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Geothermal Greenhouse Gas Emissions Reduction at Mercury NZ: Progress to Date and Challenges Ahead

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1 INTRODUCTION

Mercury NZ is actively working to reduce greenhouse gas emissions from its geothermal operation. Non-condensable gas (NCG) reinjection was first trialed at the Ngā Tamariki binary station in 2021-2022. From 2024-2025, work was carried out to increase the fraction of NCG reinjected at Ngā Tamariki. Learnings from Ngā Tamariki are being used to develop NCG reinjection strategies for the other geothermal sites operated by Mercury. Between 2026 and 2030, the program will focus upon maximizing emissions reduction at Ngā Tamariki (80% reduction), implementing NCG reinjection at other binary stations, and continuing to study and derisk emissions reduction options for flash plants.

This paper provides a high-level summary of the geothermal emissions reduction program and progress to date. Key technical considerations include gas solubility constraints in pipelines and wells, gas cleanup and compression requirements, scaling and corrosion, and understanding the fate of reinjected NCGs in geothermal reservoirs.

2 BACKGROUND

2.1 Geothermal generation at Mercury

Mercury NZ generates renewable electricity in New Zealand from wind (~2,100 GWh), hydroelectric (~4,140 GWh), and geothermal (~2,600 GWh) sources with a total installed capacity of ~8,840 GWh. Geothermal operation occurs within the Taupo Volcanic Zone (TVZ) in the North Island, across 5 stations in 4 fields, and currently accounts for 98% of the direct "Scope 1" greenhouse gas emissions reported by the company (Figure 1). While CO_2 and CH_4, the principal geothermal greenhouse gases, are naturally occurring in reservoirs, the enhanced emissions rate resulting from resource development is considered anthropogenic and taxed under the New Zealand Emissions Trading Scheme (ETS).

2.2 Emissions reduction program objectives and history

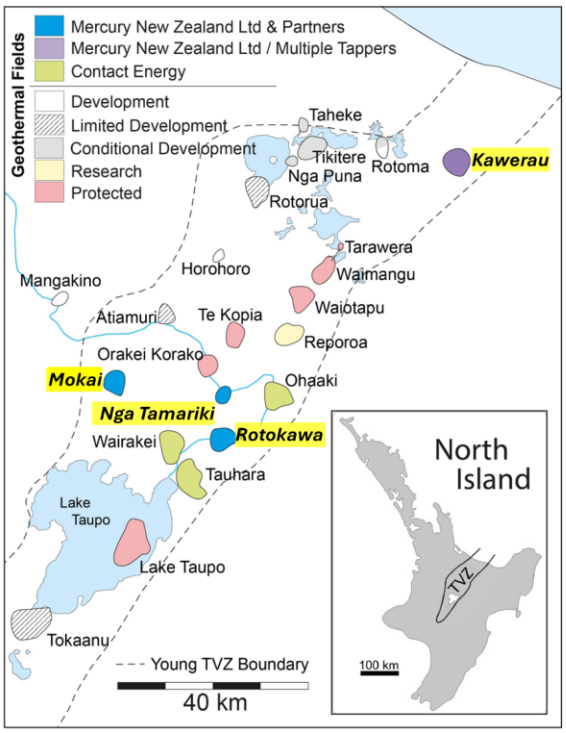
Initially (2019-2021), NCG reinjection was investigated as an alternative to acid dosing to address silica scaling in injection wells. Subsequently, the primary motivation for NCG reinjection shifted to greenhouse gas emissions reduction, reflecting company-wide targets which came into effect in 2022 under the SBTi framework. An overall strategy for geothermal emissions reduction was developed with initial focus placed upon the Ngā Tamariki binary site (Abd Ghafar et al., 2022).

Mercury's geothermal emissions reduction program has the following goals:

1. Deliver a technically and economically viable pathway to materially reduce greenhouse gas emissions from geothermal operations.
2. Ensure NCG reinjection does not compromise reservoir health, steam supply, or long-term plant performance.
3. Identify and prioritize reinjection options that leverage current assets.
4. Ensure all phases of the project effectively manage process safety and health and safety risks.
5. Investigate emerging technologies that can reduce emissions more efficiently or with lower overall risk to stations and reservoirs.

These goals are derived from both commercial and values-based objectives. In particular, Mercury adheres to Kaitiakitanga, the Māori concept of guardianship and environmental stewardship.

Classification: General



Geothermal generation and NCG reinjection at Mercury Energy in 2026

Field	Nga Tamariki		Rotokawa		Kawerau	Mokai
Station	NTM OEC1-4	NTM OEC5	RGEN	NAP	KGL	MOK
Plant type	binary	binary	binary	flash	flash	binary
Generation (MWe)	85	50	20	138	105	100
NCG reinjection	active	planned 2026	scoping	prefeas.	prefeas.	
Annual GHG emissions (kT CO_{2e})	36	21 (proj.)	21	67	96	19
Emissions reduction target	80%	80-100% (proj.)	Scoping 50-100%	scoping	scoping	

[1] 2024 calendar year emissions data

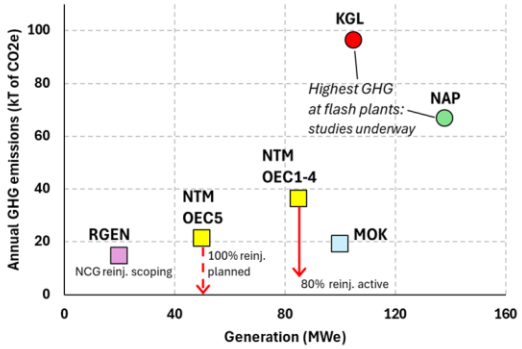


Figure 1. Locations of Mercury operated geothermal stations (yellow) within the Taupo Volcanic Zone, New Zealand (left panel) and status of NCG reinjection at each site (right panels).

3 BINARY PLANT EMISSIONS REDUCTION SUMMARY

3.1 NCG reinjection at Ngā Tamariki

The Ngā Tamariki (NTM) binary station (85 MWe) was commissioned in 2013 and consists of four identical binary Ormat Energy Converter (OEC) units with a fifth 50 MWe binary unit (OEC5) to be commissioned in late 2025 – early 2026. The plant is currently fed by four 2-3 km deep production wells located in the center of the field, which tap a hot (280-290°C) liquid reservoir (Figure 2). Reinjection is split across five wells, with an approximately 50-50% split between the northern and southern injection areas.

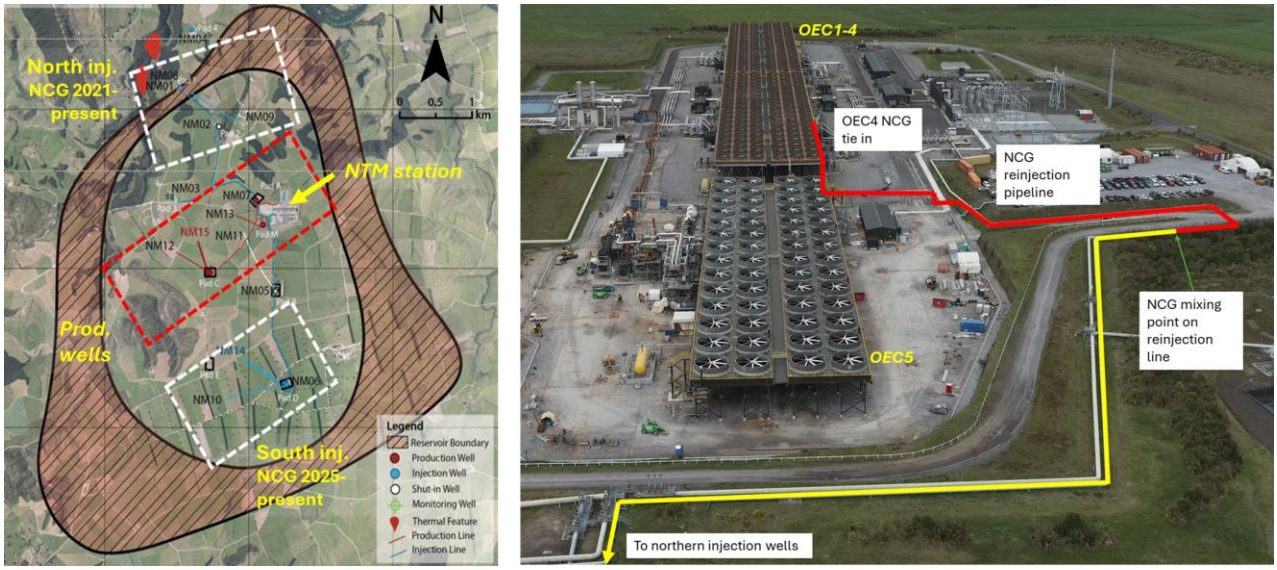


Figure 2. Ngā Tamariki geothermal field setting (left) and setup of the OEC4 NCG reinjection trial (right).

An initial NCG reinjection trial took place from 2021–2022 in which the emissions stream from the OEC4 unit was diverted to reinjection (Abd Ghafar et al., 2022). One of the key drivers in selecting Ngā Tamariki as a site for NCG reinjection trial was the relatively low upfront capital expenditure. A positive pressure differential between the NCG exhaust and the reinjection pipeline at Ngā Tamariki enables direct reinjection of gases without a compression step. Prior to, and during the 2021 trial, derisking workstreams were carried out focusing on the

geothermal reservoir, scaling risks in the injection pipeline and wells, corrosion risks, and gas breakout/ gas locking (Abd Ghafar et al., 2022).

From 2025, a unitized approach to NCG reinjection was implemented allowing for selective reinjection from each of the four existing OEC units and the new OEC5 binary unit from 2026 onwards (Figure 3). Planning is underway to reinject 80% of produced NCGs, equivalent to ~46 kt CO_{2e}/yr.

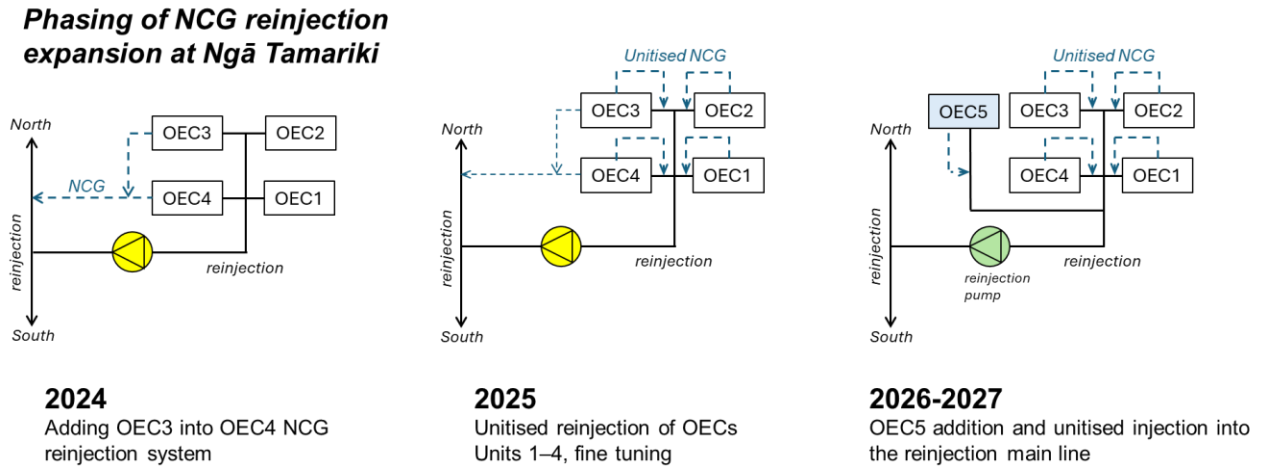


Figure 3. Timeline of NCG reinjection expansion to include the unitized reinjection from the 4 existing OEC units, and the planned rollout of NCG reinjection at the new 50 MWe OEC5 plant.

3.2 Key NCG reinjection results and learnings at Ngā Tamariki

Corrosion monitoring consists of coupons (Figure 4) and UT pipeline thickness testing. To date, measured corrosion rates in coupons have been minimal, ranging from 0.0023 mm/yr (25% NCG) to 0.0093 mm/yr (40% NCG). UT results show up to 1 mm thickness reduction at bends downstream of the NCG mixing point, but changes in pipeline wall thickness have been negligible elsewhere. Chemical analyses of scale materials on coupons (SEM-EDS) indicate that sulphide precipitates are forming a protective layer due to H_2S present in the NCG stream. This is consistent with geochemical model predictions (see Pourbaix diagram in Figure 4), which show that sulphide passivation is maintained during NCG reinjection.

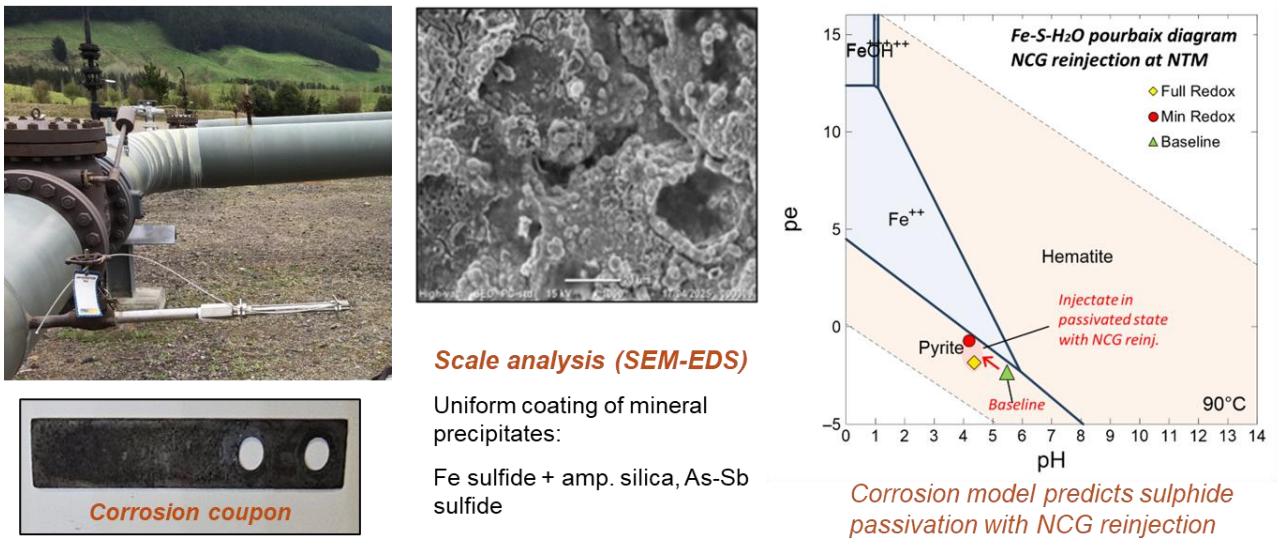


Figure 4. Corrosion coupon monitoring and geochemical modeling indicate that sulphides form a protective layer in pipelines as a result of reinjection of H_2S-containing NCG.

Gas breakout: a series of tests were carried out to determine the upper NCG reinjection limit in the northern and southern injection lines. Notably, the southern injection wells (NM6 and 10) operate under vacuum at the wellhead. It is expected that the NCGs will not fully dissolve and partial gas lock may occur in these wells. A protocol for safe venting of gas locked wells and pipelines has been put into place.

Reservoir derisking and monitoring: scaling and permeability risks were first assessed using chemical speciation software (Geochemists Workbench). Modeling predicts that calcite, anhydrite, and silica scaling risks are unlikely to materially change with NCG reinjection. Water-gas-rock interactions were simulated experimentally using autoclave tests. These tests predict slightly enhanced dissolution of reactive minerals (e.g. calcite and anhydrite) at injection well feedzones during NCG reinjection. To date, no well performance issues have occurred as a result of NCG reinjection. From 2021-2025, the fraction of NCG in production well fluid has continued to decline (Figure 5).

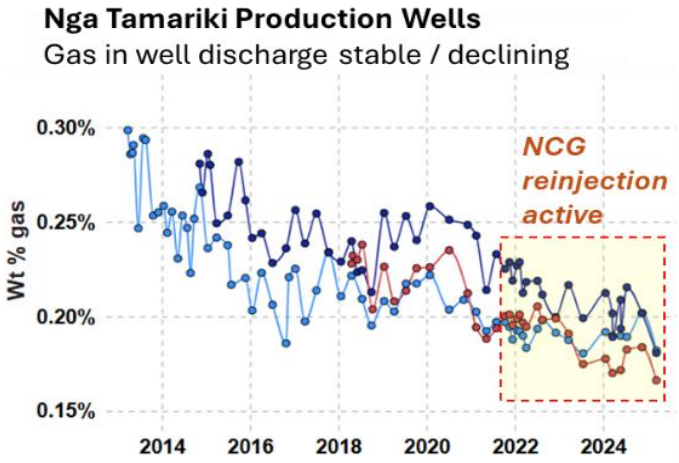


Figure 5. Ngā Tamariki wells show no increase in gas in production well sampling following the start of NCG reinjection in 2021.

3.3 Binary plant next steps

Currently, options are being scoped for NCG reinjection at the RGEN binary site at the Rotokawa field. A key challenge at RGEN is that the introduction of the NCG stream to reinjection will require a compression step. Work is underway to assess options and determine pipeline and well capacities from the standpoint of gas dissolution. If successful, NCG reinjection at RGEN has the potential to abate ~50-100% of the station emissions (~10-20 kt CO_{2e}/year). The feasibility and concept design stages for NCG reinjection at RGEN are anticipated to take place over the next 1-2 years.

4 FLASH PLANT NCG REINJECTION PREFEASIBLITY WORK

Mercury operates two flash plants, which together account for ~70% of generation-related greenhouse gas emissions. The Kawerau Geothermal Limited (KGL) plant located near the Kawerau township, Eastern Bay of Plenty Region was commissioned in 2008 and has a net generation of ~105 MWe with annual carbon emissions of ~100 kt CO_{2e}/yr as of 2025. The Ngā Awa Pūrua (NAP) site in South Waikato has a net generation of ~138 MWe with annual carbon emissions of ~65-75 kt CO_{2e}/yr as of 2025.

4.1 The flash plant challenge

NCG reinjection at Mercury's two flash plants presents additional challenges not encountered at binary sites. Both the KGL and NAP plants utilise direct contact condensers for cooling (Figure 6), which cause the NCG to become air contaminated. From the standpoint of NCG reinjection, air contamination poses three key problems:

- **Corrosion**: the presence of O_2 increases the corrosivity of the injectate. Minimizing oxygen levels is seen as a prerequisite for NCG reinjection.
- **Gas solubility**: O_2 and N_2 reduce the amount of CO_2 which can be dissolved into injectates.
- **Flammable gas species**: processed NCG streams may contain enriched H_2, CH_4, O_2, resulting in potentially flammable or explosive gas mixtures (Olafsdottir et al., 2023).

Over the last 2 years, work has been carried out to identify the key risks associated with NCG reinjection at Mercury's flash plants. From this body of work, a series of studies and trials are being developed to derisk gas processing and reinjection. In parallel, a non-reinjection pathway for emissions reduction is being investigated, focusing upon purification and sale of food-grade CO_2.

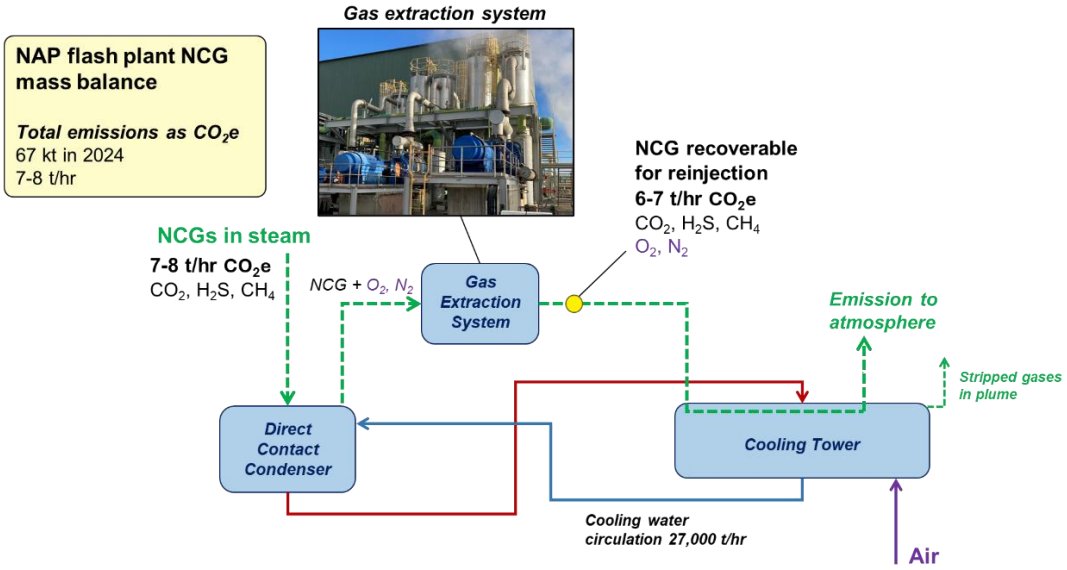


Figure 6. Schematic with gas mass balance showing the process of air contamination of the NCG stream at the 138 MWe Ngā Awa Pūrua Flash plant. Similar issues are encountered at the KGL site.

4.2 Current workstreams and next steps – NCG reinjection at flash plants

- **Gas processing technology review**: cleanup methodologies are required for both reinjection and purification of CO_2 for direct use applications. Broadly, the available technologies to remove unwanted gas species (e.g. O_2, N_2, H_2S) and other minor species can be separated into reactive (e.g. catalytic thermal oxidation) and separation / absorption methods (e.g. Olafsdottir et al., 2023; Vaccari et al., 2023). A shortlist of candidate gas cleanup technologies has been compiled for further assessment.
- **Determining reinjection and gas breakout limits**: hydraulic models provide insight into gas breakout risk and NCG reinjection limits. This work suggests that up to 50% of the KGL plant emissions can be compressed and readily reinjected in brine, while 20-30% of NAP station emissions may be reinjected.
- **Corrosion evaluation**: reinjection of NCG in hot 125-130°C acid-dosed (pH 5-5.5) brine poses a corrosion risk. The NCG streams available for reinjection at these sites contain 2-3 wt% O_2. Consequently, some combination of oxygen removal and corrosion inhibition will be required. A trial is planned at the KGL plant in 2026 to determine baseline corrosion rates across the plant.
- **Acid dose optimization**: the addition of CO_2 to brine will require optimization of the acid dosing system. In 2025, a silica polymerization study was carried out on the brine system at the KGL plant to understand fluid residence times, and scaling risks, over a range of pH settings.
- **Reservoir**: experimental and geochemical modeling work have been carried out over the last several years to understand the fate of reinjected NCG in the geothermal reservoir at Kawerau. Similar work will follow for the NAP site (Rotokawa Reservoir) over the next two years.

5 CONCLUSION

Over the last four years, Mercury has undertaken work to reduce greenhouse gas emissions from its geothermal stations. Progress and learnings at the Ngā Tamariki site inform deployment at other binary stations. Work is also underway to develop an effective emissions abatement strategy for flash plants. Meeting these challenges involves a combination of technology adaptation, process optimisation, and reservoir surveillance.

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