

5 September 2025

Preamble

1. David Dempsey is an associate professor and Karan Titus is a postdoctoral fellow at the Civil and Environmental Engineering Department at the University of Canterbury. Our research interests include geothermal systems, power generation and techno-economic assessment of emerging geothermal technologies.
2. We would like to take the opportunity to answer the questions raised in the draft Geothermal Strategy, as well as provide more detailed feedback.

Responses to Geothermal Strategy Questions

Question 1: *Are the three strategic outcomes of the strategy, centred around world-leading geothermal innovation, accelerating energy resilience and strengthening regional economies and te Ōhanga Māori, suitable, or is there more we need to consider?*

Response: These are sufficient.

Question 2: *Do the five overarching action plan goals capture the areas that are most important for achieving the vision, strategic outcomes and energy goal?*

Response: These are sufficient.

Question 3: *Does the proposed action plan correctly capture the necessary government interventions and priorities?*

Response: Not completely. See further in this submission for details.

Question 4: *Is the role for the sector clear? How can the wider geothermal sector play a role (e.g. are there specific actions that the sector could own)?*

Response: The role for the sector should be expanded to include – in addition to base load generation – the opportunity for flexible dispatch and, where appropriate, additional value-stacking beneficial to the economy, including green hydrogen for industry, CO2 use in horticulture, etc.

Question 5: *Does the strategy and proposed action plan create the right settings to enable tāngata whenua to realise their aspirations for geothermal resources in their rohe?*

We do not have a response.

Question 6: *Are there opportunities for our geothermal sector that we haven't considered?*

Response: Yes. Briefly, these are enhanced geothermal systems, hybrid-low-temperature geothermal and flexible geothermal systems. Please see further in this submission for detail.

Question 7: *Are there challenges for our geothermal sector that we haven't considered?*

Response: Yes. The major risk is that present and near-term conditions may not induce sufficient private investment to meet the 2040 generation target. Please see further in this submission.

Question 8: *Are there any other things that the strategy should include or exclude?*

Response: Our recommended inclusions for the strategy are addressed through previous answers. These are elaborated on below.

Detailed feedback

The remainder of this submission addresses four topics referred to in our responses in greater detail.

1. Overall, we support the Geothermal Strategy's promotion of geothermal power generation. Over the years, geothermal has provided NZ a reliable, cost-effective and low-emitting source of electricity. As the country shifts away from imported fossil fuels and towards domestically produced electricity, geothermal technologies have the potential to supply an increased share of baseload plus peak-time power, with zero emissions. The goal to double geothermal generation is an ambitious yet achievable, and laudable target. We believe the following information and recommendations will shape the Geothermal Strategy to be better able to achieve that goal.

Timelines to achieve generation target

2. **We recommend** the Strategy formally define the target as an additional 1200 MWe by 2040. The Strategy could describe this in terms of MWe/year, total number of plants at median size, and compare against 2005-2015 period.
 - a. New Zealand's current geothermal generation capacity sits at 1200 MWe¹. Doubling this generation in the 15 years leading to 2040 will require an average installation rate of 80 MWe/yr, or a medium-to-large development of 160 MWe every two years.

¹ Transpower (2025). Consolidated live data. <https://www.transpower.co.nz/system-operator/live-system-and-market-data/consolidated-live-data>

- b. Upfront geothermal costs in NZ range from \$5000 to \$7000/kWe². Contact Energy’s new Tauhara plant cost approximately \$5300/kWe. At these costs, the strategy’s ambition of doubling geothermal would require capital investment of \$6 to 7 billion, averaging \$420 to 500 million/year. This could be delivered by a comprehensive portfolio of geothermal generation technologies ranging from low-temperature to conventional systems to untapped superhot resources.
3. Officials may wish to consider the report Future Geothermal Generation Stack produced by Lawless Geo-Consulting in March 2020 in assessing the feasibility of the proposed 2040 target. In summary, the report notes:
 - a. Most high-temperature hydrothermal resources in New Zealand that are permissible for commercial electricity generation have already been exploited³. An estimated 735 MWe of conventionally exploitable resources remain^{4,5}.
 - b. The Lawless report highlights consenting timeframes as a key uncertainty contributing to prompt delivery of potential generation. Presuming consenting is well-managed, it may be plausible to commission this 735 MWe by 2040 under favourable market conditions.
 - c. The expected shortfall to meet the strategy’s target is in the range of 500 MWe and will be larger if projects considered by Lawless (2020) are found to be infeasible.
 - d. Outside of consenting, delays to geothermal development include:
 - (i) lack of transmission infrastructure in proximity to the resource,
 - (ii) plant design modifications after the exploration phase,
 - (iii) access to capital financing,
 - (iv) acquisition of power purchasing agreements, and
 - (v) wider energy market uncertainties such as price volatility⁶.

² Lawless Geo-Consulting (2020). Future Geothermal Generation Stack. <https://www.mbie.govt.nz/assets/future-geothermal-generation-stack.pdf>

³ Lawless Geo-Consulting (2020). Ibid.

⁴ Lawless Geo-Consulting (2020). Ibid.

⁵ Titus, K., Peer, R., Haas, J., Archer, R., & Dempsey, D. (2024). Reimagining geothermal power plants: Green hydrogen, lithium and CO2 removal from New Zealand’s future geothermal stack. In 46th New Zealand Geothermal Workshop. University of Auckland.

⁶ Wall, A., & Young, K. (2016). Doubling Geothermal Generation Capacity by 2020. A Strategic Analysis (No. NREL/TP-6A20-64925). National Renewable Energy Lab.(NREL), Golden, CO (United States).

- e. Financing was identified as the largest barrier to increasing geothermal capacity in the United States⁷. Efforts taken by the NZ Government to de-risk investment decisions may contribute to the accelerated development of geothermal.
4. To accelerate development, the Government should consider how to de-risk geothermal exploration.
- a. The draft strategy acknowledges the considerable cost and risk associated with drilling wells during field exploration. This risk is factored into private investment decisions.
 - b. As an example of how this has been addressed overseas, the French government in their geothermal strategy have proposed a Geothermal Guarantee Fund to cover the risk of geological failure of a deep geothermal well^{8,9}.
 - c. French government initiatives to bolster geothermal power developments include zero-interest rate loans for renovations from partner banks, feed-in tariffs, a premium price on top of electricity market prices to recuperate capex, as well as R&D financing for innovative technologies¹⁰.
 - d. One lever the New Zealand government might exercise to accelerate the roll-out of geothermal development is to share upfront exploration risk.
 - e. **We recommend** the Government consider a financial mechanism to share the risks of exploration or early development wells in new geothermal prospects. Examples include co-funding, matching funding, or public-private partnerships.
4. In addition, **we recommend** the Strategy estimate the shortfall of the 2040 target and technologies that are best able to cover the gap. Reports suggest this figure might be approximately 500 MWe.
- a. We note that the Strategy includes explicit acknowledgement and support for supercritical geothermal systems. We acknowledge that development timelines

⁷ Wall & Young (2016). Ibid.

⁸ Ministère de la Transition Énergétique (2023). Géothermie: un plan d'action pour accélérer son développement (Updated ed.).

https://www.ecologie.gouv.fr/sites/default/files/documents/20231222_DP_Plan-action-geothermie.pdf

⁹ ThinkGeoEnergy (2025). France publishes list of concrete measures to accelerate geothermal development. <https://www.thinkgeoenergy.com/france-publishes-list-of-concrete-measures-to-accelerate-geothermal-development/>

¹⁰ Ministère de la Transition Énergétique (2023). Ibid.

as estimated by Castalia¹¹ in their “Ambitious timeline” scenario includes the delivery of a pilot plant in 2037. Under this scenario, supercritical geothermal is one candidate to address the shortfall.

- b. There are two other geothermal technologies that should be considered as potential contributors to cover the geothermal shortfall: enhanced geothermal systems and hybrid-low-temperature geothermal systems. Both technologies exist today and have been commercially deployed, albeit in limited quantities.
5. The Strategy should consider how the target could be met if supercritical geothermal cannot successfully be deployed.

Enhanced geothermal systems (EGS)

8. EGS technology could help meet the 2040 target and is a more mature technology than supercritical¹².
 - a. EGS uses hydraulic fracturing to stimulate high temperature rock with poor circulation properties. If done successfully, externally sourced water can then be circulated through the rock for the purpose of heat extraction.
 - b. EGS technology has been in research and development since the 1970s. In the last five years, major steps have been taken towards commercialisation, largely due to the adoption of drilling technologies from the oil and gas industry, including multi-stage hydraulic fracturing and horizontal drilling.
 - c. Fervo Energy in the US is leading deployment of the technology. Their 400 MWe Cape Station development in Utah has demonstrated commercial flow rates. The company has secured a power purchase agreement with Google¹³.
 - d. Fervo Energy’s CTO, Dr Jack Norbeck, presented a keynote at the 2024 NZ Geothermal Workshop, introducing their company’s technology.
 - e. The US DOE provided investment of up to \$60 million in February 2024 for EGS pilot projects. Fervo Energy secured a further \$206 million in financial support to

¹¹ Castalia (2023). Supercritical Geothermal in New Zealand. https://cdn.prod.website-files.com/5ee80754caf15981698cc972/65430d6dcc0b4d7e4871bc09_02112023%20Final%20Report%20-%20Economic%20Value%20of%20Supercritical%20Geothermal-%20updated.pdf

¹² Aghahosseini, A., & Breyer, C. (2020). From hot rock to useful energy: A global estimate of enhanced geothermal systems potential. *Applied Energy*, 279, 115769.

¹³ Terrell, Michael (2021). With new geothermal project, it’s full steam ahead for 24/7 carbon-free energy. Google Cloud. <https://cloud.google.com/blog/products/infrastructure/google-fervo-geothermal-project-creates-carbon-free-energy>

develop Cape Station¹⁴. This demonstrates the scale in investment needed to enable frontier geothermal technologies.

- f. EGS sites can be characterised as:
 - (i) proximal to hydrothermal systems,
 - (ii) green fields with no existing geothermal generation, and
 - (iii) within superhot frontiers.
 - g. New Zealand's 2030 potential for EGS power capacity has been estimated at 49 GWe by Aghahosseini & Breyer¹⁵, though physical surveys are needed to further inform this value. This value is two orders of magnitude greater than the expected shortfall by 2040. New Zealand's formations are well suited for fracture-based flow¹⁶, inviting consideration for artificial stimulation at depths >3 km.
9. Based on this, EGS should feature in the Strategy's action plan.
- a. EGS should be classified as a next-generation geothermal technology, alongside supercritical geothermal, albeit one that has a higher technology readiness level.
 - b. EGS, being focused on stimulation practice, will tend to operate at lower temperatures and hence shallower depths than supercritical geothermal. This means that corrosion issues requiring novel material development are less of a problem.
 - c. The success of EGS primarily depends on the creation and maintenance of underground flow pathways for water. Supercritical geothermal may require the same stimulation technologies, particularly if a drilled supercritical resource is found to not have sufficient flow pathways for water. This was the case for supercritical resources drilled at Larderello (Italy)¹⁷ and Kakkonda (Japan)¹⁸.

¹⁴ Fervo Energy (2025). Fervo Energy Secures \$206 Million In New Financing To Accelerate Cape Station Development. <https://fervoenergy.com/fervo-secures-new-financing-to-accelerate-development/>

¹⁵ Aghahosseini & Breyer (2020). Ibid.

¹⁶ Melia, A., Faulkner, D. R., & McNamara, D. D. (2023). Physical property characterization of the Waipapa greywacke: An important geothermal reservoir basement rock in New Zealand. *Journal of Geophysical Research: Solid Earth*. <https://doi.org/10.1007/s00710-021-00758-8>

¹⁷ Magro et al. (2019). Drilling super-hot horizons of the Larderello geothermal field: insights from noble gases. *E3S Web of Conferences* 98, 12012. <https://doi.org/10.1051/e3sconf/20199812012>

¹⁸ Ikeuchi et al. (1998). High-temperature measurements in well WD-1A and the thermal structure of the kakkonda geothermal system, Japan. *Geothermics* 27 (5-6), 591-607

- d. **We recommend** the Strategy outline the following support:
 - (i) R&D funding into NZ-specific hydraulic stimulation technologies to support both supercritical geothermal and EGS
 - (ii) improved access to geothermal data, including a survey of hot granitic rock provinces to understand possible resource,
 - (iii) a review of the regulatory regime to determine if it is permissive of high-pressure geothermal stimulation (which may also be necessary for supercritical geothermal if stimulation is required), and
 - (iv) a review of the geothermal regulatory environment's management of induced seismic risk.

10. Induced seismicity¹⁹ is more of a risk for EGS, and potentially supercritical, geothermal technologies.

- a. Any resource development that requires stimulation of a well or long-term injection of fluid risks triggering earthquakes. This is referred to as induced seismicity.
- b. Most of NZ's geothermal systems experience induced seismicity associated with their reinjection operations. Triggered earthquakes associated with operation of NZ geothermal systems rarely exceed magnitude 4 and are therefore largely manageable.
- c. Well stimulation or long-term circulation operations associated with EGS, and potentially with supercritical geothermal systems, may experience elevated rates of earthquakes and, ultimately, larger magnitude events.
- d. Large earthquakes have led to the cancellation of geothermal projects in Basel, Switzerland²⁰ and Pohang, South Korea²¹.
- e. For other enhanced geothermal systems, induced seismicity has been managed through the use of traffic light systems²² that require a project to reduce its operations if seismicity becomes concerning.

¹⁹ Fervo Energy (2024). Fervo's Approach to Induced Seismicity Management. <https://capestation.com/fervos-approach-to-induced-seismicity-management/>

²⁰ Glanz, James (2009). Deep in Bedrock, Clean Energy and Quake Fears. *New York Times*. <https://www.nytimes.com/2009/06/24/business/energy-environment/24geotherm.html>

²¹ Voosen, Paul (2018). Second-largest earthquake in modern South Korean history tied to geothermal plant. *Science*. <https://www.science.org/content/article/second-largest-earthquake-modern-south-korean-history-tied-geothermal-plant>

²² Mignan et al. (2017). Induced seismicity closed-form traffic light system for actuarial decision-making during deep fluid injections. *Scientific Reports* 7 (13607). <https://www.nature.com/articles/s41598-017-13585-9>

Hybrid low-temperature geothermal systems

11. Bioenergy and solar generation can supplement low-temperature geothermal systems, offering an alternative to meet the 500 MWe shortfall in the 2040 target.
 - a. Hybrid geothermal systems feature the co-location of a second (generally renewable) energy source that improves the characteristics of the geothermal resource on its own.
 - b. The advantage of hybridisation is that it allows you to take advantage of low-temperature geothermal resources that may not meet an economic threshold on their own.
 - c. The disadvantage of hybridisation is that they incur additional costs (CAPEX, fuel) and project complexity.
 - d. Hybrid geothermal systems have been demonstrated for both bioenergy²³ and solar²⁴.
 - e. Bioenergy may be a particularly suitable hybrid option in NZ, given that the majority of our geothermal resource co-locates with managed forestry that provides a large supply of fuel to NZ's bioenergy sector.
 - f. Bioenergy hybrids may have additional benefits through the co-production of green (net-zero emission) CO₂ that may be usable in horticulture, and food & beverage industries, as a feedstock for petrochemical industries (methanol, synthetic aviation fuel), or for permanent geological storage.
 - g. The co-location of geothermal, forestry, bioenergy, and green CO₂ off-takers is an example of a place-based geothermal cluster promoted by the Strategy.
12. Based on this, **we recommend** hybrid geothermal should feature in the action plan. In addition, the Government should consider the following support:
 - (i) R&D funding
 - (ii) the exploration of place-based geothermal clusters (including a source of green CO₂ for other industries).
 - (iii) exploration for low-temperature systems that may have been overlooked.

²³ ThinkGeoEnergy (2016). Enel inaugurates combined biomass and geothermal plant in Italy.

<https://www.thinkgeoenergy.com/enel-inaugurates-combined-biomass-and-geothermal-plant-in-italy/>

²⁴ ThinkGeoEnergy (2021). Stillwater, NV – triple hybrid geothermal and solar plant.

<https://www.thinkgeoenergy.com/stillwater-nv-triple-hybrid-geothermal-and-solar-plant/>

Flexible geothermal technology

13. Flexible geothermal can support NZ's electricity network, as the share of renewable electricity increases, and as gas supplies become increasingly unreliable. EGS and hybrid geothermal power stations can both provide peak-time electricity.
- a. The strategy highlights geothermal's role in the electricity system as baseload generation. That is, it is not subject to the same intermittency as other renewables (solar and wind), the effects of which will require additional management as these gain prominence in our energy mix.
 - b. Generation intermittency is expected to result in negative electricity prices during periods of over-generation²⁵. In similar mature geothermal economies like California, this has resulted in both technical and economic curtailment of geothermal power plants²⁶.
 - c. Generation intermittency can be counterbalanced in the short term with grid-scale batteries of the type that major gentailers are now installing. It is presently addressed through flexible, i.e., load-following generation, such as Todd Generation's peaking natural gas plant in Taranaki²⁷ and hydro generation when available.
 - d. Geothermal has the potential to operate flexibly but has historically not done so. The principal reason has been the high initial capital requirements that generally require plants to be operated in a continuous manner to reliably recover its investment.
 - e. Flexible geothermal may require strategic Government support, especially with respect to capital recuperation, through tailored pricing schemes.
 - f. Hybrid geothermal-bioenergy plants introduce an additional lever on plant output (bioenergy burn rate), that may enable a mixed mode "baseload and peaking"

²⁵ Market Development Advisory Group. (2023). Price discovery in a renewables-based electricity system: Final recommendations. Electricity Authority. <https://www.ea.govt.nz/news/general-news/mdag-report-published-risk-management-review-underway/>

²⁶ Denholm, P., O'Connell, M., Brinkman, G., & Jorgenson, J. (2015). Overgeneration from solar energy in California: a field guide to the duck chart (No. NREL/TP-6A20-65023). National Renewable Energy Lab.(NREL), Golden, CO (United States)

²⁷ Keith, Leighton. \$100m natural gas-fired power plant in operation. Stuff. <https://www.stuff.co.nz/taranaki-daily-news/news/122193925/100m-natural-gasfired-power-plant-in-operation>

arrangement, with higher biomass burn rates called upon during peak demand with fuel stockpiled on-site during off-peak periods.

- g. Future geothermal technologies may be well-equipped to solve a range of problems in our future energy system.

14. Based on this, we recommend the Geothermal Strategy should consider the following to investigate flexible geothermal:

- (i) R&D support for early-stage flexible geothermal technology components
- (ii) financial support for flexible geothermal uptake, through purchased idling capacity or co-financing of ventures deploying the technology.

15. Thank you for the chance to make a submission. We would be happy to work with officials, should they have outstanding questions on geothermal technologies.

Yours sincerely,

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References

Aghahosseini, A., & Breyer, C. (2020). From hot rock to useful energy: A global estimate of enhanced geothermal systems potential. *Applied Energy*, 279, 115769.

Castalia (2023). Supercritical Geothermal in New Zealand. https://cdn.prod.website-files.com/5ee80754caf15981698cc972/65430d6dcc0b4d7e4871bc09_02112023%20Final%20Report%20-%20Economic%20Value%20of%20Supercritical%20Geothermal-%20updated.pdf

Denholm, P., O'Connell, M., Brinkman, G., & Jorgenson, J. (2015). Overgeneration from solar energy in California: a field guide to the duck chart (No. NREL/TP-6A20-65023). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Fervo Energy (2024). Fervo's Approach to Induced Seismicity Management.

<https://capestation.com/fervos-approach-to-induced-seismicity-management/>

Fervo Energy (2025). Fervo Energy Secures \$206 Million In New Financing To Accelerate

Cape Station Development. <https://fervoenergy.com/fervo-secures-new-financing-to-accelerate-development/>

Glanz, James (2009). Deep in Bedrock, Clean Energy and Quake Fears. *New York Times*.

<https://www.nytimes.com/2009/06/24/business/energy-environment/24geotherm.html>

Ikeuchi et al. (1998). High-temperature measurements in well WD-1A and the thermal structure of the kakkonda geothermal system, Japan. *Geothermics* 27 (5-6), 591-607.

Keith, Leighton. \$100m natural gas-fired power plant in operation. Stuff.

<https://www.stuff.co.nz/taranaki-daily-news/news/122193925/100m-natural-gas-fired-power-plant-in-operation>

Lawless Geo-Consulting (2020). Future Geothermal Generation Stack.

<https://www.mbie.govt.nz/assets/future-geothermal-generation-stack.pdf>

Magro et al. (2019). Drilling super-hot horizons of the Larderello geothermal field: insights from noble gases. E3S Web of Conferences 98, 12012.

<https://doi.org/10.1051/e3sconf/20199812012>

Market Development Advisory Group. (2023). Price discovery in a renewables-based electricity system: Final recommendations. Electricity

Authority. <https://www.ea.govt.nz/news/general-news/mdag-report-published-risk-management-review-underway/>

Melia, A., Faulkner, D. R., & McNamara, D. D. (2023). Physical property characterization of the Waipapa greywacke: An important geothermal reservoir basement rock in New

Zealand. *Journal of Geophysical Research: Solid Earth*. <https://doi.org/10.1007/s00710-021-00758-8>

Mignan et al. (2017). Induced seismicity closed-form traffic light system for actuarial decision-making during deep fluid injections. *Scientific Reports* 7 (13607).

<https://www.nature.com/articles/s41598-017-13585-9>

Ministère de la Transition Énergétique. (2023). Géothermie: un plan d'action pour accélérer son développement (Updated ed.).

https://www.ecologie.gouv.fr/sites/default/files/documents/20231222_DP_Plan-action-geothermie.pdf

Terrell, Michael (2021). With new geothermal project, it's full steam ahead for 24/7 carbon-free energy. Google Cloud. <https://cloud.google.com/blog/products/infrastructure/google-fervo-geothermal-project-creates-carbon-free-energy>

ThinkGeoEnergy (2016). Enel inaugurates combined biomass and geothermal plant in Italy. <https://www.thinkgeoenergy.com/enel-inaugurates-combined-biomass-and-geothermal-plant-in-italy/>

ThinkGeoEnergy (2021). Stillwater, NV – triple hybrid geothermal and solar plant. <https://www.thinkgeoenergy.com/stillwater-nv-triple-hybrid-geothermal-and-solar-plant/>

ThinkGeoEnergy (2025). <https://www.thinkgeoenergy.com/france-publishes-list-of-concrete-measures-to-accelerate-geothermal-development/>

Titus, K., Peer, R., Haas, J., Archer, R., & Dempsey, D. (2024). Reimagining geothermal power plants: Green hydrogen, lithium and CO2 removal from New Zealand's future geothermal stack. In 46th New Zealand Geothermal Workshop. University of Auckland.

Transpower (2025). Consolidated live data. <https://www.transpower.co.nz/system-operator/live-system-and-market-data/consolidated-live-data>

Voosen, Paul (2018). Second-largest earthquake in modern South Korean history tied to geothermal plant. *Science*. <https://www.science.org/content/article/second-largest-earthquake-modern-south-korean-history-tied-geothermal-plant>

Wall, A., & Young, K. (2016). Doubling Geothermal Generation Capacity by 2020. A Strategic Analysis (No. NREL/TP-6A20-64925). National Renewable Energy Lab.(NREL), Golden, CO (United States).