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ABBREVIATIONS

AEMO	Australian Energy Market Operator		
AUD	Australian Dollar	kWh	Kilowatt-hour, unit of energy (1 kW generated/used for 1 hour)
BOM	Bureau of Meteorology	LCOE	Levelised Cost of Energy
CSP	Concentrating Solar Power	LFR	Linear Fresnel Reflector
CST	Concentrating Solar Thermal	ML	Mega litres
DNI	Direct Normal Irradiation	MW	Mega Watt, unit of power = 1000kW
GW	Giga Watt, unit of power = 1,000,000 kW	NEM	National Electricity Market
HTF	Heat Transfer Fluid	PV	Photovoltaic
ITP	ITP Energised Group, including	REZ	Renewable Energy Zone
	ITP Thermal Pty Ltd	SEGS	Solar Energy Generating System
kW	Kilowatt, unit of power – subscript e for electric, th for thermal	VRE	Variable Renewable Energy

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Project Summary

WORLD LEADING TECHNOLOGY

The first plant of this kind in Australia, the technology to be used in Project Wentworth concentrates the heat from the sun to reach temperatures close to 600°C, stores it in molten salt tanks and uses it to produce power in a steam turbine.

POWER FOR 60,000 HOMES

The 100 MW Project Wentworth plant is expected to produce 400,000 MWh of clean electricity every year. Almost 10 million tonnes of carbon dioxide emissions will be avoided over the 30 year lifecycle of the project, the equivalent of taking 120,000 cars off the road.

DISPATCHABLE ENERGY

Thanks to its energy storage capabilities, the plant will be able to generate power when the national grid needs it most, on demand. Using a steam turbine with a synchronous generator also will help stabilise the grid. At 100 MW in capacity, the Project Wentworth plant will be among the largest Concentrating Solar Power (CSP) plants in the world. Based on power tower technology, this advanced system captures the solar radiation and stores the energy, in the form of heat, to be transformed into electricity when needed. Located in Wentworth, in South Western NSW, this is an answer to Australia's need for affordable, reliable, 24 hour a day renewable electricity.

BENEFITS

This large-scale renewable power plant is a most needed addition to the Australian power grid. Operating similarly to a conventional coal plant but with greater flexibility, this system offers generation on demand and provides stability services like frequency and voltage control to a power grid with increasing penetration of wind and solar photovoltaic (PV). The plant will create local jobs, including 1500 direct jobs during construction and 40 during operation. It will also act as a tourism drawcard for the area and it will help kickstart the uptake of CSP systems in Australia.

LOCATION

Located on "Netherby" approximately 10 km north of Wentworth, the site of the plant is in an ideal location that combines great solar resources with a strategic position in the National Electricity System. It is close to existing electricity transmission assets and in particular will be close to the new 'EnergyConnect' interconnector that will join SA with NSW and VIC.

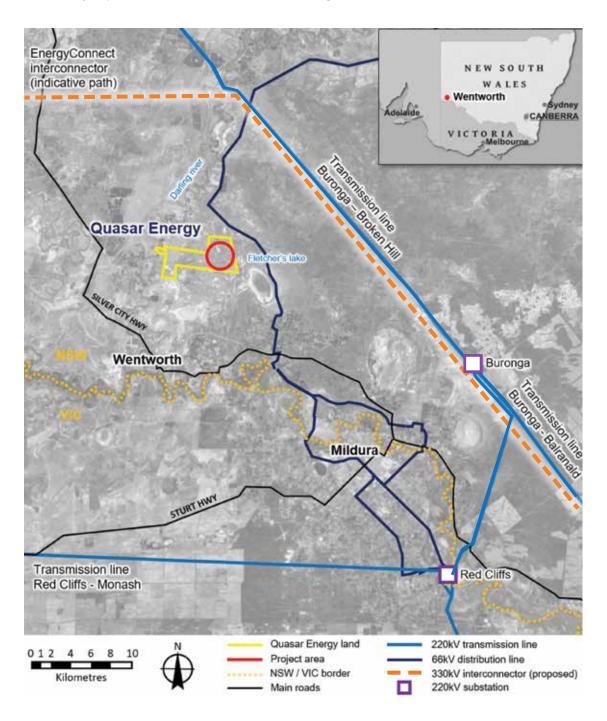
TECHNOLOGY CSP plants are a proven technology already implemented worldwide. They produce electricity the same way as fossil fuel power plants - by creating high-temperature, high-pressure steam to turn a conventional turbine. Instead of fossil fuels, they use energy from the sun. Thousands of software-controlled mirrors track the sun and reflect the sunlight to a receiver that sits atop a central tower. The heat is stored in tanks to allow generation day and night as required.

POTENTIAL

CSP plants with built in thermal energy storage are a key technology that can allow countries like Australia to achieve 100% zero emissions electricity generation as existing coal plants retire progressively over the next two decades. By being the first of its kind in Australia, Project Wentworth plant can act as a precursor for larger CSP developments in the future years.

Ideal Location

Quasar Energy is pursuing the goal of establishing solar thermal power generation in the area near Wentworth, in South Western NSW. Quasar Energy has secured 1800 hectares of freehold land currently used for grazing, on "Netherby", 10 km north of Wentworth, situated between the Darling River and Fletcher's Lake. The plant will have access to water resources and is situated in the vicinity of power transmission and distribution grids.





EXCELLENT SOLAR RESOURCE

The key factor affecting the feasibility of a CSP plant is the Direct Normal Irradiation (DNI) available in the location. The DNI solar resource in Wentworth, assessed using data from the Bureau of Meteorology (BOM), is around 2200 kWh/m² per year. This is world class and on par with, or better than, many CSP power plant sites around the world.

A highly accurate solar monitoring ground station has been established on Quasar Energy's land in order to obtain precise and reliable data to calibrate the BOM satellitebased estimates.

A KEY POSITION IN THE POWER GRID

Quasar Energy's land is positioned relatively close to the local power distribution and transmission network. Its position next to both the NSW – VIC interconnector and to the proposed 330 kV interconnector between NSW and SA gives the plant the possibility to provide its positive effects on the grid to three states.

Further confirmation of the value of Quasar Energy's land position is its inclusion in Renewable Energy Zone 13 in the Australian Energy Market Operator's (AEMO) 2018 Integrated System Plan (ISP). Renewable Energy Zones (REZ) are areas considered to have valuable renewable resources, good strategic location and are to be prioritised for future improvements to transmission capacity.

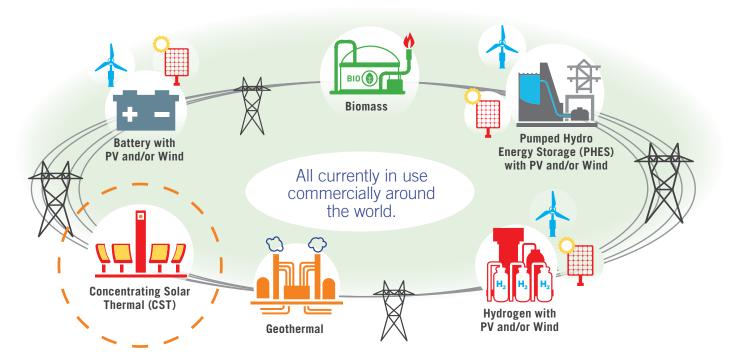
The need for dispatchable renewable power

Australia's transition to a lower emissions power grid has seen the rapid implementation of variable renewable energy (VRE) generation from wind or solar PV systems. At the same time, existing coal plants have been reaching their end of life and are progressively retiring. While this ongoing transition contributes to lowering the CO₂ emissions in the power generation sector, the variability in power from VRE renewables makes matching supply and demand a challenge and it raises concerns around the reliability of a system with declining fossil fired dispatchable generators.

A significant share of total generation needs to be dispatchable, ie provided by power generators that can raise or lower power output on demand. CSP with thermal storage is one of a range of options for achieving this with renewable energy.

WHAT IS DISPATCHABLE RENEWABLE ELECTRICITY?

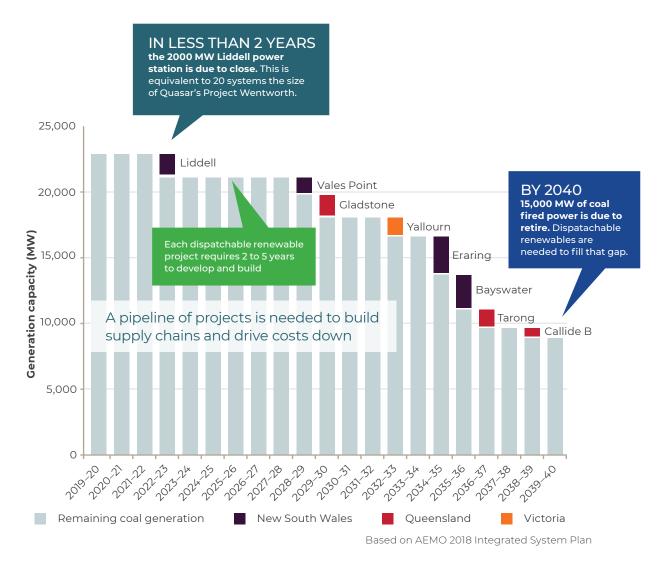
Renewable energy power plants that can vary output (up or down) at the command of the operator.



Based on ARENA 2018 Comparison of dispatchable renewable electricity options

AN URGENT MATTER

The Australian Energy Market Operator (AEMO) predicts the retirement of the majority of the National Electricity Market's (NEM) coal generation fleet over the next 20 years. This will happen progressively as plants reach the end of their working lives. The replacement of power currently produced by coal plants will have to be met by a combination of VRE systems, energy storage and backup supply and peaking.



CSP A KEY PART OF THE SOLUTION

CSP with energy storage is one of the most cost effective dispatchable renewable technologies available for longer durations of storage that are essential for the future grid. Battery systems are competitive for short duration smoothing, however, for 10 hours or more, CSP generates electricity at less than one third of the cost of PV battery systems. System-wide modelling of the uptake of new generation technology confirms the

role of CSP in a least cost low emissions generation mix¹. Using realistic performance and configuration assumptions and AEMO's 2018 ISP costs, modelling suggests that in order to achieve a reliable minimum-cost energy mix, 5.4 GW of CSP plants should be installed by 2040 in New South Wales alone. The Quasar Energy CSP plant is the first step in establishing a pipeline of such projects.

Concentrating solar power

CSP plants are renewable power systems that use the sun's radiation to generate electrical power. At the core of CSP technology are the mirrors that collect and concentrate the sun's radiation.

Unlike PV technologies, which convert sunlight directly into electricity, CSP plants first use the solar radiation to generate thermal energy, which is stored and then later used to produce power. This aspect is important as thermal energy can be easily and cheaply stored and used at different times, allowing CSP plants to provide low cost dispatchable electricity.

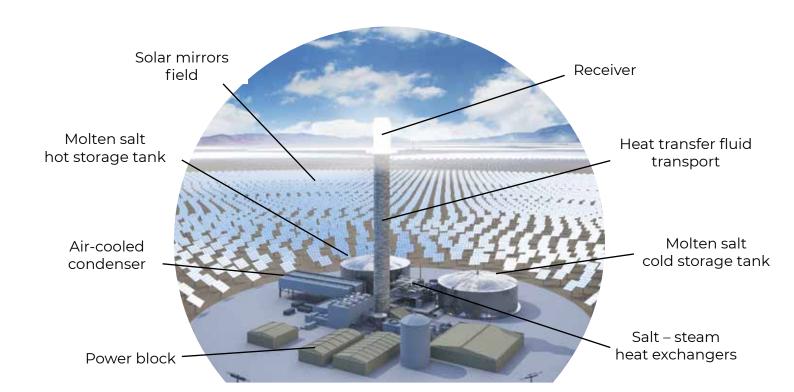
STRONG TRACK RECORD

The history of commercial CSP plants started in the USA in the second half of the 1980s. This technology has proven to be very reliable, to the point that most of the plants installed in California between 1985 and 1990 continue to operate today, beyond their life expectancy of 25–30 years.

There has been a large growth in global uptake of CSP since 2006. Like wind and solar PV before it, rapid compound growth is achievable once market signals are established.

Up until 2013, nearly all existing CSP plants were based on the parabolic trough technology. Tower plants are now increasingly favoured for their capacity to achieve higher temperatures (600°C compared to 400°C for a linear system) and more cost-effective storage.

- Carte



SOLAR WITH BUILT IN ENERGY STORAGE

The CSP systems built to date use steam turbines to generate electricity in a similar manner to fossil fuel fired power stations. These power plants are attracting increasing interest due to their ability to store large amounts of energy and provide low cost dispatchable electricity. The current industry standard approach is to use a mix of molten nitrate salts as a heat storage medium that is moved between a 'cold' tank at around 290°C to a 'hot' tank at close to 400°C for a linear system or 600°C for a tower system.

DESIGNED TO STRENGTHEN THE NETWORK

In a power grid increasingly weakened by the penetration of non-dispatchable wind and solar PV, Quasar Energy's CSP plant is designed to provide valuable grid strengthening services. This is possible as a consequence of using steam turbines that produce power through synchronous generation. This configuration provides the same inertia benefits as from conventional gas and coal plants. Furthermore, the turbines are specifically customised for fast start and are capable of ramp rates of 10% per minute.



The technology

FROM SUNSHINE TO ELECTRICITY

The process of producing power from the sun's radiation involves several steps. Firstly, the concentrating mirrors focus the solar radiation onto the receiver to heat up a heat transfer fluid to high temperatures. In the case of tower technology, molten salts are typically used as the heat transfer fluid. The same molten salts, stored in large tanks, are also used as the thermal energy storage medium. In order to produce power, the hot salts are withdrawn from the storage tank and are made to circulate through a series of heat exchangers where they generate steam by heating up water. The pressurised steam is what drives the steam turbine and this rotational motion is then converted into electrical power in the generator. The cool steam from the turbine is then condensed into water in an air-cooled condenser, recompressed and pumped back into the salt/water heat exchangers.

DOING IT WITH THE MIRRORS

For a tower power plant, the mirrors consist of an array of heliostats (large mirrors tracking the sun along two axes) that concentrate the sunlight onto a fixed receiver mounted at the top of a tower. The high level of concentration produces high temperatures and therefore high efficiency energy conversion at a single large receiver point. High temperatures also make the thermal storage cheaper as the same amount of heat can be stored in a smaller amount of thermal medium.

Project Wentworth | **DISPATCHABLE 24HR SOLAR POWER** Electric Grid THAT RECEIVER GENERATOR **POWER TURBINE Power Block** RECEIVER TOWER HELIOSTATS AIR-COOLED CONDENSER -1-------Collector Field HOT SALT TANK PUMP Tower/ **Receiver System** CONTROL ROOM Thermal Storage System

THERMAL STORAGE WITH MOLTEN SALTS

Thermal storage is what enables a CSP plant to produce 24-hour solar power. The system consists of two large insulated tanks (one hot tank and one cold tank) that store a mixture of potassium and sodium nitrate salts, at a sufficiently high temperature to maintain them in a molten state. These salts are cheap, safe and never need replacement (they already have a large market as fertilisers).

During the day, the molten salts are moved from the 'cold tank' and heated up in the receiver (close to 600°C), then they are transferred to the 'hot tank' by the use of pumps. At night, they follow the opposite path and the energy contained in the salts is used to power the steam cycle. The salts can retain their heat for weeks due to the effective insulation of the tanks. In situations when heat cannot be provided from the solar field (eg programmed maintenance), electric heaters are used to keep the salts in a molten state. In the case of forced curtailment to nearby wind and solar PV farms, the same heaters could be used to store the surplus energy in the salts to be dispatched at later times when there is a need for power. This effectively allows the plant to pursue additional revenue from energy arbitrage.

Project details

PROJECT WENTWORTH BY THE NUMBERS

- 100 MW steam turbine
- 14 hours of thermal storage
- Solar multiple: 2.8
- Located on 1800 hectares of Quasar Energy land
- Solar field area: 650 hectares
- Heliostats solar field reflective area: 1,300,000 m²
- Nominal solar field capacity: 680MW_{th}
- Tower height: 232 m
- Average annual generation: 400,000 MWh
- Storage size: 1400 MWh_e, (10 times the Hornsdale Power Reserve 'Tesla big battery')
- Boiler type: molten salt steam generator
- Cooling method: dry cooling (air cooled condenser)
- Water consumption: 121 ML/year
- Avoided CO₂ emissions: 300,000 tonnes/year

PLAR

PURDING

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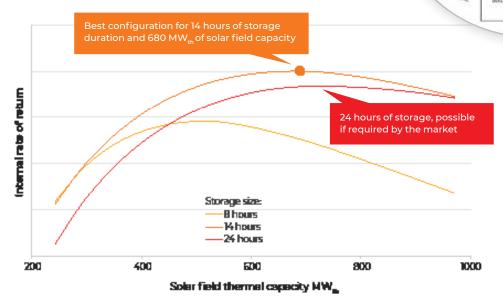
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OPTIMUM CONFIGURATION

The Quasar Energy Project Wentworth plant is designed to make the most of the changing Australian power landscape. The main parameters of the system (number of mirrors and hours of storage) were selected through sophisticated software optimisation that included forecasting the future evolution of the electricity market. This analysis method maximises the revenue, minimises the risks for the plant, and ensures the most beneficial contribution to the power grid.



CAREFUL USE OF WATER RESOURCES

By employing dry cooling, the only substantial water need is for the periodic cleaning of the mirrors. The annual total water use for the plant is estimated at 121 ML per year, equivalent to the irrigation needs of less than 15 hectares of irrigated crops in the Sunraysia region².

² Seasonal water use for grapes: 8.4 ML/ha. Data from Department of Primary Industries, Victoria.

Project benefits









A STRONGER POWER GRID

Dispatchable power, synchronous generation and flexible operation are the characteristics that make the Quasar Energy plant a key contributor to improving the reliability and strength of the local power grid.

LOCAL JOBS & SKILLS

Jobs of all skill sets will be created both during construction and throughout the 30 year life of the plant, including around 1500 direct jobs during construction and 40 ongoing roles during its operation. A local supply chain will be created for the supply and maintenance of the plant components.

NEW CLEAN INDUSTRY

This plant has the potential to kickstart the use of a new renewable technology in Australia, making the most of the excellent solar radiation resources and creating a new local industry around solar thermal technology.

TOURISM

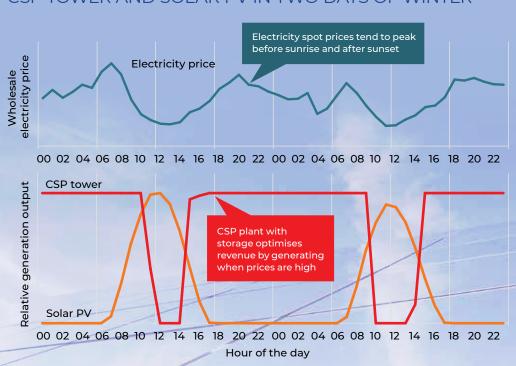
The plant will be a tourism drawcard for the area. Guided tours of the mirror field and the power block, together with learning experiences at the visitors centre can provide a close up view of this world changing technology.

COMPLEMENTING SOLAR PV

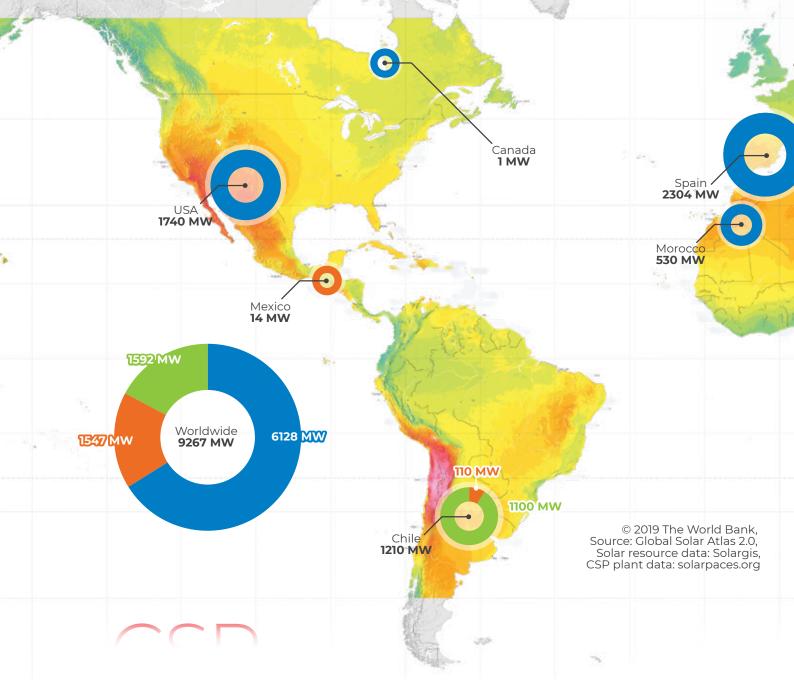
The 100 MW Quasar Energy CSP plant will be connected to a transmission grid area with high penetration of PV power, both existing and under development. While utility-scale PV systems can offer low-emission and low-cost energy, their power production is concentrated in the central hours of the day. As local demand is low during those hours, this means that most of this energy needs to be transmitted across large distances to other load centres, generating high transmission losses. Furthermore, when the transmission network does not have enough capacity, the PV farms' output needs to be curtailed.

During the evening and nights, the opposite occurs as PV systems stop generating and the local demand grows – requiring power to be transmitted from distant dispatchable generating plants. The CSP plant, being dispatchable, has the potential to complement the generation from PV systems. This means not generating during the middle of the day and using the thermal storage to move the power generation to other times, reducing the strain on transmission lines during the evening and morning demand peaks and reducing the need for an upgrade to the power grid.

The power grid will also benefit from the addition of the Quasar Energy CSP plant. As the plant uses a conventional synchronous steam turbine generator system to produce electricity, it always contributes inertia, frequency control services and voltage support when running.



ELECTRICITY PRICES AND GENERATION PROFILES FOR CSP TOWER AND SOLAR PV IN TWO DAYS OF WINTER

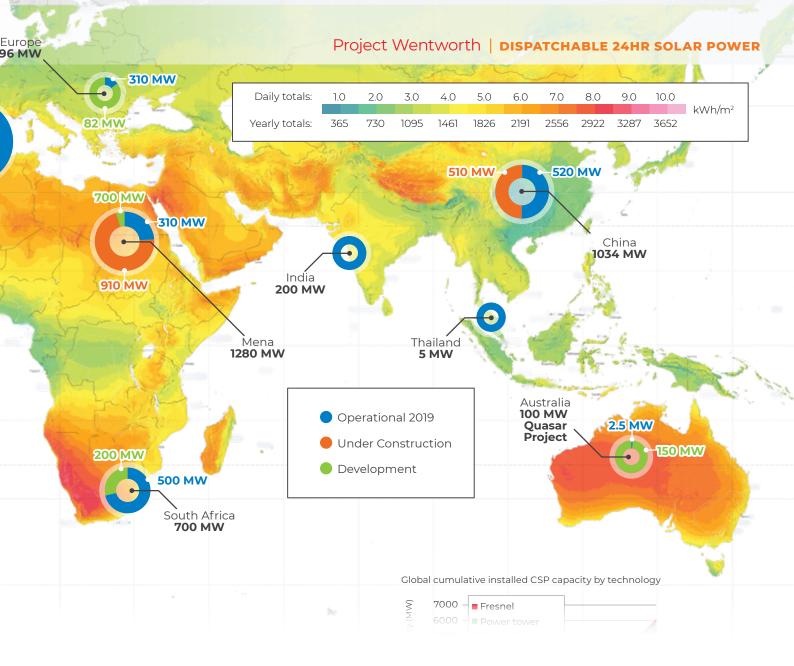


around the world

At the end of 2019 there were 120 CSP plants in operation in 19 countries giving a total installed capacity of 6.1 GW. The majority of the plants installed since 2006 have incorporated two tank molten salt thermal energy storage.

Countries with high solar resources and growing energy demand have led the way

with CSP. The USA is home to the first commercial CSP plants, as well as some recent 'first of a kind' tower systems. Spain began a resurgence of CSP uptake from 2006. Morocco, South Africa, Chile and India have all progressed. China is a recent entrant with several new plants.



I U V V LIX U I U I LIMU

The positive track record of parabolic trough systems partly explains why to this day 4.7 out of 6.1 GW of globally operating CSP plants are based on this technology. However, tower systems offer higher temperature energy collection directly to molten salt, leading to more efficient power generation and more cost effective storage of energy.

Solar tower technology has had a shorter demonstration period at the commercial scale. The first utility-scale tower plants were direct steam generating plants built in Spain after 2007 while the first molten salt tower system was built in 2011. Both the steam-based and the molten-salt based plants have been operating reliably since their completion.

Cumulat Ο 2009 2010 2011 2013 2014 2014 2015 2015 2015 2015 2018 2018 2018 2008

2000 1000

The NOOR III plant in Morocco, the largest molten salt tower plant built to date (150 MW), has been exceeding its performance targets.

The good track record of tower plants together with a more efficient way to obtain large energy storage has seen a growing share of new CSP systems adopting this technology.

To date, the global installed capacity of operational molten salt tower plants is around 600 MW, and more facilities continue to be developed and constructed.

case study Spain



IMAGE CREDIT: iStockphoto, Gemasolar Plant Seville Spain

PIONEERS OF CSP TOWER MOLTEN SALT TECHNOLOGY

In Spain, favourable policies introduced in 2007 enabled the rapid development of a leading CSP industry in a short period of time. By 2013, a total of 2.3 GW of CSP plants were installed, employing a workforce of around 20,000 professionals. During this period, Spain built the first commercial CSP tower plant with molten salt storage, the 20 MW Gemasolar plant in Seville.

Spain remains as the international CSP leader for accumulated deployment representing a third of the global capacity with 2300 MW. Currently there are a total of 50 plants under operation. Consistent levels of generation have been achieved year on year and 2.7% of the Spanish electricity demand is covered by CSP plants.

Spain currently has a total of 5200 professionals employed in the CSP industry. This has renewed their interest in the technology, with 5 GW of capacity envisaged in the 2021–2030 National Energy and Climate Plan that they recently submitted to the European Union.

CASE STUDY



IMAGE CREDIT: iStockphoto, Crescent Dunes, Nevada

THE EARLY STAGES OF CSP DEVELOPMENT

The USA pioneered the CSP industry with the world's first Solar Energy Generating Systems (SEGS) plants in the late 1980s. These plants were enabled by favourable policy measures. As incentives ceased in the early 1990s, CSP developments came to a standstill and did not resume until the construction of the Nevada Solar One plant, which completed construction in 2007.

In 2011, new measures, including loan guarantees for renewable projects, were

introduced. As a result of these measures, the USA now represents the second largest market in terms of total installed capacity with 1745 MW. In 2014, the Ivanpah Solar Power Facility a 392 MW power tower plant was completed. Furthermore, since 2014, the world's biggest parabolic trough plant, Solana, is under operation with a capacity of 280 MW. The most recently completed plant in the USA, the Crescent Dunes 100 MW molten salt tower system in Nevada, is still working through commissioning.

case study China



IMAGE CREDIT: PROTERMOSOLAR, China Shouhang Dunhuang 100 MW molten salt Solar Tower Concentrated Solar Power Plant

THE WORLD'S FASTEST GROWING CSP MARKET

China has a target of 50% renewable electricity generation by 2050. On top of consistent development of wind and solar PV, a "pilot program" for solar thermal projects was announced in 2017 with a total of 20 projects and 1.35 GW of capacity. By the end of 2018, three plants were successfully connected to the grid: Delingha 50 MW trough, Delingha 50 MW molten salt tower and Shouhang Dunhuang 100 MW salt tower. One year later, four more plants completed commissioning, for an additional 200 MW of capacity. This corresponded to half of the world's newly-built CSP capacity in 2019. Three quarters of the total installed CSP capacity consists of tower power plants, the rest being shared between parabolic trough and Fresnel technologies.

Beyond this initial pilot program, China has suggested longer term plans for around 30 GW of CSP by 2030.

CASE STUDY



IMAGE CREDIT: Keith Lovegrove, Noor III Morocco

THE LARGEST CSP TOWER MOLTEN SALT PLANT TO DATE

Morocco's implementation of CSP began with a 20 MW trough based Integrated Solar Combined Cycle project that has been operational at Ain Beni Mathar since 2008. Morocco has now announced plans to develop 2000 MW of solar energy projects, both PV and CSP, across five different sites.

The biggest project so far is the Noor Project and it was completed in 3 stages: Noor I, Noor II and Noor III. Located near Ouarzazate, the Noor complex has a total CSP capacity of 510 MW. Noor I is a 160 MW trough plant with 3 hours storage, Noor II is a 200 MW trough plant with 7 hours storage and Noor III a 150 MW molten salt tower system with 7 hours storage. Noor III is the largest CSP tower molten salt plant in the world to date and has been performing well since commissioning.

case study Chile



IMAGE CREDIT: Cerro Dominador © 2019, www.cerrodominador.com

LEADING THE WAY FOR CSP IN LATIN AMERICA

Chile has been experiencing an energy crisis, with high electricity costs that represent a hurdle for economic growth and investments, especially for energy intensive sectors like the mining industry. A significant slice of the mining activity is carried out in the northern part of the country, a desert area that also has the highest DNI resources on the planet. In this area, there is a pipeline of 9 CSP projects in the planning phase and one plant at an advanced stage of construction known as Cerro Dominador. The unit is a tower molten salt plant with a gross capacity of 110 MW and 17.5 hours of storage. This will be the first CSP system in South America. The Chilean Ministry of Energy has also developed a Chile CSP roadmap that includes plans to establish a 1 GW solar park that is intended to include six 100 MW tower systems.

CASE STUDY



IMAGE RENDER: 2020 Dubai Electricity and Water Authority, www.dewa.gov.ae

GROWING INTEREST IN CSP FOR THE MIDDLE EAST

Renewable energy has become economically attractive in the oil-rich United Arab Emirates (UAE). Inaugurated in the UAE in 2013, 100 MW Shams is one of the largest CSP plants in the world. Recently, the Dubai Electricity and Water Authority (DEWA) selected Saudi Arabia's ACWA Power and China's Shanghai Electric to build a 700 MW plant (600 MW trough with 10 hours of storage and 100 MW tower with 15 hours of storage) providing more than three times the capacity of the initial plans. The project is set to break a number of records in the CSP industry, including the largest molten salt storage system and the tallest receiver tower. Under the terms of the contract, the new plant will deliver energy at US\$0.073 per kWh which will make this a benchmark project in the world in terms of cost of generation.

Project team



DAVID WELLS - CHAIRMAN

David Wells has served in senior corporate roles over 30 years, in Australia and overseas. He has broad experience in raising capital for a variety of projects in the health, industrial and energy sectors. He is currently the founding Executive Director of Falcon Corporate Advisory, a role he has held for over 10 years. He is a past Director of Terrain Capital (5 years). David served as founding Managing Director of Sterihealth (STP: ASX), Chairman of Hyde Park Wines, and Regional Vice President of the Campbell Soup Company. David has worked in senior roles in Canada and Hong Kong over a 10 year period.

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ALLAN RITCHIE – DIRECTOR

Allan Ritchie has served as a director of several private and public listed companies in the energy sector. Allan continues to serve as Non-Executive Director (NED), previously as MD & CEO, of Hydrocarbon Dynamics (HCD:ASX). He served as MD for 3 years with Adavale Resources (ADD.ASX) and prior to that served as the ED & Deputy CEO of EPI Holdings Limited (0689.HKEX). Allan is also an investment banking professional with a career spanning 30 years of originating and structuring deals focused on the energy & resources sector and has worked in London, New York, and Asia Pacific.

allan.r@quasarenergy.com.au



MinterEllison

Technical Advisor: ITP Thermal Pty Ltd itpthermal.com

Legal Advisor: MinterEllison

Next steps how to make this happen

Quasar Energy completed a prefeasibility study for Project Wentworth in 2019 and resolved to move ahead with the project.

A solar data and weather ground-station has been installed in the location of the plant in order to validate the BOM data used in the pre-feasibility study.

The process to obtain approvals for construction and connection to the power grid is currently underway.

Quasar Energy has identified potential EPC partners and CSP technology providers.

Equipment cost estimates from suppliers of critical equipment will allow more accurate financial analysis for the financial closure phase.

Once financial closure is reached and the engineering design is in a sufficiently advanced phase, the procurement phase will begin.

Starting from the long-lead items, the procurement phase will continue beyond the start of site preparation and construction.

Once the construction is well progressed, the commissioning of each subsystem of the plant will be carried out in sequence. This phase will continue right through to the connection of the plant to the power grid.

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