SEN Sustainable Energy Now PRESENTS

Geothermal Energy in Australia

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Australian Geothermal Association

August 2023

Australian Geothermal Association

AGA is the Peak Body for Australia's geothermal sector, providing a forum for individuals and organisations interested in geothermal energy information, discussion, networking, support and advocacy.

Affiliated with the International Geothermal Association (IGA), AGA was born to promote and encourage the science, technology and development of geothermal energy in Australia.

Go to **https://www.australiangeothermal.org.au/** to start your geothermal journey

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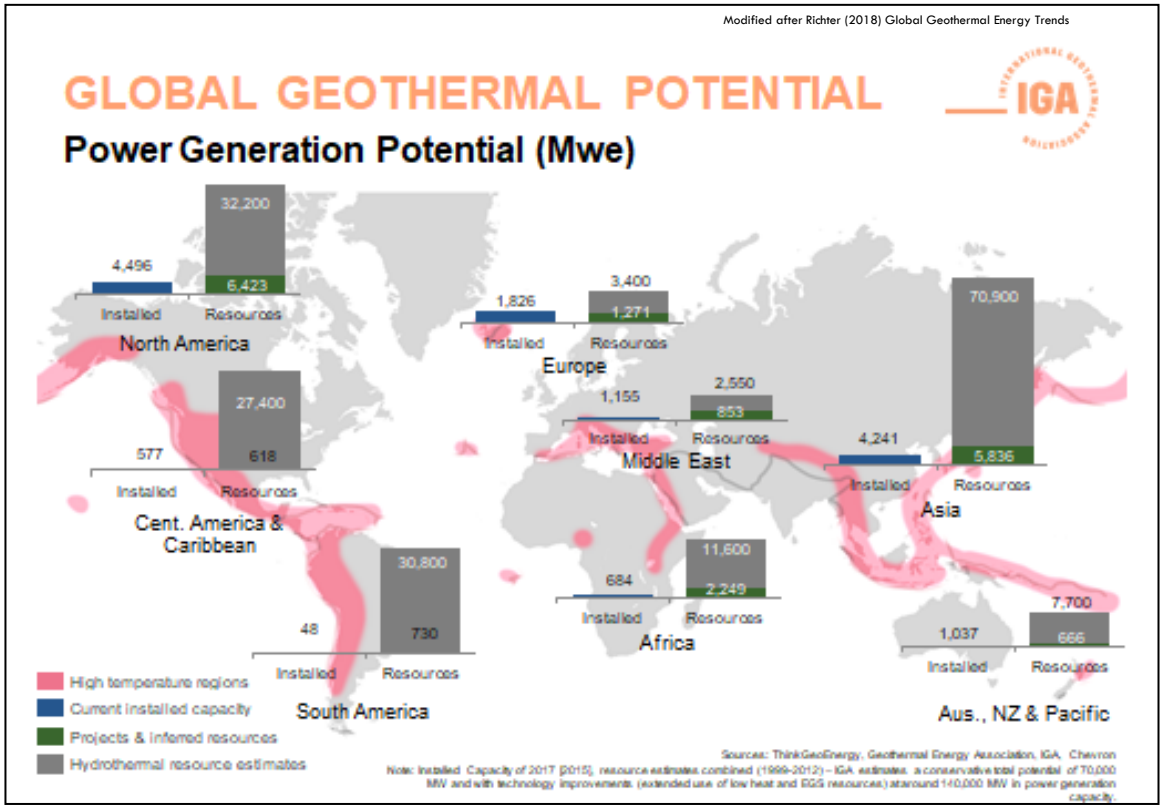
STEAM
RESOURCES

Outline

- Introduction to Geothermal
- Ground Source Heat Pumps (GSHP) and Direct Use
- Electricity
  - Binary Power Plants
  - Economics
  - Australia
- Summary and Conclusions

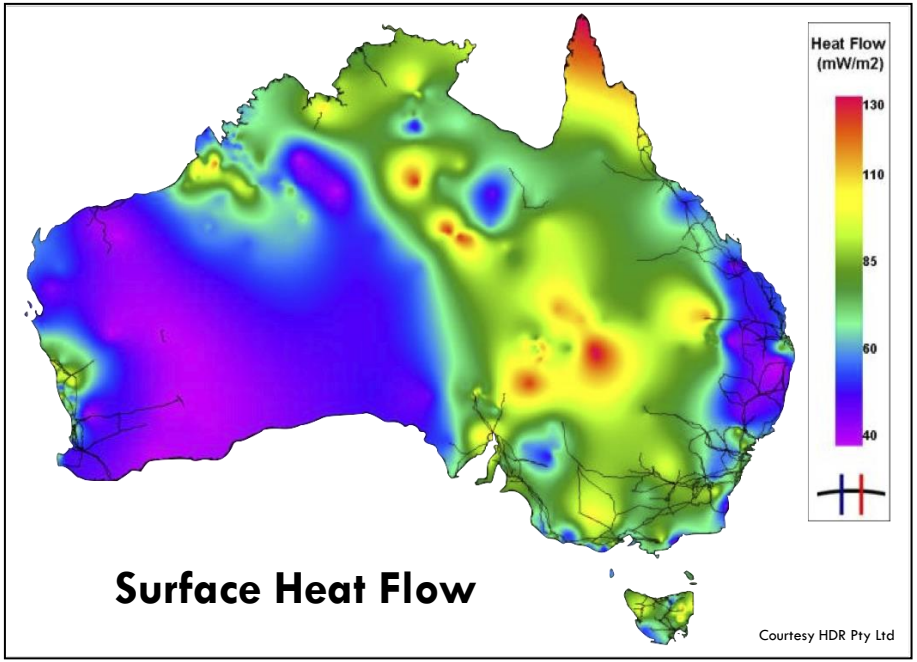
A Global Resource

- Geothermal energy is a type of renewable energy which is generated naturally within the earth and can be used directly for heating or transformed into electricity.
- Used to generate power in more than 31 countries worldwide.
- Global installed capacity of over 13,000 GW_e (IRENA, 2019).
- Potential in Australia >1 Gw_e.



Geothermal Potential in Australia

- Heat is supplied from the Earth's core (~6000°C) and radioactive decay of K, U & Th.
- Heat energy can be extracted and used directly or to generate electricity.
- The rate heat reaches the surface varies depending on variations in the geology.
- Some areas are better for geothermal than others.

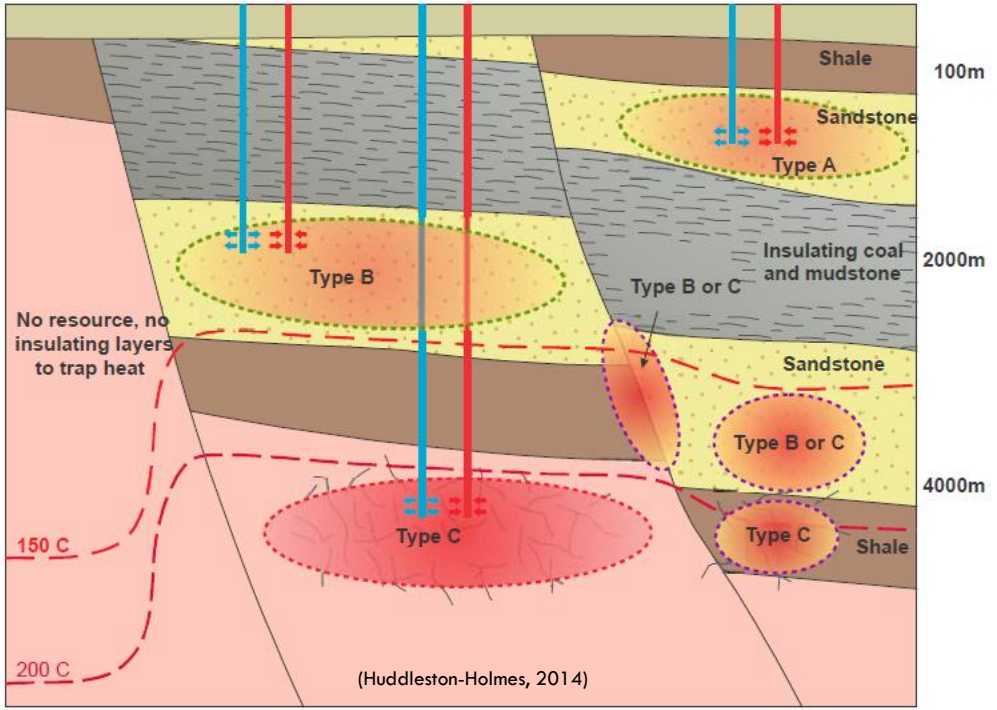


Types of Geothermal Energy

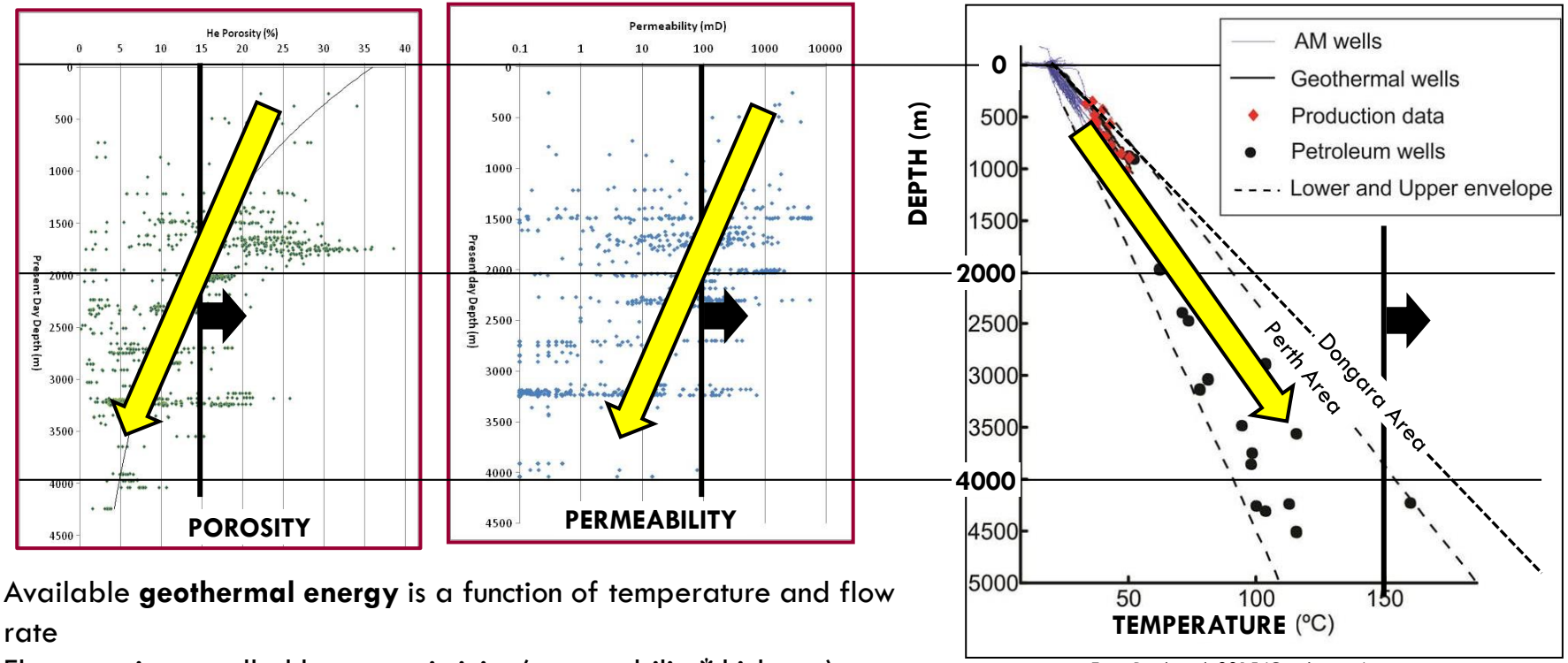
- No volcanic provinces in Australia for high temperature flash steam production.

In Australia:

- **Type A**: Shallow natural reservoirs (up to ~1500m), low temperatures (<100°C), Primarily **direct use** applications.
- **Type B**: Hot Sedimentary Aquifer (**HSA**), Deep natural reservoirs (1500-4000+m), moderate temps (100-170+°C), **Electricity** w/ binary Organic Rankin Cycle (ORC) plant.
- **Type C**: Enhanced Geothermal System (**EGS**) Deeper, higher temperature but reservoir requires enhancement. **Electricity**, w/ binary or flash steam plant.



Reservoirs and Temperatures

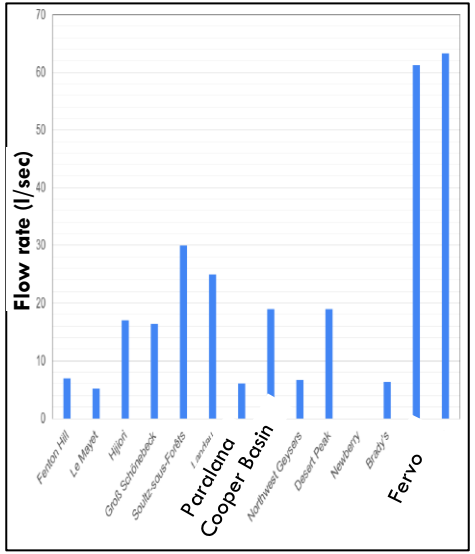


From Pujol et al. 2015 (Geothermics)

- Available **geothermal energy** is a function of temperature and flow rate
- Flow rate is controlled by transmissivity (permeability*thickness)
- Temperature increases with depth
- Transmissivity generally decreases with depth

Engineered Geothermal Systems

- Artificially creates (or enhances) a reservoir.
- Objective is to create permeability to increase flow rate.
- Need to have fracture network rather than one or two big faults for efficient heat extraction.
- Potentially increases economically accessible geothermal energy by orders of magnitude.



Fervo project in Nevada recently reported breakthrough results in July, 2023

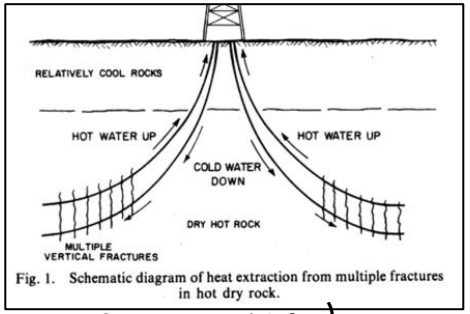
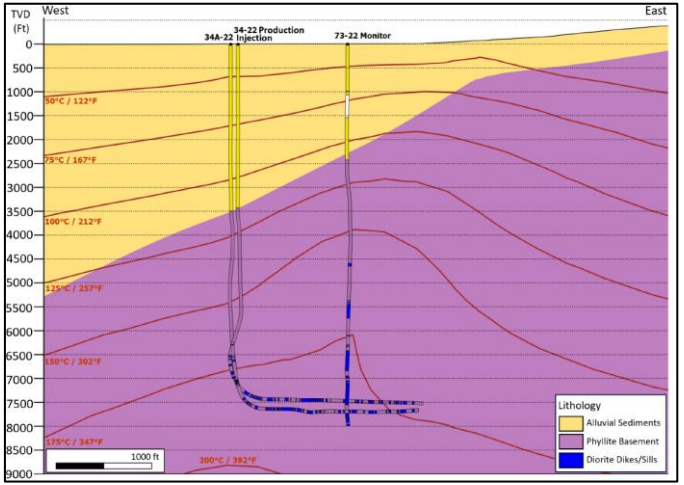


Fig. 1. Schematic diagram of heat extraction from multiple fractures in hot dry rock.

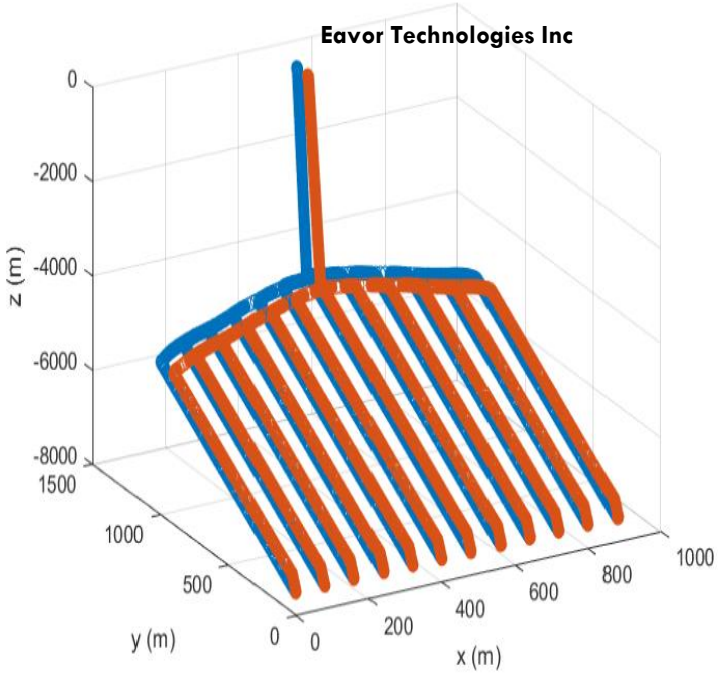
Gringarten et al. (1975)



Fervo 'Red" project (Norbeck & Latimer, 2023)

Closed Loop Systems

- Closed loop systems rely on conduction for heating.
- Slower process, so more surface area needed.
- Eliminate permeability risk.
- Work proceeding on various technologies.



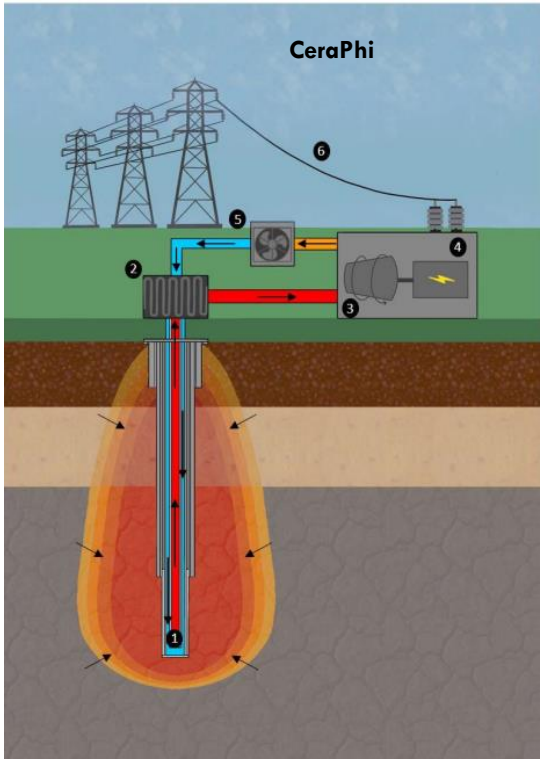


Figure 6: Eavor-Loop 2.0 has 12 laterals with total depth of approximately 7 km. Blue represents the injection side; red represents the production side. Spacing between laterals is approximately 75 m. Figure is not to scale.
Beckers and Johnson< 2022, Techno-Economic Performance of Eavor-Loop 2.0, *Proc 47th Workshop on Geothermal Res Eng*, Stanford Univ

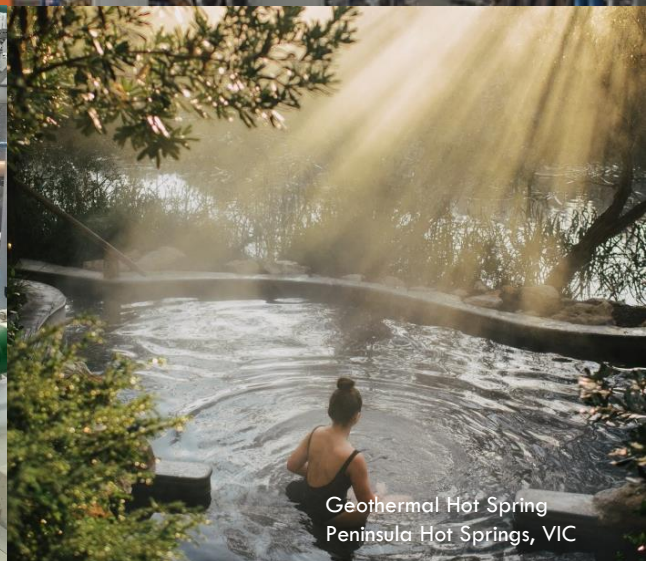
Ground Source Heat Pumps and Direct Use

Direct-use
Mainstream aquaculture, VIC

GSHP
Fremantle Leisure Centre, WA
from Evoheat

Direct-use
Pawsey Supercomputer, WA

Direct-use
Armadale Leisure Centre, WA
from Engie



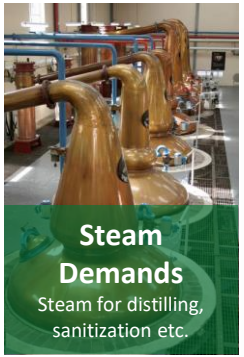
Geothermal Hot Spring
Peninsula Hot Springs, VIC

Applications and temperature ranges

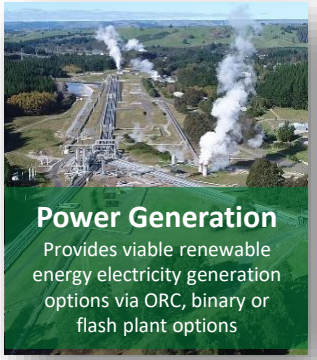
Geothermal energy can be utilised at a range of temperatures for industrial applications.
There are multiple users that use 100,000 GJ/a+ of gas for low temperature process heat in WA and VIC):

Aquaculture
Provides low-cost option of keeping consistent temperatures year-round

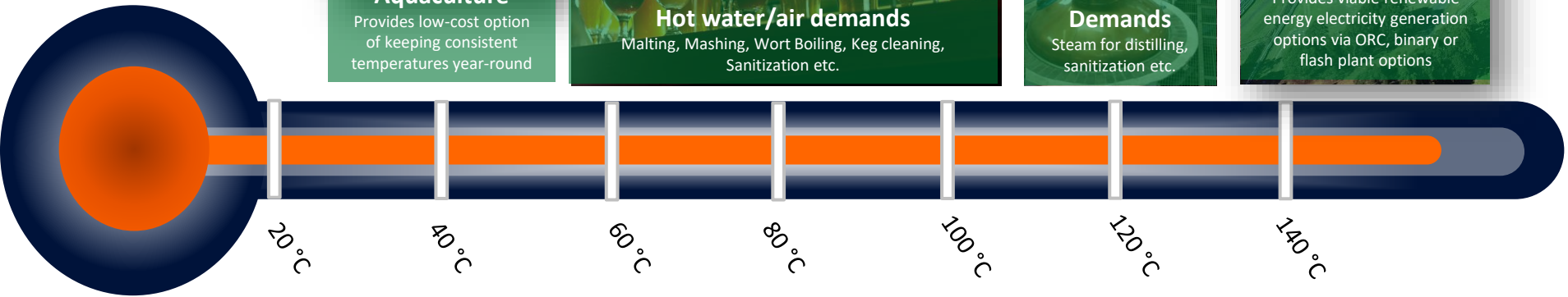
Hot water/air demands
Malting, Mashing, Wort Boiling, Keg cleaning, Sanitization etc.



Steam Demands
Steam for distilling, sanitization etc.

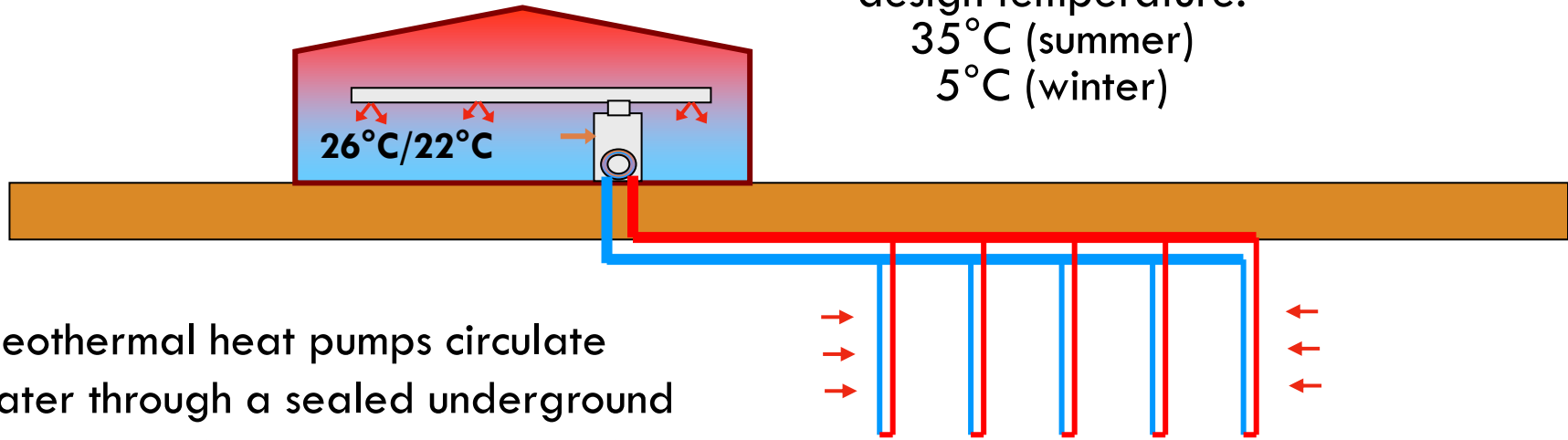


Power Generation
Provides viable renewable energy electricity generation options via ORC, binary or flash plant options



Applications in Australia already include : Pool heating, Beef sterilisation/cleaning, Aquaculture, District heating (historical), Space heating & Domestic Hot Water

Ground Source Heat Pumps



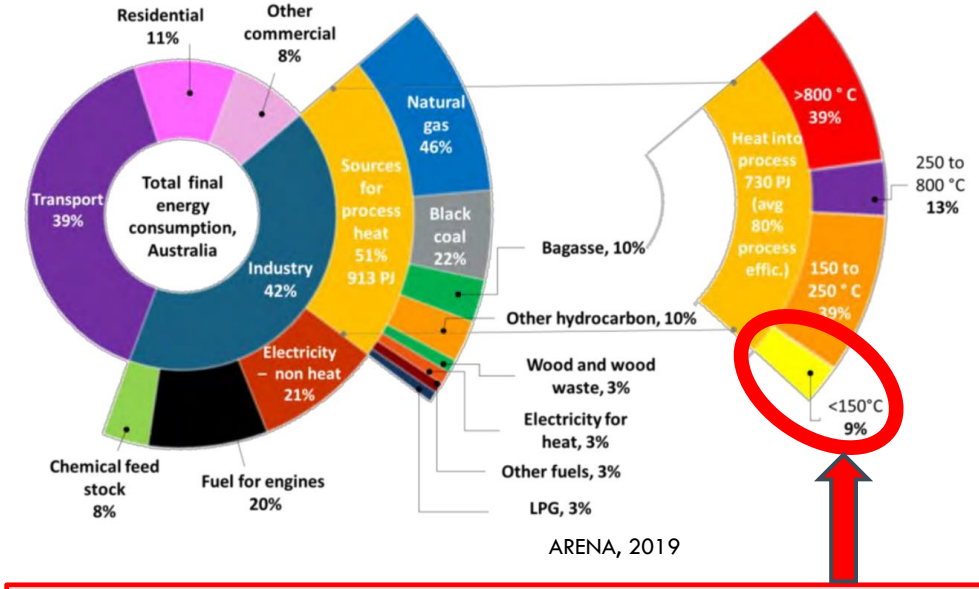
Outdoor air
design temperature:
35°C (summer)
5°C (winter)

Geothermal heat pumps circulate water through a sealed underground piping loop (or using water bores) where it is naturally warmed (or cooled) by the Earth.

Ground temperature
20°C (constant)

Direct Use Potential

- Australian industry accounts for 42% of the nation's end use energy.
- 51% of that is process heat (about 250,000 GWh).
- Huge opportunities to scale-up geothermal heating for large industrial processes (e.g. greenhouses, aquaculture, drying processes, industrial hot water processes, etc.).



Geothermal in Australia currently targeting temps up to ~190 °C (but mostly <150°C).

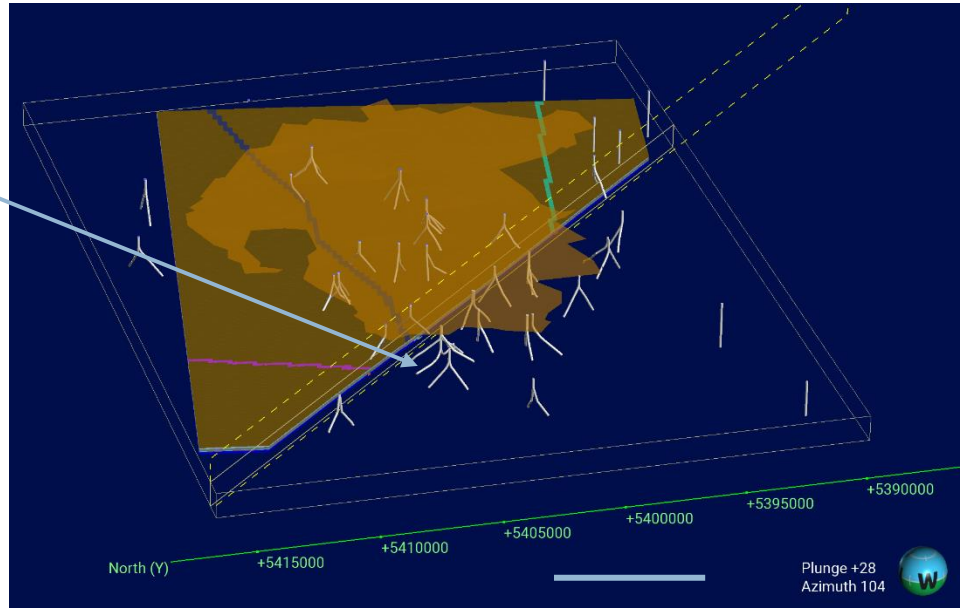
Heat demand <150°C = 82 PJ gross (~2.6 GW_{th} equiv.)

(66 PJ net, ~2.1 GW_{th} equiv.)

District Heating in Paris Basin, France

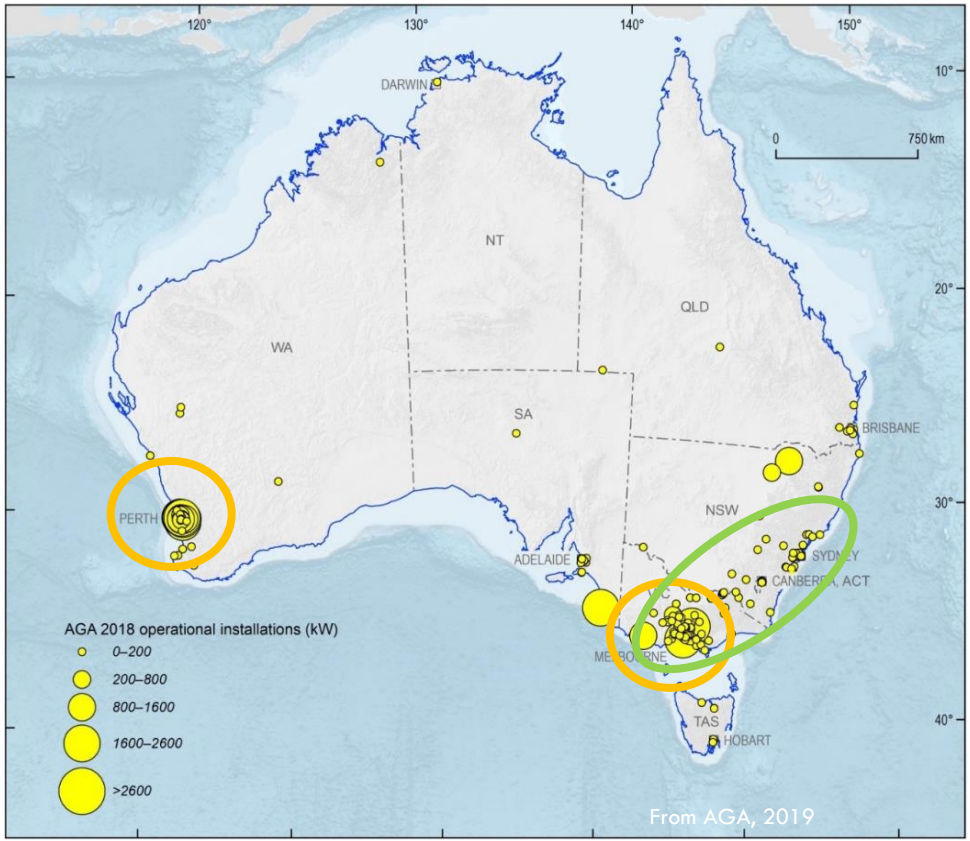
France has a 2023 target of 3,000 GWh/a of geothermal heat production, particularly in the Paris Basin (Val De Marne region highlighted).

- The area shown is about 245 km2 with 21 active operations. One of the well pairs (Cachan 3) produces 41,575 MWh/a (9,104 eq. houses).
- The Latrobe Valley (Victoria) is aiming to replicate this given its favourable subsurface and industrial heat demand.



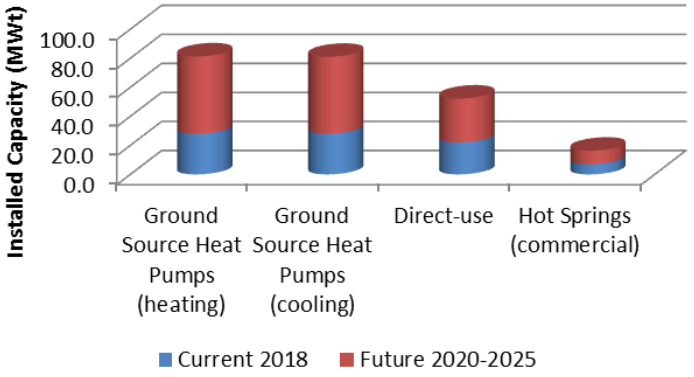
AGA 2019 Census

- AGA launched a comprehensive Census to map the type, size and distribution of Australian geothermal energy installations and projects.
  - Direct-use in WA and VIC
  - GSHP in VIC, NSW

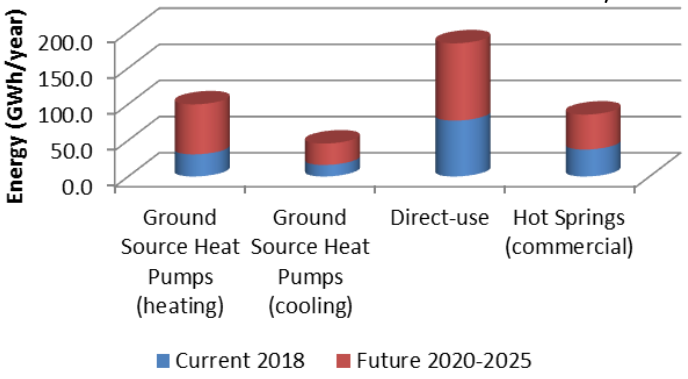


Australian Geothermal Association Census

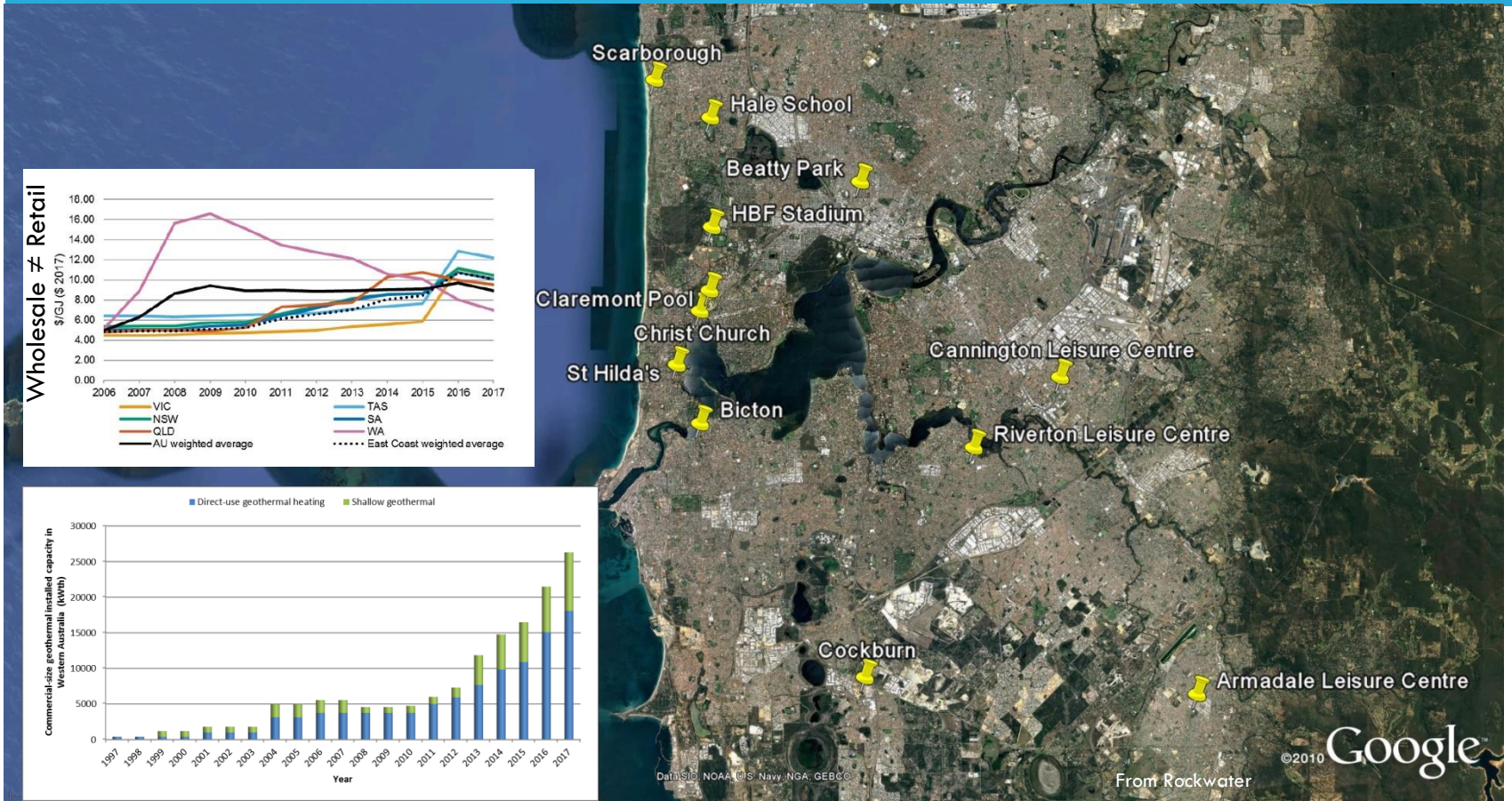
- 2018 Installed thermal capacity 85 MW_t
- 146 MW_t by 2020-2025.
- Thermal energy from the installed systems is about 156 gigawatt-hours (GWh)/year (~35% of ACT Energy consumption for HVAC in 2006).



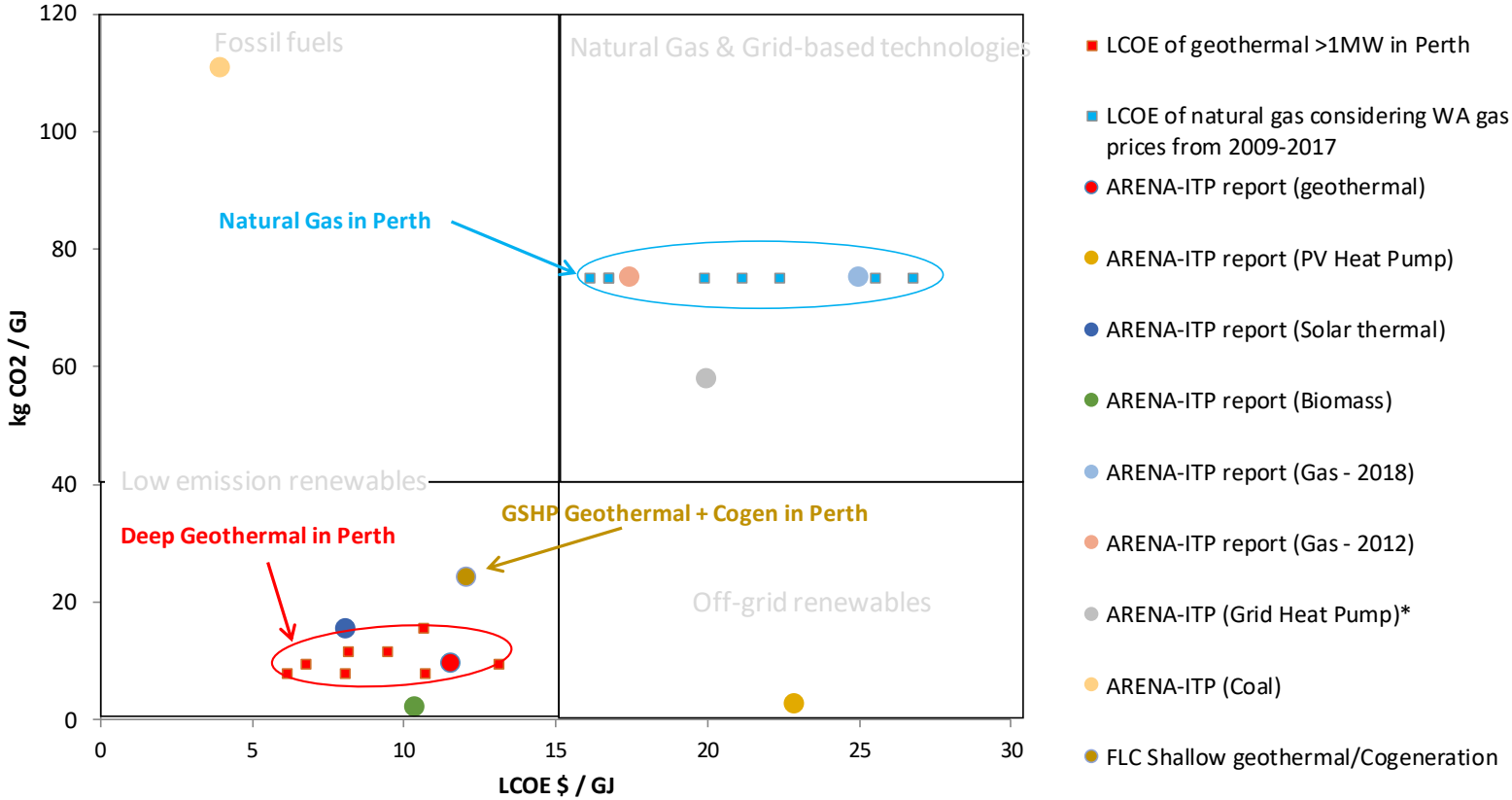
From AGA, 2019



Existing Perth –Area Direct-Use Project Locations



Economics Comparison – Gas vs Geothermal



NB: Gas LCOE includes gas boiler efficiency (80%), gas-boiler CAPEX and maintenance, cost premium on top of wholesale price for small users and tariff inflation

Economic Performance Indicators

	Beatty Park	GRAC
Net Present Value in 2013 (NPV) (Unlevered)	$1,357,359	$13,135,710
Internal Rate of Return (IRR) (Unlevered)	11%	28%
Levelized Cost of Energy (Undiscounted Energy) (/GJ)	$6.43	$7.19
Levelized Cost of Energy (Discounted Energy) (/GJ)	$15.34	$19.16
Breakeven Cost of Energy in 2023 (/GJ)	$10.85	$9.53
Payback Period (yrs)	10.9	4.0

	Frequency (years)	Amount ($AUD)	Amount ($AUD)
CAPEX	N/A	$3,956,297	$3,855,396
Geothermal Maintenance (Small Scale)	1	$8,500	$5,750
Geothermal Maintenance (Large Scale)	10	$28,000	$125,000
Geothermal Regulatory Monitoring Costs	1	$7,250	$7,250

Beatty Park Conclusion: despite some of the cost overrun with initial design of the HX (extra $435k included in CAPEX above), the project has a NPV >0 and a LCOE competitive against gas (even in the low cost environment of Perth)!

GRAC Conclusion: despite the need to build a 450 m pipeline in an urban environment to reduce the potential for thermal breakthrough, the project has a NPV >0 and a LCOE is competitive. Note that gas tariffs are currently very high in VIC which results in a very high NPV. At this tariff Air-Source heat pump would also be cheaper than gas.

Electricity

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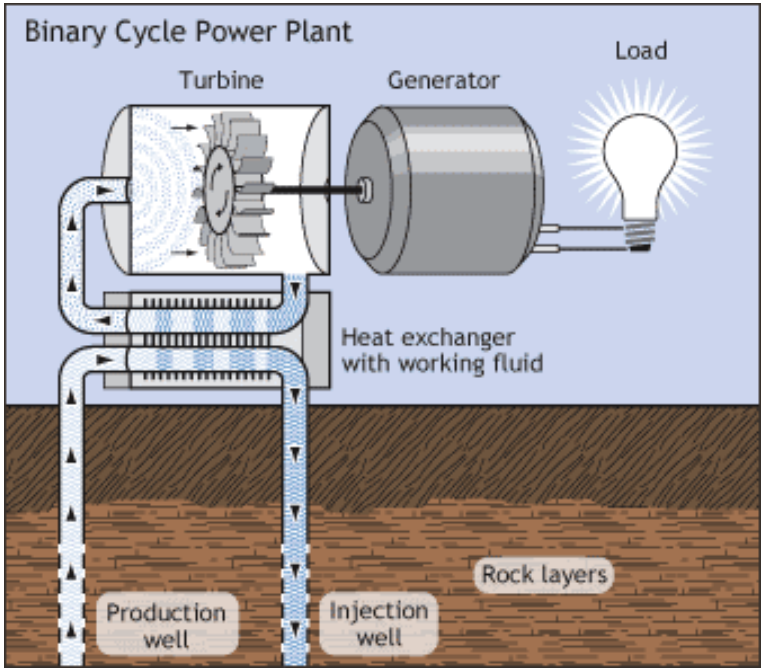
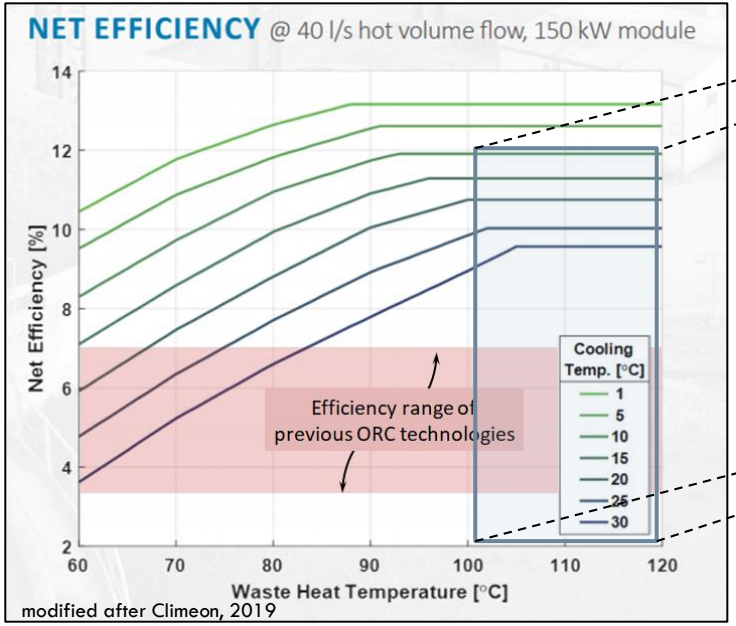
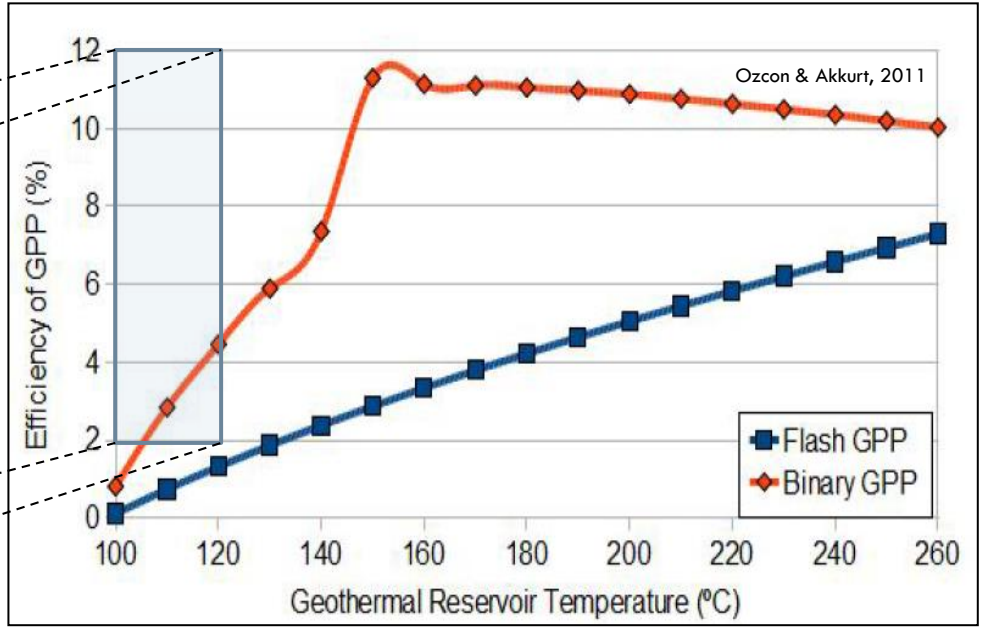
Binary Power Plants

- Binary power plants are a widely used, well established technology.
- Geothermally heated water is pumped from deep underground, run through a heat exchanger then reinjected back underground.
- A separate, isolated closed loop with an organic fluid (eg. pentane) is vaporised in the heat exchanger and used to drive the turbine, then recondensed and recycled.



Temperature versus Electricity Output





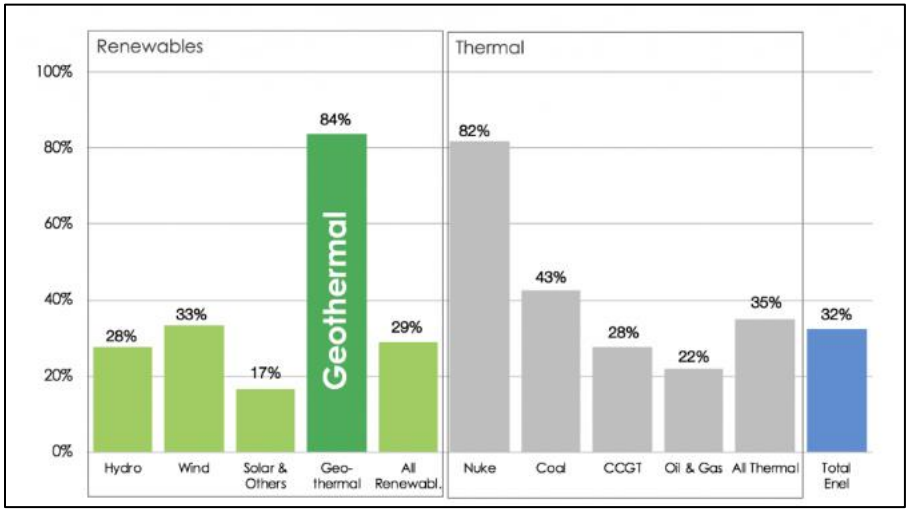
Recent technology improvements have dramatically increased the conversion efficiency in low temperature systems.

The efficiency of converting heat to power in binary plants drops off dramatically at temperatures below 150°C.

Geothermal: Base Load Power

Example based on Enel Spa energy portfolio

Capacity Factor comparison



Installed Capacity vs Generation

Technology (1H 2018)	Net Installed Capacity (MW)	Net Installed Capacity (%)*	Net Production (GWh)	Net Production (%)*
Hydro	27,835	70.0%	33,470	66.7%
Wind	7,867	19.8%	11,398	22.7%
Solar & Others	3,281	8.2%	2,369	4.7%
Geothermal	**804**	**2.0%**	**2,932**	**5.8%**
Total Renewables	**39,786**		**50,170**	

- Capacity Factor – how much of the time can electricity be produced?
- Intermittent = low capacity factor
- Base load = high capacity factor

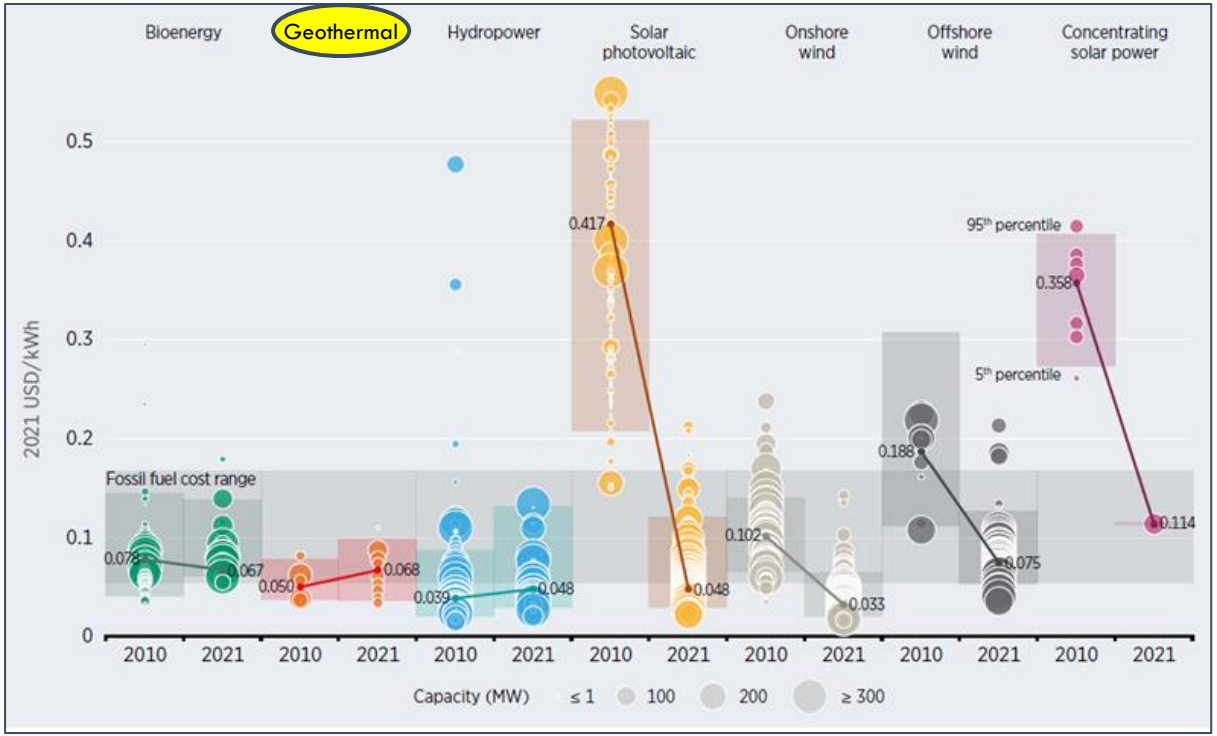
Due to high Capacity Factor, *a geothermal plant produces substantially more electricity than the same installed capacity for most other renewables.*

THINK GEOENERGY

Data from Enel Quarterly Bulletin, Q2 & 1H 2018

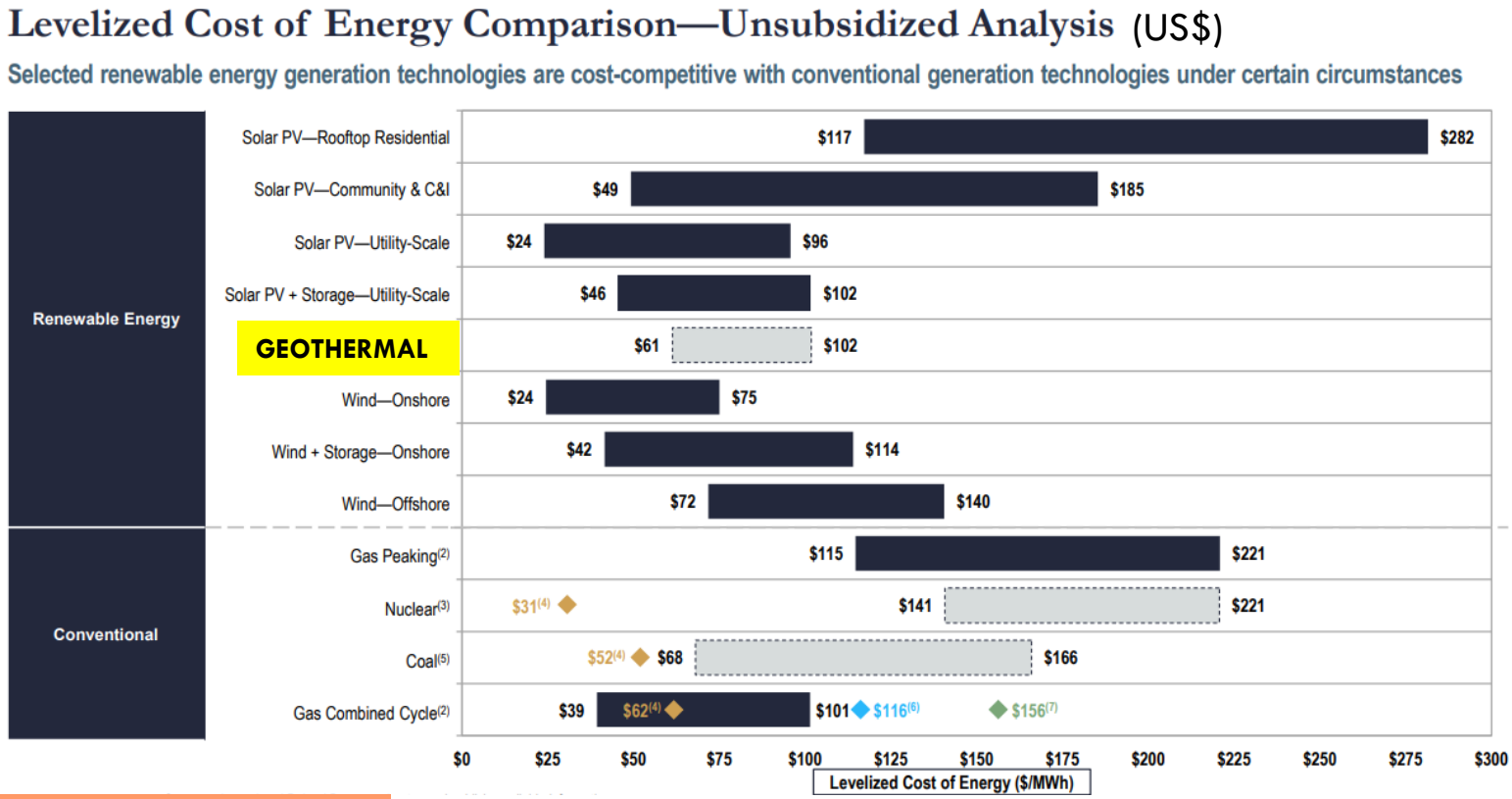
Worldwide LCOE Comparison: 2010 vs 2021

- LCOE= Levelised Cost of Electricity, a measure if full life cycle costs to allow comparison of different technologies.
- Geothermal is clearly competitive with fossil fuels.
- Although the solar PV costs, in particular, have fallen dramatically, geothermal is still competitive.
- ***These costs don't include energy storage.***



Source: IRENA (2022), *Renewable Power Generation Costs in 2021*, International Renewable Energy Agency, Abu Dhabi

LCOE Comparison - 2023

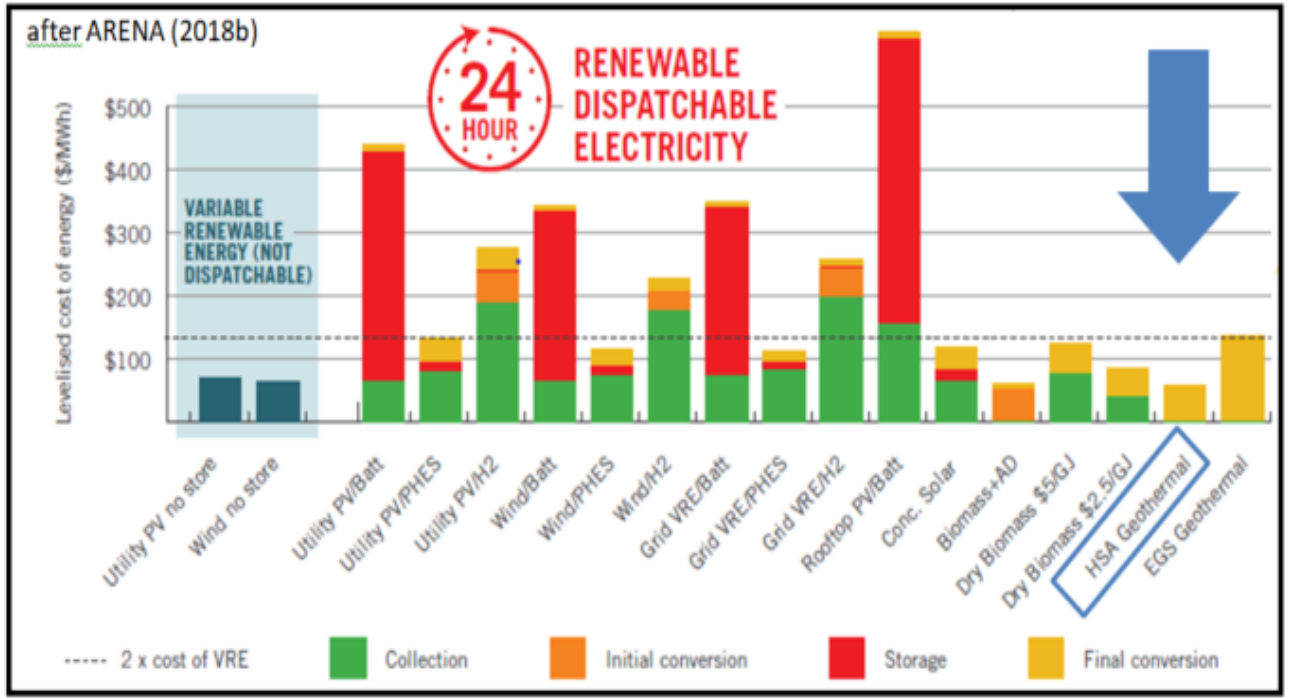


Note: Storage assumed=4 hours

Lazard (2023) Levelized Cost of Energy Analysis – Version 16, April 2023

Australia LCOE Comparison: 2018

- Study sponsored by ARENA concludes that the **best result** would be a **diverse portfolio** incorporating all the options because **each has a niche** in a renewable generation system where they offer the optimal solution
- HSA geothermal offers the lowest cost option for 24-hour 'base load' power.

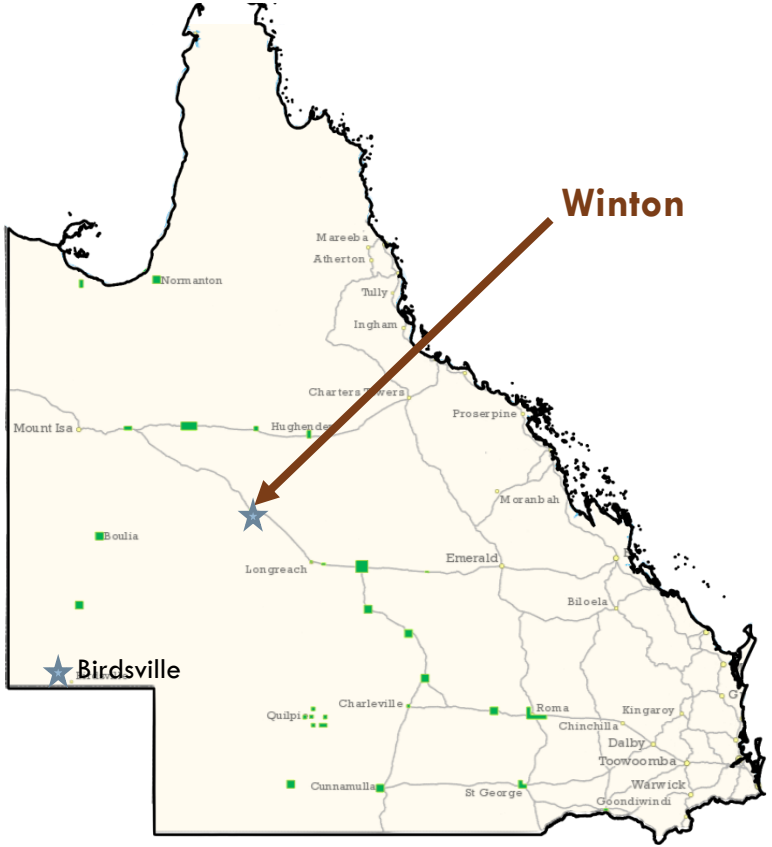


K Lovegrove, et al., 2018, Comparison of dispatchable renewable electricity options: Technologies for an orderly transition, ARENA

Geothermal Electricity in Australia

- A 310 kWe plant was built in Winton, Qld. HSA project be using 87°C water, but currently not working due to litigation.
- An 80 kWe geothermal plant in Birdsville, Qld recently ceased operation after over 20 years of reliable production (HSA project using 98°C water)

(source: Green Thermal Energy Technologies, video screenshot)



Geothermal Activity 2021 vs 2023

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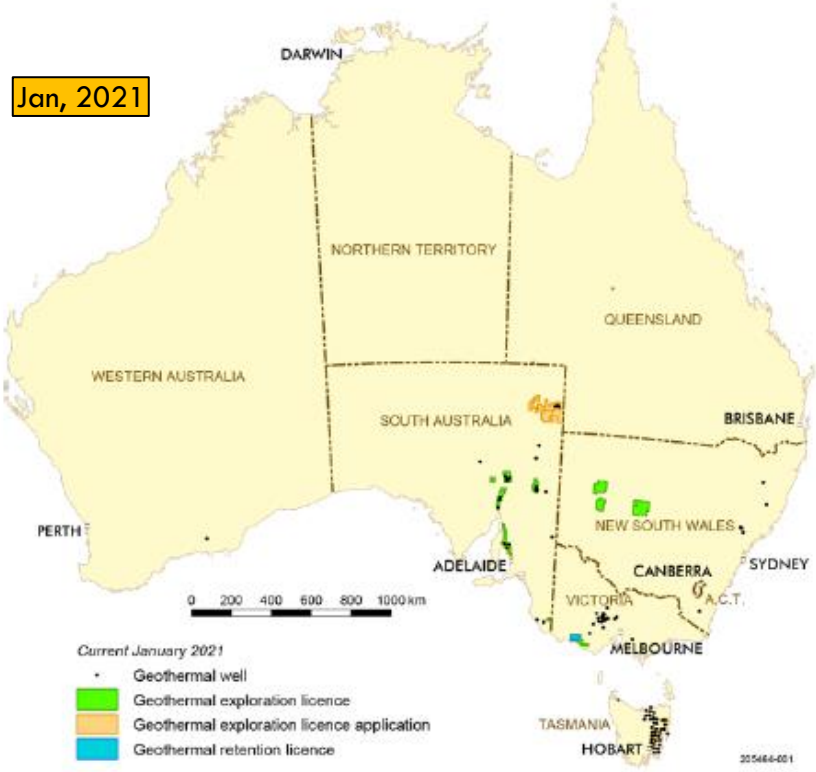
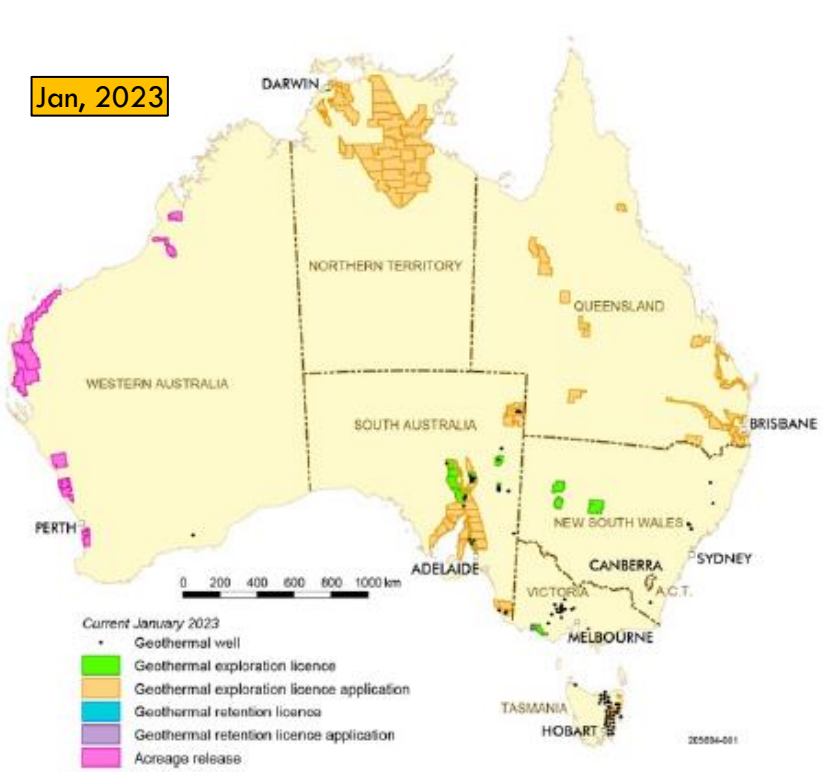
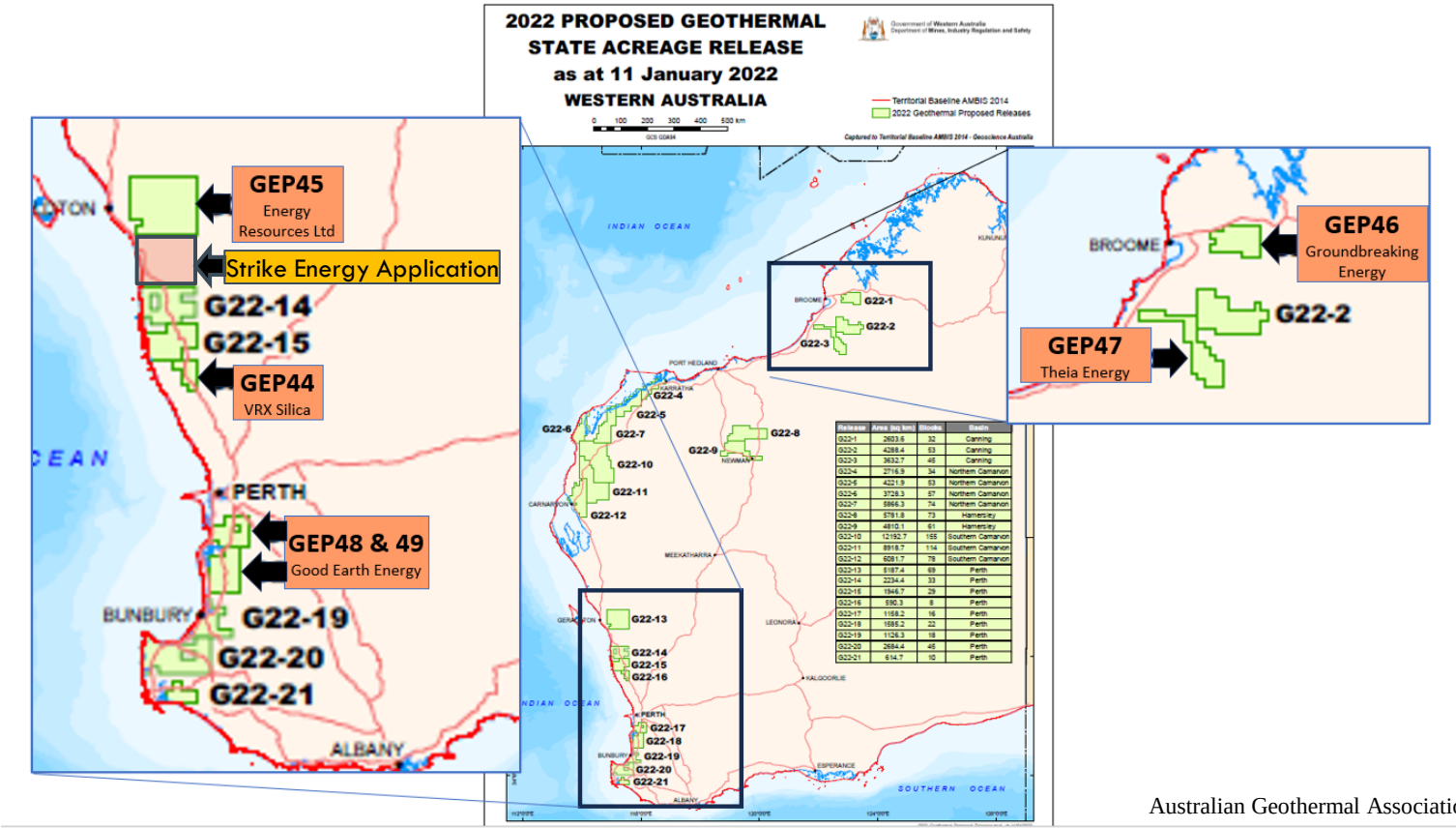




Beardsmore, et al., 2023, Country Update – Australia, *Proceedings World Geothermal Congress 2023* Beijing, China.

Geothermal Permit Applications & Awards in WA

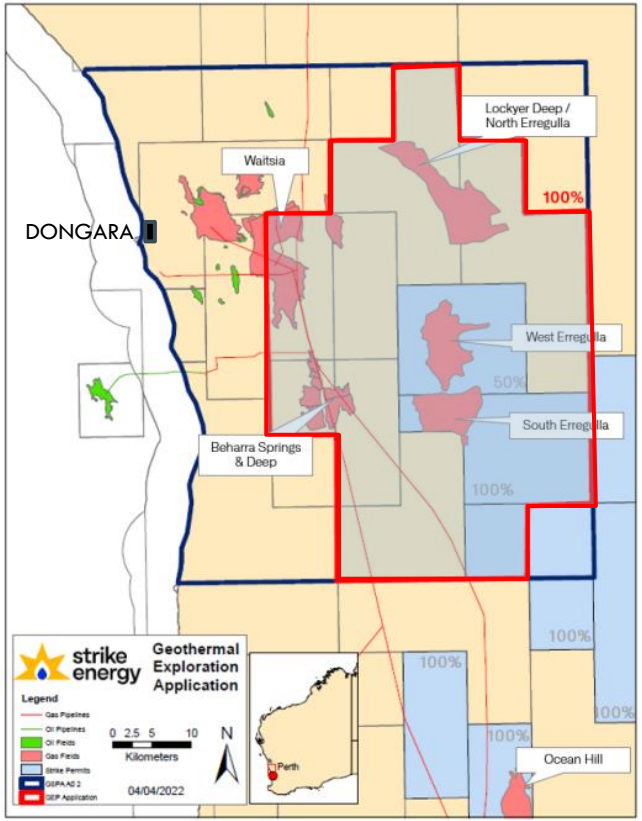


North Perth Basin Inferred Geothermal Resource

Australian Geothermal Association

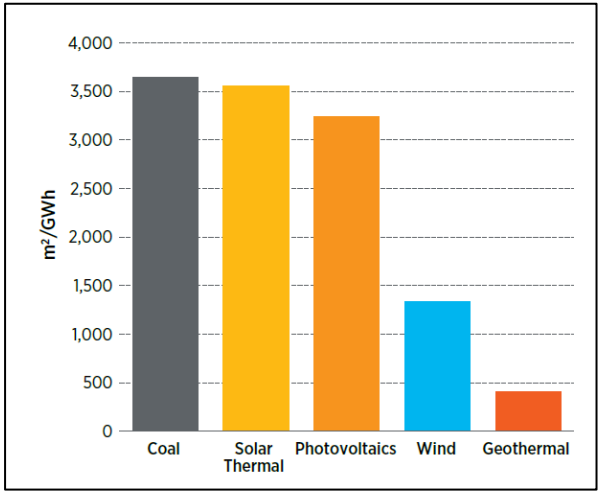
Inferred Resource

Kingia Sandstones (30-year model)		**P90 (low)**	**P50 (mid)**	**P10 (high)**
Original GSPA Area	Mapped Area (km^2)		3,513	
	Net Energy Resource (PJe)	76	244	517
	Equivalent Power Resource (MWe)	85	271	575
GEP Application Area	Mapped Area (km^2)		1,826	
	Net Energy Resource (PJe)	69	203	422
	Equivalent Power Resource (MWe)	**77**	**226**	**470**

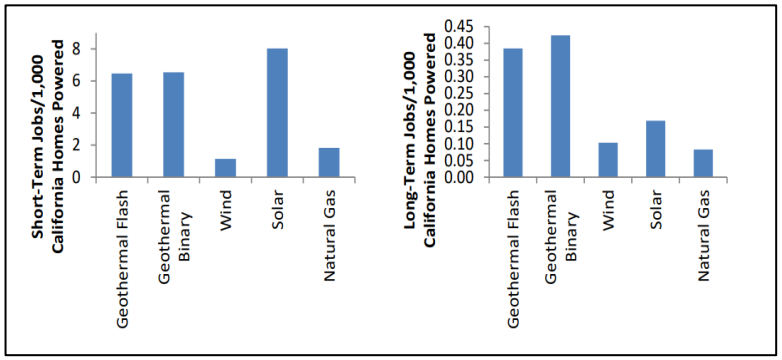


Strike Energy ASX Release, 5 May 2022

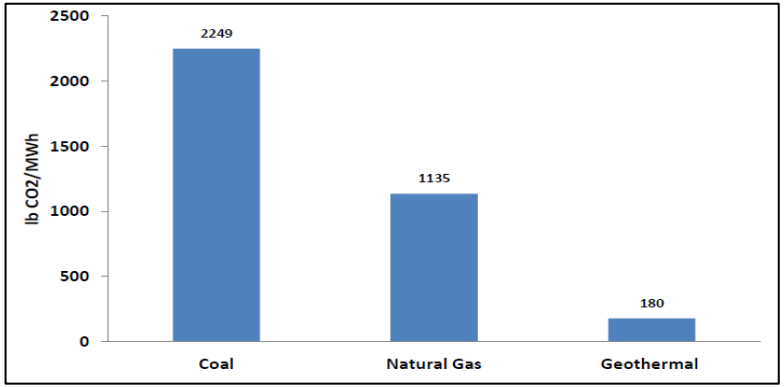
Other Advantages of Geothermal



Land Use: Small footprint



Jobs: Good opportunities for community



Carbon emissions: very low (esp. HSA)

Power Generation - Strengths and Weaknesses

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Strengths:

- Power generation produces virtually zero carbon emissions.
- Power generation is available predictably day and night year round.
- Can provide baseload power.
- Generates synchronous power - can help to stabilise electrical grid and allow addition of more intermittent power (wind and solar PV).
- Small footprint; creates jobs

Weaknesses:

- High upfront costs (especially drilling)
- Limited to areas with favourable geology (at present)
- Output affected by ambient temperature
- EGS has great potential but not yet technically or commercially viable (but recent breakthroughs reported)

Summary and Conclusions

- Geothermal provides clean, renewable energy
- Cost-competitive with fossil fuel generation
- High capacity factor = base load power generation
- Technology improvements improving economics
- HSA offers best short-medium term potential
- Good potential for remote areas eg. electricity in Great Artesian Basin
- Variety of applications from large scale electricity generation to home heating
- Direct use/GSHP a significant and growing industry in Australia


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Questions?