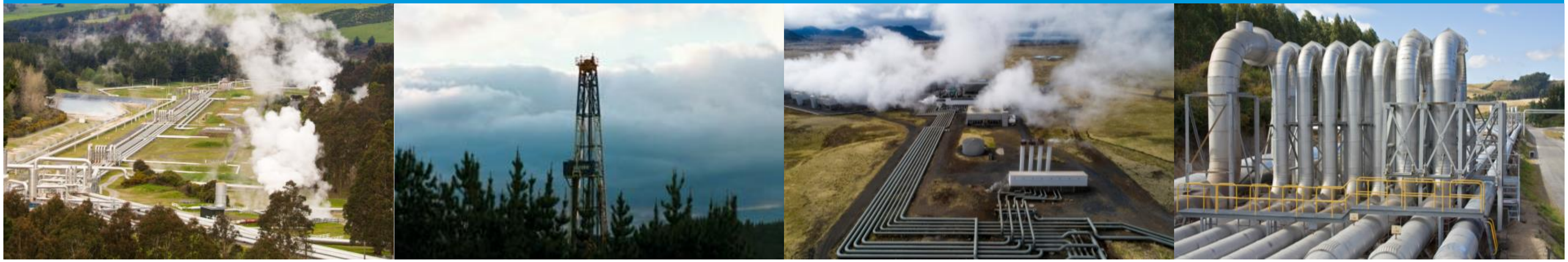
Economic Value of Supercritical Geothermal Energy in New Zealand

Presentation to 45th NZ Geothermal Workshop: Breakfast Forum

NOVEMBER 2023



Agenda

- GNS' request to Castalia
- What is SCGT?
- When could SCGT be available?
- How much capacity could SCGT provide?
- What other opportunities are there for SCGT?
- Recommended next steps

GNS asked us to analyse SCGT's economic potential

Electricity demand is expected to increase by

50%

between 2023 and 2050

Industrial energy uses currently served by gas and coal, are ripe for

DECARBONISATION

- None of the electricity market models expect much of this demand to be met by new conventional geothermal generation.
- However, GNS, a Government-owned research institute, has identified the potential for drilling deeper into New Zealand's crust in the central north island to access the hotter geothermal resources available there and extract more energy.
- GNS commissioned us to determine what the economic value of this super-critical geothermal (SCGT) resource might be.

We found that SCGT could be very valuable

SCGT could provide
30,000 GWh
of sustainable, plentiful, and reliable renewable energy to New Zealand every year

SCGT could be online by
2037
if investment occurs and regulations are aligned

Grid modelling suggests over
2,000 MW
of zero-carbon SCGT generation could be economic to build by 2050

SCGT could also provide
ABUNDANT
zero-carbon heat and electricity for off-grid industrial uses

What is SCGT?

A sustainable, plentiful, and reliable energy source

SCGT offers the same advantages … at larger scale

Sustainable

- New developments have made re-injecting 100% of CO_2 extracted during geothermal production possible.
- SCGT will use much less land area than other renewables, including conventional geothermal.

Reliable

- Like conventional geothermal, SCGT is not dependent on external weather conditions.
- Existing geothermal is operated approximately 95% of the time.

Plentiful

- Analysis from GNS suggests that up to **30,000 GWh** of electricity might be available per year from unprotected SCGT resources.
- That could supply over 75% of New Zealand's current electricity demand.

But there is much work to be done

GNS has identified three key technical challenges that remain to be solved:

Refining well construction methods at SCGT depths so that an adequate commercial well life can be achieved

Determining how to reliably produce SCGT fluids from depth, including the **management of scaling, corrosion and thermal stress issues**

Deciding or **designing the appropriate technology** to use for SCGT power generation, including any fluid processing that might be required in any energy transformation process.

When could SCGT be available?

As early as 2037

We developed two timelines for SCGT development

We developed two cases of when SCGT could be available: baseline and ambitious

Stage	Baseline case	Ambitious case
Scientific and technical progress	2024 to 2038	2024 to 2033
Regulatory approvals	2036 to 2038	2033
Design and construction of the first plant	2039 to 2044	2034 to 2037
Grid synchronization	**2045**	**2037**

Our estimates rely on:

- Comparing SCGT's R&D timelines with other technologies, including shale gas and solar PV
- Utilizing data on consenting and construction timelines for clean energy projects in New Zealand and abroad.

Other energy sources developed quickly

Conventional geothermal	Wairakei was 2nd geothermal power station in the world.	Serious consideration in NZ began in 1945. The first power station was commissioned in 1958. Entire station in 1963.
Shale oil and gas	First US government research begun in 1970s. Barnett Shale gas reserves became economic to tap in 1997. →	Shale is now 75% of US natural gas production.
Solar PV	Initial development was slow: First cells produced in 1954. →	But rapid uptake since 2000: Solar is now the cheapest energy source in human history in some circumstances.

We adopted the ambitious timeline for modelling

The ambitious timeline better answers questions about the potential value of SCGT to the energy system.

ENGINEERING CHALLENGES

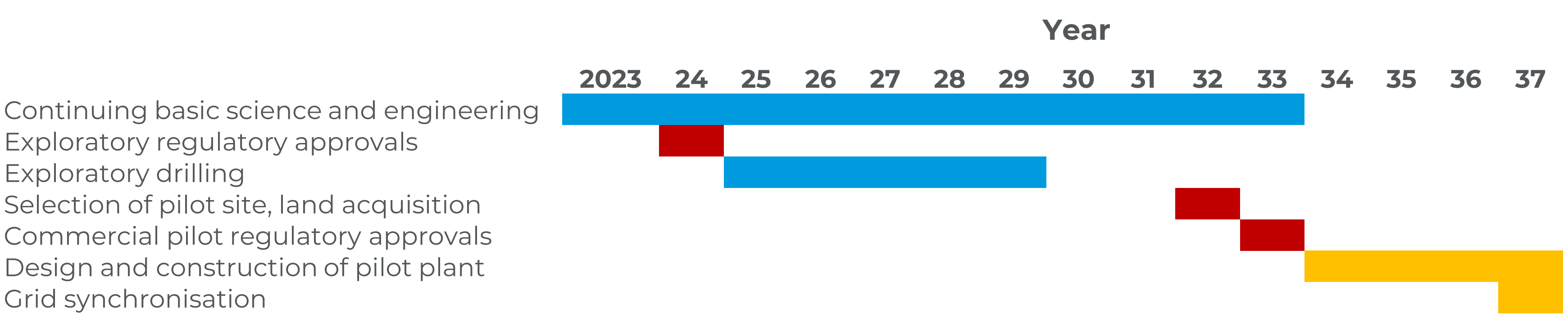
SCGT challenges are mostly engineering. These are solvable with sufficient resources, as opposed to being fundamental scientific issues.

REGULATORY BARRIERS

In response to the urgent need for decarbonization, Government action can address regulatory barriers (eg, RMA fast-tracking available to hydro, wind, solar)

Our ambitious timeline

The timeline below represents Castalia's estimate, informed by GNS and the history of energy research, for the potential duration required for SCGT to become operational if all conditions align.



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How much capacity could SCGT provide?

Over 2,000 MW to the electricity grid by 2050

Electricity demand will increase by 50% by 2050

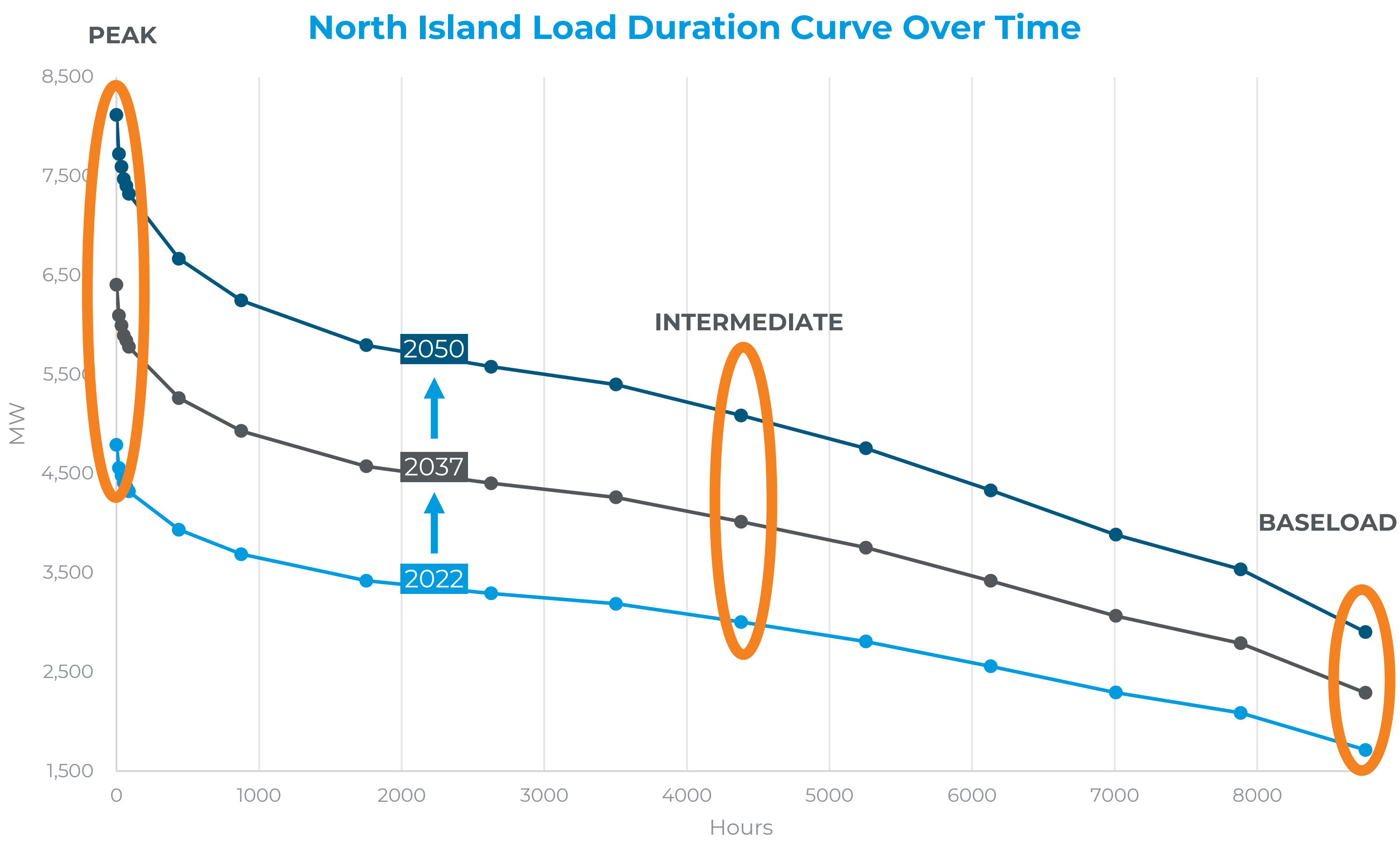
ANTICIPATED ELECTRICITY DEMAND SURGE

- Forecasters predict a significant 25-year increase in electricity demand
- Our projections are based on the Climate Change Commission's (CCC) demonstration path with 50% demand growth by 2050
- The main drivers are electrification of industry and transport, alongside population and economic expansion

NORTH ISLAND DOMINANCE

- We forecast that two-thirds of this growth will be in the North Island, in line with the current NI share of non-Tiwai electricity use
- This will increase all forms of load: Peak, baseload, and intermediate.
- We assume the North Island load-duration curve will retain the same shape.

We forecast demand growth across the load profile



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The North Island grid will be capacity-constrained

ENERGY AND CAPACITY

The electricity market must **ensure both energy and capacity** requirements are met. Energy constraints ensure total yearly demand is satisfied, while capacity constraints ensure peak demand can be met at any time

NORTH ISLAND (NI) WINTER CAPACITY MARGIN

VRE, although cost-effective, are not dependable during peak times. Consequently, Transpower **'de-rates' wind and solar energy** when calculating the North Island (NI) Winter Capacity Margin

PEAKING ROLE OF VRE

Our modelling adopts Transpower's estimates for the peaking role of VRE to determine **the cheapest way to provide sufficient NI capacity** after 2037

We approximated a Generation Expansion Model

Stage 1: Determine electricity demand

Demand forecast

- **CCC's Reference Pathway overall demand forecast**
- **Data from the Electricity Authority about the distribution of load over 2022**

Stage 2: Ascertain options for supply

New VRE

- Wind
- Solar

New firm capacity

- **SCGT**
- Gas
- Batteries
- Overbuilt wind
- Overbuilt solar

Stage 3: Determine least cost supply

- **Variable wind and solar determination**
- **Screening curve for remaining firm generation needed**
- **Battery storage cost calculation**

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A combination of technologies will be cheapest

We used 'screening curves' to depict various technologies' roles in the future grid

Screening Curve

Some technologies excel at 'peaking' functions, including gas peakers and short-term energy storage (e.g., batteries)

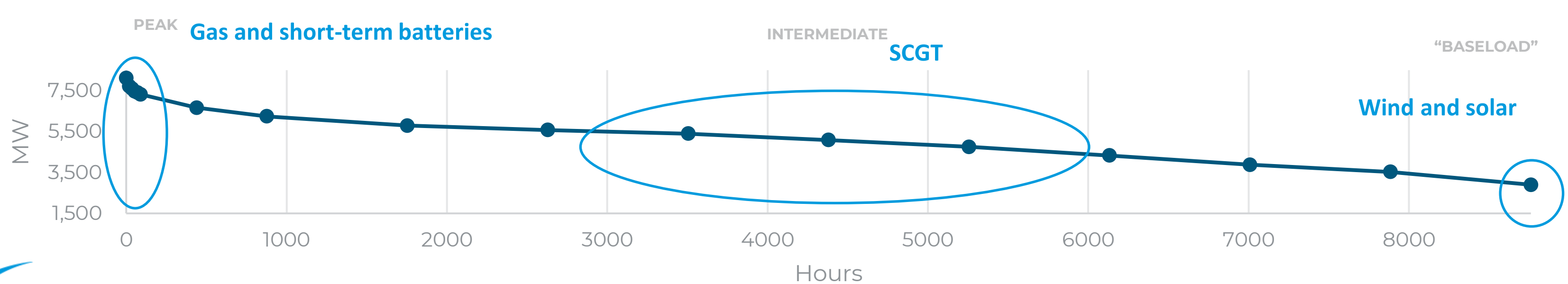
Peaking Technologies

Other technologies are proficient at supplying cost-effective energy during capacity-unconstrained periods, such as wind and solar

Cost-Effective Energy

SCGT's low operating costs and high reliability make it ideal for 'intermediate load' scenarios. In these situations, where wind and solar are less reliable but demand is high, SCGT proves more cost-effective than gas or batteries for meeting demand

SCGT's Unique Role



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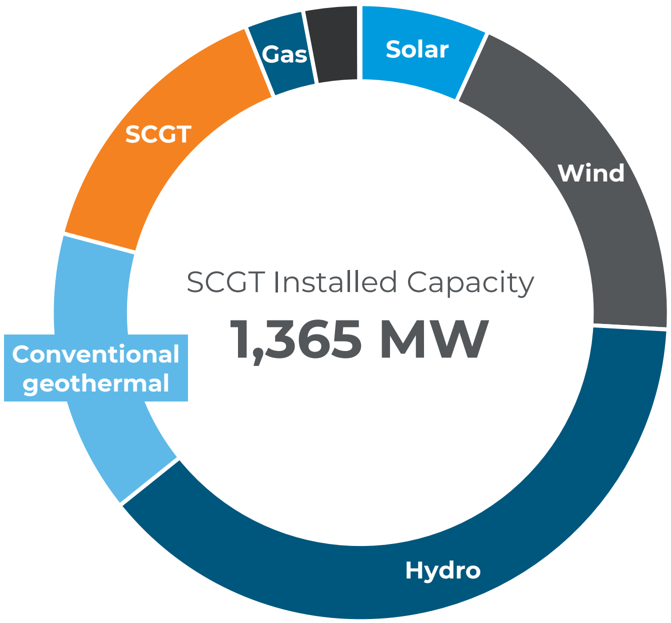
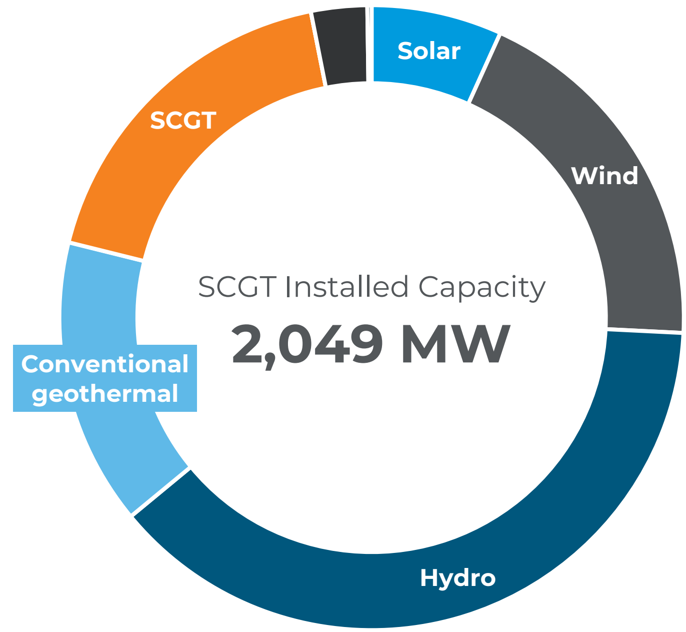
There is a significant role for SCGT– with or without gas

Generation mix in 2050 when thermals are allowed

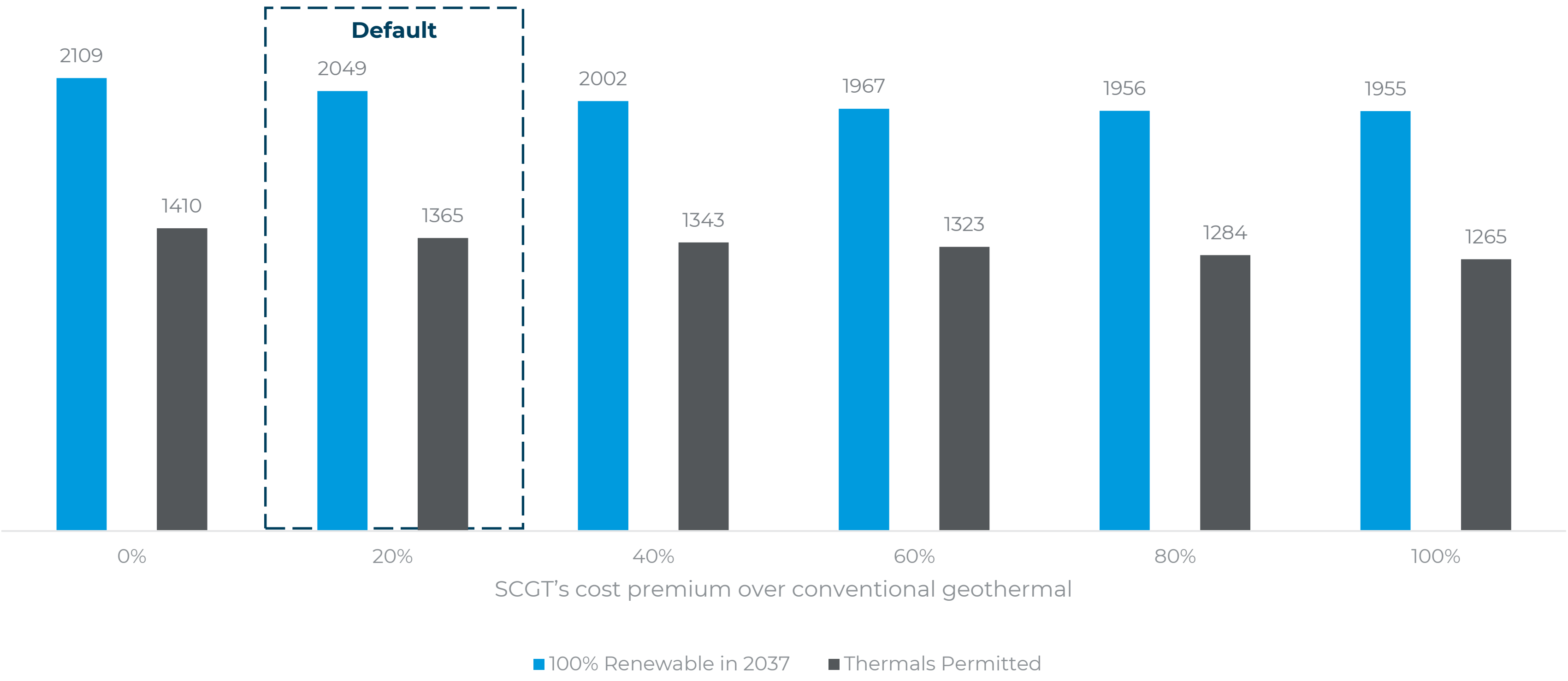


Generation mix in 2050 with a 100% renewables policy



And this role is robust to higher costs

SCGT installed capacity in 2050



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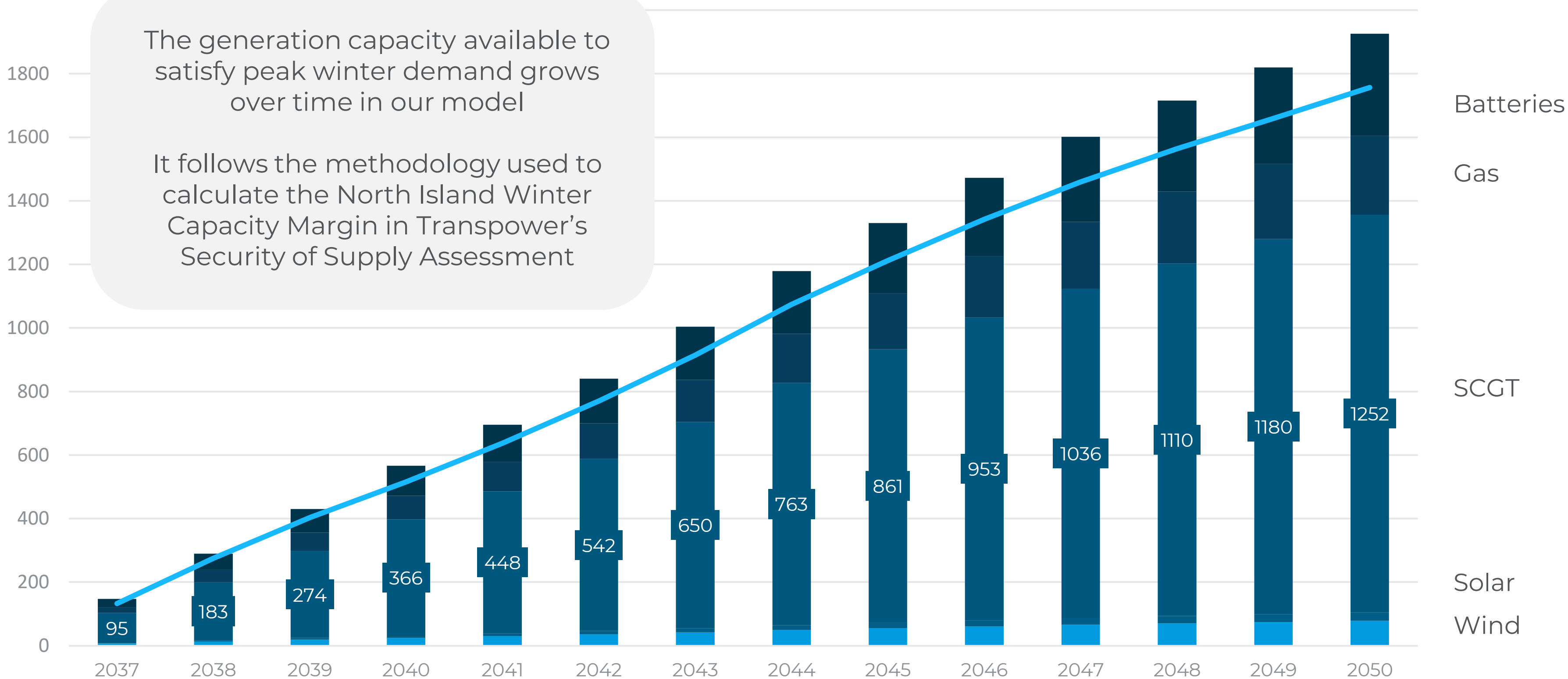
SCGT contributes to maintaining energy security

Peak demand growth is met by peak generation capacity

The generation capacity available to satisfy peak winter demand grows over time in our model

It follows the methodology used to calculate the North Island Winter Capacity Margin in Transpower's Security of Supply Assessment



Values shown are MW of Transpower-rated peak capacity

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Our model may underestimate SCGT’s value

MODEL GAP

No hourly dispatch decisions

While the model effectively identifies cost-effective new generation and estimates SCGT capacity based on the North Island load-duration curve changes, it does not determine the System Operator's technology dispatch for hourly electricity demand.

POTENTIAL OTHER VALUE OF SCGT

Lower electricity prices and higher water levels

With its low 'short-run marginal costs,' SCGT is poised to be dispatched frequently, displacing hydro generation, reducing electricity prices, and supporting higher water levels for long-term storage and renewable energy stability.

Other opportunities for SCGT:

Off-grid energy for industry

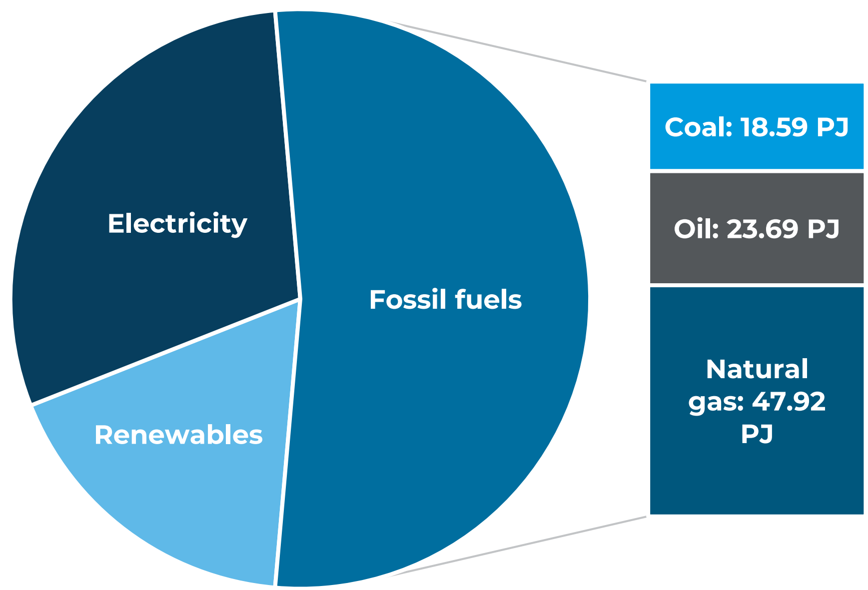
Future demand for renewable heat from SCGT

Conventional geothermal is already used in dairy processing and for processing wood products

SCGT could also be used for industrial applications in the central North Island.

This use-case is likely to be co-located with electricity generation, due to the 'tick size' of SCGT being high (say >100MWth per well)

More than half of industrial energy is still directly sourced from fossil fuels

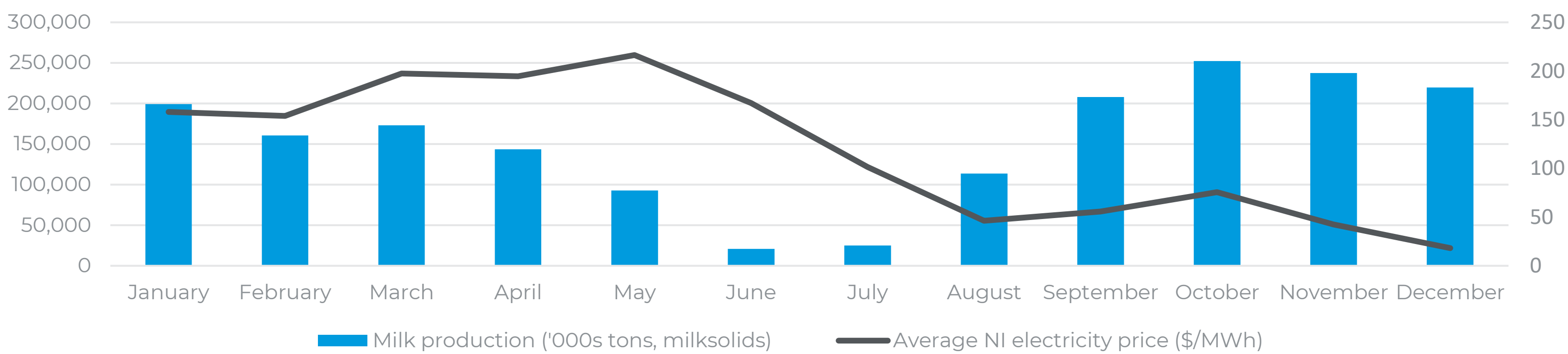


MBIE Energy Balance Tables, 2022

An SCGT-heated mega dairy factory could be viable

- NI dairy factories use approximately **15 PJ** of mostly natural gas energy a year.
- We tested the possibility of supplying one mega-factory with SCGT. Its peak thermal energy demand of ~1500 MW could be satisfied by ~ 15 SCGT wells.
- With our specific assumptions, a dairy heat/electricity co-generating plant of that size earnt roughly as much revenue as an electricity-only plant.

Dairy factory energy demand is inversely correlated with electricity prices



Data from DCANZ and EA for 2022

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SCGT could also be used to dry wood as feedstock

Conventional geothermal is already widely used for timber processing and wood pellet production.

SCGT has the potential to significantly increase its production, potentially replacing coal in various applications such as coal boilers in South Island dairy factories or coal power stations

A 2023 trial showed this is technically feasible with the three 250-MW Rankine units at the Huntly power station, using Canadian black biomass

It would take ~655,000 tons of white pellets to feed Huntly at an 80% capacity factor for three months. That would require **402 GWh of energy** to dry, which is ~3,500 well-hours of SCGT energy

Recommended next steps

Recommended next steps

SCGT represents a significant opportunity for abundant, zero-emissions, least-cost energy for New Zealand, provided that
1. Investment solves technical challenges and
2. Regulatory and policy settings are supportive.

We recommend:

- Communicate findings to key public sector stakeholders: MBIE, Climate Change Commission, Ministry for the Environment
- Engage with key partners: Mana whenua and landowners
- Engage with potential funding partners in New Zealand and overseas: Renewable energy developers, oil and gas sector and infrastructure investors

Q&A

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Thinking for a better world.

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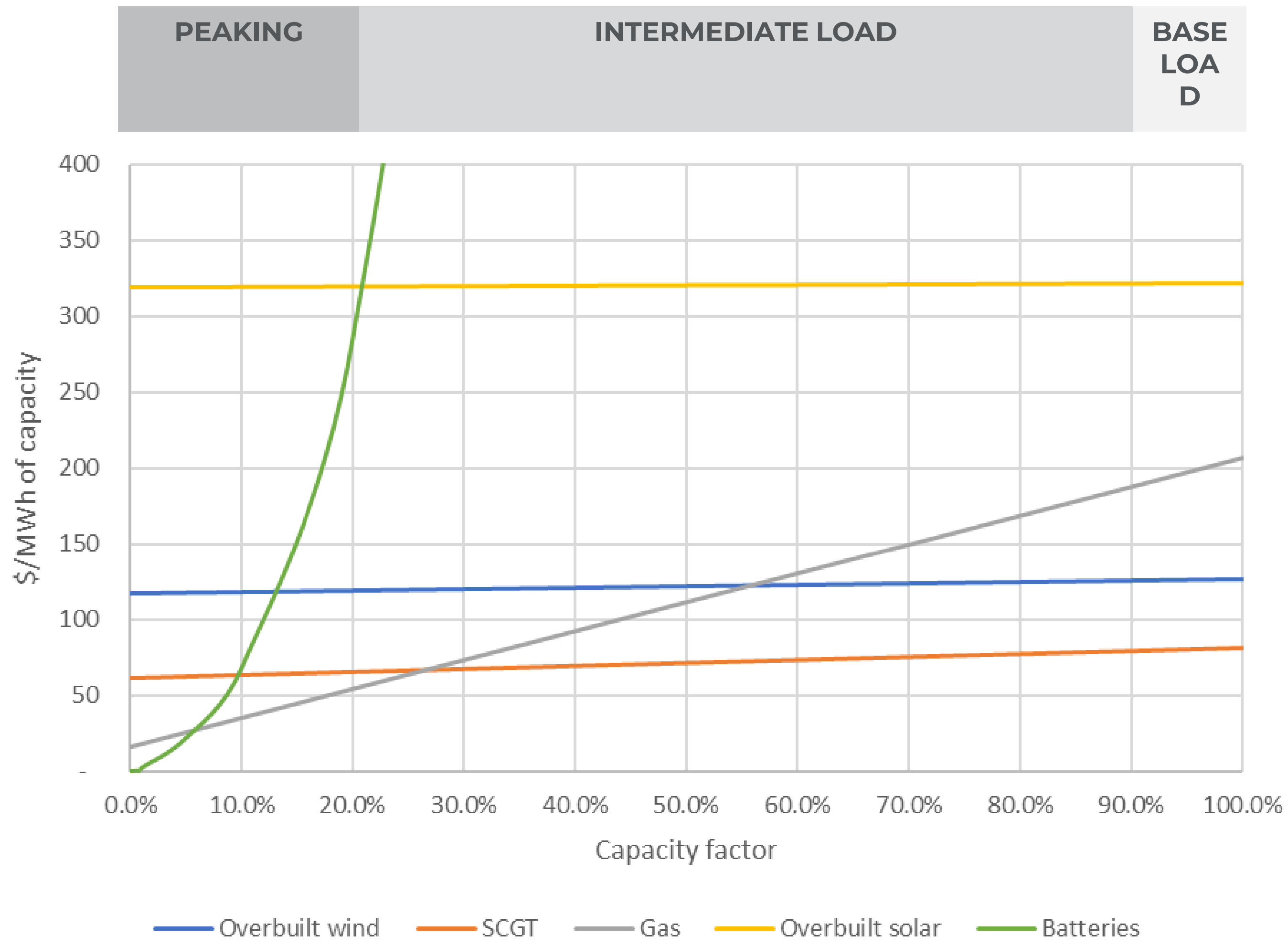
APPENDIX

New Zealand’s SC generation inventory

Location	Stored heat (exa-joules)	Capacity (MWe)	Generation (GWh/yr)
Kawerau	58	412	3428
S Tikitere	24	169	1408
Haroharo	99	706	5877
SW Reporoa	36	260	2166
W Ohaaki	20	143	1188
W Ngatamariki	21	149	1243
Rotokawa	63	451	3757
Mokai	19	137	1143
Wairakei	19	137	1143
Tauhara	58	412	3428
Tokaanu	38	275	2285
Ngawha	38	275	2285
Total	**493**	**3527**	**29351**

We evaluate different technologies in different roles



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