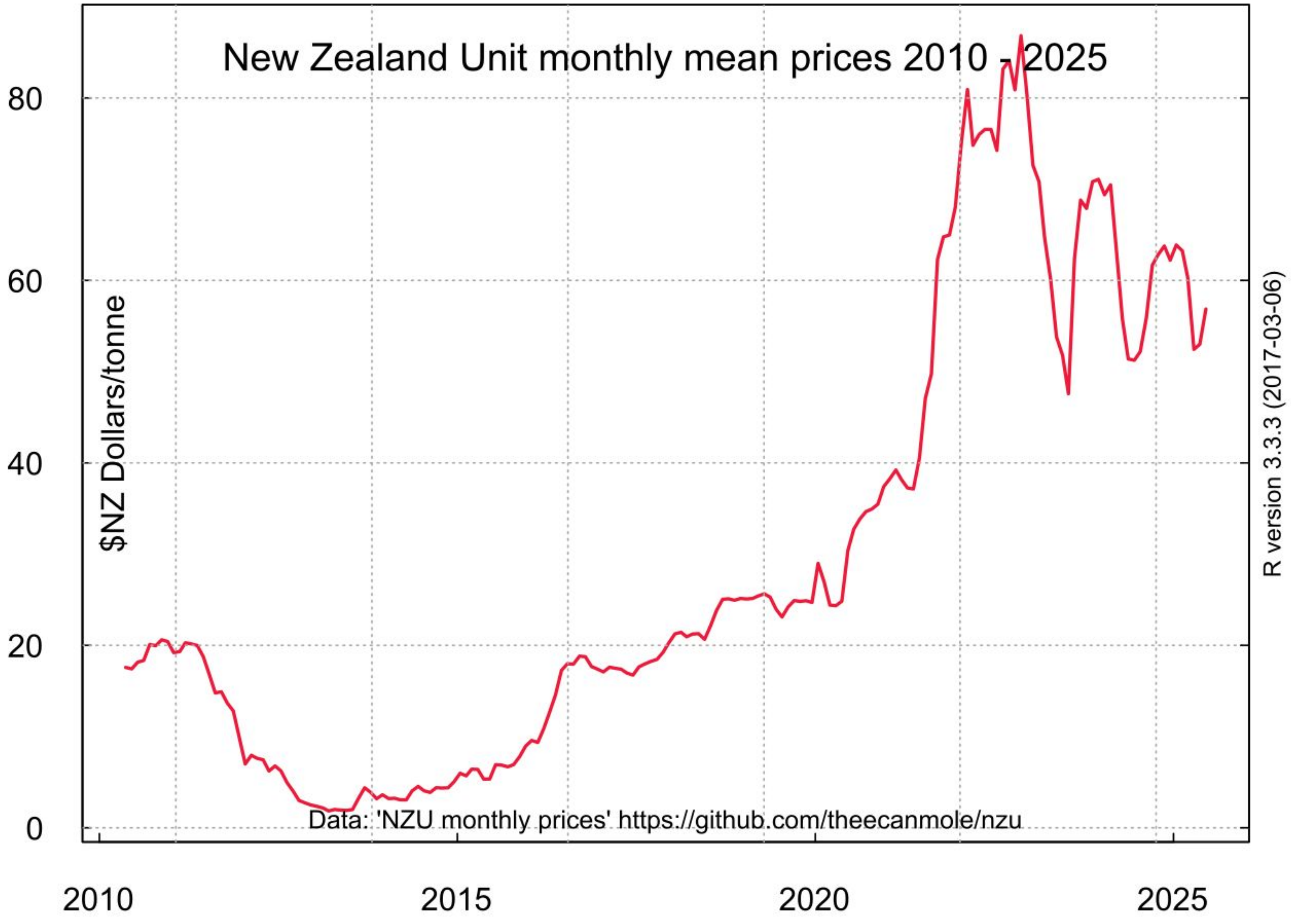
New Zealand Geothermal Association

Presentation:

NZGA Pre-Seminar Presentation:

New Zealand's Geothermal Carbon Emissions: Mitigations and Emerging Opportunities



Source: Data; Theecanmole. (2016). New Zealand emission unit (NZU) monthly prices 2010 to 2016: V1.0.01 [Data set]. Zenodo. http://doi.org/10.5281/zenodo.221328

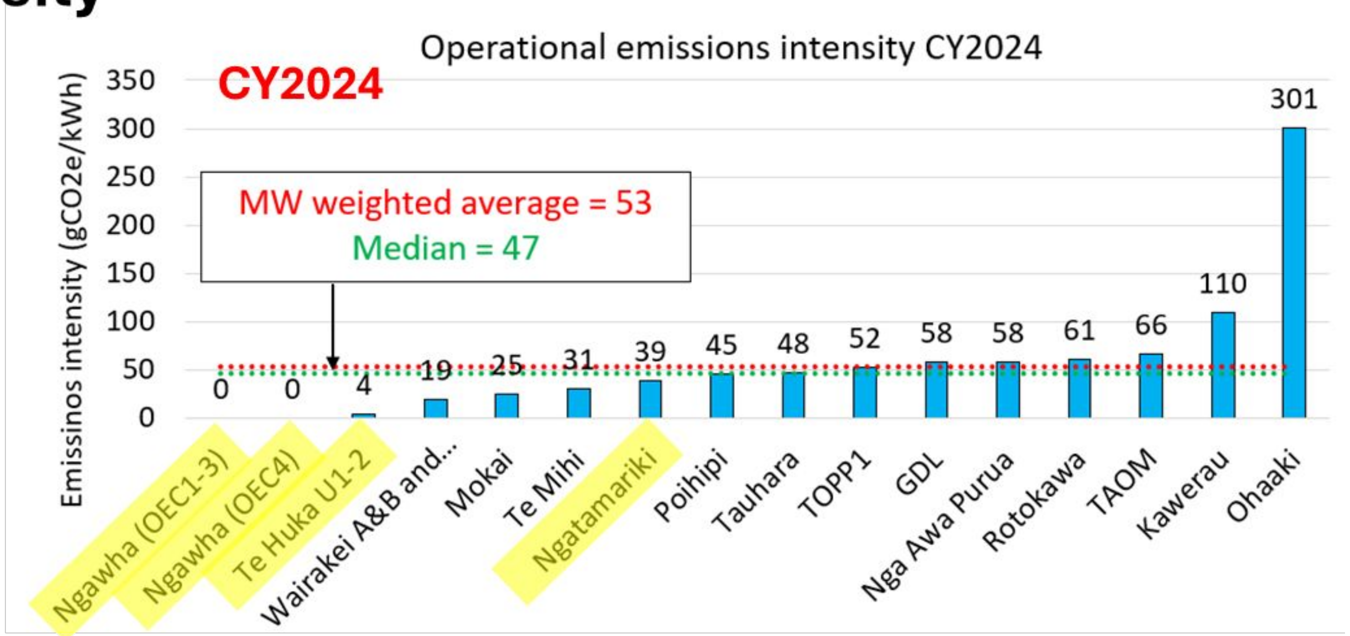
New Zealand Geothermal Association

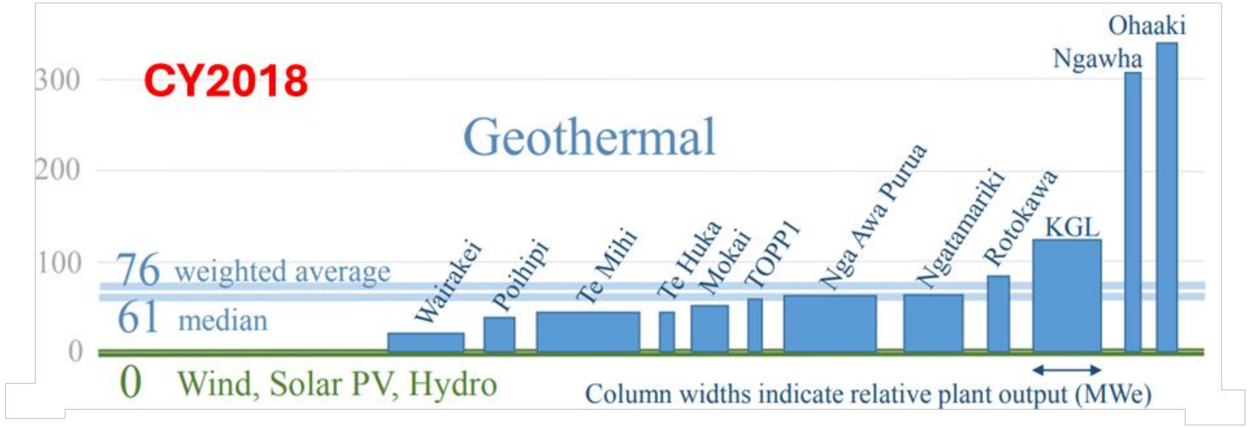
New Zealand's Geothermal CO_2 Trend

PRESENTED BY:
Dr Katie McLean, Senior Reservoir Engineer, Contact Energy

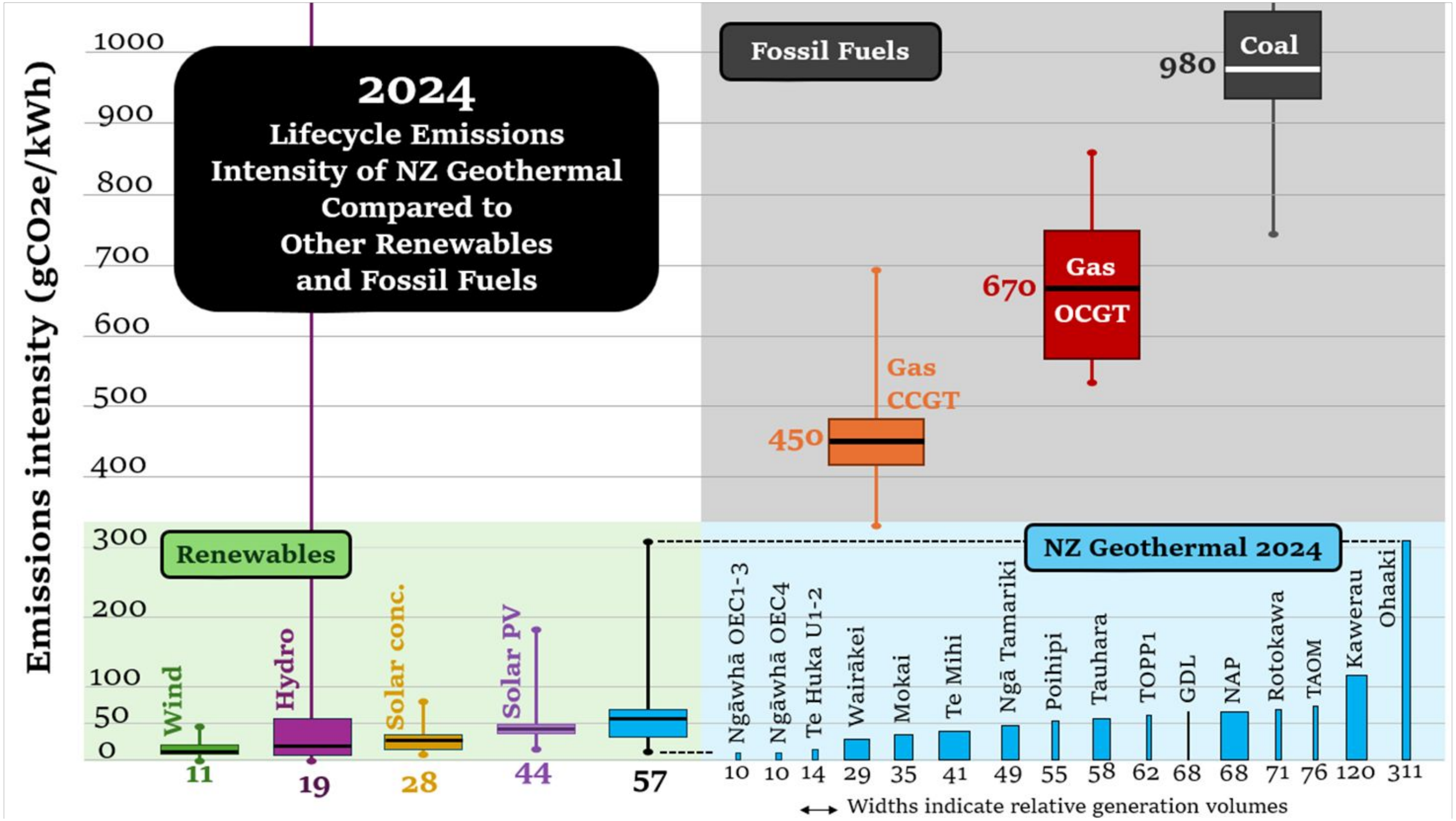
CY2024 operational emissions intensity

- Emissions released directly during power generation.
- MW-weighted average = 53 gCO_2e/kWh
- Median = 47 gCO_2e/kWh
- Wairakei used to be the lowest, but not anymore due to CO_2 reinjection.
- 100% CO_2 reinjection at all Ngāwhā plants and Te Huka U1-2.
- Partial reinjection at Ngā Tamariki.
- Ohaaki now alone as an outlier since Ngāwhā disappeared.





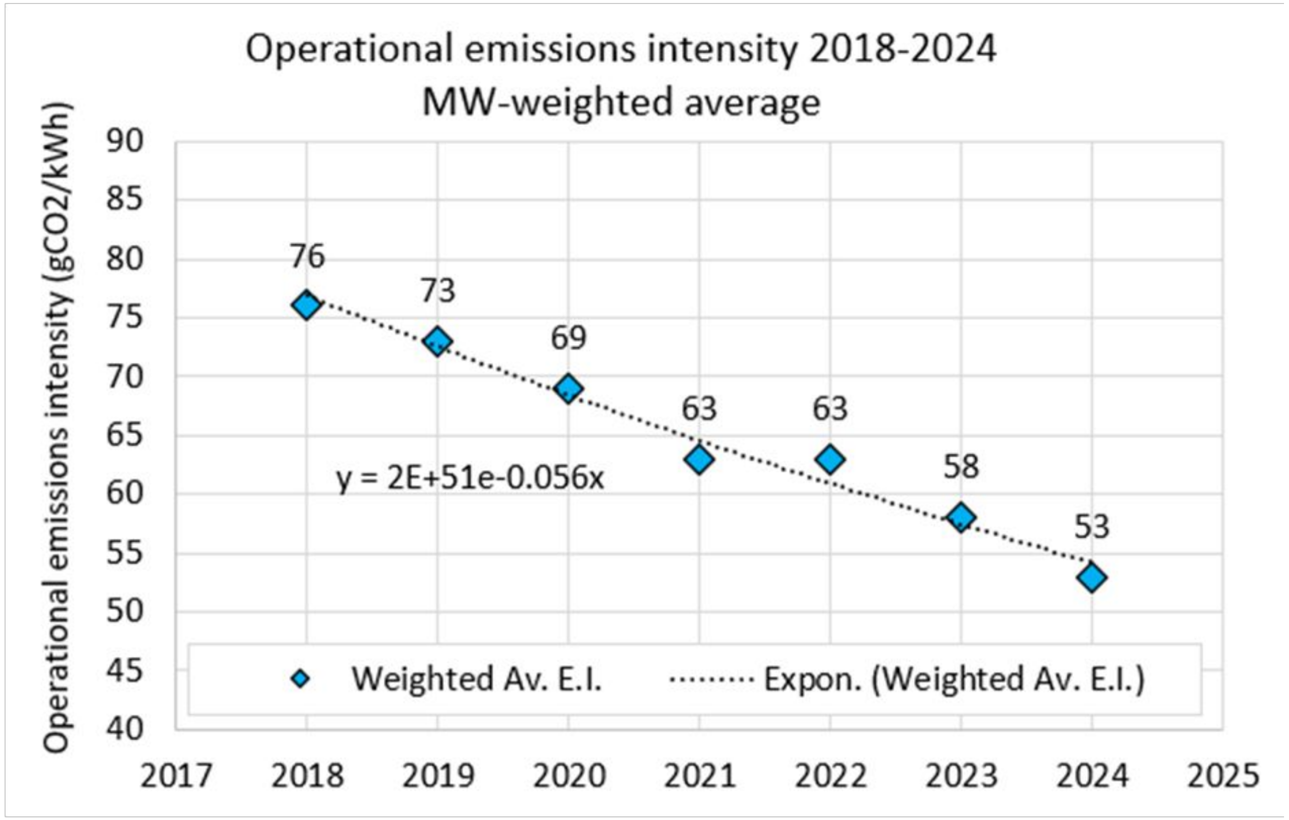
CY2024 lifecycle emissions intensity



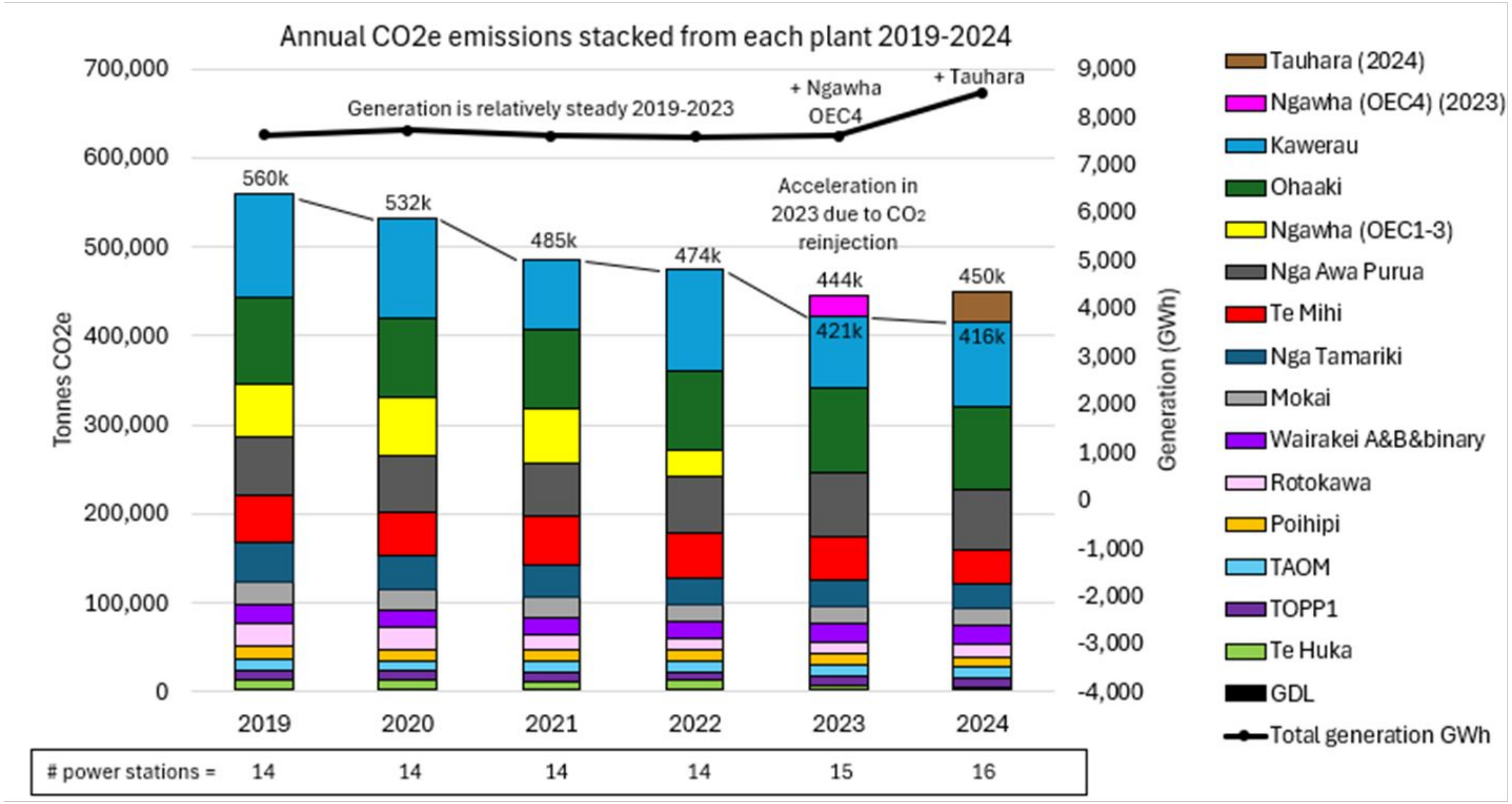
- Necessary to compare to other energy types.
- On top of operational emissions, includes estimates of emissions from materials/ construction and decommissioning (+10).
- Big picture same as previous years.
- Renewables an order of magnitude less than fossil fuels.
- Increasing overlap of geothermal with other renewables.

Trends - operational emissions intensity

- Trend continues to decline.
- Decline prior to 2021 was due to degassing/stabilisation of gas levels in the geothermal reservoirs.
- Was slowing signs of stabilising 2021-2022.
- Decline continues again from 2023 onwards.
- A significant contribution to this is from CO_2 reinjection.

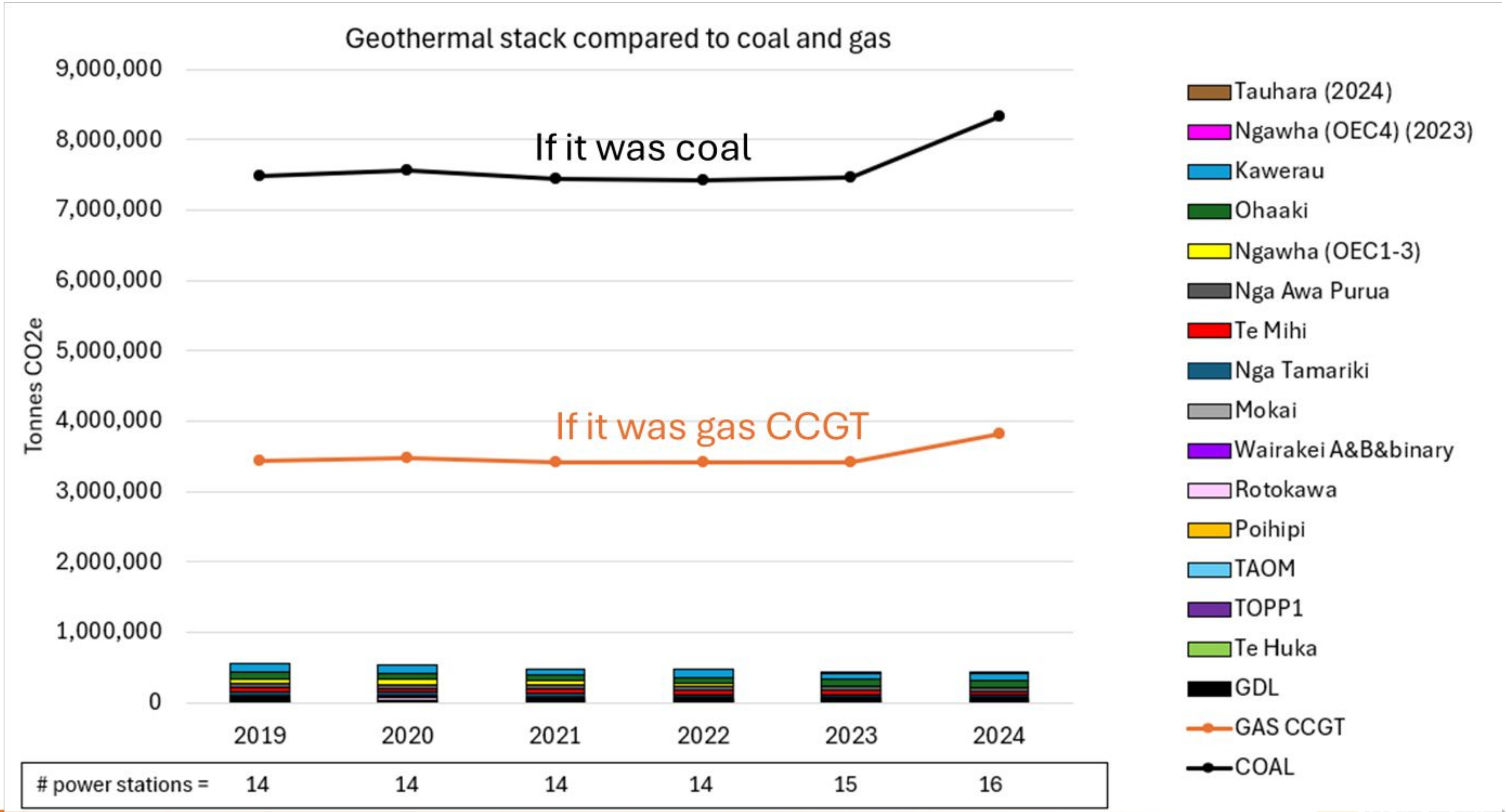


Trends – tonnes of emissions



- Declining trend for the same 14 stations.
- Acceleration of decline in 2023 due to CO_2 reinjection, particularly Ngāwhā OEC1-3.
- Ngāwhā OEC4 appeared in 2023 then disappeared due to CO_2 reinjection.
- Tauhara appeared in 2024: ↑ generation but similar overall emissions.
- If the breakdown was ignored it looks like the emissions have gone up slightly which is not the whole story.

Trends – tonnes of emissions



Key points

- NZ geothermal emissions intensity is comparable with other renewable energy sources.
- Geothermal plays a significant role in lowering NZ's electricity emissions.
- Emissions are continuing to decline for NZ geothermal power stations.
- A significant contributor to this is CO_2 reinjection, also reservoir degassing.
- CO_2 reinjection activities are set to expand.

New Zealand Geothermal Association

NZ geothermal industry: Climate Change Regulations Update - DEFs, UEFs and NCG Reinjection

PRESENTED BY:

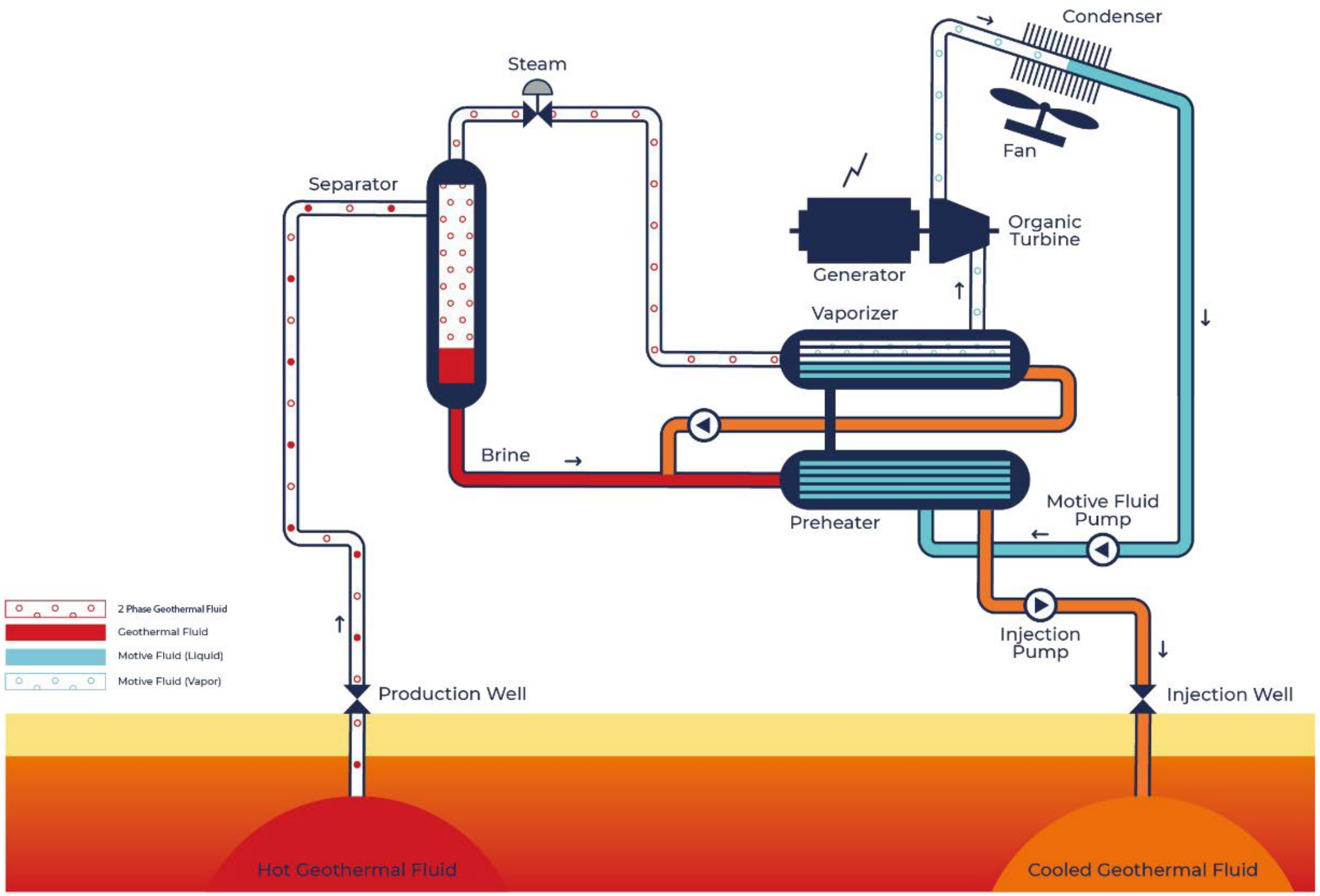
Ian Richardson, Innovation & Special Projects, Contact Energy

First major review of the Climate Change (Unique Emissions Factors) Regulations since its introduction in 2009

- Ministry for the Environment Consulted with the geothermal industry and NZGA to update the UEF Regulations – bring them up to date with changes in industry practice and also to improve ease of use.
- Additional emissions calculations methodologies added, including mass balance to determine Unique Emissions Factors (UEF)
- Geothermal brine now included in calculations in additional to steam and condensate
- NCG reinjection better accounted for in the regulations
- Section 16 (2C) specific to plants with 100% NCG reinjection
  - Enables verification of permanent connection of NCG reinjection systems
  - Includes *de minimus* of up to 4000t/yr emissions to account for start-up/shut-down and trips.

Methods for accounting for NCG reinjection are now clearly specified and described

TWO-PHASE BINARY GEOTHERMAL POWER PLANT



Climate Change (Stationary Energy and Industrial Processes) Regulations 2009

- Updated Default Emissions Factors (DEFs) for geothermal fluid (Schedule 2, Table 6)
  - Addition of Miraka Milk, Nga Tamariki, Ngawha 3, Te Ahi O Maui, Te Huka, Te Mihi, TOPP1, Mokai Greenhouse, Tauhara Tenon
  - Reduction in emissions factors (significant):
    - Kawerau sites, Nga Awa Purua, Rotokawa, Ngawha, Ohaaki and Wairakei
  - Increased emissions factors (minor):
    - Mokai, Poihipi
  - New plant DEF remains at 0.03TCO_2e/T steam – incentivising new facilities to undertake to UEF process for at least the first 3 years of operation

Ministry for the Environment have been consulting on changes to the DEF calculation process:

- Intention that DEFs will be updated each year and will be the rolling average of the previous 3 years UEF values (or DEF where no UEF is available).
- This will enable DEFs to be updated regularly without additional costs to the regulator
- Reduce the need to undertake the UEF process until there are significant changes in emissions factors – remove need to undertake UEF process because the DEF is out of date (requiring significant time and cost to operators).

Table 4: Proposed 2026 geothermal DEF values using option 1 date range

Class – Geothermal fluid used by:	Type of value	Year 2022	2023	2024	Proposed DEF value for 2026 (option 1)
Part A					
Kawerau II	UEF	0.0152	0.0156	0.0143	0.015033
Kawerau Industrial	Current DEF	0.0174	0.0174	0.0174	0.0174
Kawerau KA24	UEF	0.0119	0.0119	0.0119	0.0119
Miraka Milk	Current DEF	0.0053	0.0053	0.0053	0.0053
Mokai I and II	UEF	0.00418	0.00382	0.00382	0.0039
Ngā Awa Purua	UEF	0.0087	0.0087	0.0087	0.0087
Ngā Tamariki	UEF	0.0073	0.0073	0.0069	0.0072
Ngāwhā I and II	UEF	0.0442	0	0	0.0147
Ngāwhā III	UEF			0	0.0437
	Current DEF	0.0655	0.0655		
Ohaaki	UEF	0.0333	0.0333	0.0333	0.0333
Poihipi Road	Current DEF	0.0051	0.0051	0.0051	0.0051
Rotokawa I	UEF	0.0119	0.0119	0.0119	0.0119
Te Ahi o Maui	UEF	0.0106	0.0113	0.0119	0.0113
Te Huka	UEF	0.0073	0.00358	0.00061	0.0038
Te Mihi	UEF	0.0044	0.0041	0.0045	0.0043
Topp 1	UEF	0.0102	0.0088	0.0088	0.0093
Wairakei Station site	UEF	0.0022	0.0023	0.0022	0.0022
Tauhara	UEF			0.0056	0.0237
	Current DEF	0.0300	0.0300		

New Zealand Geothermal Association

Topic 1: CO_2 emissions capture & reinjection at three geothermal power plants in New Zealand

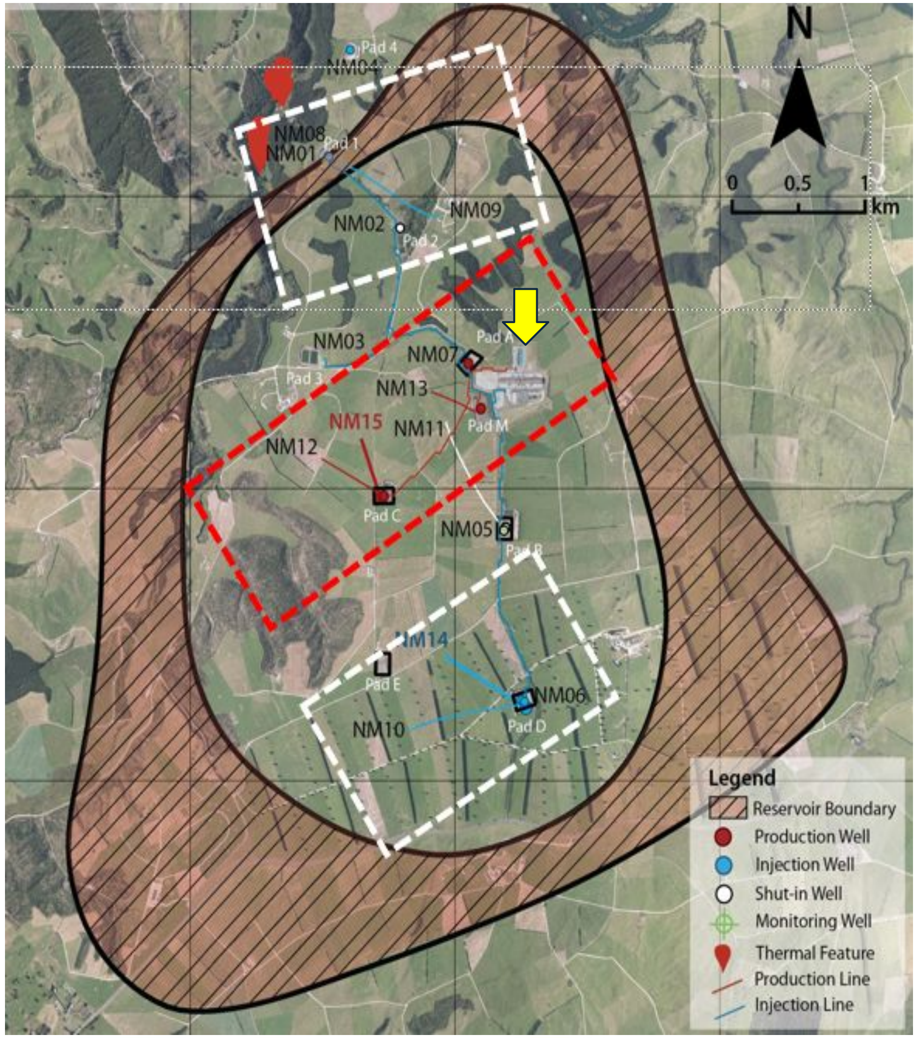
Ngā Tamariki: Project Overview, Challenges, Learnings & Results

PRESENTED BY:

Mr Farrell Siega, Geoscience Manager, Mercury

Ngā Tamariki Field and Power Station

- **86 MW** 4 OEC Units Binary Power Plant commissioned in 2013
- **50 MW** OEC5 Unit under construction for 2026 target commissioning
- Fluid supply from 4 production wells; reinjection into 5 reinjection wells
- **~55,000 tonnes CO2e per year** including new OEC5 unit

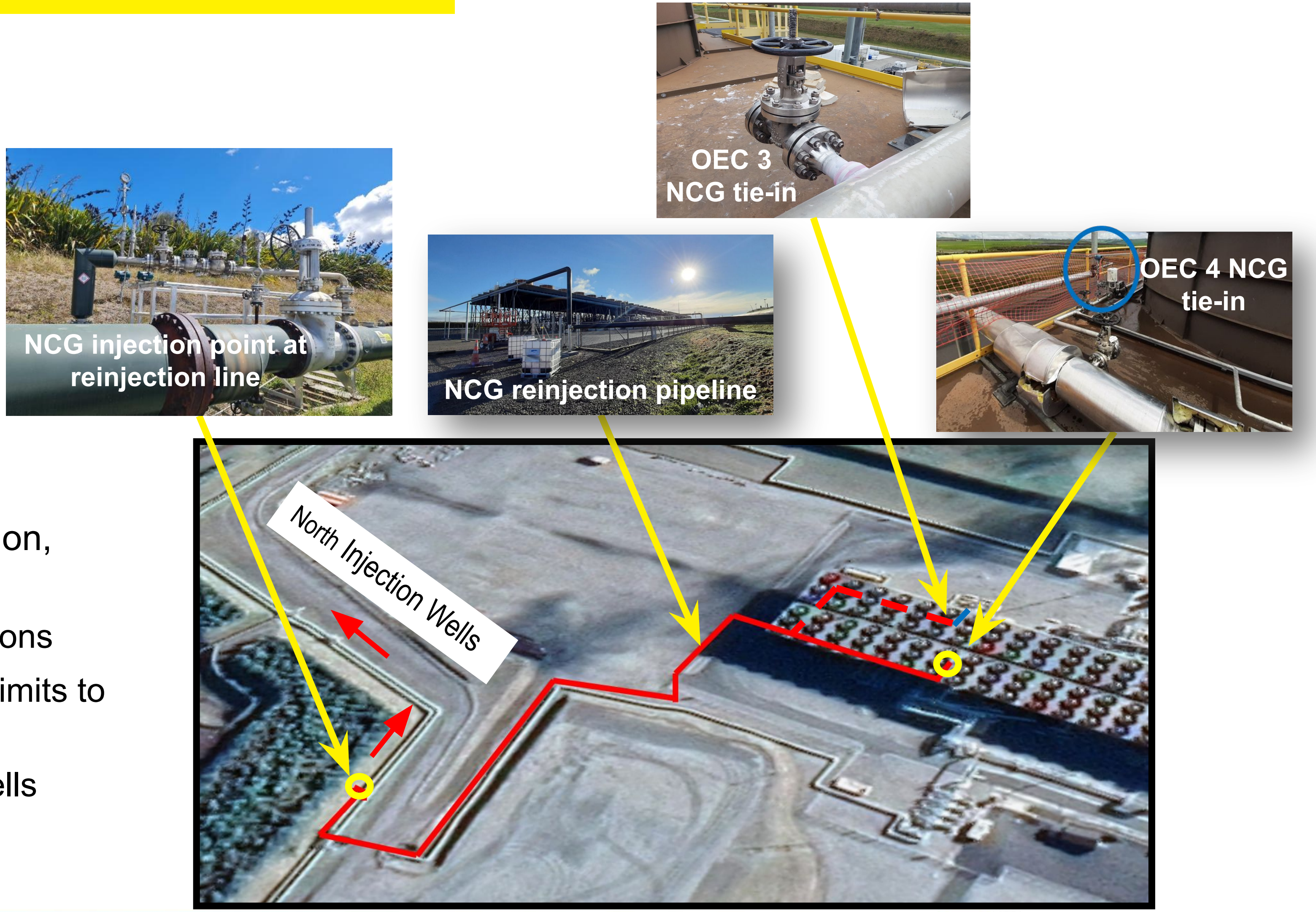


NCG Reinjection History at Ngā Tamariki

NCG REINJECTION SYSTEM IN 2024

- First unit (OEC4) NCG reinjection commissioned in October 2021
- Second unit (OEC3) NCG reinjection commissioned in August 2024
- Total NCG reinjection at ~40%

- A phased approach strategy for NCG reinjection, based on key drivers:
  - Reduce carbon emissions from geo operations
  - Understand NCG solubility and reinjection limits to manage plant operational risks
  - Study long term effects on reservoir and wells



NCG Reinjection History at Ngā Tamariki

- We have taken a similar phased approach strategy for NCG reinjection from 2025 and beyond
- Our NCG reinjection targets:
  - 2025 at >70% of total emissions (33,000 tCO2e/yr) from OEC1-4 units
  - 2027 at 80% of total emissions (55,000 tCO2e/yr) from the 5 OEC units

2021 – COMPLETED

NCG Reinjection Trial: OEC4 NCG reinjection

2024 – COMPLETED

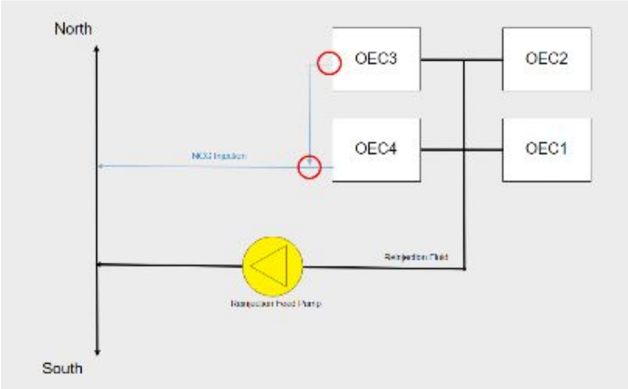
Phase 1: Adding OEC3 into OEC4 NCG reinjection system

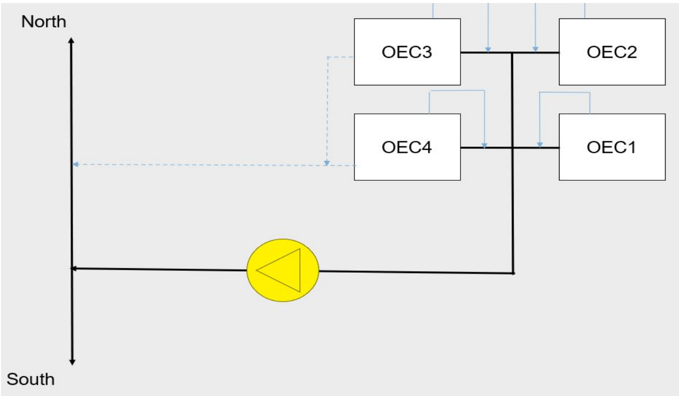
2025 – COMPLETED

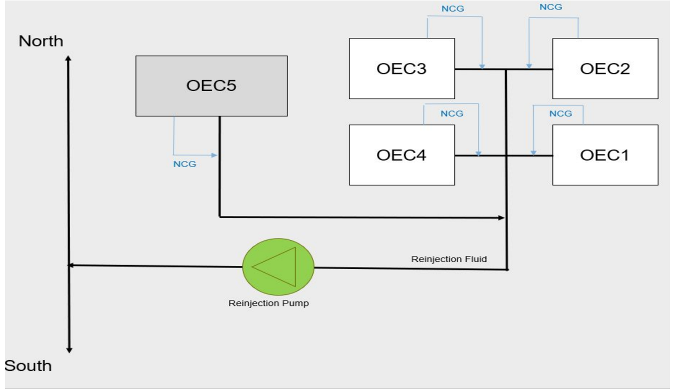
Phase 2: Unitised reinjection of all OECs – Units 1 to 4, fine tuning

2026 - 2027 – PLANNED

Final Phase: OEC5 addition and unitised injection into the reinjection main line







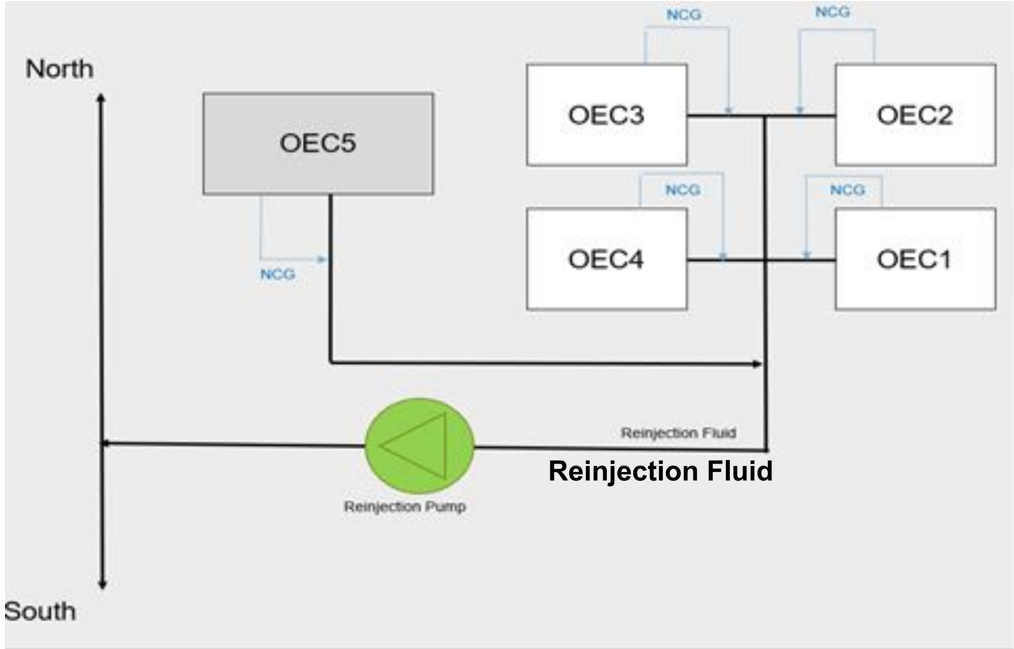
NCG Reinjection Challenges

Gas Breakout Pressure (GBOP) - OPERATIONAL

2025 and Beyond:

- Amount of NCG reinjected at Nga Tamariki will increase using both NORTH and SOUTH reinjection wells
- Key issues:
  - South reinjection wells at vacuum or lower WHP
  - GBOP varies depending on amount of NCG reinjected (table)
  - If GBOP > Injection line pressure to SOUTH
    - ➔ we anticipate NCG to not fully dissolved in reinjected fluid
    - ➔ risk of gas lock in reinjection wells and affects well acceptance
- Trial completed for NCG reinjection to NORTH and SOUTH
  - Achieved up to 75% NCG reinjection (short term) from all 4 existing OEC units
  - Fine tuning on-going, considering the addition of OEC5

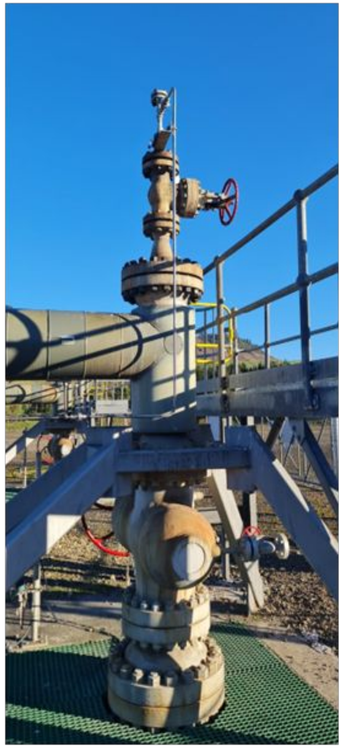
	No NCG reinjection	NCG reinjection 1 x OEC	NCG reinjection 2 x OECs
% total NCG flow	**23%** total NCG	**43%** total NCG	**62%** total NCG
GBOP	**1.8 barg**	**3.1 barg**	**4.2 barg**



NCG Reinjection Challenges

Operational – Venting Process for Gas Lock Scenario

- **During the trial:** a temporary vent system was installed to vent NCGs from injection wells if required.
- **At current normal operation** – a permanent hard piping is now installed to vent NCGs from injection wells to a safe location.

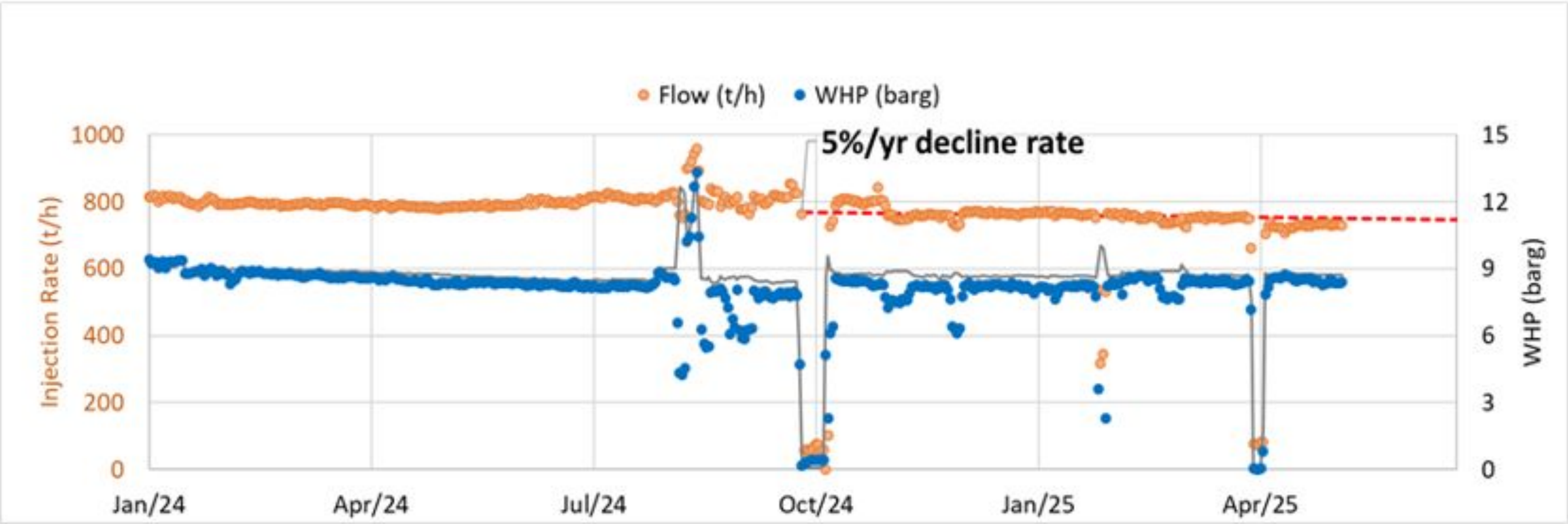


NCG Reinjection Key Learnings

REINJECTION WELL PERFORMANCE

In the last 2 yrs

- Relatively lower injection decline at **5% per year**
- Need to continue monitoring to confirm long term trends

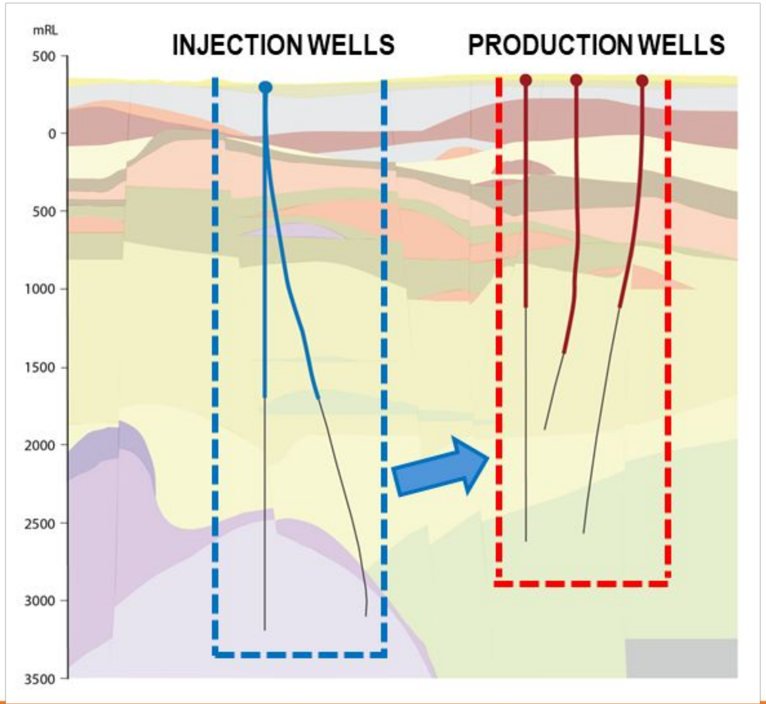


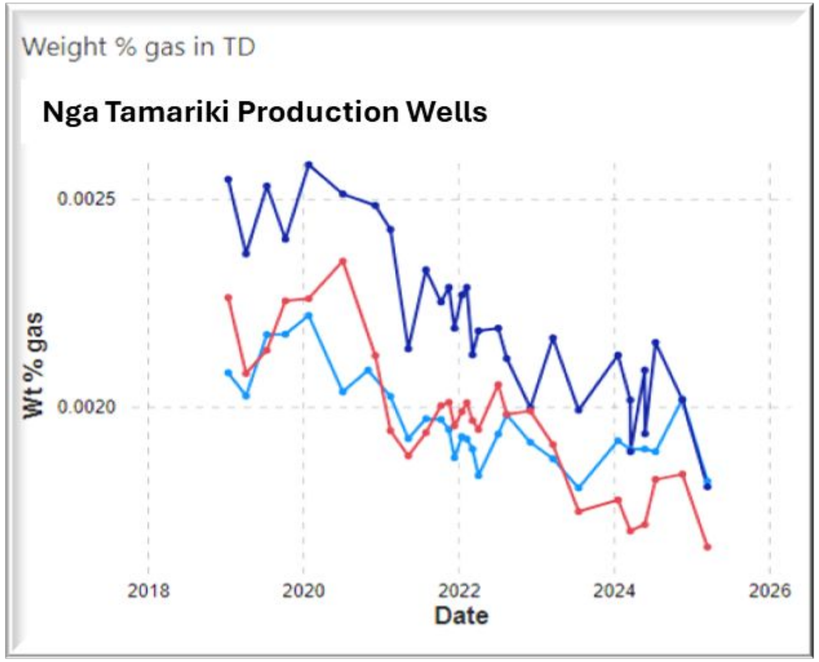
NCG Reinjection Key Learnings

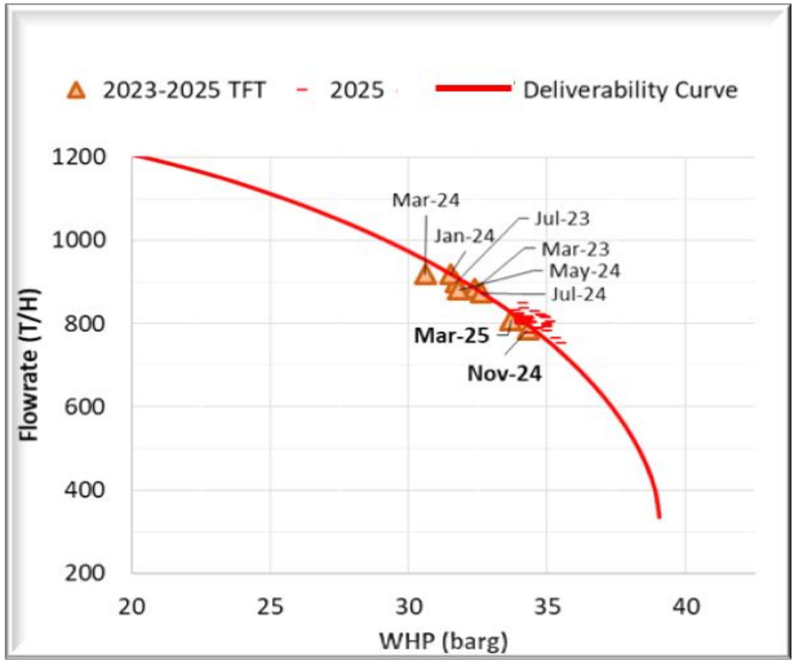
PRODUCTION WELL PERFORMANCE

No reinjected NCG returns to the production area

- Gas concentrations remained low, continuing with degassing trend
- No scaling observed for well closest to injection well – stable well performance







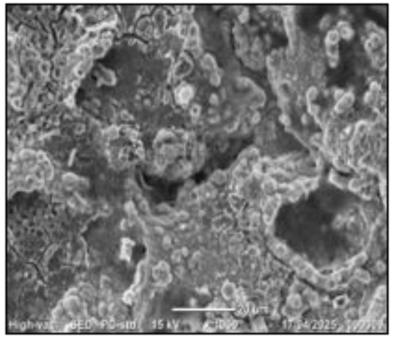
NCG Reinjection Key Learnings

CORROSION MONITORING

- Measured corrosion rates using coupons in pipelines considered minimal at rates of:
  - 0.0023 mm/yr for 25% NCG reinjection
  - 0.0093 mm/yr for 40% NCG reinjection
- UT thickness monitoring at nine (9) locations from injection point to wellhead
  > Max wall thickness reduction ~ 1 mm at bends downstream of the mixer

  > Other locations have minimal thickness reduction

  > Camera run showed the line is evenly coated with thin scales



Corrosion Coupon *corrosion allowance ~3mm

Scale Analysis

- Uniform coating of mineral precipitates
- Fe sulfide + Am silica, As-Sb sulfide

UT Monitoring

Summary and Results

EMISSION REDUCTION – NGA TAMARIKI STATION		
Current - 2025	**Target**	**Notes**
40%	**80%**	Half way of the target emission reduction 80% is equivalent to 10% of Mercury's total emission reduction target

Key Observations at Present		
Reinjection Well Performance	Green	Lower capacity decline
Production Wells Performance	Green	No gas returns observed, scaling risk not currently an issue
Gas locking and solubility	Yellow	Not an issue, operationally manageable at current NCG reinjection/pipeline configuration; Further confirmation at high NCG reinjection target
Plant operation and output	Green	No impact at present
Corrosion	Yellow	Acceptable, less on the well side, within pipeline corrosion allowance

New Zealand Geothermal Association

Topic 1: CO_2 emissions capture & reinjection at three geothermal power plants in New Zealand

Te Huka: Project Overview, Challenges, Learnings & Results

PRESENTED BY:

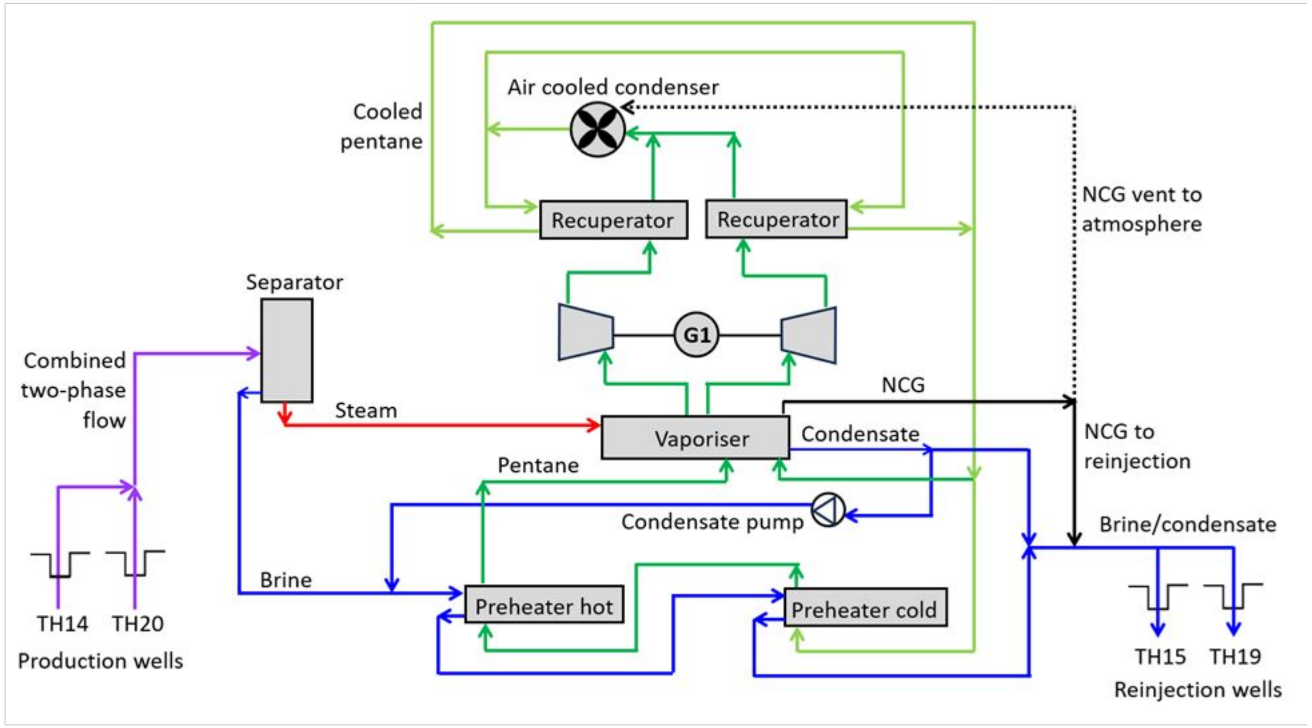
Ian Richardson, Innovation & Special Projects, Contact Energy

Contact Energy

- Contact Energy is an electricity generator and retailer in New Zealand
- Geothermal, Hydroelectric and Thermal generation – solar under construction, wind going through consent application
- 7 Geothermal power plants (>600MW), another under construction (100MW)
- >200,000t/y CO_2e emissions from geothermal generation
- Goal to be net zero emission by 2035

Te Huka

- 25MWe (net) binary power plant – 2 Ormat units (OEC)
- Located on the Tauhara geothermal field
- Commissioned in 2011
- ~1000t/hr production fluid (200t/hr steam)
- 9 barg steam pressure
- ~10,000t/y CO_2e emissions



Plant Selection

- Oxygen free gas composition
- Good gas to liquid ratio (~0.1%)
- Good gas pressure with slightly lower reinjection pressure
- Passive NCG Reinjection since commissioning (~18.8%)
- Small section of the reservoir
- Gas and liquid conduits located close together

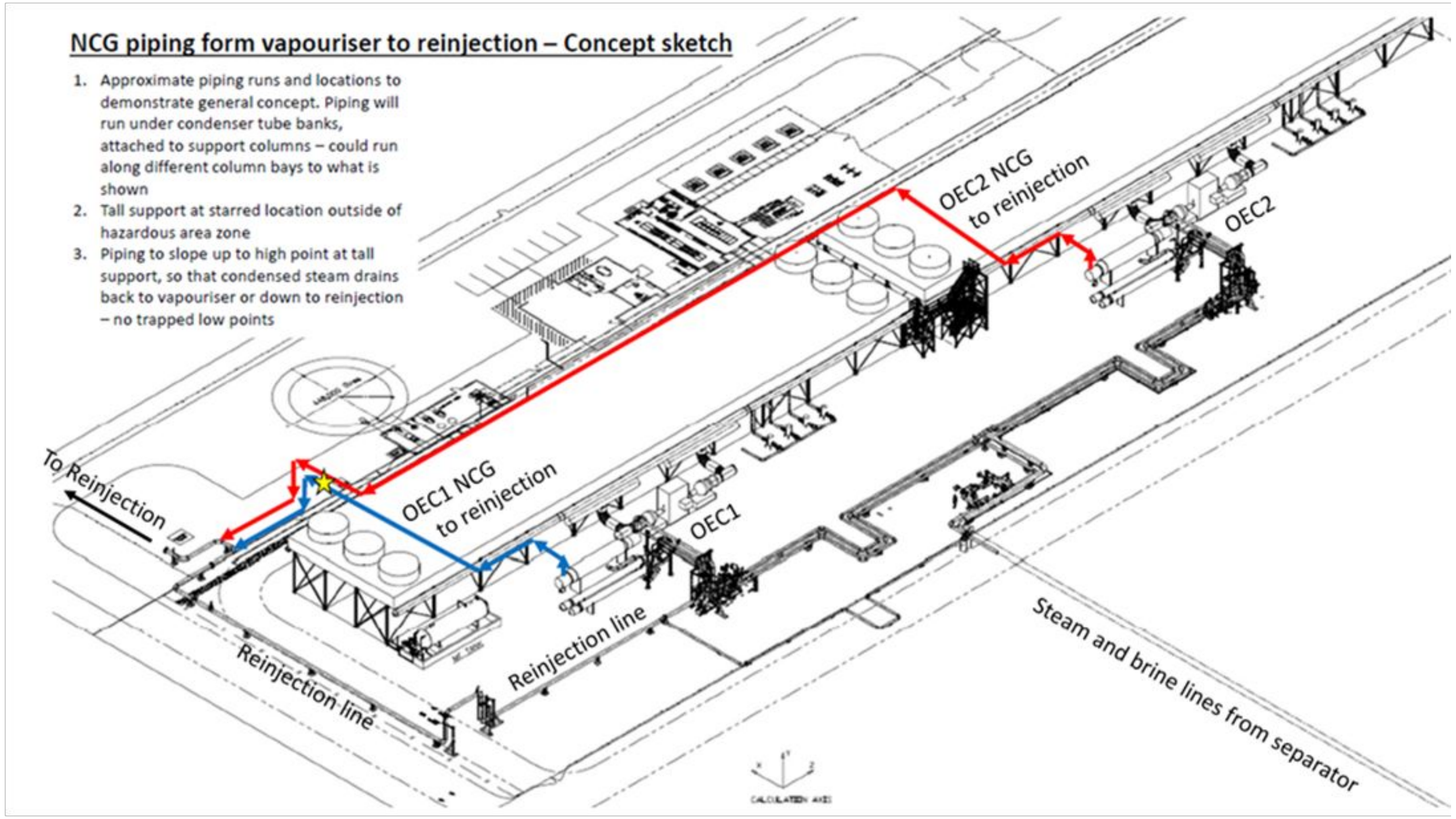
Te Huka NCG Composition

Component	%Weight
CO_2	94.62%
H_2S	3.23%
NH_3	0.25%
H_2	0.018%
CH_4	0.68%
N_2	1.19%
Ar	0.016%
He	0.00007%

Risks

- Corrosion, Deposition and Scaling
- Reservoir impacts
  - Injectivity
  - Gas breakthrough
- Operational control
  - Reinjection pressure control
  - Steam flow control
- Safety
  - Concentrated NCG conduits
  - Higher H_2S in Reinjection fluid

Te Huka NCG Reinjection Concept



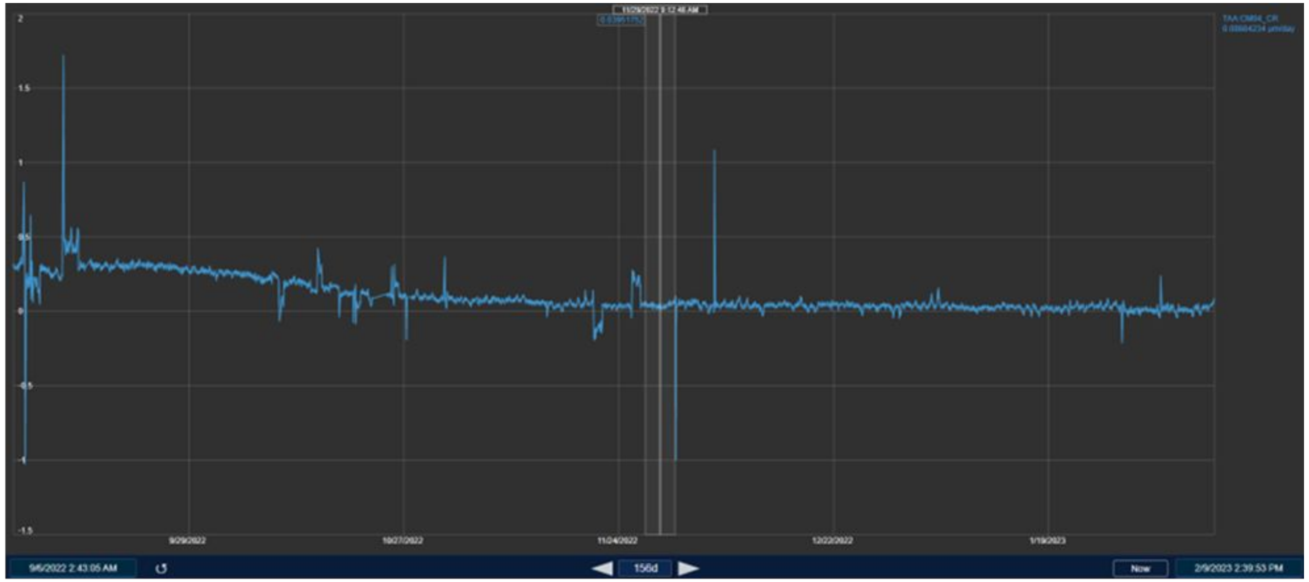
NCG Reinjection

Te Huka NCG Unit 1 Reinjection

- NCG Conduits run from each unit to Reinjection system
- SIL rated stop and control valves
- Gas sparges installed in Reinjection piping
- Control system tuned to operate in vent and reinjection mode
- H_2S detection and automated plant trip

Results

- 100% NCG Reinjection
- Stable reinjection at all normal plant loads
- No impacts to reinjection system or reservoir observed to date
- Operation below breakout pressure undertaken without issue
- Corrosion monitoring and inspection indicate no change
- Reduced odour concern (H_2S)
- Reduced plant noise



Te Huka Reinjection Flow and Pressure Data

Corrosion Inspection – NCG Injection point

May 2022 – Pre injection

April 2023

October 2023

Air Ingress Trials

- Trials undertaken at Te Huka to measure the impact of air ingress on corrosion rates
- 3ppm oxygen in reinjection fluid
  - Representative of gland steam air in-leakage on flash plant
  - Representative of gas absorber outlet conditions for direct contact condenser plants
- Significant corrosion observed over 35 days of coupon exposure
- Corrosion resistant alloys likely required for flash plant NCG reinjection
- Investigating potential for corrosion inhibitor for this application

Number	Site	Date installed	Date Removed	Air Ingress 205lpm (days)	Time in Service (days)	Mass (g)	Mass (g)	Mass (g)	Mass (g)		Overall		Air ingress
							Scale & Coupon	Coupon	Scale	Mass loss (g)	Corrosion loss (mm)	Corrosion rate (mm/yr)	Corrosion rate (mm/yr)
1	CM Site1	1/08/2024	2/10/2024	35	62	14.138	14.172	14.16	0.012	-0.022	-0.0013	-0.0076	-0.0134
2	Tenon Y-line	1/08/2024	2/10/2024	35	62	14.153	11.395	9.578	1.817	4.575	0.2669	1.5713	2.7835
3	TH16	2/08/2024	2/10/2024	35	61	14.169	12.026	10.741	1.285	3.428	0.2000	1.1967	2.0856
4	TH15	31/07/2024	2/10/2024	35	63	14.133	14.074	14.062	0.012	0.071	0.0041	0.0240	0.0432

What Next?

Te Huka 3

- NCG Reinjection included in the design
- Successfully commissioned and operational

Te Mihi 2

- NCG Reinjection included in the design

Flash Plants

- Work ongoing
- Technically feasible
- Economically challenging

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New Zealand Geothermal Association

Topic 1: CO_2 emissions capture & reinjection at three geothermal power plants in New Zealand

Ngāwhā: Project Overview

PRESENTED BY:

Dr Katie McLean Senior Reservoir Engineer, Contact Energy, on behalf of Top Energy

NZ’s First Zero-Carbon Geothermal Generator

Ngāwhā represents a 25-year strategic initiative by Top Energy to harness geothermal energy and improve economic prosperity in the Far North:

- Ngāwhā Generation Limited (NGL) formed as a wholly-owned subsidiary of Top Energy in 1996.
- Its first power station was commissioned in 1998.
- On 31st December 2020 NGL commissioned its third power station OEC4.
- OEC4 transformed the region into a net exporter of electricity, providing energy independence and the flow-on benefits to one of New Zealand’s most socio-economically challenged communities.

Just one month later, the Climate Change Commission recommended the eventual closure of Ngāwhā’s operation to reduce carbon emissions - a huge shock to the company.

- Top Energy responded by launching an ambitious sustainability strategy that would achieve what was once thought impossible.

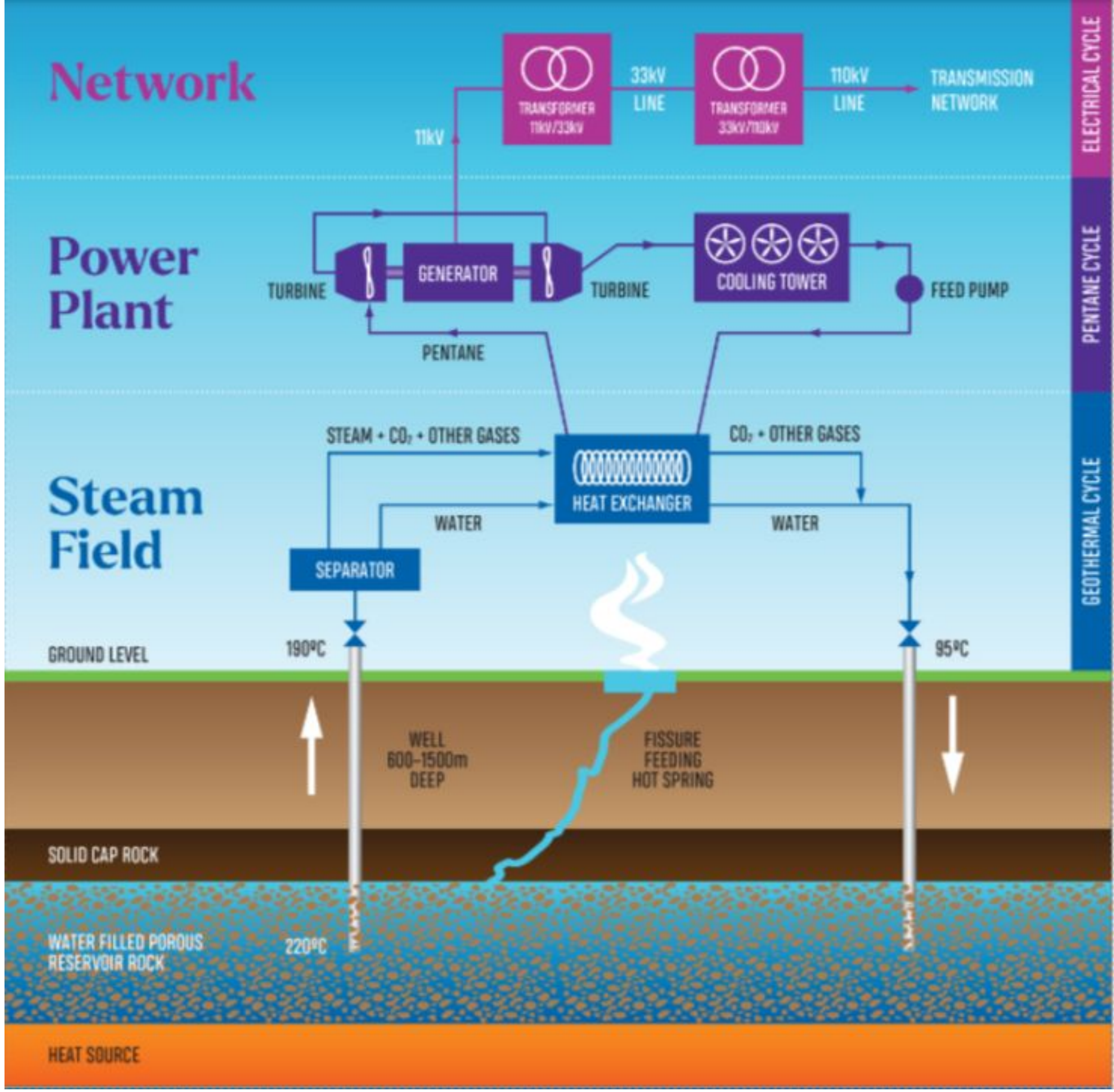
In 2023, NGL became NZ’s first zero carbon geothermal power station operator, providing 57 MW of electricity.

Innovation & Ngāwhā’s Path to Decarbonisation

NGL pioneered innovative technology and methods to reinject 100% of non-condensable gases extracted during generation.

- Non-Condensable Gas Reinjection (NCGR) captures and reinjects greenhouse gases to the geothermal reservoir, creating a fully closed loop system.
- In 2022, trials began at OEC1 and OEC2 to test NCGR. OEC3 and OEC4 followed in 2023.
- In 2024, NGL had become New Zealand’s first zero carbon emitting geothermal generator.
- In 2025, NCGR is now part of business as usual.

Avoids 128,000 tons of emissions per year.
The same a removing 30,000 cars off the road.



Te Hiku o te Ika (The Far North) is Powered By Emission-Free Geothermal Energy

Ngāwhā is a national first with global relevance:

- Recognised by the Environmental Protection Authority with a Unique Emission Factor of zero.
- Reinjecting greenhouse gases has previously been considered a risk not worth taking by experts.
- New Zealand's climate change policy made it a necessity.
- NGL has shown reinjection can be low-cost, low-risk and transformative.

From one of New Zealand's highest-emitting geothermal stations, Ngāwhā is now a leader in sustainable geothermal energy, sharing knowledge to support sector-wide decarbonisation.

Ko Ngāwhā he puna hiko toitu.
Ngāwhā serves as the cornerstone of sustainable energy.

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Topic 2: Geothermal CO_2 capture & use

Project Update: Extremophile Feedstocks

PRESENTED BY:

Andy Blair, Director of Business & Innovation &
Co-founder, Upflow

Sam Houwers
Strategic Project Manager
Mercury

Session Chair

Farrell Siega
Geoscience Manager
Mercury

Dr Katie McLean
Senior Reservoir Engineer
Contact Energy

Ian RIchardson
Innovation & Special Projects
Contact Energy

Andy Blair
Director Business &
Innovation & Co-founder
Upflow

Submit written questions here

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