations are in turn connected to the Meendah (MBS) 110/33kV Bulk Supply Substation. The Eagle Farm sites cover a variety of connection types covering both shared and dedicated transformers, LV (415V) and HV (11kV) connections, as well as shared and dedicated feeders. Between them, they represent the most common connection types for industrial customers.

The following table summarises the key metrics for the Eagle Farm sites:

Table 1 - Summary of Eagle Farm Sites

Site	Peak Load (kW)	Solar (kW AC)	Export (kW AC)	Production (MWh/yr)	Estimated % consumed on-site
Site 1, Eagle Farm QLD 4009	2,500	1,050	1,050	1,652	85
Site 2, Eagle Farm QLD 4009	100	250	100	392	30
Site 3, Eagle Farm QLD 4009	1,900	1,900	1,900	3,089	75
Site 4, Eagle Farm QLD 4009	70	450	400	679	14
Site 5, Eagle Farm QLD 4009	2,900	3,300	TBC	5,036	62
Site 6, Eagle Farm QLD 4009	220	500	400	854	44
Site 7, Eagle Farm QLD 4009	90	300	200	474	35
Site 8, Eagle Farm QLD 4009	160	150	150	210	97
Site 9, Eagle Farm QLD 4009	90	200	100	359	43
Site 10, Eagle Farm QLD 4009	20	50	50	81	30
Site 11, Eagle Farm QLD 4009	80	500	300	786	23
Site 12, Pinkenba QLD 4008	160	550	300	892	44

3 Technical Considerations

EPCT sought a technical solution that maximised the use of the available roof-tops while maintaining a required level of return on investment for the project.

3.1 Overview

Grid stability, inherent with large swings in renewable generation, is a core facet of the system and is an integral part of the design. Grid level control is available to Energex to further enhance the systems integration to the 11kV network.

The proposed high security solution has been carefully considered to match all Energex requirements, covering both infrastructure standards and access standards.

The system is designed to operate as a virtual generator, with solar, reactive power, battery energy storage systems and high spec protection / control systems operating in full synchronisation to enable the safe and efficient flow of energy.

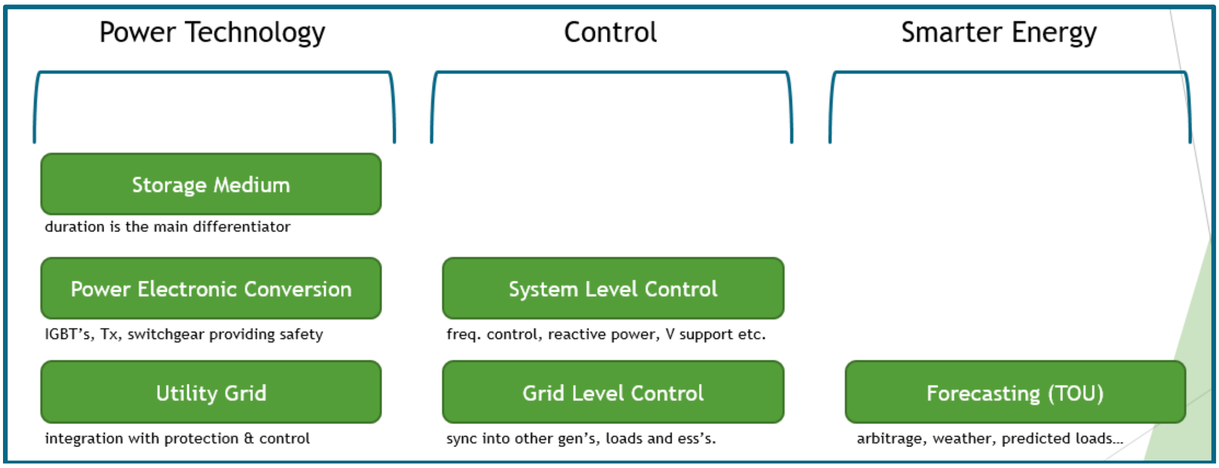

Fig 3.1: EPCT 3-tiered approach as applied to G.James

3.2 Photovoltaic Array

The selection of solar panels for this project were primarily governed by the following considerations:

- Reliability, warranty and performance over a 20+ year period.
- Value for money.

- Physical size – not just largest size, but optimum sizing to fit maximum panels between skylights.
- Open circuit voltages – compatibility with preferred inverter product without compromising string size and yield.
- Brisbane geographical area (higher temps).

With higher power inverters we inherently use more PV Modules. This results in more PV Modules per string into each MPPT input of the Inverter. The Vmax DC input of the Inverter is calculated by the sum of the Voc of each PV Module at the lowest ambient temperature. Using a PV Module with a high Voc quickly exceeds the Vmax limit of the Inverter requiring shorter strings which leads to lower loading and efficiency curves of the Inverter.

The result of this analysis led to the discounting of some brands of panels because of their higher open-circuit voltages.

EPCT selected the Canadian Solar CS6K-275P panel for the Narangba installation and CS6K-285P for the Eagle Farm installations. The difference in panel capacity between sites is due to an improvement in cell efficiency and performance by the Canadian Solar factory between installation dates for the Narangba and Eagle Farm sites.

3.2.1 Panel Maximum Power Point (MPP) matching

EPCT primary goal of matching a PV array to an inverter is to ensure that the inverter can capture the highest percentage of the available energy that the array produces during all the environmental conditions anticipated at the site.

A core aspect of this is to ensure the minimum and maximum string voltages (dependant on local weather conditions) are designed to be within the inverters optimum MPPT range.

For Brisbane, we have used a minimum of **5degC**, with an average maximum of **38degC**. Using the formula below, we have ensured the array is optimally matched to the inverters specified.

$$V_{adj} = V_{oc} + (\textit{temperature differential x temperature coefficient of } V_{oc})$$

The relatively low open circuit Voltage (Voc) of the CS6K panels allow the efficient use of longer strings whilst still operating within the inverters optimum MPP curves.

Project Name		**Document No.**	**1AU0010S0302**	
Site / Location				
Inverter Type	**SMA Core1**	Module Type	**CanadianSolar CS6K-270P (Qtech)**	
Inverters (No. of)	**38**	Location Low Temp	5.00	deg C
Inverter Pmax	50,000	Module P	270	max. power
Inverter Vmax input	1,000	Module Voc	37.9	open circuit
Inverter Vmpp max	1,000	Module Vmp	30.8	at max. power
Inverter Vmpp min	150.0	Module Isc	9.32	short circuit
Inverter Imax	72.5	Module Ip	15.0	max. series fuse rating
No. of MPP Inputs	6	Module Temp (Voc)	0.0031	coefficient
Max. Strings per MPP	2	Module Voc adj	40.25	
		Module Size (mm)	1,650 x 992	
		Fuse (A)	14	min. size (where required)

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Smarter Energy

System Metrics	
DC Nameplate (kWp)	**2,322**
AC Nameplate (kW)	**1,900**
Total Panels:	**8,600**
Overall PV to Inv Ratio:	**1.22**

Worst Case VDrop	C. Size	Length	Power	Nom. Volt	Current	Vdrop	Vdrop %	Allowed	
DC VDrop (string)	2.5	50	5,400	805.00	6.71	13.68	1.7%	24.15	PASS
DC VDrop (array)	4.0	25	10,800	805.00	13.42	8.45	1.0%	24.15	PASS

Worst Case Vdrop	C. Size	Length	Power	Nom. Volt	Current	Volt Drop	Allowed	
AC Vdrop (Inv to PP)	10.0	10	50,000	415	208.68	8.10	20.75	PASS
AC Vdrop (PP to SDB)	50.0	50	75,000	415	313.02	12.43	20.75	PASS

	String 1 No. P	String 2 No. P	String 3 No. P	String 4 No. P	PV to Inv. Ratio	Total V Array	Total I Array	No. of Strings	(Sa - 1) x Isc	SF Req'd?	No. of Fuses	Panels
Inverter 1 - MPPT 1	20	20			1.30	805.00	18.64	2.00	9.32	No	6	40
- MPPT 2	20	20				805.00	18.64	2.00	9.32	No	6	40
- MPPT 3	20	20				805.00	18.64	2.00	9.32	No	0	40
- MPPT 4	20	20				805.00	18.64	2.00	9.32	No	0	40
- MPPT 5	20	20				805.00	18.64	2.00	9.32	No	0	40
- MPPT 6	20	20				805.00	18.64	2.00	9.32	No	0	40

Fig 3.2: Project calculation from Site 3 showing optimum matching of the CS6K-270P panels to the SMA inverter.

3.2.2 Panel Layout / Orientation

Panel orientation is almost wholly determined by the existing roof configurations (both tilt and azimuth. Typical tilts across the project sites are 8 degrees.

To maximise yield against financial return, a detailed orientation analysis for each site was undertaken. Flush mount systems have been specified for east, north, south and west facing roofs, with limited fixed tilts being used for flat roofs. Although row-on-row shading is a concern at higher tilt angles (for the south facing roofs), this occurs in the early morning and late afternoon when the sun's angle to the modules, and thus the power output, is very low in any event. In addition, more shading occurs in the winter when time-of-day (TOD) multipliers and irradiance are low. In this regard, we have optimised the energy yield against the capital costs of tilts and supporting infrastructure.

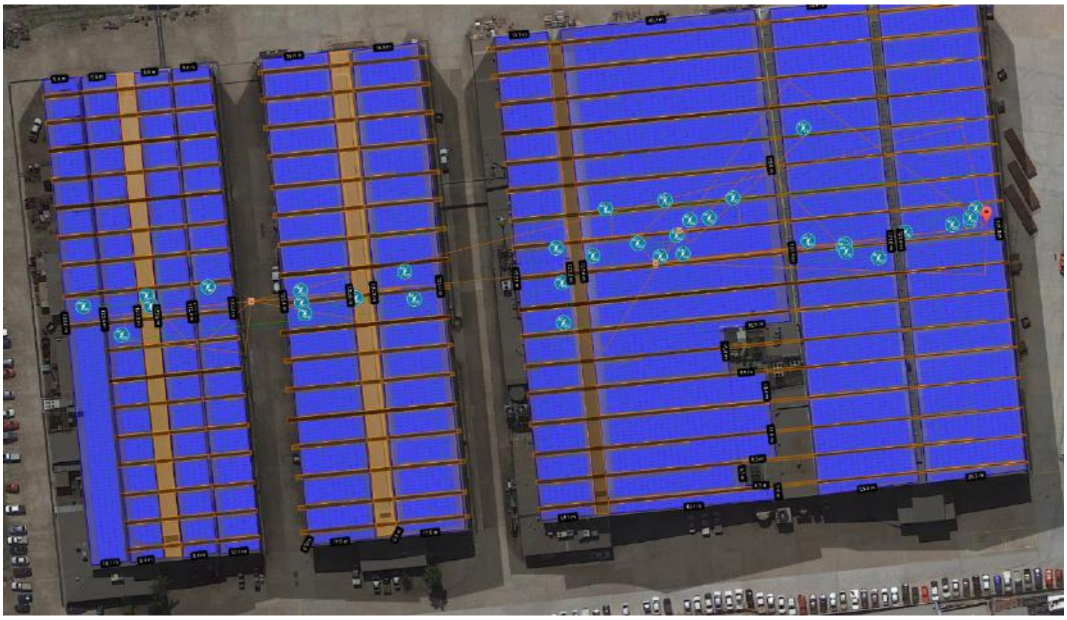

Fig 3.4: Site 3 (22 Want Street) example of panel orientation. The orange east / west lines are the skylight exclusion zones.

Of relevance to this project are the existing skylights in the building roofs ("lazerlight" translucent sheeting). The requirement to keep these clear at all instances is a major driver of portrait / landscape orientation and panel size.

The quantity and placement of solar panels for this project were ultimately constrained by the size, orientation and structural capacity of the G.James rooftops. EPCT then had options in terms of selection of inverters (string inverters vs centralised inverters) and even whether to keep the existing connection points or connect multiple sites either via the Energex network or a private network.

Connecting multiple sites was considered a viable option if export capacity could not be secured but as export capacity was granted it was ultimately decided not to do so. Connecting multiple sites via the Energex network would have been both costly and time consuming and would still have attracted network charges, while connection via a private network would have also required EPCT to get a distribution licence (or exemption) and permission to run private cabling through public land/road reserves.

Once the topography of the overall system was determined, each site underwent a detailed design process, from structural assessment, rail and panel placement, string and inverter configuration, PV protection panel design and integration into the existing site main switchboard for each site.

In some cases, where the maximum permitted export capacity was constrained by transformer capacity, the system size was reduced accordingly – as the system output would have been severely constrained on an almost permanent basis.

3.2.3 Panel Tilts

In area-constrained scenarios such as commercial rooftops, the most profitable system design results from packing the modules closely together and reducing the tilt angle. These two variables go hand in hand: by dropping the tilt of the modules, we reduce the row spacing without incurring a significant amount of interrow shading.

Whilst reducing tilts by approximately 5deg reduces specific yield by 5% at most locations, the reduced spacing increases the system capacity by 40%. Therefore, the overall energy production grows by 35%. The area-constrained design is even slightly more profitable.

While the 5% lower productivity would typically translate to a lower profit margin, the larger array is able to amortise the fixed costs over a larger base. As a result, the ROI of the system is significantly improved.

3.3 Inverters

Knowing that grid integration (covered in detail in following Section) and remote operability would be our primary challenges for this project, priority was placed on selecting an inverter with extensive capability in these areas. From previous experience, SMA inverters were considered the market-leading option in terms of both grid integration and remote operability for commercial-scale systems.

Large scale commercial PV installations are best suited to use distributed inverters for collation of energy from the arrays. This is due to the high level of system availability should one unit fail and the ease of installation due to the lower voltage parameters (maximum 1,000Vdc and 415Vac).

EPCT, working in close cooperation with SMA engineers in Germany, have identified the Sunny Tripower Core1 as being of optimal benefit for the high control specifications and grid integration requirements for this project. This unit was identified by EPCT and SMA for use on this project before it was released onto the worldwide market.

This unit is at the leading edge of inverter technology, giving numerous benefits from yield optimisation through to greatly reduced installation costs through its multiple string inputs (12) and MPPT trackers (6).

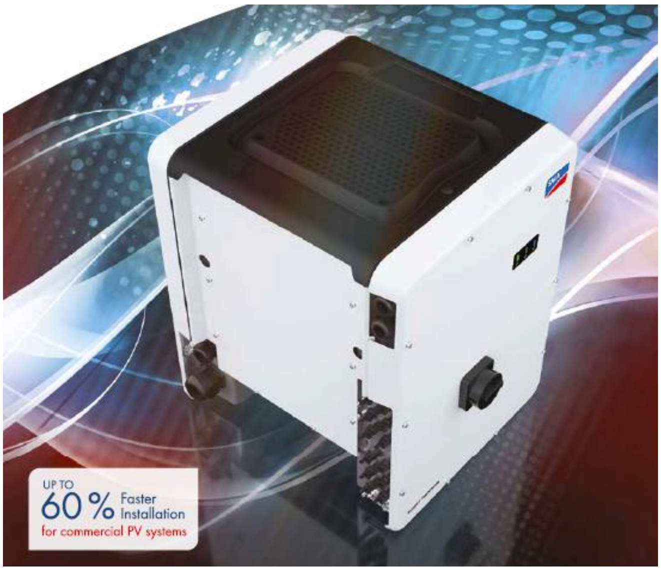

Fig 3.5: Core1 SMA Inverter used for the G.James sites

Two other SMA products, the Power Plant Controller (PPC) and Data Manager (DM) would also be utilised for further level of functionality and control for the larger sites.

The selected inverters also have an additional level of grid support functionality (e.g. Q-at-night, remote DNSP control of inverter control mode) which was not taken up by Energex at this time but may prove beneficial in the future.

The level of technical support received from SMA Germany has also led to this project being used by SMA as the flagship project for this new technology in its southern hemisphere marketing.

3.3.1 Radial vs Ring Inverter Connection

EPCT have used a Radial connection methodology for the Project sites due to the following advantages:

- Outage contingency: Failure of one inverter will have minimal impact on remaining installed capacity.
- Cable Sizing: 0.415kV collector cable sizing is greatly reduced as cables are rated per inverter capacity.

3.3.2 Sizing Ratio

The goal of EPCT was to configure the system components for maximum energy throughput from the PV panels to the industrial load and export to the Energex grid, whilst optimising specific yield.

Deploying large scale PV systems in Australia is an exercise in optimising the Levelised Cost of Energy (LCOE). In recent years, falling module prices and increasingly competitive market conditions have pushed dc-to-ac ratios to previously unseen levels.

In order to utilise the system components to their full capacity, and to optimise specific yield, the peak array power should always be greater than the inverter capacity. Oversizing the array ensures that the inverter is driven to its maximum output, at least during the best sun hours of the day.

The only impacts that an oversized array have on system output are to bring the inverter up to its best efficiency a little earlier in the day and to drive the inverter at full power for longer periods of time.

Since the area under the power curve is the energy delivered, the “fatter” curve equates to more kWh, even if the peak output is limited to the maximum inverter capacity. As an array ages, the number of hours per year that the inverter is driven to full output power decreases.

An oversized array helps ensure that the inverter will reach full capacity over the full 20-year life of a typical system.

For the purposes of this project, EPCT have used a minimum Sizing Ratio of **1.20** up to a maximum of **1.45**.

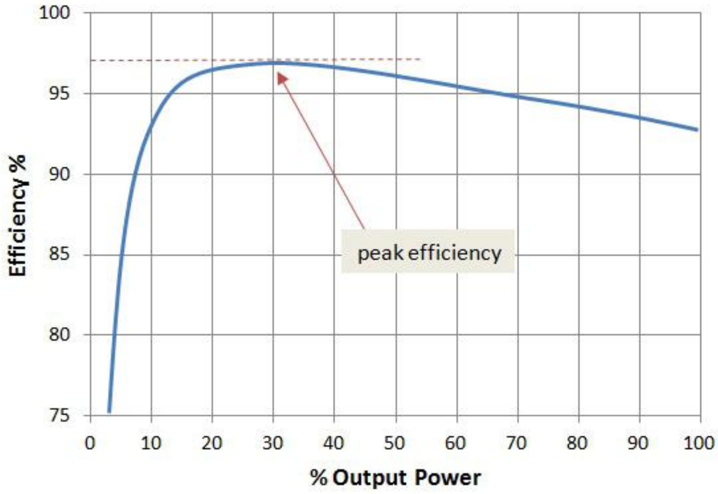

Fig 3.6: Example of how EPCT target the efficiency of the Inverter via a slightly oversized PV array.

3.4 Energex Grid Integration

EPCT reviewed the solar installations on the Energex network in the third quarter of 2017. Only 196 installations of 30kW or more had been made, with just 29 being above 100kW in size. Only six export-enable solar systems above 100kW had been installed on the Energex network, two of which we were confident to be on dedicated feeders. In the commercial/industrial setting, it was extremely rare for an export-enable solar system of substance to be approved.

Forty-eight systems of between 90kW and 100kW had been installed on the Energex network before September 2017. Sixteen, or just one-third are export enabled. Based on our experience working with solar installers we were confident that the vast majority, if not all of these systems, were installed at locations with significant loads and rarely export power.

Clearly, as well as providing a solution that was cost effective and technically feasible, EPCT would need to convince Energex of the technical merits of its solution to be granted a connection agreement including the right to export power to the grid.

Over an 18-month period that began in December 2016 when EPCT made connection enquires for the G.James sites at Narangba and Eagle Farm, EPCT liaised with Energex engineers to find a path to export enabled connection agreements for these sites. Key concerns for Energex included:

- protection coordination;

- voltage control;
- frequency control;
- unbalance;
- neutral voltage displacement;
- transformer capacity; and
- reverse power flow.

EPCT initially attempted to have the sites assessed on a feeder-by-feeder basis, in the belief that the feeder-level control that could be achieved by the installation would result in higher amounts of solar export being permitted than by looking at each site in isolation. In hindsight, this caused delays in the Energex process. However, without this approach the final technical solution may not have been achieved.

EPCT was able to achieve the voltage control objective through demonstration of inverter capability to not only control but improve voltage control at the point of connection.

At the time of enquiry, neutral voltage displacement (NVD) protection was mandated by Energex for export-enabled solar connections over 200kW. Although EPCT mounted a compelling technical argument against the need for NVD protection, it wasn't until the relevant connection standard was changed in September 2017 that the NVD requirement was waived for the G.James sites.

The technical challenge of transformer capacity is an inherent property of the physical connection at each site. Through technical collaboration, EPCT was able to push the export limit for each site to as close as possible to the transformer rating, far higher than had been permitted on the Energex network previously. Export limits in excess of the values realised could only be achieved through physical replacement of the existing transformer. As transformer size tends to safely exceed the site load, upgrading existing transformers already in excess of site load was deemed to be commercially unfeasible at this time.

In total, EPCT secured 5,150kW of export capacity for the connection points. When completed, the G.James project will almost double the approved export capacity of commercial roof-top solar systems in Southeast Queensland.

3.4.1 Grid Stability

The proliferation of PV on medium and low voltage distribution grids requires Energex to manage negative load levelling impacts at times of high solar energy production and the rapid (and repeated) changes in generation due to environmental effects. The identified negative load levelling impacts have the potential to affect the behaviour of the traditional distribution grid, and require our consideration of:

- Protection coordination (the need to reprogram protection setting and potentially introduce additional protection equipment);
- Voltage control (rise, fluctuations and flicker);
- Frequency control;
- Unbalance; and
- Reverse power flow.

Each issue has been addressed by EPCT in the design of the proposed system. The specific grid stability concerns identified above have been addressed through the use of:

1. Protection: Primary and Secondary protection systems in multiple layers.
2. Voltage Control: Reactive Power Droop via the inverters, injecting and absorbing reactive power as required. Ramp control (see below) for fluctuations and flicker.
3. Frequency and Voltage Control: Ramp Control Up via inverters, Ramp Control Down via battery energy storage system with cloud camera.
4. Unbalance: Inverter and Relay Protection functionality.
5. Reverse Power Flow: Inverter and Relay Protection functionality.

Note: the calculated battery capacity is minimised by undertaking detailed engineering for rates of change (array orientation and size, cloud speed) and short-term forecast capability using weather cameras. The energy storage solution can be a single installation per 11kV feeder.

EPCT has worked in close coordination with SMA engineers in Germany, allowing proven grid stability technologies to be applied for Energex.

Please see the following Section for details of the Grid Management Capability this project has provided to Energex. Importantly for Energex, the inverters can be easily configured for rapid runback should there be thermal limitations in the Energex distribution network during normal or during contingency conditions. Furthermore, they have very good low voltage ride through protection capability, good frequency ride through and rapid post fault power recovery.

3.4.2 Grid Management Capability

Unlike a conventional power plant, a PV inverter system has customisable control features that allow them to provide grid management functions. They can assist in stabilising power in a manner that would otherwise incur additional costs (SVC's, STACOM's etc).
The inverters can receive and implement the target values as specified by Energex using all standard transfer protocols.

For the G.James solar installations, we have utilised state of the art Power Plant Controllers (PPC's) from SMA. This allows EPCT to coordinate the disparate sites around Eagle Farm as Virtual Generators.

These operate in a Closed Loop system giving extremely accurate pickup from Point of Connection and fast operation to the distributed inverters via Speedwire.

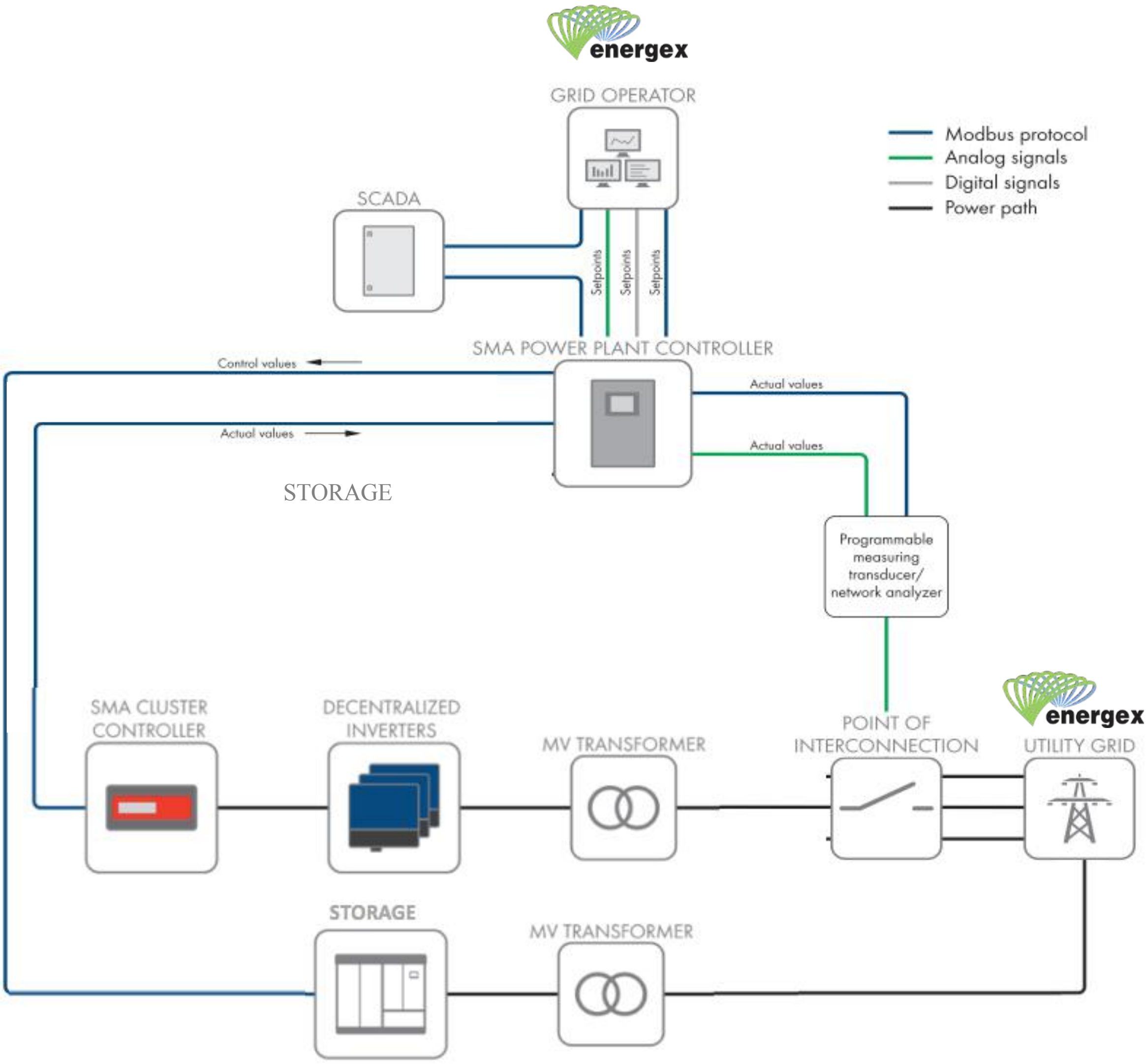

Fig 3.7: Operations diagram for G.James sites.

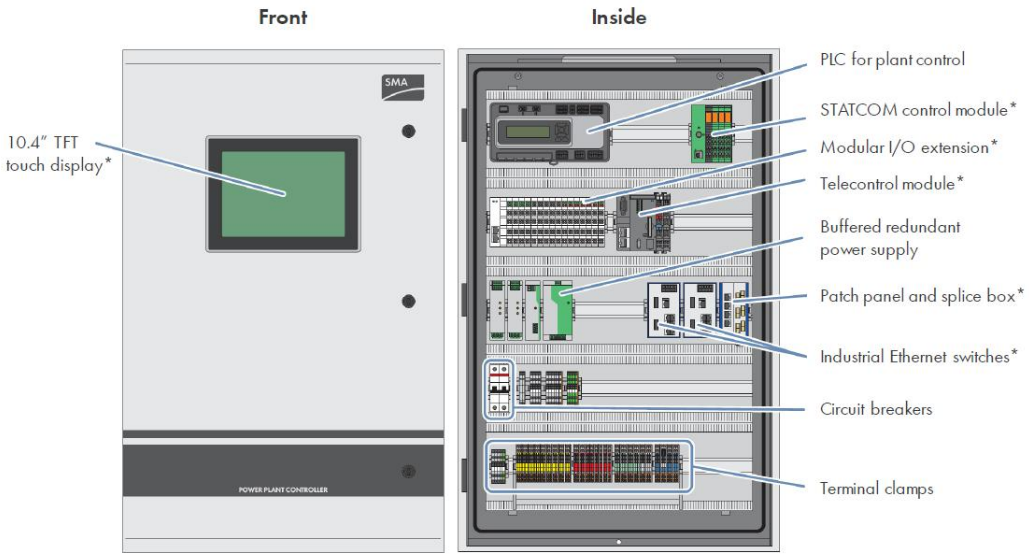

Fig 3.8: Layout of the SMA Power Plant Controller.

Of main benefit to the Energex distribution feeders connecting the G.James sites:

3.4.2.1 Active Power Control

- Constant setpoint for P
- Characteristic curves: P(f) or P(V)
- Feed-in limitation incl. “Zero-Feed-In” when required during specified constraints
- Active Power Reserve

3.4.2.2 Reactive Power Control

- Constant setpoint Q, cos Ø, tan Ø
- Characteristic curve Q(V), cos Ø (P), tan Ø (V)
- Q at Night / Q on Demand
- Individual Reactive Power Generation

3.4.2.3 Voltage Control

- Automatic voltage control (AVR)
- Voltage - reactive power droop
- Apparent Power Limitation
- Ramp Rate Control

EPCT anticipated that Energex would require some form of reactive power compensation to enable export of solar into the grid. EPCT proposed to achieve this through the use of static synchronous compensators (STATCOM’s).

Following detailed technical discussions with Energex and further development of inverter technology during the design phase (the selected Core 1 inverters contain the same technology as STATCOMs and can operate in all four quadrants), it became clear that sufficient control could be exercised at the point of connection via the PPC without the need for separate STATCOMs and they were removed from the design.

3.5 Structural engineering

Many of the buildings available for solar installation occupied by G.James date back to World War II. The United States had a large military presence in Brisbane, and what is now the industrial suburb of Eagle Farm was then used for the assembly of US fighter aircraft.

In order to maximise the use of the available roof-tops, an initial structural engineering assessment of the load bearing capacity and associated wind-loadings for each building was undertaken. The structural material and the spacing of purloin at the Narangba site placed limits on the quantity of solar that could be installed. Our analysis concluded that not only was it economically justified to install additional railing to support the installation of solar when the purloin spacing was too large, but that the south-facing sides of roof-tops could also be economically used.

A full structural engineering review of the Eagle Farm sites will only be undertaken after financial close has been reached.

3.6 Protection panel design

Protection panel design has been undertaken in close cooperation with EPCT, Energex engineers and EPCT's protection panel suppliers (PM Controls). The overall emphasis is threefold:

a) Compliance with grid specifications
b) Safety in operation
c) Reduction of cost using replicated control and protection grading systems.

The outcome of the collaboration between EPCT, Energex and PM Controls was to design a larger protection panel which is represented below:

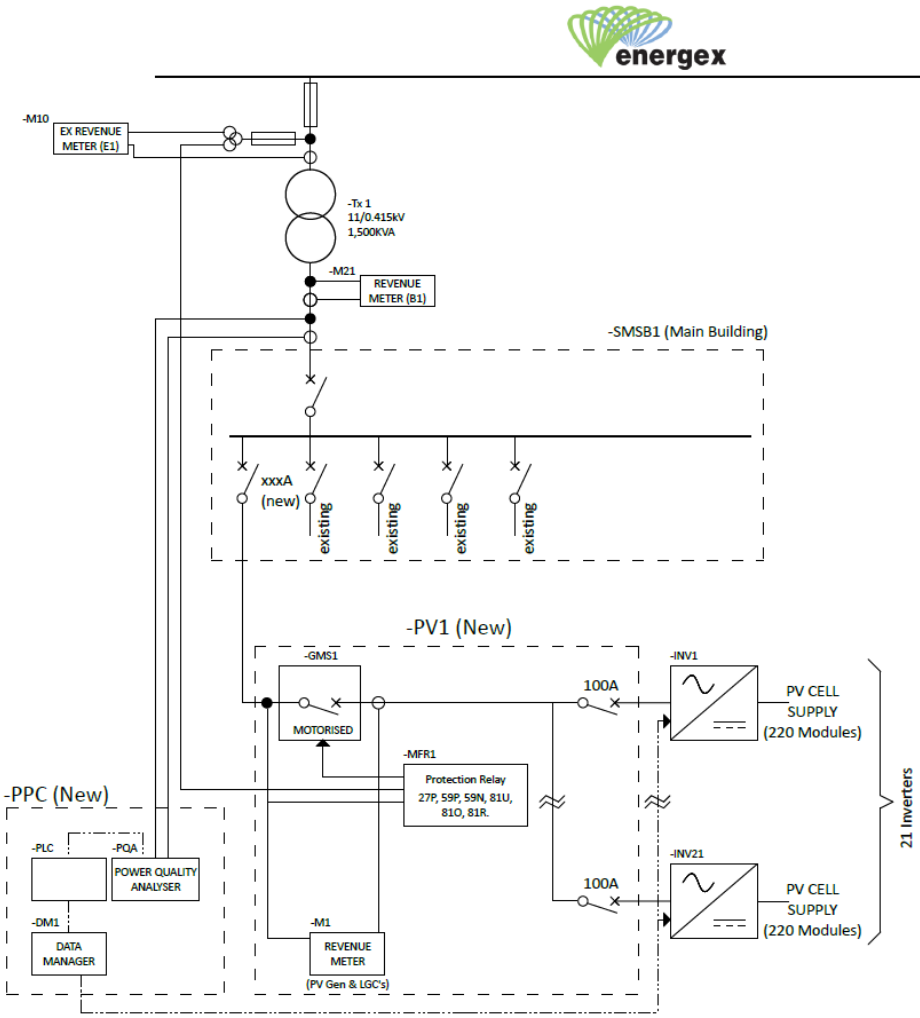

Fig 3.9: Protection system for a 1,050kVA installation.

3.7 Battery energy storage solution

EPC Technologies investigated the installation of high energy density lithium-ion battery systems on the 11kV feeders currently supplying the G.James industrial loads.

Each Battery Energy Storage System ("BESS") can be configured to provide controlled active power during sudden reductions (ramp down) of PV generation (cloud cover), allowing full control of the ramp rate. It should be noted that any sudden increases (ramp up) of PV generation is being controlled via the inverters.

The minimum size of each BESS is dependent on the ramp rate control, which is yet to be determined in conjunction with the Energex. We are currently targeting 6 x 500kW/1MWh units to be housed in 40ft containers at the two of the sites. These sites were chosen for commercial reasons. We gain economies of scale by focusing on the larger sites with lower capital cost per kWh of storage. These two sites also offer the greatest potential return on investment for BESS due to the expected post-solar load shape and current structure of network tariffs. It should be noted that the site-based variation in commercial outcomes is limited to these factors, as the market revenues from ancillary services and energy arbitrage are neutral as to location. Critically, from a technical perspective, the ramp rate control features are operable across all solar connected to each feeder, allowing flexibility across the portfolio.

Other sites will be considered as a second phase, with potentially smaller BESS at other sites, and/or the addition of capacity at these first two major sites. This second phase will be informed by the commercial value provided by the initial installations, as there remains considerable uncertainty associated with each element of revenue generated by the BESS.

The SMA Hybrid Controller 2.0 is well placed to undertake the BESS control function, giving a high level of open architecture. This allows EPCT to integrate and control the BESS's as part of the virtual generation system.

3.7.1 Communication

Communication between the PPC's, Data Managers and Core 1 inverters is via SMA's proprietary Speedwire (WiFi is available, however EPCT have opted for more secure fixed line communications).

Revenue communication is via MODBUS to local modems.

Top tier control / configuration of the system is via SMA's online portal.

3.7.2 Metering

Three types of metering devices have been employed for this project.

1) EDMI Mk10A units have been used for main revenue metering (export).
2) EDMI Mk10H units have been used for sub-metering to capture the LGC's at source.
3) SMA's Energy Meters have been used to coordinate reverse current in-feeds to the export control systems.

Selection of the revenue meters has been driven by AEMO / NER parameter requirements and ease of integration into EPCT's communication systems.

4 Installation

From a bankability perspective, we initially sought a construction contractor to provide a fixed price for the procurement and construction of the proposed power station. However, after initial enquiries it became evident that no medium or large-scale construction companies were operating in the roof-top solar industry. Further, those that were prepared to enter this market anticipated charging a premium reflective of the uncertainty that they faced and the risks that they perceived. They would subcontract roof-top installers, effectively charging a premium for their oversight and overall construction planning. A solution reliant on the participation of a medium or large-scale construction company would render the project uneconomic.

EPCT elected to directly use existing roof-top solar installers. We directly appointed Act Now Energy Solutions (Act Now) for the Narangba installation and have worked with them to complete the detailed system design and in the optimisation process. This approach has been rewarded with a high-quality approach to installation, and significant savings through optimisation.

5 Regulatory considerations

For the purposes of this demonstration project, EPCT sought to achieve all the necessary regulatory approvals directly. We anticipated that regulatory issues will be addressed through engagement with Energex, the Australian Energy Market Operator (AEMO), the Australian Energy Regulator (AER), and the Queensland Government. However additional engagement was also required with the Australian Energy Market Commission (AEMC), the Australian Competition and Consumer Commission (ACCC) and the Clean Energy Regulator (CER).

5.1 Australian Energy Regulator

Gaining a retail licence exemption for behind-the-meter energy sales is a straight-forward online process on the Australian Energy Regulator's website. It is an automated approval process for behind-the-meter sales to commercial customers. We received our retail licence exemption in the name of Smarter Energy Holdings Pty Ltd, applicable for all states in Australia in August 2017. If, as a result of our funding agreements, another entity is used as the contracting entity for the Power Purchase Agreement (PPA), EPCT will need to seek an additional retail licence exemption.

In May 2018, EPCT and G.James received an exemption from the requirement to register as a network service provider from the AER.

5.2 Queensland Government

The Queensland Government is responsible for issuing distribution licences and distribution licence exemptions in Queensland. It is a conflicted role, as the Queensland Government also owns the distribution and transmission network services companies in Queensland (Energex, Ergon and Powerlink).

EPCT meet with the Queensland Department of Energy and Water Services (DEWS) to understand the licencing requirements for the following physical outcomes:

- A battery installation directly connected to an Energex feeder or substation located on either public or private land;
- A STATCOM installation connected to an Energex feeder or substation; and
- A feeder connecting multiple sites and solar installations (in a similar way to a microgrid).

It should be noted that in Queensland we are able to rely on the special approval given under section 130 of the Electricity Regulation 2006 for generators under 30MW in capacity.

While supportive of our business model, DEWS highlighted some challenges with our proposed approach. We were informed that there may be issues associated with a private company accessing its equipment situated on public land, and that the regulations are designed only for the government-owned network companies.

As it turned out, we did not need to pursue an exemption from a distribution licence or seek to retain ownership of a dedicated distribution feeder, as lower cost solutions behind-the-meter solutions were available.

5.3 Australian Energy Market Operator

The AEMO registered EPCT as a Small Generation Aggregator (SGA) in February 2018 after a five-month application process. The extended application period was a result of the requirement of market participations to use AustraClear, and an extended review by the AEMO of EPCT's proposed connection and metering arrangements.

Clause 3.15.2 of the National Electricity Market Rules (the Rules) requires AEMO to provide an Electronic Funds Transfer (EFT) facility for all Market Participants, and for Market Participants to use that facility.

AustraClear is an antiquated and expensive funds transfer facility. It requires a Windows-based machine running version 8 (or lower) of Windows. EPCT received excellent support from ASX personnel but found the registration and software installation processes to be extremely cumbersome and time consuming. EPCT raised its concerns about the transparency and level of AustraClear's fees with the ASX and the ACCC. It also informed the AEMO and was pleased to hear that it is looking to introduce an alternative EFT facility in the near future.

5.4 Clean Energy Regulator

EPCT is in the process of registering its first facility with the Clean Energy Regulator. Our general registration has been approved as has our registered person application. No issues with this process have arisen to date, as it is simply a matter of stepping through the online process on the Clean Energy Regulator's REC Registry website. We expect to complete this process for our first facility by the end of July 2018.

5.5 Energex

Initial enquiries were made with Energex about each of the connection agreements in December 2016. For each application EPCT paid standard enquiry fees as follows:

Address	Amount
Site 1	6,568.06
Site 2	5,217.00
Site 3	5,217.70
Site 4	4,348.08
Site 5	5,217.70
Site 6	1,490.28
Site 7	6,706.26
Site 8	1,490.28
Site 9	6,706.26
Site 10	1,490.28
Site 11	6,706.26
Site 12	6,706.26
Narangba 1	1,490.28
Narangba 2	6,706.26
	66,060.96

We also paid $21,740.40 for a network study that Energex required. Energex self-performed this network study and we were not provided a copy of it.

It was evident throughout the feasibility study that the formal and standardised application process at Energex needed to be challenged so that our application was considered on its technical merits. The Energex personnel that EPCT engaged with were generally supportive and worked hard on our behalf to promote and process our applications internally. However, it has been a time consuming and costly process as we pushed the boundaries of what had been accepted previously.

6 Commercial Considerations

The financial feasibility of export-enabled roof-top solar is more complicated than either typical roof-top solar or large-scale solar farms.

6.1 Capital cost

Roof-top solar has an advantage over solar farms in that the primary use of the site remains unchanged. For most roof-tops in Australia, there are no planning approval requirements, and the use of the roof-top is typically granted as part of the overall power purchase agreement. By comparison, solar farms must purchase or lease land, and undergo local government, environmental and heritage approvals for the change of use of the site and solar farm construction. Were it not for the requirement for all solar installations to receive network connection approval, roof-top solar should be far quicker to construct.

Racking for roof-top installation is cheaper than ground-mounted framing on a per megawatt basis, however the time and manpower needed to install roof-top systems results in a higher overall cost. In addition, there are scale economies associated with inverter technology and other connection assets.

6.2 Financial Assessment

Within the constraints of always considering viable technical solutions, we tested a number of scenarios for the financial feasibility of the demonstration project. The critical variables for the financial viability of the project are:

CRITICAL FINANCIAL VARIABLES
Term of PPA
Pricing of PPA
Pricing and structure of network charges
Wholesale electricity prices
Large-scale Generation Certificates

Table 2: Critical Financial Variables

As with most roof-top solar projects, the price and term of the Power Purchase Agreement provide the revenue and revenue certainty needed to bank the project. For the demonstration project these factors are marginally reduced due to the quantum of energy being sold directly into the wholesale electricity market. However, the uncertain nature of market-based cashflows places more emphasis on the certainty of PPA cash flows.

The level and structure of network charges is fundamental to the success of the behind-the-meter energy and BESS. In Southeast Queensland, industrial and commercial businesses purchasing more than 100MWh of electricity annually face demand usage network charges based on their highest half-hour of energy consumption each month (measured in kiloVoltAmps (kVA)). This charge is the primary driver for energy storage, a critical capital cost. Secondary drivers for the need for energy storage include the available revenue streams for energy storage (e.g. energy arbitrage, ancillary services, etc), the nature of the industrial load, and the size of solar solution that can be installed. For the demonstration project, the export limits were not a key determinant of energy storage.

The project economics of the demonstration project were diminished during the course of the feasibility project as wholesale electricity prices retreated, and Large-scale Generation Certificates (LGCs) prices collapsed. The market's perception of future electricity prices and future incentives for renewable energy and carbon became critical to securing the necessary capital to proceed with the demonstration project.

6.3 Commercial Approach

EPCT appointed financial advisors for the demonstration project to run a process to introduce an equity partner. Through a formal selection process, New Energy Solar were selected to fund the project implementation. New Energy Solar and EPCT would own the generators, leasing roof space and selling power. After the PPA period the assets would be transferred to G.James.

With New Energy Solar's support, EPCT has been able to formalise all the necessary documentation to implement the demonstration project. This includes a proposed Power Purchase Agreement and supporting lease agreements, an Engineering, Procurement and Construction Agreement, an Asset Management agreement, and an Operating & Maintenance Agreement. Protocols for equipment and installation testing have been finalised, and insurance requirements defined. These agreements complement the market relationships established with the AEMO and Clean Energy Regulator.

Consequentially, a complete contractual arrangement has been defined between funders, developers, operators and the host and off-taker of the demonstration project.

6.3.1 Large Generation Certificates

During the course of the feasibility study the price for LGCs declined significantly as it emerged that existing projects would create a surplus of renewable energy against the 2020 target. Average forward prices for the 2019-2030 period sunk from approximately $55/LGC to zero.

This significantly reduced the available returns from the project.

6.3.2 Power Purchase Agreement

As noted above, the price and duration of the PPA are critical financial variables for the success of the project. The terms of the agreements reached with G.James are confidential.

6.3.3 Market Participation

EPCT registered as a Small Generator Aggregator and will sell energy not consumed by G.James directly into the NEM.

6.4 Feasibility Assessment

It is evident that, at the time of concluding this feasibility report, the revenue required to cover the capital costs of the project exceeds the sum total of the available revenue streams. In reaching this conclusion, we observed:

- The need to provide an economic return to investors
- The need to provide the industrial customer with a solution which reduced its energy costs over the life of the project.
- That the expected revenue from market sales of Queensland solar installations have fallen sharply in recent months, and that medium-term expectations are heavily influenced by current policy debates
- LGC revenue is now expected to be only a small contributor to the overall project
- The benefits provided by energy storage are highly uncertain and will not necessarily accrue to the project.