
Solar Thermal Power

The Next Resources Boom

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Covering

- Solar Resource – Australian Context
- Solar Resource – Global Context
- Quick Primer – Concentrated Solar Power
- Technology Status
- Commercial Status
- Partnering with Fossil Fuels



Why Solar Thermal Power

- Intrinsically includes a highly efficient energy storage mechanism – heat.
- Provides fully dispatchable power
- Integrates well with fossil fuel during an extended transition and to cover solar outages
- Backup to a Solar Thermal plant is fossil fuel heating – remaining balance of plant (steam and electricity) are common
- Minimal waste, minimal environmental footprint, wide geographic distribution within Australia

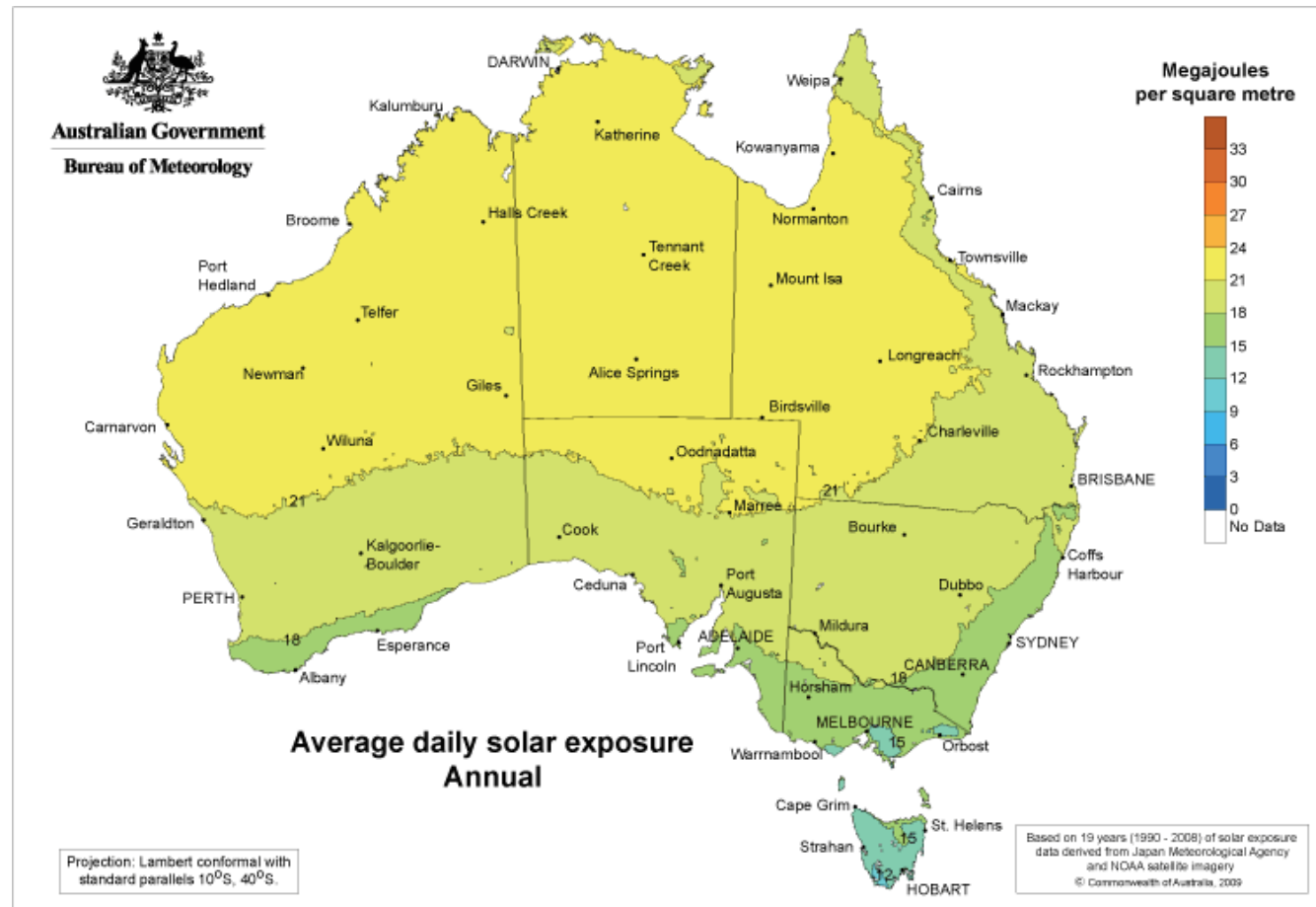


Solar Resource – Australian Context

- FY10 – Electricity Usage 241,600 GWh
- If Electricity can reduce emissions, other energy forms will transfer across
 - Transport
 - Heating



Australian Average Solar Resource



Direct Normal Irradiance (DNI)
Eg. Mt Isa – Birdsville – Approx 2100 kWh /sqm /year
Note – 1 MJ/sqm/day = 101.4 kWh/sqm/yr

How Much Area is Required?

- Example – Parabolic Troughs
- ~15-18% efficient in turning mirror area into electricity
- Total site efficiency ~3%
- Summary
 - 250,000 GWh/yr – total Australian Electricity in FY10
 - 797 square km of mirrors (28 km x 28 km)
 - 3835 square km of land (62 km x 62 km)

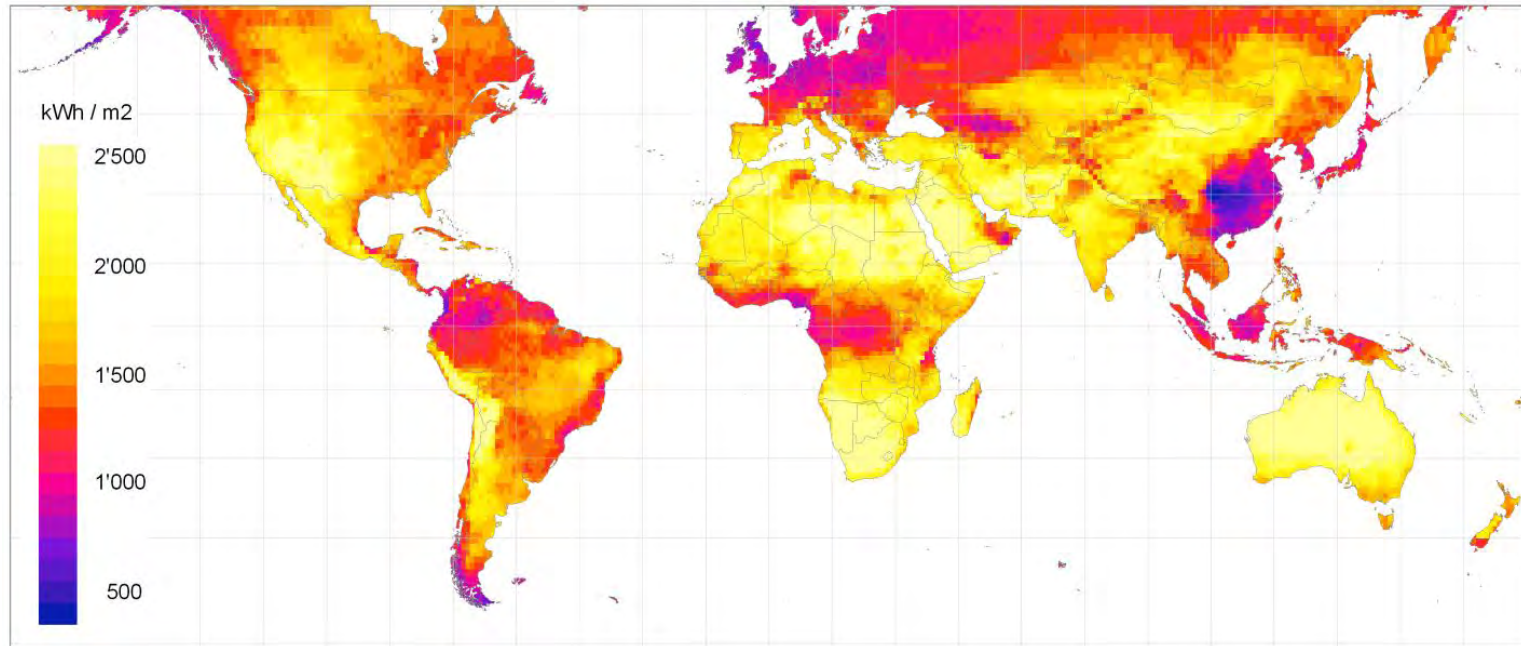


CSP Area Required for Total Australian FY10 Electricity Generation

- 797 square km of mirrors
 - ~QLD open cut coal pits
- 3835 square km of land
 - ~QLD operational coal mining areas
- More realistically, plants would be distributed along electric/gas infrastructure



Solar Resource – Global Context

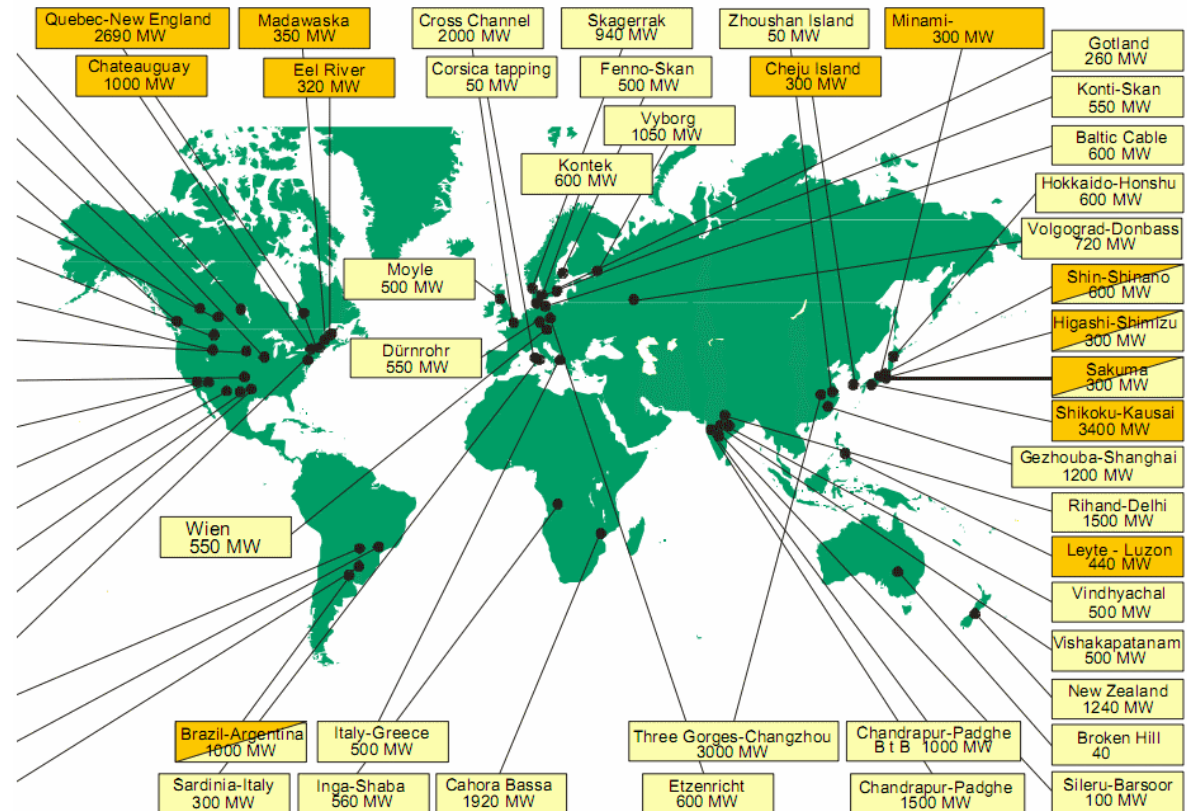


- Solar is a natural resource that Australia has in abundance
- HVDC Lines – opening up the world's grids



High Voltage DC Lines

- HVDC runs of 2000+ km
- Transmitted power of 3GW
- Losses ~3% per 1000 km.



Desertec – Driven by Germany

- MENA generation
- 50/50 consumption in
 - Western Europe
 - Northern Africa
- All of Western Europe is within 4000 km



Masdar - UAE

- Eastern Europe and Western Asia are within 4000 km

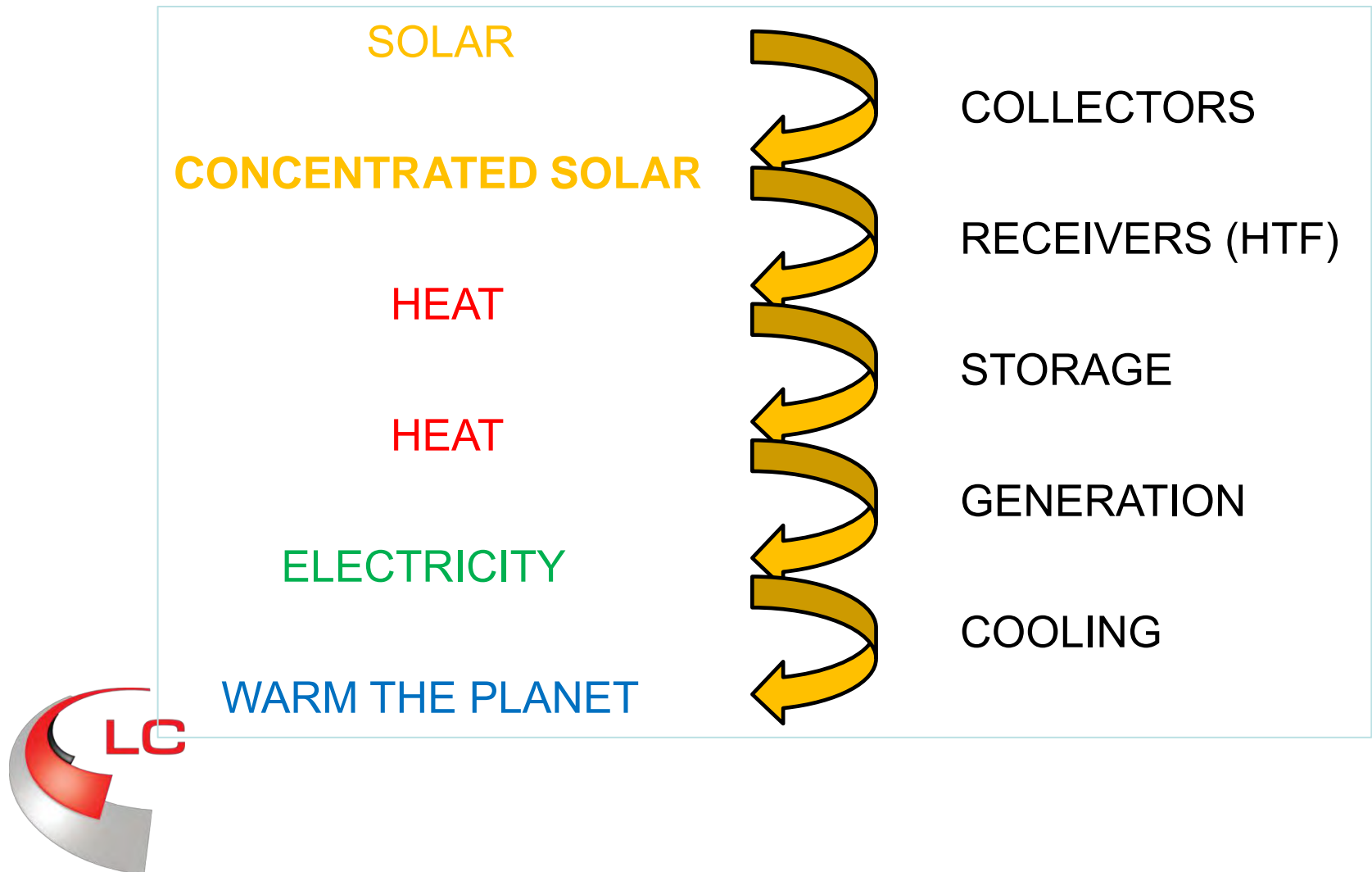


Australia

- Indonesia, Philippines and SE Asia are within 4000 km
- China, Japan and Korea are within 6000 km



Quick Primer - CSP

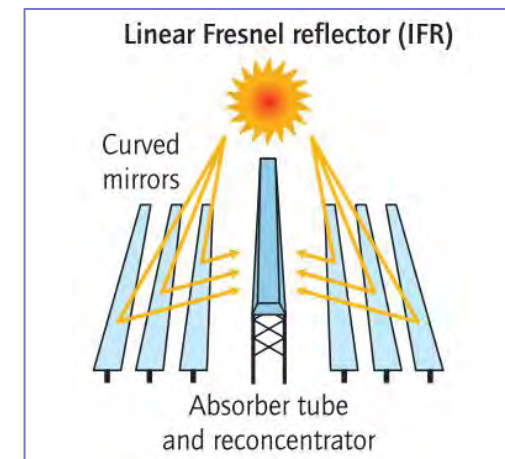
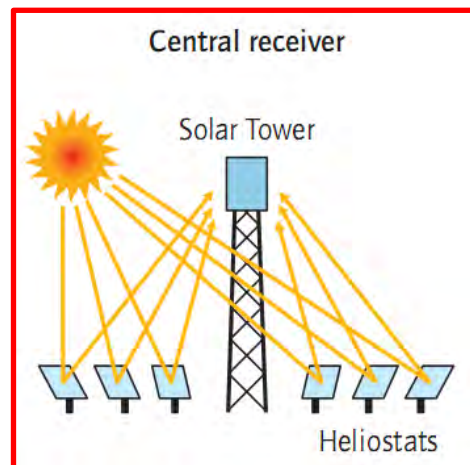
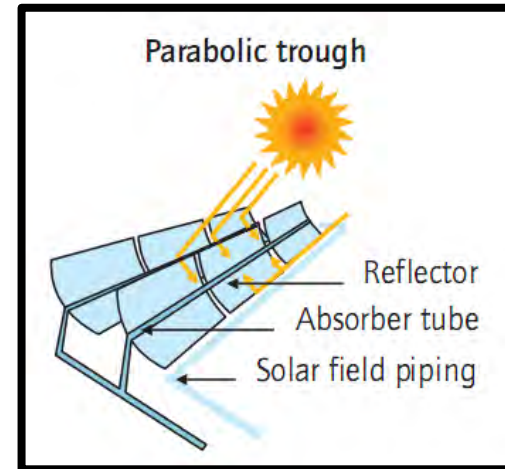
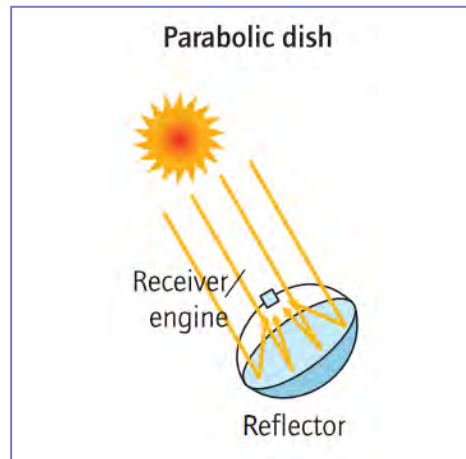


Technologies

- Colour coding of technologies for next few slides
 - **Dominant Technology**
 - Practical Technology, but not dominant
 - **Practical Technology becoming dominant**
 - New technology needing further development



Collectors



Receivers – Heat Transfer Fluids

- **Thermal Oil**
- Water
- **Molten Salt**
- Air
- CO₂

Heat Transfer Fluid (HTF) selection drives thermodynamic options and efficiency.

Thermal Oil has a maximum operating temp of 390°C. Any leaks can soak into and contaminate the ground.

Molten Salt is typically a mix of Sodium Nitrate and Potassium Nitrate. It melts at ~240°C, and is usable at temperatures of up to ~580°C. In this range it flows like water, is quite corrosive, and any leaks solidify.



Storage of Heat

| | |
|------------------------|-------------|
| • Geological Aquifers* | Months |
| • Molten Salt | Weeks |
| • Molten Salt | Days |
| • Steam | Hours |
| • Air | Hours |



* Eg. Storage of heat for central heating in Europe.

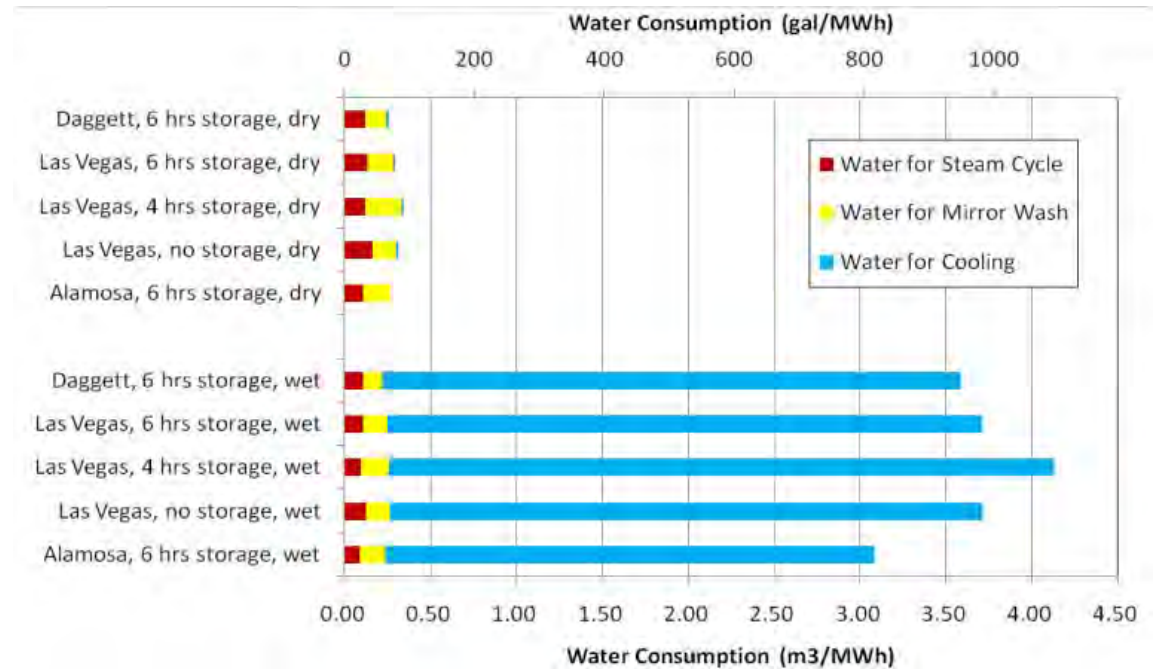
Generation

- Rankine Steam Cycle
- Mature Products



Cooling

- **Wet**
- **Dry**



- Solar Thermal Power favours deserts. Dry cooling is essential.



Technical Status

- 94% of commissioned installations are
 - Parabolic Trough, heating Oil. About half provide storage of up to 7 hours using molten salt.
- New technologies commissioned in the last two years at commercial scale
 - Towers and Parabolic Troughs heating molten salt direct
 - Storage of 15+ hours – 24 hr per day operation
 - Linear Fresnell with high temperature water (>500 deg C)
- Under construction – Commissioning within two years
 - Larger PT plants (280 MW Solana)
 - Larger Towers with molten salt (370 MW Ivanpah)
 - Dry Cooling

Technology for Australian Need

- Direct heating of Molten Salt, probably by Tower
- Hybridisation with fossil fuel (with fossil fuel supporting the CSP plant, not vice versa)
- Dry cooling
- Cost of construction in remote locations and Australia
- Operation in desert locations
- All these have been done before, but will be demonstrated in the CSP context at commercial scale in the next two years.



Cost

- Levelized Cost of Energy – LCOE
- Depends on
 - Solar Resource – higher DNI better (>2000)
 - PPA period (>20 years)
 - Subsidies, Loans etc
 - Cost of construction, location, local content etc.
- Look at the PPA's

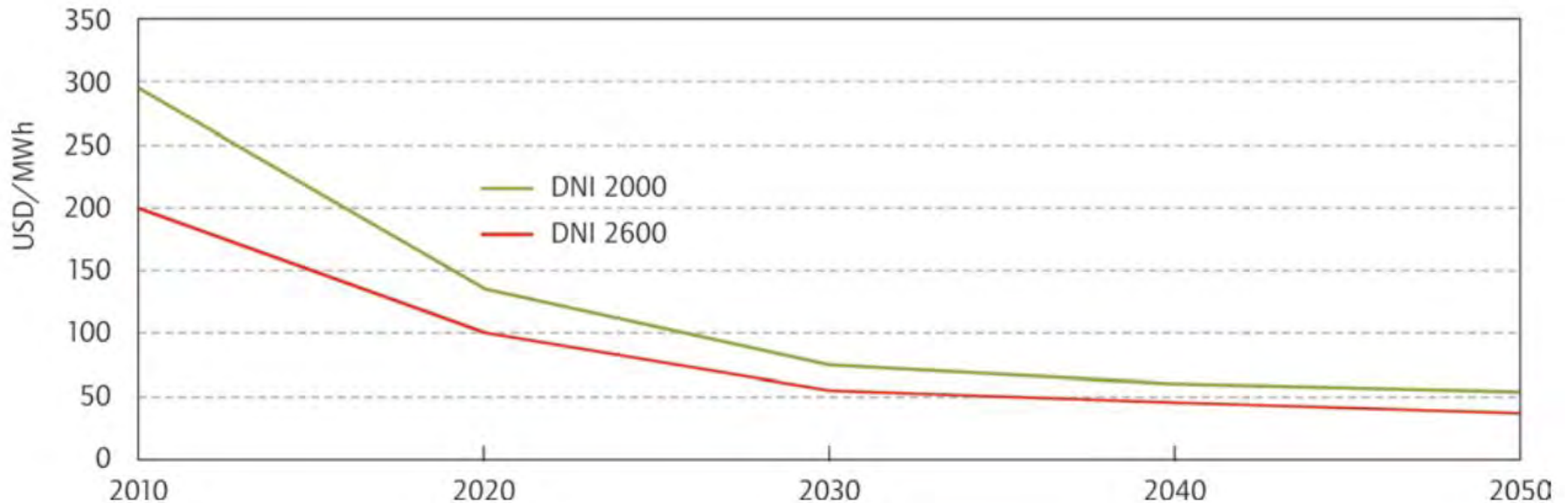


PPA's

- Spanish FIT of 27 Euro c/kWh (US 35c/kWh) created a rush. So we know this is a good profit making figure.
- Recent Indian tenders of 10.5-12.24 INR/kWh (US 21-25 c/kWh) are probably close to break even
- Ivanpah – 110 MW Solar Reserve Molten Salt Tower – US 13c/kWh PPA, but with \$737m loan guarantee and higher DNI
- + discussions with manufacturers
- <50 MW plants w DNI 2000 ~ US 20-24 c/kWh
- >50 MW plants w DNI 2500 ~ US 14-16 c/kWh



IEA Forecast



- US, European and Indian projects
- For Australia, with DNI ~2200 kWh/sqm/yr, expect CSP to be competitive with PPA ~AUS 12-18c/kWh by 2020

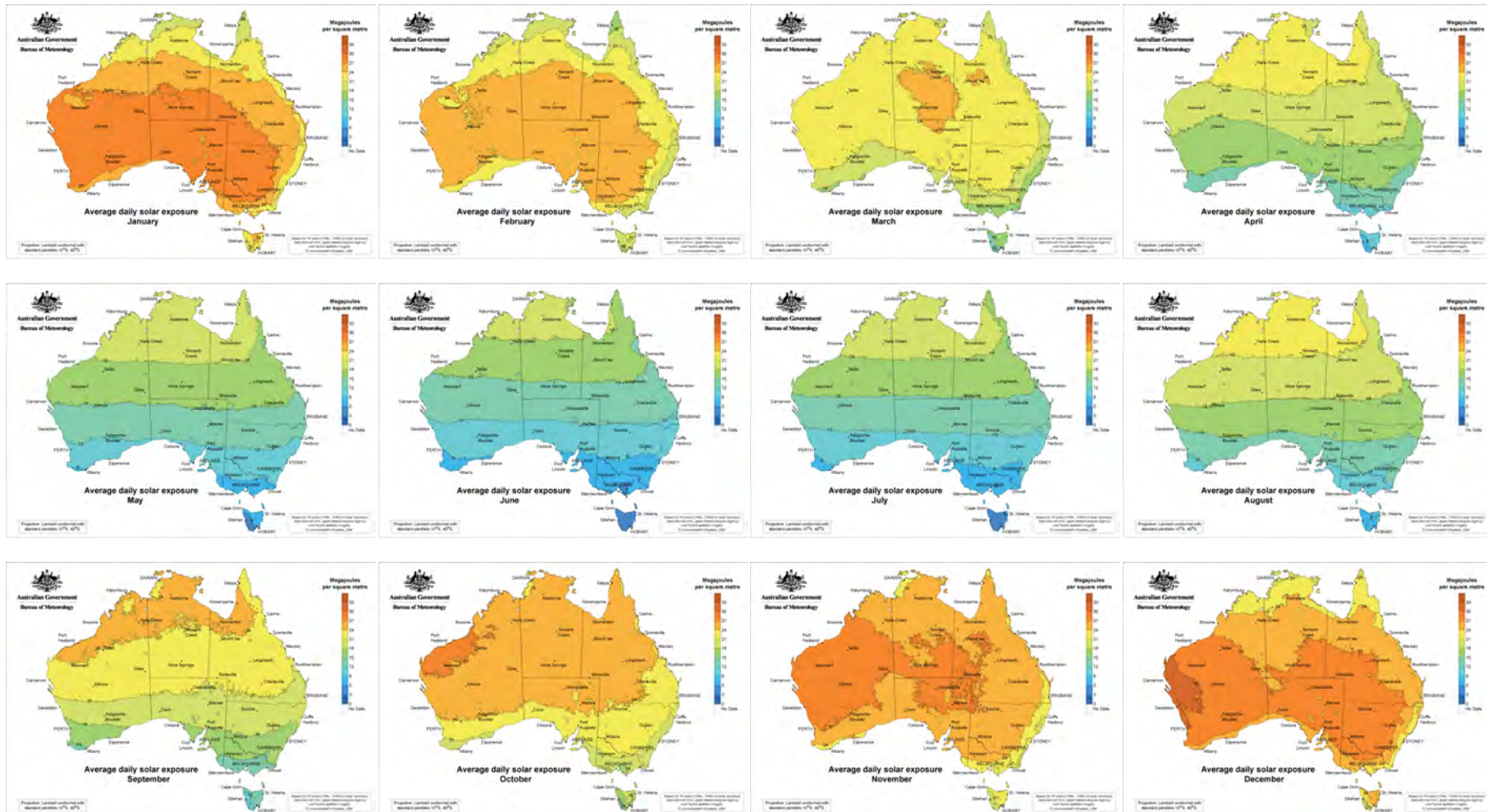


The Value of Storage

- US Target for CSP is US 6 c/kWh – doesn't differentiate between systems w&wo storage
- Studies* suggest dispatchability is worth US 3-5 c/kWh
- Additional storage cost doesn't substantially increase the LCOE due to the higher capacity factor
- Should be represented in PPA's in the future



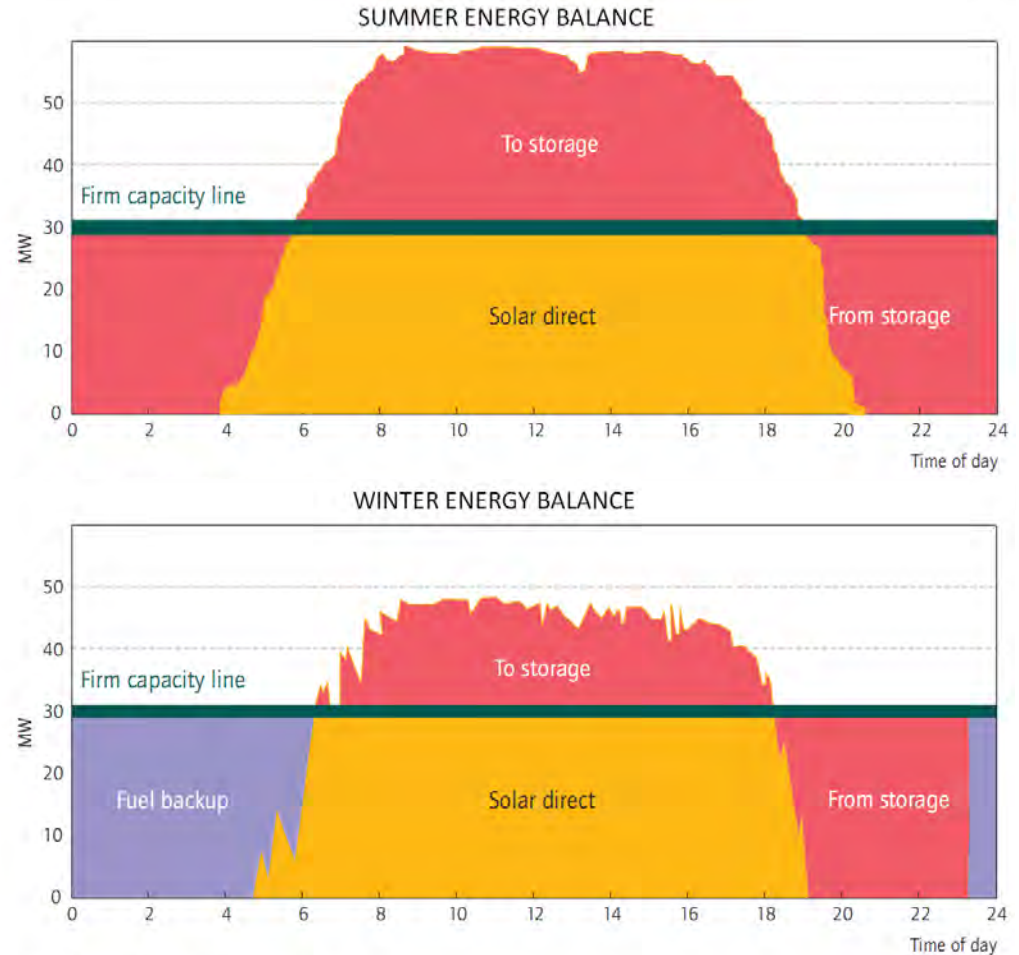
Partnership with Fossil Fuel



Need to achieve consistent output despite varying DNI

Partnership with Fossil Fuel

- Target the plant to achieve 24 hr output for the DNI during summer, and compensate during winter with fossil fuel
- Total Gas contribution ~22%. Average CO₂ emissions for the year are 100 kg CO₂/MWh
- Current Qld Average ~910 kg CO₂/MWh



Source: Geyer, 2007, SolarPACES Annual Report.



And in context?

- Western Mineral Province
- National Electricity Market ~ 6c/kWh
(Qld and NSW base price, Q1 2011)
- Cu String – estimated premium 8-12 c/kWh
- Gas price, currently \$3.5/GJ, expected to go to \$7.5/GJ when LNG train starts -> +4c/kWh in fuel costs
- Estimated cost for WMP ~14c/kWh on gas, now. After 2023, probably 18c/kWh or more.
- Mines running on diesel ~45c/kWh.



Summary

- Solar is a natural resource that Australia has in abundance.
- HVDC technology makes it exportable as electricity in the future
- There are niche opportunities for which CSP is likely to be cost competitive before 2020
- CSP is a complementary technology to fossil fuel, particularly gas.



Thanks to

- SolarPaces, ESTELA, DLR, CIEMAT
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- Abengoa
- ABARE
- Qld Resources Council

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