



V A S T S O L A R

MANUFACTURING AND OTHER CHALLENGES: UNDERTAKING R&D AND CONSTRUCTION IN REGIONAL AUSTRALIA – KNOWLEDGE SHARING NARRATIVE REPORT

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1 Our Story

The Australian Renewable Energy Agency (ARENA), and its predecessor the Australian Solar Institute, have provided grant funding and other valuable support to Vast Solar since 2012. This support has assisted Vast Solar to develop the world's first modular concentrated solar thermal power (CSP) technology that uses sodium as the heat transfer fluid.

This journey has involved the development of three substantive sites at which different elements of Vast Solar's unique CSP technology have been trialed, tested, refined, scaled and ultimately, delivered. This journey culminated in the delivery of the Jemalong CSP Pilot Plant which incorporates five CSP modules.

Vast Solar completed commissioning of the 1.1MWe Jemalong CSP Pilot Plant in June 2018, having first delivered power to the grid from the Pilot in January 2017. The Pilot Plant is a fully realised proof of concept of Vast Solar's CSP technology. It is an Australian world-first.

The journey to realise the CSP Pilot Plant would not have been possible without the support of ARENA which supplemented the private sector investment.

Knowledge Sharing forms part of Vast Solar's agreements with ARENA. Vast Solar has undertaken to share information via events and activities as documented in the Knowledge Sharing Plan agreed with ARENA.

This narrative report presents a discussion of issues and challenges experienced by Vast Solar as the company undertook manufacturing and construction of the Pilot Plant in regional Australia. The report concludes with some insights and lessons learnt along the way with regard to Vast Solar's journey to develop new CSP technology and to then build a world-first CSP Pilot Plant in regional Australia.



2 Introduction

2.1 Manufacturing and other challenges: Undertaking R&D and construction in regional Australia

This report provides an overview and discussion of some of the practical challenges (and opportunities!) that Vast Solar experienced as the company embarked and travelled upon the journey to undertake R&D development, trailing and testing of various aspects of our CSP technology at a rural location in western New South Wales. Construction of the 1MW CSP Pilot Plant at Jemalong, located some 36 kilometres west of Forbes on the Lachlan Valley Way, commenced in late 2013, subsequent to receipt of the Development Application approval from Forbes Shire Council that was received in September 2013. Construction of the plant was completed by late 2016, ready for grid connection in early 2017 and subsequent final commissioning and operation throughout 2018. Construction of the Pilot Plant project followed and built upon learning's from the construction of two preceding small research and demonstration sites that each tested particular aspects of the technology, the second of which was also located at Jemalong.

This report focuses on our experience in constructing the Pilot Plant. The Pilot Plant is an industrial site. It includes elements of heavy engineering, such as the power block, as well as new and novel engineering elements that are at the heart of Vast Solar's intellectual property and technological achievements. These novel engineered elements include the system of high temperature piping that contains and transfers the sodium heat transfer fluid, towers, receivers and a total almost 3,500 heliostats. All of these elements were either fully or in large part manufactured and constructed on site.

2.1.1 Facets

All of the heliostat facets were custom manufactured on site on a production line installed in a small factory. This entailed the purchase, importation and commissioning of an Expanded Polystyrene Block (EPB) manufacturing machine that was used to create moulds for the facets. Nine CNC routers completed the facet 'production line' and were used to cut and shape the polystyrene substrate. Adhesive bonded the glass to the curved surface and the remainder of the block was encased in zinc-alum sheet for weather proofing, stiffness and protection.



2.1.2 Receivers

At the top of each tower is a receiver. The receiver is an array of pipes with sodium flowing through them that are heated by the sunlight reflected from the heliostat facets. The tubes are covered in a special coating that maximises sunlight absorption and at the same time minimises thermal losses. The receiver is an integral part of the Vast Solar technology and is the result of over 8 years of development. The receiver design went through a number of iterations throughout the construction and commissioning of the Pilot Plant. Three distinct designs were fabricated, installed and tested at the plant.

2.1.3 HTF Piping

The network of pipes that are part of the heat transfer system had to be laid and pressure welded in—situ and this was one of the most significant and costly construction tasks. Construction of the heat transfer system involved construction, installation and connections of all the equipment necessary to circulate sodium through the receiver and distribution piping to storage tanks and the steam generator.

2.1.4 Purchased Equipment

Construction of the Pilot Plant involved the sourcing, freight and installation of a range of purchased equipment and materials. Large items included the steam turbine, generator, control systems, air-cooled condenser and water treatment plant. Major materials and components included the sodium, heliostat drives, valves and the suite of equipment that was required for on site engineering, construction and manufacturing. Our turbine was manufactured by G-Team, a Czech company specialising in making small steam turbines for industrial heat recovery applications that was especially imported for the Pilot Plant.

Materials sourcing, human resources, accommodation, telecommunications and freight challenges were all part of the journey that was embarked upon and completed by a passionate team who were determined to get the job done.



3 Our journey

3.1 Opportunities welcomed

3.1.1 Site selection

Novel technology development, manufacture and construction is often best located in proximity to universities, industry and other centres of technical excellence and practical know-how: that is, in proximity to or embedded within “clusters” of expertise and capacity.

Why then, did Vast Solar elect to locate its technology development and Pilot Plant manufacture and construction activities in the heart of one of the richest primary producing areas of New South Wales?

There were a number of good reasons why Vast Solar chose to locate Pilot Plant operations at Jemalong.

First, our major private investor was able to make available a secure, well located site of several hectares ideal for the purpose. The chosen site has a very good solar resource and enjoys grid connection to Essential Energy’s West Jemalong Substation. The site is not subject to flooding, and possesses good local road access to a major road, the Lachlan Valley Way, that in turn connects to a major highway. The site is located some kilometres from the nearest neighbours, mitigating potential concern about visual, traffic and other potential impacts.

Second, the site is located within Twynam Station, a property that delivers professional management and operations and enjoys the respect of the local community and of neighbouring property owners. These factors added value to our journey as it helped link Vast Solar into the local community and in due course with local groups such as local Emergency Services and the local NSW Rural Fire Fighting Service – connections that were of value to Vast Solar when we had a sodium fire in 2015 and in subsequent years as fire management plans were, with other standard items, integral parts of professional WHS and Emergency Management plans and protocols.



Third, Forbes and the greater Forbes Shire region enjoy good road and rail freight facilities and infrastructure and the Council and community were welcoming of innovative new business and employment opportunities.

Fourth, the site is located within range of Sydney and Canberra where we have important university research partners. Although some distance from Canberra, the site is located in good road proximity to Canberra that is a hub for universities, research and renewable energy innovation. Vast Solar has a close research partnerships and collaborations with teams at the Australian National University (ANU) and at the University of New South Wales (UNSW) and regular visits by researchers and Vast Solar personnel between ANU, UNSW and the Jemalong site have been a feature of our R&D and pilot construction journey.

Further, the ACT and regional Council's of central western NSW region have planned and put in place initiatives to become a renewable energy business region accompanied by a renewable energy tourist "trail". During and subsequent to the pilot's commencement Parkes and Forbes have seen significant solar project developments and Vast Solar has actively contributed to renewable energy initiatives led by the ACT Government in addition to developing and offering to market a 50MW PV project at Jemalong.

3.1.2 Forbes Shire - A warm and welcoming place to do business

The Forbes Shire Council on their website and elsewhere declare that they take a proactive approach to encouraging economic development within the Shire and, specifically, to encouraging job growth and wealth creation within the community.

Vast Solar's experience of working with Forbes Shire Council consistently confirms the above and we have enjoyed the opportunity to develop Vast Solar in a warm and welcoming business community. We have found Council's elected representatives and staff to be positive, engaging and always forthcoming with ideas within their mandate to assist.

A good example of proactive support provided by Council has been joint initiatives undertaken to establish the Jemalong Regional Education Centre (JREC). This recommissioned accommodation facility provides affordable accommodation to research and related personnel. Forbes Shire Council has a vision to establish Forbes as a regional central of medical service, research and excellence. To that end they encourage and facilitate researchers and associated



personnel to visit and work in the region. In 2013/2014 Vast Solar management provided support to Council in their plans to develop JREC. Since then, Vast Solar has held a longstanding relationship with JREC that has provided affordable accommodation and related IT services to visiting Vast Solar researchers and on site staff and contractors. This facility and the peer environment afforded by it has been of considerable value to Vast Solar as we have welcomed researchers and other personnel to visit and work at our relatively remote site from 2014-2019.

Forbes Shire Council staff have consistently provided proactive professional environmental and planning services and support to Vast Solar. Council staff and elected representative have visited our site on numerous occasions and often at their request.

Vast Solar has worked with Council on community consultation and engagement activities to deliver planning approvals processes for the CSP Pilot Plant. The Development Application for the Pilot Plant was submitted to Forbes Council in mid 2013, and documents about the proposal were placed on public display between 14 June 2013 and 15 July 2013. Community consultation sessions were held and positive community feedback received, including three submissions. The Development Application for the Pilot Plant was approved and the DA consent received in September 2013.

When Vast Solar experienced a sodium fire in 2015 Council fire services and other experts were ready to assist. Consequent Environmental Evaluation studies and associated remediation plans and recommendations have been seamlessly reviewed, approved and readily addressed. The cooperative and collaborative approach to this event and subsequent reports have enhanced collective knowledge about a relatively new industrial material (sodium) and how to deal with emergency situations and related environmental remediation issues that have proven to be straight forward and harmless to the environment.

3.2 Manufacturing and construction challenges encountered

Although Vast Solar has operated – physically and organisationally – in proximity to ARENA, key universities that include ANU and UNSW as well as research member organisations of ASTRI, The Australian Solar Thermal Research Initiative, now headed by CSIRO, it is hard to develop a break-through technology in isolation. Specifically, the lack of industrial supply chain partners – regionally and nationally – has hampered our growth.



To source many of the specialist materials and knowledge pertaining to them and related systems, we have had to deal extensively with overseas companies, mainly in Europe and Asia. Dealing with parties at a distance slows down progress from simple things like having to wait a day (timezone) to call a specific supplier with a simple question, to weeks or months waiting for prototype fabrication and shipping. Some of these challenges would have been experienced even if we had been located in a capital city and near an international transport hub but many were exacerbated by our regional location. Furthermore, certain challenges encountered in the manufacturing and construction of our Pilot Plant arose directly from our regional and rural location. These challenges are elaborated below.

3.2.1 Logistics – Telecommunications

Good mobile telephone coverage and reliable, secure internet services are essential for any business, especially a technology development company dealing with large amounts of sensitive data located in a remote area.

Vast Solar staff and consultants relied upon their mobile phones for telecommunications. The Jemalong region is one of New South Wales's many blackspots resulting in unreliable coverage. This was an irritating logistical and disruptive nuisance to our researchers and staff and made spontaneous communications between the on site team, our Sydney HQ and all business partners at times difficult.

Further, internet connection was often unreliable and/or very slow. This meant we were required to design and operate independent IT systems between site and Sydney HQ. The process made seamless communications and data management and sharing at times cumbersome.

Various interim solutions were explored and following numerous investments throughout 2016 and 2017, including repeater/signal booster systems, physical extensions to the internet antenna pole and the use of a new local service provider for data access, along with a slight improvement in overall telecommunications in the region, connectivity to the site improved to a relatively moderate level of reliability. Ultimately, the issue was solved by line-of-sight NBN from Forbes and Parkes via a costly and custom installation.

3.2.2 Talent and labour supply



The majority of Vast Solar's core team have been with the company since its inception, live in Forbes and commute to site at Jemalong each day. The core team has generally ranged in size from 12-17 people and expanded during periods of intensive activity. Many of the team are relatively young engineers and have resided in shared rental accommodation or at JREC. At times securing sufficient quality accommodation has been a challenge.

Construction of the Pilot Plant involved extensive manufacturing of heliostat facets and pressure welding of the extensive network of HTF pipe and construction of the sodium hot and cold tank storage infrastructure. As a relatively small project that involved multiple, novel elements, construction of the Pilot Plant was not suitable to be undertaken by a contracted engineering construction company. Rather, Vast Solar assumed responsibility for overall construction project management, labour sourcing, procurement and delivery.

At the height of the manufacturing and construction period a construction workforce of approximately 35-40 people were required on site (inclusive of Vast Solar's full-time team of 12-17 people). Expert consultants and contractors, such as high voltage electricians, were secured from within the region that is generally well serviced by expert small firms who provide services to regional mining, industrial and rural operations. Labour constraints in some key areas were however a challenge.

3.2.2.1 Expert high pressure welders

Australia has a talented pool of pressure welders due to its oil and gas and mining industries. At the time the Pilot Plant was constructed, the mining and Queensland gas booms were underway and the availability of talent with these skills in the Forbes region was either very limited or very expensive to secure.

Vast Solar addressed this challenge by utilising skilled foreign workers. We recruited two international, highly qualified pressure welders on 457 Visas following registration of the business as a Business Sponsor with the Department of Immigration.

3.2.2.2 Manufacturing and construction workforce

Securing sufficient numbers of reliable, skilled construction labouring staff was a challenge. Vast Solar addressed this challenge by contracting local labour hire companies to recruit and secure casual labourers to work with us. Overall, while our experience with the labour hire companies



themselves was positive and constructive, we found the calibre of local casual labour variable with limited ability to commit to several months of work. While this is understandable in a casual workforce, it presented further challenges in that our already pressed technical supervisory staff had to invest considerable – and repetitive – time in supervisory oversight and training of incoming labourers. This was especially the case with regard to the on site manufacture and installation of the heliostats. Outwardly simple, the task of manufacturing and mounting the custom designed heliostat facets required considerable attention to detail and precision and consequent high levels of supervision.

One of the advantages of undertaking manufacture and construction activities in regional Australia was the ability to readily recruit and employ international backpackers who were keen to secure well paid casual labouring work in such an area in order to be eligible to extend their working holiday Visa entitlements. Over the course of the construction of the Pilot Plant we employed some 5-10 backpackers on labouring tasks. Overall, their performance on the job was of a high standard. They performed well at the tasks given to them and they performed for the duration of the period for which they were employed.

3.2.3 Logistics – Sourcing of materials and components

As a business sourcing components and materials for a new and novel technology, Vast Solar at times experienced challenges to identify and to then import the required material or component. In some cases delays would have been incurred wherever we were located. The combination of relatively poor internet connectivity, timezone differences and freight delays (and/or obstacles) generated logistical challenges including:

- Rapid freight logistics: For international imports and/or those from major Australian cities, our experience was that overnight freight was rarely possible. More often than not, standard “Overnight Delivery” was more like 2 days to Forbes, and sometimes 4 days, and/or the alternative was to pay a very high premium for overnight delivery.
- Maintenance support: similar to the above challenge, we have found working in regional Australia has often meant that ‘same day or next day’ service and maintenance support is often delivered with at least 24 hours excess. For example, an inverter essential to secure power supply and software backup recently failed on a Friday. We were assured of maintenance/replacement support within 24 hours but this was delivered on a



Tuesday, with a consequent hold on data management and upgrading for a period of some 5 days.

- Unique materials and component supply issues: The above overnight freight issues compound time delays experienced by the necessity of sourcing unique materials or components only available from overseas. In most cases such components and materials (eg. unique sensors from Germany or Holland) can be sourced from Australian retailers but with lead times of at least 4-6 weeks with consequent delays to construction.
- Expense to import unique materials and components from overseas: Freight costs to major cities plus further freight costs to regional Australia. A good example is high temperature thermal paste for which there is no Australian manufacturer or importer/retailer.
- Procuring standard materials: Our construction experience indicated that quite standard materials – such as Schedule 80 High Pressure Pipes – could be difficult and expensive to procure. Such piping is a relatively common input to mining and engineering projects but we were surprised by stock lead times and availability from within Australia, from Australian suppliers.

3.2.4 Construction inputs – Equipment Supply and Hire

Construction of the Pilot Plant, along with regular maintenance of key plant elements including the solar towers and receivers, meant it was necessary to procure and/or hire specialist equipment for one-off construction and periodical maintenance tasks. Such equipment requirements included cranes and cherry-pickers for high and overhead work, bob-cats, specialist welding and drilling equipment. The town of Forbes is not home to any of the major equipment hire companies, but they are in business in Orange and Parkes, towns relatively nearby. This meant that it was possible to hire equipment in a timely manner for key tasks, albeit at not inconsiderable transport and hire cost.

3.3 Team logistics and regular on site management meetings



The Vast Solar management team is committed to regular team meetings and coordination. While much can be done by internet, phone and tele-conferencing, in-situ team meetings are optimal especially during construction, commissioning and trouble-shooting phases. The Pilot Plant is accessible from Sydney by road (a 5 hour drive) and by air (flights to Parkes, 1 hour, car hire and drive a further hour). Commuting by key team members to and from Forbes/Parkes and Sydney has been and continues to be integral to strong governance, team management and morale. It does however involve financial and management time costs.

In September 2016 the Forbes Greater Region experienced what is now generally considered to have been a very significant, 1 in 100 year flood. The physical Pilot Plant site was virtually unaffected by the flood and performed well during the flood event that lasted some six weeks. All major regional roads were closed for a period of 2-4 weeks. This meant that the Pilot Plant – then in the final stages of construction – had to be shutdown for several weeks as the majority of full time staff and casual labourers were not resident on Twynam Station and were unable to commute to work. Vast Solar had skeleton staff and event plans in place and the site was not adversely affected in any way. The flood did however present management and logistical challenges to that although readily overcome, did impact upon the overall project budget and delay completion of construction.



1. 4 Insights and Sharing Points

Vast Solar has appreciated the opportunity to be a member of the Jemalong and greater Forbes region community. We have found working in regional Australia to offer numerous benefits and to be in tune with our goals as a company developing technology suited and targeted to regional sustainable development. It has, accordingly, been timely and appropriate to develop the business in regional Australia but this has not been without challenges and financial cost.

Over the course of the Pilot Plant's construction Vast Solar created in excess of fifty jobs and many permanent roles in operations and engineering. In addition, Vast Solar procured services and materials from local consultants and businesses, injecting in excess of \$5,000,000 into the local economy.

Along the way we have experienced challenges associated with doing business in regional Australia. IT and telecommunications have been dreadful and the costs of sourcing, securing and training skilled personnel and labour have been high.

Australia is an extremely hard place to develop a novel industrial technology and our experience suggests that doing this in a regional location adds further challenges.

Vast Solar has been fortunate to overcome challenges associated with working in a regional location by virtue of the professional determination and focus of our dedicated investors, management and operations team, along with the implicit and explicit encouragement of a supportive local community and Forbes Shire Council.

Ends.