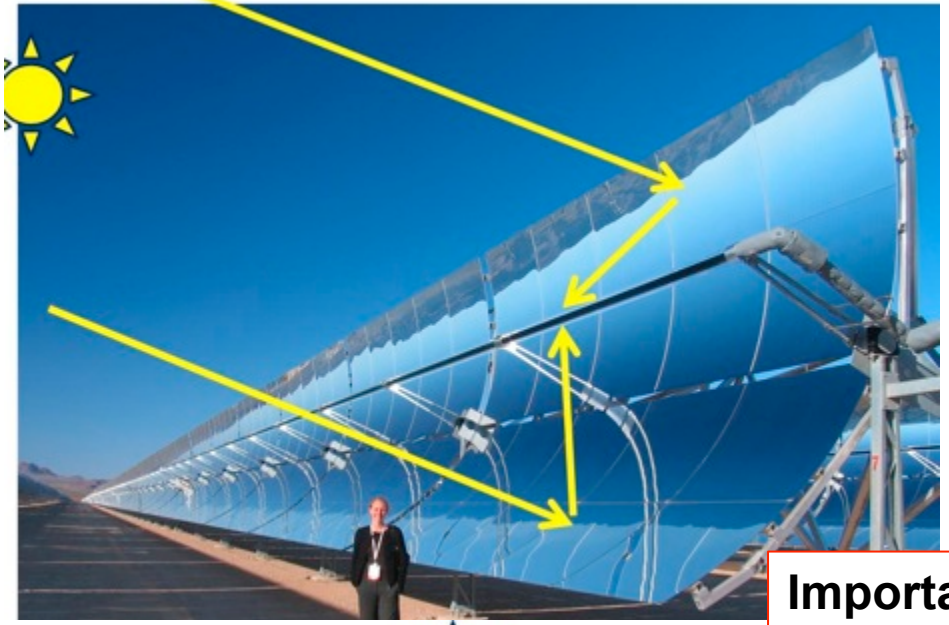
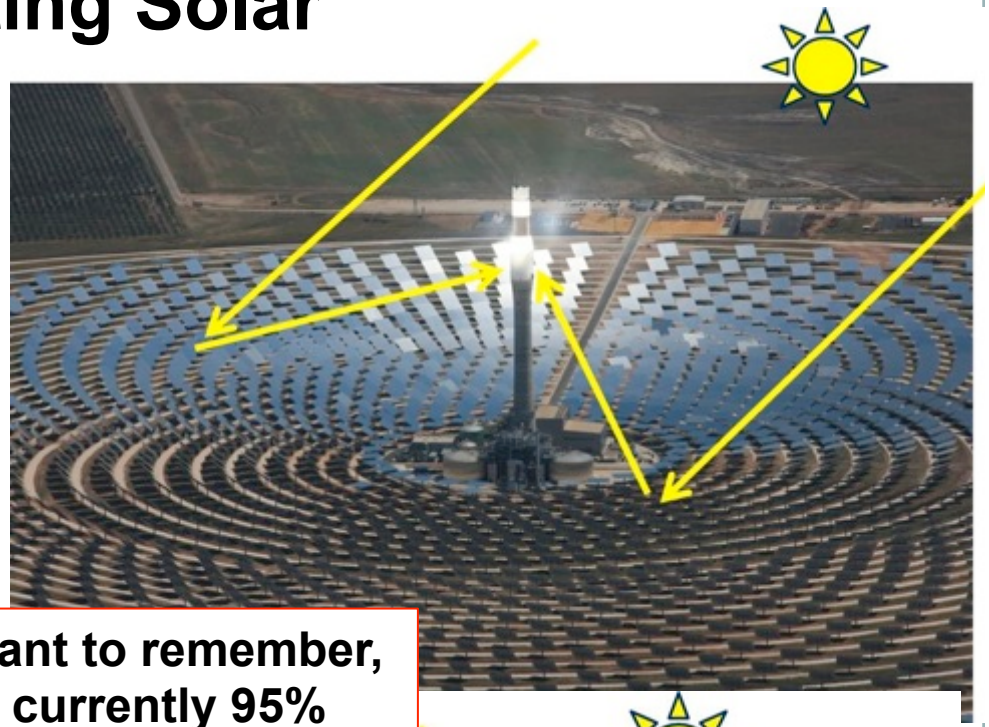
Concentrating Solar Thermal – a key part of the clean energy revolution

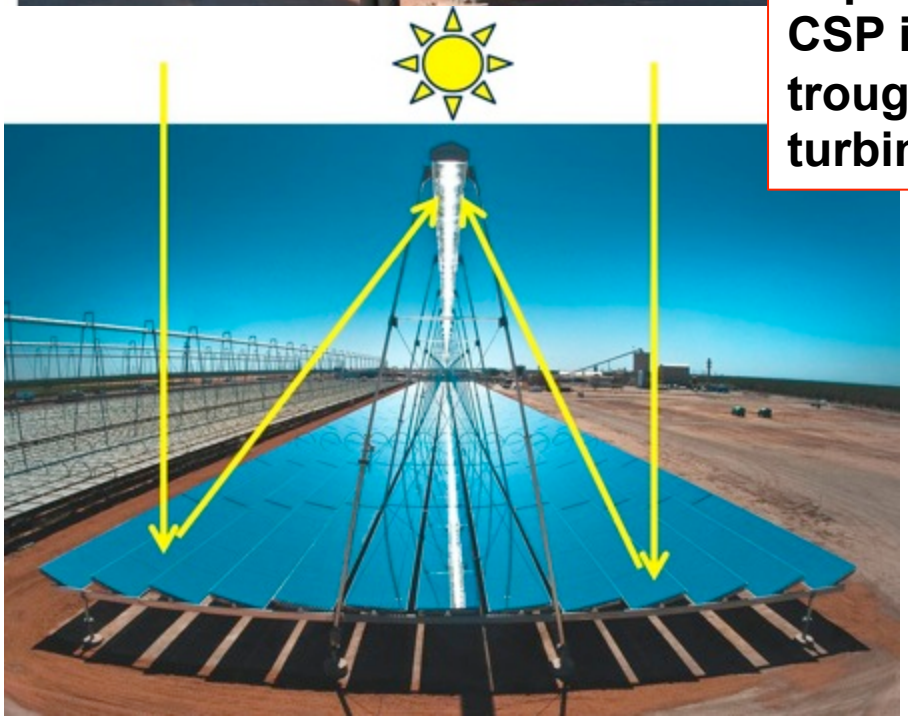
Dr Keith Lovegrove
Head – Solar Thermal, IT Power Group
http://www.itpowergroup.com

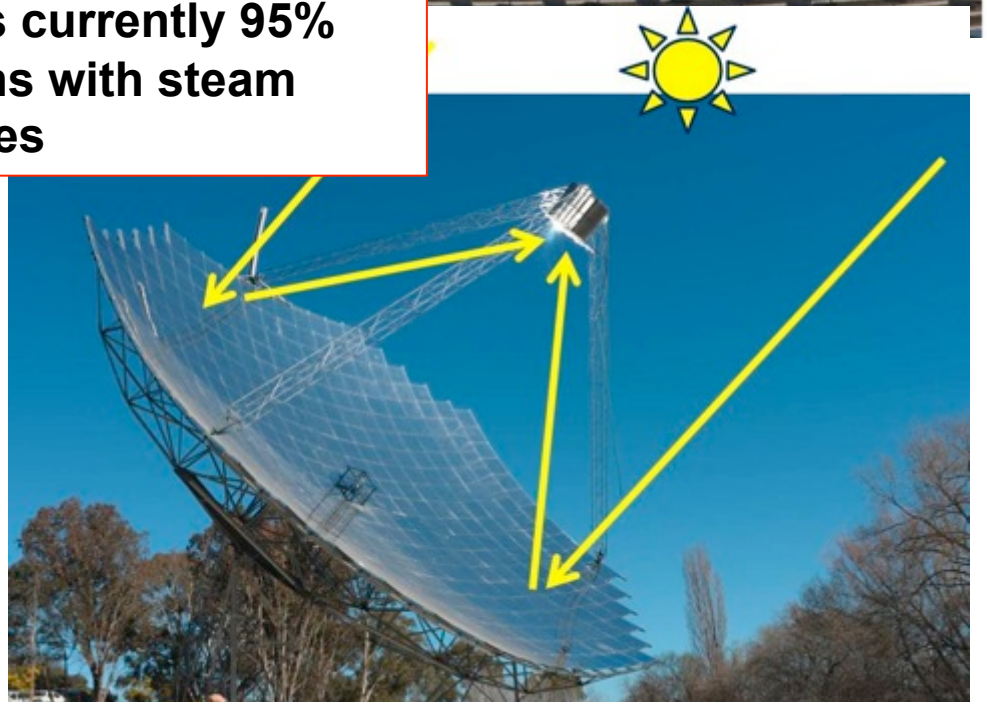
Concentrating Solar



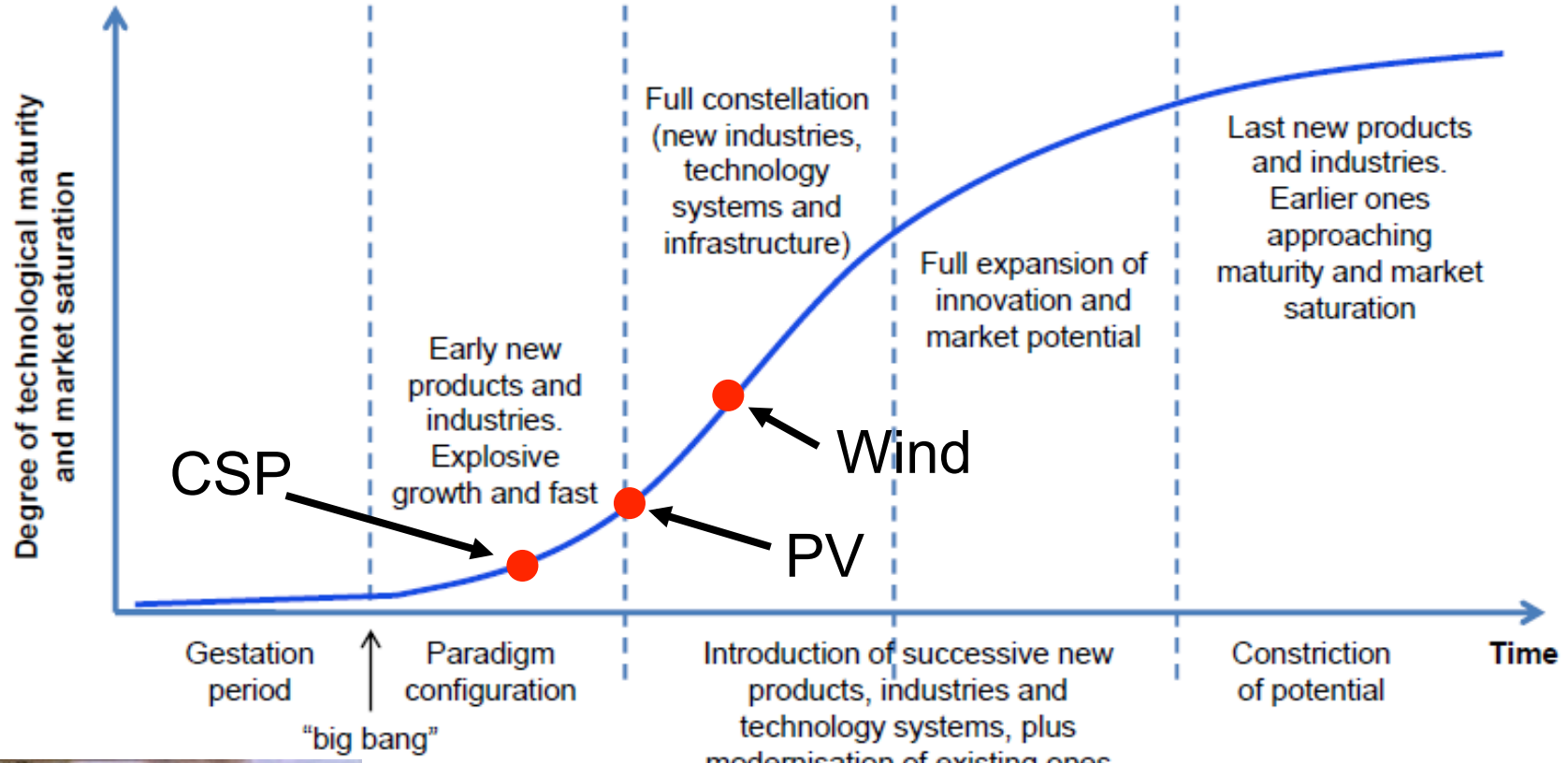


Important to remember, CSP is currently 95% troughs with steam turbines



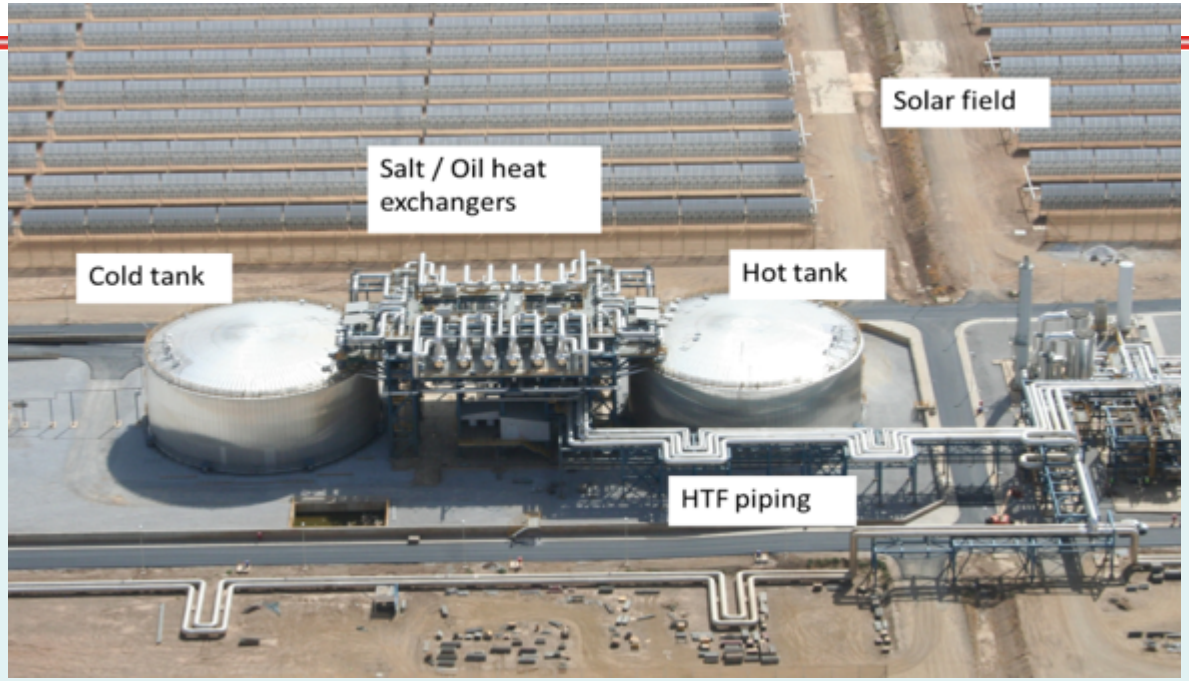


Lifecycle of an energy technology revolution



PÉREZ C. (2002), *Technological Revolutions and Financial Capital. The Dynamics of Bubbles and Golden Ages*, Edward Elgar, Cheltenham.

Proven Thermal Energy Storage is CSP's big competitive advantage



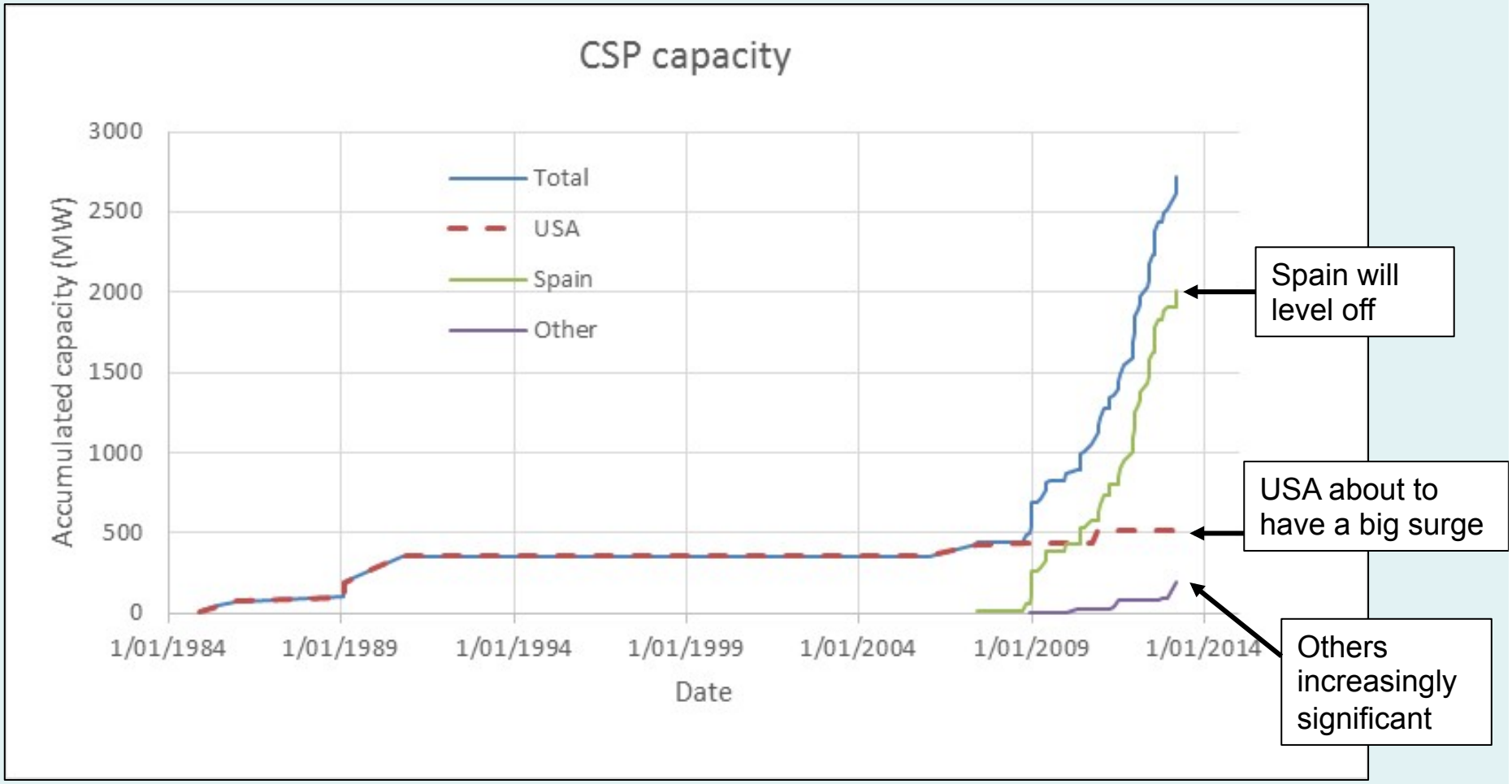
Background pic, Andasol 3 courtesy Ferrostaal

- Thermal storage is "integrated" – improves output, little or no extra cost
- Two tank molten salt is proven / standard (62% plants in Spain)
- A Higher temperature range makes it cheaper
- Salt tanks have electrical heaters as ultimate back up.
- A CSP system could simultaneously offer electricity storage at 30 - 40% round trip efficiency

CSP offers

- **Dispatchable energy supply:** the range of baseload to peaking
- **Extensions for existing technologies**: hybrid with coal and gas plants to enable least-cost transition.
- **Emission reduction**: 10GW of capacity would reduce by roughly 15% of current sector emissions.
- **Clean energy sector growth:** more of the value is created in the country of installation and the capability exists for the processes needed.
- **Community-supported generation:** need not compete for land or water. Every 100MW system would create around 500 job years during construction and 20 O&M jobs mostly in regional areas.
- **Potential for future solar fuels**: For domestic and export markets.

History of CSP deployment



Key International CSP market developments

- Spain: projects approved for old FIT gradually finish then slow .
- USA: 5 plants under construction to 1.28GW$_e$, recent announcement of a new joint Abengoa, Brightsource tower system.
- India: 20GW Solar by 2022 JNNSM, first phase 470MW$_e$ CSP under construction – first 50MW plant on line June 2013.
- Saudi Arabia: 25GW target for CSP by 2030.
- Italy: Generous FIT; aiming for 250MW$_e$ by 2020, proposals to 400MW for Sicily and Sardinia.
- Morocco: 42% solar by 2020, yet to announce FIT, final bidding for first 160MW of CSP at 500MW Ouazazate site.
- South Africa: 1 GW CSP by 2030, 200MW allocated to 1x trough and 1 x tower projects.
- Chile? Others?

And

Brightsource's Ivanpah 400MW$_e$ system beginning commissioning

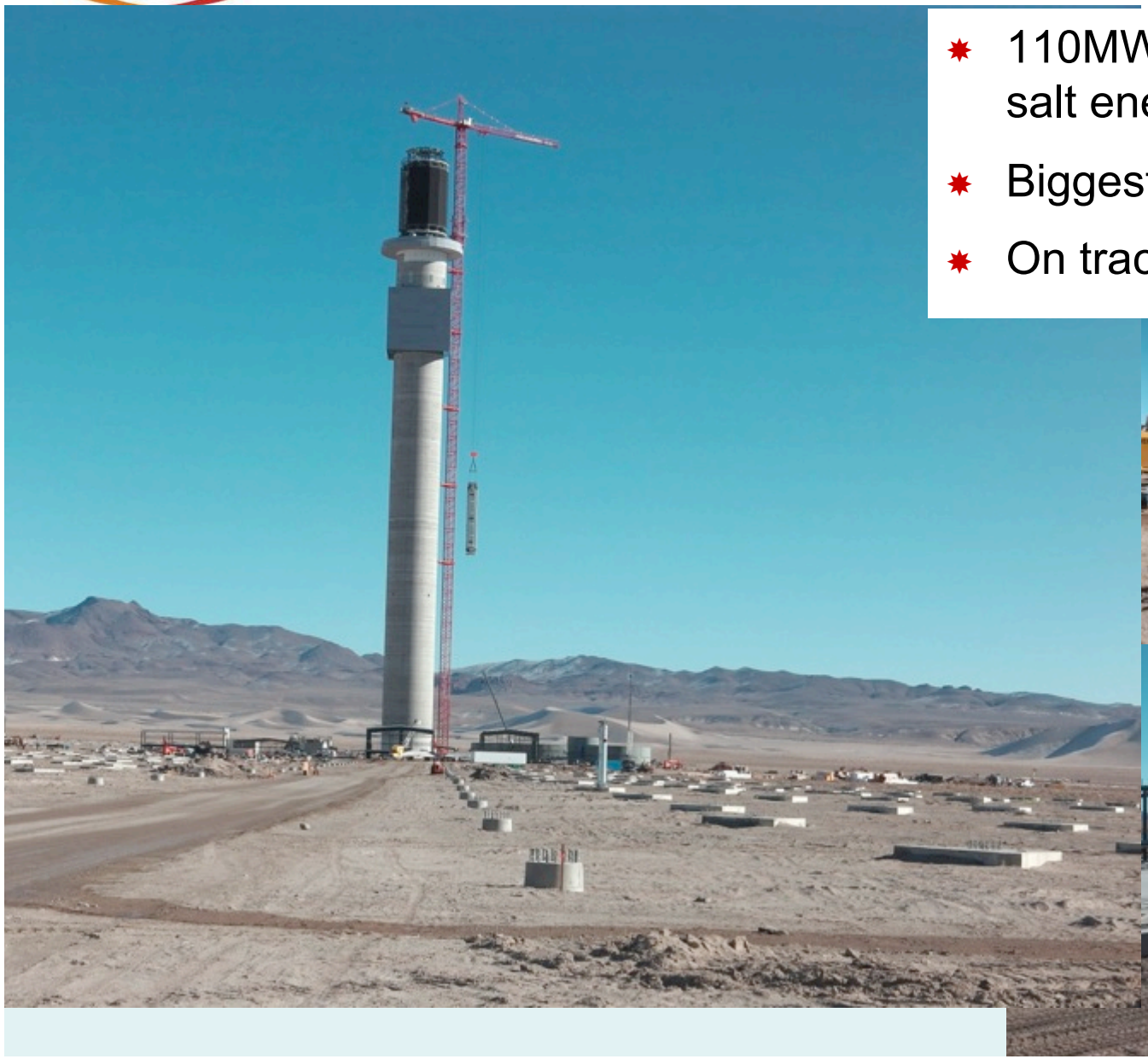
Ivanpah Overview

- 392 MW electric for PG&E and SCE
- Bechtel as EPC with financing participation
- Siemens Turbine/Riley Boiler
- $1.63B DOE loan guarantee
- ITC cash grant eligible
- NRG Energy lead project investor
- Google secondary project investor
- Financial close – April 2011
- Commenced construction October 2010

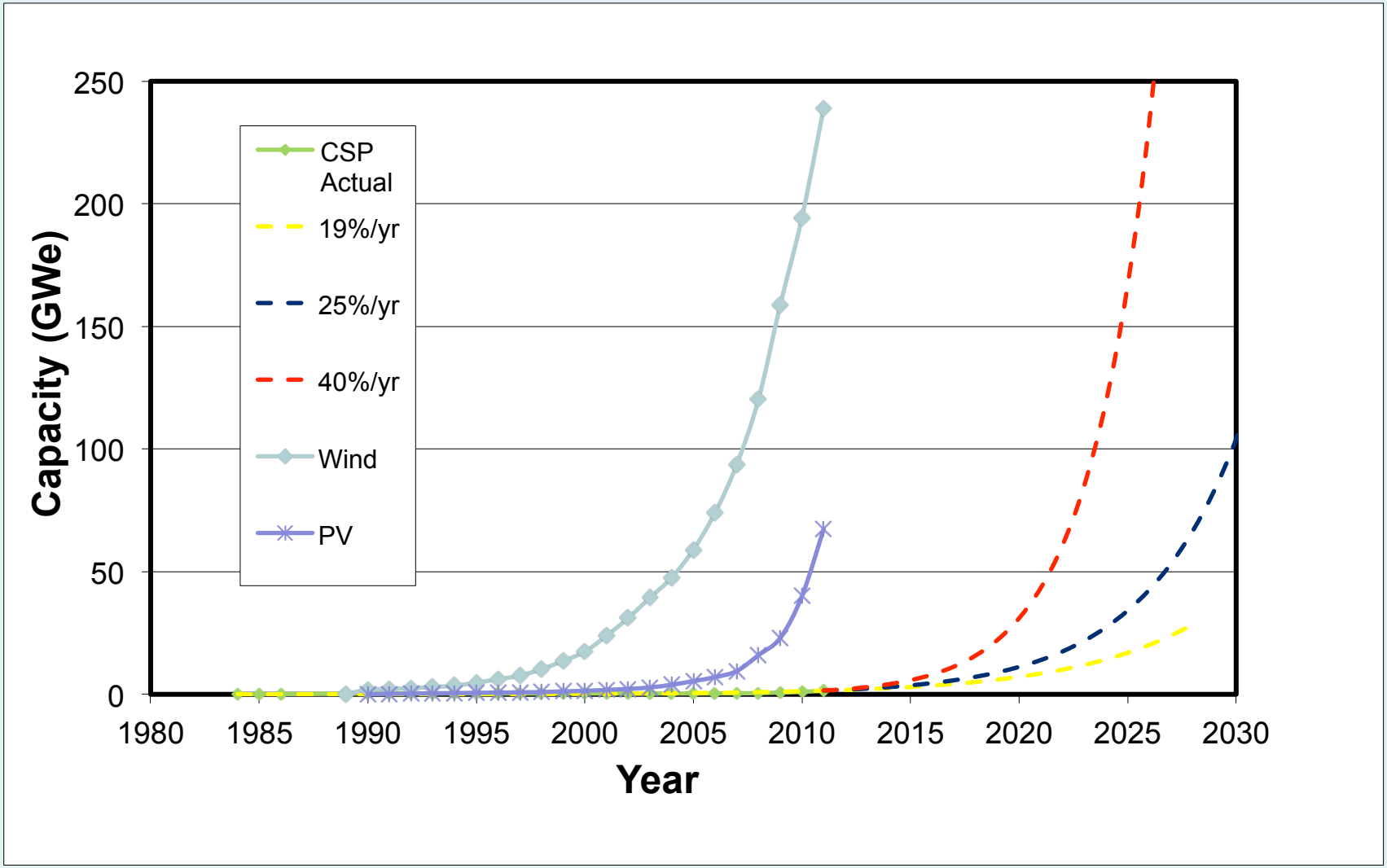
NRG RILEYPower A Babcock Power Inc. Company Google

Solar Reserve's Crescent Dunes project

- 110MW$_e$ with 10 hours molten salt energy storage
- Biggest ever tower system
- On track for end 2013

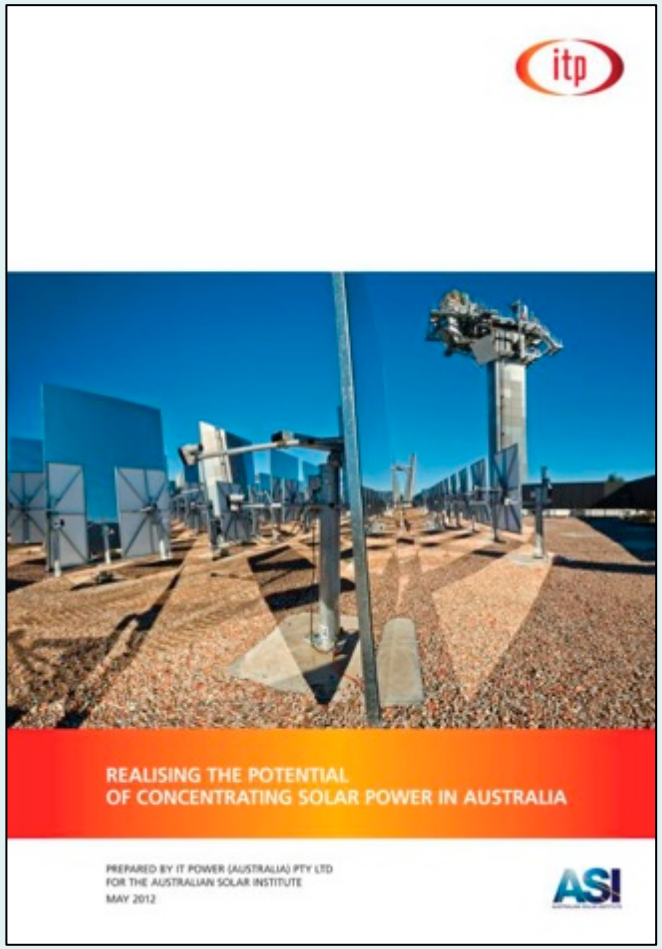


CSP in context – the next big thing?

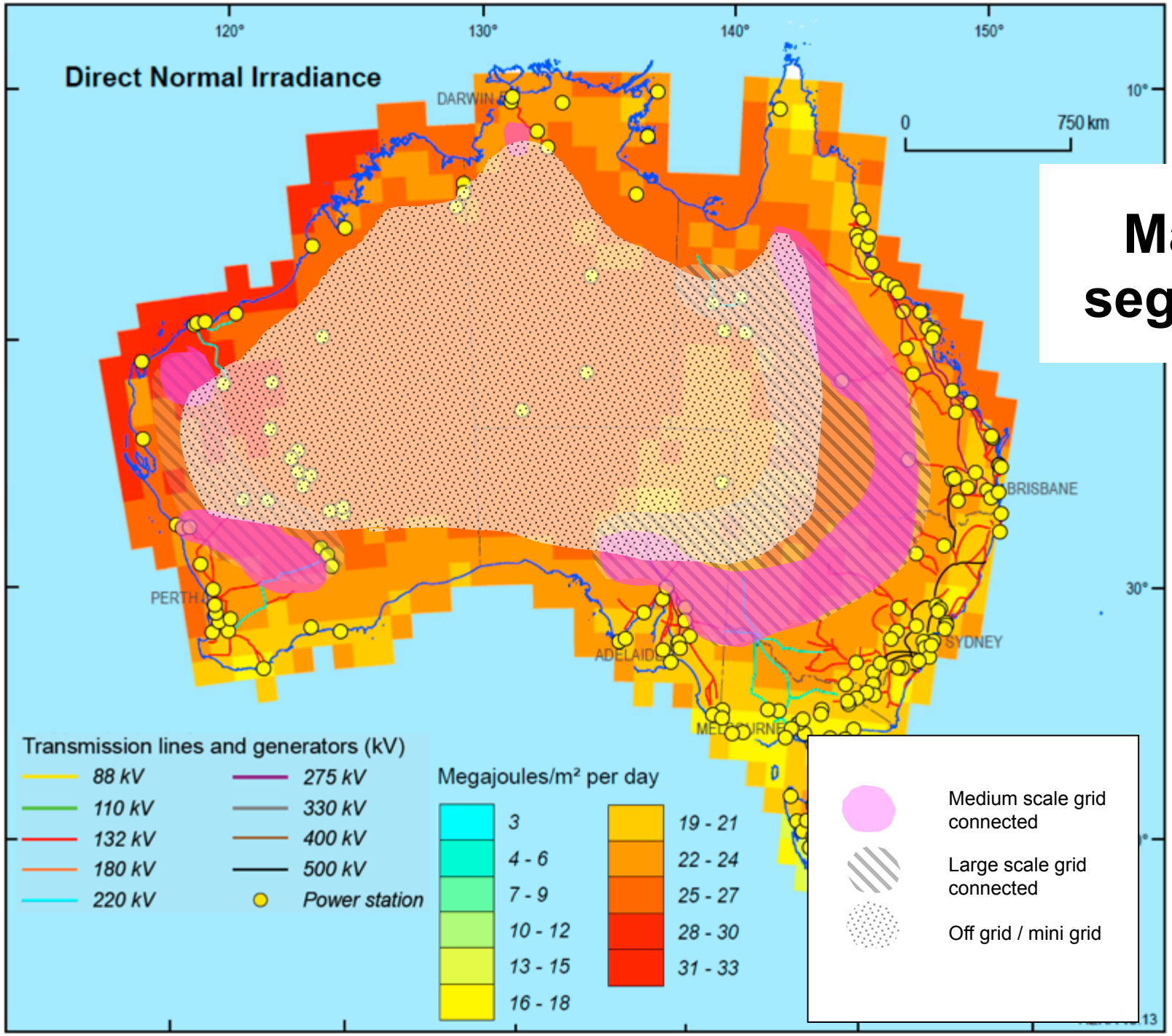


IT Power's 2012 study on CSP potential in Australia

- Commissioned by the federal government's "Australian Solar Institute"
- Reviews previous investigations of the potential for CSP in Australia.
- Establishes a best estimate of current costs
- Analyses the value of CSP electricity in the market place
- Analyses the various potential market segments for CSP electricity in Australia
- Examines the challenges in Australia
- Identifies pathways for CSP industry development.
- http://www.australiansolarinstitute.com.au/reports/.aspx



Market segments



Published and confidential data lead to 2012 AUD cost parameters

Subsystem	Per unit cost	Note / unit
Concentrator field (excluding receivers and HTF)	402	$/kWth capacity, delivered to power island at design point
Receiver/ transfer system (including receivers, HTF, piping, Tower as appropriate)	246	$/kWth capacity, delivered to power island at design point
Thermal Storage System	80	$kWhth of installed thermal energy storage capacity
Power block	882	$/kW$_e$ output capacity
BOP and Other	529	$/kW$_e$ output capacity
Indirect project costs	25%	Of subtotal of others (=20% of total)

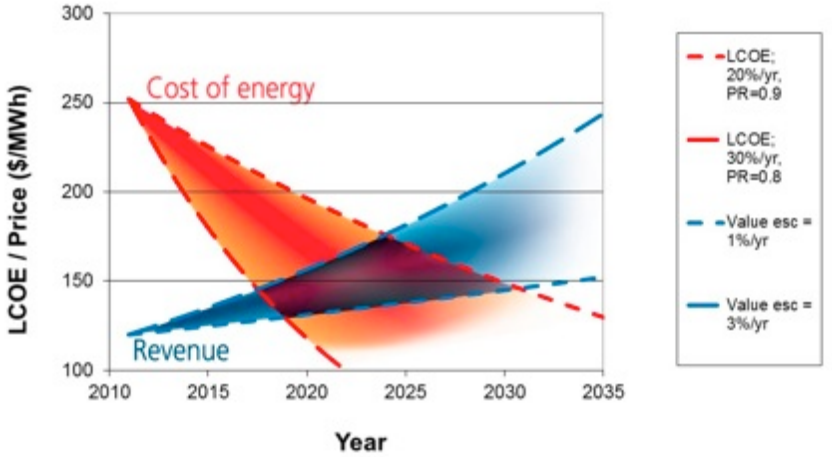
- Thermal Storage System actually T dependant: $(150/(T_h-T_c))$x 80$/kWh$_{th}$
- Dependence on system size, both direct and via power block efficiency

Installed cost examples

	No storage (lowest capital cost)	2 hours storage (approx min LCOE)	5 hours storage (earns higher value)
Configuration	100 MW_e block, 350 MW_{th} field, 21% cap factor at 2,400 kWh/m^2/ year	100 MW_e block, 395 MW_{th} field, 30% cap factor at 2,400 kWh/m^2/ year	100 MW_e block, 526 MW_{th} field, 40% cap factor at 2,400 kWh/m^2/year
Specific installed cost (AUD 2012)	\$4653 / kW_e	\$5534 / kW_e	\$7350 / kW_e

Key findings from 2012 study

- Around 15GW could be realistically installed without major grid extensions
- In a competitive market, a system configured for peaking operation could earn 2 x pool average
- A “baseline” trough plant with no storage in Longreach would have an LCOE of $250/MWh
- Maximum current income from such a system would be around $110/MWh
- An optimum level of energy storage reduces LCOE
- Cost and value will converge in 6 -18 years



Challenges

- The current cost gap is the biggest challenge, if this is not bridged there will be no CSP deployment in Australia
- Others
  - Building confidence in Australia among off-takers, financiers and governments.
  - Potential to avoid line losses or network augmentation that CSP could provide are not rewarded well under current market settings.
  - Small systems for mining and off grid applications appear closest to matching energy cost to customer value, however there are other key barriers in this market segment.
  - Lack of transmission infrastructure to optimal solar locations.

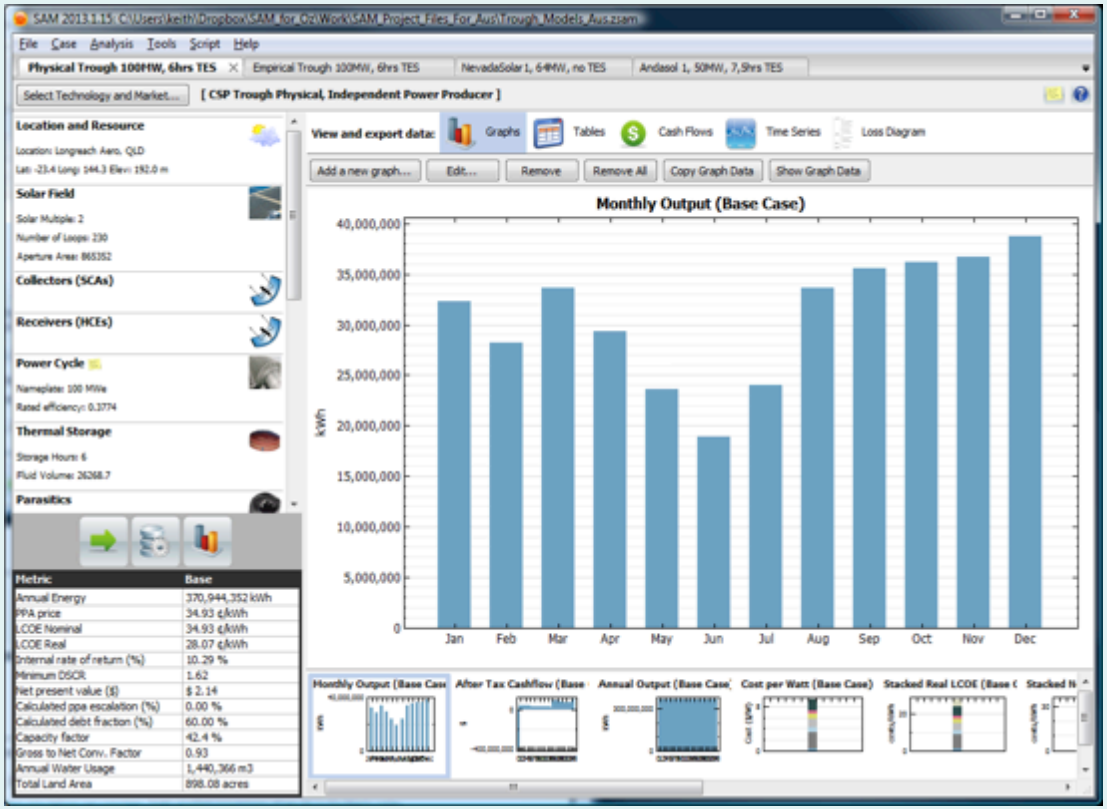
Kogan Creek Solar Boost will be Australia's first commercial CSP plant

- CS Energy and AREVA Solar
- South West Queensland
- 44 MW_e solar thermal addition to 750 MW coal-fired Power Station
- AREVA Solar CLFR Technology
- 500 metres x 600 metres (30 hectares)
- 14 x 500 metre long Solar Steam Generators (SSGs)
- $104.7 million
- Practical completion by mid 2013

A solar reflector at AREVA Solar's temporary assembly facility in Dalby

SAM for Australian CSP Stakeholders

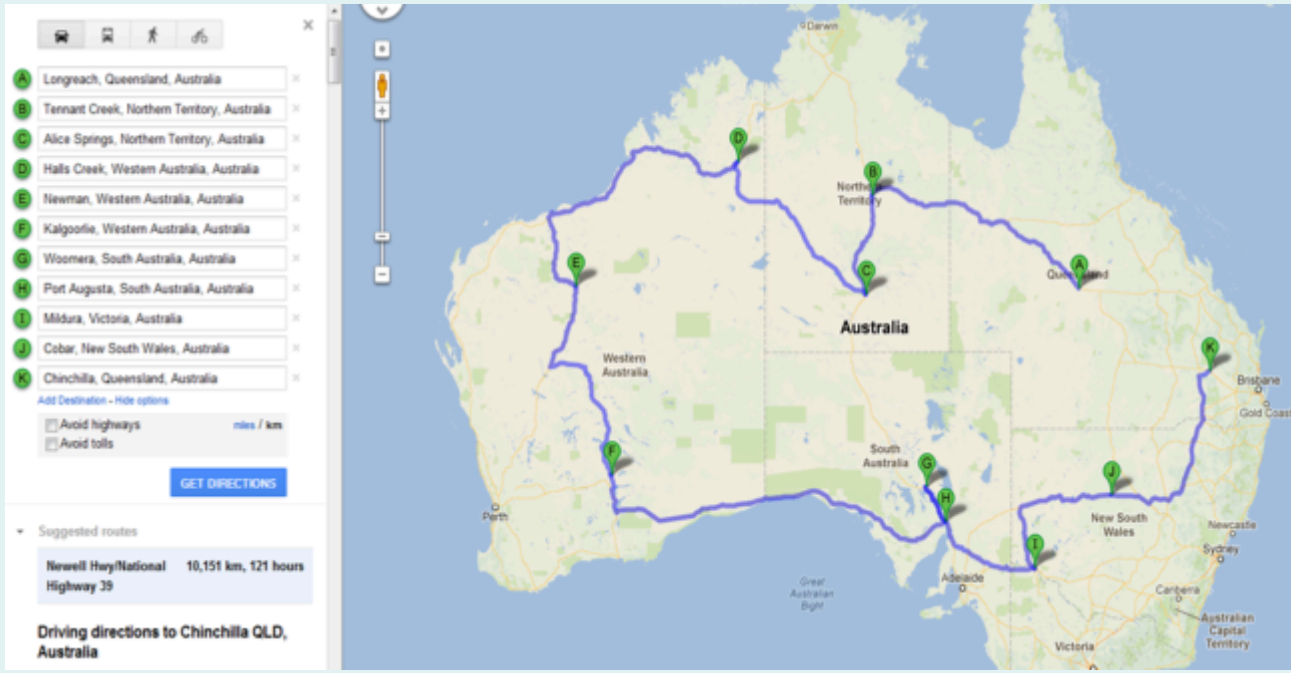
- NREL's "System Advisor Model"
  - predicts generation and cost of energy for range of technologies
  - Is particularly adapted to CSP systems
  - Half hourly time resolution
  - But financial settings are very US centric



- Austela project, executed by IT Power with NREL support, funded by ARENA
- Aiming to improve accessibility to a tool that helps quantify and understand the value proposition for CSP

SAM for Australian CSP Stakeholders

- A set of “project files” for trough, tower, LFR and dish, with Australian costs and financial settings that are consistent with 2012 study
- An Australian Companion Guide for SAM
- A set of real year TMY3 format solar data files for prospective locations
  - Best, worst and closest to typical real years based on available BOM data



- Preview at: http://www.oramacommunications.com.au/staging/austela_cms

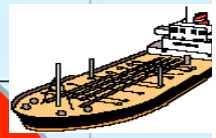
Technology specific costing consistent with 2012 study

- Detailed cost parameters established on principal all technologies without storage should be $250/MWh at Longreach
- Users can scale costs as desired
- Needed logical consistency across cases for common items (eg power block)
- In 2013 can say with some certainty that tower with salt storage has a cost advantage

Case	Concentrator type	Real LCOE (2012 AUD $/MWh)
Nevada Solar 1, 64MWe no TES	Trough	251.4
Physical Trough 100MW 6 hrs TES	Trough	236.7
Empirical Trough 100MW, 6 hrs TES	Trough	239.0
Andasol 1, 50MW, 7.5hrs TES	Trough	249.9
Direct Steam Power Tower 100MW	Tower	230.4
Molten Salt Tower 100MW, 10 hours TES	Tower	175.6
Gemasolar, 17MW, 15 Hours TES	Tower	143.8
Dish Stirling 100MW no storage	Dish	242.3
Linear Fresnel 100 MW no storage	LFR	232.4
Novatec Solar Boiler 42MW no storage	LFR	209.5

Future vision

Energy Type	$/GJ
Black coal (export)	3.40
Oil and oil products	17.88
LNG (export)	7.30
Uranium (export)	0.19
Brown coal	0.70
Brown coal + $23/t CO_{2e}	2.70
Bagasse East	0.80
Diesel excise free	26.03
CST electricity	69.44
Max CST elect Revenue	35
Conc. Solar Radiation	7.50



All of Japan's primary energy from this area

Exporting solar fuels to Japan and South Korea and ….

Conclusions

- CST is growing strongly globally, about 1 decade behind PV.
- CST offers high value dispatchable renewable electricity generation.
- CST offers the developer country a bigger position in the value chain.
- Need to build CST power systems to build experience and supply chain.
- Renewable Energy Policy should adapt to reward storage and dispatchability with preferential tariffs
- CST power systems are an ideal foundation to move to solar fuels.

Read more in new book

www.woodheadpublishing.com/7693