LLOYD ENERGY SYSTEMS PTY LIMITED

LAKE CARGELLIGO SOLAR THERMAL PROJECT

Advanced Electricity Storage Technologies Program

FINAL PUBLIC REPORT

to the

Commonwealth of Australia

as represented by and acting through

The Department of Resources, Energy and Tourism

Report has been prepared in the context of and for the purpose of completion of the AEST Program Funding Agreement for the Lake Cargelligo Solar Thermal Project.

5 August 2011

PUBLIC DOCUMENT

CONTENTS

PUBLIC DOCUMENT

1. OVERVIEW

1.1. Project

Lloyd Energy Systems received a $5 million grant as part of the AEST Program to deliver the Lake Cargelligo Solar Thermal Project.

1.2. Program and Project Objective

The objective of the AEST Program was to demonstrate that the intermittent generation of electricity from renewable energy can be enhanced through the development and application of solar thermal energy storage technology.

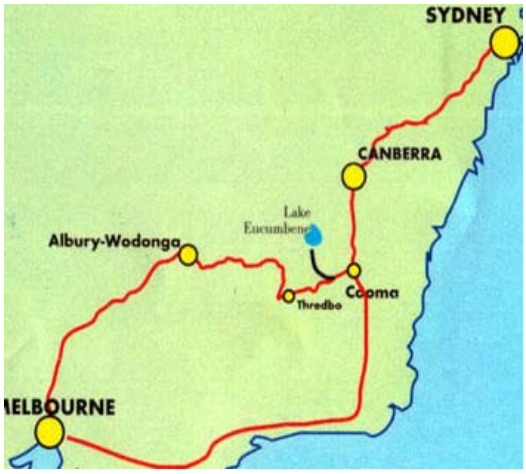
The key objective of this Project was to demonstrate that solar thermal energy could be collected when available and delivered on demand through the use of sensible thermal energy storage with low storage losses. The successful capture of this solar thermal energy could then be used to produce electricity and therefore improve access to power in remote areas, grid stability, power quality and overall electricity reliability.

1.3. Location

The Project was conducted in 2 stages:

Stage 1: Build a test graphite solar storage receiver ("**SSR**") and heliostat array at Cooma, New South Wales approximately 400km South of Sydney.

Stage 2: Build a Solar Thermal Power Plant at Lake Cargelligo, in the central west of New South Wales approximately 600km West of Sydney. The Project site is located approximately 4km from the township of Lake Cargelligo, which has a population of 1,300 people.



Lake Cargelligo

1.4. Technology

Background

The core graphite thermal storage technology was developed in Australia by Lloyd Energy Systems. Over 15 years of research and development has gone into building the world's first graphite based solar thermal storage system. This system leverages the unique characteristics of graphite – specifically;

- High specific heat with moderate emissivity
- Stable material (does not suffer a phase change) over a wide temperature range of up to 1500°C
- Low coefficient of expansion
- Good thermal conductivity

In 2009, Lloyd Energy Systems became a subsidiary of Graphite Energy.

Project

The Project uses concentrated solar power focused into a graphite SSR, set out in a multi tower solar array. The Project included building a solar thermal power plant which consists of eight SSR's each mounted on its own tower, with dedicated dual axis tracking reflective heliostat fields of approximately 760m^2.

Each of the SSR's are effectively an on demand steam generator, which is connected by a steam manifold that delivers the steam to the balance of plant and a $3MW_e$ steam turbine generator, which is in turn connected to the Australian National Electricity Market.

2. PROJECT OUTCOMES

Through the completion of the Project, thermal energy has been effectively stored when available and extracted on demand, thus enhancing the value of an intermittent source of renewable energy, enabling:

- Generation of steam independent of the primary solar energy source
- Energy is made available on a steady and consistent basis avoiding intra-day solar volatility or cloud intermittency
- Plant and equipment to be more efficiently used because the energy can be extracted from the storage medium in a controlled and predictable manner, thus achieving higher energy output from the renewable energy source
- Production of electricity
- Distributed energy generation that can reliably provide network support

The specific project achievements include:

2.1. Construction

The construction of a substantial megawatt scale plant suitable for the demonstration and validation of the technology which will enable further commercialisation activities including:

- Construction of an 8 tower solar array with 620 dual axis tracking heliostats
- Installation of 8 SSR's
- Development in conjunction with suppliers, a dual axis tracking heliostat system with substantially higher target tracking specification than previously available in the market
- Installation of a balance of plant suitable for the production of steam over a wide variety of steam conditions, as many potential users have varying steam production requirements for either industrial use or electrical generation

Steam Plant Design	**Minimum**	**Maximum**
Temperature:	200°C	500°C
Pressure:	20 bar	50 bar
Flow Rate:	1.5 tonnes / hour	10.0 tonnes / hour

- Design and commissioning of the steam management and control system which will form the basis of future plants
- Installation of a 3.0 MW_e steam turbine generator connected to the National Electricity Market

2.2. Steam Performance

The Project has demonstrated that thermal energy can be effectively stored from an intermittent energy source and extracted on demand in a reliable and predictable manner. Steam has been produced at the Lake Cargelligo Solar Thermal Plant at temperatures between 200°C - 500°C and various pressures up to 50 bar. The actual steam tests have successfully validated SSR design assumptions around delivering consistent steam conditions. Further testing will be undertaken over the next 12-18 months to continue to improve system performance.

2.3. Electricity

The Project has successfully generated electricity through the production of steam via a renewable energy source. Under its current design the Lake Cargelligo Solar Thermal Plant has the capacity to generate 3MW_e for 1 hour. The operation of the plant to produce electricity is not currently a commercially viable proposition due to existing low electricity generator tariff levels. The Project will continue to explore opportunities to make the production of electricity a

viable commercial objective where electricity can be generated to improve access to power in remote areas.

2.4. Social and economic benefits

While not a specific objective of the AEST Program, the Project has also demonstrated that significant economic and social benefits can be achieved from implementing renewable energy projects as a form of distributed energy in regional and rural locations, including direct employment and training, support of existing and the development of new local industry and suppliers, and general indirect economic stimulus within the local economy during a period of severe drought.

2.5. Pathway to product commercialisation

The pathway to commercialise new and innovative technology is not always a well defined roadmap. In order to support organisations on this pathway, NASA has developed a nine step Technical Readiness Level (TRL) framework now used by the US Department of Energy when reviewing US technology deployment and that can be used to define current and future product commercialisation activities. Based on the current Lake Cargelligo Plant status, it has achieved TRL6 where "system prototyping has been demonstrated in a relevant end-to-end environment".

2.6. Next Steps

In order to move the technology to a level of commercialisation and achieve TRL9, future investment will be required at Lake Cargelligo to undertake the following activities:

a) Testing – although modelling activities have been validated with actual data, more data points are required before full system performance can be guaranteed to both financiers and construction partners. In order to achieve this objective, a detailed testing program and schedule has been developed that will be conducted over the next 2 years

b) Regulatory approval – in order to supply, operate and deploy the SSR into projects around the world, the SSR must achieve regulatory compliance in both fit for purpose design and performance. In order to achieve the required levels of regulatory certification a significant level of actual performance data, material fatigue stress levels and design assumptions is required. This is currently underway and will be completed over the next 2 years

c) Project development – the key to commercialisation is to build a pipeline of projects that will support technology deployment. Current project development activities have focused on the USA and Europe markets due to attractive renewable energy incentives. Although there has been significant interest in the technology, technology risk levels and financing challenges have hindered global project development activities

3. APPROPRIATENESS

This project addresses the key challenges within the concentrated solar power ("**CSP**") industry of storage, intermittency and the consistent production of steam.

In order to increase the likelihood of success, the Project was broken into two distinct stages;

- Stage 1– development of a single prototype of the SSR at the Lloyd Energy System's Cooma facility
- Stage 2 – Fabrication, construction, installation and commissioning of the Lake Cargelligo Solar Thermal Plant

This two stage process enabled project risks to be identified and managed effectively prior to the full 8 module SSR roll-out at Lake Cargelligo.

4. EFFECTIVENESS

The Project has demonstrated a very effective means of storing an intermittent renewable energy source and converting it into a known and manageably supply of energy that can be used as required, rather than as produced, with minimal losses.

Energy storage is essential for the long term viability of the CSP industry because it:

- Allows the collection of all of the thermal energy when it is available without having to worry about if it is an optimal time to generate
- Dampens the fluctuation in the actual rate of direct normal incidence radiation ("**DNI**") caused by cloud cover and other atmospheric conditions, which allows the stored energy to be extracted in a controlled and uniform manner and increases the consistency of the steam production and the consequent electrical production
- Allows renewable energy to better match demand, because it is no longer dependent on the time of collection
- Allows the plant to fulfil other functions within the electrical generation and distribution system, other than being an intermittent generator. With the addition of large scale reliable

energy storage, CSP can also provide stand-by capacity and network support to alleviate the need to upgrade transmission infrastructure which may be stretched beyond its capacity for only relatively brief periods during times of peak demand

The SSR has the unique advantage of having embedded storage. The storage is not an additional component or add on, but an integral part of the technology's design.

The embedded nature of the energy storage in the SSR not only allows it to more effectively meet the needs of the CSP industry described above, it also provides the plant owners with enormous operational flexibility. The manner in which the energy is to be extracted from the storage can be changed to suit the production requirements at any given time.

CONCLUSION

Overall project objectives have been successfully achieved and the SSR technology is on the pathway to commercialisation. Specific achievements include; the world first construction of a substantial megawatt scale plant that can demonstrate the performance of the graphite based solar storage receiver; steam has been made available on a steady and consistent basis avoiding intra-day solar volatility or cloud intermittency; the production of electricity; significant social and economic benefits have been achieved within the Lake Cargelligo town and surrounding region due to project investment; and, a viable pathway for commercialisation has been identified based on industry standard guidelines.