AGEA
Australian Geothermal Energy Association

Australia's collaboration on GEOTHERMAL POWER GENERATION

Reykjavik, Iceland

August 27-28, 2008

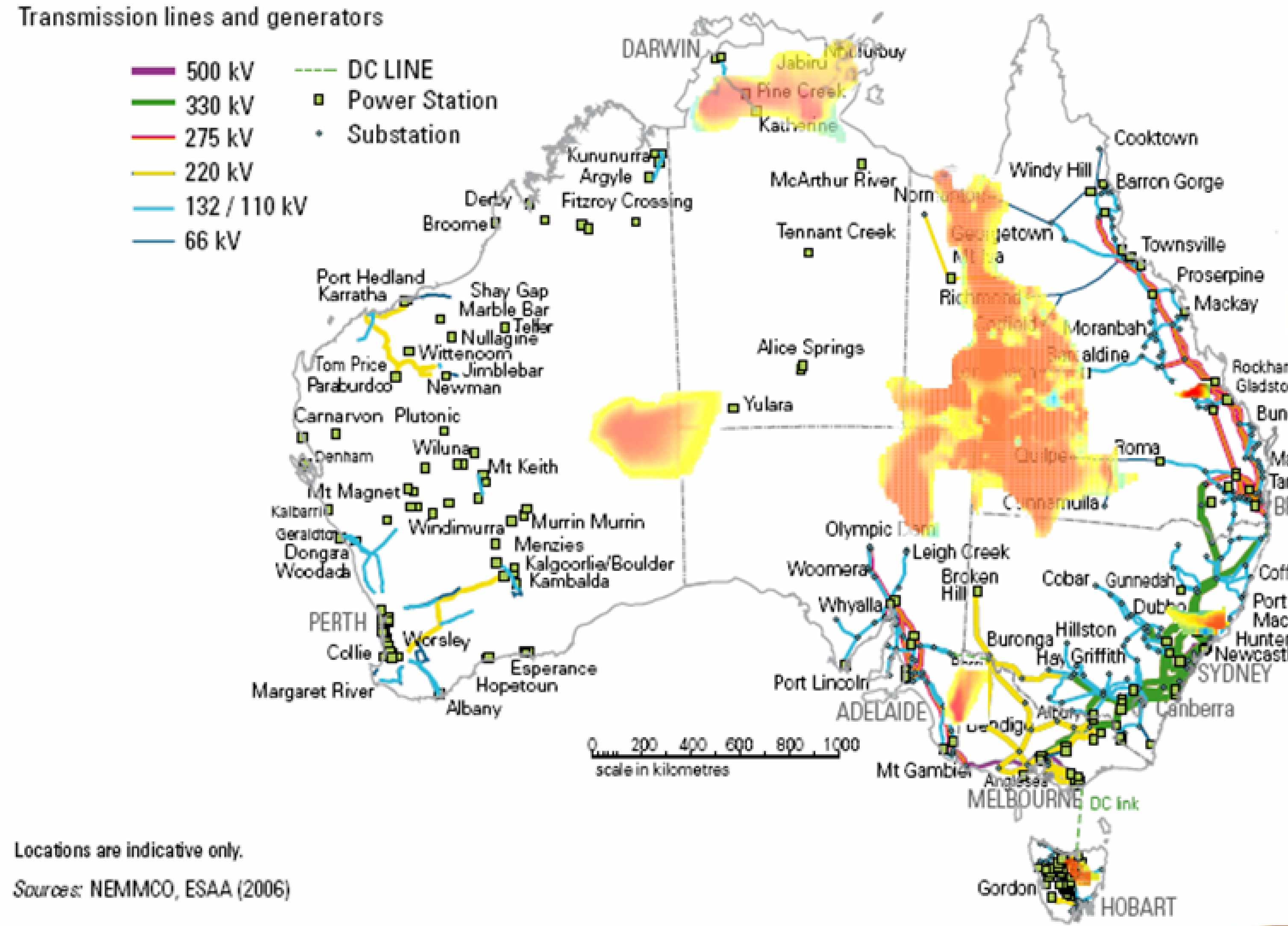
Power Generation Issues

- Impediments to geothermal generation
- Maximising net power output
- Need to increase generation efficiency
- Cooling issues & water requirements
- Brine injection
- High T, high P reservoirs
- Combining with other renewables

Impediments to Power Generation

- Unlike solar energy, geothermal plants need to be larger than a certain size to be feasible at all. At least two holes are required to access an EGS resource so the minimum plant size is 4-10 MWe
- There are no large manufacturers providing turnkey solutions and sharing the generators' risk
- Geothermal resources are at much lower temperatures than coal fired plant temperatures and power plant efficiencies are much lower for geothermal - coal-fired plants achieve over 60% of their theoretical limit
- Water requirements for circulation and cooling
- The highest enthalpy geothermal resource in Australia is in the interior of the continent away from the electricity grid

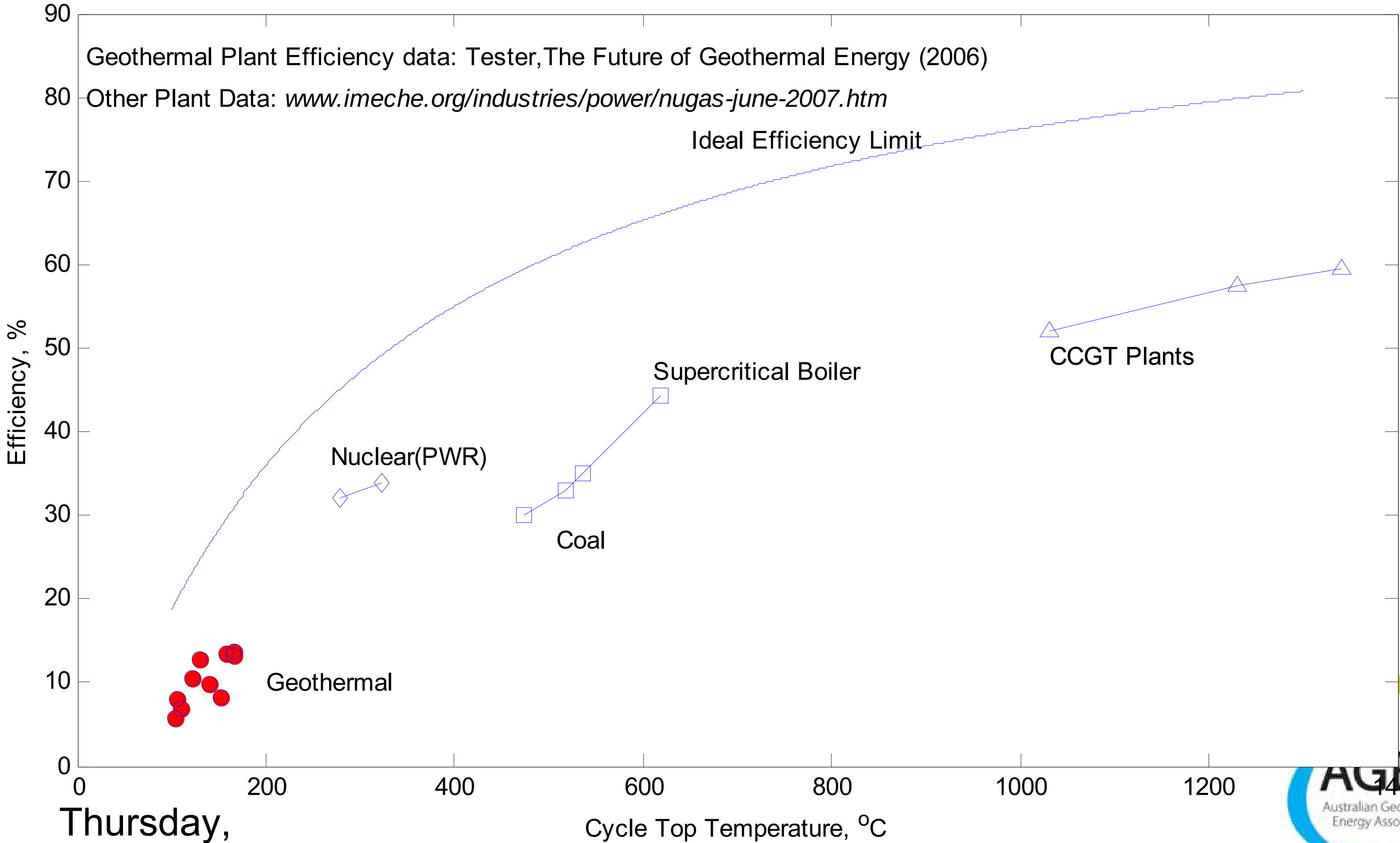
Remote Location of Hottest Resources



Research objectives

- Power conversion
  - Cycle design and optimisation
  - Key enabling technologies
- Heat removal
  - Heat exchanger optimisation
  - Heat exchangers for high pressured reservoirs
  - Key enabling technologies

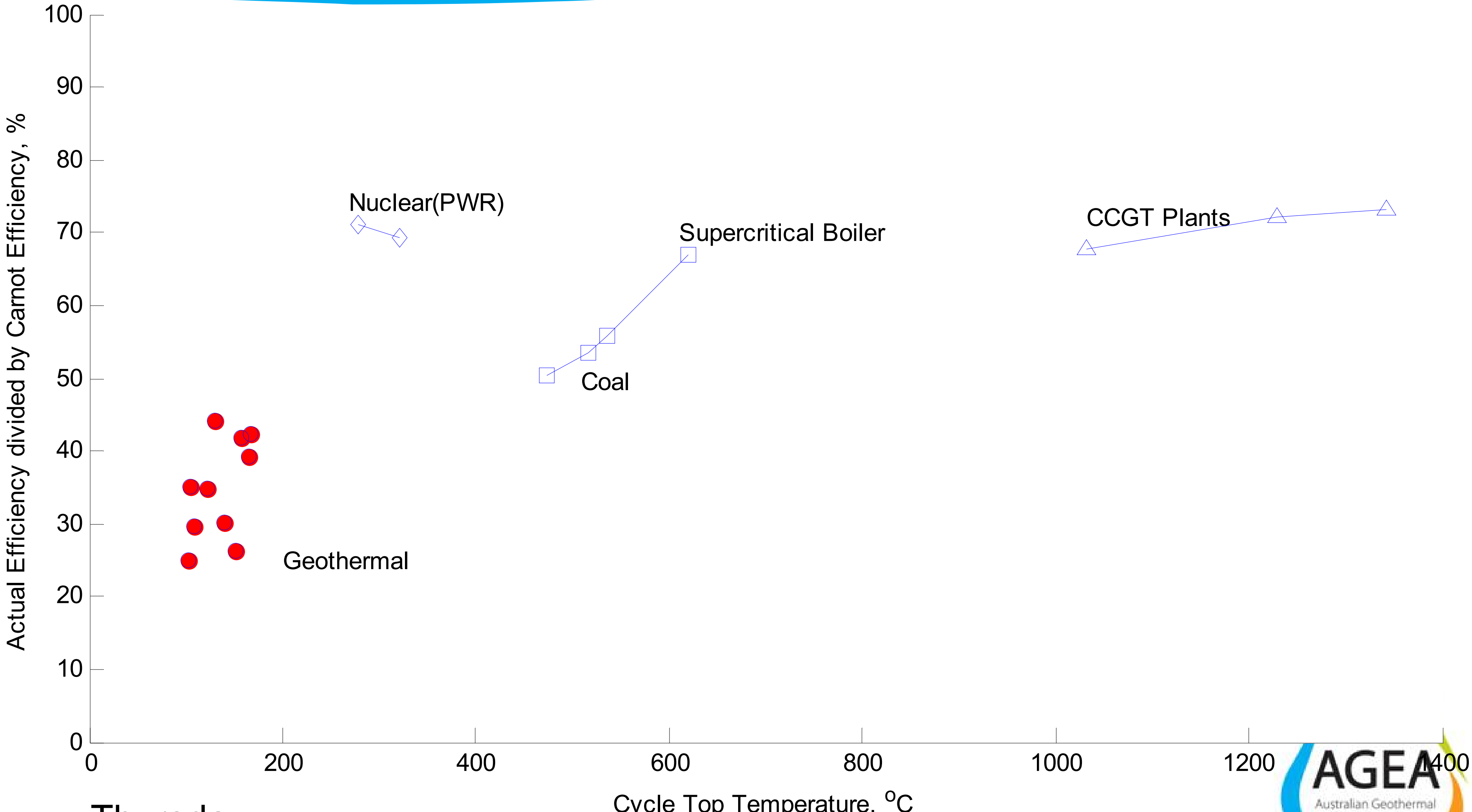
GEOTHERMAL - COMPARATIVE EFFICIENCY



Thursday, September 11,

There’s room to improve

Actual / Ideal Efficiencies (% Carnot)



Increasing Plant Efficiency

- A new paradigm is needed
  - New working fluid in binary plant (currently Kalina with ammonia water , ORC with iso-pentane/iso-butane)
  - New injection/circulating fluid for EGS
- Could CO_2 Geothermal Siphon be a solution for both?
  - D Brown ,K Pruess, H Gurenci
  - Gurgenci, H, Rudolph, V, Saha, T, and Lu, M. Challenges for geothermal energy utilisation 2008 - single-loop geothermal siphon power generator; using supercritical CO_2 cycle without a binary plant
- What other options are there?

AGEA
Australian Geothermal Energy Association

GEOTHERMAL SIPHON vs BINARY PLANT

EGS Binary Plant Advantages:

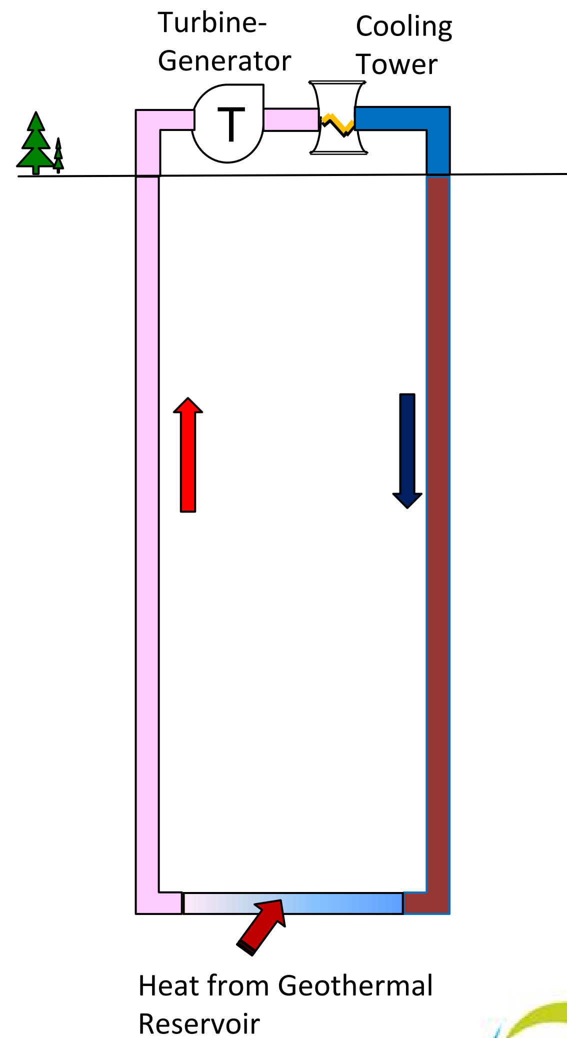
- Access to huge resources around the globe ✓
- Higher efficiency at low temperatures (compared to steam) ✓
- Non-corrosive working fluid in turbine ✓
- Completely dry expansion ✓
- Condensing temperatures can be lower

EGS Binary Plant Disadvantages

- ~~Additional heat exchanger to boil the cycle fluid~~
  - ~~Extra costs and efficiency losses~~
- ~~Huge brine flow rates are needed~~
- ~~Submersible pump required~~

CO2 Issues & uncertainties

- Long term effects
- Large quantities of CO2 are needed, have to be transported
- Geochemistry of super-critical CO2
- Interaction of CO2 with pore-water
- CO2 leakage



Water Requirements

- Water is increasingly a precious resource (eg Australia, Western USA, India, E Africa)
- Water generally has to be re-injected for reservoir maintenance or environmental reasons – usually into the same aquifer to avoid chemical reactions
- Increasing cooling efficiency of power plants
- Desert semi-desert environments - requires air-cooling/condensing of working fluid
- or a means of using salt water/brine for as a sheath for cooling plants
- Is there a means of evaporative sheaths to condense plant working fluid?

Maximising Net Power Output

- Reduction of parasitic power
  - consumed by fans and pumps in plant
  - reducing down hole pumping requirements

- Stabilising diurnal temperature variation
  - by innovative plant cooling
  - by using other renewables to offset loss of plant efficiency during the day

Water Requirements

- Water is increasingly a precious resource (eg Australia, Western USA, India, E Africa)
- Water generally has to be re-injected for reservoir maintenance or environmental reasons – usually into the same aquifer to avoid adverse chemical reactions
- Increasing cooling efficiency of power plants
- Desert semi-desert environments - requires air-cooling/condensing of working fluid
- or a means of using salt water/brine for as a sheath for cooling plants
- Is there a means of evaporative sheaths to condense plant working fluid?

Brine Injection & Production

- Supply of high T pumps which can pump high volumes of hot water from normal diameter casing/tubing ie that don’t require special casing/tubing sizes and that don’t have high parasitic power consumption.
- For production - most electrical submersible pumps (ESPs) have been designed for the petroleum industry not for geothermal waters where higher flow rates are generally required
- Pump durability
- Easier, less frequent pump maintenance

Slide 13

Combining With Other Renewables

- Combining solar thermal with geothermal energy in desert environments to increase T of lower enthalpy geothermal fluid or
- Using geothermal energy to boost T for solar generation
- Requires exponential increase in efficiency to offset extra capital cost of two systems

AGEA Australian Geothermal Energy Association

Co-operative Research Objectives

- Where do we go next?

What is the Catch?

- This is a new concept
- There are questions that can only be answered by scientific investigation
- Large quantities of CO_2 are needed to get the geothermal siphon running
- Transportation of CO_2

AGEA
Australian Geothermal Energy Association

Known Unknowns

- Geochemistry of supercritical CO_2
- The interaction with pore water
- How to dry off a wet reservoir?
- Long-term effects
  - in terms of reservoir connectivity
  - CO_2 leakage (only relevant if carbon credits are used to reduce the cost of obtaining CO_2)
- Supercritical CO_2 turbine and air-cooled heat exchanger needed
  - (will also apply the solar thermal power applications)