

Geothermal: Power of Hot Water

WORLD MAP



MSc (Otago Univ. 1987)

Dip. Energy Tech. (Univ Auckland, 1989)

PhD (Geology, Univ. Auckland, 1994)

Okayama Univ., (JSPS Post Doc 1994-5)

Kingston Morrison Ltd (NZ, Indonesia 1995-9)

Kochi Uni., (Monbusho Post Doc, 1999)

Tohoku Univ., (JSPS / Faculty 2000-3)

GNS Science (Geothermal Sci, 2003-19)

Baseload Capital Sweden AB (Aug. 2019 -)



Introducing ...



BASELOAD
CAPITAL

📍 Head Office

📍 Local Holding Company



Capital & structure

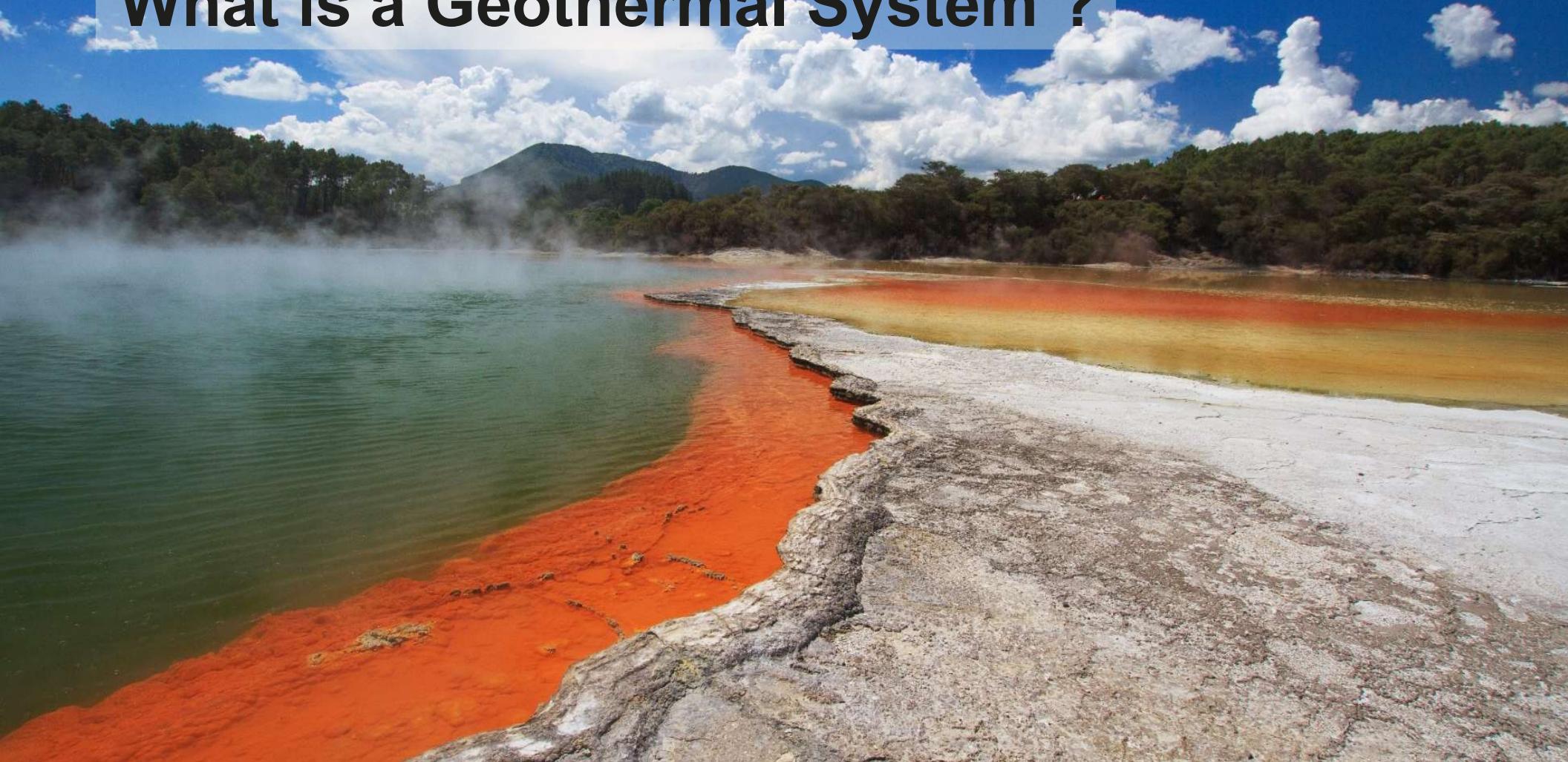
Baseload Capital is an investment entity that offers early stage capital, equity and/or debt, to accelerate geothermal projects



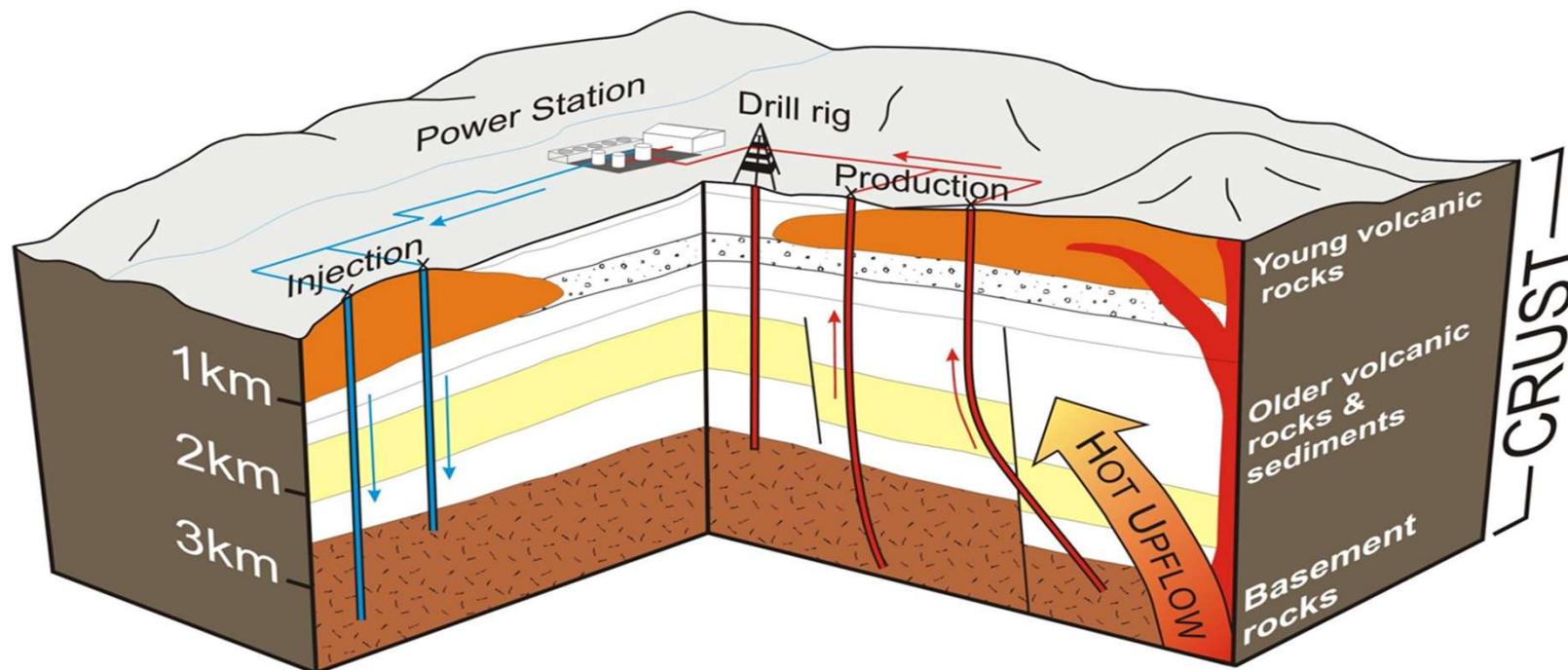
Project Development

Baseload Power develops, builds and operates Heat Power plants. This is done by identifying geothermal resources, facilitating land lease agreement and offtake agreements

What is a Geothermal System ?



What is a Geothermal System ?



Geothermal System :

A transfer of heat energy to the earth's surface

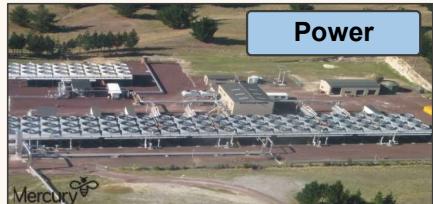
Geothermal Energy :

Resource for direct use (residential, industrial) or electricity generation



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Development Potential ?





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Is a geothermal project possible ?



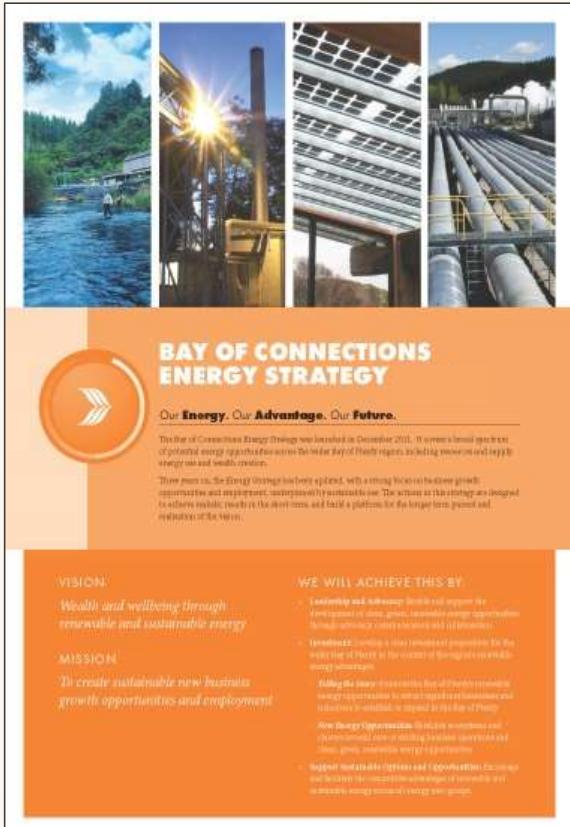
Wairakei 14 MWe Binary Plant

- Understanding system hydrology and structure reduces development risk.
- Appropriately selected and scaled development will mitigate environmental effects.
- Important developers and regulators engage with the local community, to meld aspirations.



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Enabler of Economic Development

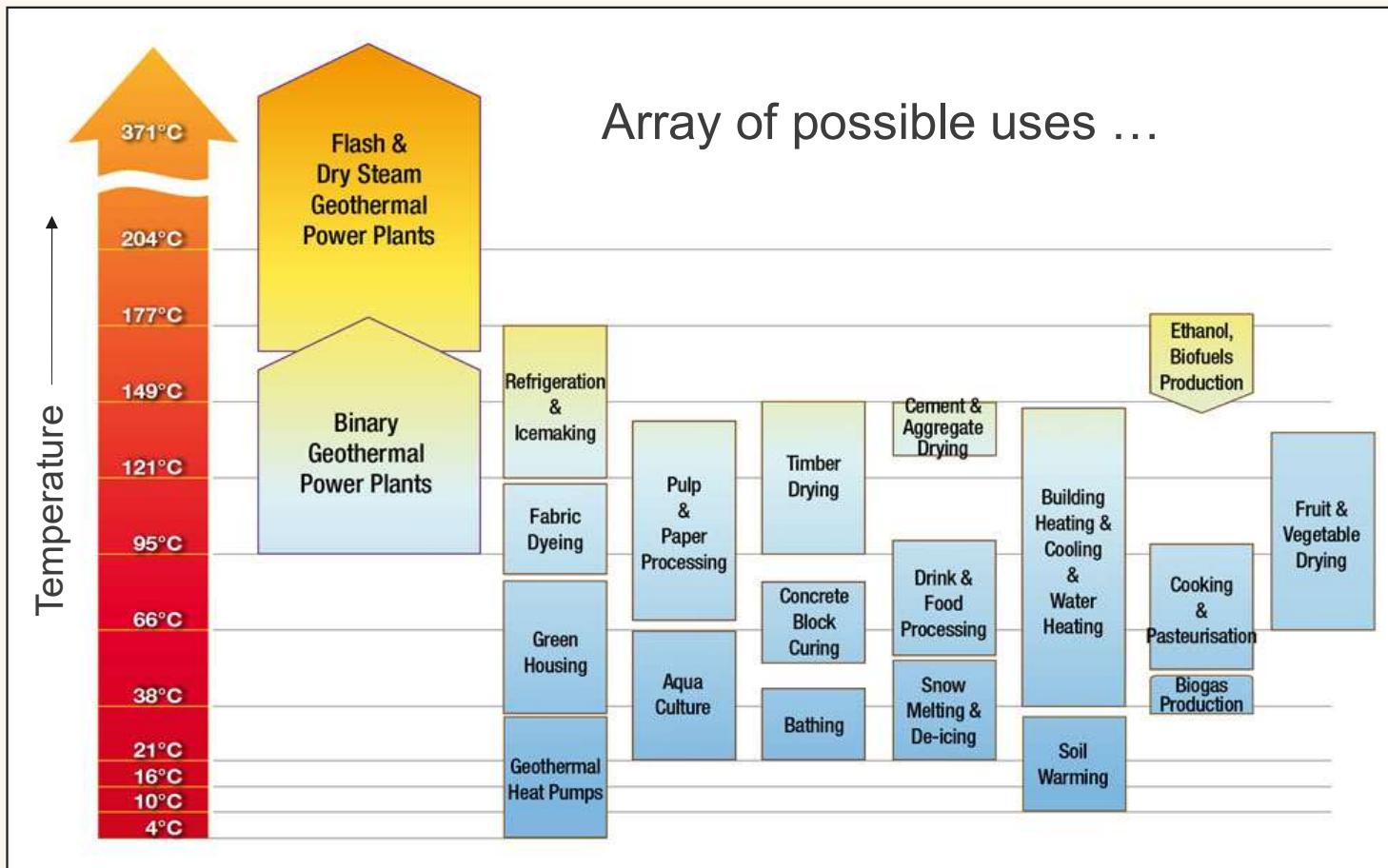


- Geothermal key enabler of regional economic development
- Sustainable new business growth opportunities and employment

Focus:

- **Engage:** industry, Government, indigenous communities, public
- **Promote:** renewable advantages to the region
- **Connect:** heat suppliers and heat users
- **Training:** increase knowledge and community skills
- **Advocate:** incentives and initiatives

Uses of Geothermal Energy

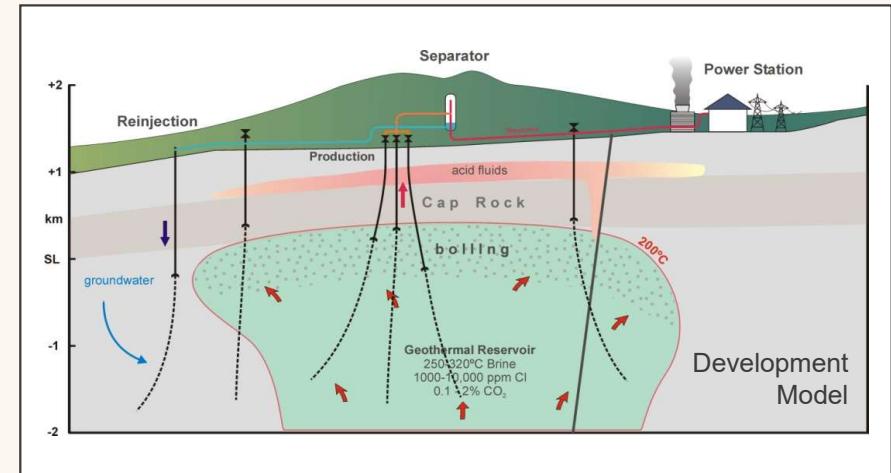
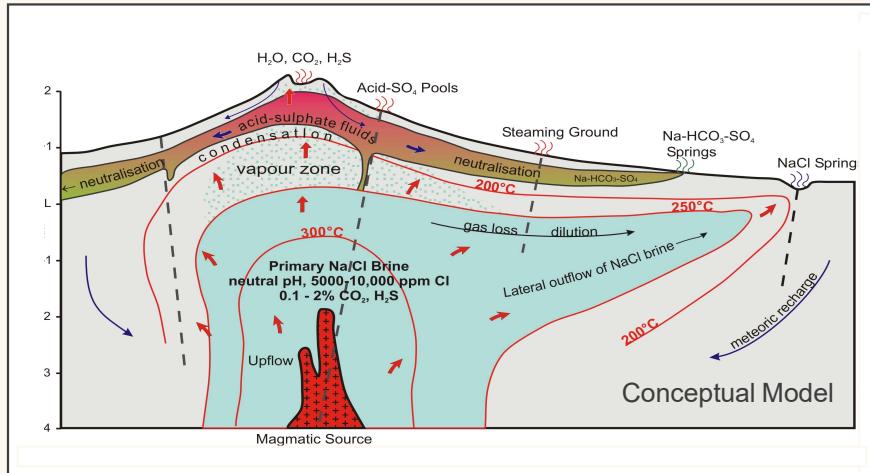


Geoscience = Lower Risk

Integrate all resource data to understand the system



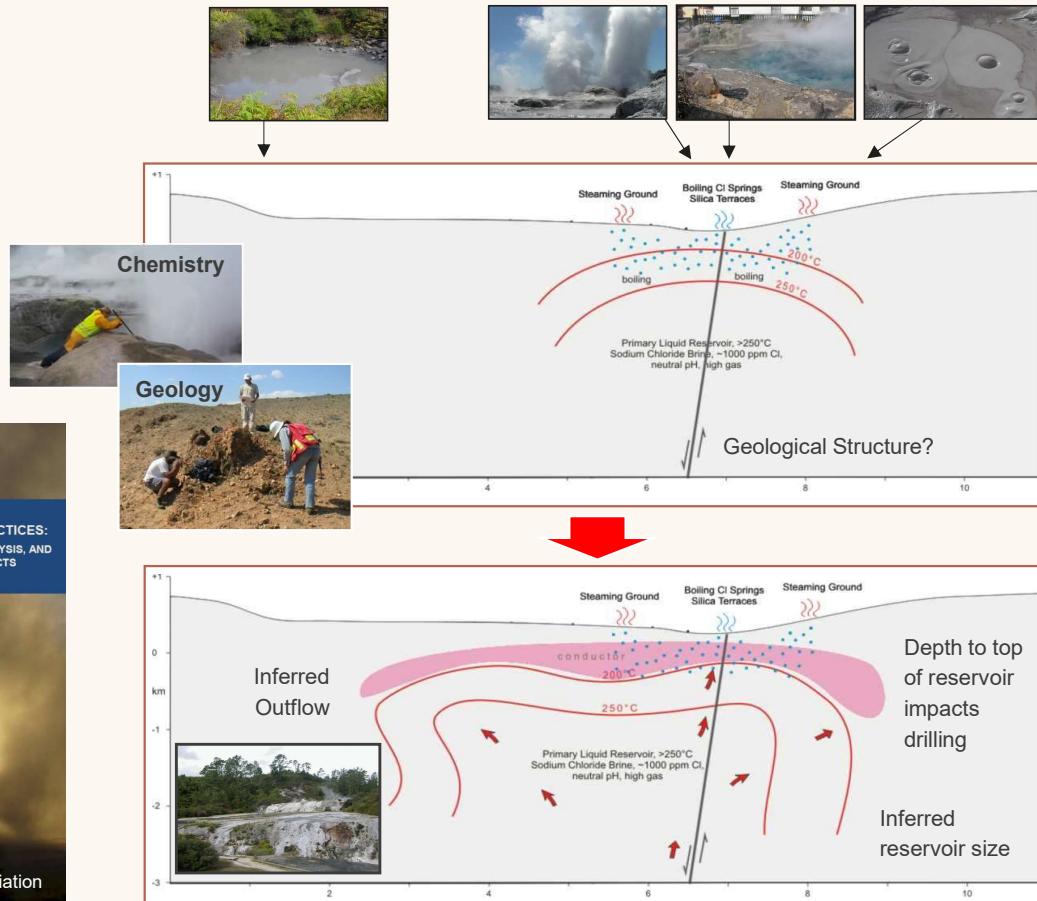
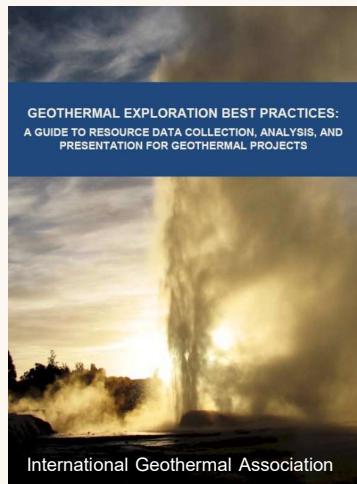
Establish science strategy that aids decision making



Most geothermal resources have positive development attributes, also features that could be problematic or limit utilisation

- Temperature, Permeability
- Benign fluid chemistry
- Shallow reservoir (depth to drill)
- Geological hazards

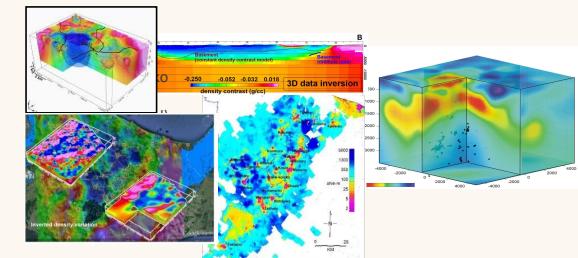
Resource Characterisation



Characterise the system

- hydrology
- origin of fluids / flow paths
- reservoir temperature ?
- development-limiting issues ?
- reservoir extent ?

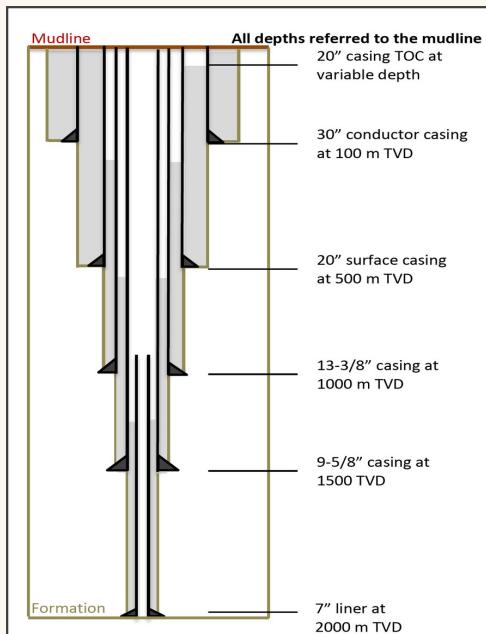
Success of the geophysical survey
usually depends on a combination of
techniques to delineate the system





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Geothermal Drilling



Equipment & techniques used for drilling deep (>1 km depth) geothermal wells adapted from petroleum industry



- Require **practices** that differ from conventional oil, gas or water drilling
- Key difference is nature of the formation fluids, and how they are controlled
- Target **permeable** (c.f. “under pressured”) zones, and maintain “balanced” conditions by plugging losses. Drill with aerated water to preserve fluid paths.

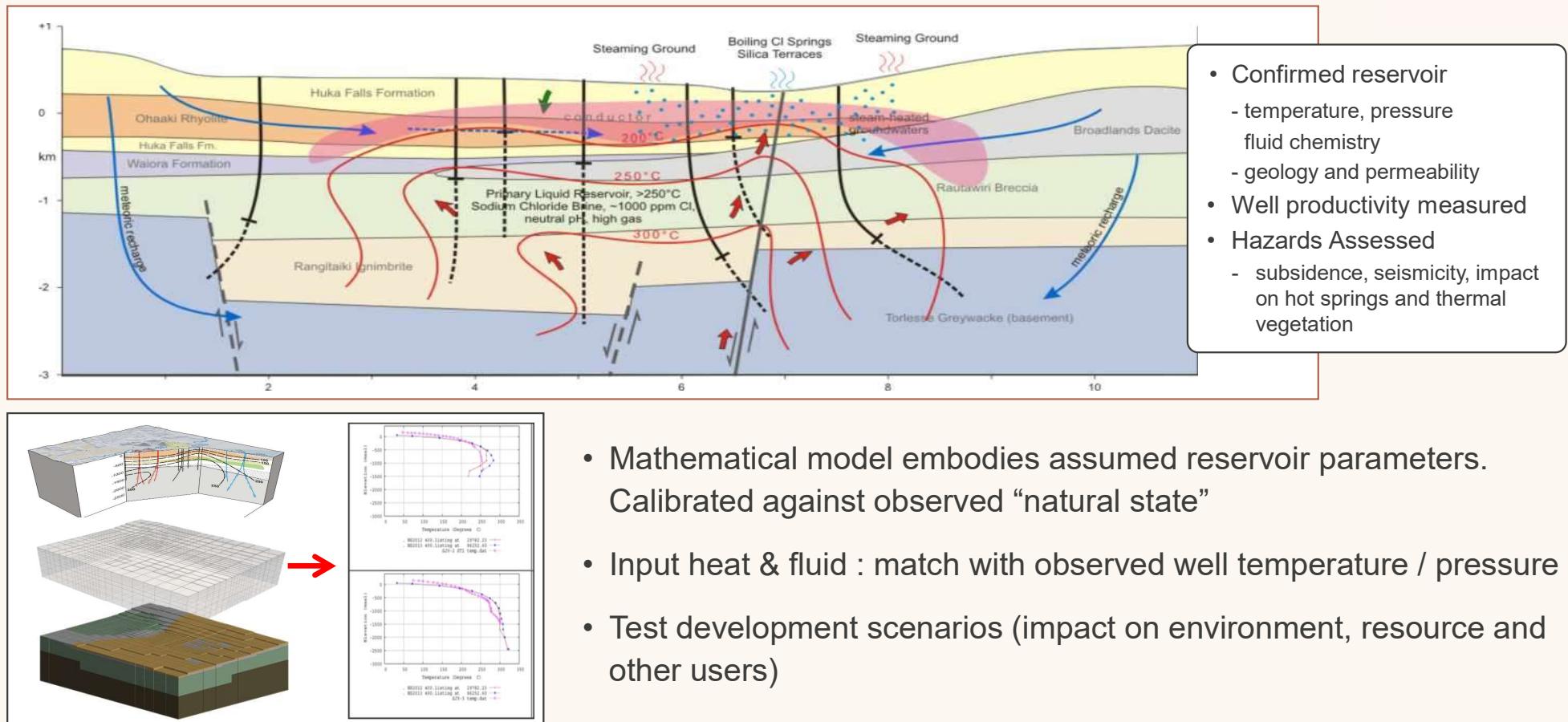
Then and now ...



Modern wells are...

- larger diameter than early wells... (13 3/8" production casing typical, compared to 8 5/8" in early wells)
- much deeper than early wells... (1000 - 3500m+ deep)

Conceptual & Numerical Modelling



Data from well testing



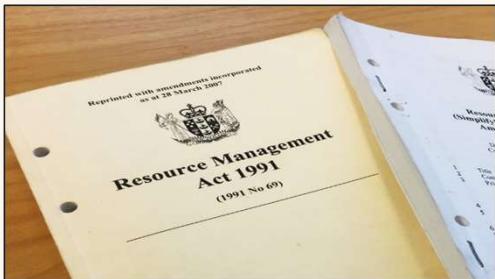
Discharge through Silencer



Vertical
Discharge

Resource Management

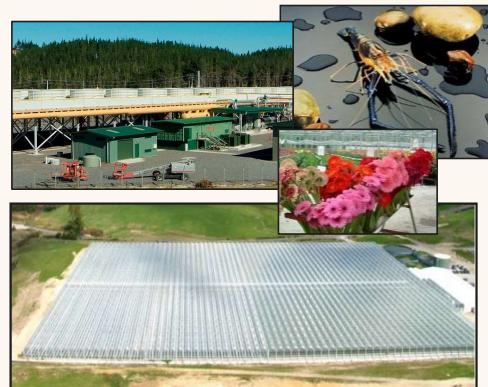
Management Framework



- Resource Management Act (1991)
- Local Government focus
- Public / Iwi Consultation



Community Aspiration



and Engagement



Environmental Monitoring



- Identify areas need to manage
- Detect physical / chemical change
- Model future utilisation



Local Government Functions



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Geothermal System Management Plans

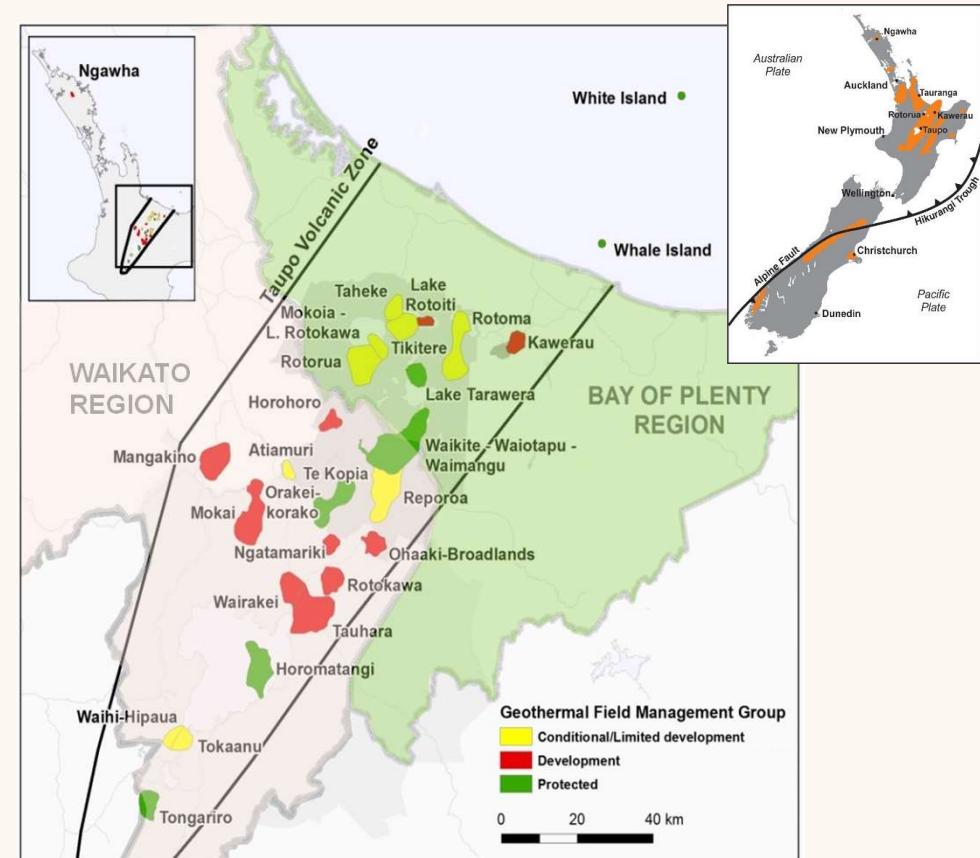
- Classification of systems for different uses
- Confer consented allocation
- A 'whole system' system management plan
- Balance multiple values, uses and users

Informed by science and community values

Management of effects

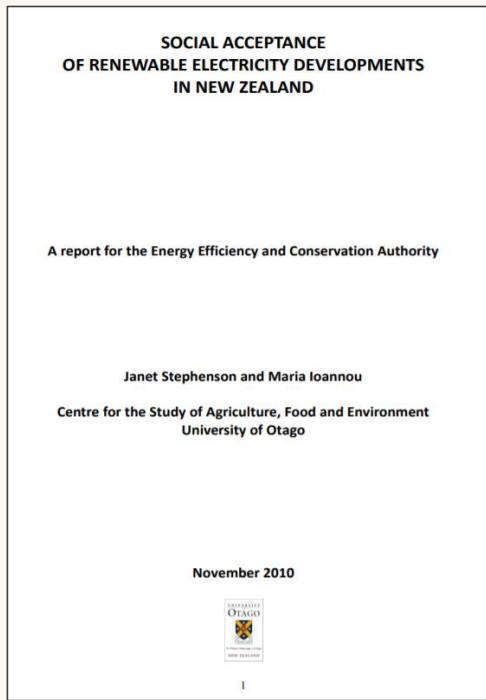
Managed through **consents**, require understanding of :

- The state or 'health' of the geothermal system
- How the system responds to use
- Baseline and ongoing surface feature monitoring



Public Acceptance

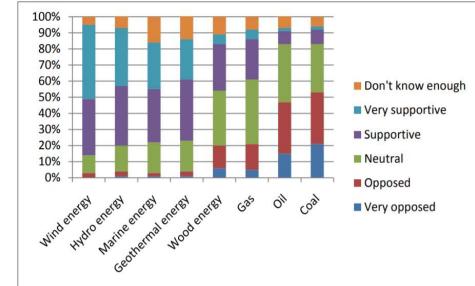
Public uncertainty and information gaps affect acceptance to implementation of new technology.



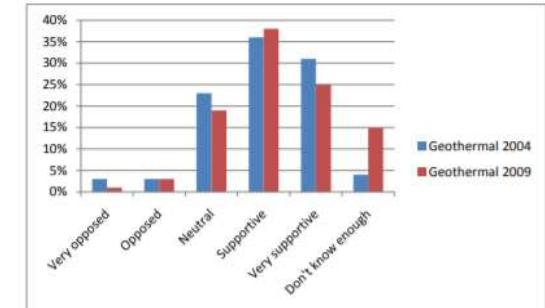
Factors affecting acceptance : (i) limited knowledge about technology, (ii) unfavourable media coverage, (iii) uncertainty about reversibility and predictability of adverse effects on hot springs, (iv) concerns of water use and seismic activity, (v) low levels of community participation and project consultation.

	Wind energy	Hydro energy	Marine energy	Geothermal energy	Wood energy	Gas	Oil	Coal
Very opposed	0%	1%	1%	1%	6%	5%	15%	21%
Opposed	3%	3%	2%	3%	14%	16%	32%	32%
Neutral	11%	16%	19%	19%	34%	40%	36%	30%
Supportive	35%	37%	33%	38%	29%	25%	8%	9%
Very supportive	46%	36%	29%	25%	6%	6%	2%	2%
Don't know enough	5%	8%	16%	15%	11%	8%	8%	6%

EECA (2009)



EECA Consumer Public Opinion Survey



Public opinion on geothermal electricity generation (EECA 2009)

Indigenous Communities



Māori are tangata whenua. Not people in the land or over the land, but people of it.



Members of Te Kapa Haka o Te Whanau-a-Apanui. Credit: Martin Hunter / Getty



Kaitiakitanga - Guardianship

Ngātoroirangi Rock Carving, Taupo. Flickr by Abaconda Management Group/ CC BY-SA 2.0

What could go wrong ?



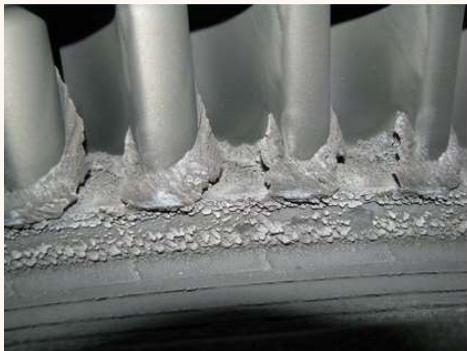
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Silica deposit in
geothermal fluid line
(left) and steam turbine
(below left / right)



Antimony sulphide
deposition on a heat
exchanger from a
geothermal (binary)
power plant.



...on rotating blades



on diaphragm blades



Corrosion on the
diaphragm blades of
a geothermal steam
turbine



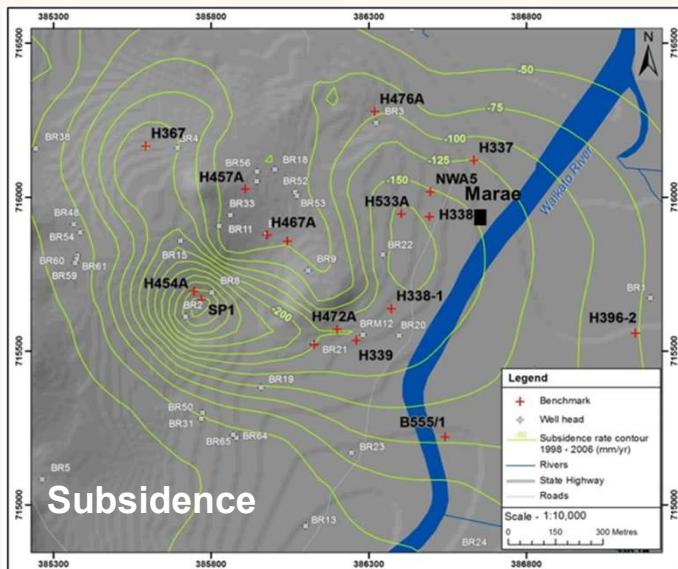
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Environmental Risks

Environmental Risks	Avoidance measures	Remediation measures	Mitigation measures	Relative cost	Relative Risk
Discharge effluent - surface water contamination	Reinject all mineralised liquid discharges	Re-instate natural surface water quality	Replace or treat affected water supplies	Large	High
Discharge effluent - groundwater contamination	Avoid injection into potable aquifers of groundwater	Pump out & treat, or reinject into geothermal aquifer	Replace or treat affected water supplies	Large	Medium
Gas emissions (H2S, Hg, CO2)	H2S abatement, NCG injection	Plant forests	Compensate or relocate affected inhabitants	Moderate	Medium
Hot spring interference	Use injection to sustain shallow pressure/temperature	Restore dormant thermal features by targetted injection	Create new thermal features using waste hot water/steam	Minor	Medium
Induced subsidence or heave	Use injection to manage pressures	Repair/relocate affected structures	Enhance public amenities	Moderate	Low
Large magnitude induced seismicity	Limit injection pressure/temperature gradients	Repair induced seismicity damage	Construct quake-safe public amenities	Moderate	Low
Hydrothermal eruptions-landslides	Control shallow steam pressure, slope stabilisation	Repair damage, restabilize slopes	Reconstruction, enhance new features	Minor	Low
Noise	Remote site selection, low noise fans/pumps	Noise screens	Compensate or relocate residents	Minor	Medium
Powerplant/pipe visual effects	low profile structures, buried pipes	Camouflage painting, vegetation screening	Tourist facility enhancement	Minor	High
Unsustainable utilisation rate	Conservatively sized development stages	Production-injection strategy changes	Retire resource to allow recovery	Large	Low

Environmental Impacts

Wairakei Geothermal Field



Thermal Decline
Spa Park / Otumukeke Stream



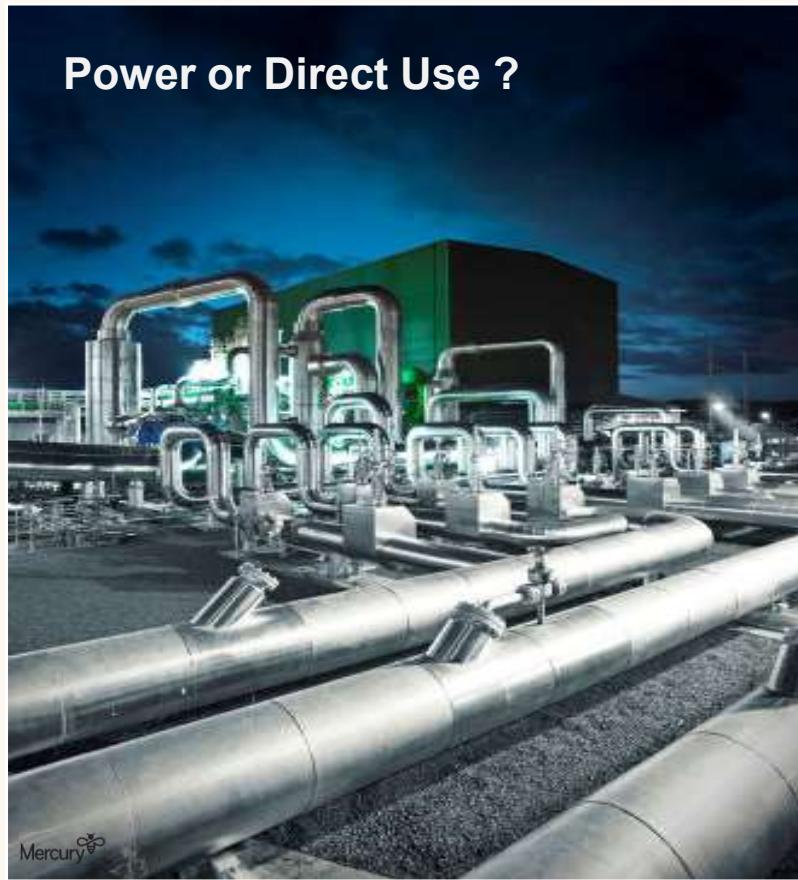
Increased thermal activity, Taupo



Application of Geothermal Energy



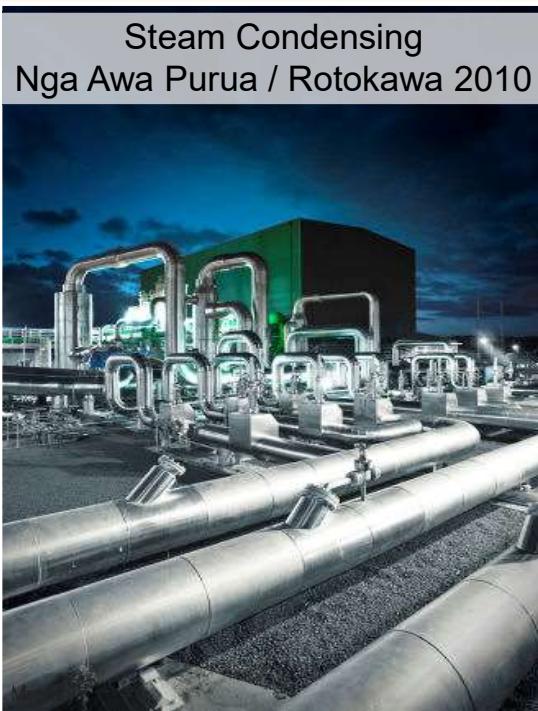
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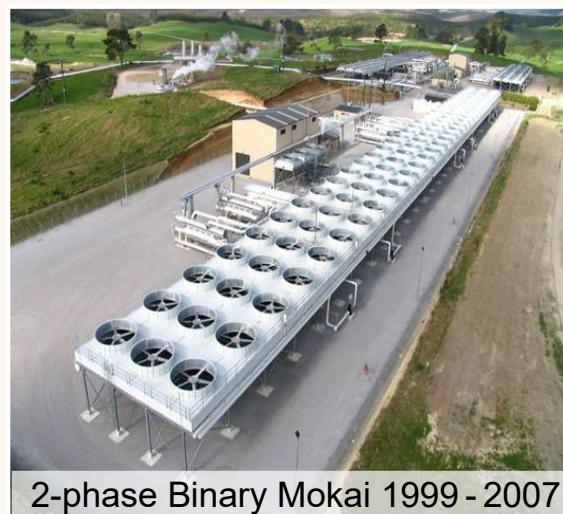
Examples of Power Generation



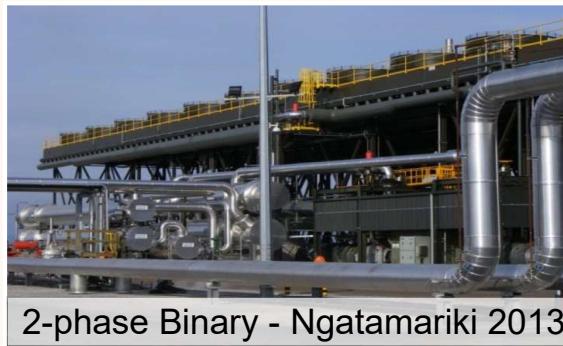
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Steam Condensing
Nga Awa Purua / Rotokawa 2010



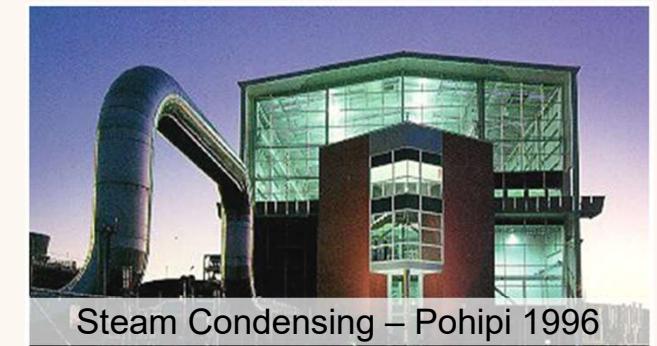
2-phase Binary Mokai 1999 - 2007



2-phase Binary - Ngatamariki 2013

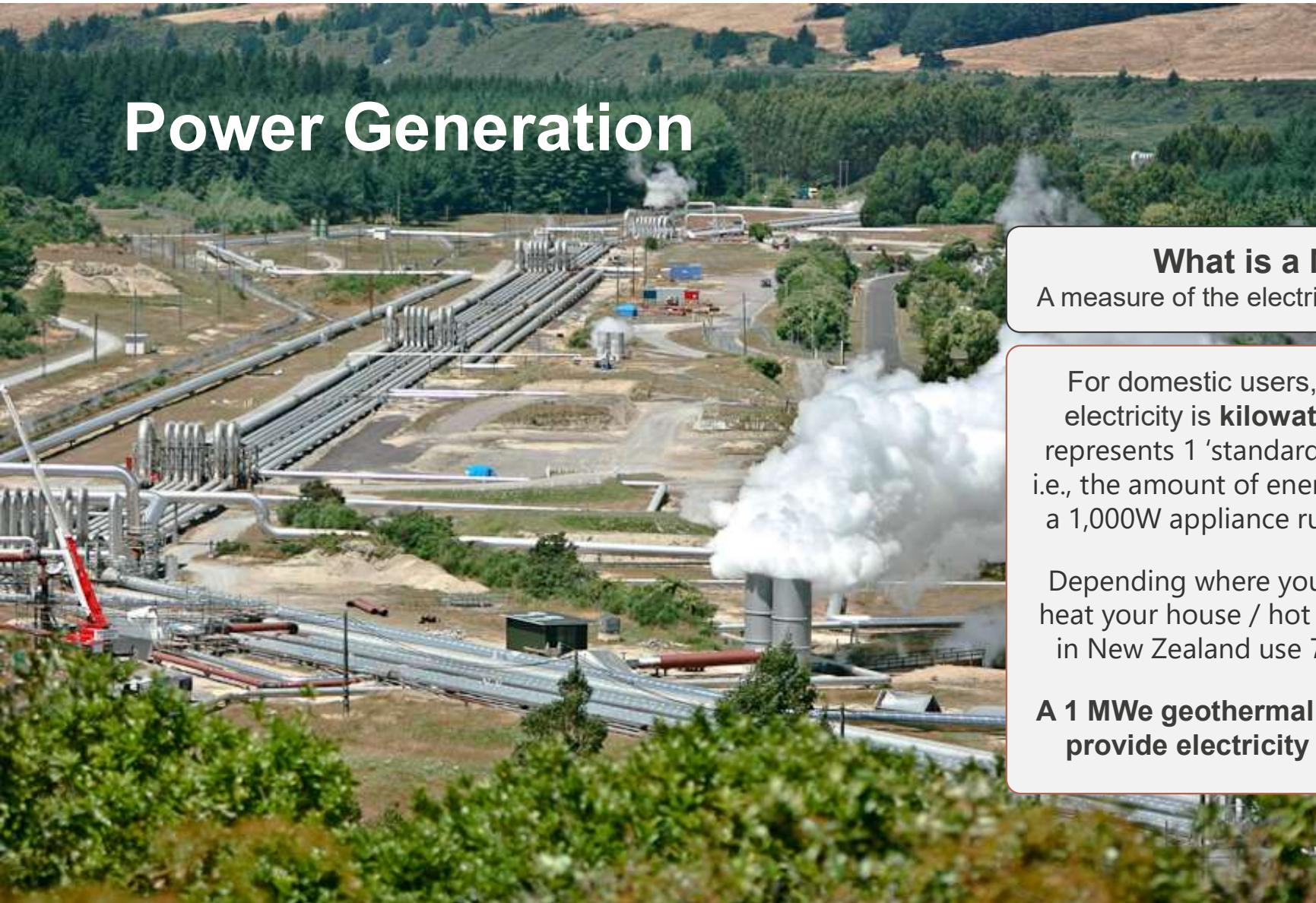


Wairakei Flash (1958) / Binary (2005)



Steam Condensing – Pohipi 1996

Mercury



Power Generation



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What is a MWe* ?

A measure of the electricity output of a plant

For domestic users, the basic unit of electricity is **kilowatt hour** (kWh) – it represents 1 'standard unit' of electricity. i.e., the amount of energy used if you kept a 1,000W appliance running for an hour.

Depending where you live and how you heat your house / hot water, most homes in New Zealand use 7-8,000 kWh/year

A 1 MWe geothermal plant expected to provide electricity for ~800 homes



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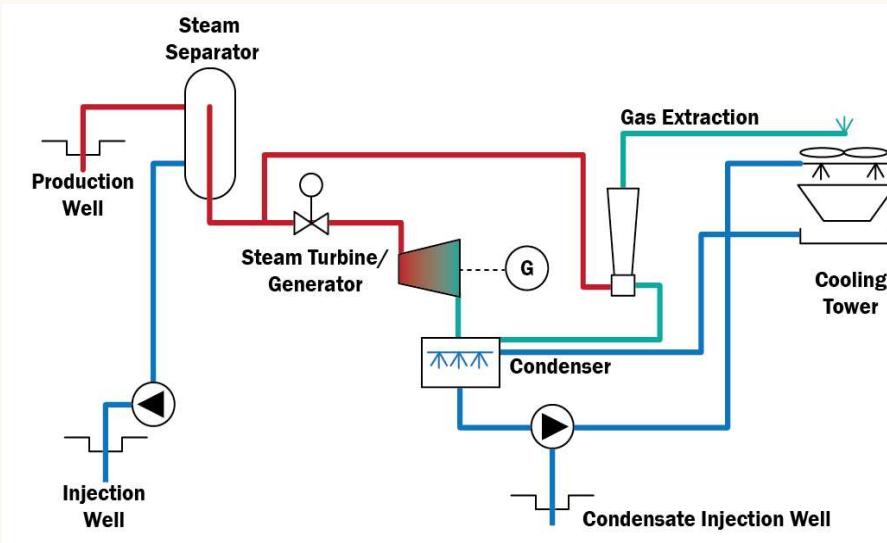
Flash-Type Power Plants



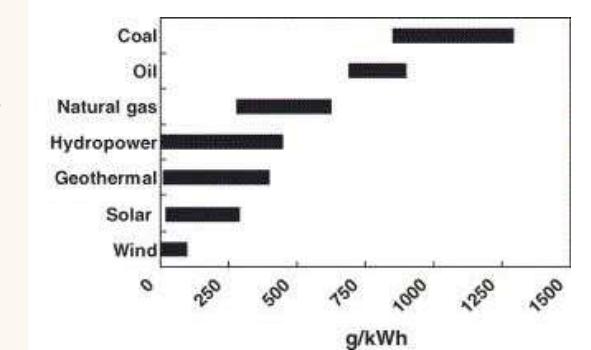
Kawerau
Dual Pressure Flash



NgaAwa Purua, Rotokawa
Triple flash, 325 t, 140 MWe



Typically, geothermal power stations emit 5% of CO₂ and 1% of SO₂ emissions of comparable sized coal-fired plants.



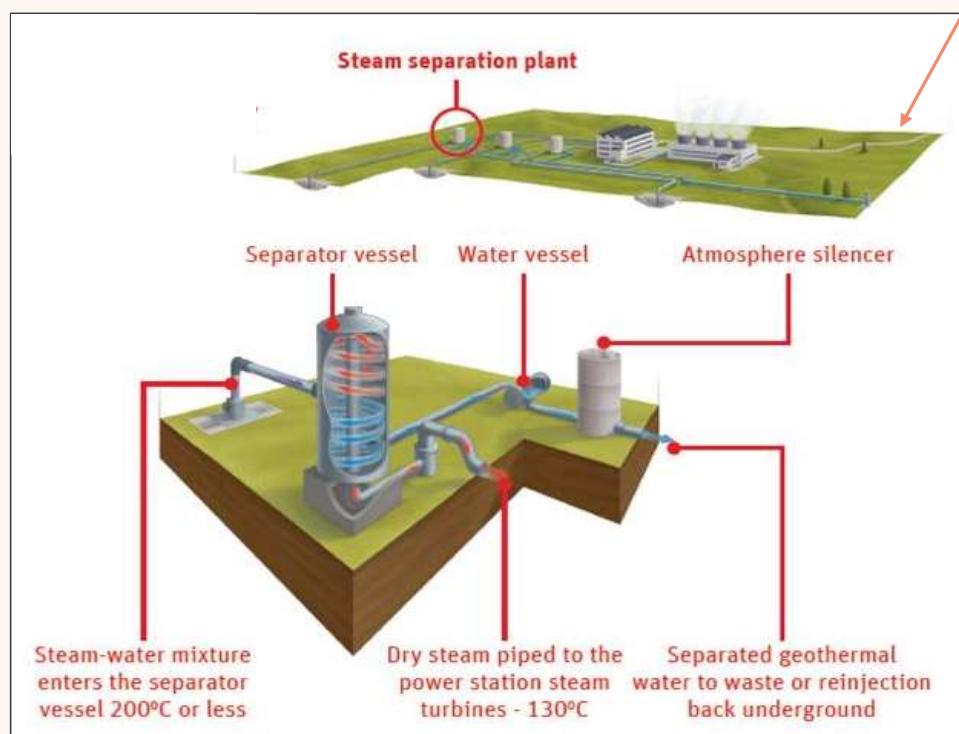
Steamfield Design



Separator Plant



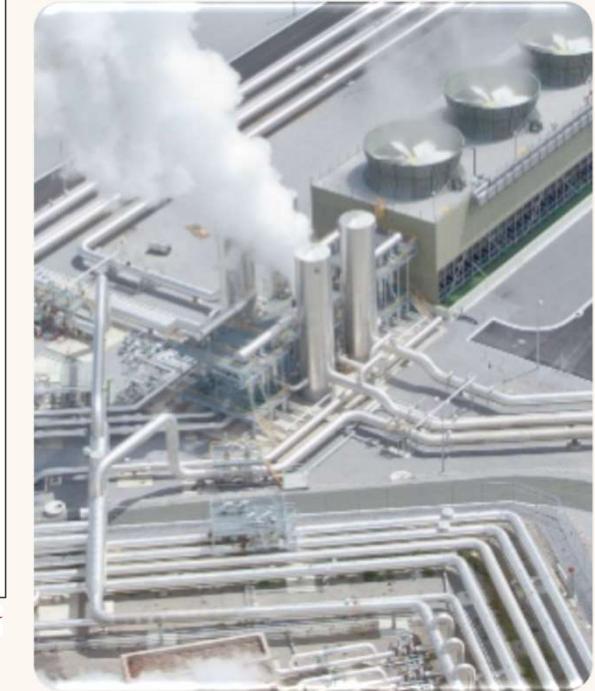
Production/ Injection Well



Contact



Monitoring Well





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Wairakei A, B, Binary Plants

Bioreactor

Sulphur eating bacteria reduce discharge of dissolved H_2S to Waikato River.



Wairakei Binary (14 MW, 2005)



Wairakei A (1958)

Wairakei B

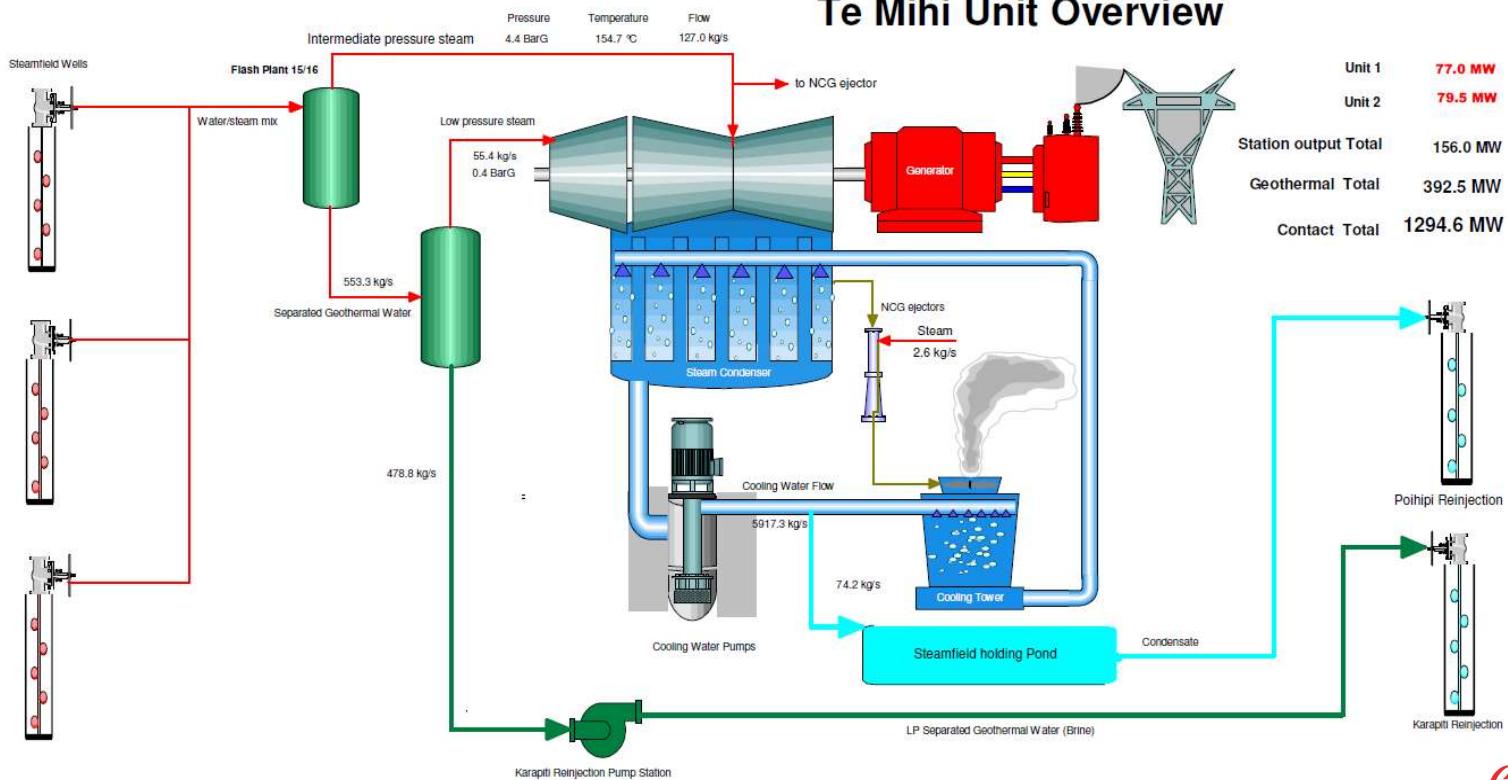
Contact



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Te Mihi Power Plant (166 MWe gross, 2014)

Te Mihi Unit Overview



Turbine Hall



Cooling Towers



Steam Turbines

Contact



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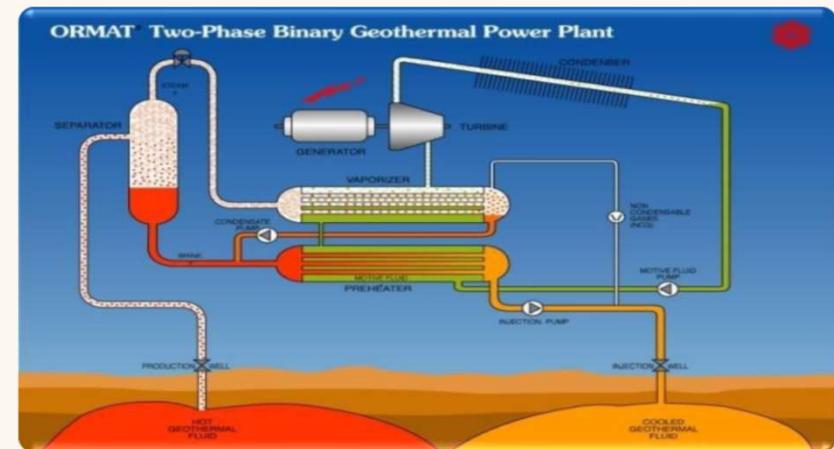
Binary Power Plants



Ngatamariki 82 MWe Geothermal Power Station

(Mercury NZ / Tauhara North No.2 Trust)

Binary cycle geothermal plants have almost no air emissions or liquid waste.



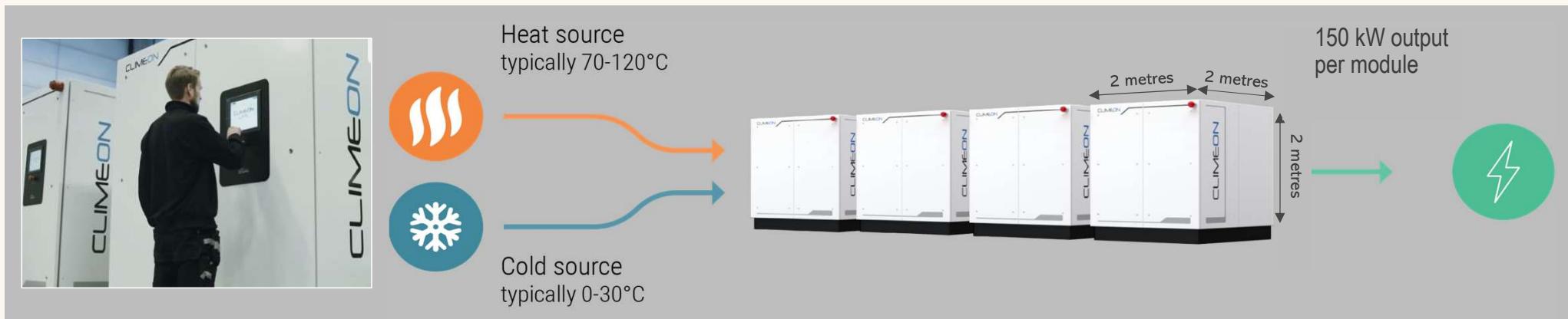
1980's / 2004-2009	Wells drilled by the Crown / Mighty River Power exploration
Nov 2009	Resource Consent for development lodged
May 2010	Consent granted
Sept 2011 - Dec 2012	Development drilling campaign
Sept 2011	82MW ORMAT Binary Cycle Plant Construction Began
Aug 2013	Ngatamariki Power Plant Commissioned



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Climeon Heat Power

Using the principles of an Organic Rankine Cycle, at low pressure, the Climeon system exploits the temperature difference between hot and cold water to generate electricity



Each module consists of:

- Evaporator : transfers heat to the internal working fluid
- Turbine-generator : conversion of thermal energy to electricity
- Cooling system : transfers heat out of the module to the cool water circuit





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Examples of Direct Use

Tenon, Wairakei



Mokai



Mokai

Waikite

Benefits of Direct Use

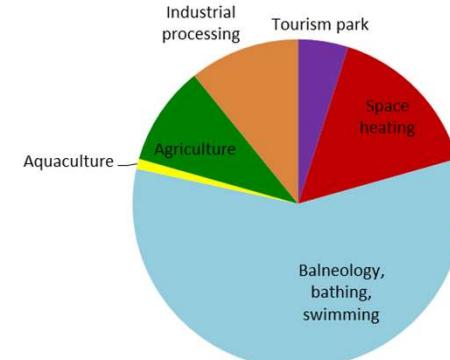
- Indigenous, reliable energy supply
- Utilise low temperatures resources, in potential off-grid locations
- High thermal efficiency
- Minimum start-up time
- Impacts regional development
- Minimal environmental footprint
- Sustainable resource utilisation
- Low carbon footprint

Reduction in imported fuel

- Can use conventional water well drilling

New Zealand Direct Use Applications

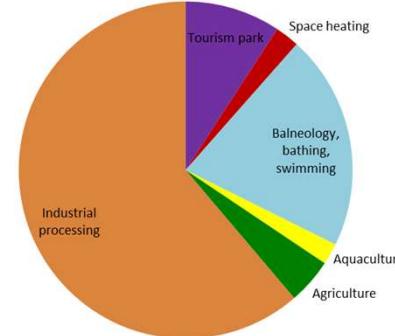
Bathing most common



Energy Use

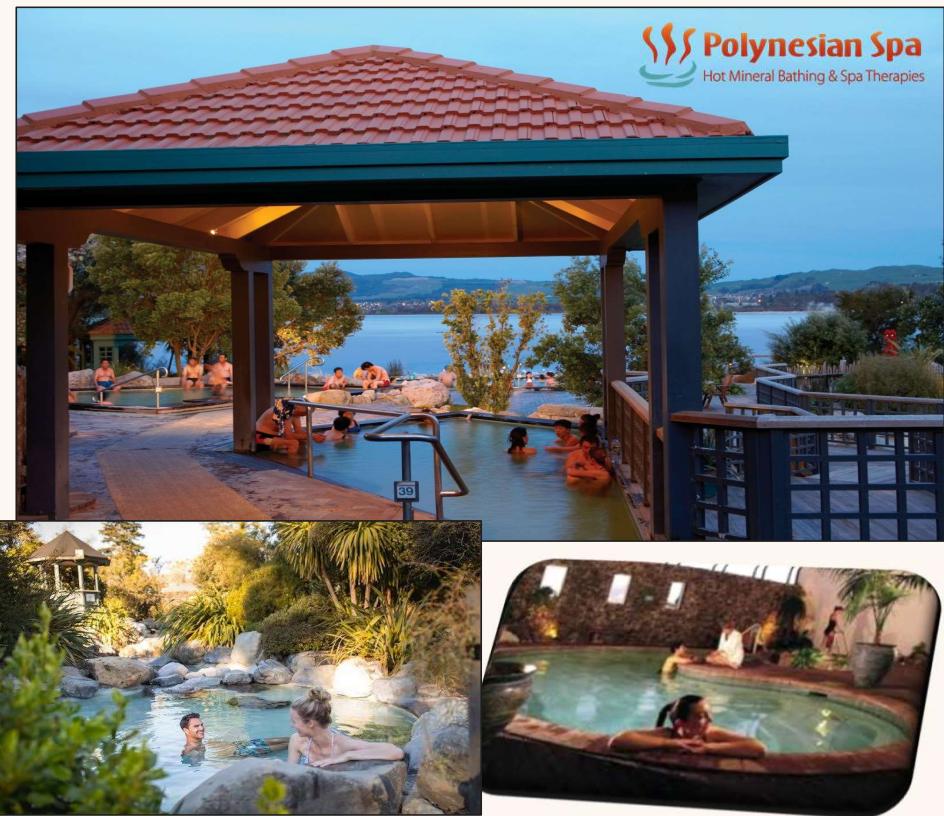
Processing includes :

- Timber drying
- Pulp & paper processing
- Tissue making
- Milk drying
- Honey processing



Bathing and Tourism

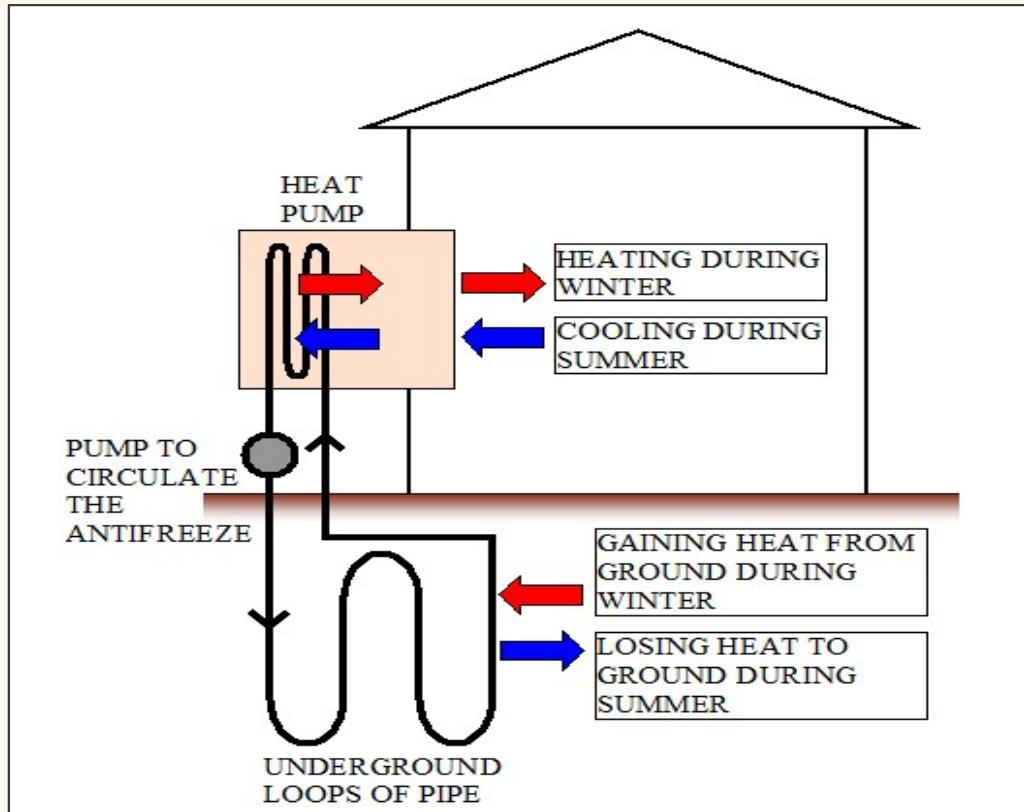
Rotorua Geothermal Field





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Ground-Sourced Heat Pumps



PlentyFlora

Horohoro – Geothermally Heated Glasshouse



case study 8

Geothermal Hot House for Gerberas

By Lisa Lind (GNS Science), Diana Bradshaw (GNS Science) and Jo Bell



PlentyFlora's gerberas are grown with the help of geothermal energy used to heat the greenhouse.

For Rotorua gerbera growers, Harald and Connie Esendem of PlentyFlora, making use of the area's geothermal energy is key to offsetting the harsh winter conditions.

"To grow gerberas successfully and have a smooth operation our main requirement is to avoid too many, or too fast, fluctuations in temperature. We have a tropical plant from South Africa so creating a similar climate in the greenhouse is important," says Connie.

"We are fortunate to have ready access to geothermal energy which provides us with the right environment for the flowers," says Harald.

Commercial growers are mainly in Auckland, and while Harald says they try to import flowers from overseas, there is not as cold as in Rotorua.

"The majority of other gerbera glasshouses around New Zealand would use waste oil as the source for their heating requirements."

PlentyFlora's greenhouse is heated by geothermal energy from two shallow geothermal bores. The original, older bore produces 100°C geothermal fluid. This fluid is heated to 60°C and then used as heating water that is circulated through stainless steel pipes adjacent to the plants in an open, closed heating system.

The new bore, drilled two years ago, produces geothermal fluid that is used directly in the greenhouse, predominantly for heating, but also for overhead irrigation. Cooled geothermal water is then injected back into the shallow geothermal reservoir.

In addition, a bio diesel peak-heating system on a fan coil unit forces hot air on the plants when needed.

Key Benefits:

- Geothermal energy provides heat to keep the temperature above the minimum seasonal temperature of 14°C
- Reduced cost for heating requirements

Key Features:

- More than 600,000 gerberas grown annually at PlentyFlora
- Two geothermal bores are the primary heat source for the greenhouse all year round



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Honey Processing - Arataki



Waiotapu Geothermal Field





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Kiln Drying – Thermal Kilns

Ohaaki Geothermal Field – “Thermally enhanced firewood”



Industrial Direct Heat Applications



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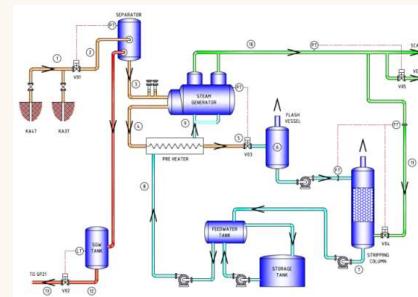
Wairakei - Tauhara



Kawerau



Mokai





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Timber and Pulp Processing

earth energy: accessible; reliable; renewable

Tenon's Earth Energy Solution

case study 1



Tenon's timber drying kilns at its Taupo plant use earth energy from low temperature geothermal sources.

Harnessing a naturally occurring energy source has proved a big plus for Tenon's wood processing plant on the Tauhara Geothermal Field near Taupo.

The move to eco-friendly and renewable geothermal energy for heating their nine timber-drying kilns has proved beneficial in terms of economics as well as productivity, says Darryl Robinson.

"Previously we burned natural gas to generate the heat required for the kilns. The natural gas stream is passed through the heat exchangers which heats the kiln's internal pressure system, in turn heating the kilns to dry the wood ready for further processing."

Darryl says an increase in cost of natural gas encouraged Tenon to look for alternative ways to heat the kilns.

Key Benefits:

- Reduced running costs
- Increased productivity
- Renewable and eco-friendly
- Easy to operate
- Reliable

Key Features:

- Geothermal heat plant with an installed capacity of 27 MW to heat 9 timber drying kilns
- Commissioned in 2006

Tauhara Geothermal Field - 30 MWt Direct Heat



Heat Exchanger
(Delivery)



Heat Plant
(during construction)



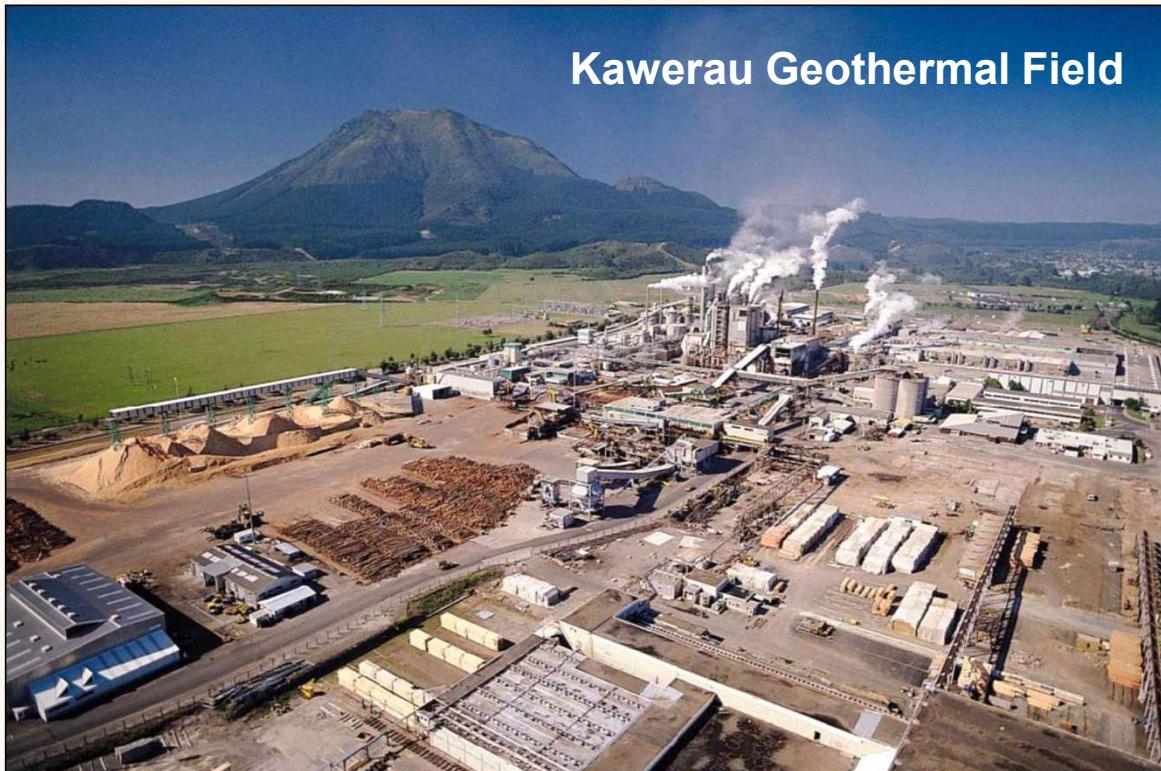
Heat Plant



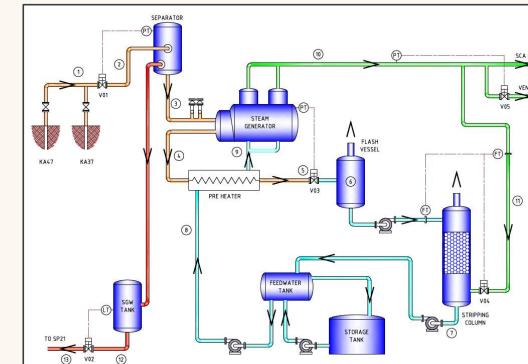


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Timber and Pulp Processing



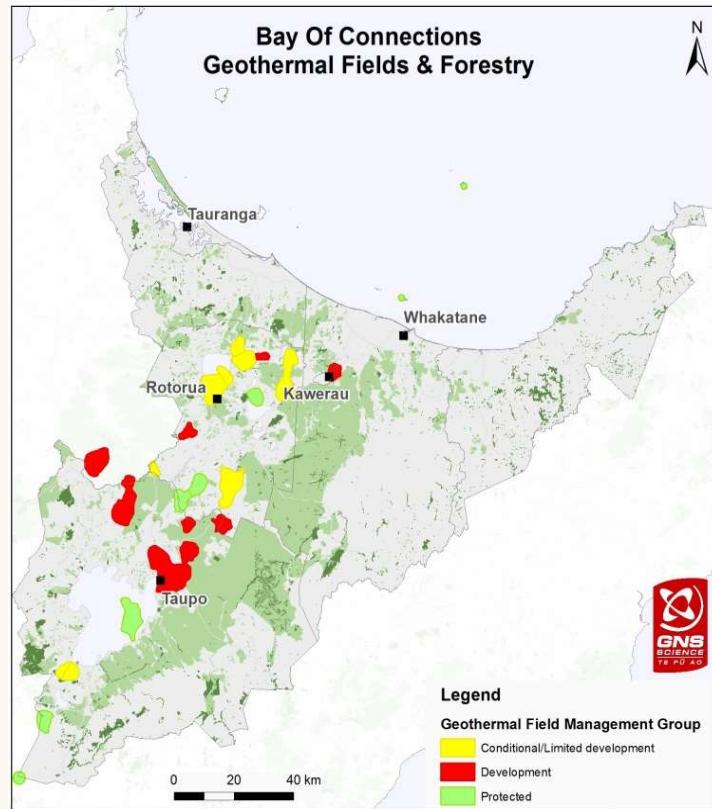
Kawerau Geothermal Field



World's largest geothermal heat user (>4 PJ/annum)

Clean steam plant

Co-Location: Geothermal / Forestry



- Asaleo Tissue
- Norske Skog
- Sequel Lumber
- CHH Wood Products
- Tenon
- Natures Flame



Agriculture



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Mokai Geothermal Field – 11ha Geothermally Heated Glasshouse



Dairy

Mokai Geothermal Field – Miraka (est. 2011)

- 60,000 cows from 100 farms within 85 km of plant
- 300 ML of milk processed annually
- Export milk powder and UHT products
- Whai Ora smoothies
- Waste solids to worm farm / fluids for irrigation



Aquiculture

Wairakei Geothermal Field – Huka Prawn Park



case study 4

Geothermal Energy Helps to Grow Prawns
By Lisa Lind (DNZ Science), Libby O'Brien and Jo Bell

earth energy: accessible; reliable; renewable

Manukan Freshwater Prawns (Macrobrachium carcinus) are farmed in 27°C-30°C ponds at Huka Prawn Park.

The only geothermally heated prawn farm in the world is right here in New Zealand and it harnesses renewable earth energy as a secret to its success.

The geothermal fluid is passed through a heat exchanger to heat water for grow-out ponds and then passes through a heat recovery system to turn the park into an environmental education centre. The park has 11 prawn production ponds and 10 smaller finishing ponds that remain between 27°C and 30°C.

The design for the park was unique as it required no engineers only required for the geothermal system. A small number of staff look after the system which also provides an eco-friendly 7.8 tonnes/year of prawns to the park's restaurants. The park utilises the geothermal energy to heat the water for the ponds from 2.75 hectares of ponds.

Key Benefits:

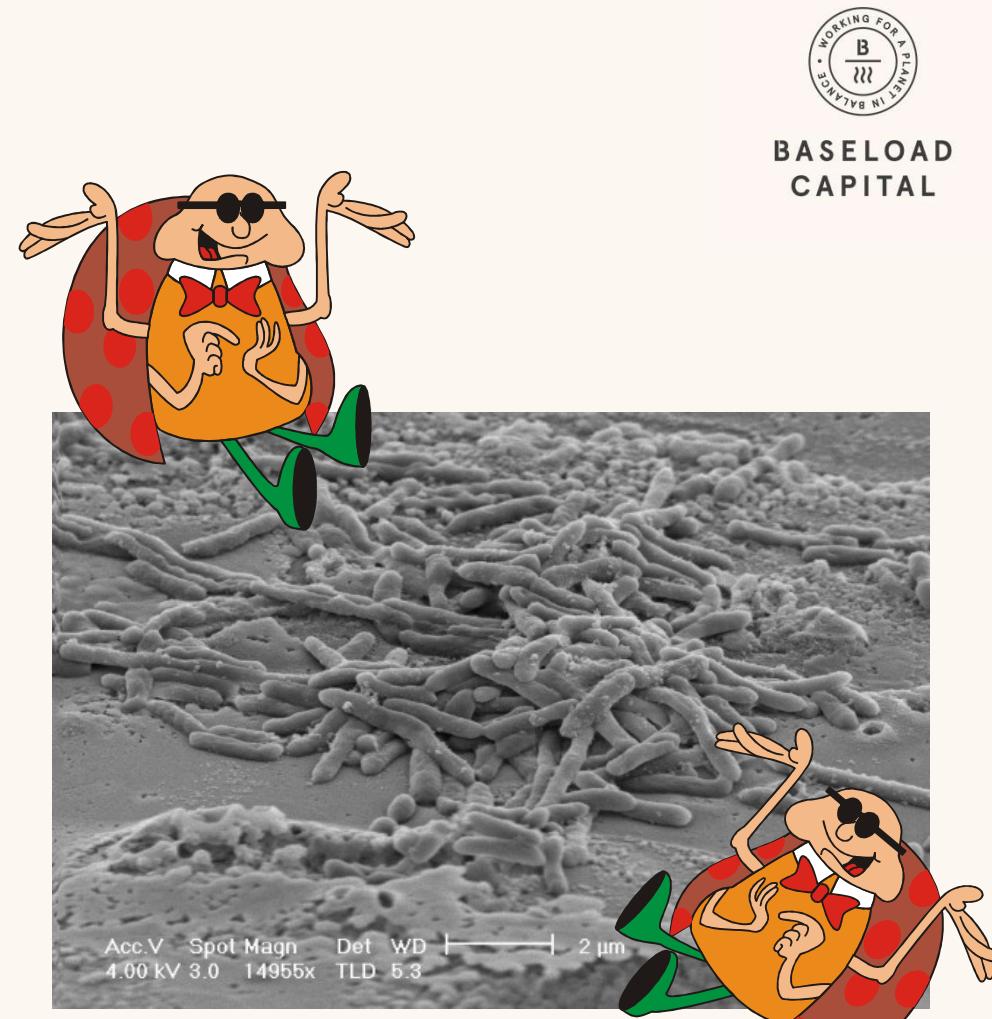
- Easy to meet required temperature
- Controlled optimal water temperature
- Economic principle
- Aquaculture
- Tourism venue
- Utilises geothermal waste heat from adjacent geothermal power station
- Supplies an eco-friendly 7.8 tonnes of prawns annually from 2.75 hectares of ponds utilising "Kiwi ingenuity".

DNZ SCIENCE



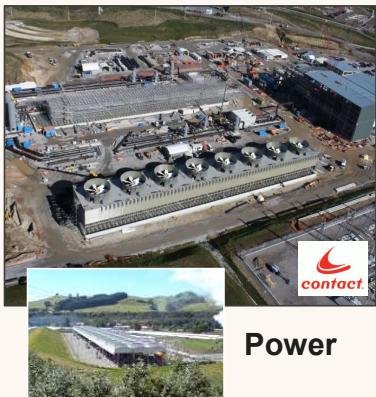
Extremophiles

- Organisms living in extreme environments
- Abilities with promise for biotechnology processes, bio fuels, carbon recycling, medicine, mine waste rehabilitation
- GNS Science has collected >1200 novel extremophiles from NZ thermal features
- GNS 1000 Springs Project

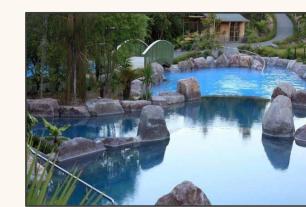
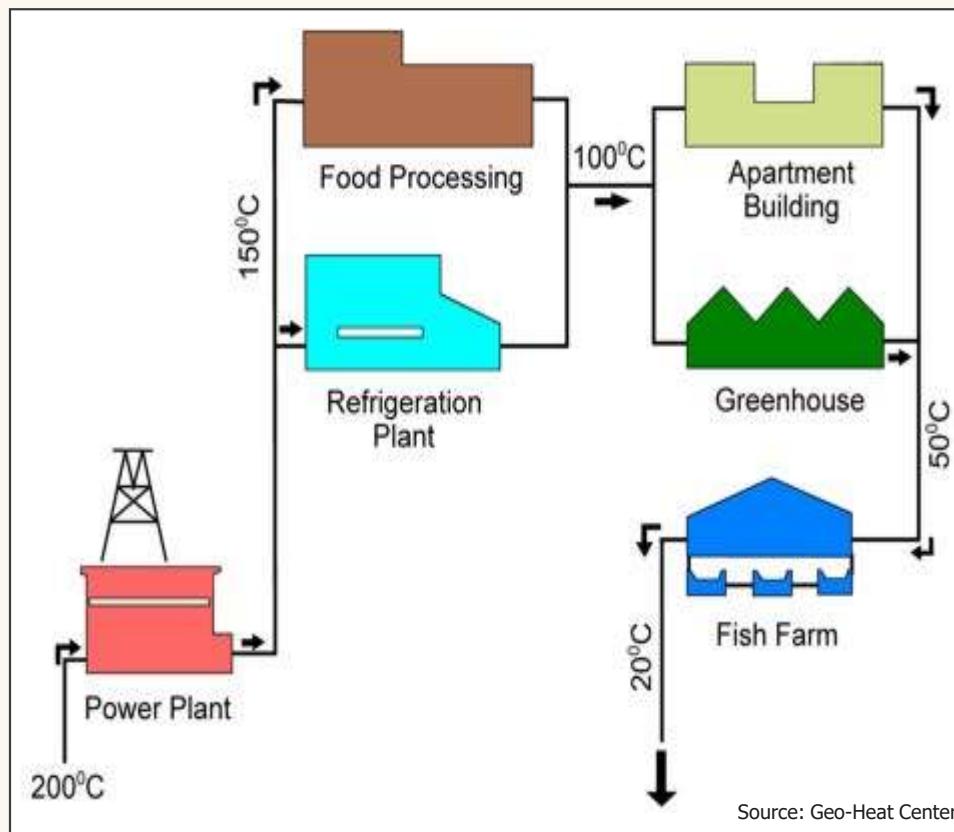


Integrated Cascade Use

Wairakei - Tauhara



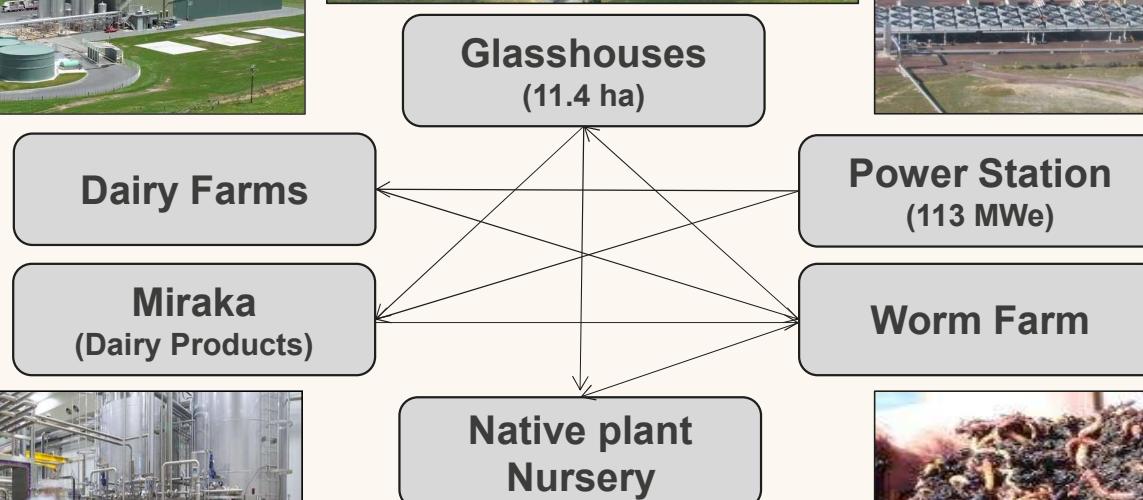
Pine mouldings, building boards



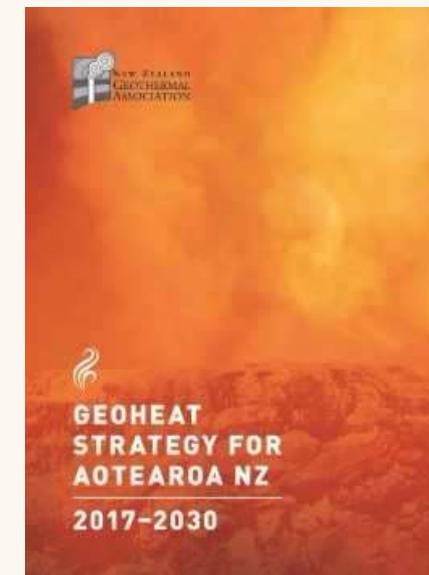
Integrated Use – Tuaropaki Trust



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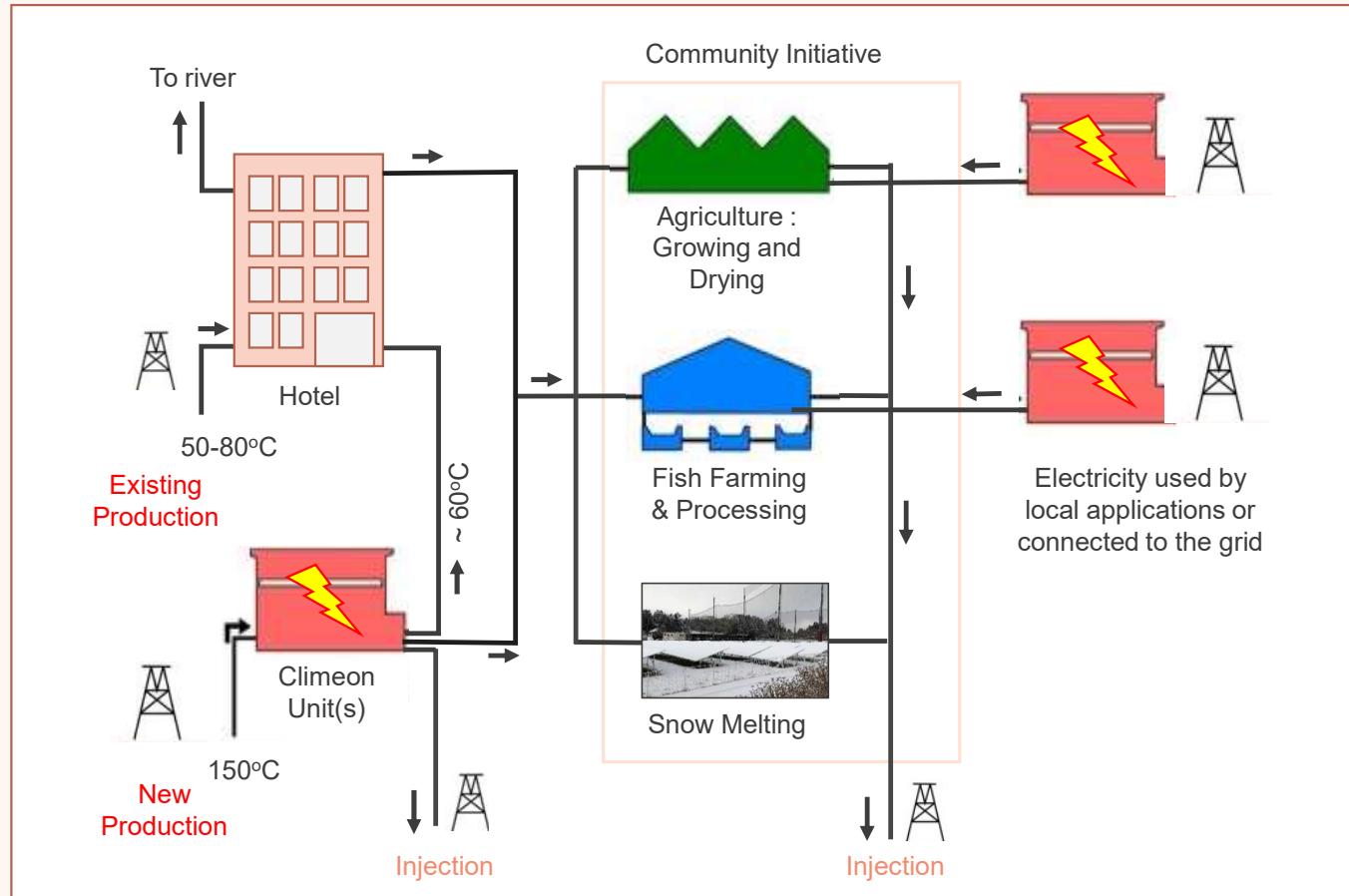
Maori Trust





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Integrated Use – Baseload Power



Midori (60 kWe)



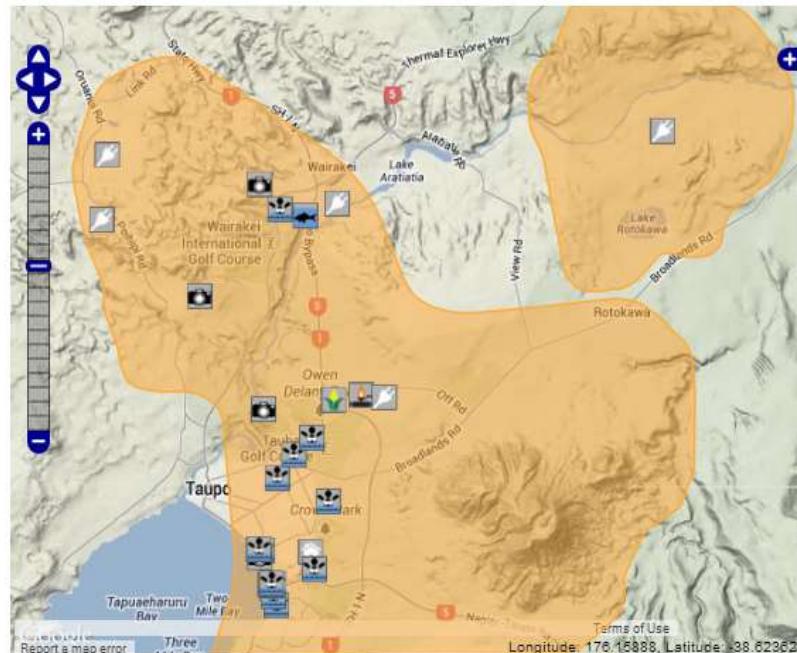
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Geothermal Use Database

-  **Electricity Generation** – Power Stations
-  **Aquaculture** – Rearing fish, eels, prawns in ponds
-  **Agriculture** – Greenhouses, flowers and crops
-  **Bathing** – Balneology, pools and spas
-  **Industrial Process Heat** – Timber / food processing
-  **Tourism** – Commercial / non-commercial
-  **Space Heating** – District heating schemes
-  **Ground-Source Heating** – Commercial / residential

Geothermal use map

<http://data.gns.cri.nz/geothermal/>



Double-click to zoom in, and drag to pan. Hold down the shift key and drag to zoom to a particular region.

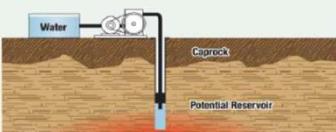
Enhanced Geothermal Systems

How

an Enhanced Geothermal System works

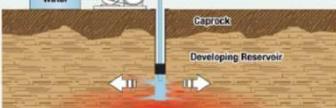
1 Injection Well

An injection well is drilled into hot basement rock that has limited permeability and fluid content. All of this activity occurs considerably below water tables, and at depths greater than 5000 feet. This particular type of geothermal reservoir represents an enormous potential energy resource!



2 Injecting Water

Water is injected at sufficient pressure to ensure fracturing, or open existing fractures within the developing reservoir and hot basement rock.



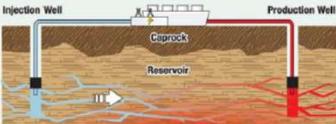
3 Hydro-fracture

Pumping of water is continued to extend fractures and reopen old fractures some distance from the injection wellbore and throughout the developing reservoir and hot basement rock. This is a crucial step in the EGS process.



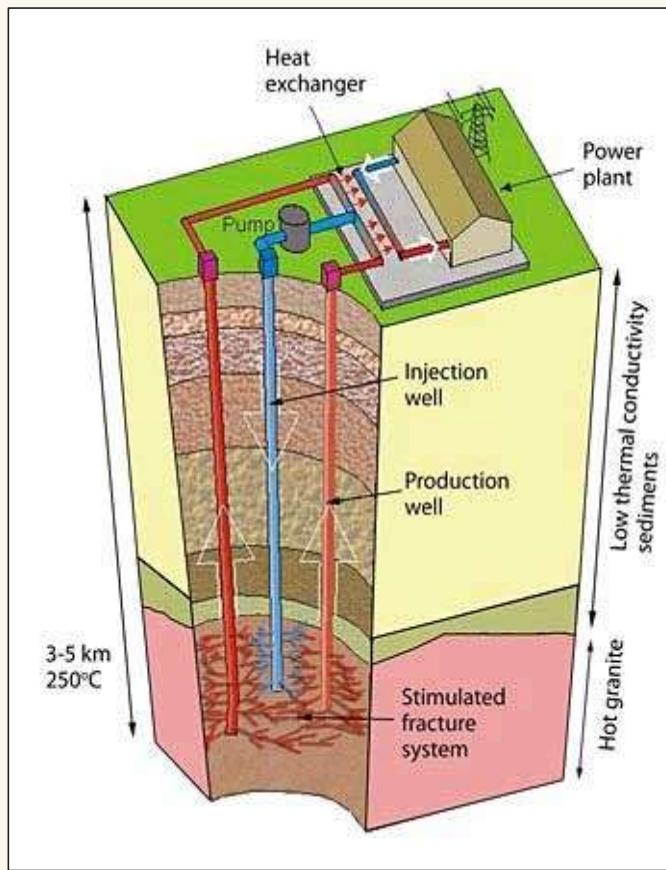
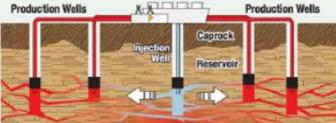
4

A production well is drilled with the intent to intersect the stimulated fracture system created in the previous step, and circulate water to extract the heat from the hot basement rock with improved permeability.



5

Additional production wells are drilled to extract heat from large volumes of hot basement rock to meet power generation requirements. Now a previously unused but large energy resource is available for clean, geothermal power generation.



We aim to enhance or 'engineer' the geothermal reservoir for production of heat over an extended timeframe.

The aim is for greater efficiency and sustainability for extraction of heat energy from hydrothermal fields.

The US DOE goal was to increase geothermal production to 20,000 MWe by 2020. The goal was not achieved, but the aspiration continues.

Hydrogen Technologies



Hydrogen can be used to produce, store and move energy. It is abundant in compound form, but can be separated from water or hydrocarbons.

Hydrogen from hydrocarbons (natural gas, coal) creates carbon emissions. **Green hydrogen** from a renewable energy source have no carbon or carbon monoxide emissions.

Electrolysis (application of an electric current to split water into hydrogen and oxygen) used for hydrogen production.

Most hydrogen technologies require large amounts of expensive electric power and heat, which can pose safety concerns. More efficient technologies are being investigated.

Additional power to compress hydrogen for storage / transportation.

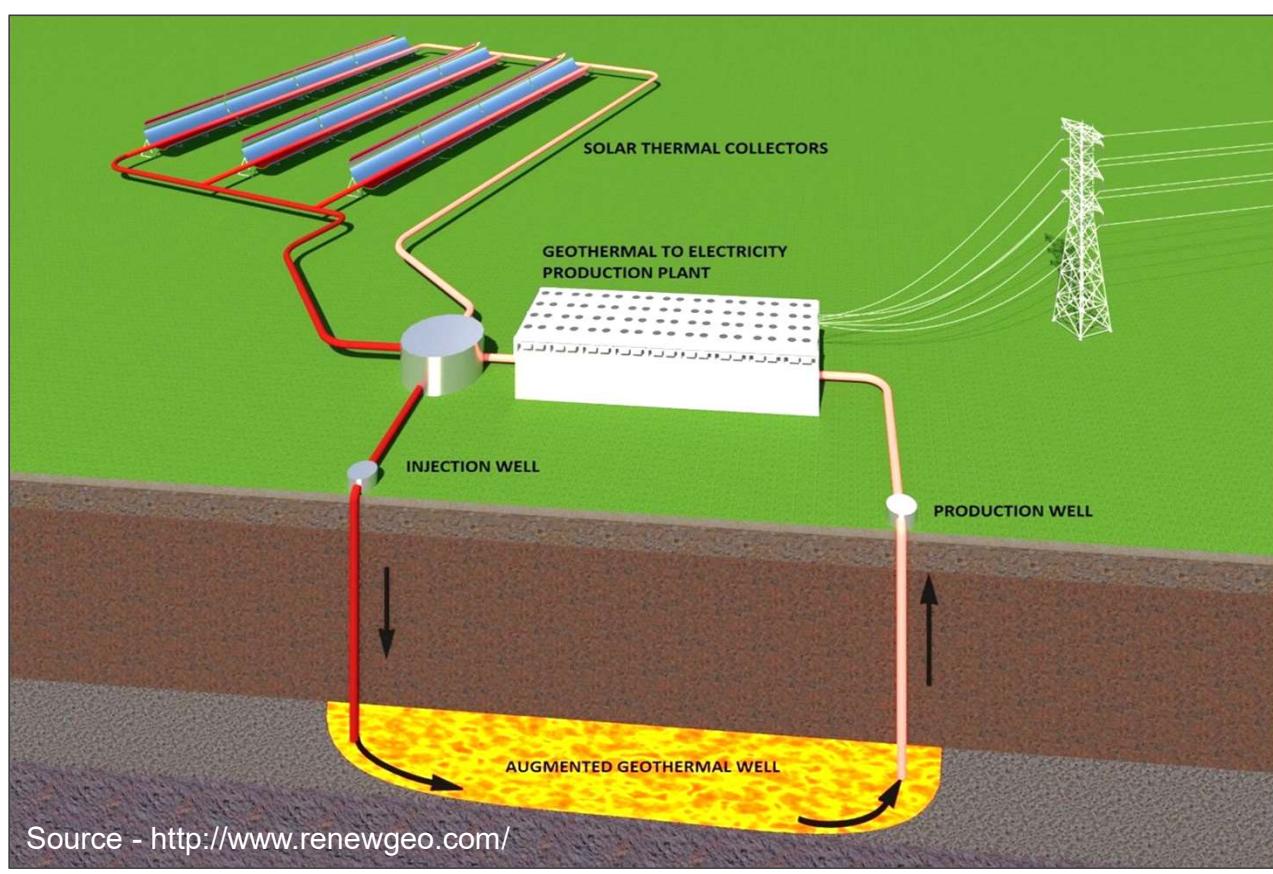


GreenFire Energy project at Coso, funded by California Energy Commission, Shell Oil, Electric Power Research Institute & J-POWER (Japan) – and contributions from industry partners.



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Combined geothermal - solar



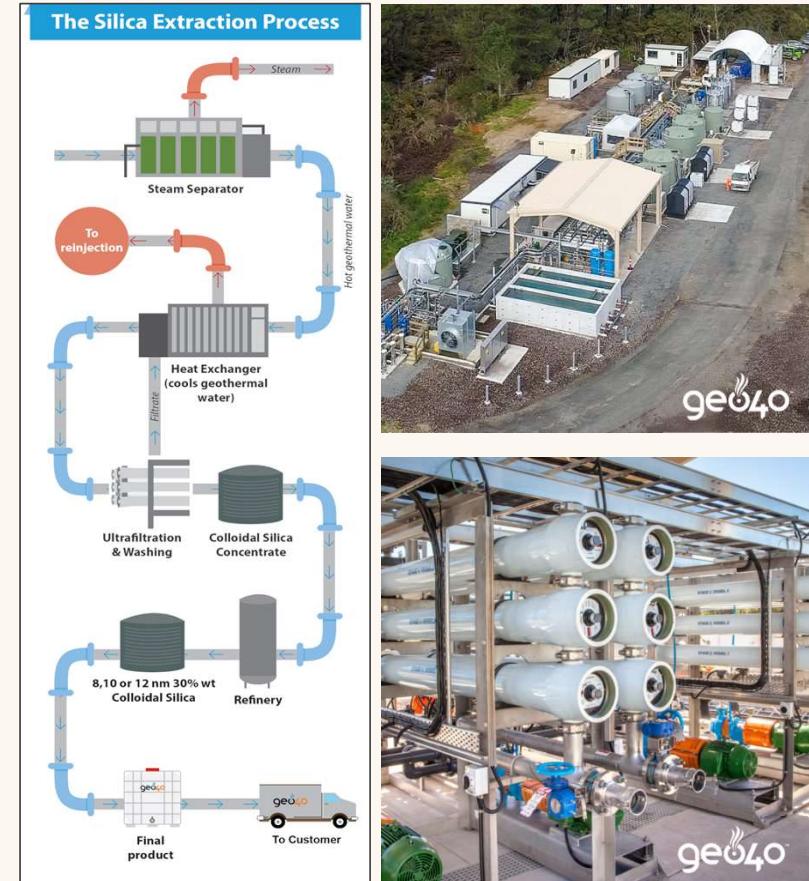
Innovative technologies are being developed (e.g. RenewGeo in the US) to collect solar energy (in the form of heat) that can be injected to create a 'synthetic'/engineered geothermal resource.

The heat is stored underground to create a "thermal battery" that can be tapped and transformed into carbon free electricity.

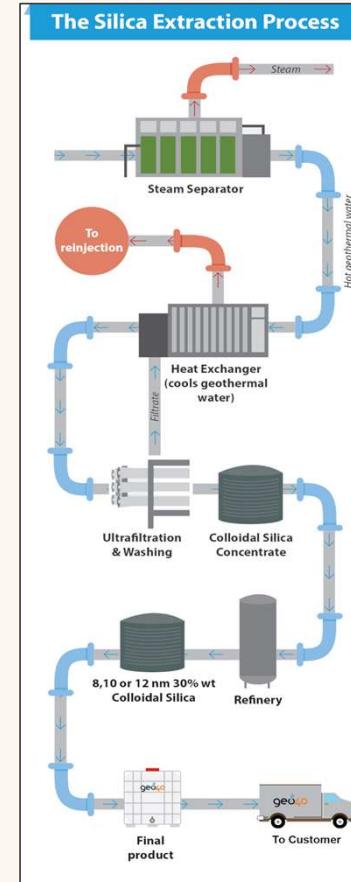
Mineral Extraction - Silica



- Water leaving separation plant is close to silica saturation.
- Geo40 receives the water and cools it to below saturation point
- Silica forms discrete colloidal silica particles of 1nm – 2nm diam.
- Particles are aged and filtered using a continuous ultrafiltration and washing circuit to concentrate the silica to 4wt% solution
- Up to 10,500 tonnes of high grade silica sourced each year



Mineral Extraction - Silica



- Filtrate from the process is low in silica and able to be used for further mineral (lithium ?) extraction
- The filtrate is used to cool incoming geothermal water, then reheated and pumped to injection wells at the edge of the field
- Filtrate water leaving the plant is low on silica and cannot cause scaling in pipework and reinjection wells, saving costs for the power generator.
- Before it gets injected, the hot low silica geothermal water can be used for heating, or further power generation.

Raised Awareness

- Share experience and expertise
 - Early adopters / Established operators / Case Studies



www.gns.cri.nz/earhenergy



Technical Reports



Case Studies

Conclusions



- Geothermal power development driven mainly by economics rather than policy (in NZ, no subsidy, feed-in tariff or other economic support)
- Growth in geothermal electricity capacity linked to demand, enthusiasm for lower emission energy technologies, and fossil-fuelled power plant replacement
- Geothermal electricity sector has focused on efficiency and operational improvements
- Timeline for new geothermal power projects typically 5-6 years
- Spectrum of direct geothermal uses with community and regional economic impact, and innovative technologies / new applications (e.g. hydrogen, integrated solar-geothermal etc)

