Improving SAM cases for CSP modelling in Australia

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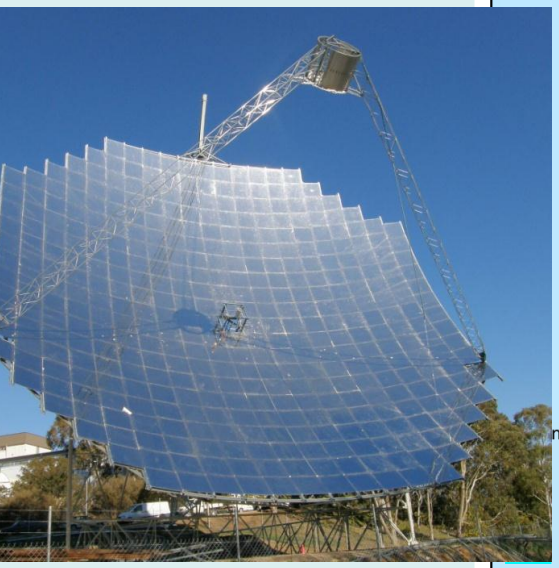
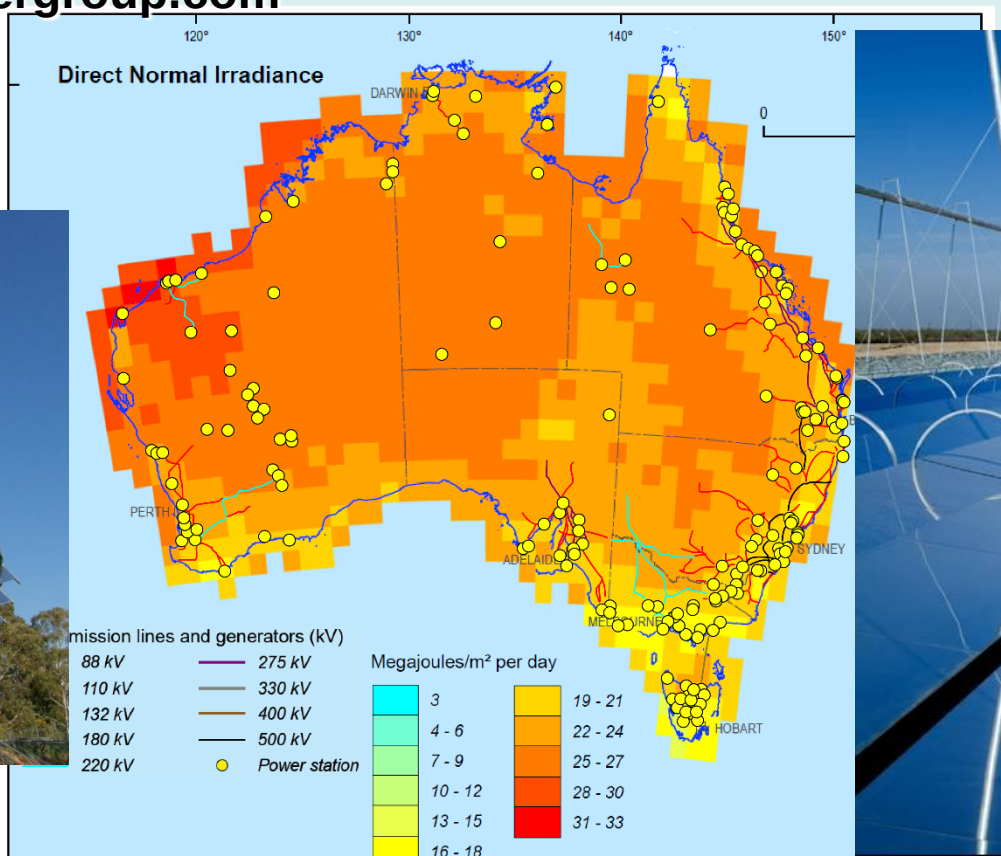
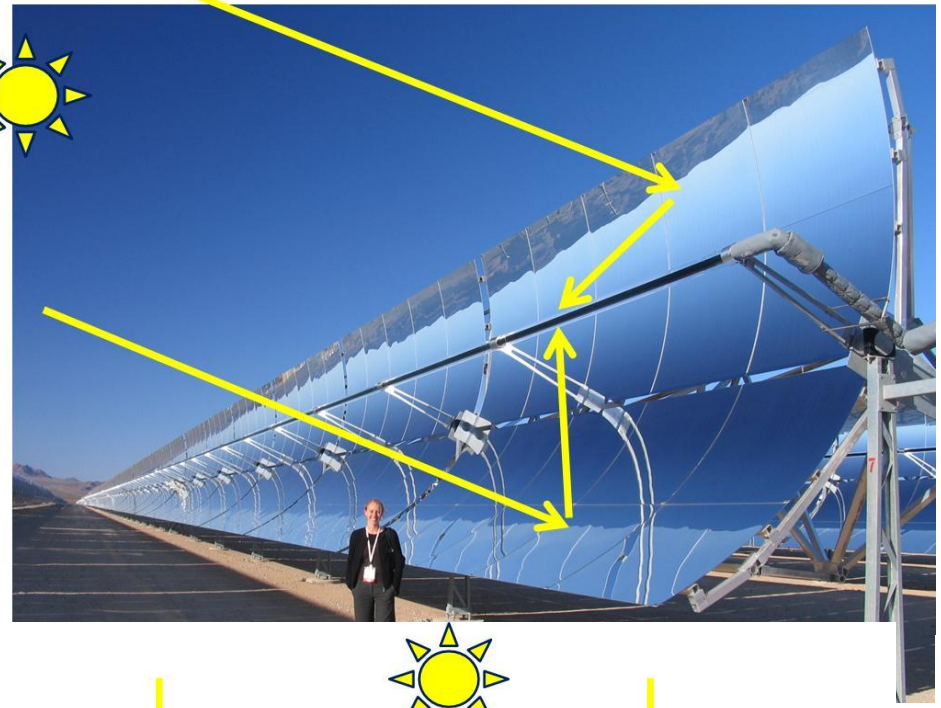
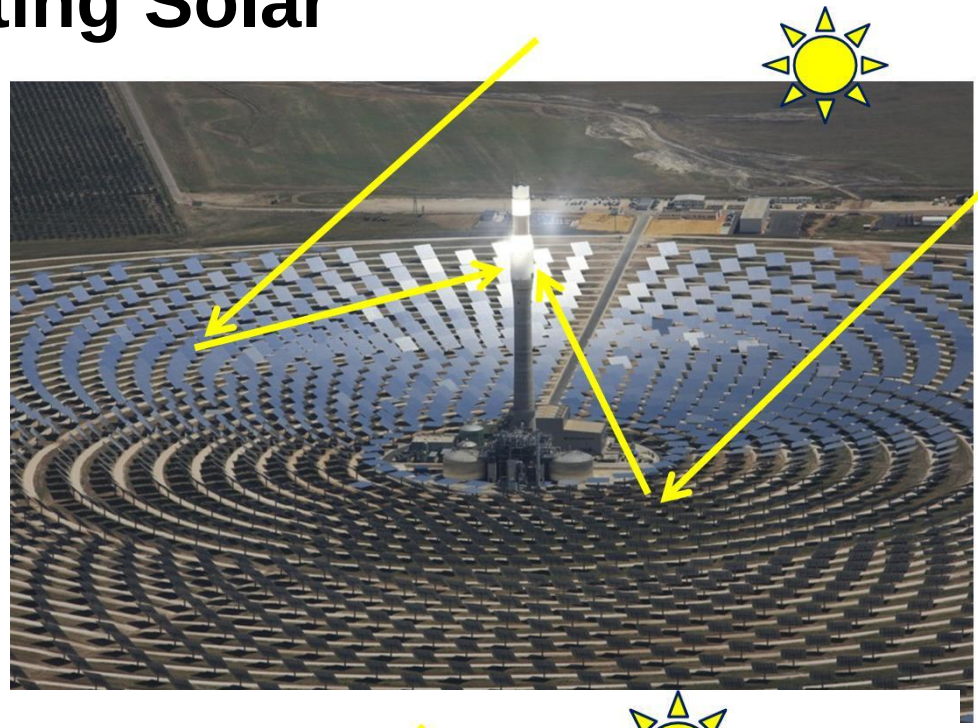
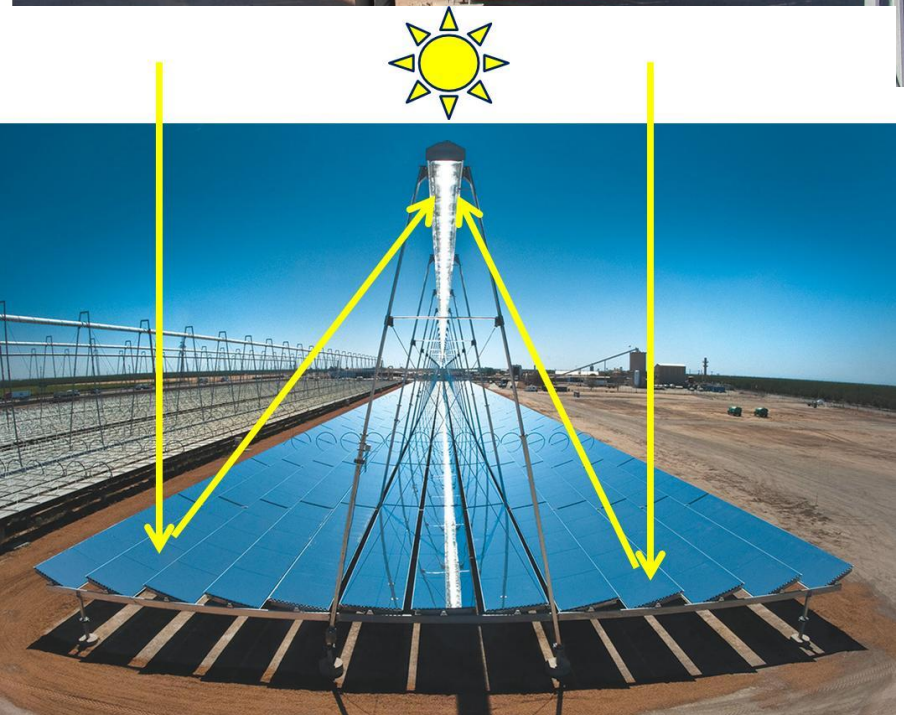


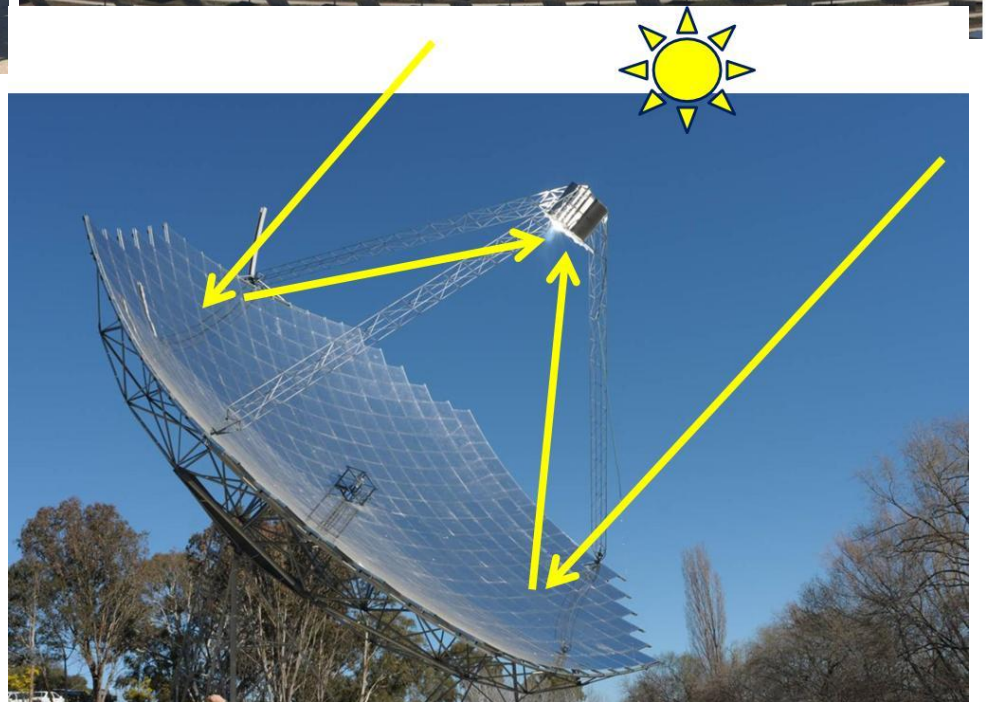


Concentrating Solar







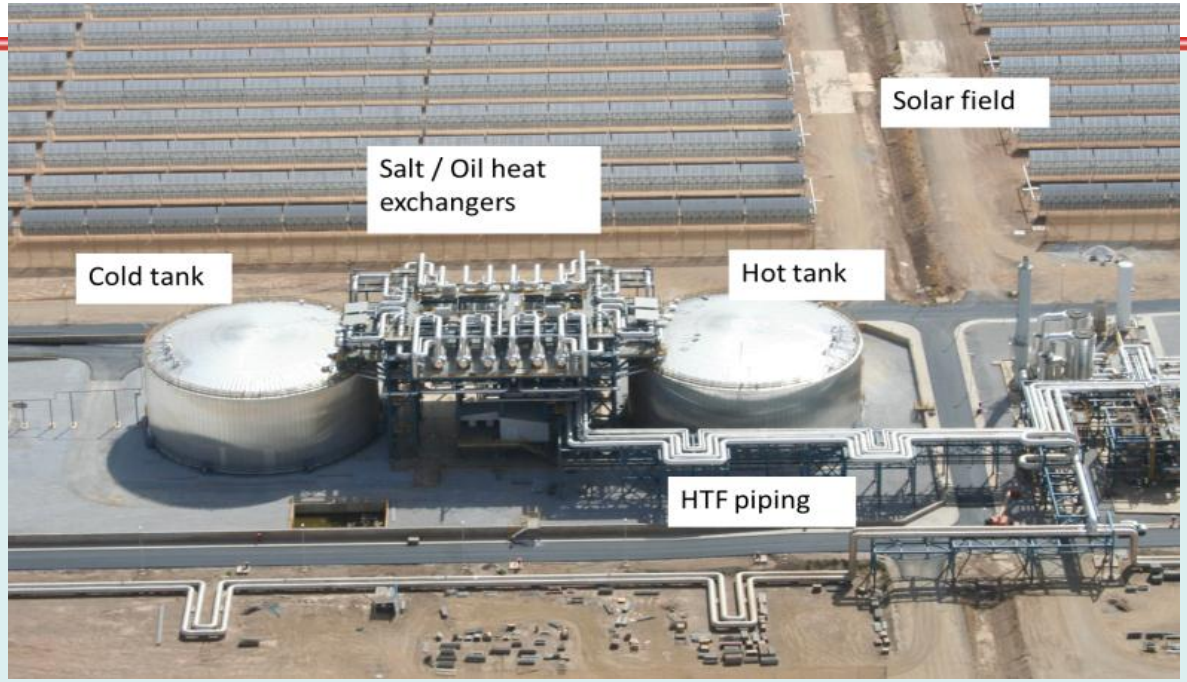


Kogan Creek Solar Boost will be Australia's first commercial CSP plant

- 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

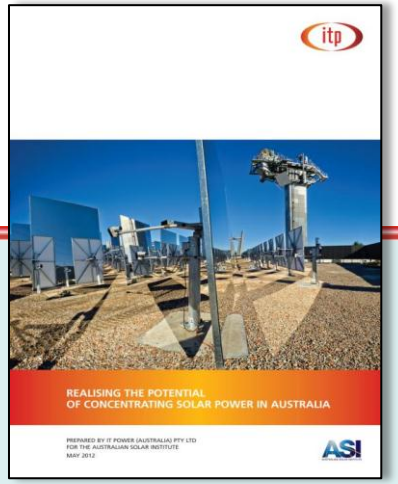
Proven Thermal Energy Storage is CSP's big competitive advantage



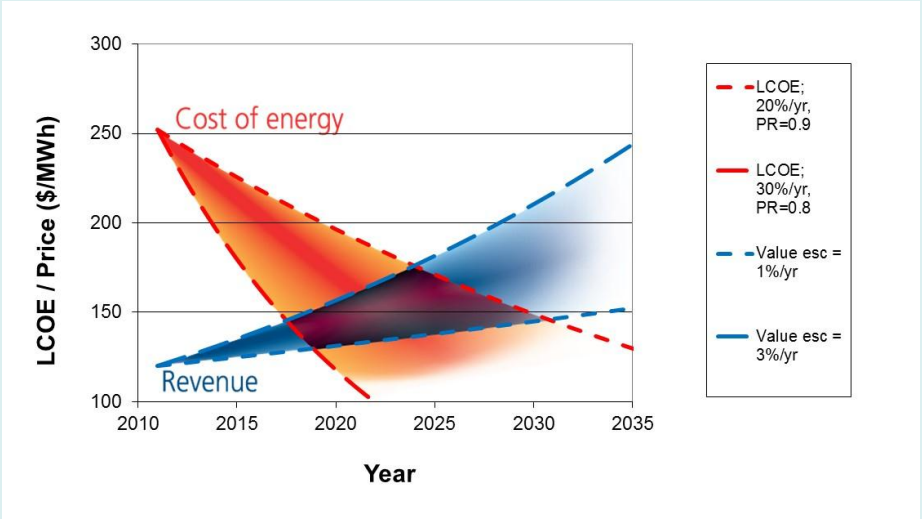
Background pic, Andasol 3 courtesy Ferrostaal

- 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

Key findings from ITP's 2012 CSP Australia study

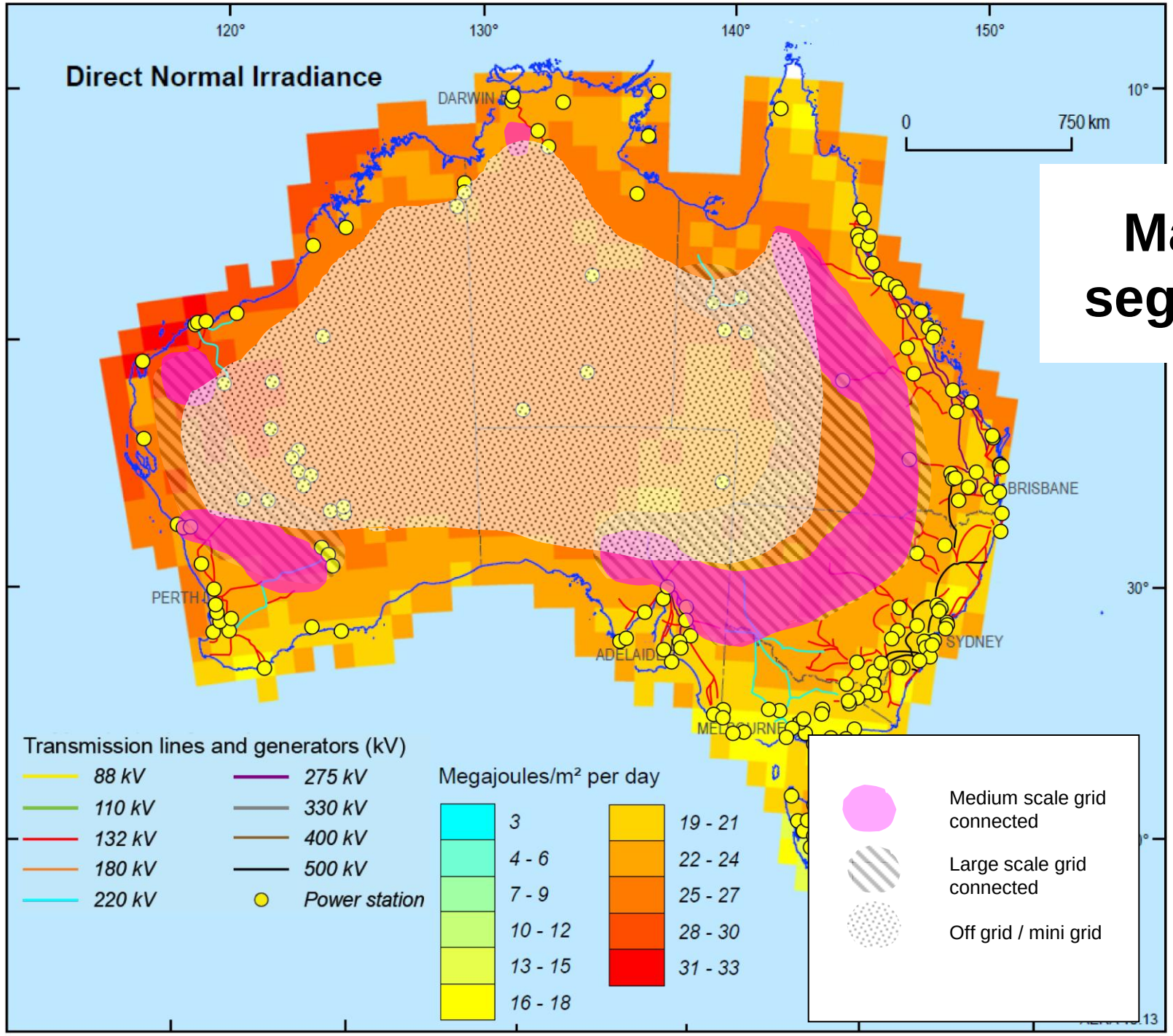


- Around 15GW could be realistically installed without major grid extensions
- In a competitive market, a system configured for peaking operation could earn 2 x pool average
- A "baseline" trough plant with no storage in Longreach would have an LCOE of $250/MWh
- Maximum current income from such a system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



- http://www.australiansolarinstitute.com.au/reports/.aspx

Market segments



Published and confidential data lead to 2012 AUD cost parameters - technology neutral

Subsystem	Per unit cost (AUD)	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)

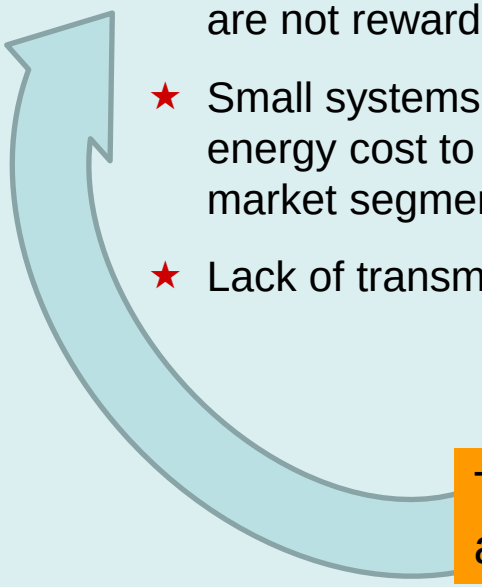
- Thermal Storage System actually T dependant: $(150/(T_h-T_c))$x 80$/kWh$_{th}$
- Dependence on system size, both direct and via power block efficiency

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

Challenges for CSP in Australia

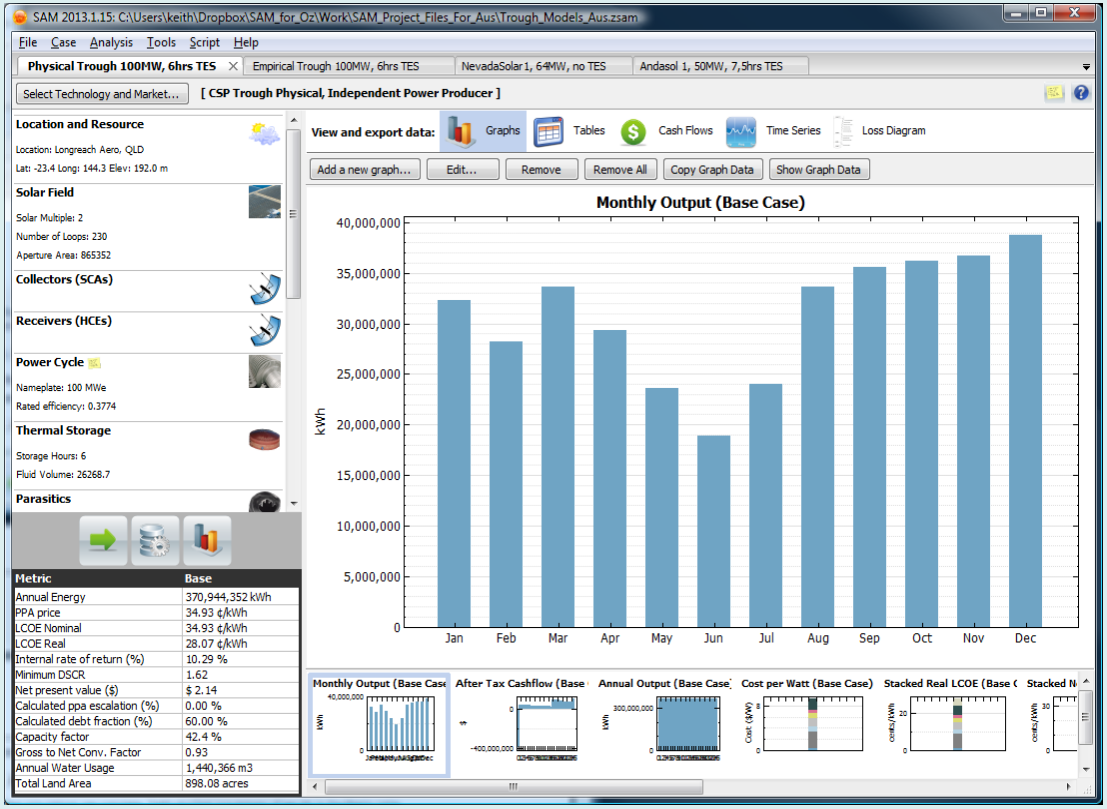
- The current cost gap is the biggest challenge, if this is not bridged there will be no CSP deployment in Australia
- Others
  - Building confidence in Australia among off-takers, financiers and governments.
  - Potential to avoid line losses or network augmentation that CSP could provide are not rewarded 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.



This project with SAM attempts to address

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

The NREL System Advisor Model for Australian CSP Stakeholders (SAM)

Predicting the output of a CSP system is a complex process. Thermal systems include multiple subsystem whose behaviour at any point in time depends not only on the instantaneous conditions the whole system experiences, but also the recent history of its operation.

There is a range of approaches to modelling CSP systems and it is an on-going area of R&D. One of the most respected is the free to use System Advisor Model (SAM) developed by the National Renewable Energy Laboratory (NREL) in the USA.

The SAM model is general purpose in nature and can predict hourly, monthly and annual output of CSP, CPV, flat plate PV and also a range of other renewable energy systems. There has been an extensive body of work around its application to CSP systems in particular.

Australian Government
Australian Renewable Energy Agency

itp

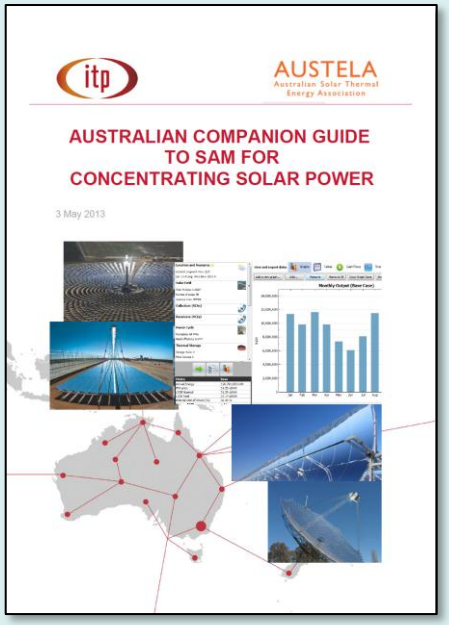
The material on this page was developed by AUSTELA under a project supported by the Australian Renewable Energy Agency, **ARENA**. The work was carried out by **ITP** working in collaboration with members of NREL's SAM team.

This project has produced three resources for public use:

- The "Australian Companion Guide to SAM for Concentrating Solar Power" (pdf).
- A collection of SAM project files with financial settings for Australian Conditions (zip).
- A selection of solar data files for input to SAM for selected representative Australian sites and years (zip).

The key document from this project is the "Australian Companion Guide to SAM for Concentrating Solar Power" This guide includes

Australian Companion Guide to SAM for Concentrating Solar Power



- To be used in conjunction with the SAM help system
- Step by step instruction on using the specific Cases and solar data provided for Australia

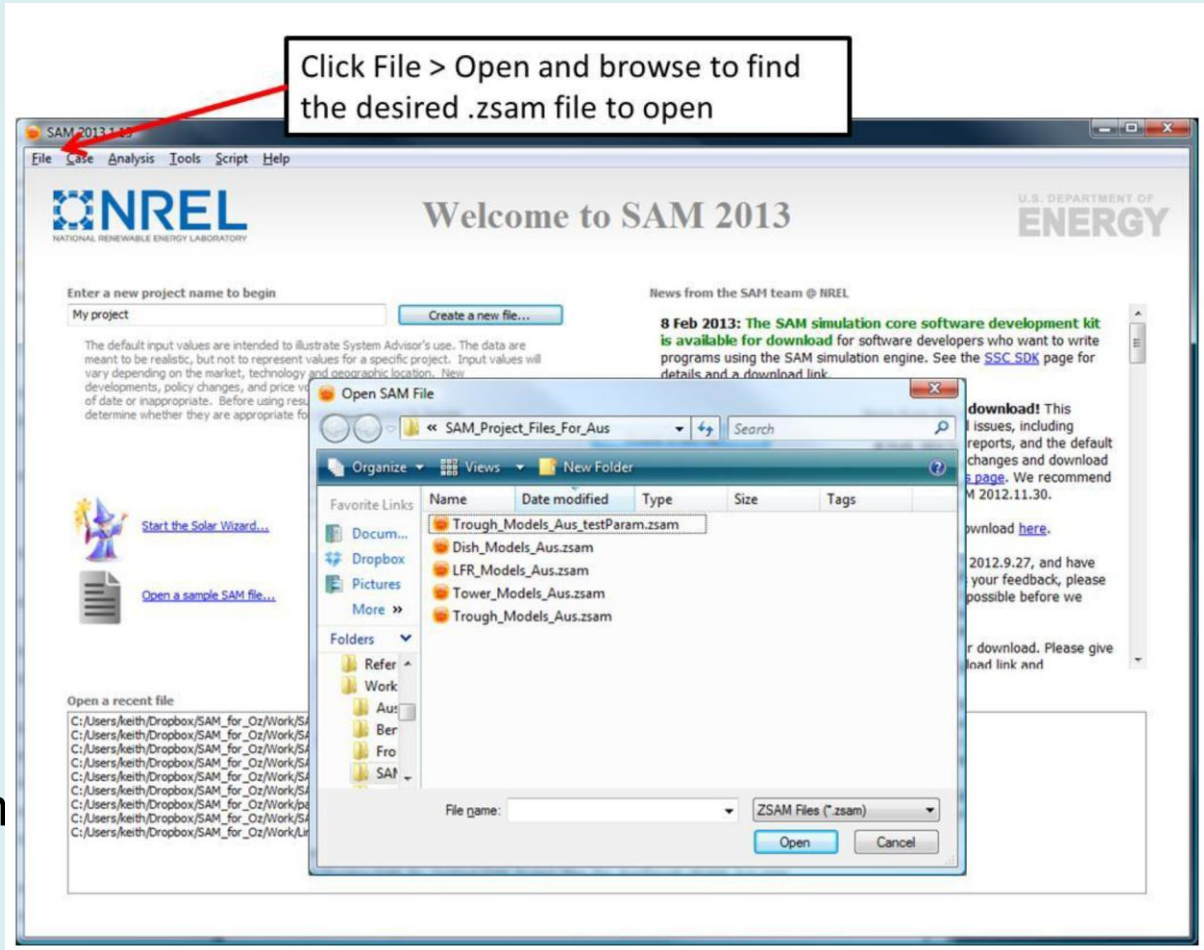


Figure 3: Opening a project file.

Adaptation of existing CSP cases

Case	Concentrator type
Nevada Solar 1, 64MWe no TES	Trough
Physical Trough 100MW 6 hrs TES	Trough
Empirical Trough 100MW, 6 hrs TES	Trough
Andasol 1, 50MW, 7.5hrs TES	Trough
Direct Steam Power Tower 100MW	Tower
Molten Salt Tower 100MW, 10 hours TES	Tower
Gemasolar, 17MW, 15 Hours TES	Tower
Dish Stirling 100MW no storage	Dish
Linear Fresnel 100 MW no storage	LFR
Novatec Solar Boiler 42MW no storage	LFR

- A mix of “real system” and “hypothetical” cases adapted from NREL / SAM with physical performance parameters unchanged.
- Organised into “project files” for trough, tower, LFR and dish.
- Financial parameters set for Australia.
- Cost parameters set for Australia but input via excel exchange and inclusion of user variables for overall scaling of costs.

Making sense of LCOE in SAM

- For Australian (non US) SAM users, the LCOE calculation is hard to understand because:
  - All incentives assumed are included within the calculated LCOE's
  - IRR is included within the LCOE calculation
  - There are incentives and terminology that don't apply / is unfamiliar to Australians (eg PTC - Production Tax Credit , MACR – Modified Accelerated Cost Recovery)
- So for the Aussies:
  - All incentives removed
  - "Specify target IRR" chosen and IRR and nominal discount rate made equal
  - No state taxes
  - Straight line 20 year depreciation for federal tax
  - Other settings as per the 2012 study

LCOE Reconciliation for 64MW trough

USER INPUTS	Unit	calculation from CSP in Aust Study	Values in Nevada Solar 1 case	Difference
Name plate capacity	kW_e	64,000	64,000	
Annual generation	kWh_e	128,794,000	128,791,480	-0.002%
Overnight Capital cost	$	$ 308,490,560	$ 308,558,260	0.022%
Capital cost after construction	$	$ 327,000,000	$ 327,071,750	0.022%
Loan fraction of total		0.6	0.6	
Loan period	year	15	15	
Loan interest rate (nominal)	/year	7.78%	7.78%	
Discount rate for equity (nominal)	/year	10.29%	10.29%	
Tax Rate	/year	30.00%	30.00%	
Depreciation period	year	20	20	
Project Life	year	25	25	
Salvage value	$	$ 16,350,000	$ 16,353,588	0.022%
Variable o&m (year 1)	$/kWh_e$	0.018	0.018	
Fixed O&M	/year	0	0	
Inflation	/year	2.50%	2.50%	
CALCULATED	.	.	.	.
Capacity factor		22.97%	22.9%	
Installed cost / unit capacity	$/kW_e$	$ 5,109		
Loan amount	$	$ 196,200,000	$ 196,243,053	0.022%
Equity amount	$	$ 130,800,000		
Annualisation factor for loan	/year	11.53%		
Annual loan payment	$/year	$ 22,614,969		
Real discount rate for equity		7.60%	7.60%	
Nominal LCOE if energy sales taxed	$/kWh	0.31344	0.3129	-0.174%
Real LCOE energy sales taxed	$/kWh	0.25185	0.2514	-0.177%

Technology specific costing consistent with 2012 study

- Detailed cost parameters established on principal all technologies without storage should be $252/MWh at Longreach
- Users can scale costs as desired
- Needed logical consistency across cases for common items eg:
  - Steam turbine power block same for all technologies
  - Heliostats same with or without storage
- Some variation of assumed definitions (power block / BOP)
- Some simplification
  - one O&M category
  - no contingency
  - single indirects value
  - rounding to whole dollar

Trough cost parameters

Trough Case		Nevada Solar 1, 64MW trough no TES	Physical Trough, 100MW, 6hrs TES	Empirical Trough, 100MW, 6hrs TES	Andasol1, 50MW, 7.5hrs TES	Adjusted values
Parameter	Unit	Original (USD)	Original (USD)	Original (USD)	Original (USD)	2012 AUD
Directs						
Site Improvements	$/m^2	28	30	30	28	32
Solar Field / heliostat field	$/m^2	271	270	270	270	314
HTF System	$/m^2	75	80	80	78	90
Subtotal area related	$/m^2	374	380	380	376	
Storage	$/kWh$_{th}$	0	80	80	80	80
Fossil Backup	$/kW$_e$	0	0	0	60	0
Power Plant	$/kW$_e$	916	830	830	850	790
Balance of Plant	$/kW$_e$	0	110	110	105	474
Contingency	%	10	7	7	7	0
Indirects						
EPC and owner	%	16.5	11	11	11	25
Land	$/acre	0	10000	10000	0	0
Land	%	7.40	0	0	2	0
Operation and Maintenance						
Fixed annual cost	$/yr	0	0	0	0	0
Fixed cost by capacity	$/kW-yr	65	65	65	65	0
Variable cost by generation	$/MWh	3	4	4	3	18
Fossil fuel cost		6	0	0	6	0

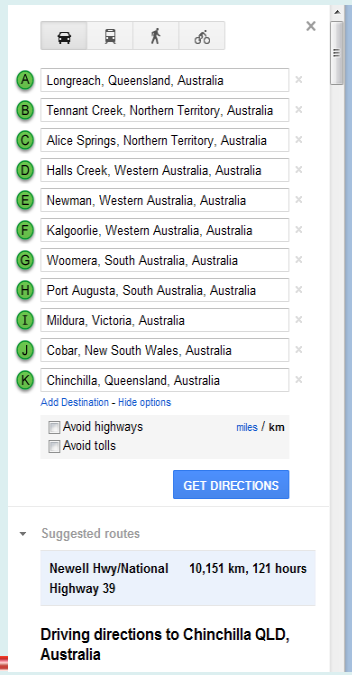
Departure from technology neutrality

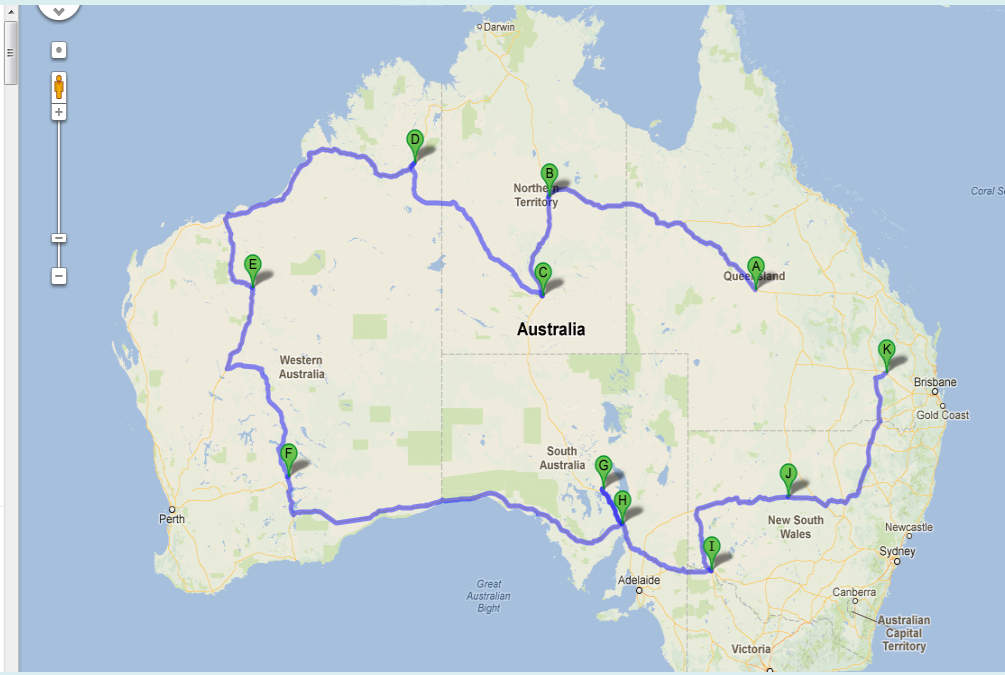
- In 2013 can say with some certainty that tower with salt storage has a lower LCOE

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

Solar Data files

- The files on the Energy Plus website are known to contain faults
- Best available satellite based data from Australian Bureau of Meteorology used
- A set of real year TMY3 format solar data files for representative prospective locations
  - Best, worst and closest to typical real years based on available BOM data





Conclusions

- SAM is an extremely valuable tool to assist educated stakeholders to understand the capabilities and advantages of CSP systems
- This project has attempted to make the financial aspects of SAM in particular more accessible to Australian Stakeholders
- Whilst the previous detailed study of CSP potential in Australia was technology neutral, logical attention to the interpretation of cost factors for SAM cases makes it apparent that Tower with salt storage has a strong present cost advantage