Geothermal in New Zealand
– an overlooked carbon friendly energy source

Photo Credits
[1] Truss compari tomatoes – Courtesy Gourmet Mokai
[2] Frutura Thermal-Gemüsewelt, Austria – Courtesy B Carey
[3] Hoogweg capsicum greenhouses – Courtesy Hoogweg Paprikakwekerijen

Brian Carey
10 September 2024
Presentation to the Carbon and Energy Professionals Online Webinar

Tēnā koutou ….

- **Brian Carey**
  - GNS Science – Geothermal Specialist
  - IEA Geothermal – Executive Secretary
  - Life member of the New Zealand Geothermal Association (NZGA)

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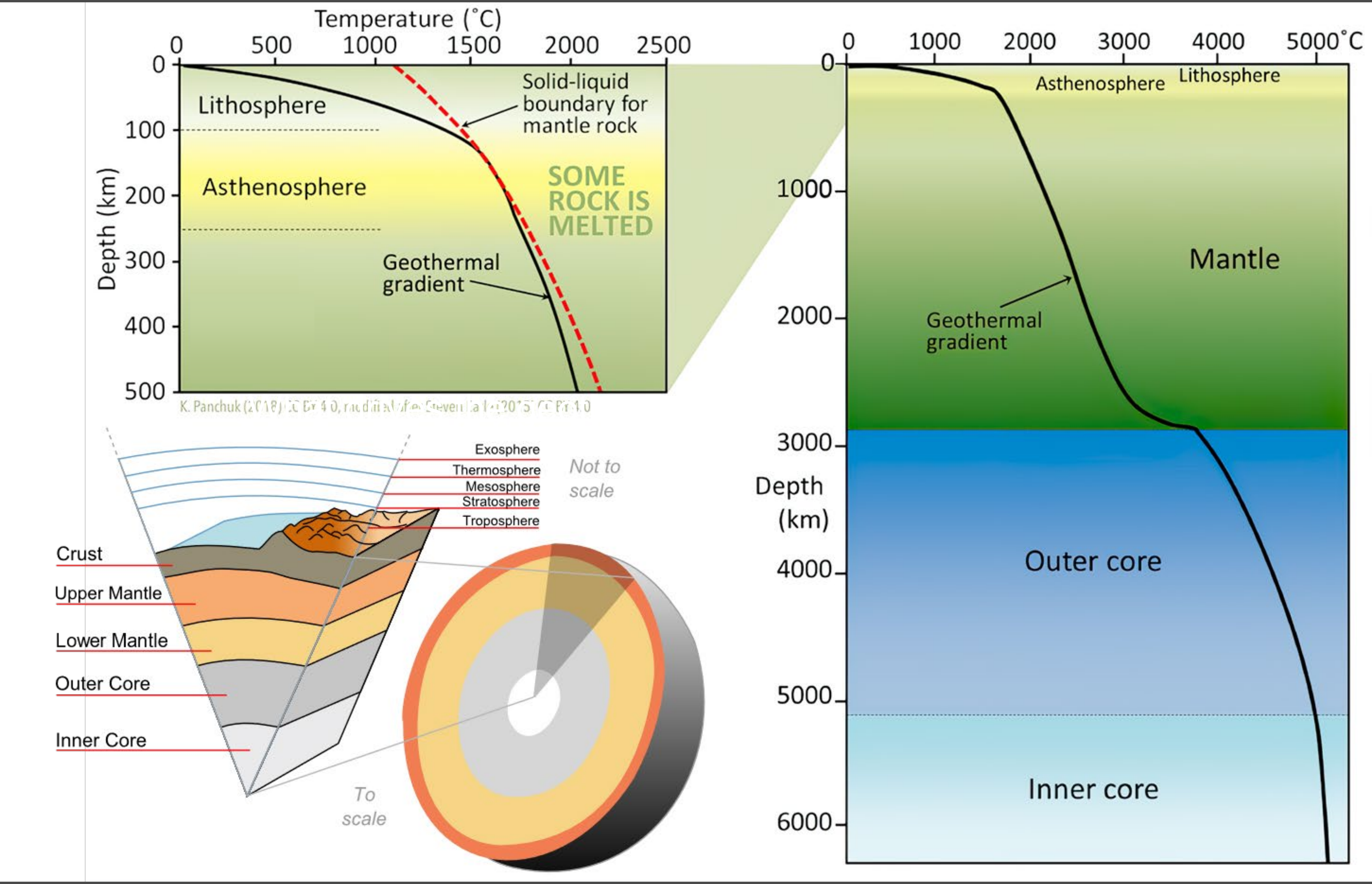
An overlooked carbon friendly energy source

- **Canvas ……**
  - RMA definitions
  - Step back - Geothermal - Ambient through Superhot
  - Carbon Emissions
    - Climate Change Commission
    - Changes in the geothermal power industry
    - Geothermal process heat carbon profile
  - Geothermal in the EECA Regional Energy Transition Accelerator
  - Geoheat – the NZGA Geothermal Process Heat Initiative
  - Case Studies

Renewable Geothermal

- **RMA Definitions**
  - **renewable energy** means energy produced from solar, wind, hydro, **geothermal**, biomass, tidal, wave, and ocean current sources
  - **geothermal energy** means energy derived or derivable from and produced within the earth by natural heat phenomena; and includes all geothermal water
    - Geothermal water is 30°C and greater
    - Geothermal energy however is at whatever temperature it might be

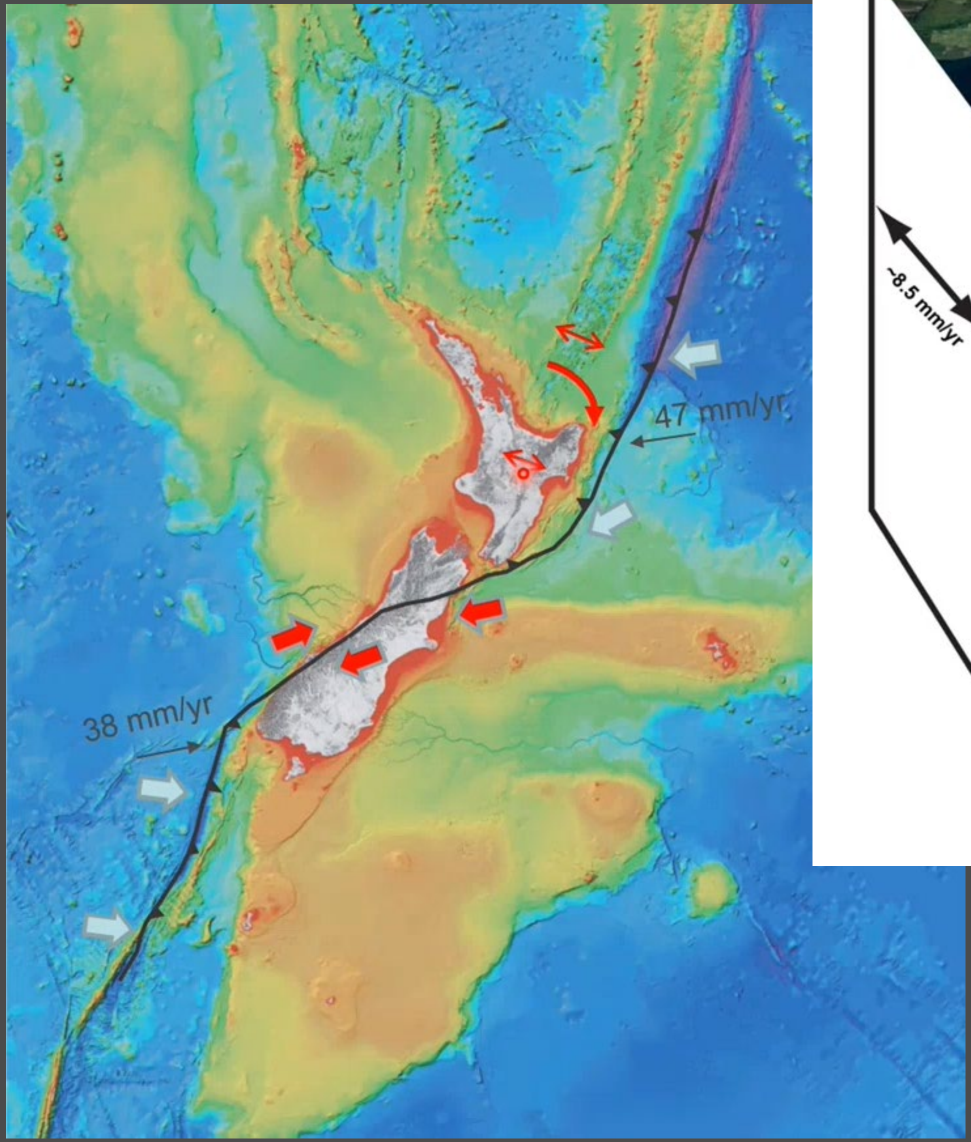
Step back - What drives geothermal

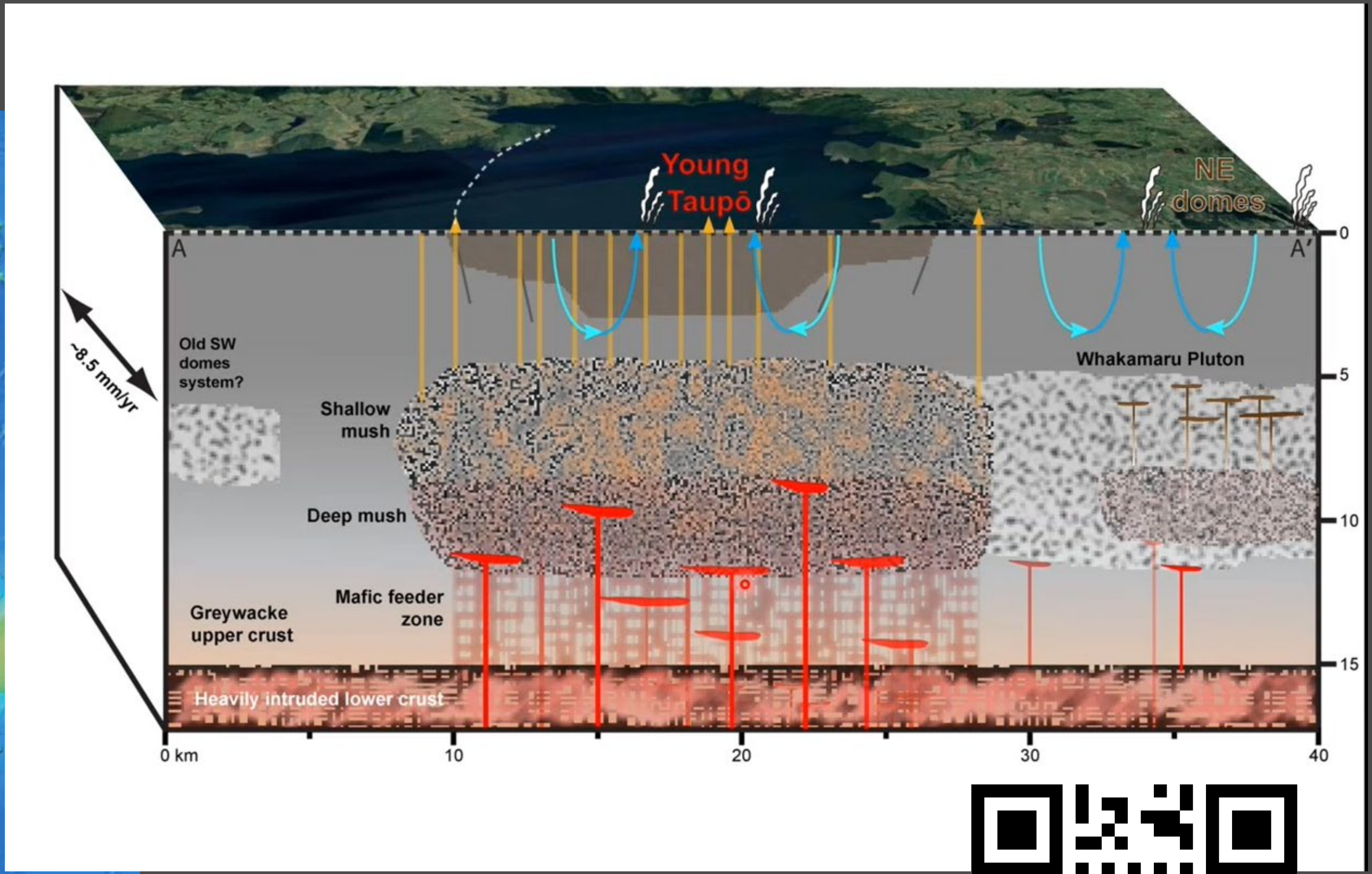


Heat transfer processes

- **Bring the heat from the core to the surface**
  - Convection
  - Conduction
- **Basically, geothermal energy is**
  - abundant,
  - almost limitless,
  - driven by basic earth processes
- **Magma is involved in the heat transfer processes**
  - For New Zealand being on the plate boundary this has a lot to do with both volcanism and geothermal

Plate processes





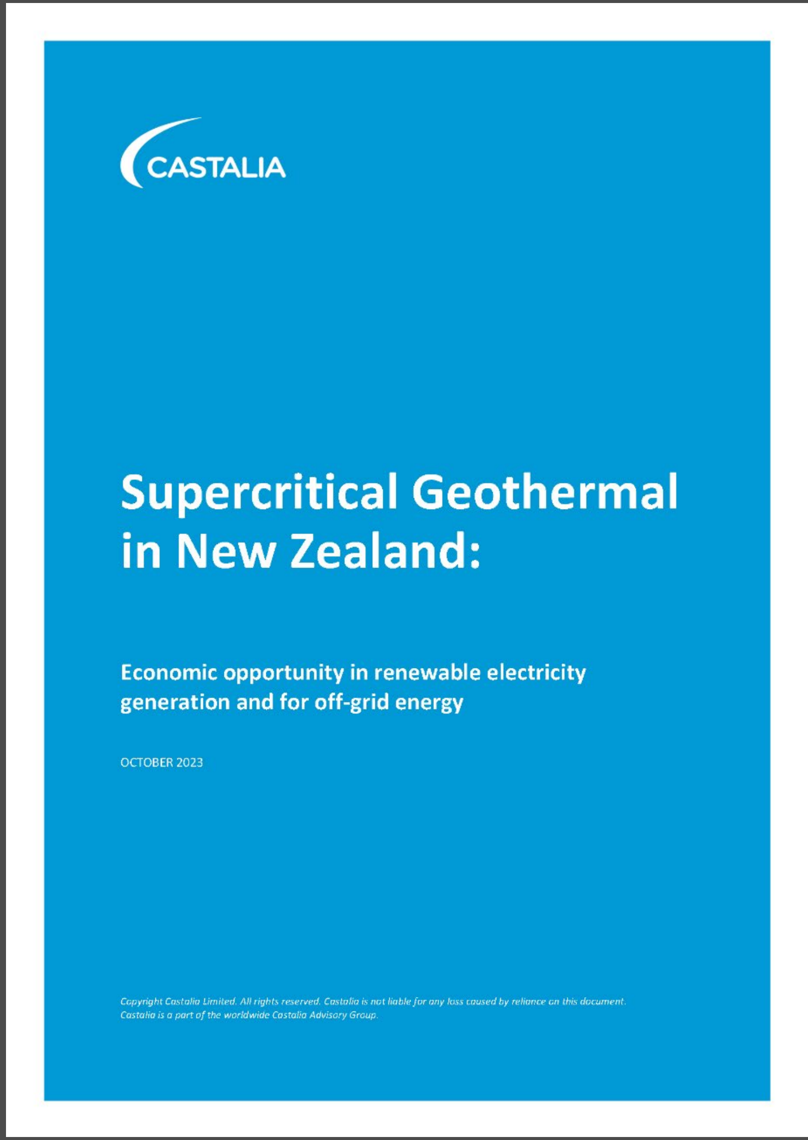
Magma has distinct densities
Temperatures 600 to 1200 C

in NZ in the top few km

- Ambient geothermal conditions 10 – 15^{o}C - near surface
- through to Superhot > 400^{o}C – as shallow as 4 to 6 km

- Current maximum temperature measured in any NZ well is 337^{o}C
- And NZ is yet to drill into supercritical water in a geothermal resource
  - For pure water - temperature 374^{o}C pressure 220 bar
- NZ superhot / supercritical geothermal potential is significant…
- As is the opportunity …. 1.4 to 2 GW of capacity for a nation with rapidly growing demand for electricity
  - Grid currently has 10 GW installed
  - 5 Sept 24 Transpower data
    - ~5 GW operating
    - 1.1 GW of conventional geothermal
  - 2037 grid capacity of 16 GW.

The Potential and the Opportunity

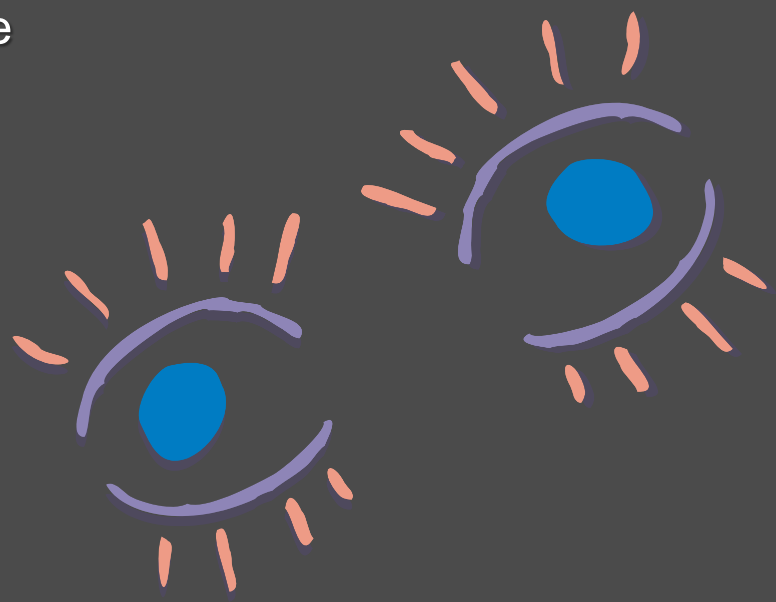


Find out more about superhot geothermal

- **Geothermal the Next Generation**
- **MBIE Endeavour Funded research**
  - Contract C05X1904
  - Scheduled completion March 2025
- **Updates tab is a great place to start**
- **https://www.geothermalnextgeneration.com/updates**

Shift now to Geothermal in low carbon New Zealand

- Climate Change Commission advice and reports
- Proposed National Policy on Renewable Electricity Generation
- Carbon Emissions
  - Changes in the geothermal power industry
  - Geothermal process heat carbon profile



Climate Change Commission (CCC) - 2021

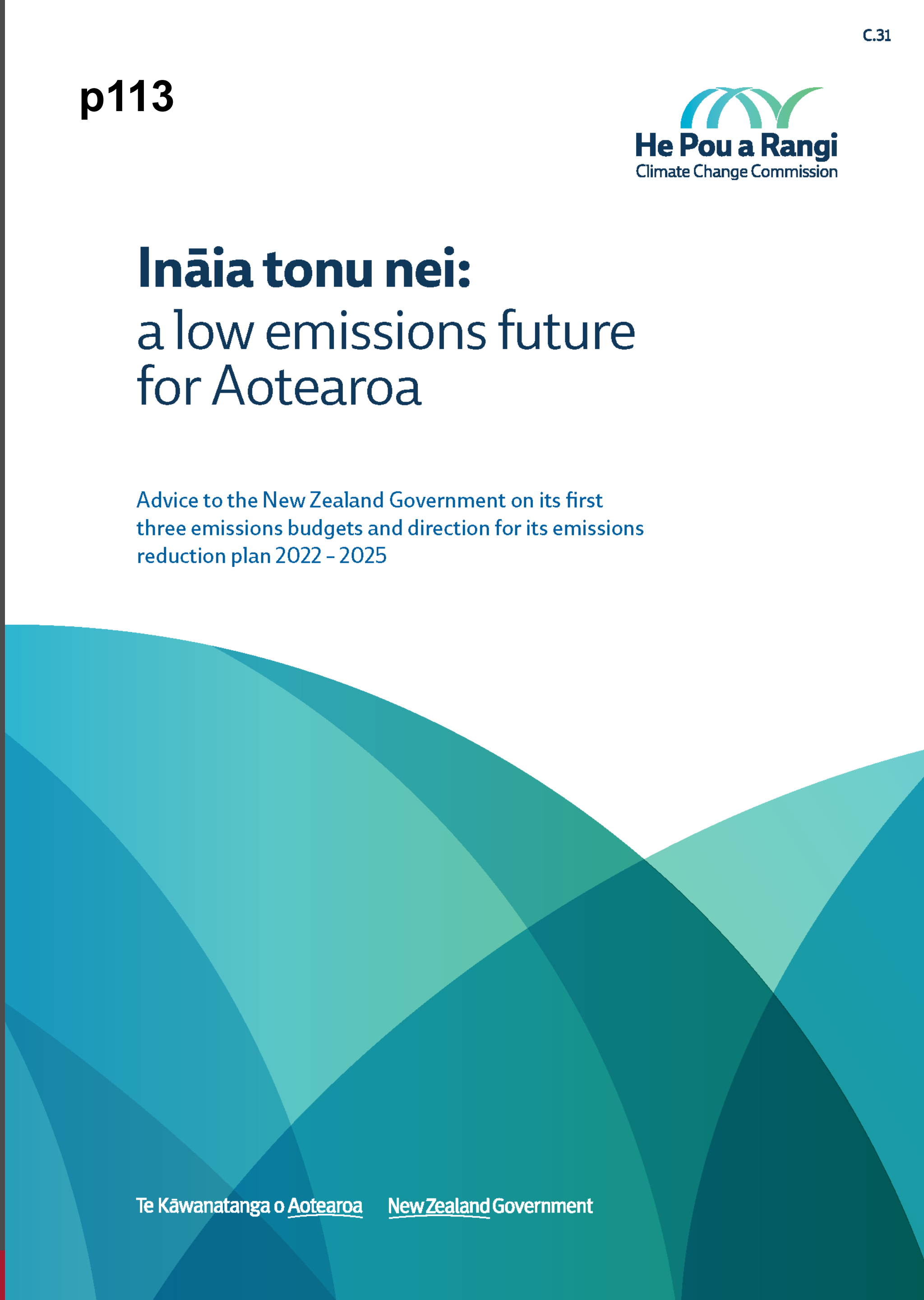
- **Developed a restrictive / restricted view of geothermal energy**
  - January 2021 – Advice to government - ***close down*** the high emitting geothermal electricity generating facilities
  - May 2021 – position moderated - Scenario modelled with geothermal ***emission intensity declining*** by 6% per annum
  - However, the CCC weren't prepared to accept that a ***step change*** in geothermal technology might occur
-

Climate Change Commission Advice to Government

- **31 January 2021**
- **Some geothermal fields have high emissions from their geothermal fluid, with an equivalent emissions intensity as gas generation. *In our path these high emitting geothermal fields would close before 2030* reducing geothermal emissions by around 25% while only reducing generation by 6%.**

Moderated a little bit by May 2021

- Some geothermal fields have high emissions from their geothermal fluid, with an equivalent emissions intensity to fossil gas generation. In the demonstration path these high emitting geothermal fields would continue to operate. **However, these high emitting fields have naturally degassed in recent years and we assume a continuation of their historic rate of reduction in emissions intensity.** Geothermal power generation increases 23% while emissions increase 6% above 2019 levels by 2035.



C.31

p113

He Pou a Rangi
Climate Change Commission

Ināia tonu nei:
a low emissions future for Aotearoa

Advice to the New Zealand Government on its first three emissions budgets and direction for its emissions reduction plan 2022 – 2025

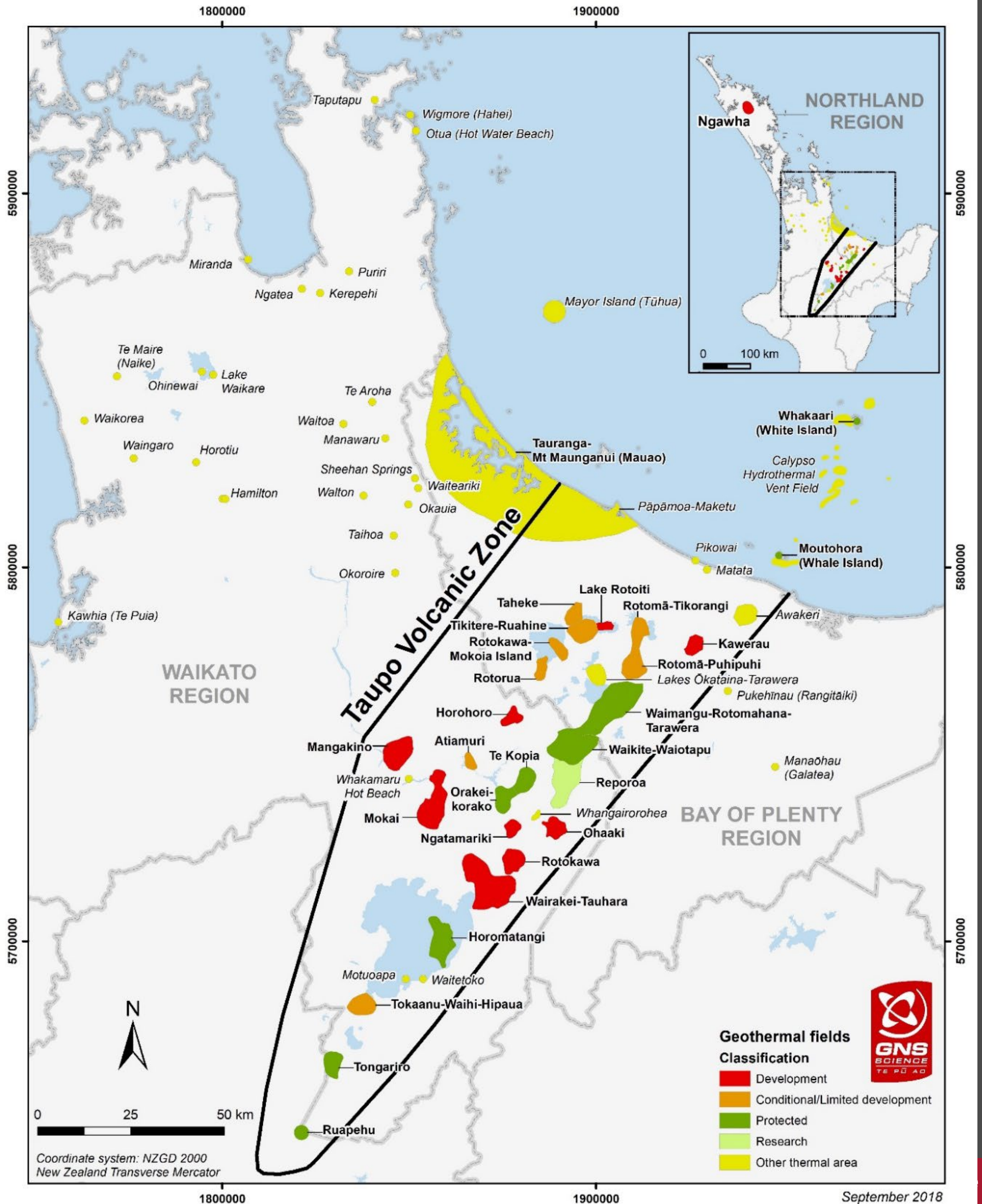
Te Kāwanatanga o Aotearoa New Zealand Government

Proposed National Policy Statement

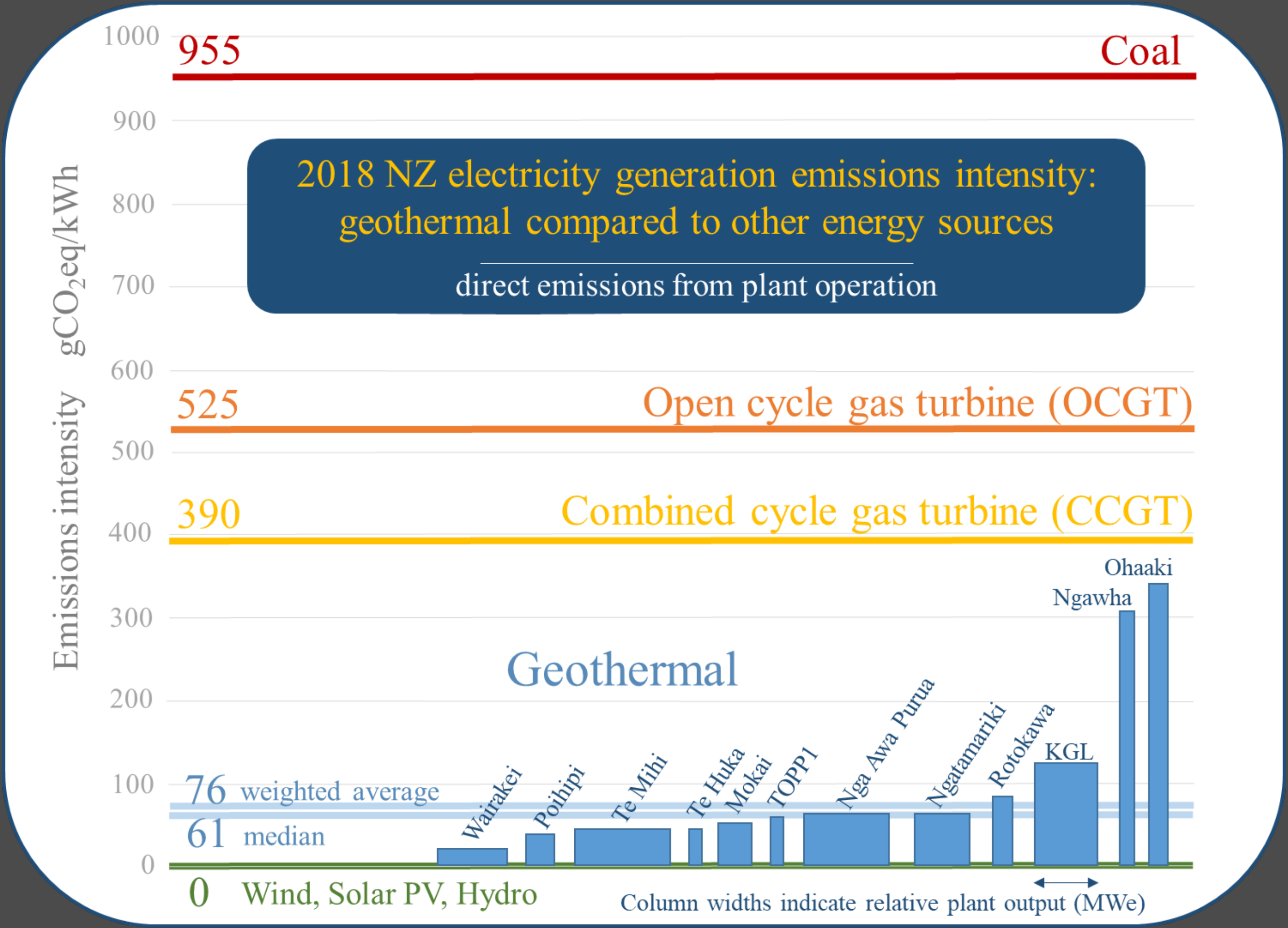
- **Renewable electricity generation 30 March 2023**
  - The word Geothermal occurred once in the text.
    - included in the definition of Renewable Electricity Generation (REG)
    - But ***excluded*** elsewhere
  - Importantly Geothermal ***excluded from the Maintaining and Increasing generation*** output section

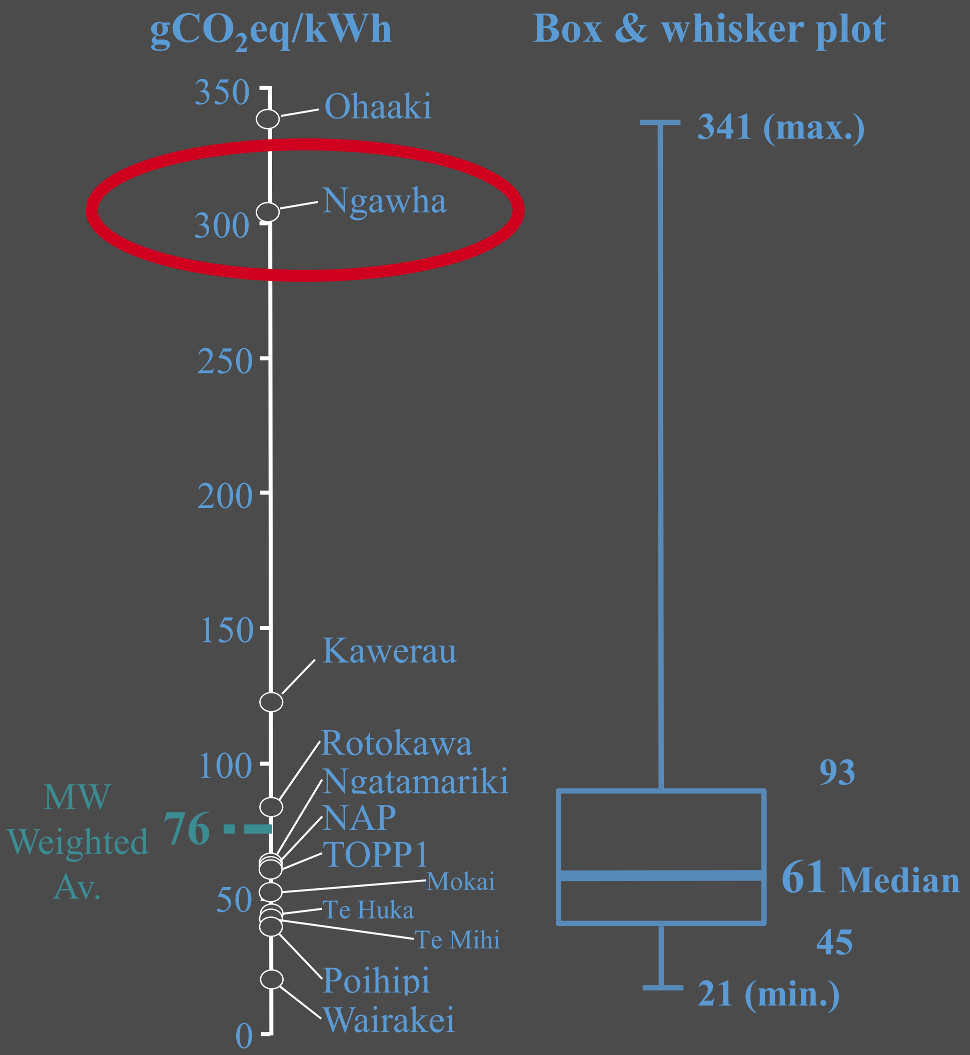
Locator table and map

Facility	Field
Wairakei	Wairakei
Te Mihi	Wairakei
Poihipi	Wairakei
Ohaaki	Ohaaki
Te Huka	Tauhara
Rotokawa	Rotokawa
Nga Awa Purua (NAP)	Rotokawa
Mokai	Mokai
Ngatamariki	Ngatamariki
KGL	Kawerau
TOPP1	Kawerau
Ngawha	Ngawha



Geothermal Electricity Emissions Intensity – 2018 in blue





Mclean, K. Richardson, I., 2019 Greenhouse gas emissions from New Zealand geothermal power generation in context, NZGW 2019
URL Link

A step change is happening now ….

- **Ngawha – Top Energy / Ngawha Generation**
  - Was second highest emissions intensity level for a New Zealand geothermal power generation facility in 2018
- **~300 g CO_2e / kWh**
- **Research and plant modifications**
    - OEC 1 and OEC 2 trials July to December 2022
    - Concept proven with 28,000 t CO_2e / annum reinjected
    - May 2023 100,000 t CO_2e / annum reinjected
    - December 2023 128,000 t CO_2e / annum reinjected

The step change ….

- **Ngawha Generation**
  - December 2023 operational atmospheric CO_2e emissions are **nil**
  - Emissions intensity now 0 g CO_2e / kwh (from ~ 300 in 2022)
- **Video to watch**

And other geothermal power generators are well underway

- **Mercury**
  - Nga Tamariki – currently 25% of the gas produced is being reinjected
  - Programme in place for increasing this
- **Contact**
  - Te Huka plants – gas produced is all being reinjected

- **Changes are happening at pace ….**

And what of the Policy framework ….

- **Geothermal electricity generation is heading towards low operational emissions intensity**
- **0 gCO_2e / kWh ?**

- **How long will it take for**
  - New Zealand's policy analysts to catch up ?
  - And for the policy framework to catch up ?

Carbon Profile of Geothermal Energy in Process Heat

Three geothermal fluid types

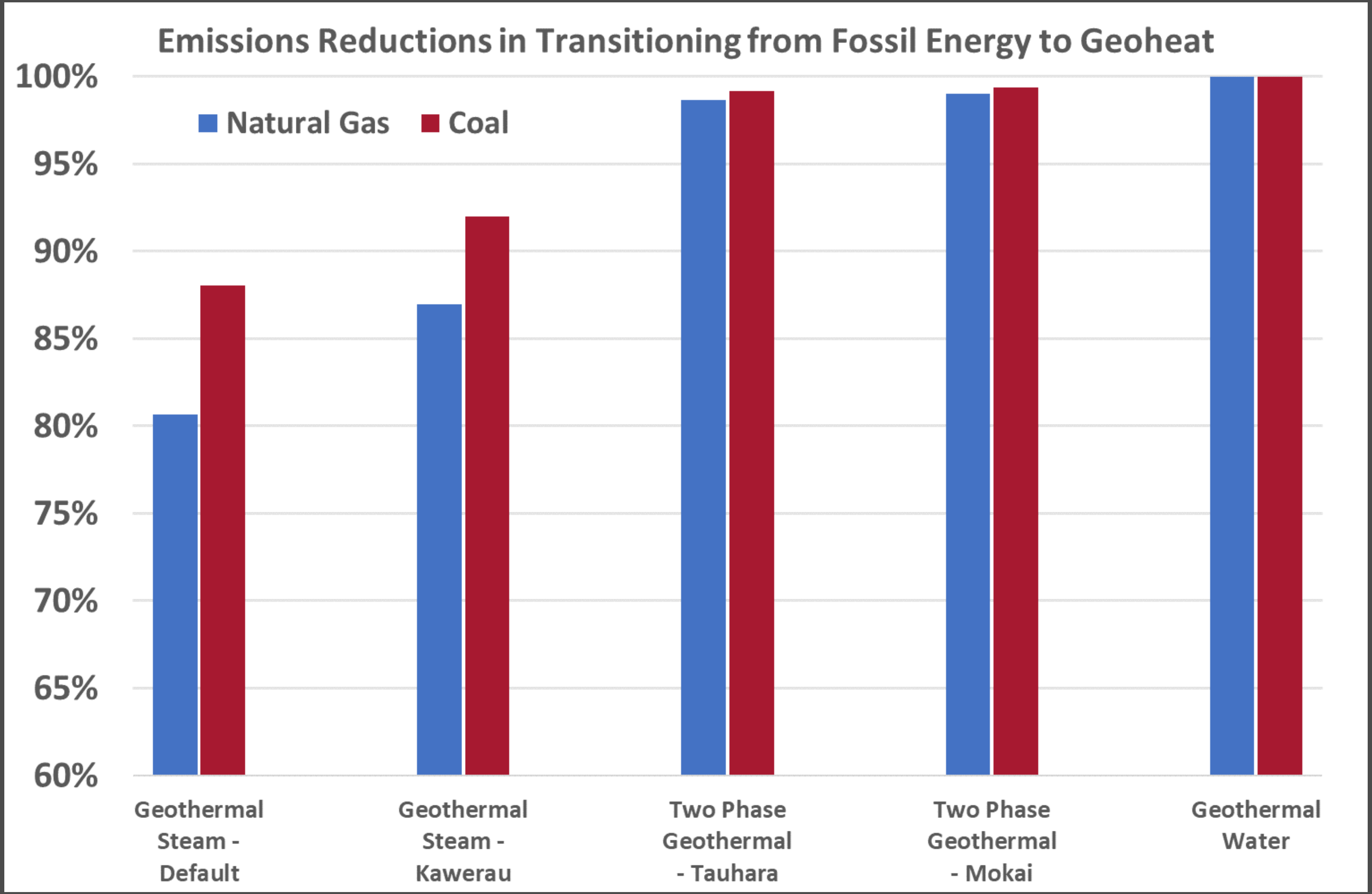
- **In the process heat sector**
  - Geothermal steam
  - Geothermal two phase (mixtures of steam and water)
  - Geothermal water
- **Show unabated geothermal carbon profile relative to fossil energy**

Unabated carbon profile - compared to Natural Gas

Type		tCO_2e/t	GJ/t	tCO_2e/GJ	Emissions Reduction (%)
Coal (Sub-bituminous)				0.09043	
Natural Gas (National Average)				0.05573	
Unabated Geothermal					
Steam	Geothermal Steam (default)	0.03	2.78	0.01079	**81%**
	Kawerau - Steam	0.0202	2.78	0.00727	**87%**
Two Phase	Tauhara - two phase	0.0009	1.2	0.00075	**99%**
	Mokai - two Phase	0.0009	1.6	0.00056	**99%**
Water	Geothermal Water (100^{o}C)	0	0.4	0	**100%**
	Water (15^{o}C)	0	0.06	0	**100%**

For data sources, assumptions and constraints refer to the Geoheat Low Emissions Profile Table in the 2024- 2025 Action Plan

Plot in a different way - relative to Natural Gas and Coal

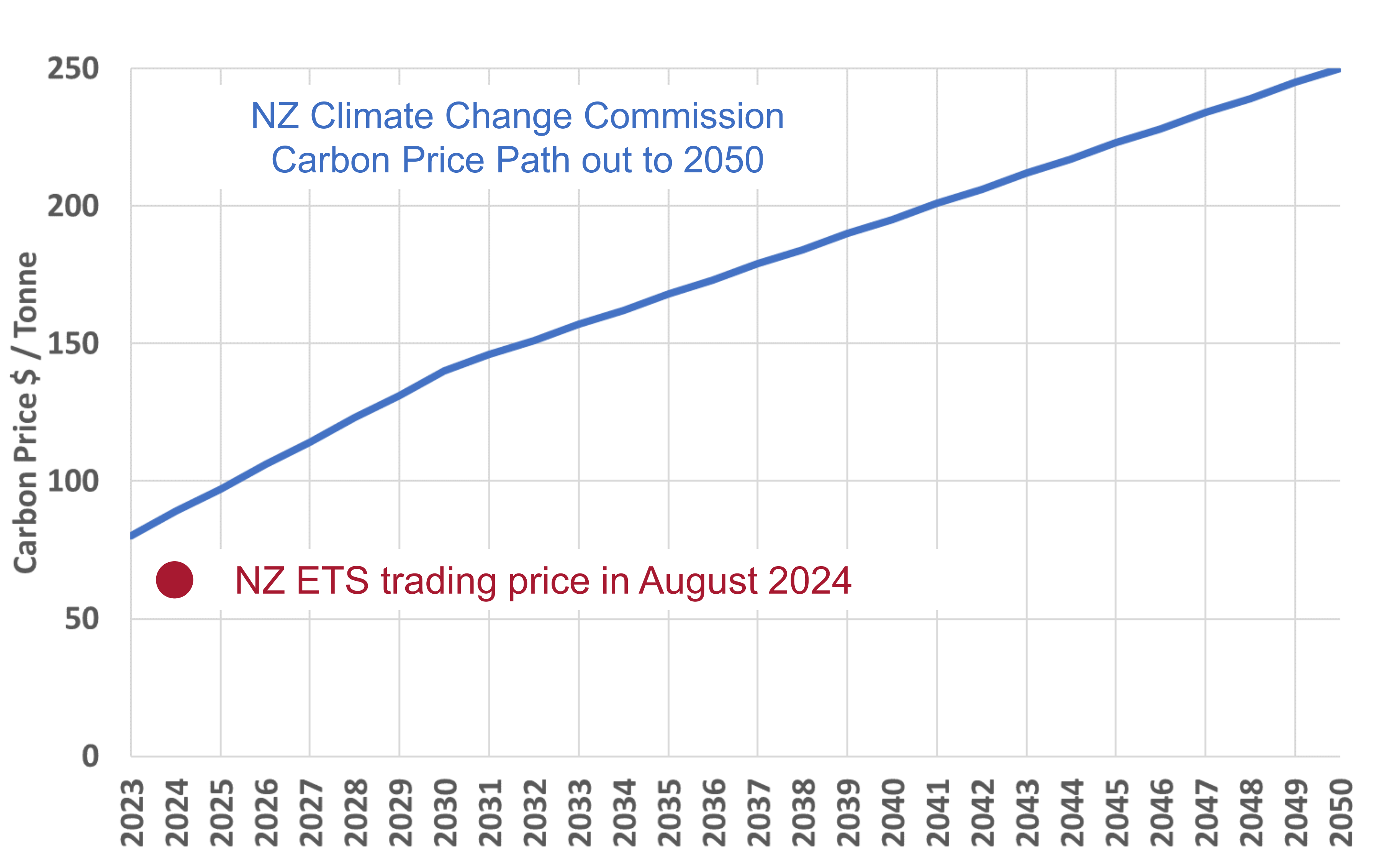


Cost effective by fuel type – Carbon $70 / tonne

Fuel Type	$/GJ	Emissions Factor tCO_2e/GJ	Carbon Costs	Conversion Factor	Total Cost $/GJ Delivered
Geothermal - Steam	8	0.0073	$0.51	0.83	**$10.25**
Electricity - Heat Pump COP 3.5	43.34	0.0206	$1.44	3.5	$12.38
Biomass	13	0	$0.00	0.8	$16.25
Gas	11.57	0.0557	$3.90	0.85	$18.20
Coal	9	0.0944	$6.61	0.78	$20.01
Wood Pellets	18	0	$0.00	0.9	$20.00
Electricity - Resistance	43.34	0.0206	$1.44	0.99	$43.78

For data sources, assumptions and constraints refer to the Geoheat Delivers Cost Effective Energy Table in the 2024- 2025 Action Plan

Geoheat only going to get better with time ...



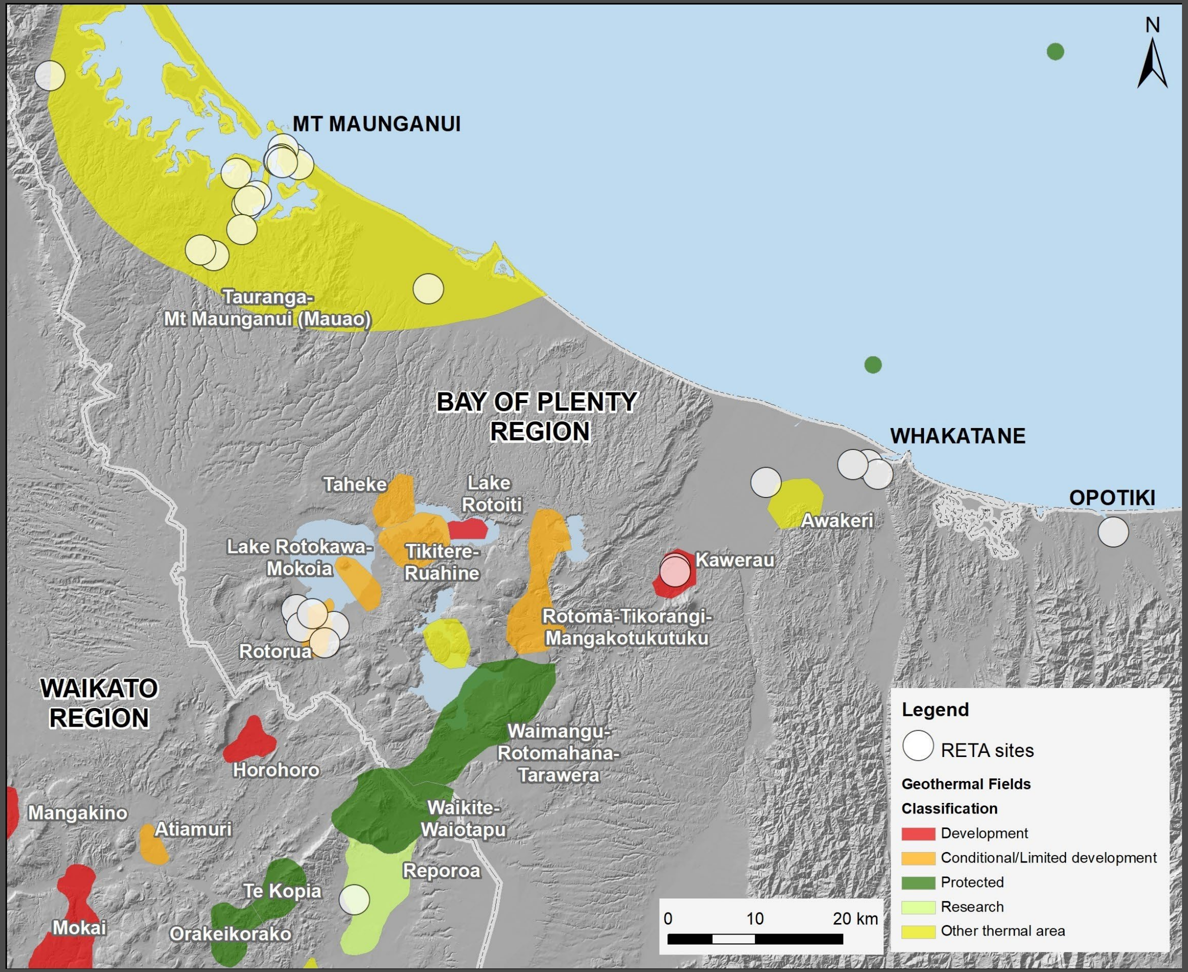
EECA Regional Energy Transition Accelerator (RETA)

- **Bay of Plenty RETA – included geothermal**
- **EECA contracted GNS Science**
  - support consultancy from Dobbie Engineers and GeoExchange
- **BOP RETA Output released in May 2024**

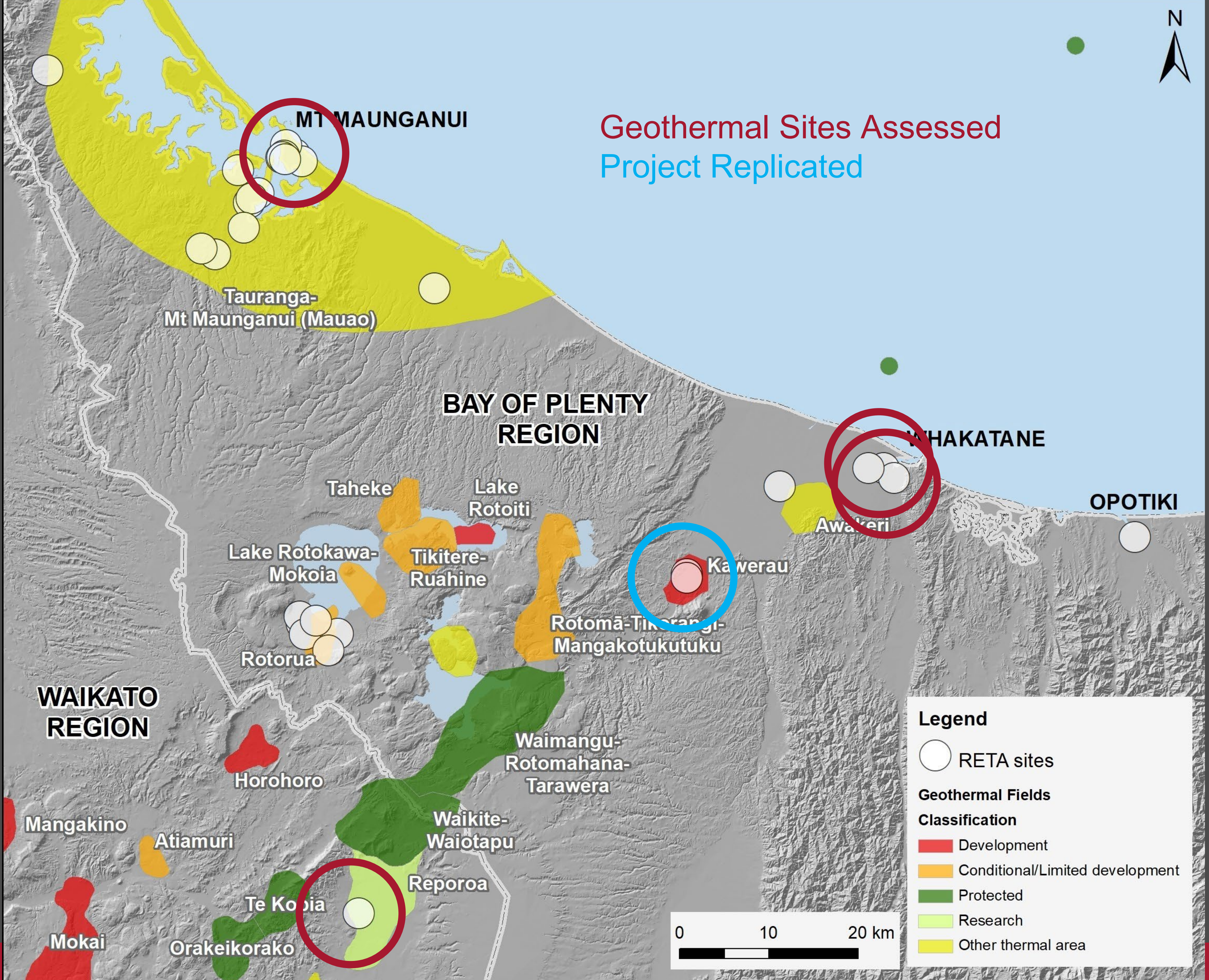
QR / URL Link to documents

GNS Science geothermal report QR / URL Link

EECA RETA in the broader Bay of Plenty



– EECA 28 sites in the area
– 4 selected for geothermal assessment
– 1 other site which was a project replication



Geothermal Sites Assessed
Project Replicated
N
MT MAUNGANUI
Tauranga-
Mt Maunganui (Mauao)
BAY OF PLENTY
REGION
WHAKATANE
OPOTIKI
Awakeri
Kawerau
Taheke
Lake
Rotoiti
Lake Rotokawa-
Mokoia
Tikitere-
Ruahine
Rotomā-Tikorangi-
Mangakotukutuku
Rotorua
WAIKATO
REGION
Waimangu-
Rotomahana-
Tarawera
Horohoro
Mangakino
Atiamuri
Waikite-
Waiotapu
Reporoa
Te Kopia
Mokai
Orakeikorako
0
10
20 km
Legend
RETA sites
Geothermal Fields
Classification
Development
Conditional/Limited development
Protected
Research
Other thermal area

Sites analysed

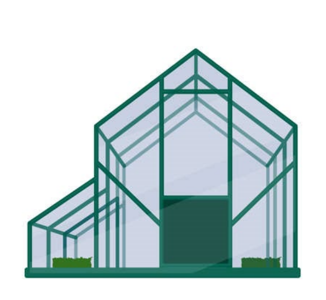
- Whakatāne Hospital:
  Geothermal / ground source heat pump (GSHP) technology, aquifer water.
- Whakatāne Growers:
  GSHP technology, aquifer water.
- Dominion Salt – Mount Maunganui:
  HTGSHP technology, ~45°C aquifer water supplying 120°C steam.
- Fonterra Reporoa:
  High temperature geothermal direct use, assessed with 260°C geothermal water.
- Essity Kawerau
  Paper machine – project replication

Whakatane Hospital ~750 tonnes CO_2e pa

- Currently uses natural gas
- Arrangement of older and newer facilities
- Natural gas steam boilers, Air Source Heat Pumps (ASHP) for cooling
- Total annual energy - heating 3.7 GWh, cooling 2.3 GWh.
- Two options ASHP and GSHP considered
- GSHP using 15°C Matahina aquifer water at a depth of ~400m

Scenario		**Capital Cost**	**Operating Cost**	**Operating Costs**	**20-Year Cost Savings**	**Simple Payback**	**Emissions Reduction**
			(Year 1)	**(20 Years)**		**(Years)**	**(%)**
Existing gas costs (heat only)		-	**$320,000**	-	-	-	
	ASHPs	$4,588,500	$644,386	$14,828,576			
New + Old Buildings	GSHPs	**$5,607,853**	**$262,083**	$6,831,248	$7,997,328	**2.6**	**89**
	Difference	$1,019,353	$383,303	$7,997,328			

Whakatāne Growers ~3500 tonnes CO_2e pa



- 3.2 Hectares of greenhouse
- Currently uses natural gas and coal
- Peak thermal load 4.8 MW_{th}
- Annual energy 9.4 GWh
- GSHP using 15°C Matahina aquifer water at a depth of 250 to 450m
- Peak electrical load for 100% GSHP solution reduced by 30% relative ASHP

Scenario	Capital Cost	Operating Fuel Costs	Operating Fuel Costs	20-Year Cost Saving	Payback	Emissions Reduction
		(Year 1)	(20 Years)		(Years)	(%)
Existing Boilers	-	**$829,139**	-	-	-	
ASHP	$4,880,000	$1,634,159	$41,215,647			
GSHPs 100%	**$6,570,000**	**$959,345**	$25,777,965	$15,437,682	**2.4**	**93**
50 / 50 GSHP / ASHP	$6,822,000	$1,112,598	$29,895,929	$11,319,718	3.6	91

GEOEXCHANGE

What if the aquifer water is warmer ?

- **Such as in the broader Tauranga area**
  - And elsewhere, Hauraki Plains, Helensville, etc ?
  - Looking for heat to be supplied at 65 / 70°C water for horticulture
- **Significant savings accrue with an increase in water temperature from 15°C up to 30°C**

Heat Pump Type (Source Temperature)	Nominal System COP	Energy Savings Relative to ASHP	Energy Savings Relative to GSHP at 15°C
ASHP - (Whakatāne Growers)	2	-	-
GSHP (15°C) (Whakatāne Growers)	2.77	**28%**	-
GSHP (20°C)	3.2	**38%**	**14%**
GSHP (25°C)	3.6	**44%**	**24%**
GSHP (30°C)	4	**50%**	**31%**

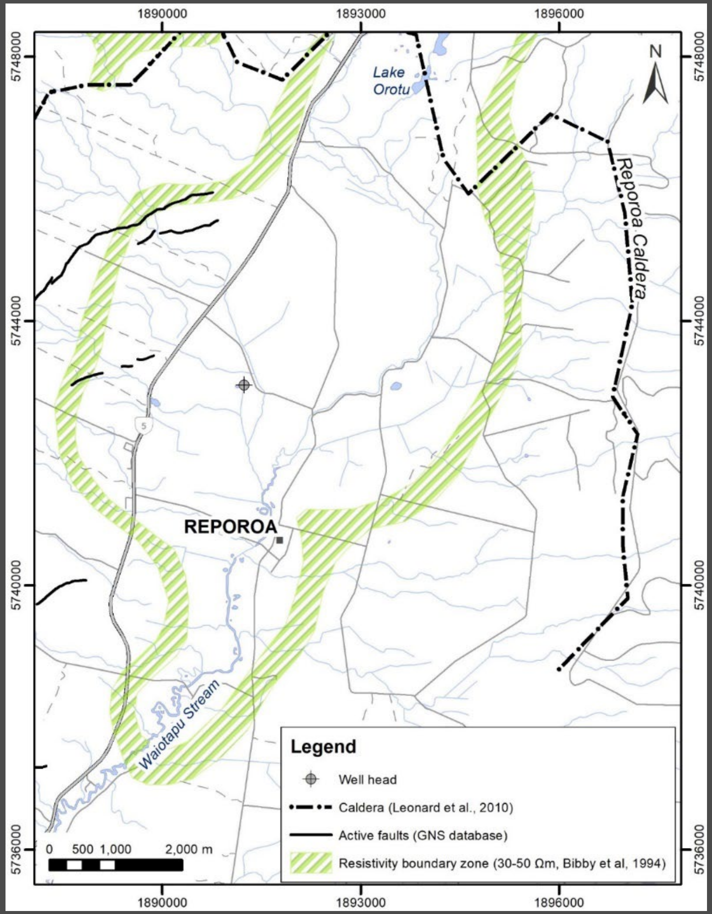
GEOEXCHANGE

Mount Maunganui Industrial Area ~1400 tonnes CO_2e pa

- **Dominion Salt – 24/7 drying operation**
  - Two Fluid Bed Dryers receive steam directly from a natural gas boiler
  - combined total of 900 kg/h steam at 120°C
- **Decarbonisation options are electric boiler or HTGSHP.**
- **HTGSHP**
  - using 45°C aquifer water (160 to 340m) from under the area
  - HTGSHP has higher capital cost (5.2 M) relative to electric boiler (0.7M)
  - Reduces annual energy use by more than 64% compared to electric
  - Payback ~4 years
  - Benefit of a substantial reduction in electrical load capacity compared to an electric boiler
  - Emission reduction for this steam raising application 89%

Reporoa ~15,000 tonnes CO_2e pa

- **Requires proving a geothermal resource**
- **User only requires a relatively modest amount**
  - 30-40 MW_{th}
- **Exploratory activity required**
  - ~$18.5m
- **Regional Plan change to facilitate energy extraction required**
  - ~$750k
- **Then production and injection drilling**
  - ~$24m
- **Wellhead to end user(s) bespoke design**
  - Using two phase geothermal to produce culinary grade steam to replace natural gas generated steam in the factory.
  - ~$24m
- **Emissions reduction**
  - 93% for the application and 63% for site overall.



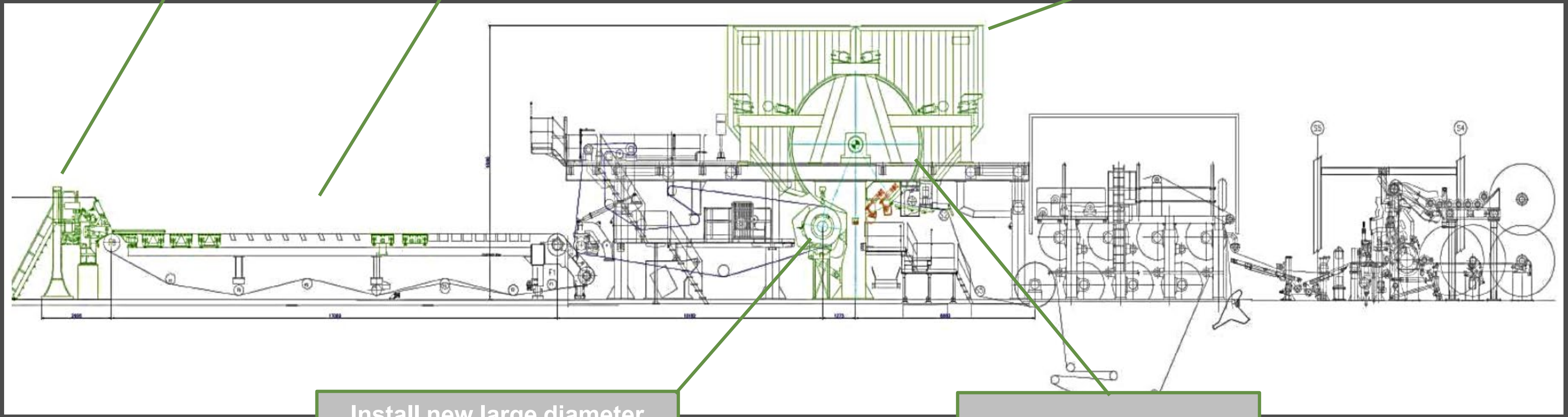
Essity – Been there done that since 2010

- **2010 phased out a natural gas boiler**
  - moved to a geothermal supply
  - Reducing their carbon emissions by ~40%
    17,000 tonnes CO_2e per annum
- **Now converting one of two large tissue drum dryers to use geothermal energy – moving from natural gas**
  - First paper machine in the world to use geothermal to power the hood and drying drum
  - Installation underway, once operational
    - the 2025 year carbon emissions estimated to be 66% less than in 2009

essity

Essity Kawerau KPM3 Rebuild Overview

The project scope covers replacement of the Headbox, Hoods with Steam Hoods, Yankee and Suction Press Roll



Hood temperatures reduce from 350 to 180 °C

Pulp

Saving 1,300 tons of pulp per annum through optimised paper weight while enhancing the machine's unique capabilities.

Energy

Switching fuel source and making the production process more energy efficient.

CO_2e

Protecting our future and the environment by pioneering the use of geothermal steam sourced from local Iwi.

Waste

Modernising the machine reduces our waste which improves the machine's capacity and profitability.

Kawerau Paper Machine 3 Rebuild

Geothermal Steam Powered Hoods

Investment	EECA GIDI Grant	tCO_2e
15.5	1.65	6,500
NZDm	NZDm	pa reduction

essity

EECA TE TARI TIAKI PŪNGAO ENERGY EFFICIENCY & CONSERVATION AUTHORITY

Investment versus CO_2e pa eliminated

Site	Geothermal options capital (NZ $ Million)	CO_2e pa Eliminated (tonnes)	Net Emissions reduction (%)
Whakatāne Hospital	5.6	750	89
Whakatāne Growers	6.6	3,400	93
Dominion Salt HTGSHP steam application	5.2	1,300	89 / 10
Reporoa Dairy Factory steam application	70	15,900	93 / 67
Essity second paper machine conversion	15.5	6,500	90 / 25

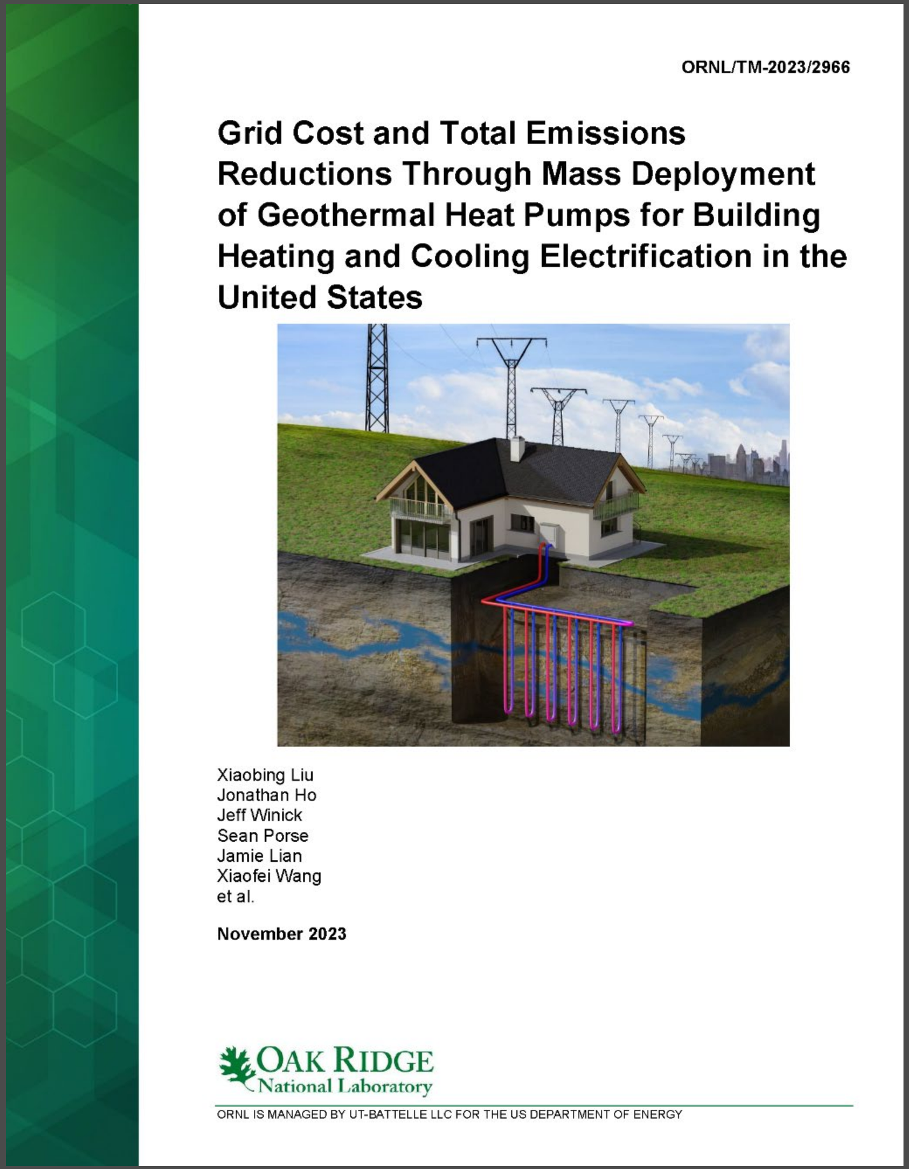
In the Marginal Abatement Cost optimal pathway, EECA identified Geothermal as the optimal fuel for all five cases

And what of Policy ….

- **Local decisions and expenditure on local resources**
  - Reduce the requirement for generation capacity, and grid and network capacity upgrades
- **What policy might further encourage these local energy solutions**
- **And what of avoided cost considerations ?**

Benefits of Geothermal heat pumps on grid / network / local electrical infrastructure

- US - Oak Ridge NL Report looks at the residential sector
- *The most notable result of this study, however, is that GHPs coupled …. are primarily a gridcost reduction tool and technology ….*
- In NZ Expect network cost reduction to be equally applicable to cases with larger local heat loads that adopt geothermal heat pump technology..


ORNL/TM-2023/2966

Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States

Xiaobing Liu
Jonathan Ho
Jeff Winick
Sean Porse
Jamie Lian
Xiaofei Wang
et al.

November 2023

OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

To Connect on the EECA geothermal work

- **GeoExchange**
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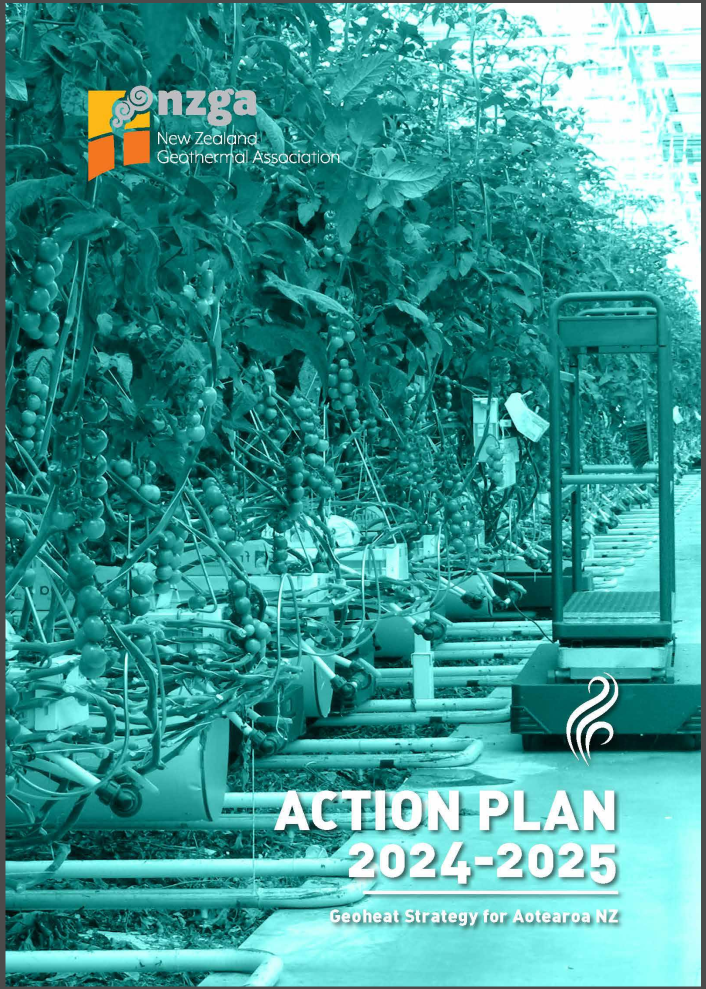
  - Brian Carey b.carey@gns.cri.nz
- **EECA**
  - Oliver Howitt Oliver.Howitt@eeca.govt.nz

NZGA Geoheat Strategy and Action Plans

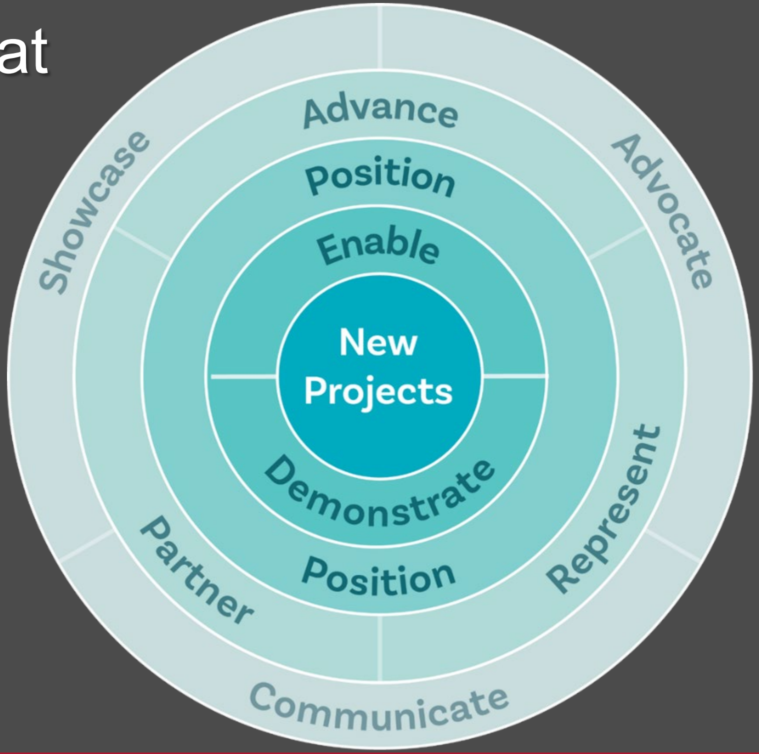
nzga
New Zealand
Geothermal Association



URL to NZGA Geoheat Web page – [URL Link]

What's it all about ….

- **Opening New Zealand's eyes to geothermal process heat energy**
  - Geothermal can heat and cool
- **Geothermal is right across NZ**
- **Getting new projects committed to and operational**
  - Enjoying the carbon benefits from using Geoheat
- **Intra – organisational Action Group**
  - Voluntary
  - About collaboration
- **Interested in participating**
  - Email committee@nzgeothermal.org.nz



Why Geoheat

- Geothermal heat for large process industries is ….

Low carbon

Available

Cost effective

Proven at scale

Renewable

Low risk

And MORE …….

- Attracts investment into the regions
- Contributes to regional economic growth
- Value-adds - Builds on natural strengths and sits downstream of primary industries in the region
- Presents opportunities for Māori investment and asset ownership
- Typically involves industries with above average economic productivity
- Creates jobs lifting skills and incomes

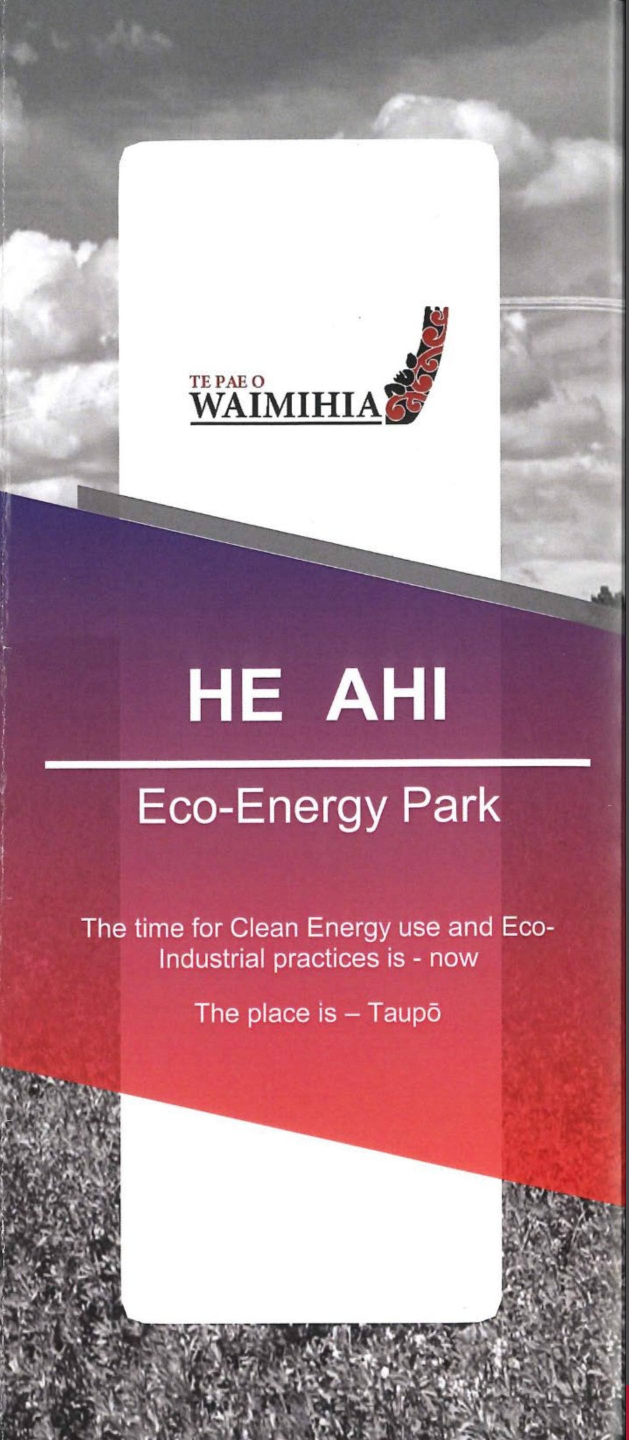
Four Case Studies in the 2024 -2025 Action Plan

- **Tnue – Fertiliser manufacturer**
- **Gourmet Mokai – Tomato and Capsicum Grower**
- **Miraka – Milk powder and UHT products producer**
- **Mount Maunganui – hypothetical drying operation**
  - High temperature heat pump
  - Based on Dominion Salt drying operation in the EECA RETA BOP

Tnue – Tauhara, Taupō

- Manufacturing controlled release membrane covered fertiliser granules
  - Nitrogen and carbon benefits
- First operational business at He Ahi – next slide
  - March 2024
- Geoheat supply capacity 1.2 MW_{th}

  Eliminates 800 tonnes carbon per annum



He Ahi, Eco-Energy Park - Taupō

- **~40 sites in preparation**

  https://www.tepaeowaimihia.com/projects

- **Geothermal energy available under contract from Contact Energy to ~ 16 sites**
- **Gets over the geothermal capital hurdle for smaller / medium sized Geoheat users**

Blandina Diamond <blandina.diamond@tpow.co.nz>

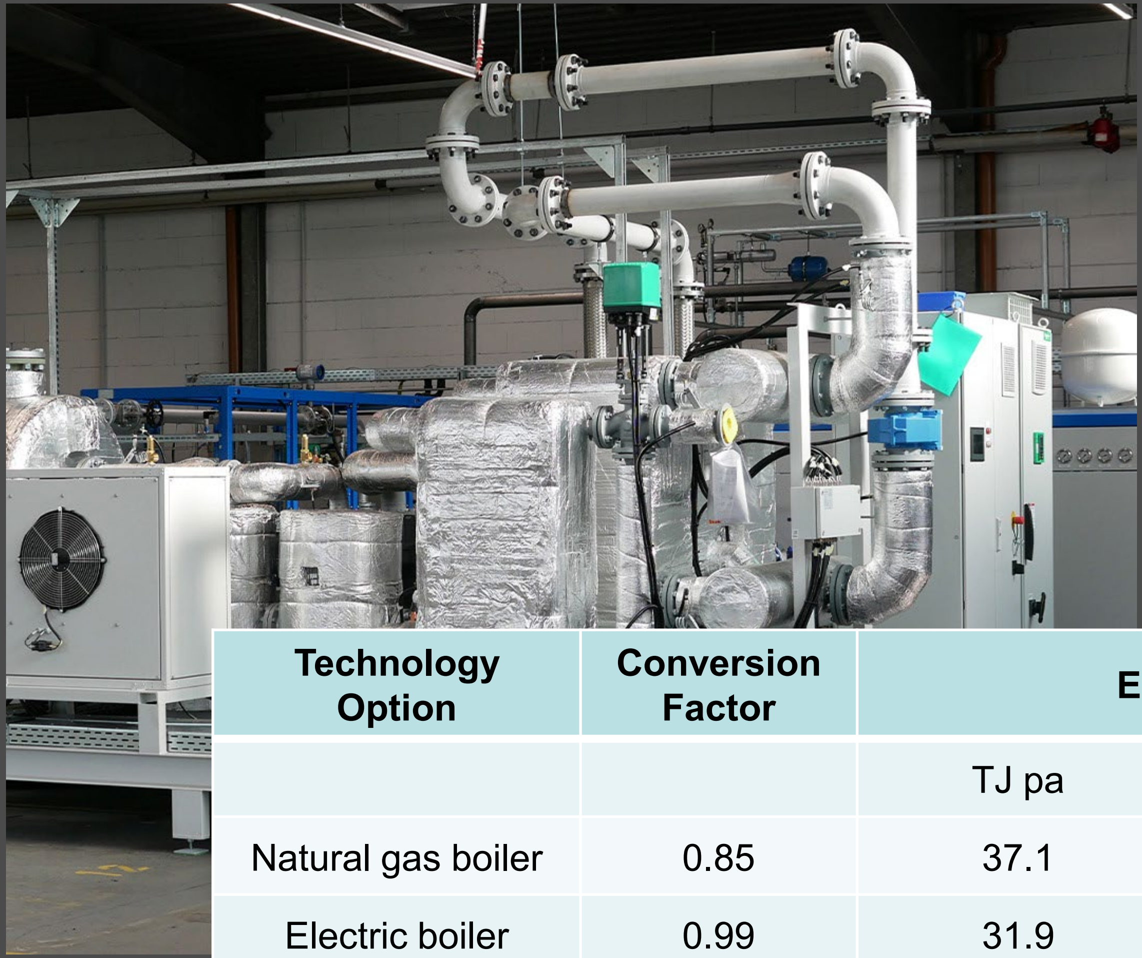
Gourmet Mokai - Mokai

- **12 hectare greenhouse**
  - 4275 t pa tomatoes
  - 900 t pa capsicum
- **24 MW geothermal heat supply**
  - Two 12 MW heat exchangers
  - Shell side 95^{o}C water to the greenhouse heat storage tanks
- **LED lights in two hectares**
  - Extends tomato growing period

Miraka - Mokai

- **300 million litres of milk pa**
  - Powder and UHT
- **Leader in low carbon emissions dairy**
  - 93% renewable now
- **Geothermal heat plant operational since 2011**
  - 30 t/hr of 20 barg process steam
  - 2 trains for 100% redundancy
- **Factory also uses geothermal generated electricity from TPC**
- **Over all 92% lower carbon emissions than if coal fired**

High Temperature Heat Pump – Mount Maunganui



- 45°C water source at ~400m
- Ideal for HT Geothermal Heat Pumps (HTGSHP)
- 1MW 120°C steam production
- Currently likely to be natural gas fired

Technology Option	Conversion Factor	Energy		Emissions	
		TJ pa	Reduction	tCO_2e pa	Reduction
Natural gas boiler	0.85	37.1		1996	
Electric boiler	0.99	31.9	14%	657	67%
HTGSHP	2.8	11.3	70%	232	88%

To connect on the NZGA Geoheat work

nzga
New Zealand
Geothermal Association

- **Interested in participating**
  - Email committee@nzgeothermal.org.nz

And that is me done for the session …..

- I have enjoyed it – I trust you have also …..

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