Climate Futures

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Alternative energy – the benefits of integration

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The current debate …

"Coal fired power stations are death factories. Close them"

Dr James Hansen, Director NASA's Goddard Institute Space Studies, 19 Feb 2009
http://www.lighterfootprints.org/2009/02/coal-fired-power-stations-are-death.html

"The refurbishment of existing coal fired power stations undermines the effort to increase end-use energy efficiency … and renewable energy"

The Australian Greens Climate Change and Energy Policy, http://greens.org.au/node/764

"Ramp down coal, ramp up gas, invest in renewables"

Science Alert, March 6, 2009, http://www.sciencealert.com.au/opinions/20090603-18885.html

Nuclear Power, Renewables or Clean Coal? Energy Options for Australia

Public Forum: Melbourne, Feb 2008, http://www.foe.org.au/events

Energy Forum sees debate over coal Vs Renewables

All Business, Oct 2008 www.allbusiness.com/energy-utilities/utilities-industry-electric-power/11693660-1.html

Seminar Overview

Key challenges to many alterative energy technologies

Benefits of integrating alternative and existing fossil fuel systems

- solar & fossil hybrids
- geothermal and fossil hybrids

Benefits of integrating different alternative thermal systems

- geothermal and solar thermal hybrids

Possibilities of utilising alternative energy transport systems

- pipelines to transport of alternative thermal power

Introduction

We need to implement low CO_2 technologies rapidly:

- Current State & Federal targets: 60% reduction in CO_2 by 2050
- Garnaut Report: 90% reduction by 2050

Typical challenges for alternative energy technologies

- Existing infrastructure typically takes 10-30 years to replace
- Many renewable sources are located a long way from the load
- It is more difficult to match energy demand to supply
- Getting up the “technology learning – scale-up” curve

We need to transform existing industry and develop new ones

- gradual transitions facilitate economic stability

Existing Costs of Alternative Generation

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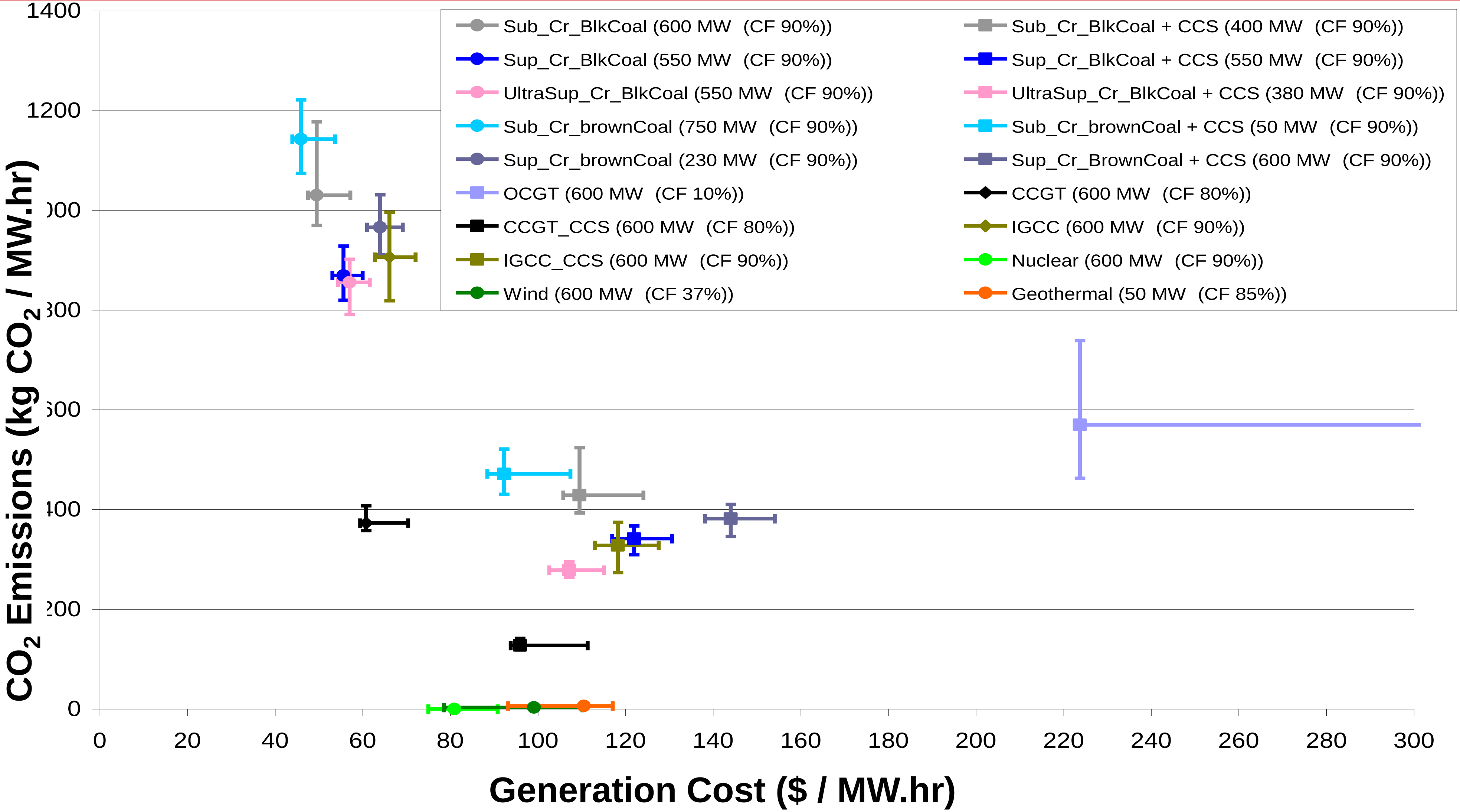
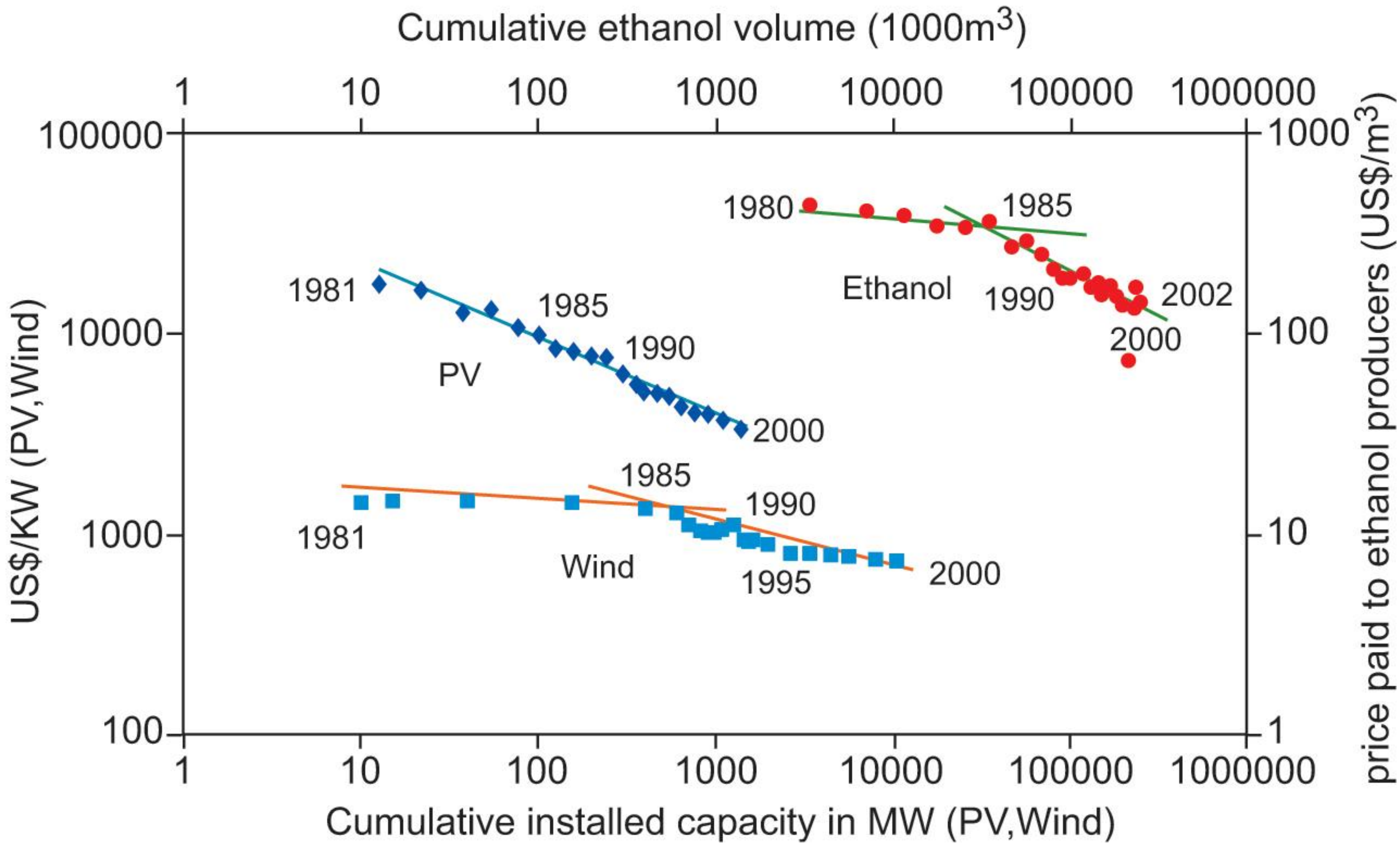


Source: ESIPC Annual Report, 2008

Typical Technology Learning Curve



Source: IPCC 4th Assessment Report
Report 3, “Mitigation of Climate Change”

Typical Technology Learning Curve

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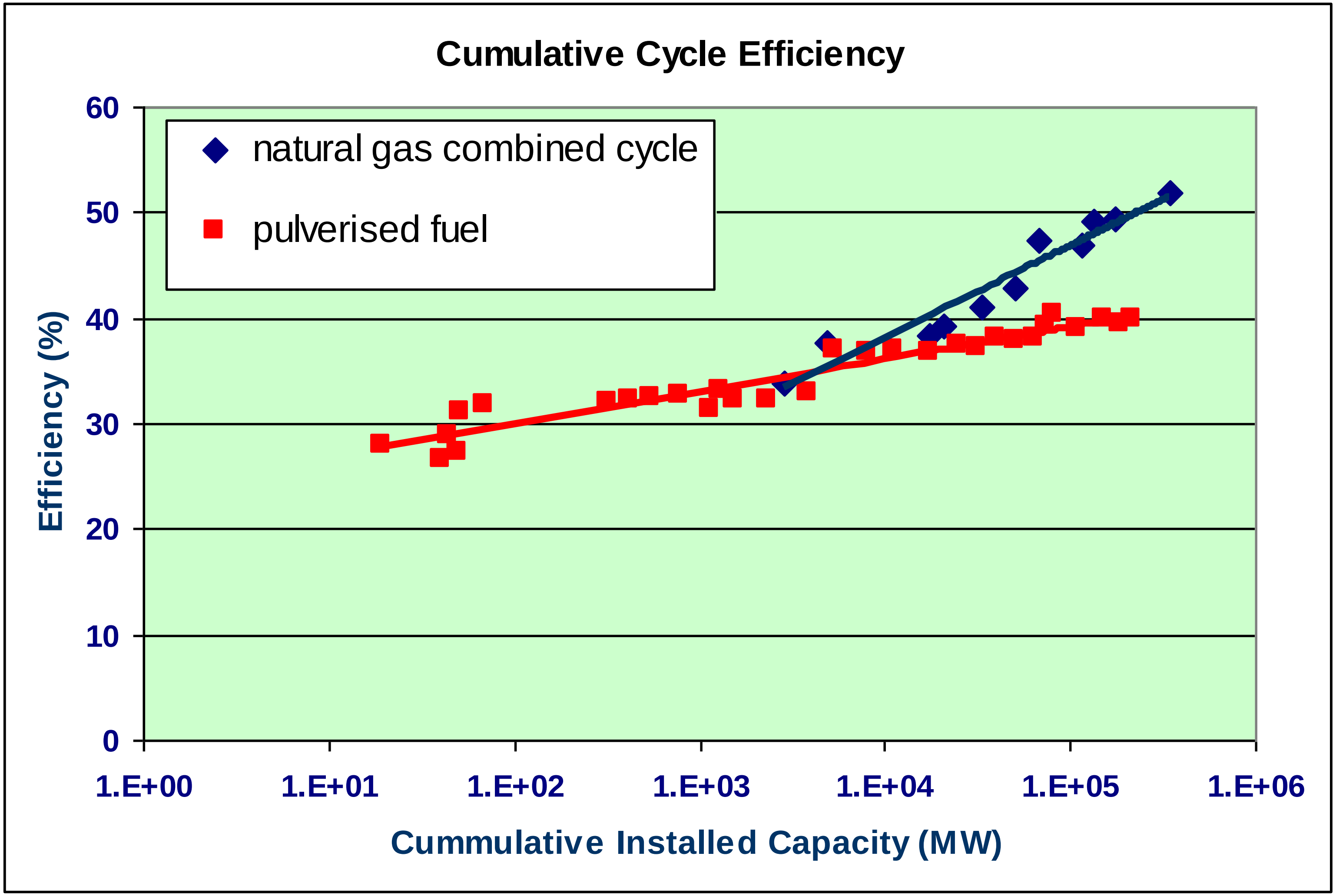
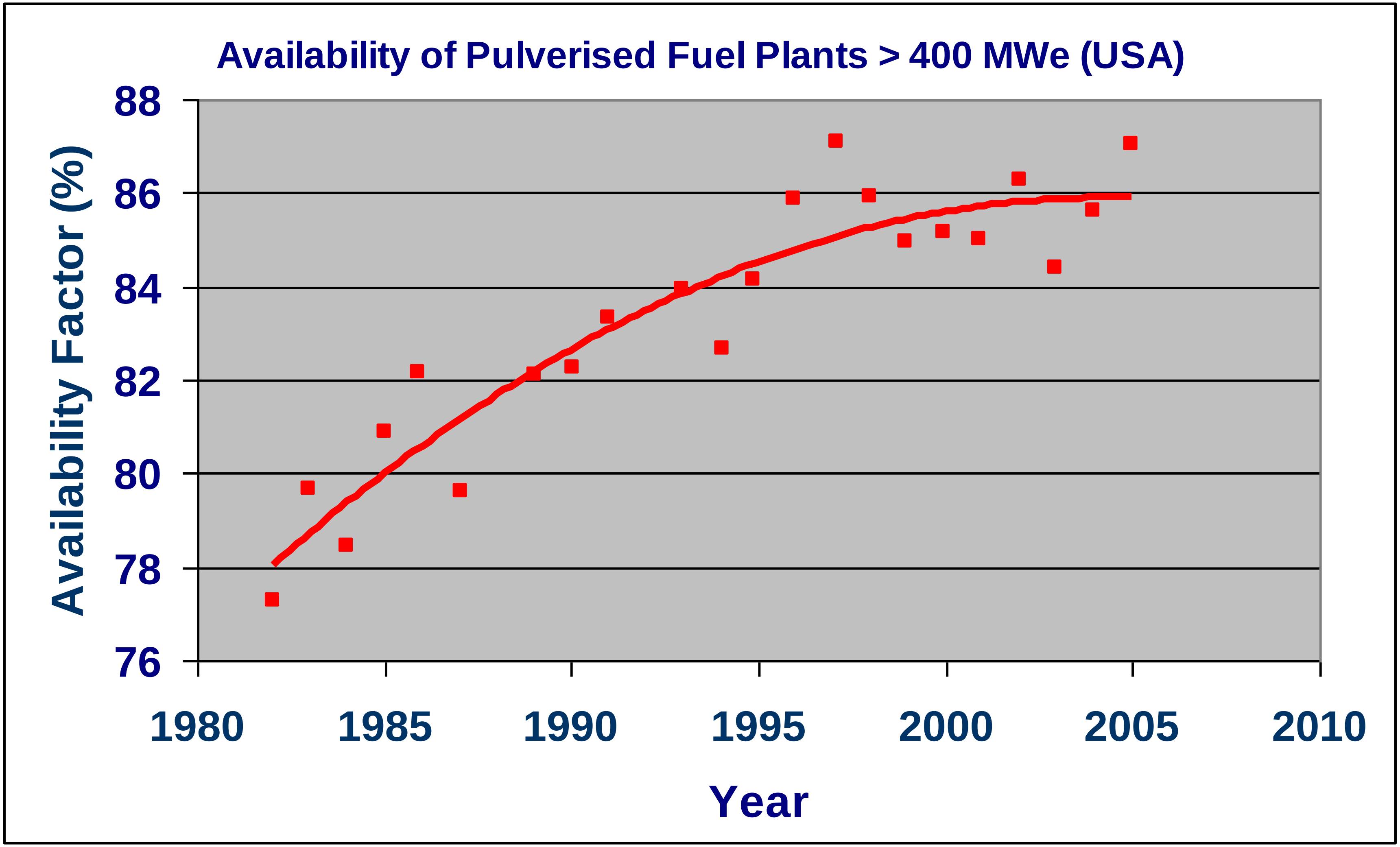


Source: "NERC Generating Availability Data System"
www.nerc.com/page.php?cid=4%c43.2005

Typical Technology Learning Curve



Source: “NERC Generating Availability Data System”
www.nerc.com/page.php?cid=4%c43.2005

Options to increase take-up of alternative energy

Carbon trading – makes high CO_2 emitters more expensive:

- This is occurring, but slowly
- Governments seek to minimise such additional costs

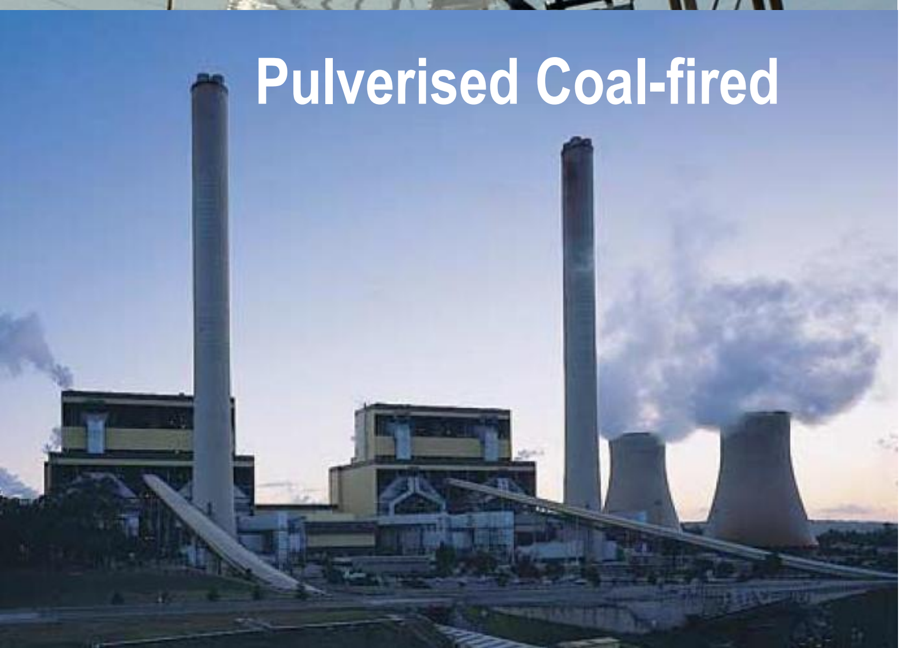
Invest in their development to accelerate learning curve

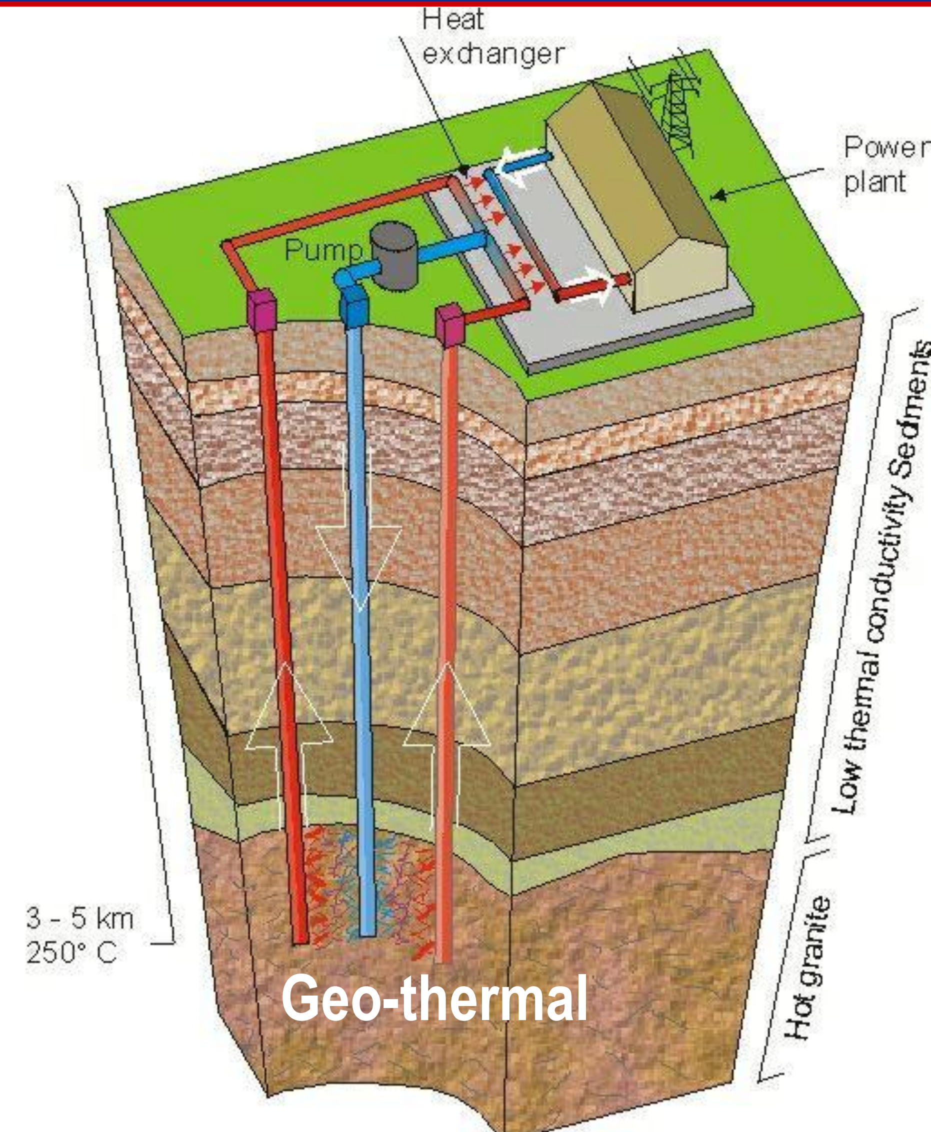
- important to do, but still takes time

Identify synergies & niches where costs are lower

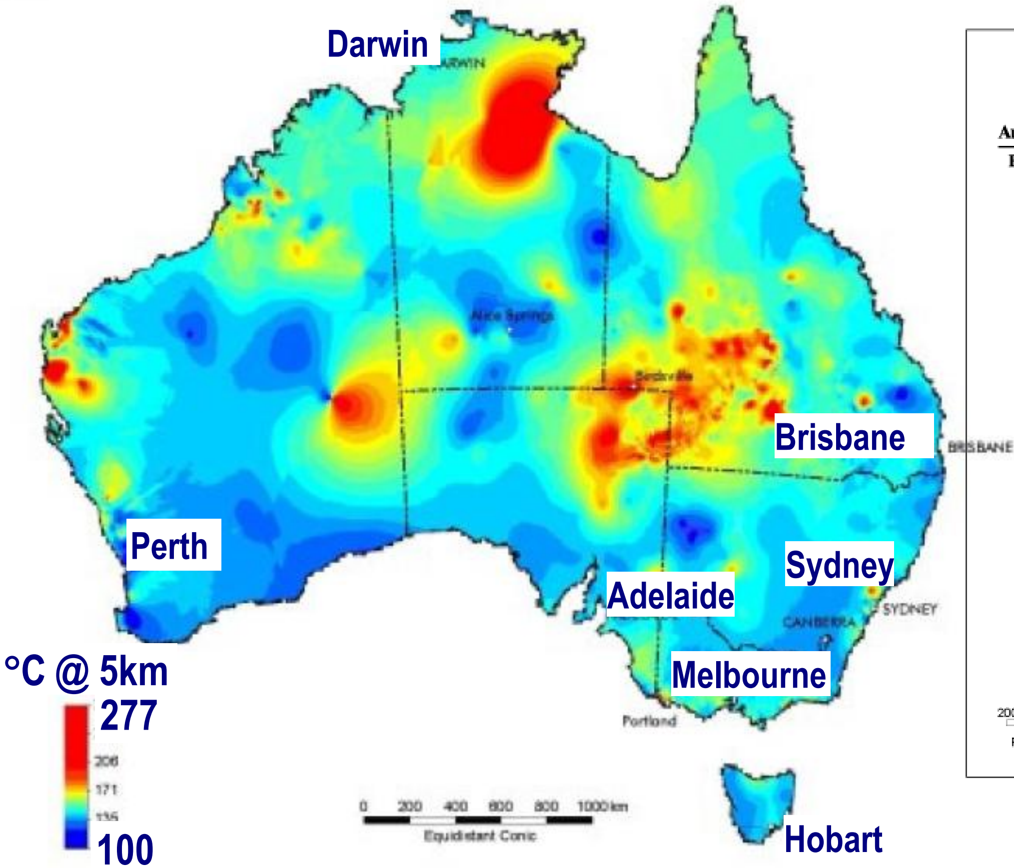
- helps to advance technologies along the learning curve

What is a thermal energy system?



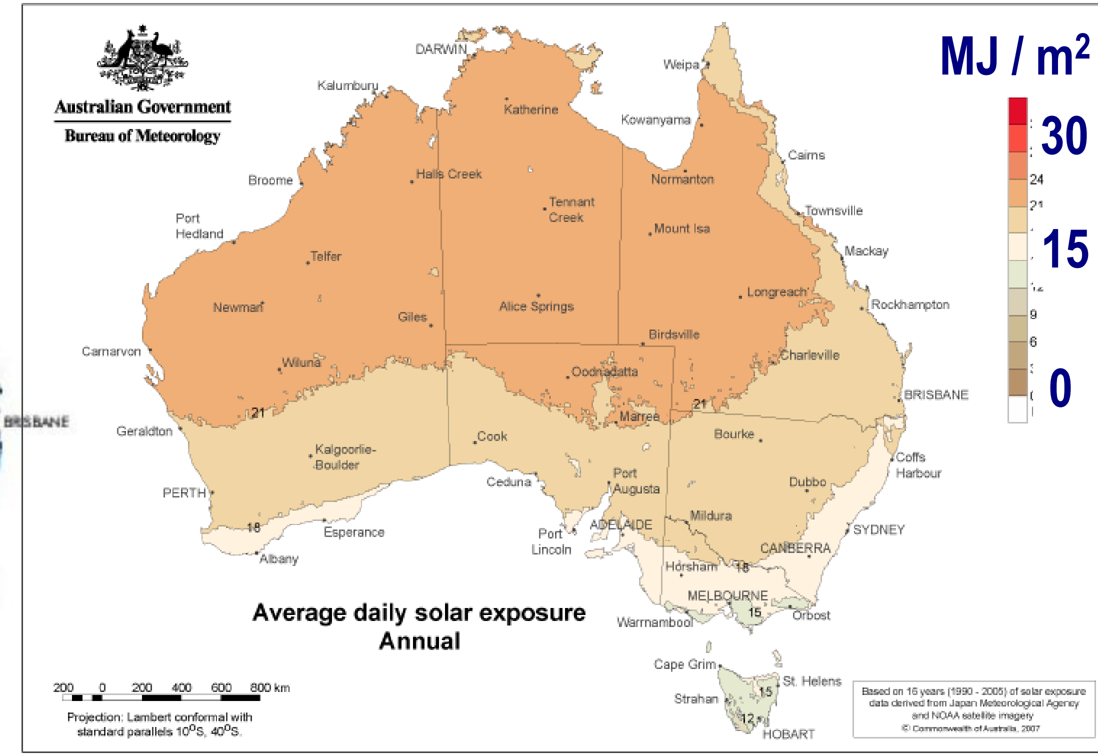


Locations of maximum natural thermal energy



Geothermal Temperature Contours

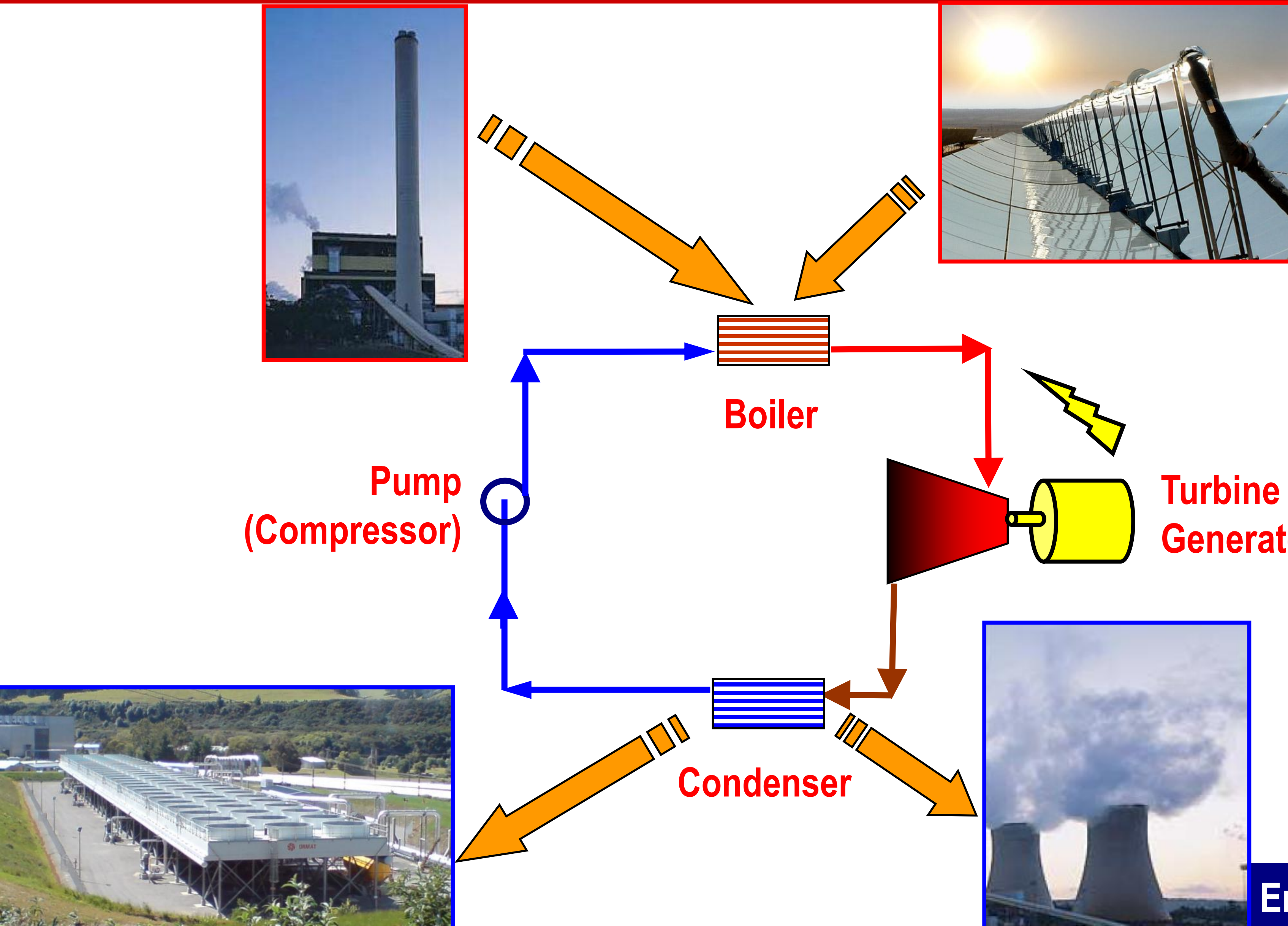
Source: PIRSA



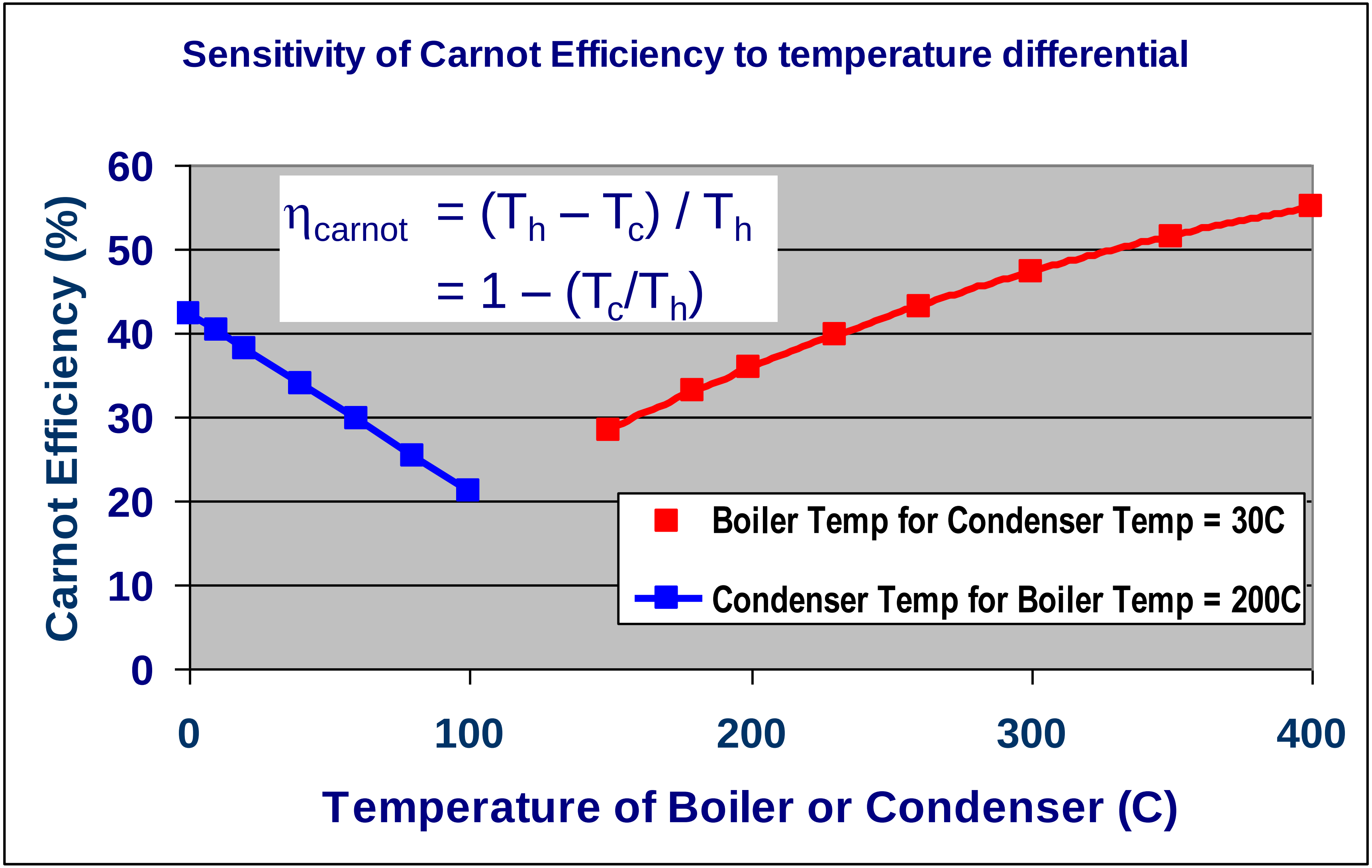
Solar energy radiation flux contours

Source: Bureau of Meteorology

What is a thermal energy system?



The influence of temperature differential



Advantages of Thermal Energy Systems

Different types of cycles can be integrated

- gas turbine, steam turbine, organic Rankine, … etc

Different types of heat sources can be integrated

- solar, fossil fuel, biomass, geothermal, … etc

High efficiency relative to most other systems (e.g. PV)

- 50% efficiency now, 60% expected

Learning can be transferred between energy sources:

- fossil-fuel spin-off to alternative thermal energy systems

Advantages of integrating alternative with fossil

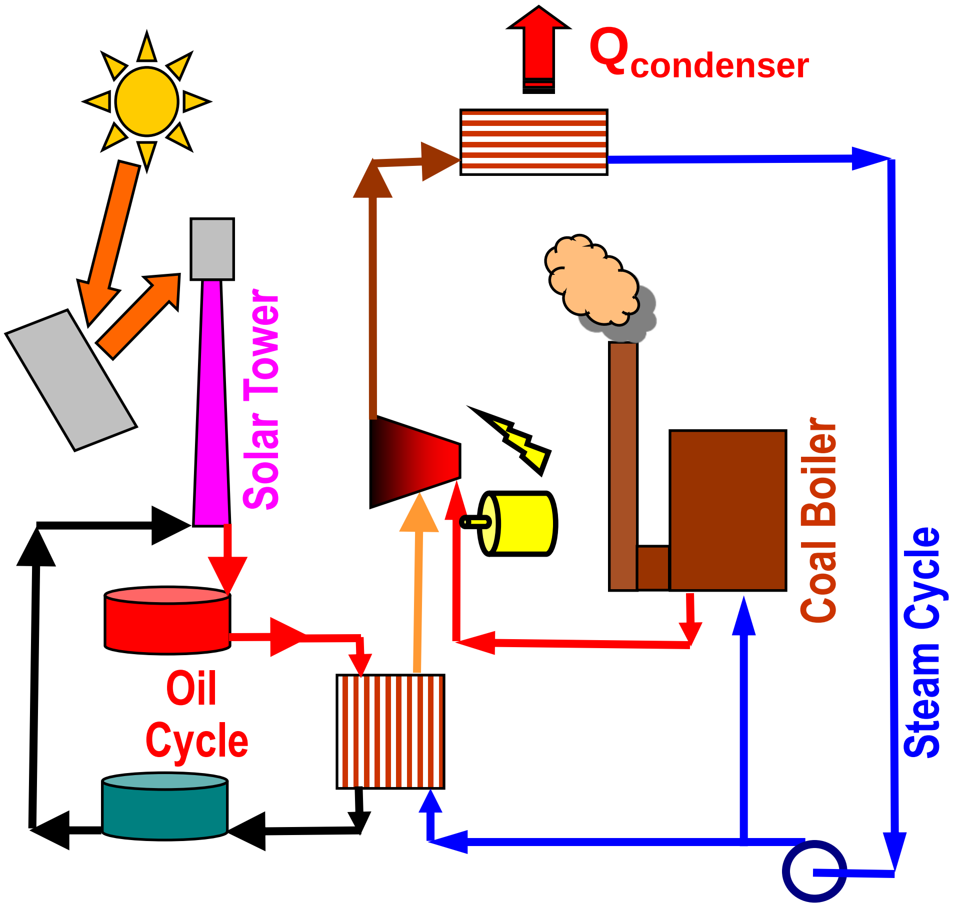
Reduced capital relative to stand-alone system

- much of the required infrastructure is already available
- less need for storage
- no risk – plant can operate as at present

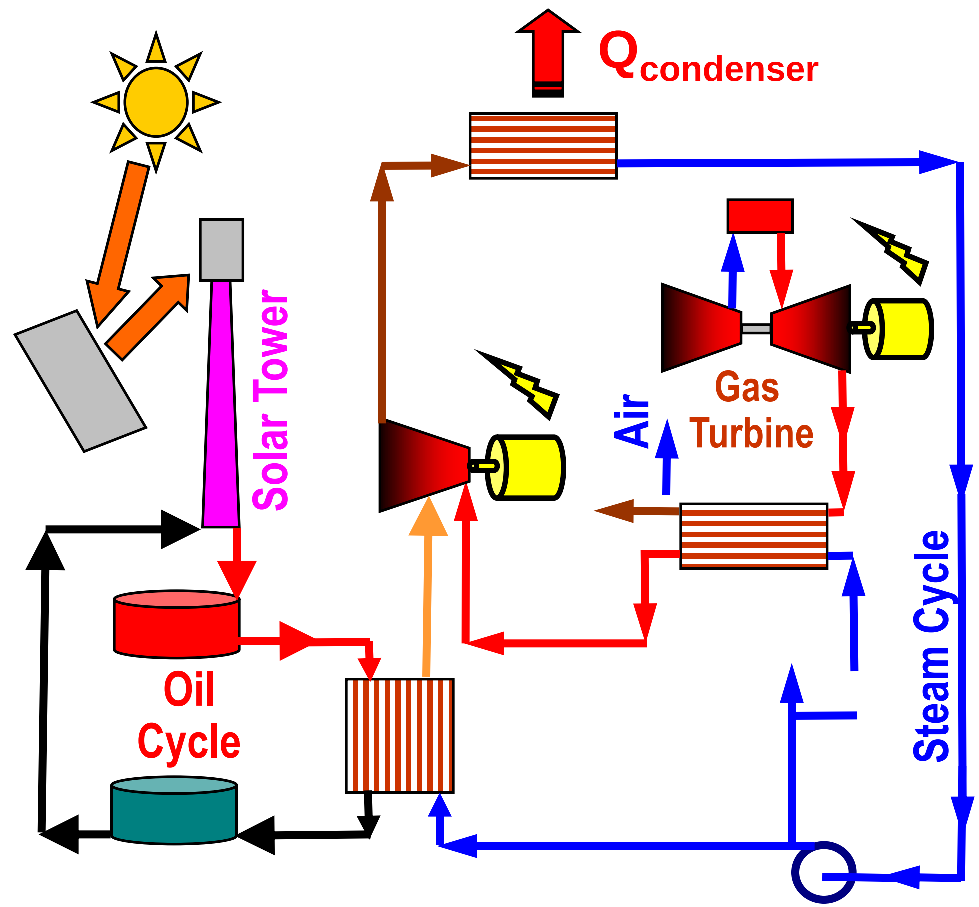
Other benefits:

- increased rate of technology deployment – technology learning
- taps into existing infrastructure
- potential synergies – higher efficiency than two stand-alone systems

Options for solar– fossil hybrids

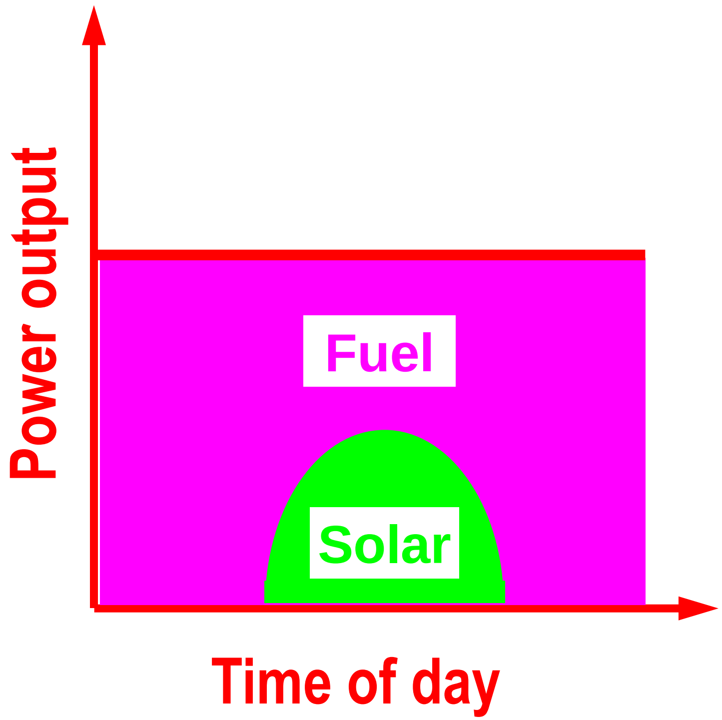


Coal + solar booster

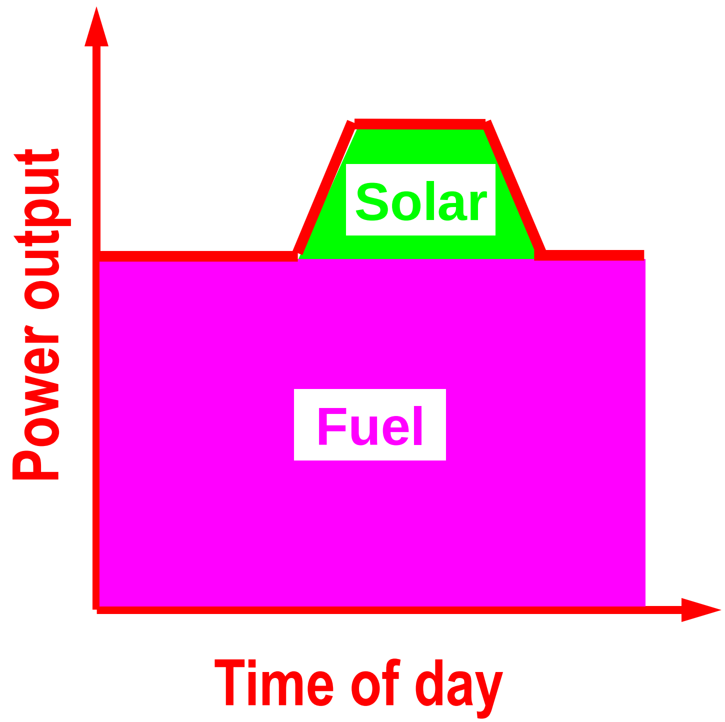


Gas / Steam Turbines + solar boost

Power boost Vs Fuel Saver



Fuel saver, no storage



Power booster, with storage

Power Booster Vs Fuel Saver

Fuel saver mode:

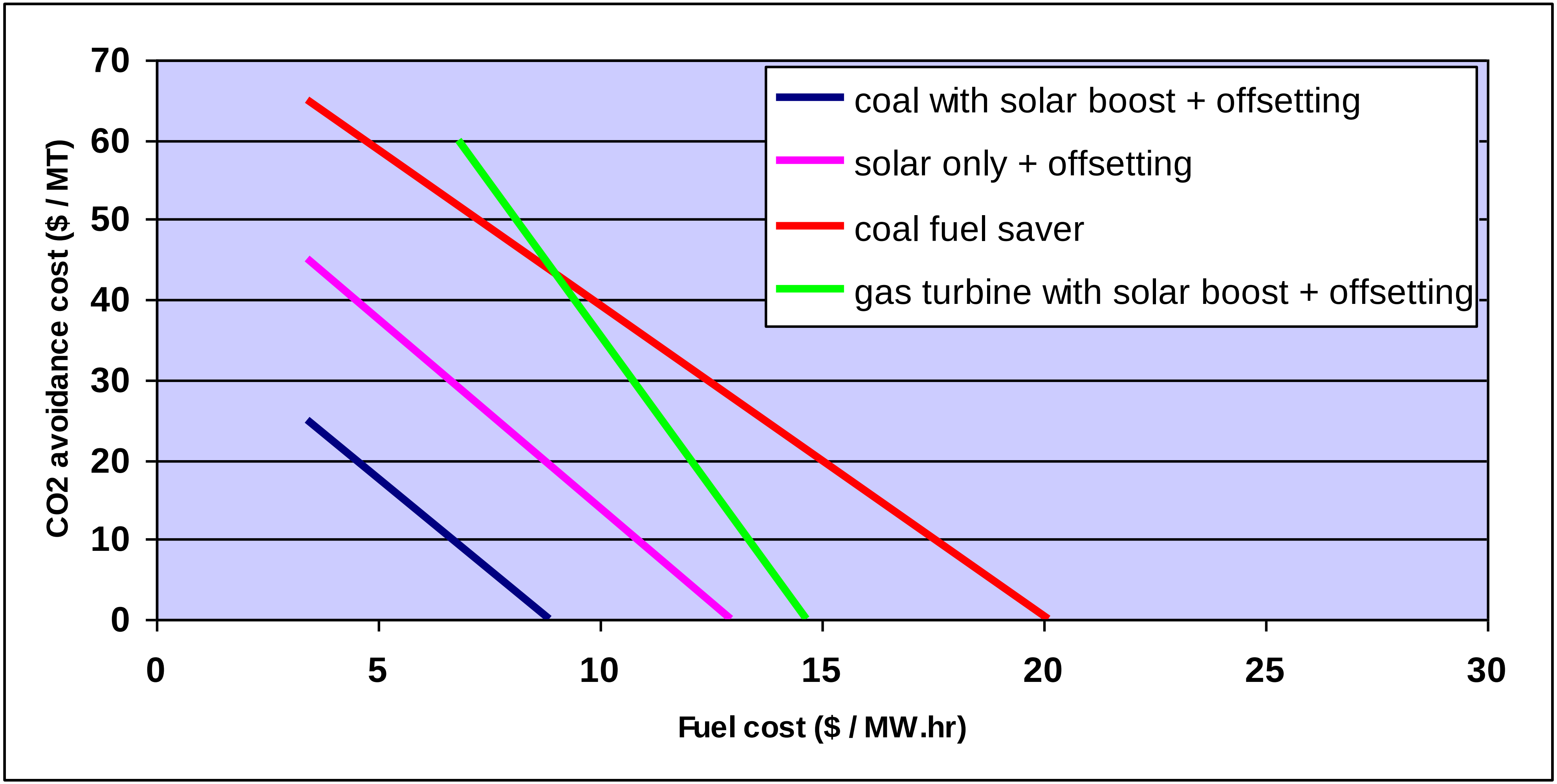
- avoids need for storage
- higher efficiency than two stand-alone systems
- reduces CO_2 emissions relative to coal plant alone

Power booster mode:

- adds commercial value by avoiding the need to build new plant
- requires an over-sized turbine relative to base-load
  - limited to 35% boost to avoid turbine losses in fuel-only mode
- boost energy is low CO_2

Source: Kolb, G.J. *Solar Energy*, **62**, 51-61 (1998)

Solar thermal – fossil-fuel hybrids: typical costs



Source: Kolb, G.J. *Solar Energy*, **62**, 51-61 (1998)

Case study – Loy Yang Power Station

General Assumptions for assessment		
Average Insolation	790	W/ m^2
Average Sunshine hours per day	6	hrs
Fuel Costs	0.02	$/kW.hr
Electricity peak price	370	$/MW.hr

Assumptions for Solar Collectors			
Collector	Temperature (°C)	Thermal Efficiency (%)	Cost ($ / m^2)
Flat Plate	40	40	$75
Vac. Tube	200	40	$110
Compact Linear Fresnel Reflector	250	30	$165
Concentrator	350	40	$200

Parameters not considered			
Land cost	Carbon Trading	Interest rate, Maint. Insurance, Depreciation	Turbine upgrade (for power boost)

Source: E. Hu, Y.P. Yang, A. Nishumara and F. Yilmaz. *Applied Energy*, (2009) to appear

Case study – Loy Yang Power Station

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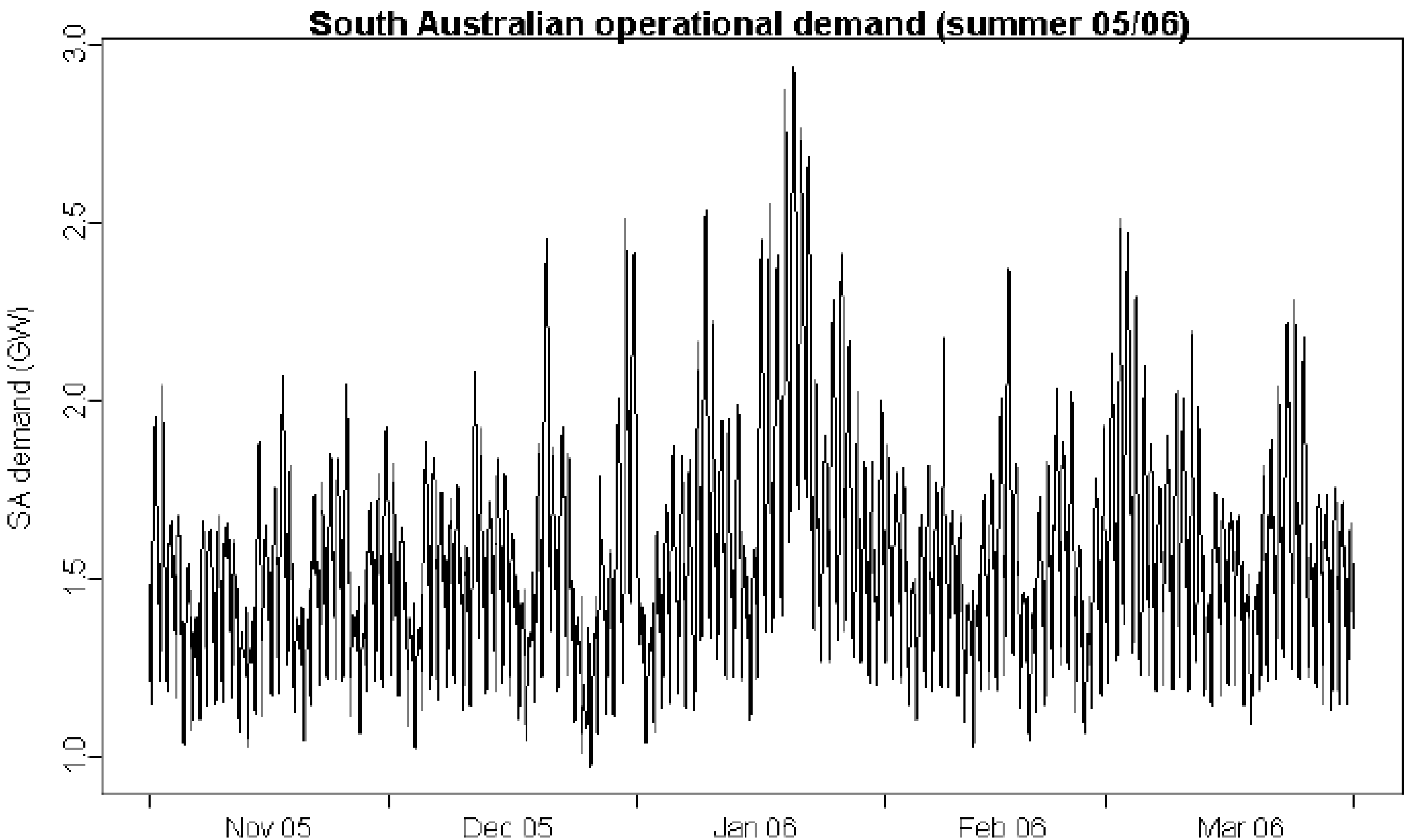
	100% Replacement of closed feedwater heaters		*100% Replacement of IPH2 feedwater heaters*	
	Power Boost	**Fuel Saver**	**Power Boost**	**Fuel Saver**
Gen Output (MWe)	**573**	**500**	**521**	**501**
Efficiency Gain (%)	**6.7**	**6.7**	**2.0**	**2.0**
Extra income ($ pa)	**$58m**	**$0.61m**	**$17.1m**	**$0.51m**
Power station CO_2 reduction	**0 %**	**3.15%**	**0.04%**	**1.02%**
Collector Area (m^2)	**978,000**	**855,000**	**228,000**	**219,000**
Collector cost	**$116m**	**$102m**	**$25m**	**$24m**
Payback (years)	**2**	**37**	**1.5**	**17**

Source: E. Hu, Y.P. Yang, A. Nishumara and F. Yilmaz. *Applied Energy*, (2009) to appear

Need for capacity follow demand



Source: ESIPC, Annual Report, 2007

Addressing supply-demand mismatch

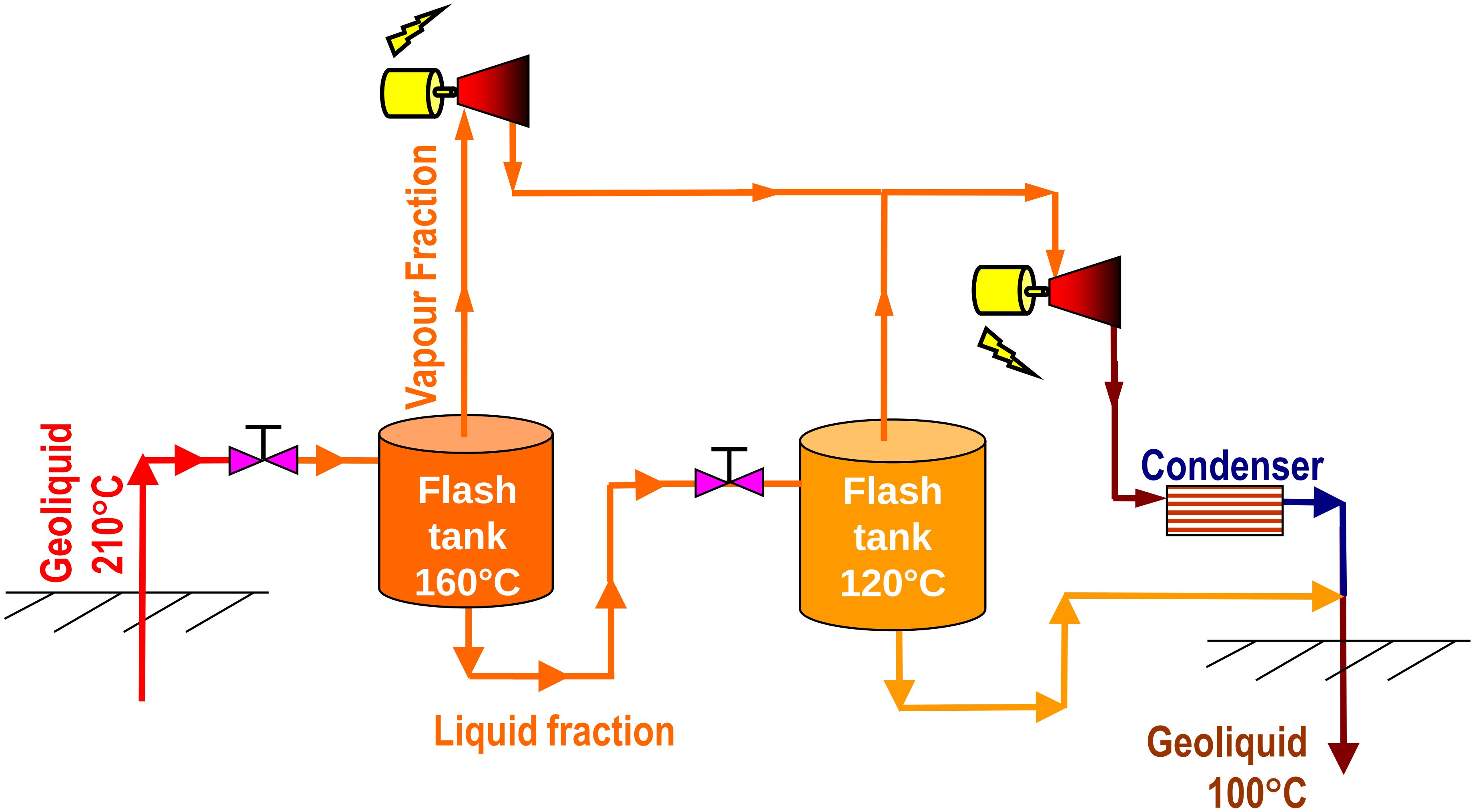
Options to address this challenge for thermal systems

- use thermal energy storage (thermal oils or molten salts)
- integrate with an existing fossil-fuel plant
- integrate complementary thermal sources (geothermal & solar)

General options for energy storage are presently expensive:

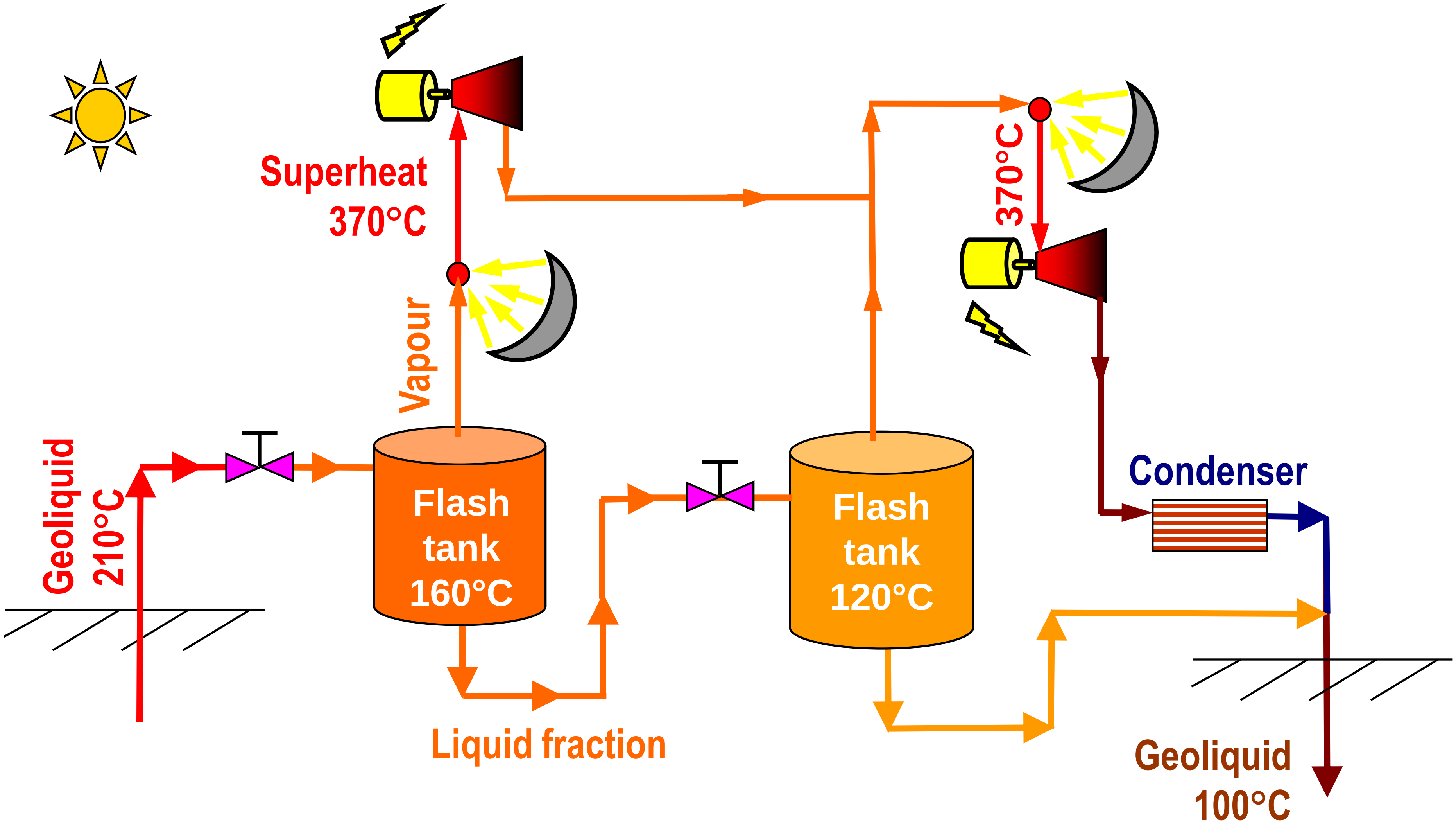
- hydro-power: established, 50% energy loss, requires water & space
- Hydrogen: emerging – presently with niche viability
- Minerals (e.g. lime-stone): long-term potential
- Other (e.g. liquid metal hydrides): long-term potential

Geo-thermal double flash plant alone



Note: 210 °C is a typical target exit temperature for enhanced geothermal systems

Geo-thermal double flash with solar superheat



Synergies: more output than from each alone

Cycle	*Output*
Double Flash alone	**5.0 MW**
Separated Solar thermal + Double Flash	**6.1 MW**
Integrated Solar thermal + Double Flash	**7.2 MW**
Synergy	**1.1 MW**
Synergy as fraction of integrated	**15%**

Conditions: 100 L/s geofluid flow at 210 C and 19.3 bar.
Condensing at 30 °C.

Other features of this system

Uses double flash: simple and low capital geothermal system

- lower cost than organic Rankine and other systems
- without boost has 5% less efficiency and output at these conditions
- has highest synergy with solar boost, so well matched

Uses thermal oil storage: low cost and reliable

- molten salts allow higher temp, but at higher cost and complexity
- this temp boost (to 370 °C) avoids compromising turbine efficiency

Reduces thermal storage re solar alone

- no need for night-time storage, only some peak following

Explanation for synergy

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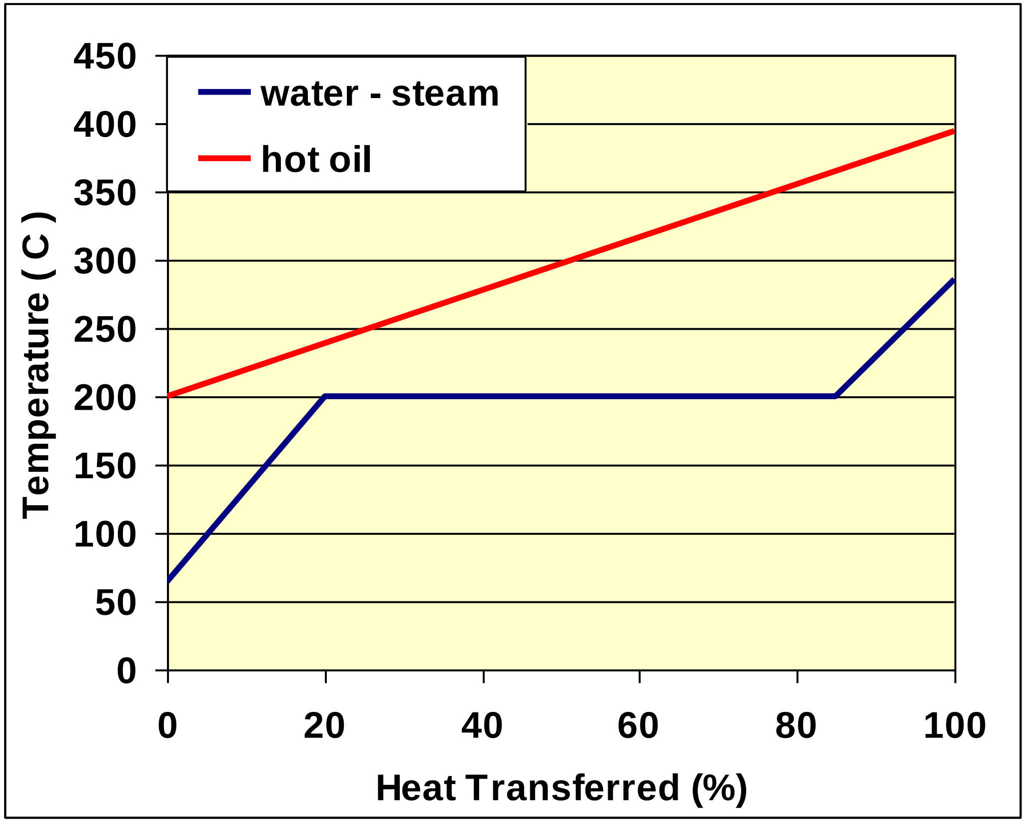
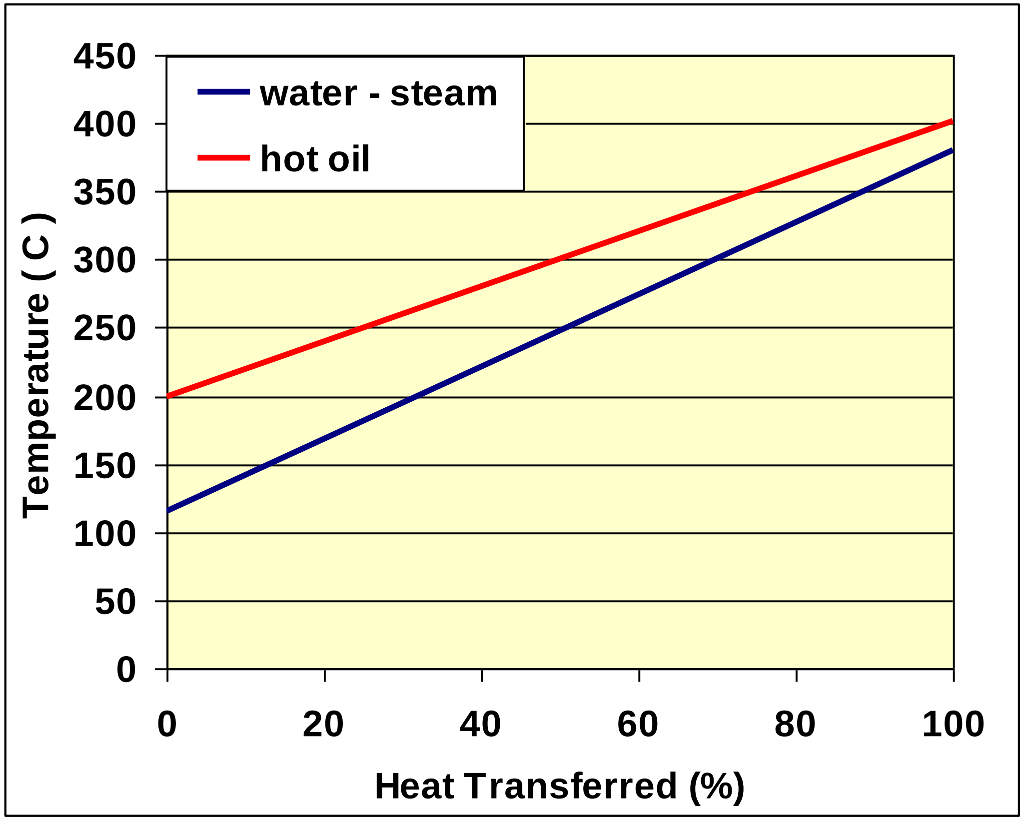
Temperature history of both fluids through boiler

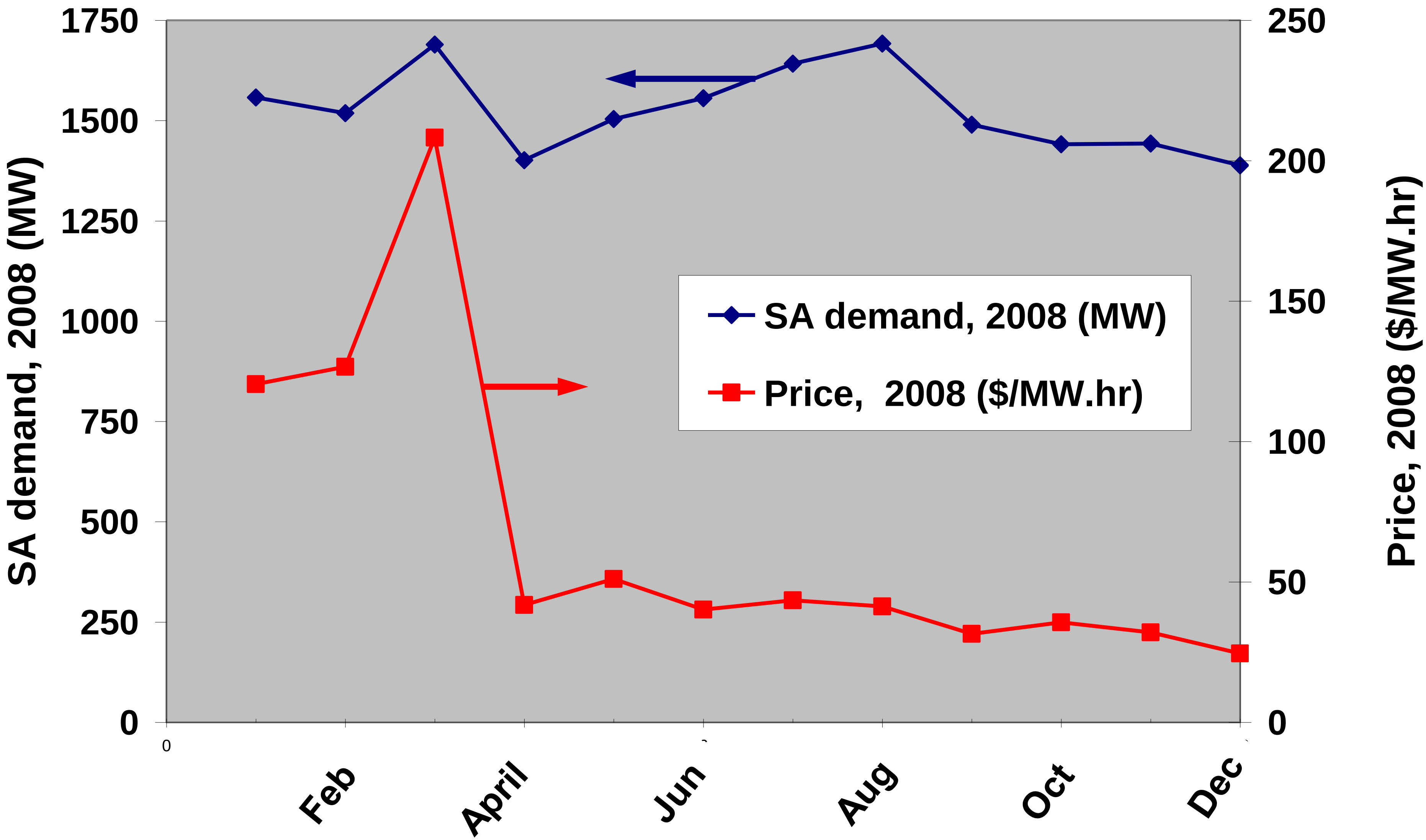




Solar thermal for entire process

Solar thermal for superheat only

Profitability depends on matching demand



Source: ESIPC, 2007

Comparison of solar & geothermal with demand

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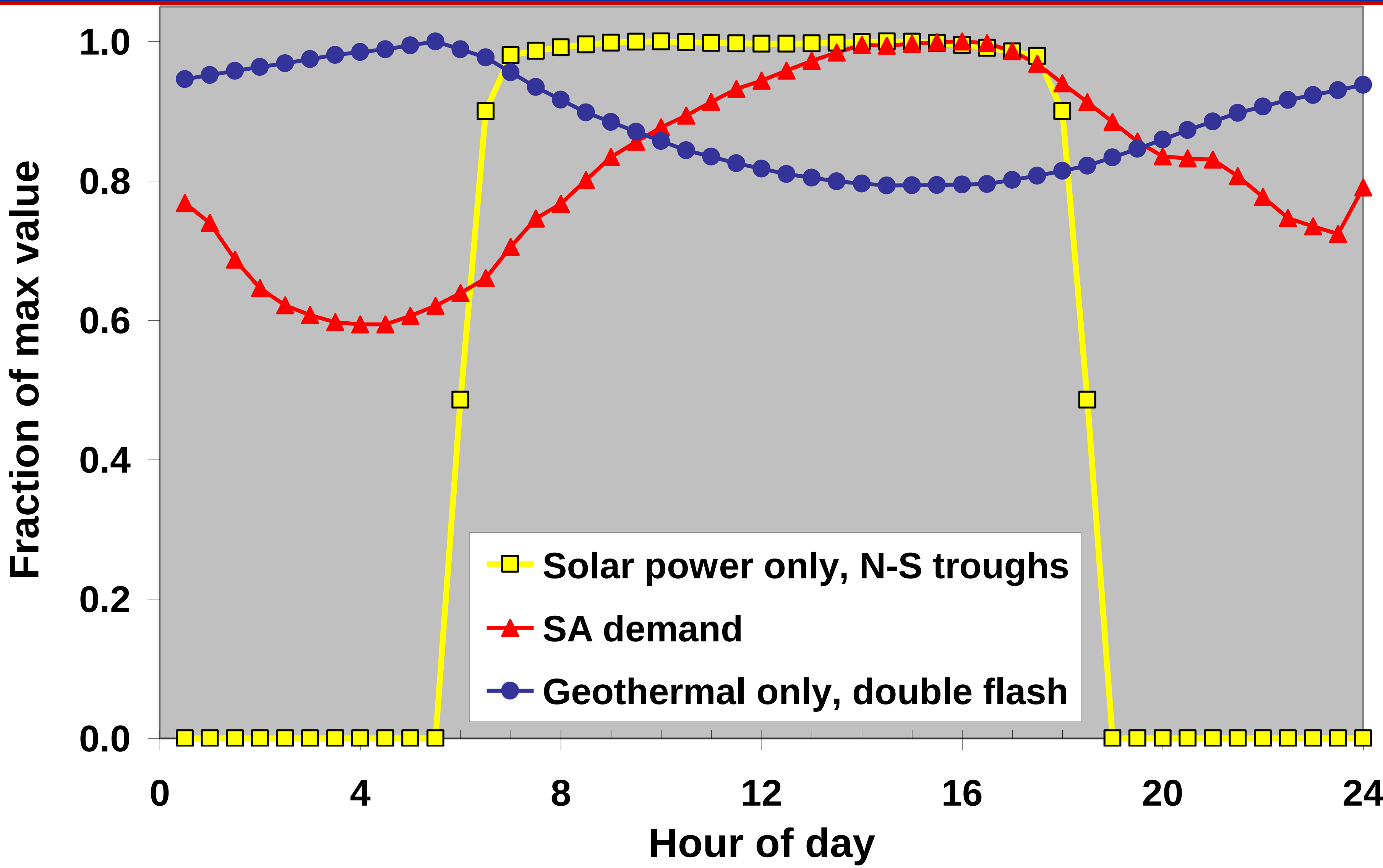
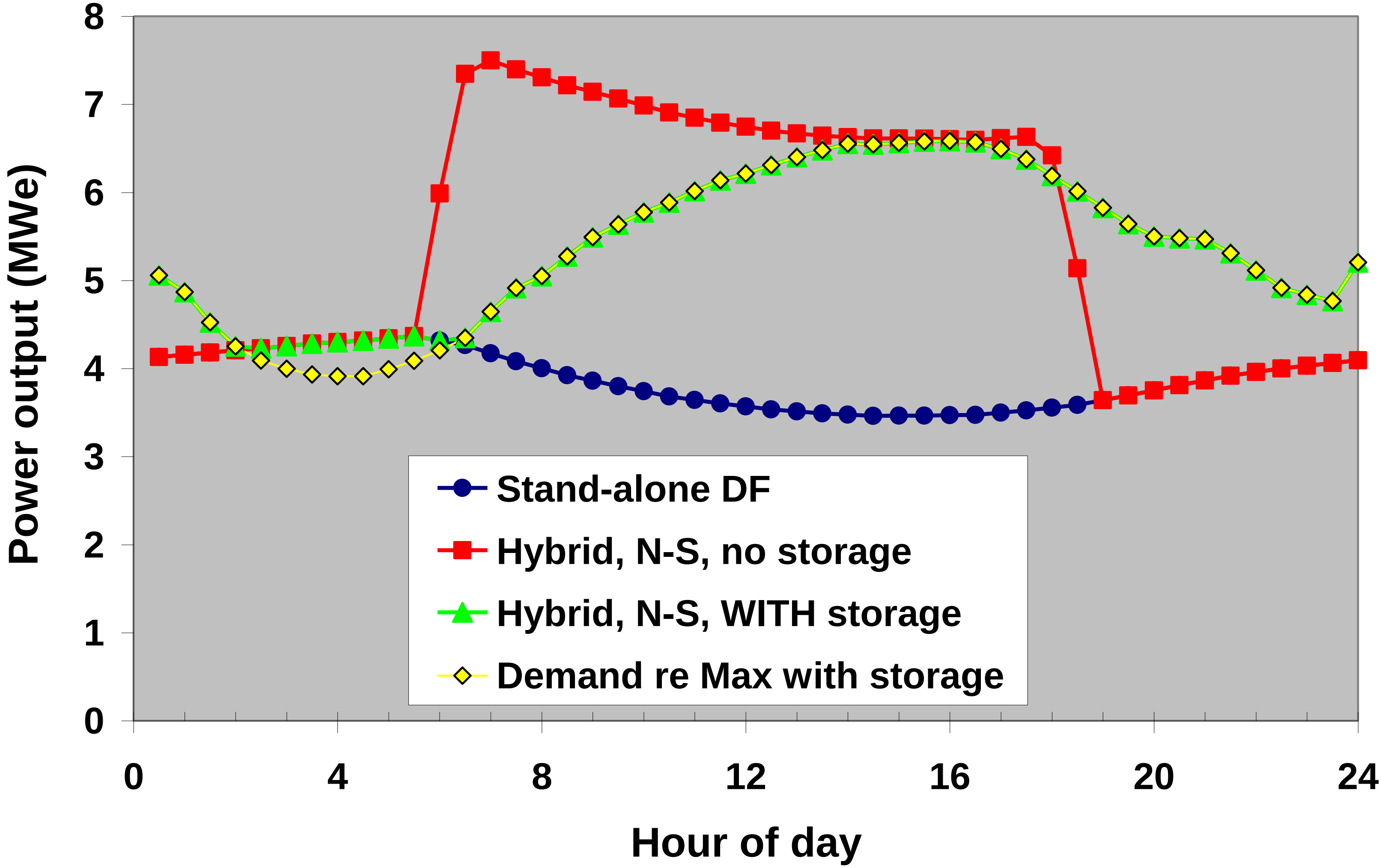
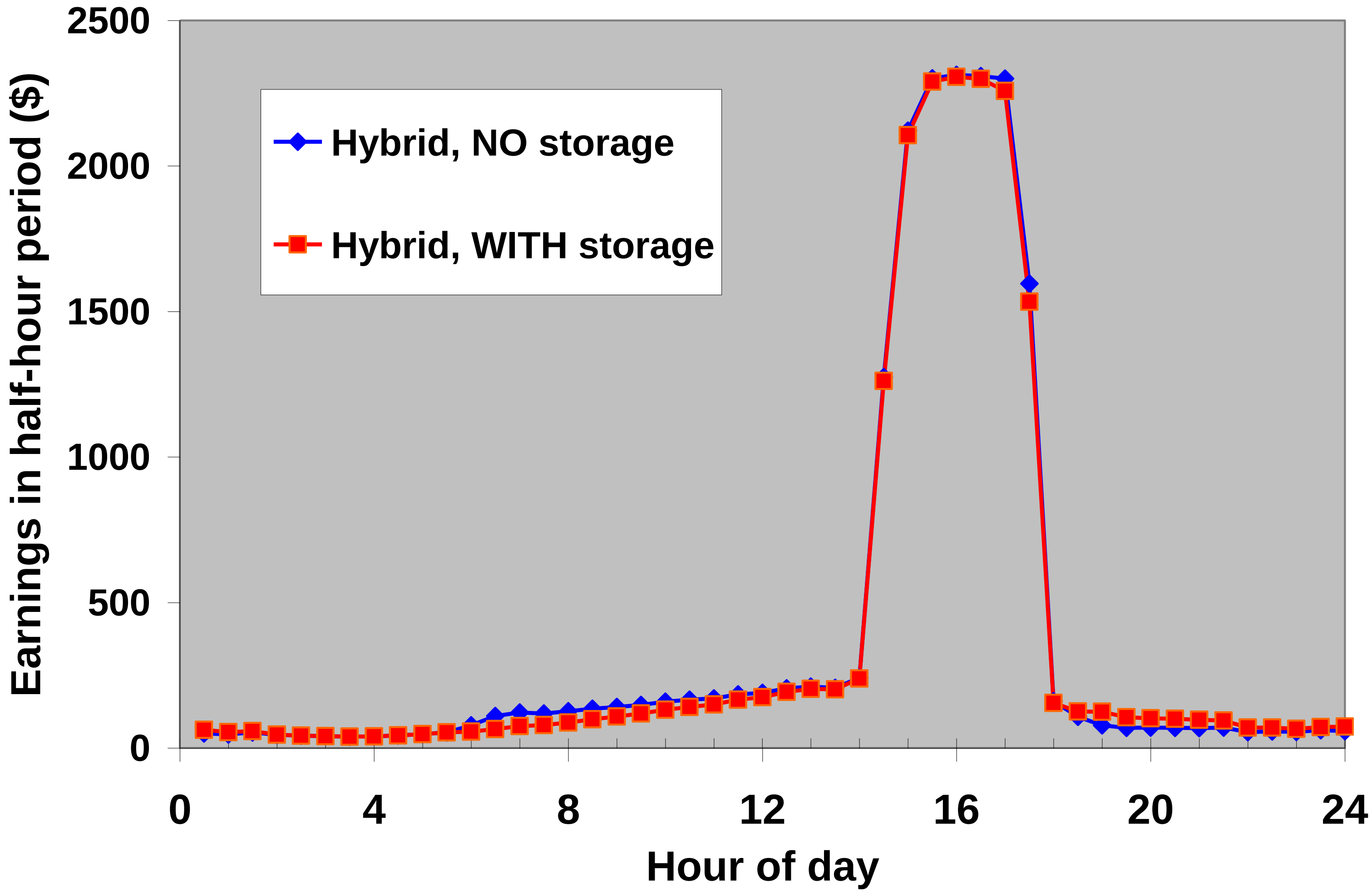


Comparison of solar & geothermal with demand



- Assumes no cloud
- Other output profiles are possible with storage

Daily earnings for hybrid systems with and without storage



- Based on average temps (Moomba) and SA prices for Jan 2008
- Based on previous load-following curves – others are possible

Benefits of geo-solar hybrids

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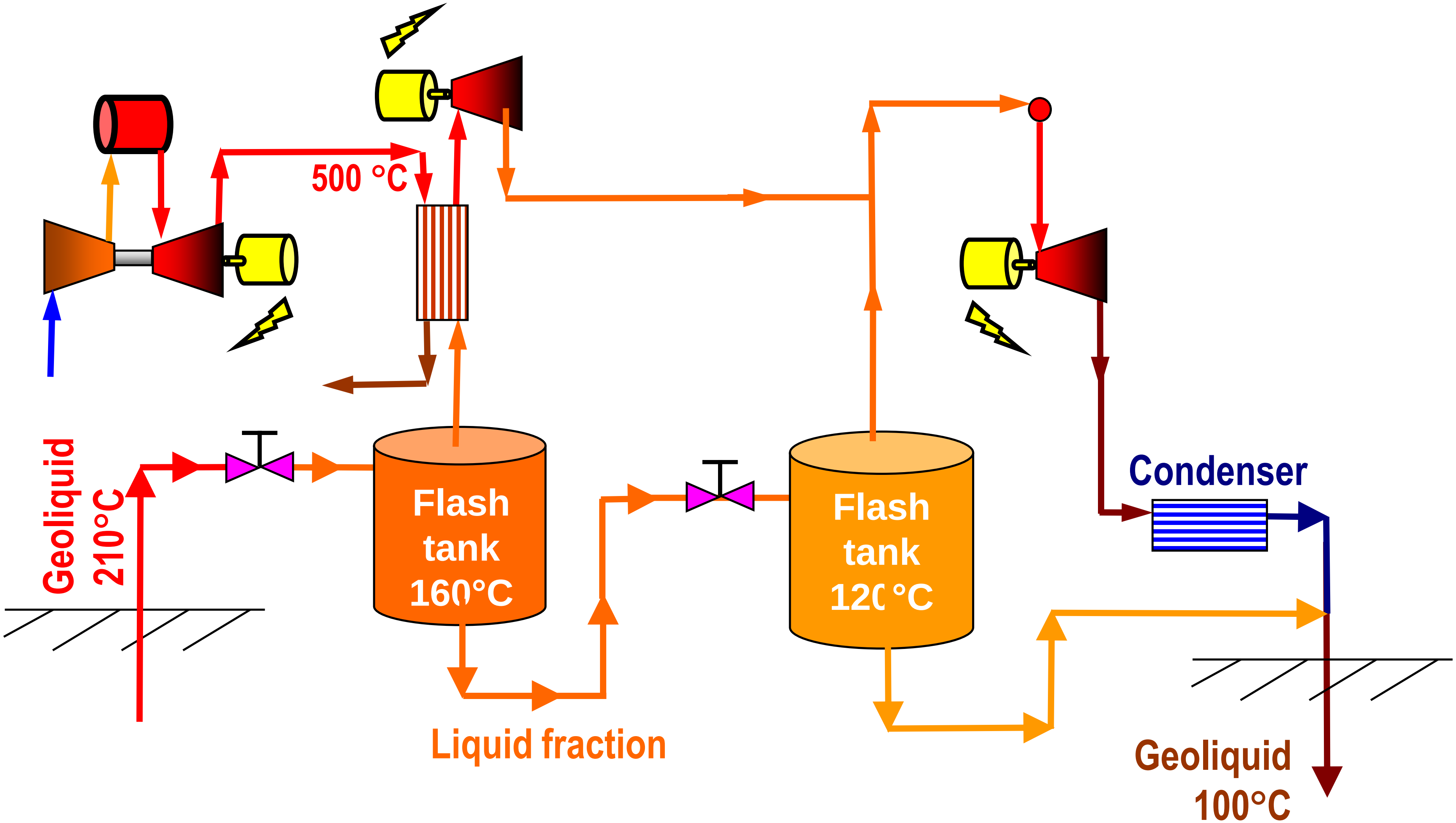
Solar boost provides 78% more earnings for 43% more energy:

- doubles viability of solar thermal (& also reduces need for storage)
  - based on above Jan 2008 conditions in SA

Storage provides greater capacity to attract peak prices:

- in event of intermittent cloud
- in event of fluctuation in peak demand relative to insolation

Geo-thermal integrated with gas turbine

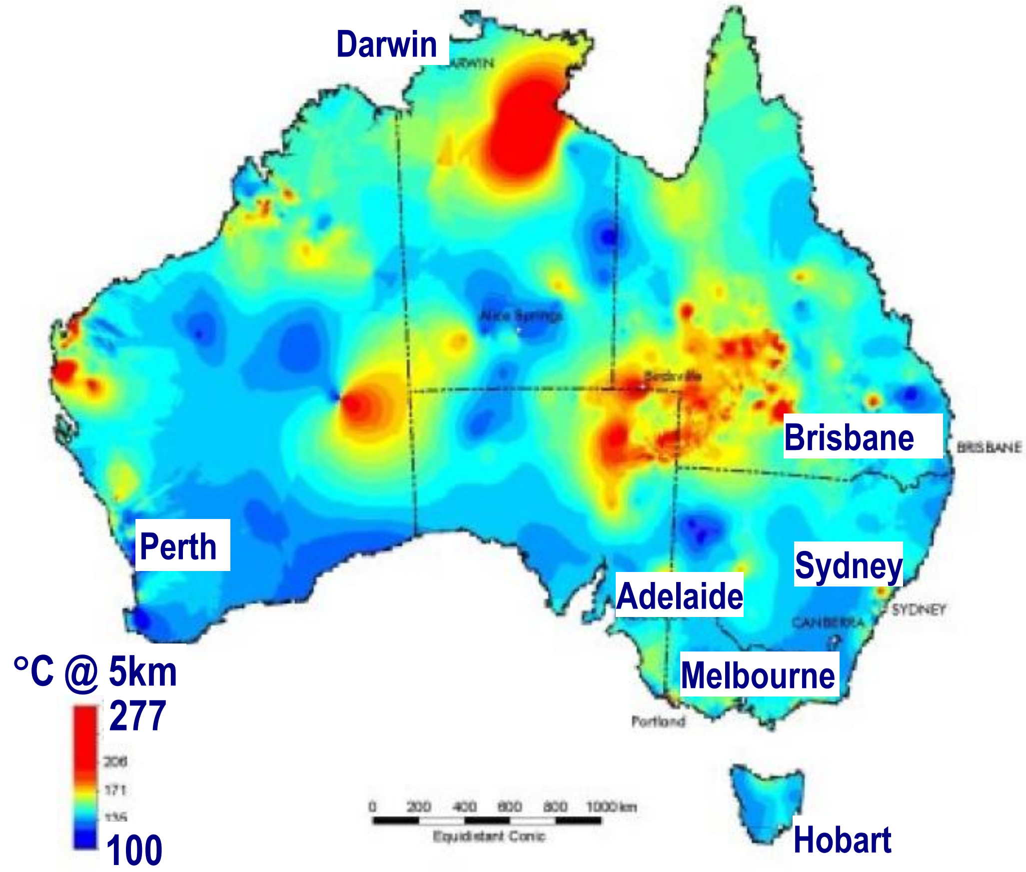


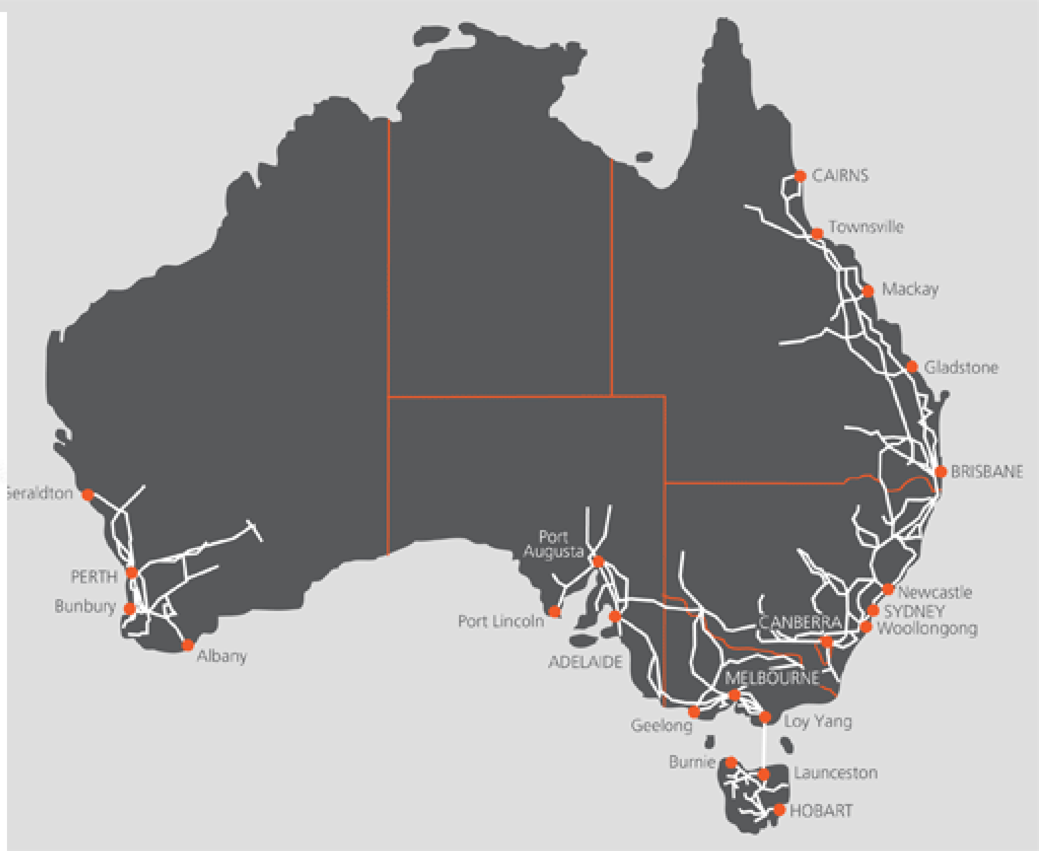
Synergies of geothermal – gas turbine

Cycle	*Output*
Double Flash alone	**5.7 MW**
Gas Turbine alone	**5.5 MW**
Rankine Steam Cycle alone	**1.1 MW**
Integrated Gas turbine + Double Flash	**14.0 MW**
Synergy	**1.4 MW**
Synergy as fraction of integrated	**10%**

Conditions: 100 L/s geofluid flow at 210 °C
Condensing at 97 °C.

Proximity to the Grid - Geothermal

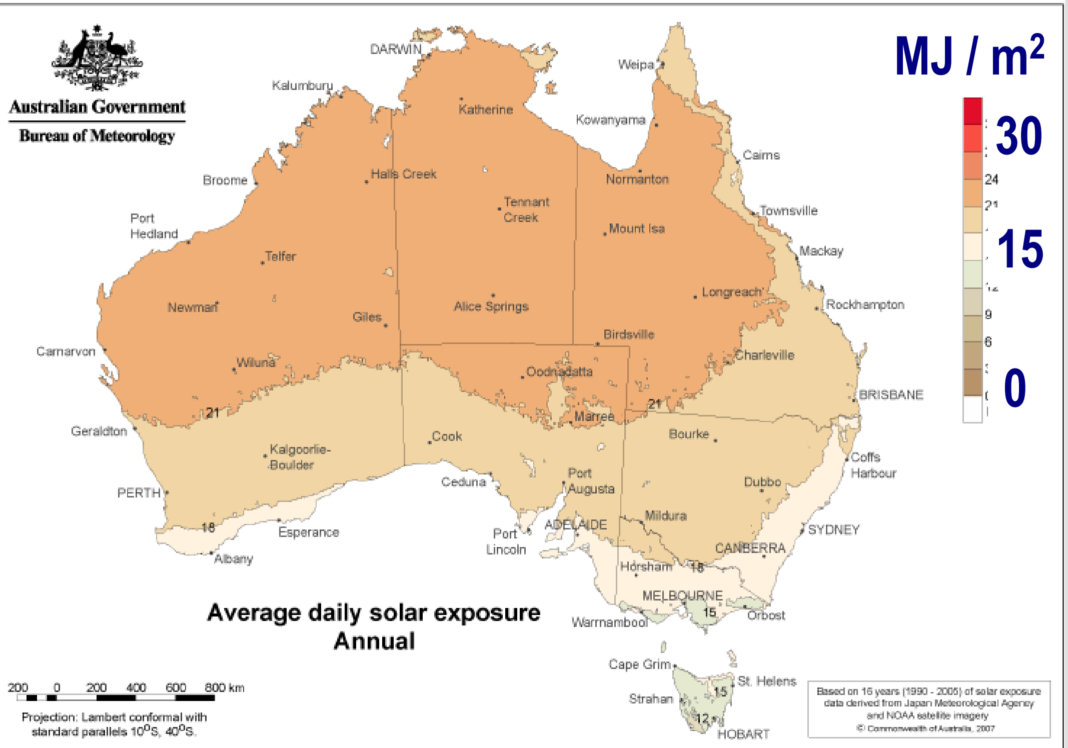




Source: PIRSA

Source: www.gridaustralia.com.au

Proximity to the Grid – Solar Thermal



Source: www.gridaustralia.com.au

Proximity to Pipelines – Geothermal and Solar

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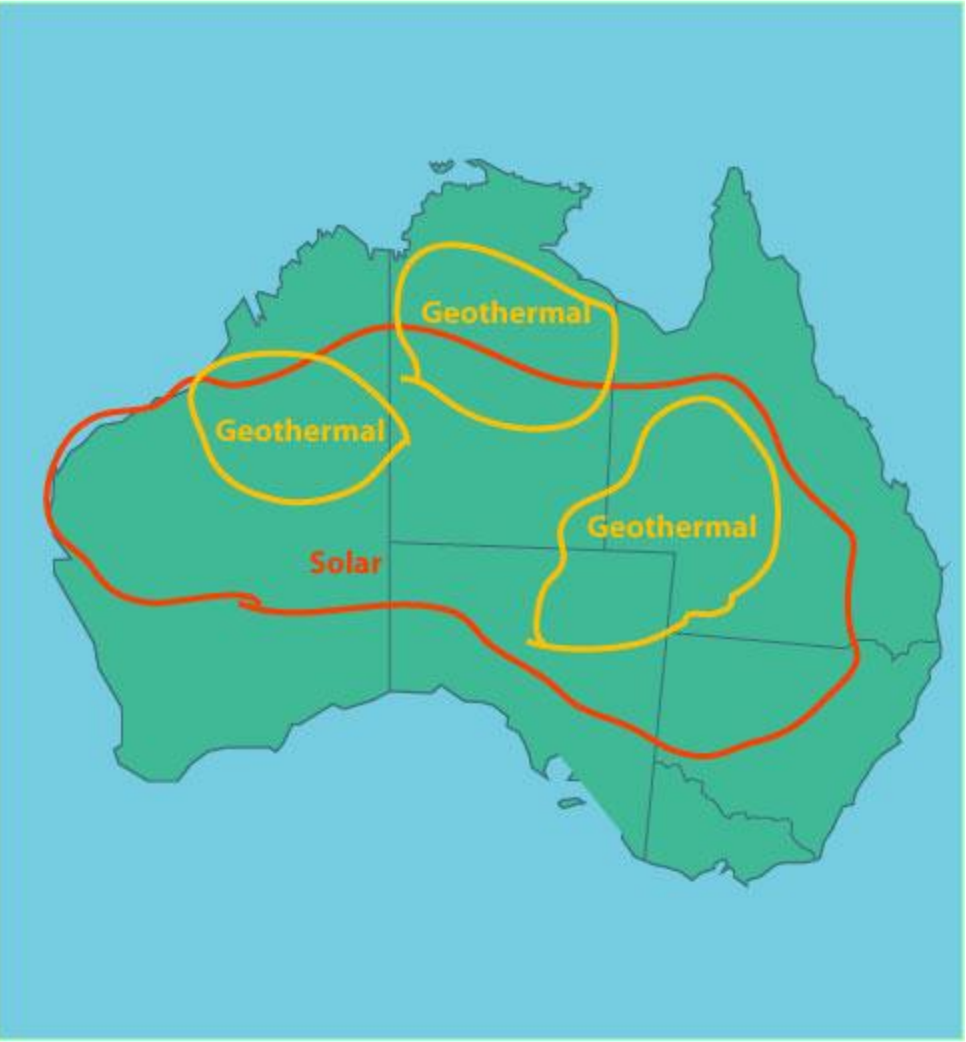
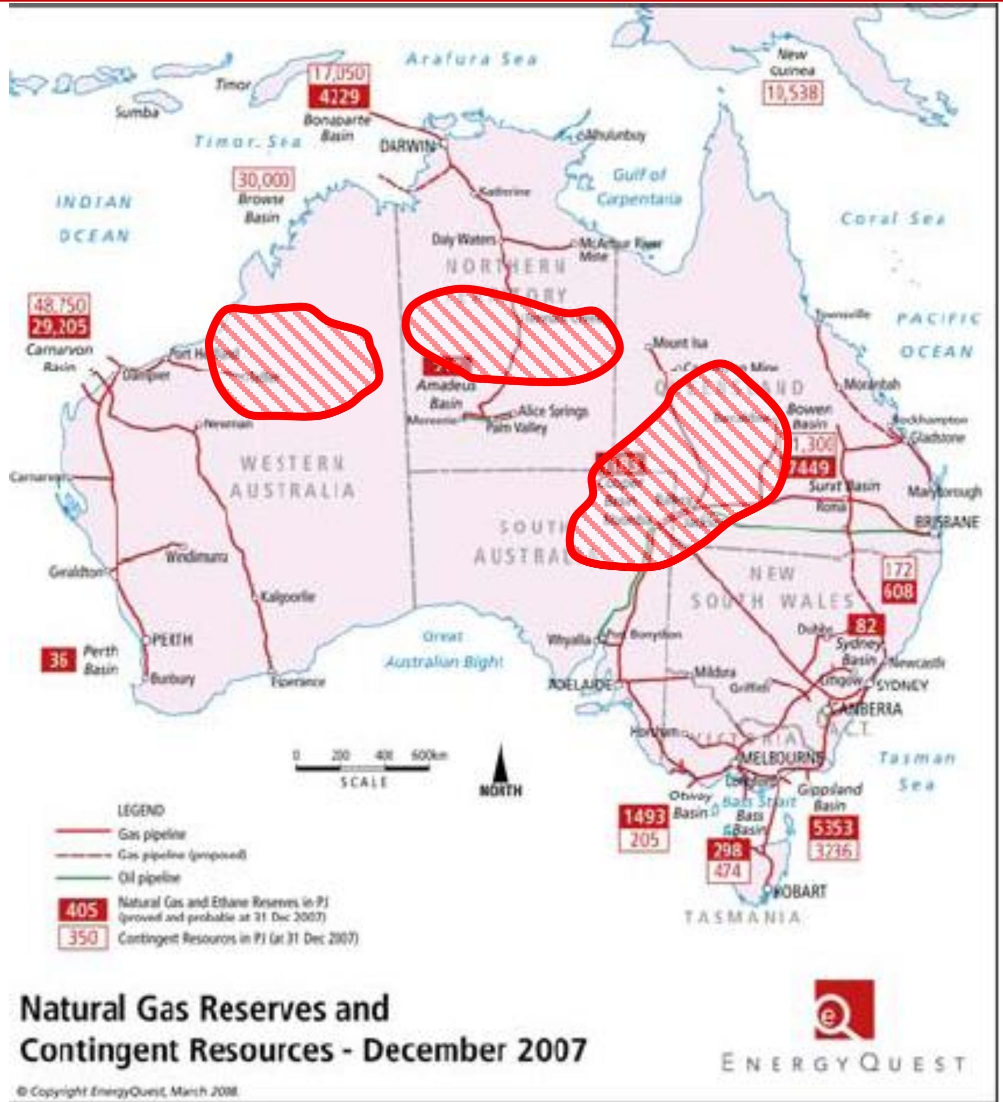




Source: www.desertec-australia.org

Geothermal Energy in Australia

Established in other countries where:

- hot water is at the surface
- cold water is available for cooling

Not established in Australia where:

- hot rocks 3-5 km underground
- no water for cooling condenser
- operating in remote desert locations

Hence there is a need to develop the technology in stages:

- to resolve technical issues & establish investor confidence
- this requires energy transport at "demonstration scales"

Can pipes be viable for clean energy transport?

Potential advantages in the short term

- electrical transmission only viable at very large scale
- natural gas pipe-lines have good proximity to geo & solar
- "clean" gas can be used to store energy

Potential disadvantages in the short term:

- gas is a lower value product than electricity

Potential advantages for the long term:

- can establish technology learning curve for future energy carriers
  - methanol: high value transport fuel, lower cost pipes
  - hydrogen: potentially high value future energy carrier

Approach to feasibility assessment of energy transport in existing pipes

Assumed energy source – typical 50 MW geothermal plant

- Ormat Organic Rankine Cycle (most established system)
- Geo-liquid surface temperature: 210 °C
- Ambient conditions based on Moomba (data available, typical)

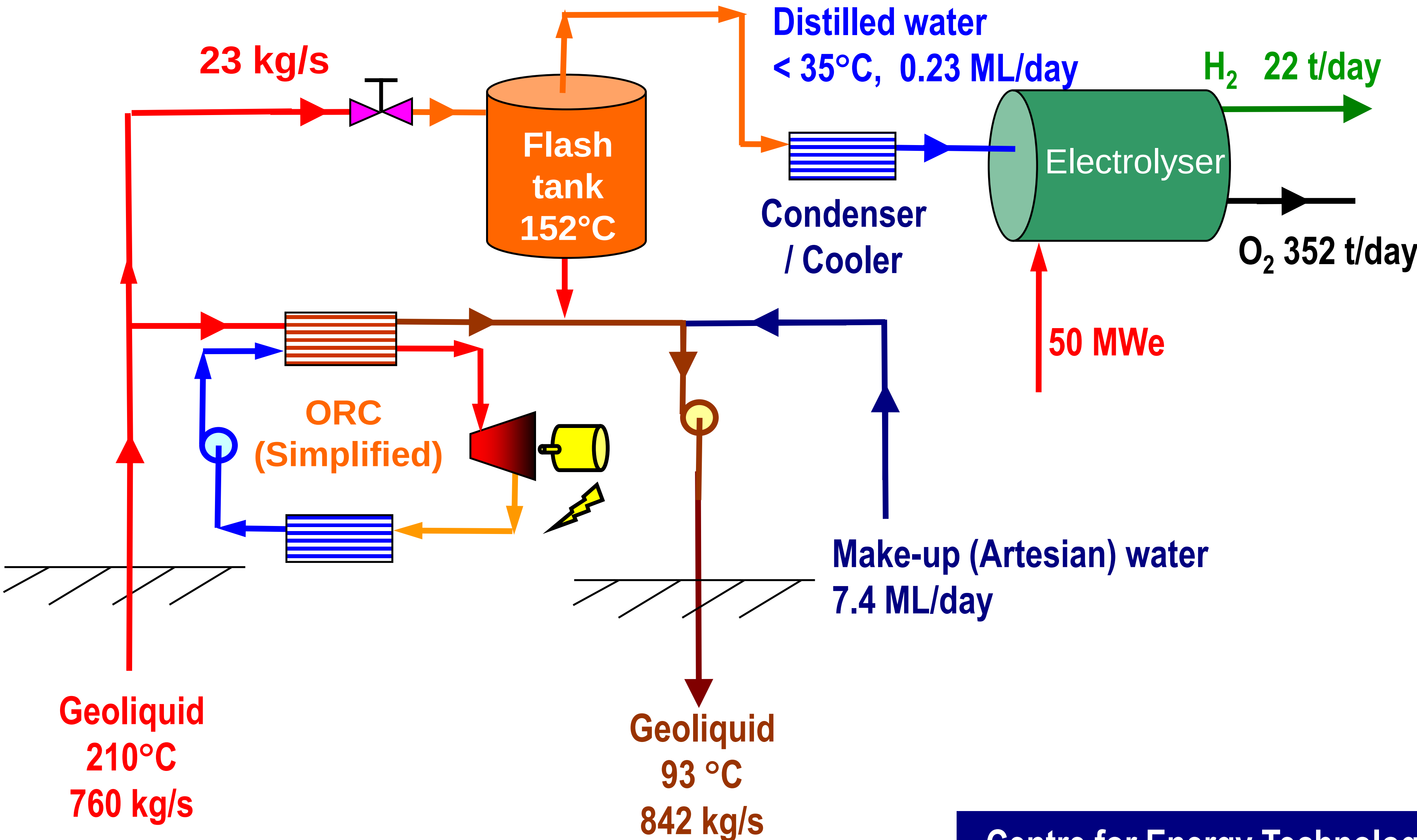
Options assessed to generate gas:

- electrolysis to produce H_2
- electrolysis followed by methanation to produce CH_4

Key issues to assess:

- electrolysis requirements (water source & purity, temperature, etc)
- impact on gas composition and end user
- impact on pipe-line integrity

System to provide pure water for electrolysis



Requirements for 50 MW electrolysis plant can be met by:

- Water at about 3% of make-up water by flashing
  - other methods are possible (e.g. reverse osmosis)
- Cooling by refrigeration, requiring 10% parasitic loss
  - more efficient methods are possible (e.g. absorption refrig.)

Overall efficiency:

- electrolysis is 70% efficient
  - more efficient if oxygen could be utilised
- 20 MW parasitic losses (assumed 15 MW reservoir + 5 MW refrig.)

Total capital cost estimate: $70m

- based on Stat-Oil electrolysis plant
- much cheaper than grid connection

Assessment of Hythane

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Hythane (natural gas + H_2) has been evaluated internationally

- Investigated in European Natural-Hy Project (www.naturalhy.net/).
- here would result in 5 ± 3 (vol %) blends

Impact on end-users of replacing natural gas with hythane:

- lean pre-mixed gas turbines would be effected by variable ratio
- other uses not expected to be adversely influenced

Impact on pipe-line infrastructure of hydrogen addition:

- significant risk to pipe-lines due to hydrogen embrittlement etc.
- existing H_2 pipeline systems use lower pressure & smaller diameter
- methane is a better option

Assessment of Methanation

The principles of methanation are well established

1. $CO_2 + 4H_2 \Leftrightarrow CH_4 + 2H_2O$ $\Delta H = -165$ kJ/mol
2. $CO + 3H_2 \Leftrightarrow CH_4 + H_2O$ $\Delta H = -205$ kJ/mol

Reaction (1) is favoured at 350 °C and requires a catalyst

Technology for reaction (1) is available at demonstration scale:

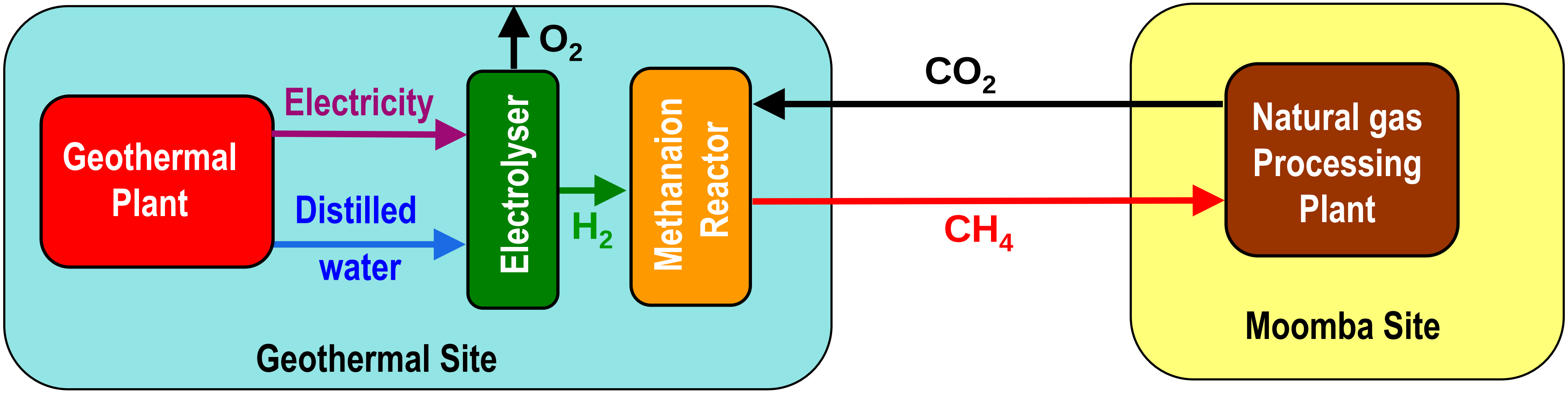
- Patent and reported by Hashimoto et al (2008, 2009)

Key issues from assessment:

- Estimated cost is $5m
- Total efficiency (electricity to methane) is 55% (cf 70% for H_2)
- Potential synergies: waste heat for refrigeration, water …

Source: Hashimoto, K, et al", Journal of Physics: Conference Series 144 (2009) 012009, IOP Publishing

Key Location Options for SA



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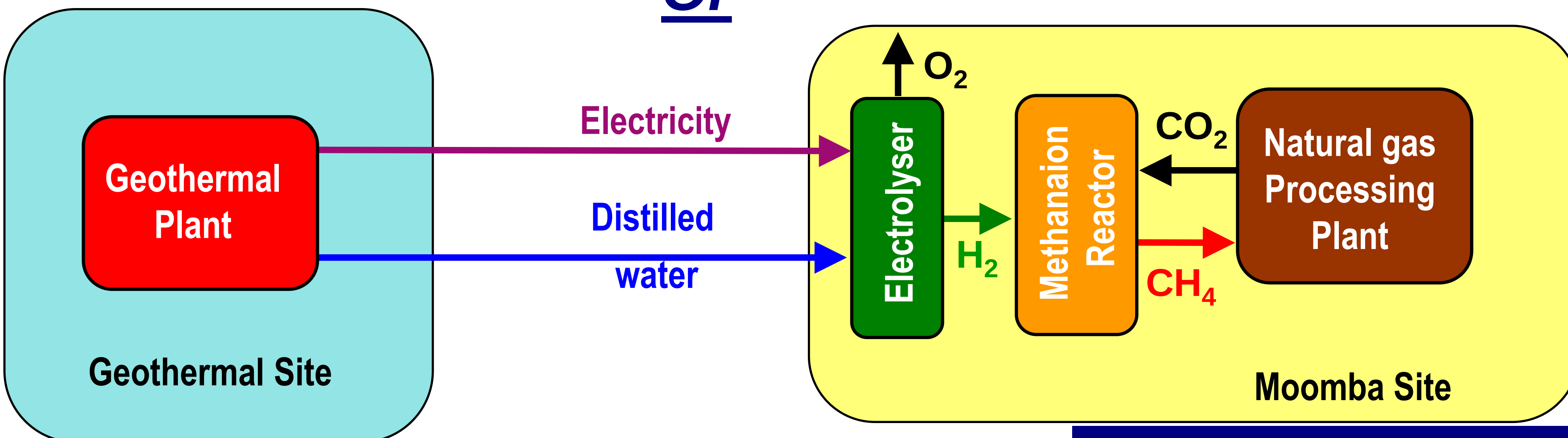

Summary of Pipe-line transport option

The conversion of electricity to methane is viable

- Lower cost than building a transmission line, where close to pipe-
- As a lower value product than electricity, it will require a niche

A number of options may be available to increase viability:

- Utilise oxygen (e.g. for gasification of biomass (algae) or coal)
- Utilise waste heat from methanation plant for refrigeration & water

Technical steps to demonstration:

- Establish a 500 kW electrolysis to CH_4 plant at Moomba
  - Corresponds to one of the 20 parallel units for 50MW plant

Source: Hashimoto, K, et al", Journal of Physics: Conference Series 144 (2009) 012009, IOP Publishing

Conclusions

Integrated thermal plants can offer benefits over stand-alone:

- improved viability by better capacity to load-match
- synergy – improved efficiency
- reduced capital cost: less storage and/or smaller solar arrays
- geothermal and solar thermal are particularly synergistic

Integrating alternative and fossil fuel plants can offer:

- reduced costs by utilising existing infrastructure
- more rapid transition along the technology learning curve

Pipe-lines can offer viable alternative energy transport media:

- remote methanation is lower cost than transmission lines
- investing in prototypes can support future fuels, eg methanol or H_2