Geothermal: Power of Hot Water Utilisation of the Earth's Heat Energy

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Introducing …

Head Office

Local Holding Company

BASELOAD CAPITAL

Capital & structure

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

BASELOAD POWER

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 ?

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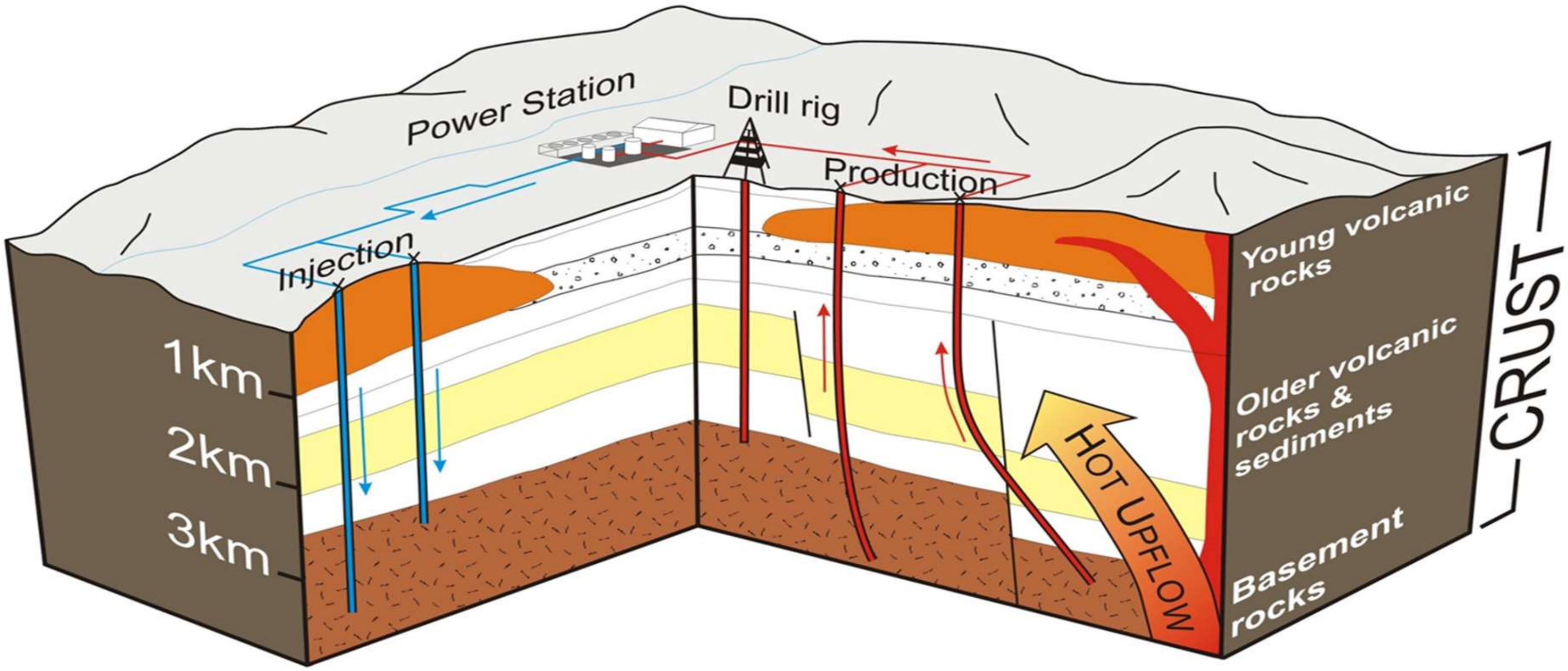

Geothermal System :
A transfer of heat energy to the earth's surface

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

Development Potential ?

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Is a geothermal project possible ?

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?

- 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.

Enabler of Economic Development

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- 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

WORKING FOR A PLANET IN BALANCE
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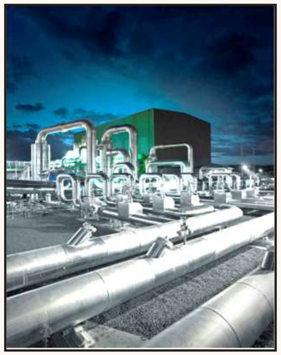

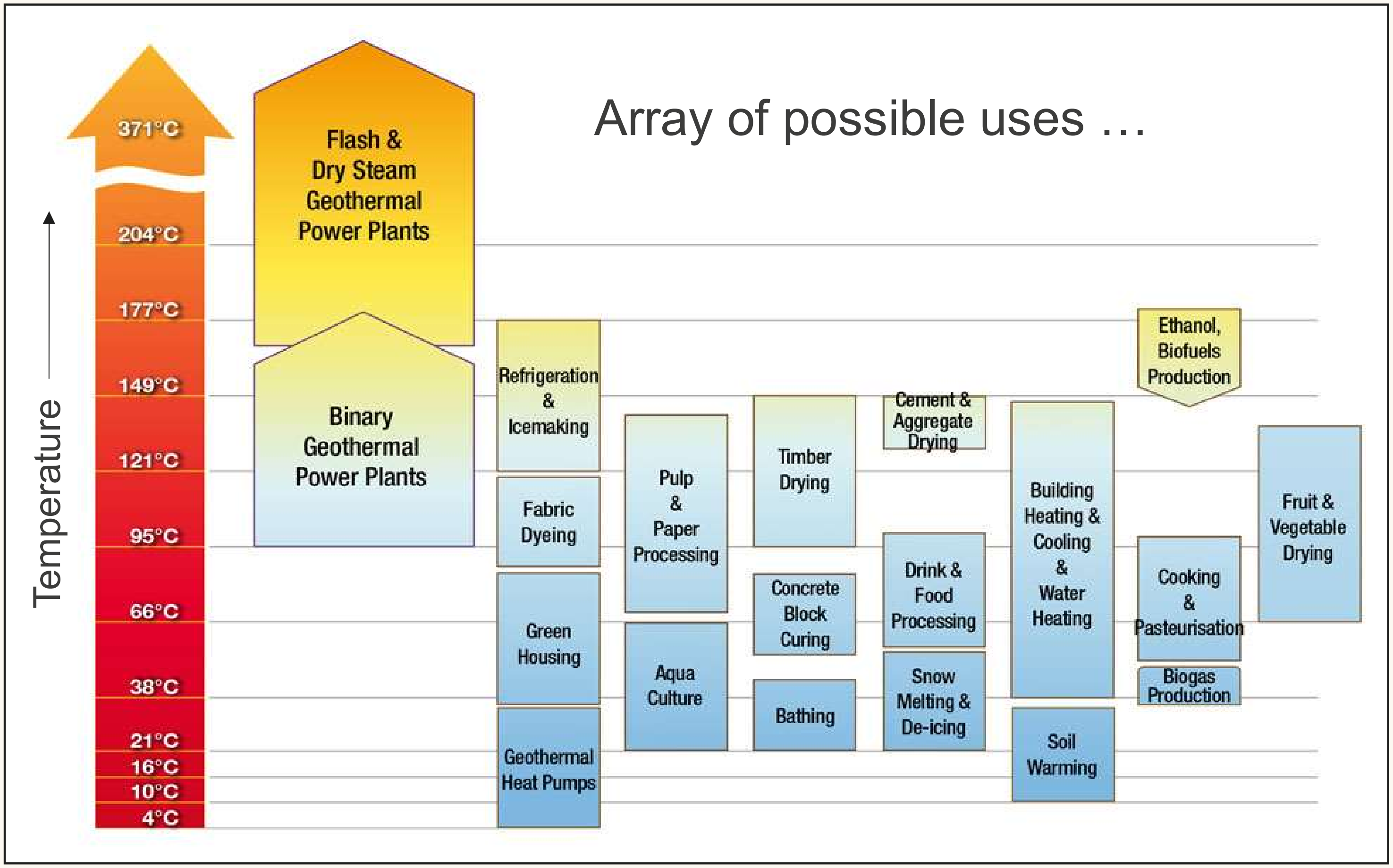



Geoscience = Lower Risk

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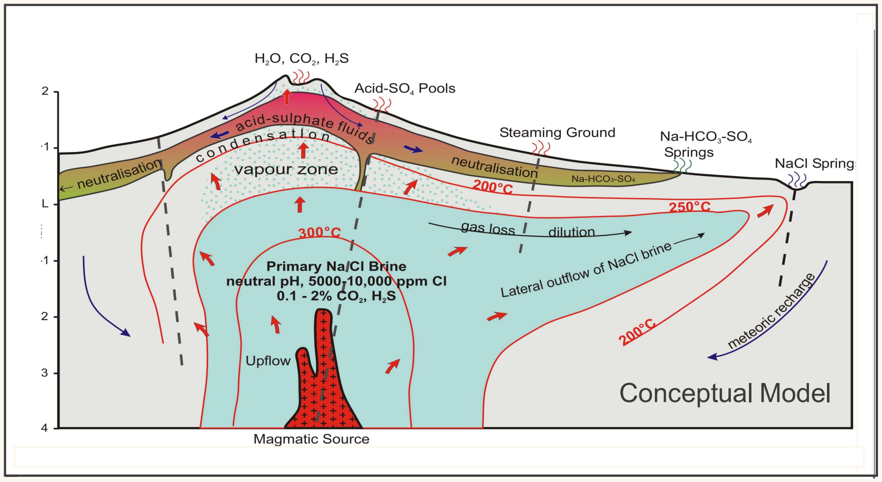
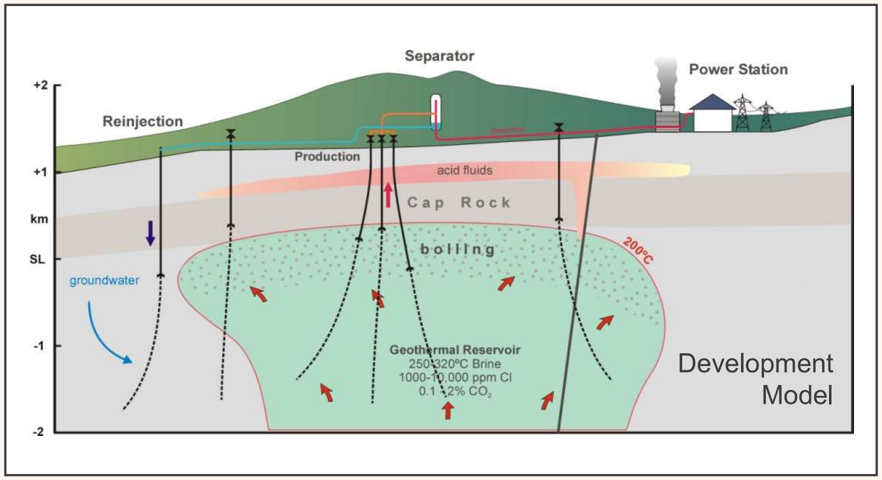
Integrate all resource data to understand the system

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

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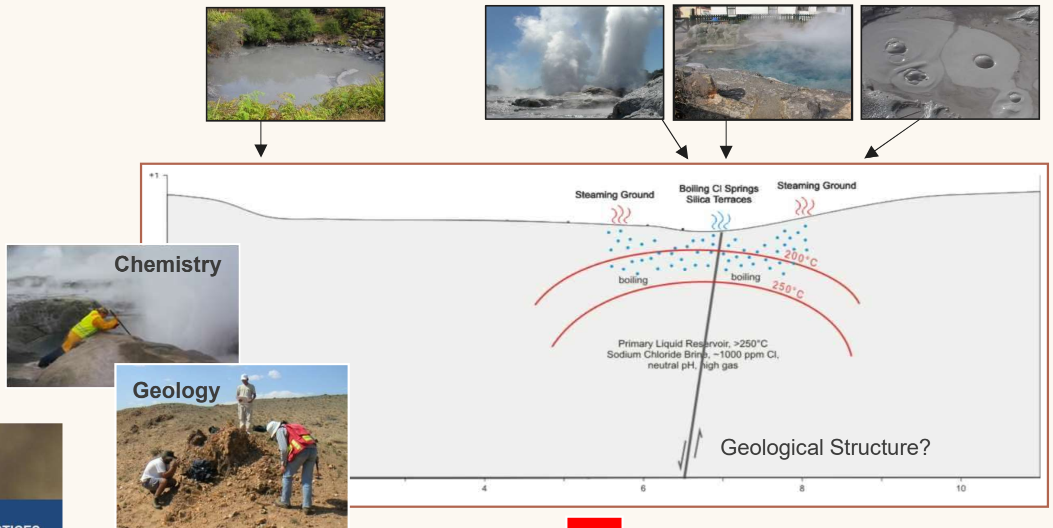
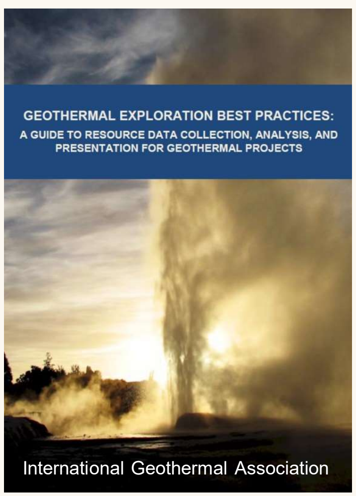
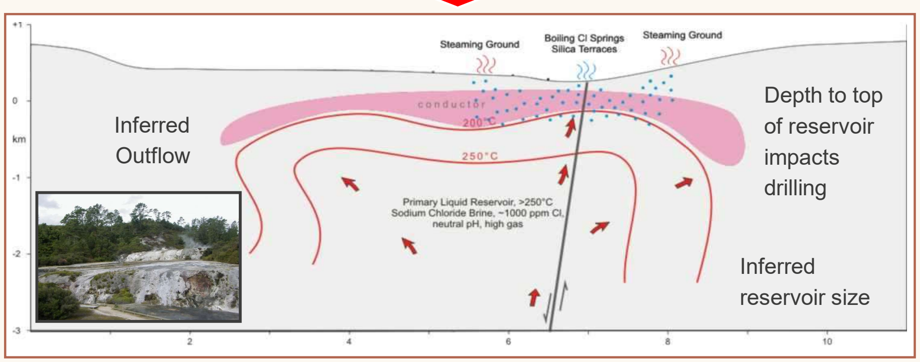


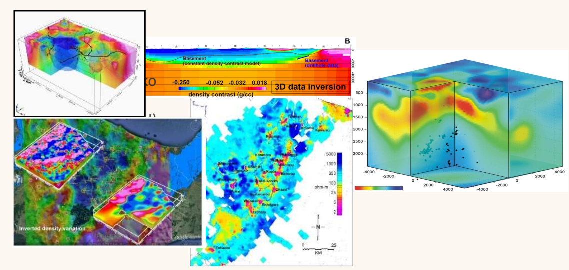




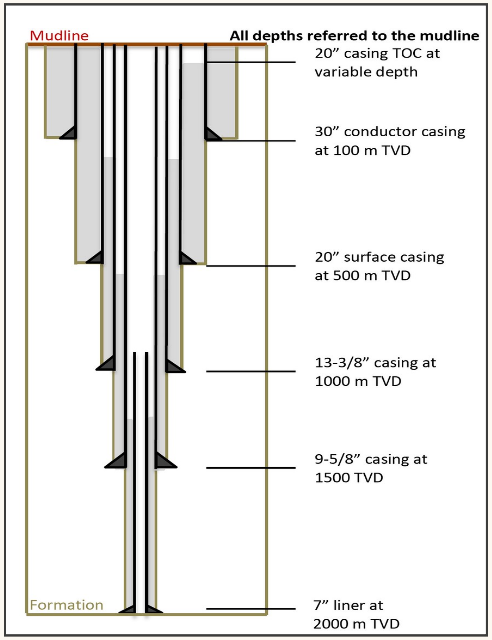
Characterise the system

- 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



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 …

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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

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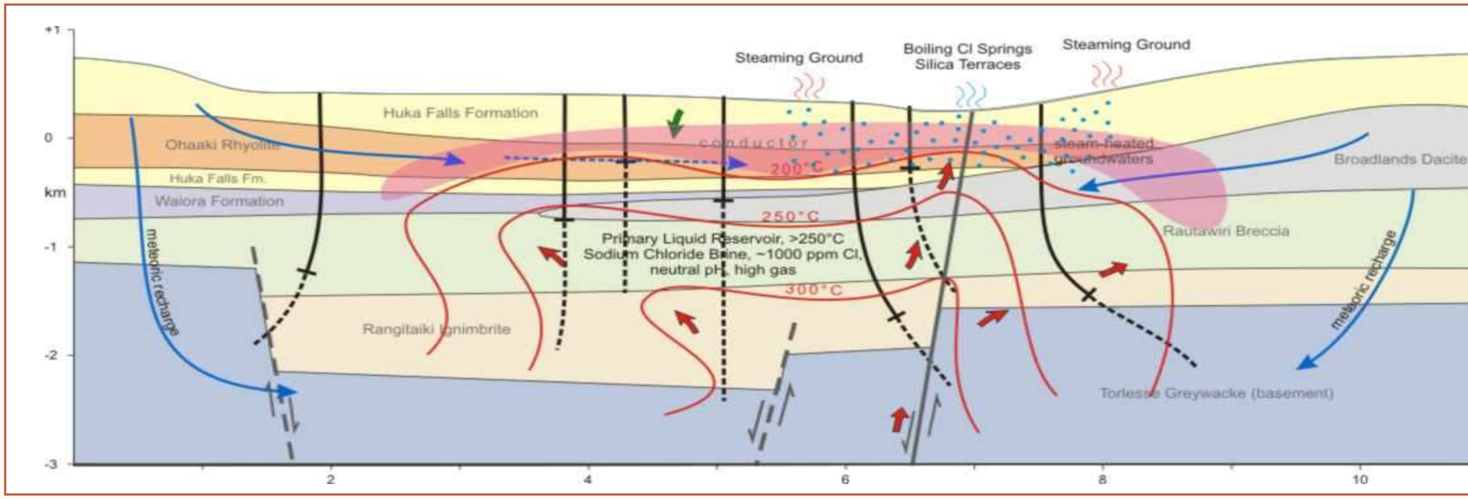
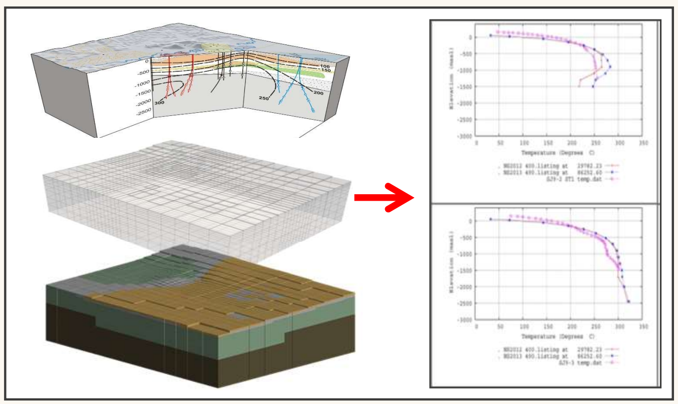


- Confirmed reservoir
  - temperature, pressure fluid chemistry
  - geology and permeability
- Well productivity measured
- Hazards Assessed
  - subsidence, seismicity, impact on hot springs and thermal vegetation



- Mathematical model embodies assumed reservoir parameters. Calibrated against observed "natural state"
- Input heat & fluid : match with observed well temperature / pressure
- Test development scenarios (impact on environment, resource and other users)

Data from well testing

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Resource Management

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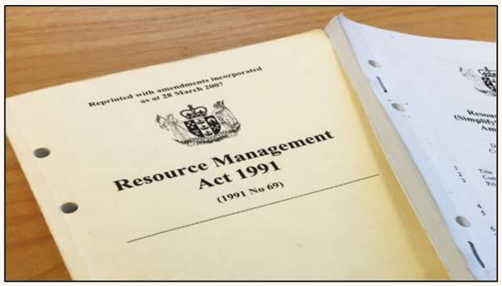
Management Framework

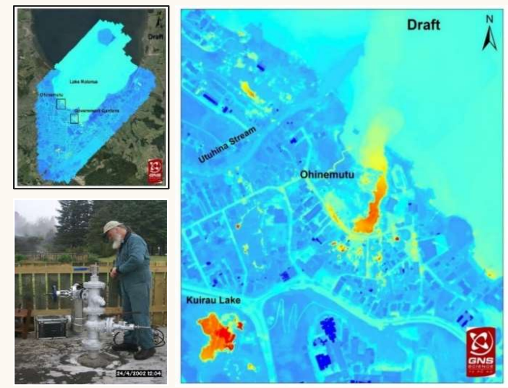


- Resource Management Act (1991)
- Local Government focus
- Public / Iwi Consultation

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

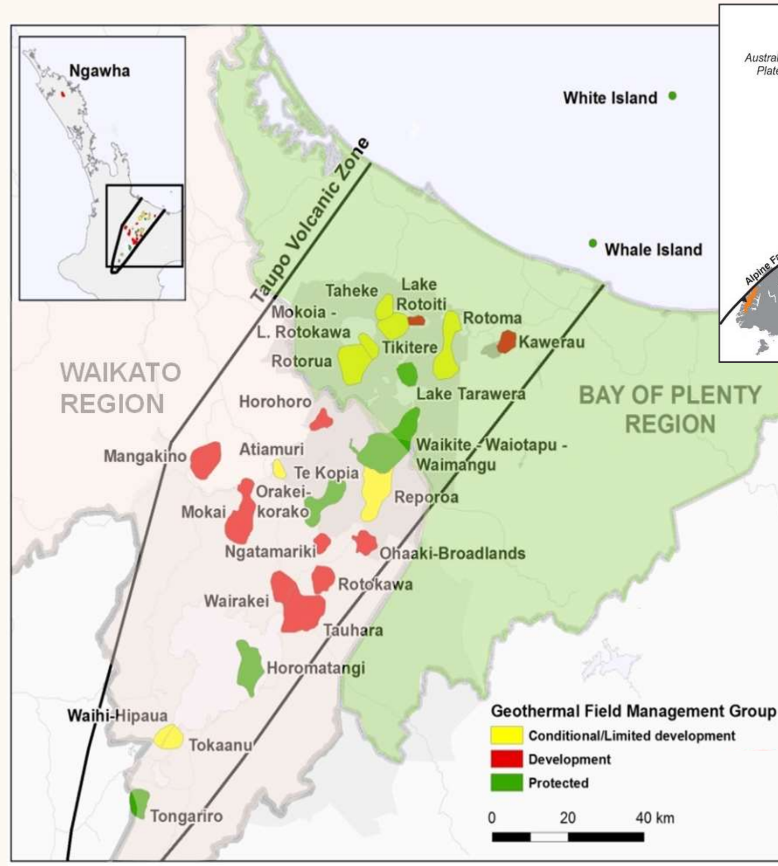
- Classification of systems for different uses
- Confer consented allocation
- A ‘whole system’ system management plan
- Balance multiple values, uses and users

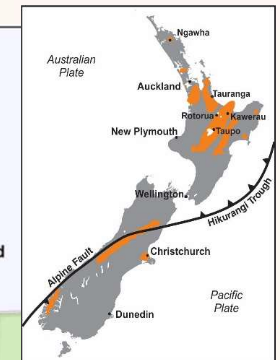
Informed by science <u>and</u> community values

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

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

SOCIAL ACCEPTANCE OF RENEWABLE ELECTRICITY DEVELOPMENTS IN NEW ZEALAND

A report for the Energy Efficiency and Conservation Authority

Janet Stephenson and Maria Ioannou

Centre for the Study of Agriculture, Food and Environment
University of Otago

November 2010

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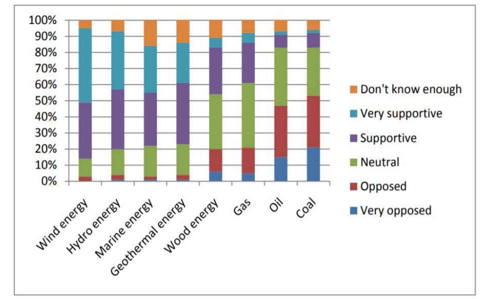
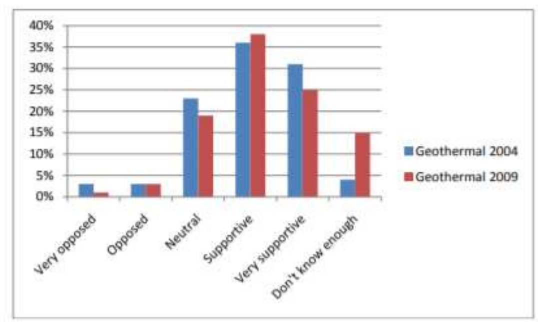
Factors affecting acceptance : (i) limited knowledge about technology, (ii) unfavourable media coverage, (iii) uncertainty about reversibility and predictability of adverse effects on hot springs, (iv) concerns of water use and seismic activity, (v) low levels of community participation and project consultation.

	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

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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

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

What could go wrong ?

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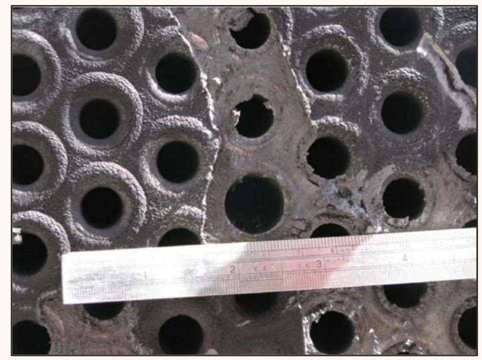
Silica deposit in geothermal fluid line (left) and steam turbine (below left / right)

…on rotating blades

on diaphragm blades



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

Corrosion on the diaphragm blades of a geothermal steam turbine

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	Camoflage 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

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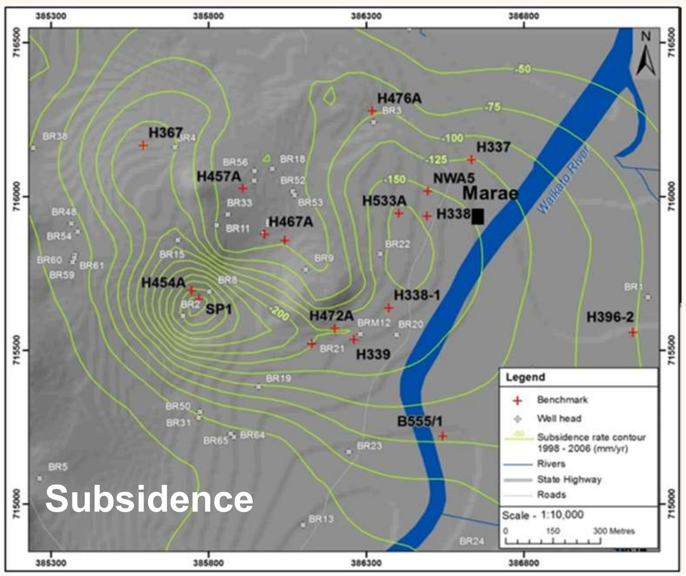
Wairakei Geothermal Field



Subsidence

Thermal Decline
Spa Park / Otumukeke Stream

Increased thermal activity, Taupo

Application of Geothermal Energy

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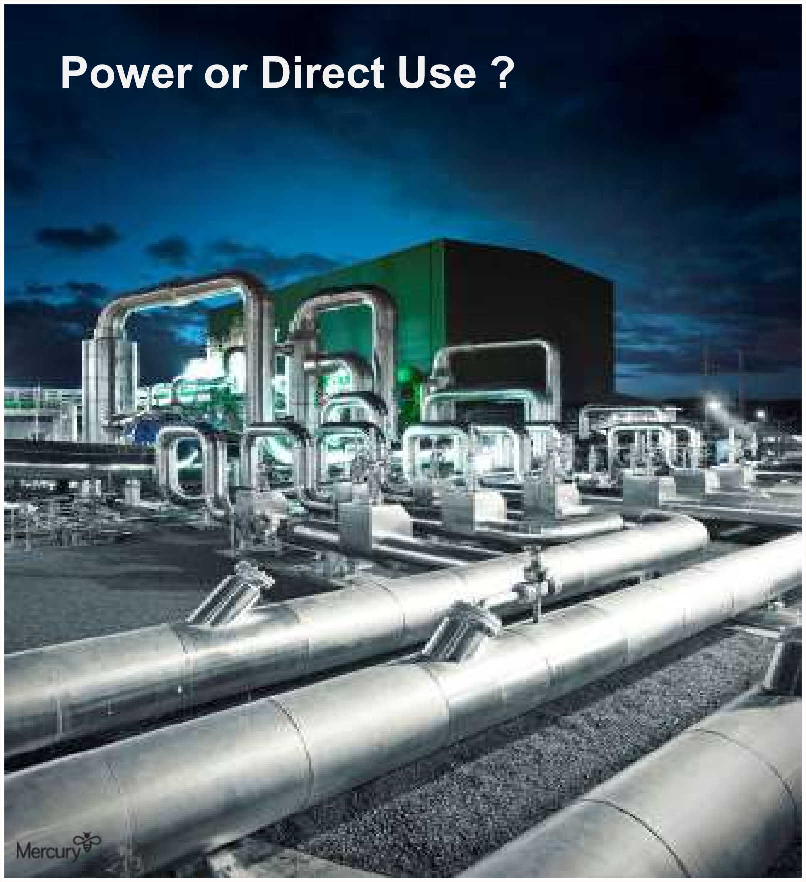

Examples of Power Generation

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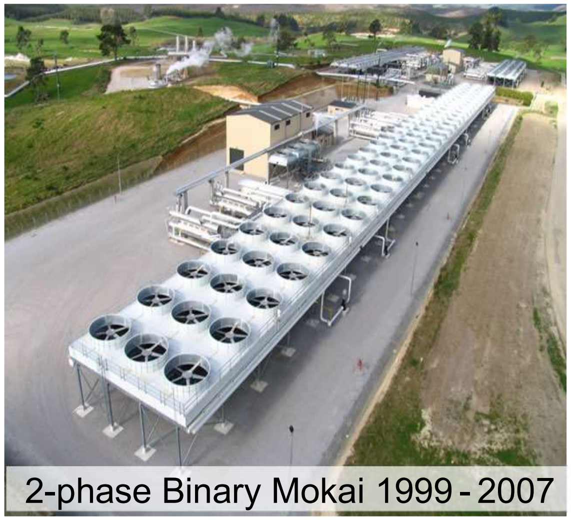
Steam Condensing
Nga Awa Purua / Rotokawa 2010

Mercury

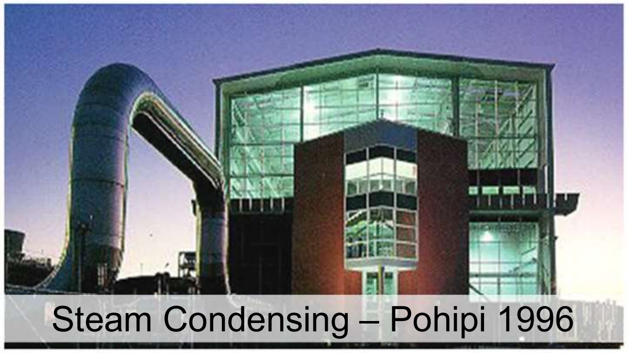


2-phase Binary Mokai 1999 - 2007

2-phase Binary - Ngatamariki 2013

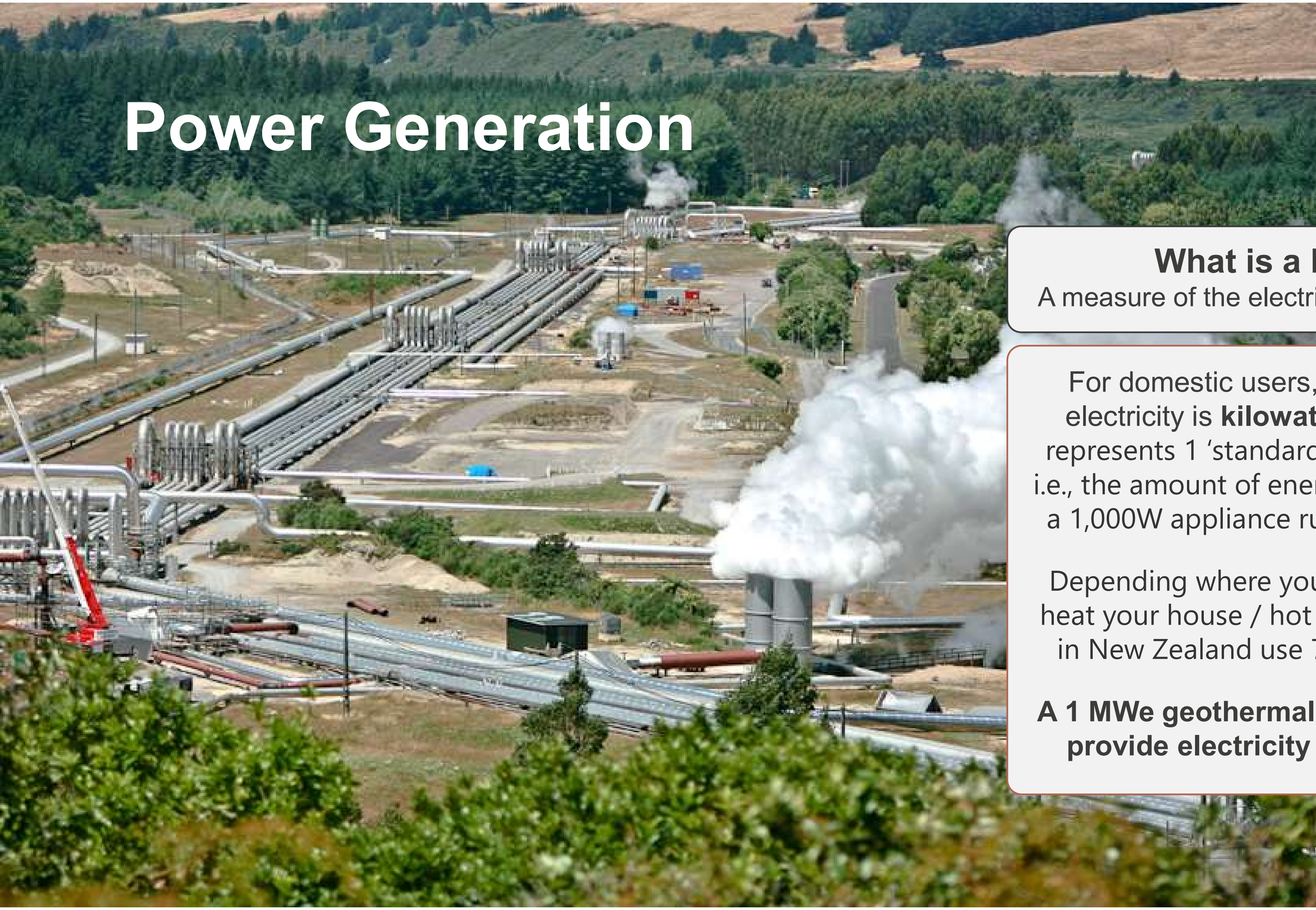
Contact

Wairakei Flash (1958) / Binary (2005)



Steam Condensing – Pohipi 1996

Power Generation



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What is a MWe* ?

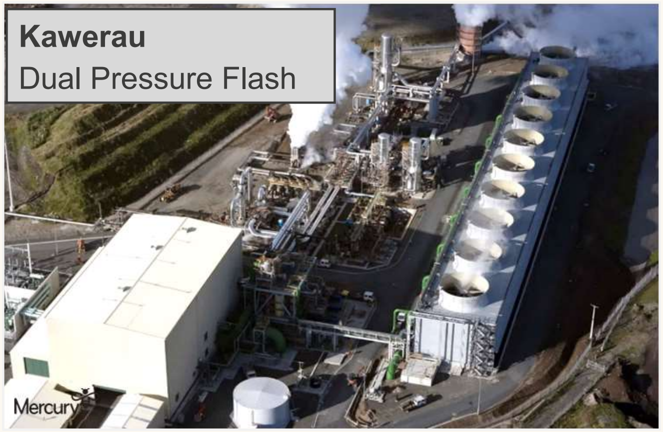
A measure of the electricity output of a plant

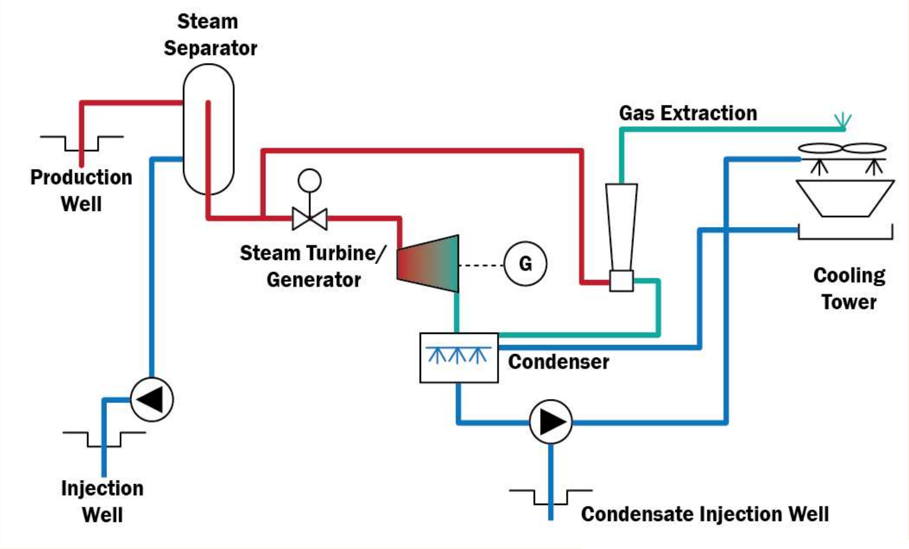
For domestic users, the basic unit of electricity is **kilowatt hour** (kWh) – it represents 1 'standard unit' of electricity. i.e., the amount of energy used if you kept a 1,000W appliance running for an hour.

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

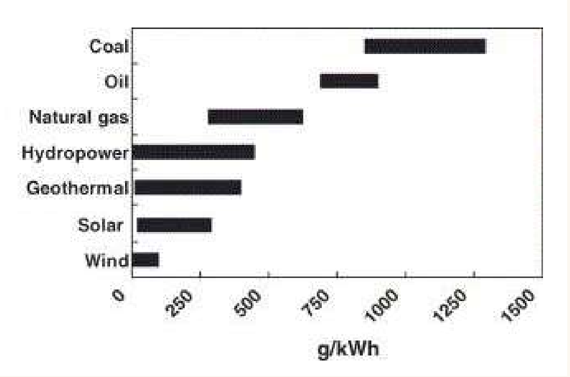
A 1 MWe geothermal plant expected to provide electricity for ~800 homes

Flash-Type Power Plants





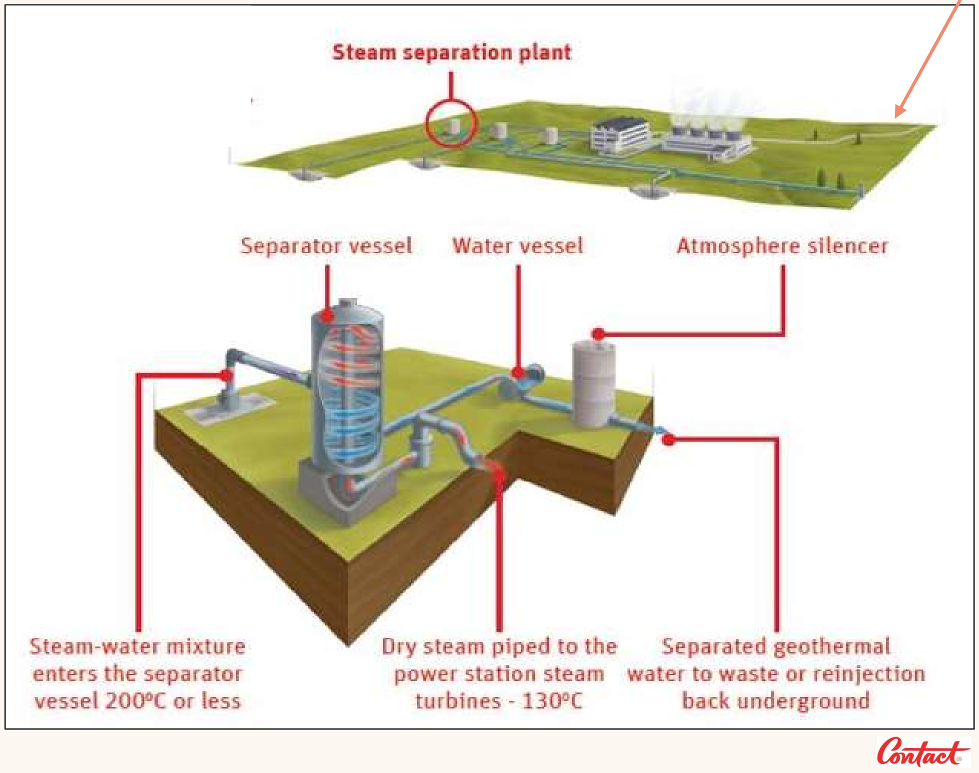
Typically, geothermal power stations emit 5% of CO_2 and 1% of SO_2 emissions of comparable sized coal-fired plants.



Steamfield Design

Separator Plant

Production/ Injection Well



Monitoring Well

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Wairakei A, B, Binary Plants

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Bioreactor

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

Te Mihi Power Plant (166 MWe gross, 2014)

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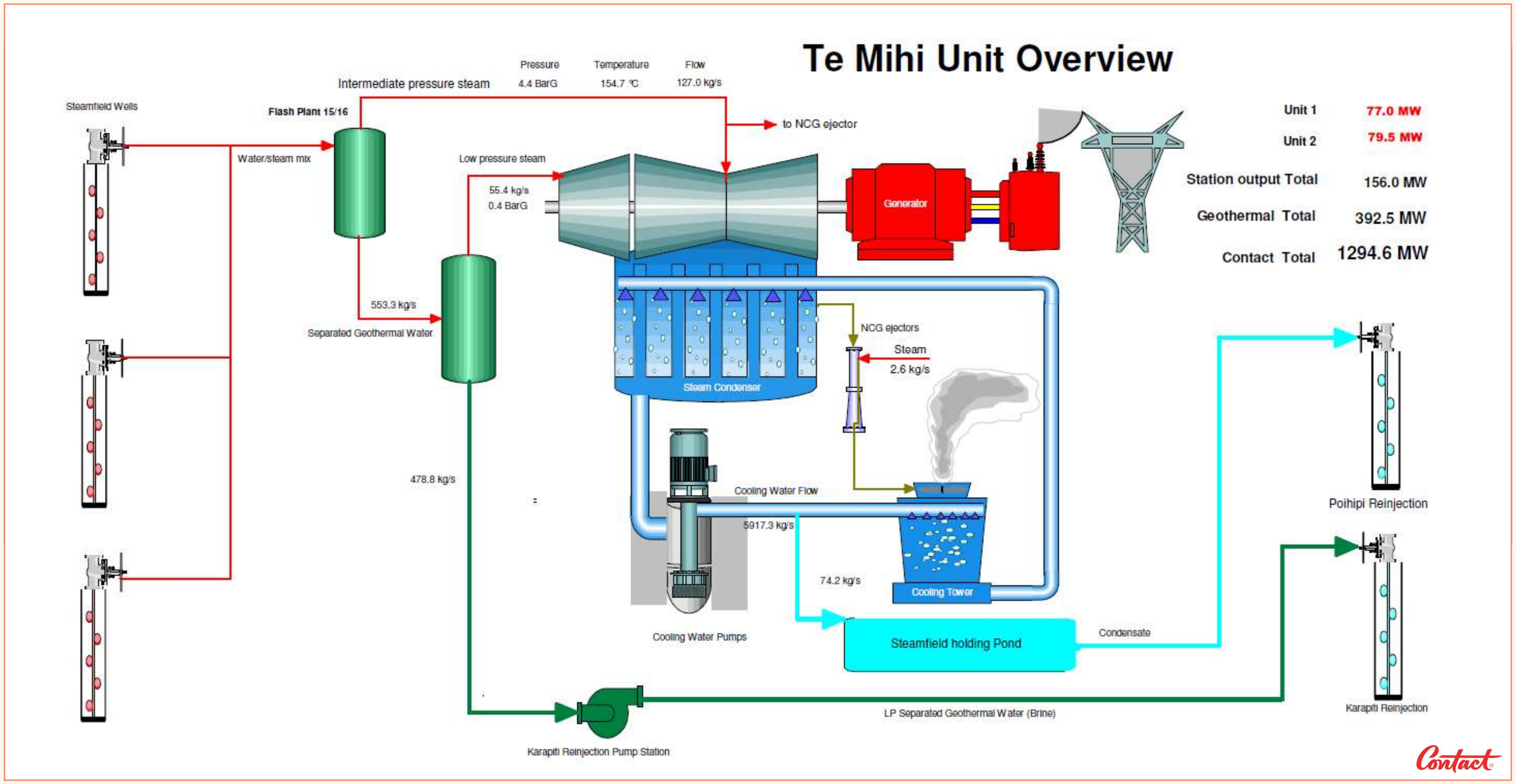
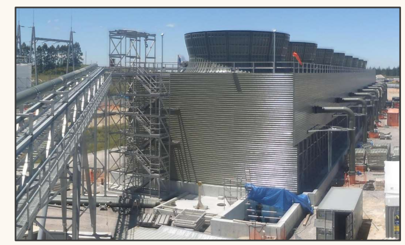


Turbine Hall



Cooling Towers

Steam Turbines

Binary Power Plants

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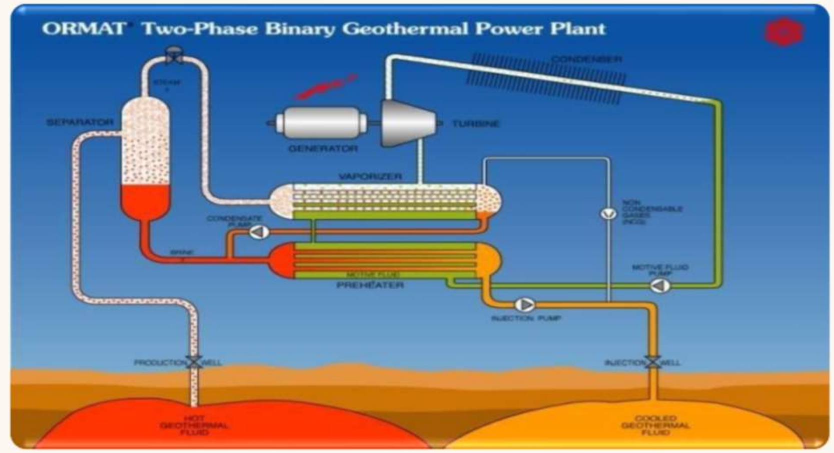

Ngatamariki 82 MWe Geothermal Power Station
(Mercury NZ / Tauhara North No.2 Trust)

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

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

Climeon Heat Power

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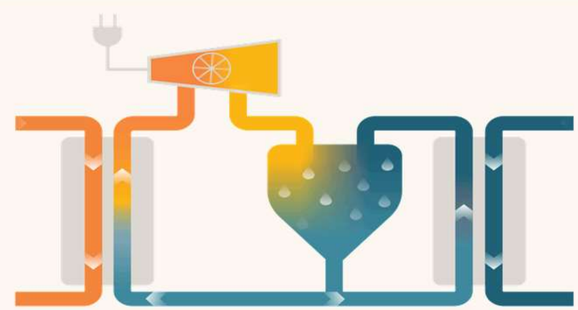
Using the principles of an Organic Rankine Cycle, at low pressure, the Climeon system exploits the temperature difference between hot and cold water to generate electricity

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



Examples of Direct Use

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Benefits of Direct Use

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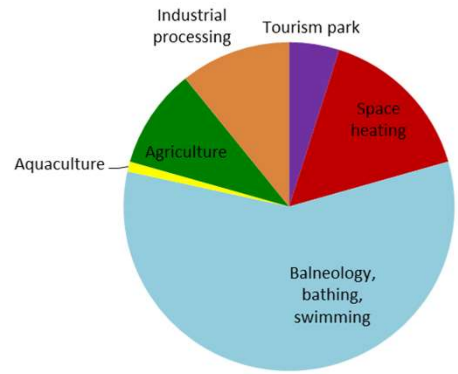
- Indigenous, reliable energy supply
- Utilise low temperatures resources, in potential off-grid locations
- High thermal efficiency
- Minimum start-up time
- Impacts regional development
- Minimal environmental footprint
- Sustainable resource utilisation
- Low carbon footprint

  Reduction in imported fuel
- Can use conventional water well drilling

New Zealand Direct Use Applications

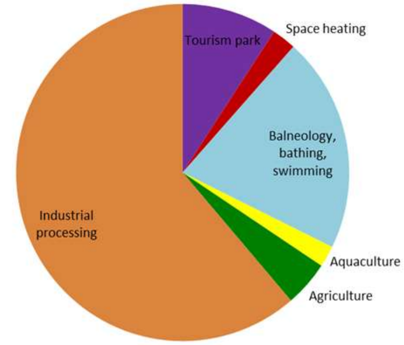
Bathing most common



Energy Use

Processing includes :

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



Bathing and Tourism

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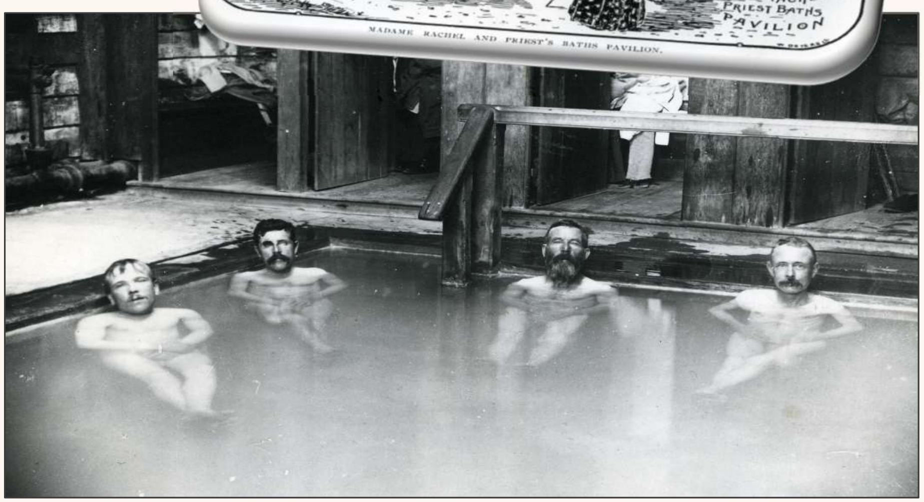
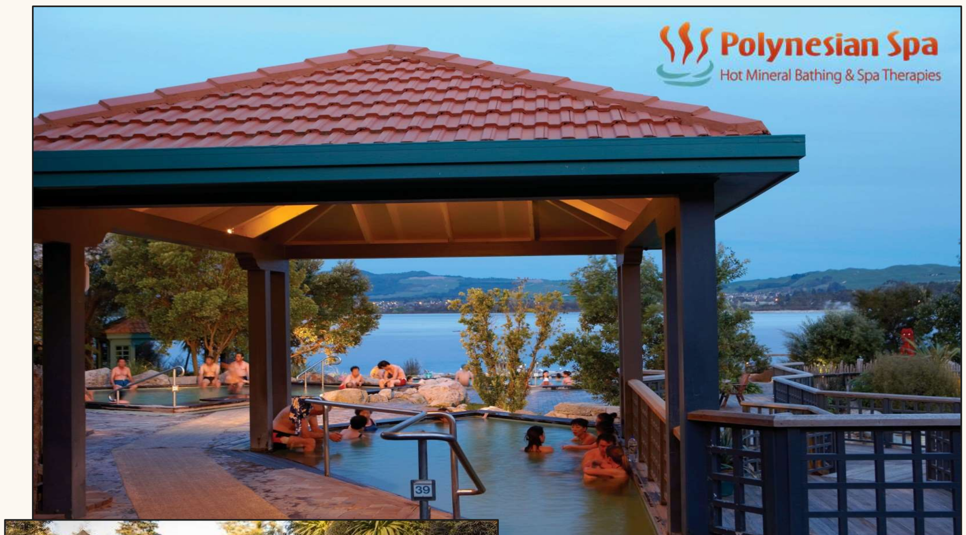
Rotorua Geothermal Field





Ground-Sourced Heat Pumps

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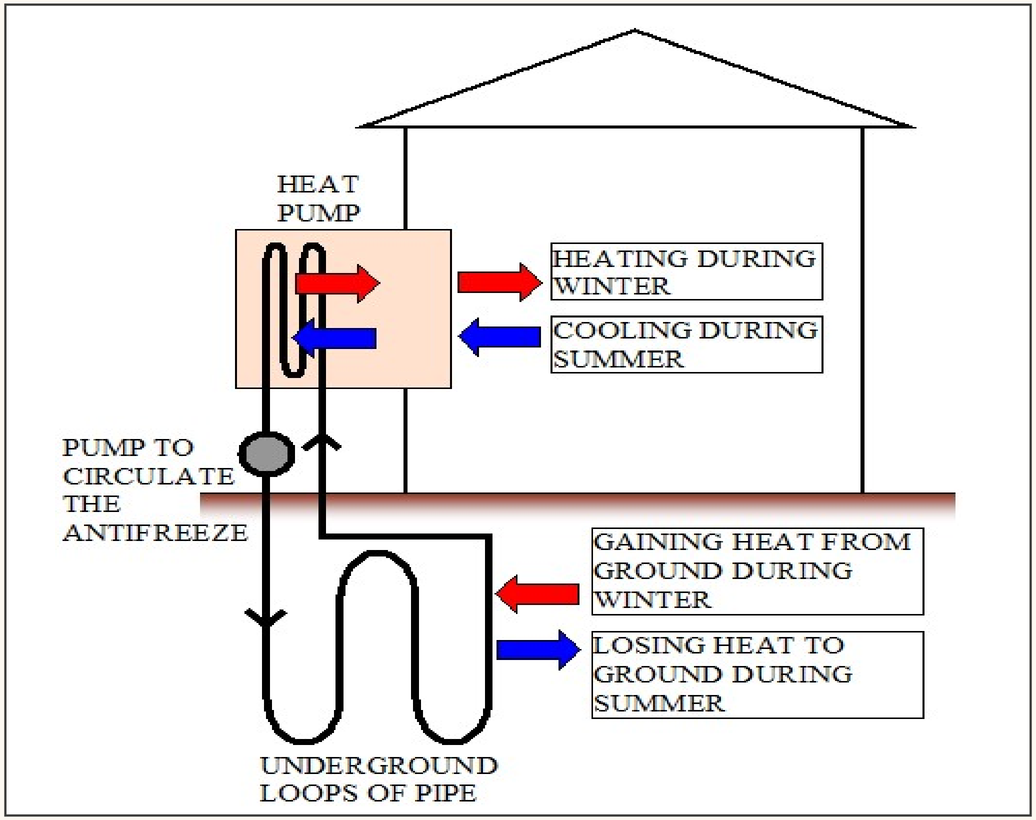
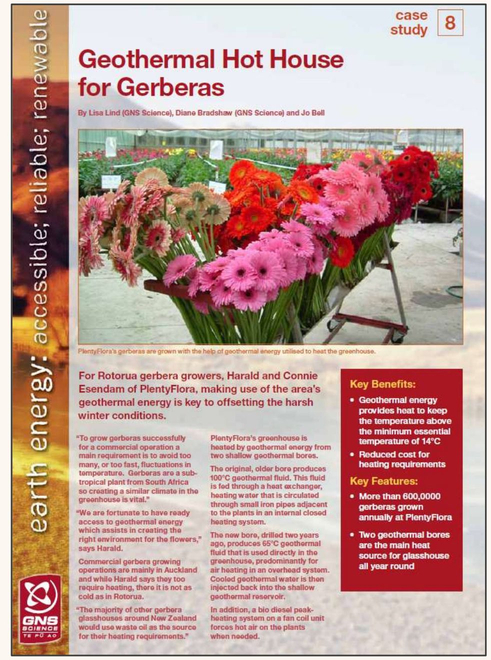


Photo: Ingramswaterandair.com

Photo: https://greenerideal.com

PlentyFlora

Horohoro – Geothermally Heated Glasshouse


earth energy: accessible; reliable; renewable

case study 8

Geothermal Hot House for Gerberas

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

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

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

"To grow gerberas successfully for a commercial operation a main requirement is to avoid too many, or too fast, fluctuations in temperature. Gerberas are a sub-tropical plant from South Africa so creating a similar climate in the greenhouse is vital."

"We are fortunate to have ready access to geothermal energy which assists in creating the right environment for the flowers," says Harald.

Commercial gerbera growing operations are mainly in Auckland and while Harald says they too require heating, there it 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 fed through a heat exchanger, heating water that is circulated through small iron pipes adjacent to the plants in an internal closed heating system.

The new bore, drilled two years ago, produces 65°C geothermal fluid that is used directly in the greenhouse, predominantly for air heating in an overhead system. 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 essential temperature of 14°C
- Reduced cost for heating requirements

Key Features:

- More than 600,0000 gerberas grown annually at PlentyFlora
- Two geothermal bores are the main heat source for glasshouse all year round

GNS SCIENCE TE PŪ AO

Honey Processing - Arataki

Waiotapu Geothermal Field

Kiln Drying – Thermal Kilns

Ohaaki Geothermal Field – “Thermally enhanced firewood”

Industrial Direct Heat Applications

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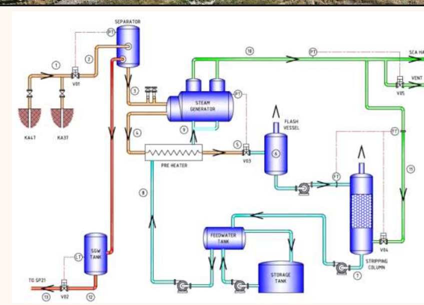
Tenon – Wood Solutions to the World

Wairakei - Tauhara

Norske Skog

Kawerau



MIRAKA – nurturing our world

Mokai

Timber and Pulp Processing

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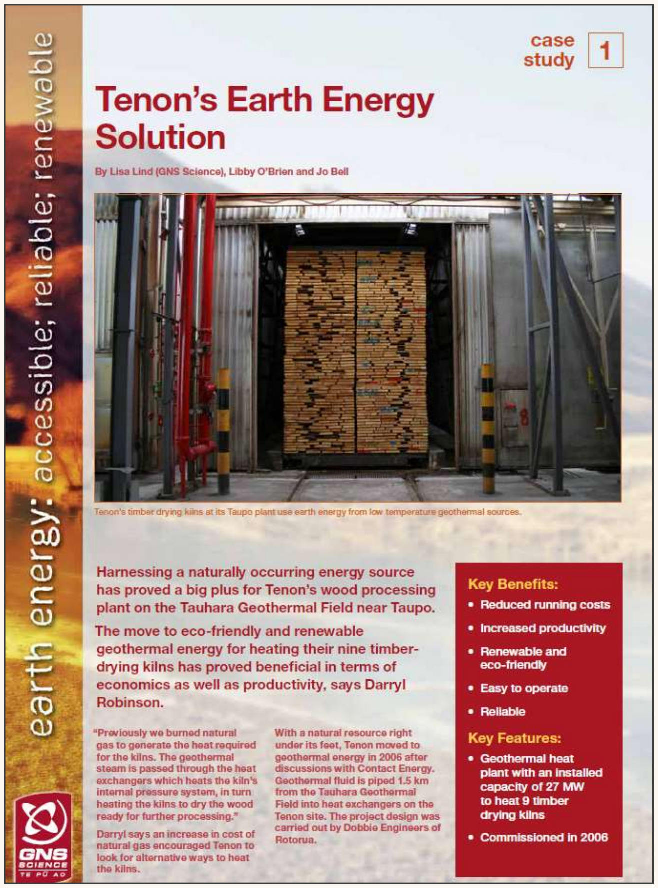

earth energy: accessible; reliable; renewable

case study 1

Tenon's Earth Energy Solution

By Lisa Lind (GNS Science), Libby O'Brien and Jo Bell

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 geothermal steam 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.

With a natural resource right under its feet, Tenon moved to geothermal energy in 2006 after discussions with Contact Energy. Geothermal fluid is piped 1.5 km from the Tauhara Geothermal Field into heat exchangers on the Tenon site. The project design was carried out by Dobbie Engineers of Rotorua.

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

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Tauhara Geothermal Field - 30 MWt Direct Heat

Heat Exchanger (Delivery)

Heat Plant

Heat Plant (during construction)

Timber and Pulp Processing

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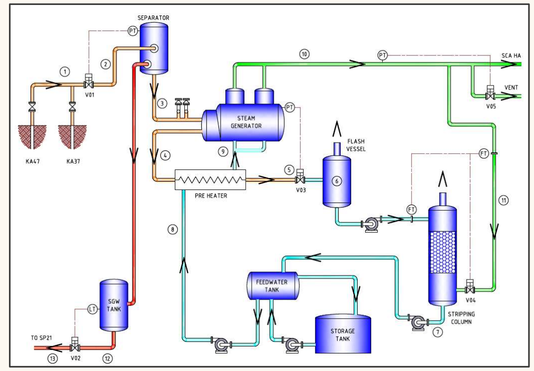
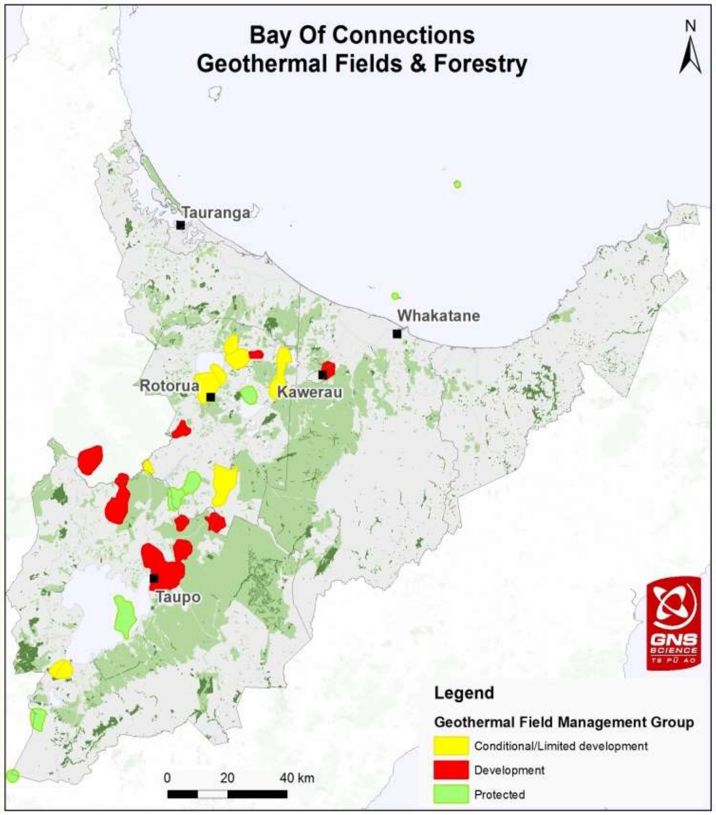
World's largest geothermal heat user (>4 PJ / annum)



Clean steam plant

Co-Location: Geothermal / Forestry



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

Agriculture

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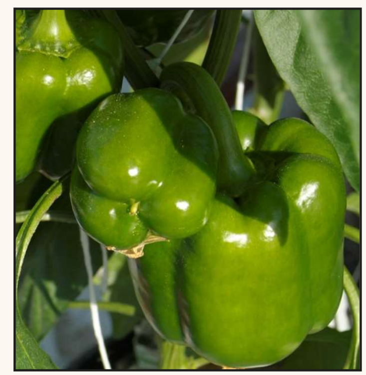
Mokai Geothermal Field – 11ha Geothermally Heated Glasshouse



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

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Aquiculture

BASELOAD CAPITAL

Wairakei Geothermal Field – Huka Prawn Park

earth energy: accessible; reliable; renewable

case study 4

Geothermal Energy Helps to Grow Prawns

By Lisa Lind (GNS Science), Libby O'Brien and Jo Bell

Malaysian Freshwater Prawns (*macrobrachium rosenbergii*) are farmed in 27°C–31°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 Huka Prawn Park, near Taupo, was built in 1987. Current managing partner, Richard Klein, took over the project in 1991 and began to turn the park into an aquaculture tourism venture.

"Contact Energy owns the Wairakei Geothermal Power Station situated next door to the park, and we've been able to make an arrangement to make use of discharge water from the station. The discharge from the Ormat Binary Plant sits between 96°C to 98°C with a flow rate of 450 tonnes per hour in winter when night time ambient temperatures may fall to - 2°C. This arrangement provides us with access to low cost and environmentally friendly heated water."

The geothermal fluid is passed through a heat exchanger to heat water for grow-out ponds and tanks in the hatchery and nursery as part of the process of growing prawns for the on-site restaurant. The park has 11 prawn production ponds and 2 dedicated prawn fishing ponds that remain between 27°C to 31°C.

The design for the park was completed in-house with engineers only required for the initial stages of building the system. A small number of staff look after the system which supplies a sustainable and eco-friendly 7.8 tonnes/year of prawns from 2.75 hectares of the ponds to the park's restaurant. The park is working towards automation utilising "kiwi ingenuity".

Key Benefits:

- Easy to meet required temperature
- Controlled optimal growth temperature
- Economically viable

Key Features:

- Founded in 1987
- Aquaculture tourism venture uses geothermal waste heat from adjacent geothermal power station
- Supplies an eco-friendly 7.8 tonnes of prawns produced from 2.75 hectares of ponds to the park restaurant

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Extremophiles

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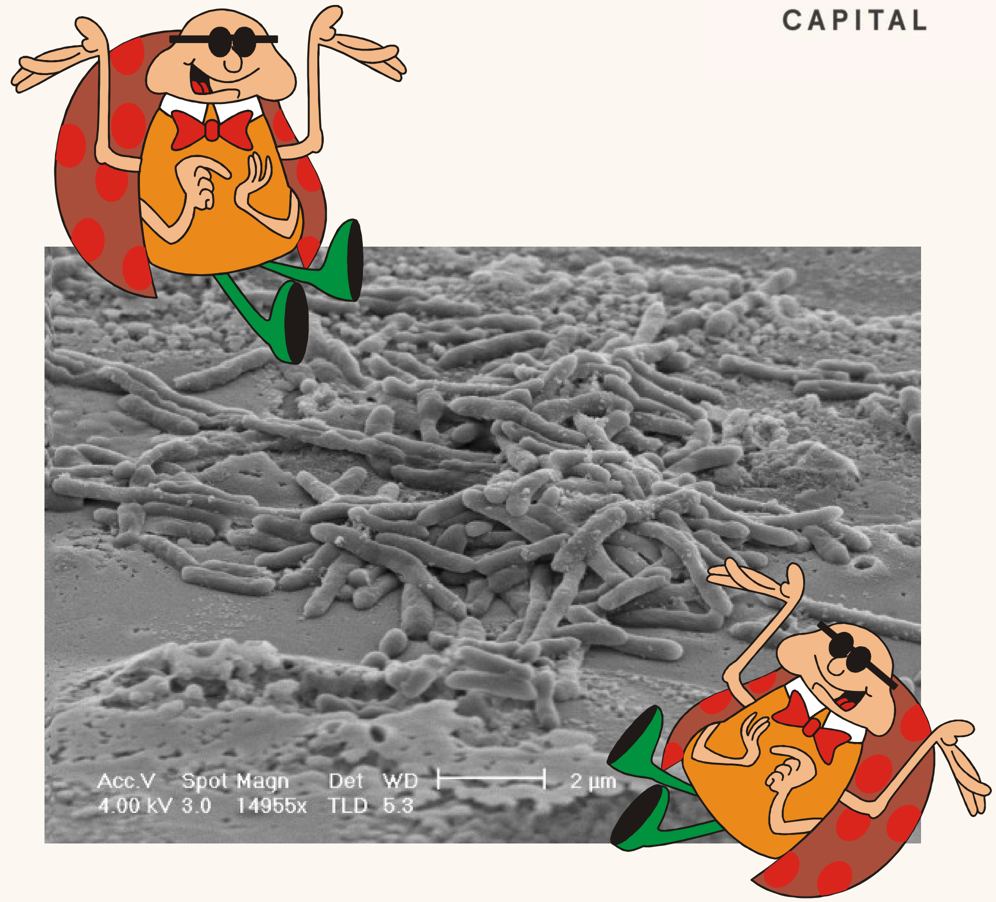
- Organisms living in extreme environments
- Abilities with promise for biotechnology processes, bio fuels, carbon recycling, medicine, mine waste rehabilitation
- GNS Science has collected >1200 novel extremophiles from NZ thermal features
- GNS 1000 Springs Project



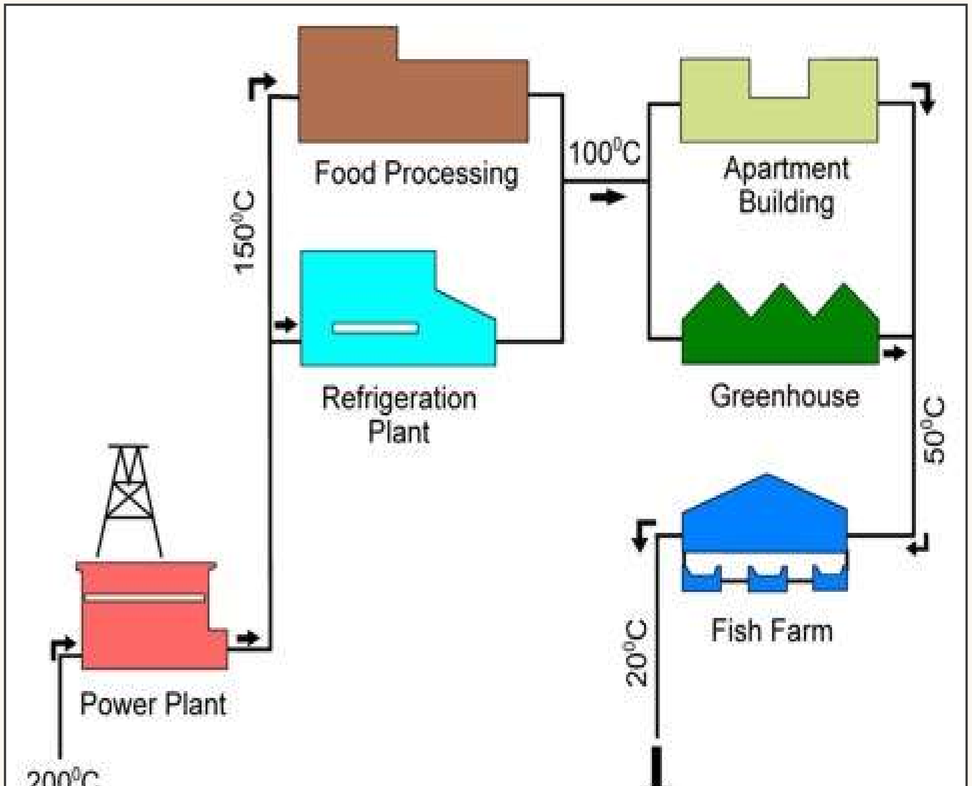
Integrated Cascade Use

BASELOAD CAPITAL

Wairakei - Tauhara

Power

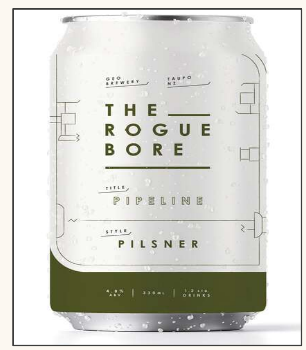
Pine mouldings, building boards



Source: Geo-Heat Center

Prawn Farm

Wairakei Terraces



Brewing

Integrated Use – Tuaropaki Trust

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Glasshouses
(11.4 ha)

Dairy Farms

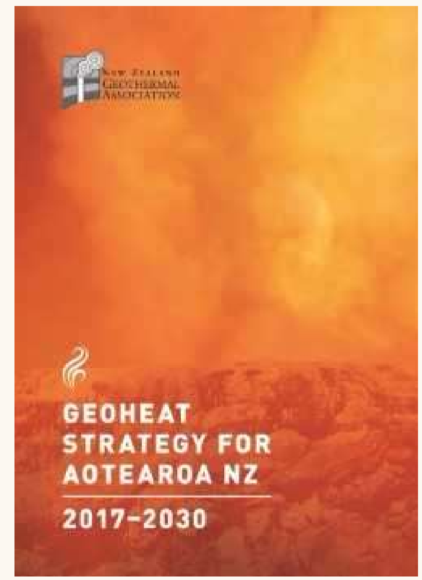
Power Station
(113 MWe)

Miraka
(Dairy Products)

Worm Farm

Native plant Nursery

Maori Trust



Integrated Use – Baseload Power

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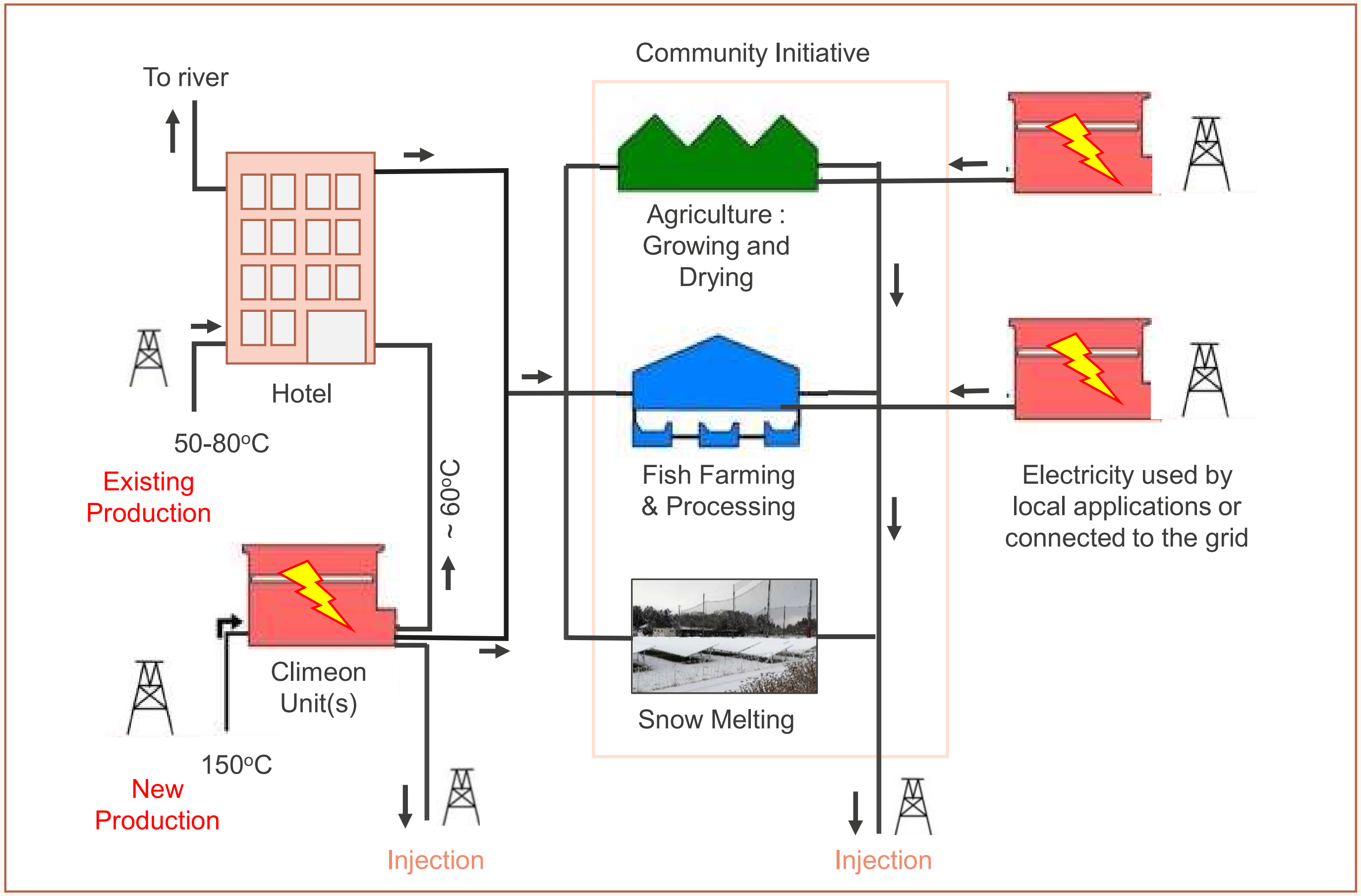

Midori (60 kWe)

Geothermal Use Database

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Electricity Generation – Power Stations

Aquaculture – Rearing fish, eels, prawns in ponds

Agriculture – Greenhouses, flowers and crops

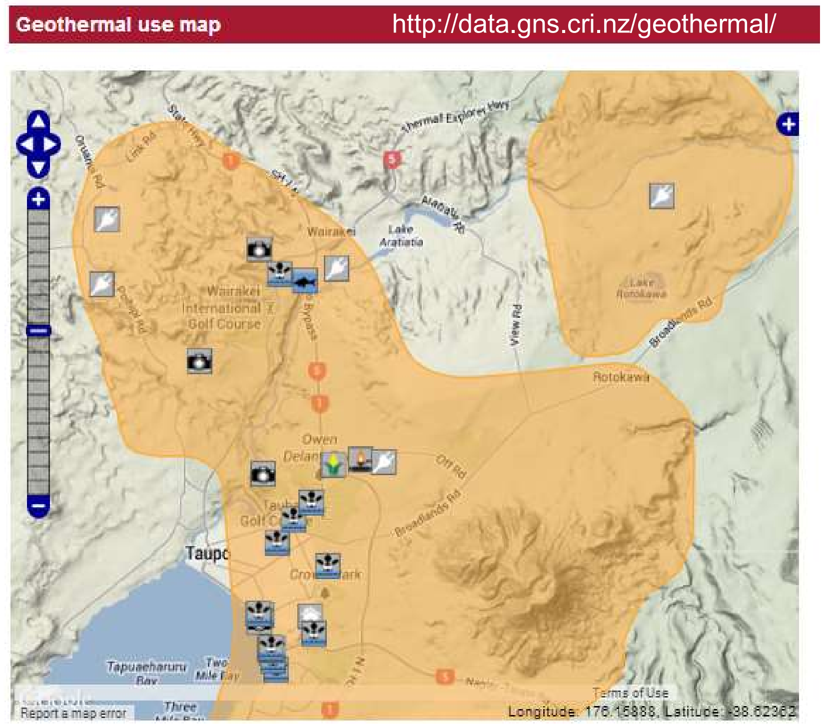
Bathing – Balneology, pools and spas

Industrial Process Heat – Timber / food processing

Tourism – Commercial / non-commercial

Space Heating – District heating schemes

Ground-Source Heating – Commercial / residential



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

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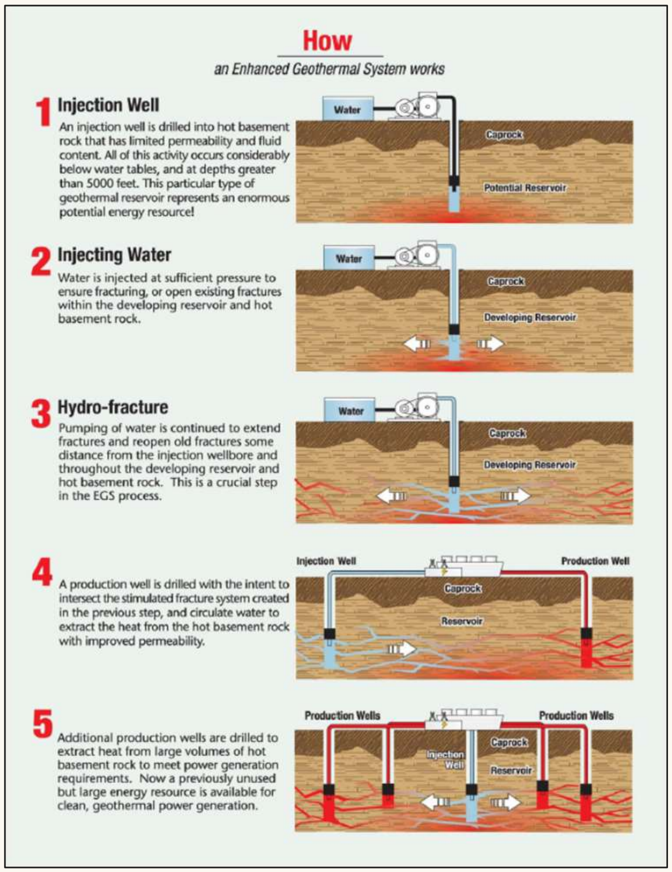

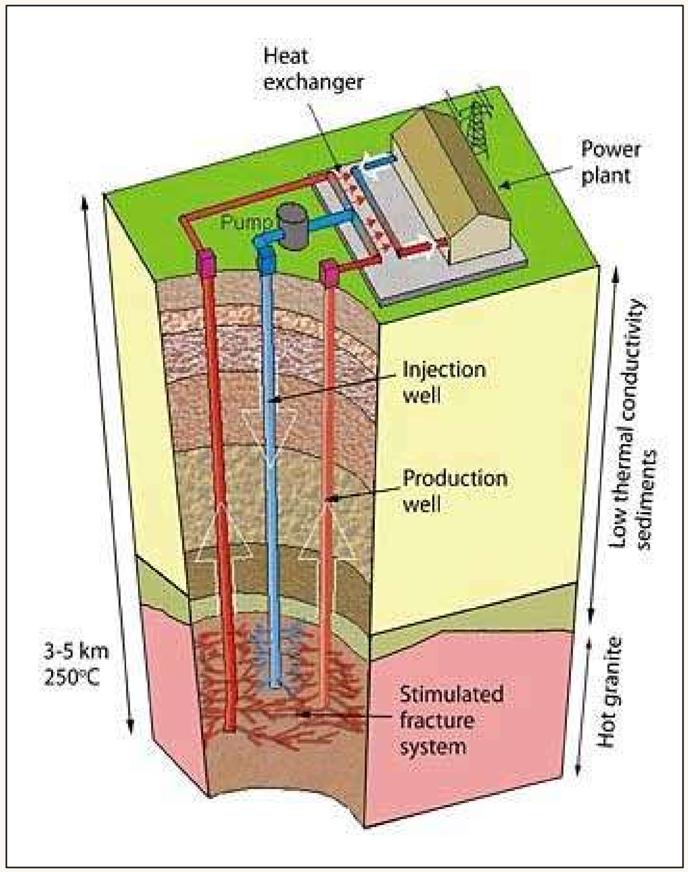

We aim to enhance or 'engineer' the geothermal reservoir for production of heat over an extended timeframe.

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

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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.

Combined geothermal - solar

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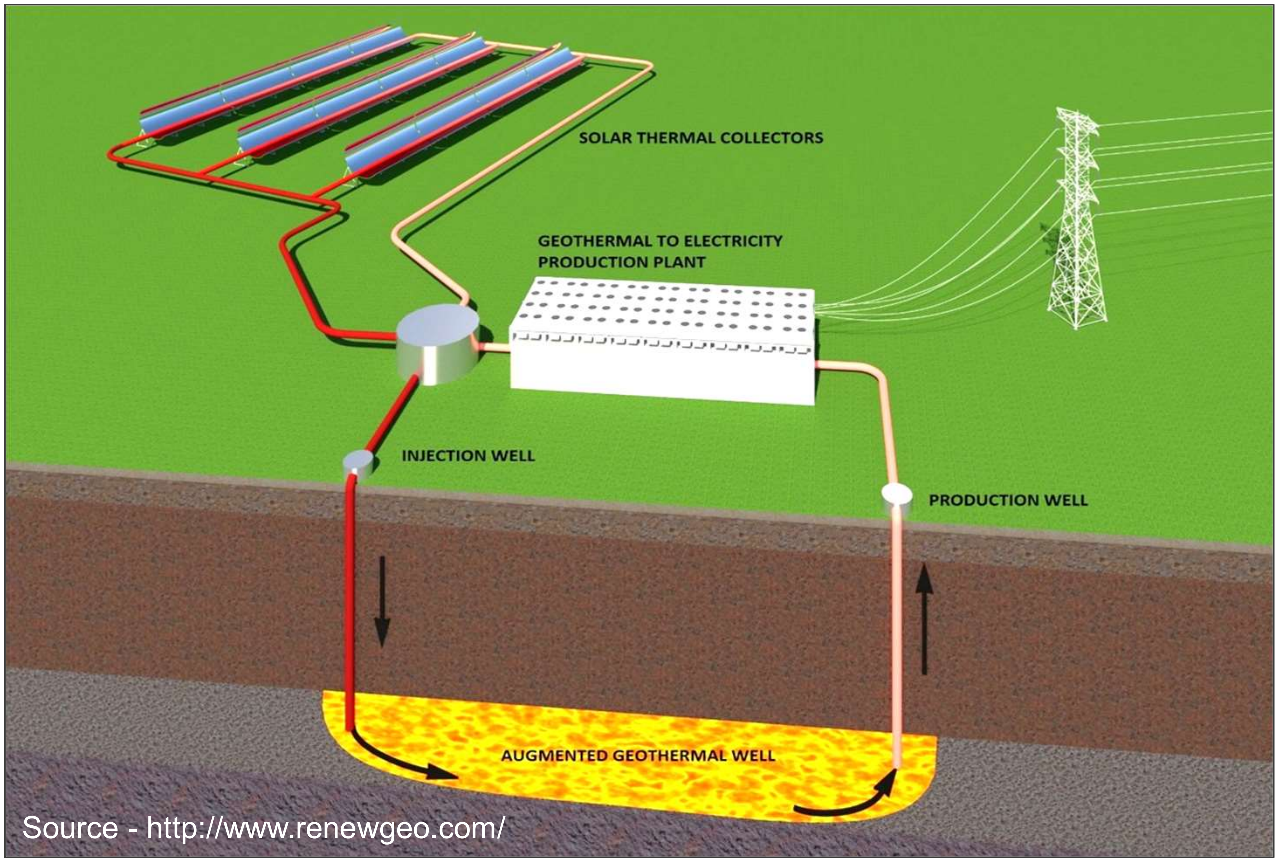

Innovative technologies are being developed (e.g. RenewGeo in the US) to collect solar energy (in the form of heat) that can be injected to create a 'synthetic' / engineered geothermal resource.

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

Mineral Extraction - Silica

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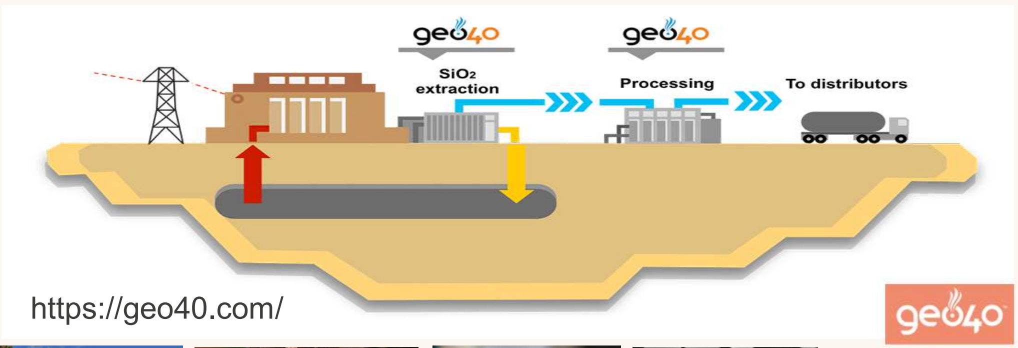
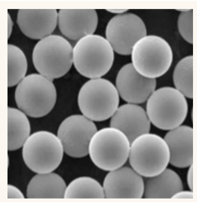
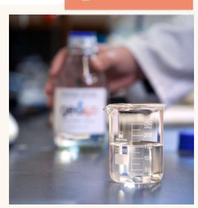
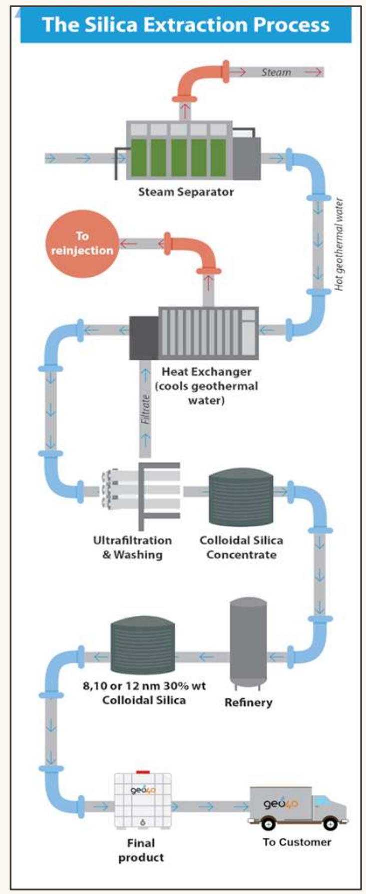




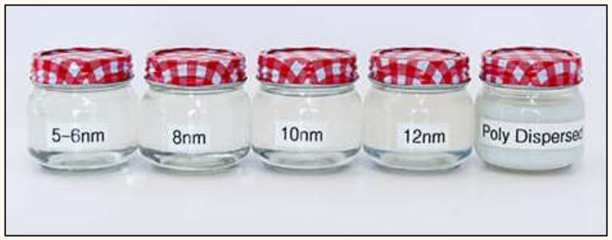


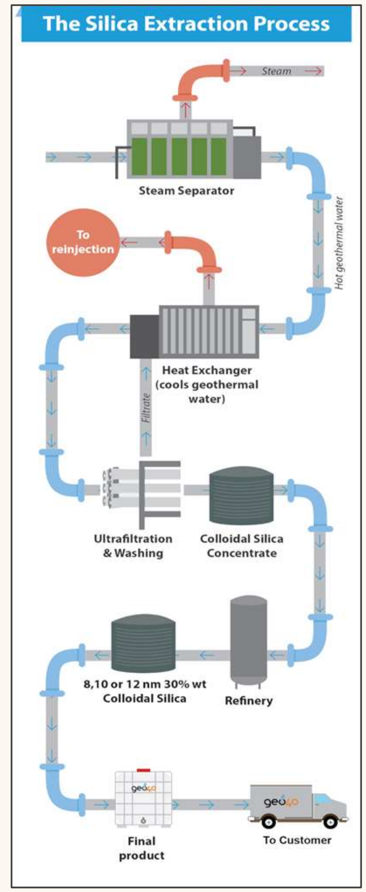
- Water leaving separation plant is close to silica saturation.
- Geo40 receives the water and cools it to below saturation point
- Silica forms discrete colloidal silica particles of 1nm – 2nm diam.
- Particles are aged and filtered using a continuous ultrafiltration and washing circuit to concentrate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



Mineral Extraction - Silica

BASELOAD CAPITAL





- 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

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

www.gns.cri.nz/earthenergy

Technical Reports

Case Studies

Conclusions

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- 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)

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Kia Ora