The Aotearoa Circle

Energy Sector Climate Change Scenarios

Mihi

Tukua te wairua, māna e whakahaumanu, e whakaora te rerehua o Aotearoa mō ngā uri whakaheke.

Hei arataki i ā mātou mahi me tā mātou whāinga matua kia hono ai te ira tangata ki te taiao.

Tōia mai rā te kaha me te ngākau pono kia hautū tahi ai tātou ki ngā āwhā arahi kia ora ake te ao tukupū.

Kia poipoia mō āke tonu atu.

Whakamaua kia tina, Hui e! Tāiki e!

Greeting

Release the spirit, to restore Aotearoa's natural beauty for future generations.

To guide our work and purpose in connecting people with the environment.

Let us draw in strength and integrity to meet the headwinds of today and lead for a better planet.

Ensuring it is nurtured forever.

United we affirm!

Whakatauki

He rangi tā matawhāiti,

He rangi tā matawhānui

Narrow vision

Restricted opportunities

Wide vision – plentiful opportunities

Opening Statement

Energy Sector Climate Change Scenarios

There is much for the energy sector in Aotearoa to be proud of. More than 80% of our electricity comes from renewable energy sources (Energy Efficiency & Conservation Authority, 2022). We have generally embraced new technologies. We are asking ourselves hard questions about what the future looks like with respect to our transport mix, our energy security and our carbon footprint.

However, fossil fuels are still a big part of our total energy mix. We use them in our cars, in manufacturing, and (ironically) to create electricity. Clearly, there is plenty of work to do to decarbonise our energy sector.

Then there are the sector's own vulnerabilities to climate change impacts. As you will see in this report, these range from the expected, such as rainfall changes impacting hydropower generation, to the more surprising, such as a warming climate boosting termite numbers and fungal growth, which shortens the life of electricity poles.

You will also see that this report considers four possible climate change scenarios for the New Zealand energy sector. In past reports for sectors such as agriculture, tourism and marine, we have considered three scenarios or just two. The scenarios used here weave together the impacts of what we do in Aotearoa with the realities of what may happen globally - both are critical to consider. Mentioning our vulnerability to greater global forces can prompt some to ask that rather tired question "we are so small, what can we actually do?". As this report reveals, we can do a lot, both to mitigate climate change and to adapt and brace ourselves against its worst impacts.

We are better placed to do both those things as a nation and as a sector, thanks to the information and resulting thinking this report provides. I want to thank the many contributors to this work and I particularly want to call out Annabell Chartres, James Ayling, Phoebe McCartie, Hunter Douglas, and Isla Christensen at PwC New Zealand for their tireless work to bring this report to life. The Aotearoa Circle commissioned them to complete this workstream, knowing how critical it is that New Zealand has the ability to protect and evolve its energy sector and to move beyond business as usual thinking.

We cannot function without the energy sector - we cannot travel, eat, deliver healthcare or education, produce goods to export and most of us cannot work if the lights go off.

In many ways, our energy sector can lead the way to a focus on renewables. We hope that this report will help empower the sector to continue to lead and to help Aotearoa to be a leader too, as per the Trailblazers and Coordinated Effort scenarios shared here. The worst case scenario you are about to read might be, frankly, terrifying. With determination and coordination, there is no reason New Zealand cannot contemplate a much brighter future, where we enable the right balance for decarbonisation and nature restoration. More power to all those who are determined to do just that.

Vicki Watson
CEO, The Aotearoa Circle

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Executive Summary

Overview of the climate change scenarios

Climate change scenarios allow us to give structure to an uncertain future. Under the External Reporting Board's (XRB) Aotearoa Climate Standards, climate-related scenarios are defined as "*plausible, challenging descriptions of how the future may unfold. These descriptions are based on coherent and internally consistent sets of assumptions about the drivers of future physical and transition risk and opportunity.*"[1]

Instead of trying to predict the future, they paint broad pictures of how the future could plausibly look, and in doing so create a rich evidence base for testing the resilience of the sector to climate change and to the challenges it could bring. These scenarios are not predictions or forecasts, and they are designed to be challenging to confront business-as-usual thinking.

The XRB has recommended that sectors come together to develop climate scenarios to address climate-related risks and opportunities. Shared sector-level scenarios can be used as a tool for entity-level scenario analysis and broader climate risk assessment and management, streamlining the research phase and facilitating peer comparison.

The Aotearoa Circle invited key participants from across the wider energy sector, including electricity and other energy sources, to develop a set of shared climate change scenarios for use in strategic planning. These scenarios aimed to explore the focal question "*How could climate change plausibly impact the Aotearoa New Zealand energy sector?*"

This report was intended for a range of audiences, including businesses looking to undergo climate change scenario analysis, policy makers, industry bodies, and local communities. This report does not include a roadmap for adaptation of the sector or outline actions or recommendations for businesses or policy.

Four scenarios have been developed to consider the physical and transition impacts of climate change and potential responses to these impacts. These scenarios reflect challenging but plausible futures for the sector. They cover a range of plausible temperature outcomes, from a scenario where global warming is limited to less than 1.5°C, to a world with over 3°C of warming by 2080.

These scenarios also explore varying levels of ambition to address climate change, both within New Zealand and beyond. This ranges from a coordinated global approach to reach net zero, New Zealand being a leader in climate action comparatively to other countries, New Zealand as a slow follower lagging in decarbonisation, and a world where minimal efforts are made internationally towards climate change mitigation.

Every scenario comes with its own set of challenges. Reducing emissions globally to avoid the catastrophic impacts of unmitigated warming will mean fundamental changes to the ways we source and use energy, creating transition risks that will need to be managed. There are further risks that can arise if the political, social, and economic tools to manage decarbonisation are not well coordinated. Planning ahead and communicating clearly are critical for organisations to anticipate these challenges and turn them into opportunities.

Aotearoa New Zealand's energy sector covers a diverse landscape, including energy generation, transmission and distribution, and retail. A large proportion of domestic energy generation comes from renewable sources, such as onshore wind, solar, hydro, geothermal, and biomass, largely due to our favourable geography as an island nation. However, the total amount of energy we use (for example for transport and industry uses), is largely fossil-fuel based. For the remainder of this report, "sector" refers to the energy sector, including energy resources, production, distribution and storage, consumption, markets, policy and regulation, and the wider value chain.

The energy sector plays an essential role in Aotearoa New Zealand, supporting all facets of our daily lives and wellbeing and powering future generations. The delivery of secure, affordable, and low-carbon energy is also critical for successful emissions reductions across all other sectors. The energy sector can leverage the opportunity to drive the transition, using clean technology to reduce costs and enhance energy efficiency, reduce reliance on global markets, and create employment opportunities for New Zealanders.

1 External Reporting Board. (2022). *Fact sheet: Scenario analysis and climate-related disclosures.*
2 External Reporting Board. (2023). *Staff guidance. Sector scenario development.*

How to read this report: Key assumptions

The scenario narratives are a description of how risks and opportunities are realised. These risks may be able to be mitigated partially or fully, and opportunities could be captured through an appropriate strategic response at the sector or entity level. The narratives are intended to highlight where effort and planning would be required if faced with a particular scenario and they are not a reflection of the adaptive capacity or strategic priorities of organisations in the energy sector. Please refer to the XRB's Staff guidance: *Sector scenario development*[2] for further information on how to use sector-level scenarios.

These scenarios intentionally do not get specific on which energy generation sources and technologies will be prioritised or most successful under each plausible future. Instead, they describe the prevalence of and conditions to support technologies aggregated by the following categories, fossil fuels, existing renewables, emerging renewables, and non-generation technologies such as storage and carbon capture. This approach was taken to allow each entity to further explore the specific energy sources or technologies most relevant to them in their entity-level scenarios.

Similarly, the scenarios do not include quantified projections of global or national GDP, primarily due to the long timeframes explored and the lack of maturity globally in linking physical climate hazards to economic modelling. If entities wish to include specific GDP figures in their scenarios, we have identified reference scenarios that include GDP projections that align best with each of the four scenarios here, including NGFS, SSPs, and IEA scenarios. In general, GDP growth rates are inversely proportional to temperature increases in NGFS modelling. GDP growth under these assumptions would thus be highest under Coordinated Effort, then Trailblazers, then Slow Followers, and lowest under Hot House.

This report is a result of a collaborative cross-sector approach and the outputs of this project have been developed based on the collective view across participants. Please note the Energy Sector Climate Change Scenarios **do not represent the view of any individual organisation or the energy sector as a whole**.

Scenario architecture

The following page provides an overview of the scenario architecture and underlying assumptions. These scenarios have been informed by a wide range of publicly available data, including reference climate scenarios. Please see the appendix for further information on the reference scenario alignment. The time horizons for this work are 2024 - **2030** (short-term), 2031 - **2050** (medium-term), and 2051 - **2080** (long-term).

Category	Hot House	Slow Followers	Trailblazers	Coordinated Effort
Overview of the scenario	A world where minimal and fragmented efforts towards climate change mitigation have resulted in severe physical impacts. Emissions continue to rise unabated and there is continued reliance on fossil fuels. Tipping points are crossed in the Earth's systems. Transition risks are low in the short term and grow over time, due to the costs of adaptation and recovery from climate-related impacts.	A divided world where New Zealand takes a ‘bare minimum’ approach towards achieving net zero, in comparison to most other countries. The energy sector faces the tension of minimal domestic political support for decarbonisation, against growing international pressure. Technological progress is slower than other scenarios. New Zealand’s transition away from fossil fuels is ultimately driven by economics.	A world where varying levels of international cooperation results in a fragmented response to climate change. New Zealand and several others have decarbonised faster, reflecting disparities in resources and capabilities. Technological development is slower due to less conducive international conditions. Fossil fuel consumption has been largely phased out in countries leading the climate movement, with a heavy emphasis on electrification.	A world defined by a rapid global push to decarbonise in the 2020s to achieve net-zero by 2050. Rigorous climate regulations and policies are enacted rapidly across the world. Decarbonisation is achieved through a wide range of renewable energy and energy efficiency measures. Tipping points in the earth system have largely been avoided but the world still faces intensified physical climate impacts, and the pace of change threatens those that fail to keep up.
Average increase in global temperature (2080)	3.3°C	2.5°C	2.2°C	1.5°C
Global emissions	Continue to grow through the century	Peak around 2040, nearly reaching net zero by 2100	Peak in the 2030s, reaching net zero by the 2080s	Peak in the 2020s and then decline, reaching net zero by the 2050s
Severity of physical risk	Extreme	Moderate	Moderate	Lower
Severity of transition risk	Low - Moderate	Low - Moderate	High	Moderate - High
Global policy ambition	Low	Moderate overall, highly differentiated	Moderate overall, highly differentiated	Highly ambitious and coordinated
NZ policy ambition	Limited	Slow and lagging globally	Immediate and bold	Immediate and globally coordinated
Technology change	Slow	Moderate	Moderate	Fast
NZ behaviour change	Slow	Slow - Moderate	Fast	Fast

Key Concepts and Definitions

Key Concepts and Definitions

Adaptation

In human systems, the process of adjusting to actual or expected climate and its effects, to moderate harm or take advantage of beneficial opportunities. In natural systems, the process of adjusting to actual climate and its effects. Human intervention may help these systems to adjust to expected climate and its effects.[3]

Climate change

A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes or trends in the mean and/or the variability of its properties, and that persists for an extended period, typically decades to centuries. Includes natural internal climate processes and external climate forcings such as variations in solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.[3]

Impacts

The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather events), exposure and vulnerability. They are generally effects on human lives, livelihoods, health and wellbeing; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. They can be harmful or beneficial. Also known as consequences or outcomes.[3]

Just Transition

Greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities, and leaving no one behind.[4]

Mana whanake

Sustainable intergenerational prosperity.[5]

Mitigation

In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases.[3]

Plausibility

The quality of a scenario to hold enough evidence to be qualified as 'occurable'.[6]

Sustainable/sustainability

Describes conditions where natural and human systems can persist. Ecosystems continuously function, biodiversity is high, natural resources are recycled and, in the human sector, people successfully apply justice and equity.[3]

Te Taiao

The environment or natural world.[5]

Te ao Māori

The Māori worldview.[3]

Tipping points

A critical threshold beyond which a system reorganises, often abruptly and/or irreversibly.[3]

3 Ministry for the Environment. (2022). *Aotearoa New Zealand's first national adaptation plan.*
4 International Labour Organization. (2024). *Frequently asked questions on just transition.*
5 Treasury New Zealand. (2023). *He Ara Waiora: Brief overview.*
6 Wiek, et al. (2013). Plausibility indications in future scenarios. *International Journal of Foresight and Innovation Policy.*

Context and Objectives

Context and Objectives

The challenge

The energy sector faces unprecedented levels of disruption from climate change. Aotearoa New Zealand's energy sector assets will be exposed to increasing physical and transition climate risks, including regulatory pressures to decarbonise. Each of the three components of the energy trilemma, security, sustainability, and affordability, will be tested. The Intergovernmental Panel on Climate Change (IPCC) reports we need rapid and deep emissions reductions across all sectors and the energy sector has a critical role to play.[7]

Under New Zealand's mandatory climate-related disclosure (CRD) requirements, large businesses are required to perform climate change scenario analysis. Climate change scenarios provide a foundation from which critical thinking and engagement in dynamic risk management can take place, as organisations deal with a changing climate and the extreme weather events, natural resource constraints, land-use changes and supply chain disruptions that come with it. Aotearoa New Zealand's resilience is dependent on a thriving and efficient energy sector. In the face of climate change, energy sector participants, and other stakeholders, will need to explore potential climate change impacts under a range of plausible futures to become climate resilient.

The opportunity

The energy sector plays an essential role in Aotearoa New Zealand, supporting all facets of our daily lives and wellbeing and powering future generations. The delivery of secure, affordable, and low-carbon energy is also critical for successful emissions reductions across all other sectors.[8] The energy sector can leverage the opportunity to drive the transition, using clean technology to reduce costs and enhance energy efficiency, reduce reliance on global markets, and create employment opportunities for New Zealanders.

The energy sector is well progressed at an entity-level regarding climate-related disclosures and scenario analysis. This gives rise to the opportunity and need for sector-level scenarios. The XRB has recommended that sectors come together to develop climate scenarios to address climate-related risks and opportunities. Developing sector-level scenarios has several advantages, including ensuring high-quality, consistency, and comparability across entity-level disclosures, costs savings, and strengthened cross-sector collaboration.[9] Enhancing critical and strategic thinking in the face of challenging but plausible climate-related scenarios will help ensure resilience across the energy sector and Aotearoa New Zealand more broadly.

Objectives for this work

The following overarching objectives guided the development of the Energy Sector Climate Change Scenarios.

1

Translate climate science into challenging and plausible climate change scenarios

Develop a set of scenarios that reflect a range of plausible pathways for the sector. Scenarios will be co-developed by looking at the key risks, opportunities, uncertainties and driving forces faced by the sector.

2

Give visibility to the potential impacts of climate change across the energy sector value chain

Collate and articulate the potential impacts of climate change experienced by industry participants across the Aotearoa New Zealand energy sector.

7 Clarke et al. (2022). Energy systems. *Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*
8 Boston Consulting Group. (2022). *Climate change in New Zealand: The future is electric.*
9 External Reporting Board. (2023). *Staff guidance: Entity scenario development.*

Project governance

This project consisted of a tiered governance structure, with voluntary participants from across the energy sector. Please see the appendix for the organisations involved.

The **Leadership Group (LG)** provided governance and oversight of the project. They set the ambition and guided and reviewed the work of the Working Group (WG). LG responsibilities included meeting to provide input and feedback on progress and agree key decisions throughout the project.

The **Working Group (WG)** included technical experts from across the energy sector, climate science, policy and finance. The WG were key stakeholders engaging in the workshops, providing their insights and analysis to contribute to the Energy Sector Climate Change Scenarios.

The Aotearoa Circle contracted PwC New Zealand to support the development of climate change scenarios for the energy sector. PwC New Zealand acted as secretariat, offering climate change expertise, project coordination, stakeholder management, workshop facilitation, reporting and documentation.

Scope of the work

Focal question

To align on the scope of work, a guiding focal question was established. The XRB defines a focal question as "*A question that guides a project or a process by providing clarity, direction, and boundaries. A focal question should be specific, short, precise, and reflect the desired outcome of the project.*"[10] The focal question for this work is:

"How could climate change plausibly impact the Aotearoa New Zealand energy sector?"

Time horizons

A range of factors were considered in the selection of appropriate time horizons for the scenario analysis, including emissions targets, life cycles of energy sector assets and the availability of supporting climate data. The time horizons for this work are:

'**Short-term**' refers to the period 2024 - **2030** to align with the first two New Zealand emissions budgets and statements of 2030 as the decade for action.

'**Medium-term**' refers to the period 2031 - **2050** to align with New Zealand and international emissions targets, such as The Paris Agreement.

'**Long-term**' refers to the period 2051 - **2080** to account for the extended life cycle period of assets in the energy sector and variety in physical climate systems.

Defining the energy sector

Aotearoa New Zealand's energy sector covers a diverse landscape, including energy generation, transmission and distribution, and retail. A large proportion of domestic energy generation comes from renewable sources, such as onshore wind, solar, hydro, geothermal, and biomass, largely due to our favourable geography as an island nation.[11] However, the total amount of energy we use (for example for transport and industry uses), is largely fossil-fuel based.[12] Aotearoa New Zealand's energy system is ranked highly in the world for its combined equity, security, and sustainability.[13]

Figure 1: Energy balance in New Zealand, 2022

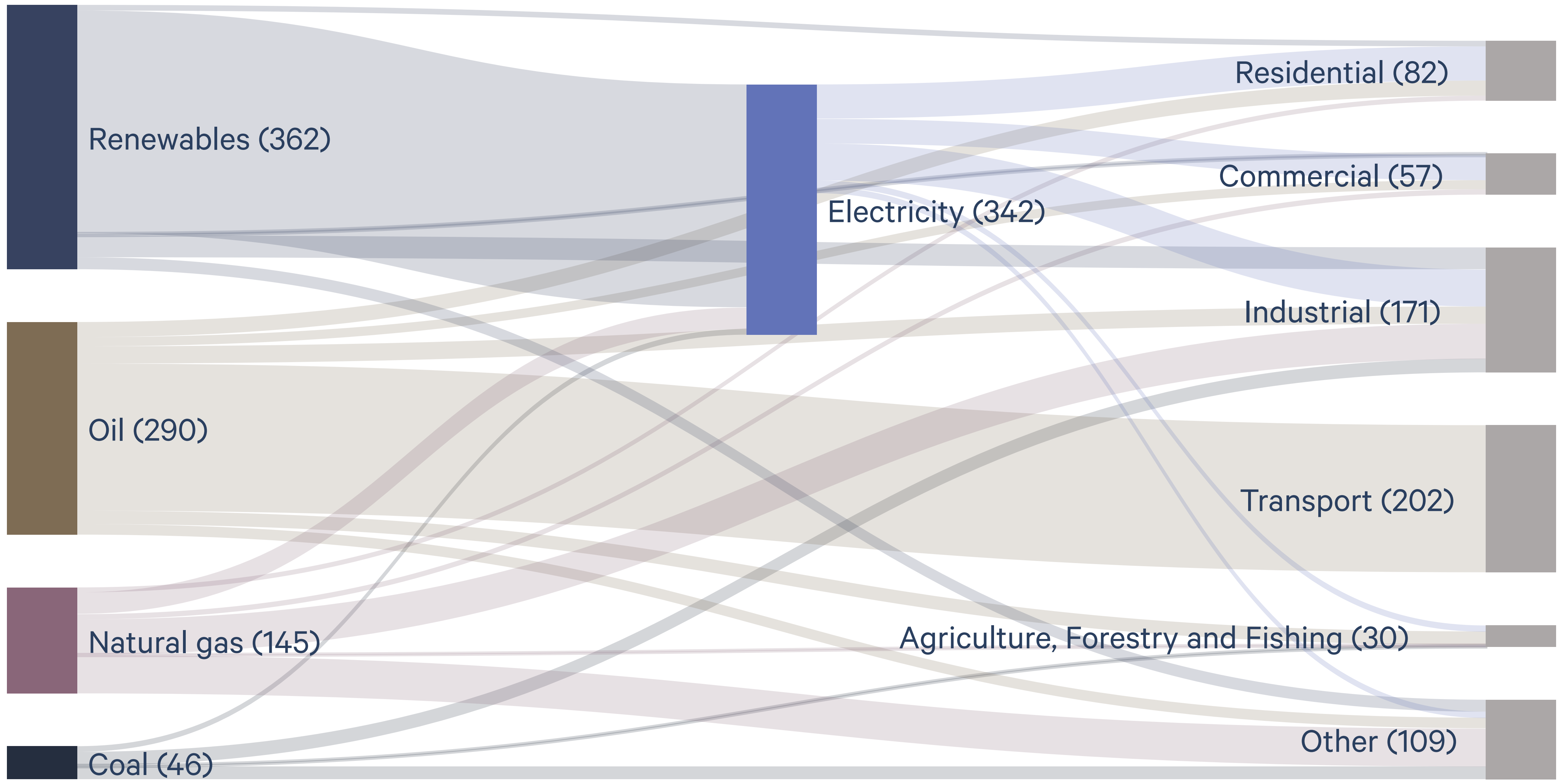


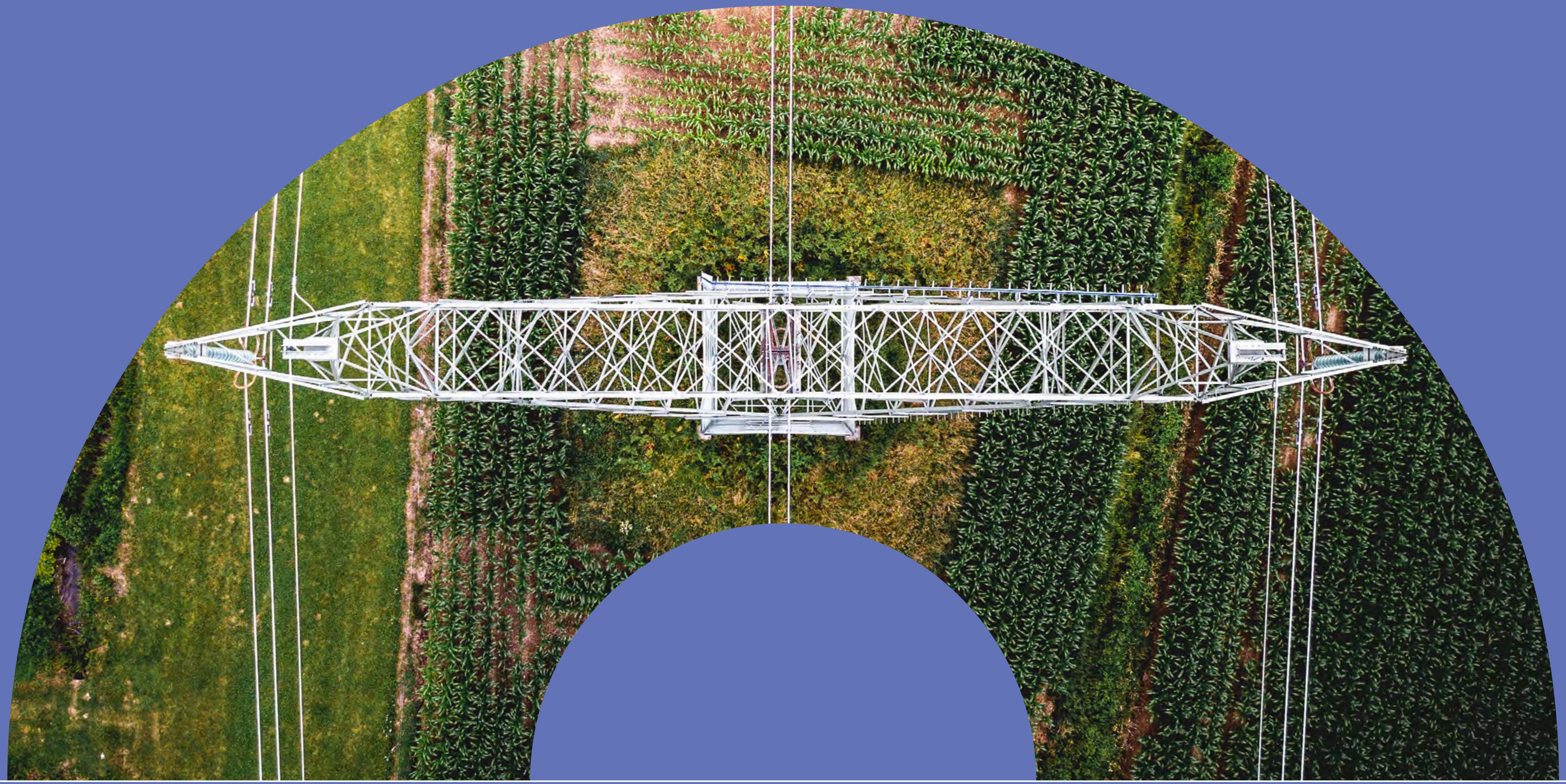
Figure 1 shows the flow of energy from source to end use by sector in New Zealand, based on 2022 data from MBIE.[14] All values are in petajoules (PJ). Flows less than 1 PJ are not shown, and international travel is excluded. 'Other' groups together cogeneration, fuel production, own use, non-energy use, such as feedstock for manufacturing, and losses. Additional losses occur during the electricity generation phase.

10 External Reporting Board. (2023). *Staff guidance. Sector scenario development.*
11 Energy Efficiency & Conservation Authority. (2022). *The future of energy in New Zealand.*
12 Ministry of Business, Innovation and Employment. (2024). *Energy in New Zealand.*
13 World Energy Council. (2022). *World energy trilemma index 2022.*
14 Ministry of Business, Innovation, and Employment. (2024). *Energy in New Zealand.*

The energy sector system boundaries as defined for this work are captured in Figure 2. This figure reflects the consensus reached by participants in this project in determining the large elements of the energy sector system but may not be exhaustive.

Figure 2: Energy sector system boundaries

Energy resources	Water	Geothermal	Wind	Solar	Fossil-based refined fuels	Oil and gas
	Coal	Bio and waste	Hydrogen			
Production	Electricity generation	Fossil-based gas, LPG, and methanol	Fossil-based refined fuels and imports	Coal mining and imports	Direct geothermal	Bio energy
	Future fuels					
Distribution and storage	Gas transmission and distribution pipelines	Gas storage	Electricity transmission and distribution	Fuel pipelines and storage	Bio energy supply chains	Transport of inputs and outputs
	Distributed energy resources (DERs)	Batteries				
Consumption	Residential	Commercial	Industrial	Transport	Resource management	Demand-side management (DSM)
	Energy efficiency					
Markets	Wholesale	Retail	Hedge markets	Carbon markets		
Policy and regulation	Regulators	Central government	Local government			
Advocacy and influencers	Tangata whenua	International markets	Media			
Wider value chain	Mana whenua	Communities of NZ	Research and advanced technologies	NGOs	Communications and data	
	Workforce	Infrastructure	Finance	Supply chain (local and global)	Emergency management services	



Energy Sector Climate Change Scenarios

Guide to using climate scenarios

Understanding critical uncertainties

Climate change scenarios allow us to give structure to an uncertain future. Rather than attempting to predict the future, they paint broad pictures of how the future could plausibly look, and in doing so create a rich evidence base for testing the resilience of the sector to climate change and to the challenges it could bring. According to the Task Force on Climate-Related Financial Disclosures (TCFD), "*in a world of uncertainty, scenarios are intended to explore alternatives that may significantly alter the basis for "business-as-usual" assumptions*".[15]

Under the Aotearoa New Zealand Climate Standards released by the XRB, climate reporting entities (CREs) are required to perform scenario analysis for their organisation. The XRB has recommended that sectors come together to develop shared sector level climate change scenarios that CREs can use. The intention of the shared sector scenarios is to ensure high-quality, consistency and comparability in disclosures across each sector and bridge the gap between global and national analysis. Sectoral collaboration will also "*provide greater comparability and lead to higher quality scenarios, while imposing fewer resource demands for CREs*".[16]

To meet the requirements set out by the XRB, CREs must analyse at least three scenarios; a scenario in which global warming is limited to 1.5°C, a scenario in which warming exceeds (or is on track to exceed) 3°C, and one other of the organisation's choosing. A spectrum of scenarios ensures that resilience is being tested considering both climate-related physical and transition risks that could manifest in the future.

Scenarios should enable us to think critically about how the sector currently operates and how it can improve its resilience to the challenges the future will bring. The TCFD cites five characteristics of high-quality scenarios:

- **Plausibility** - scenarios should be credible, possible, and believable.
- **Distinctiveness** - each scenario should include a different combination of key factors and provide differentiated messages.
- **Consistency** - scenarios should have strong internal logic, where interactions between factors, actions and reactions are consistent across scenarios and able to be logically explained.
- **Relevance** - scenarios must be decision relevant. They should provide insights that enable dynamic risk management and strategic planning.
- **Challenge** - scenarios should challenge conventional wisdom and simplistic forward thinking. They should aim to incorporate alternative pathways that challenge current assumptions.

15 Task Force on Climate-Related Financial Disclosures. (2017). *The use of scenario analysis in disclosure of climate-related risks and opportunities.*
16 External Reporting Board. (2023). *Staff guidance. Sector scenario development.*

Using sector-level scenarios

Entities should draw upon the *XRB Staff Guidance: Entity scenario development*[17] to understand how to develop their own entity-level climate-related scenarios. Energy sector entities can draw on aspects of the sector scenario analysis that are most useful and relevant to their own operations. An entity must describe the scenario analysis it has undertaken and should be able to explain why it has chosen a given set of assumptions for its own entity-level scenarios, including assumptions drawn from sector-level scenarios and any higher-level scenarios fed into sector-level scenarios.

The XRB recommends that "*reusing a sector scenarios narrative directly in an entity's own narrative is unlikely to be of much use for primary users or the entity, nor will it meet the disclosure requirements in NZ CS. Entities' scenarios narratives should focus on the specific drivers able to impact the entity's own operations, markets, strategy, and business model. However, an entity's narrative could refer to relevant aspects of a sector narrative*".[17]

Purpose of this report

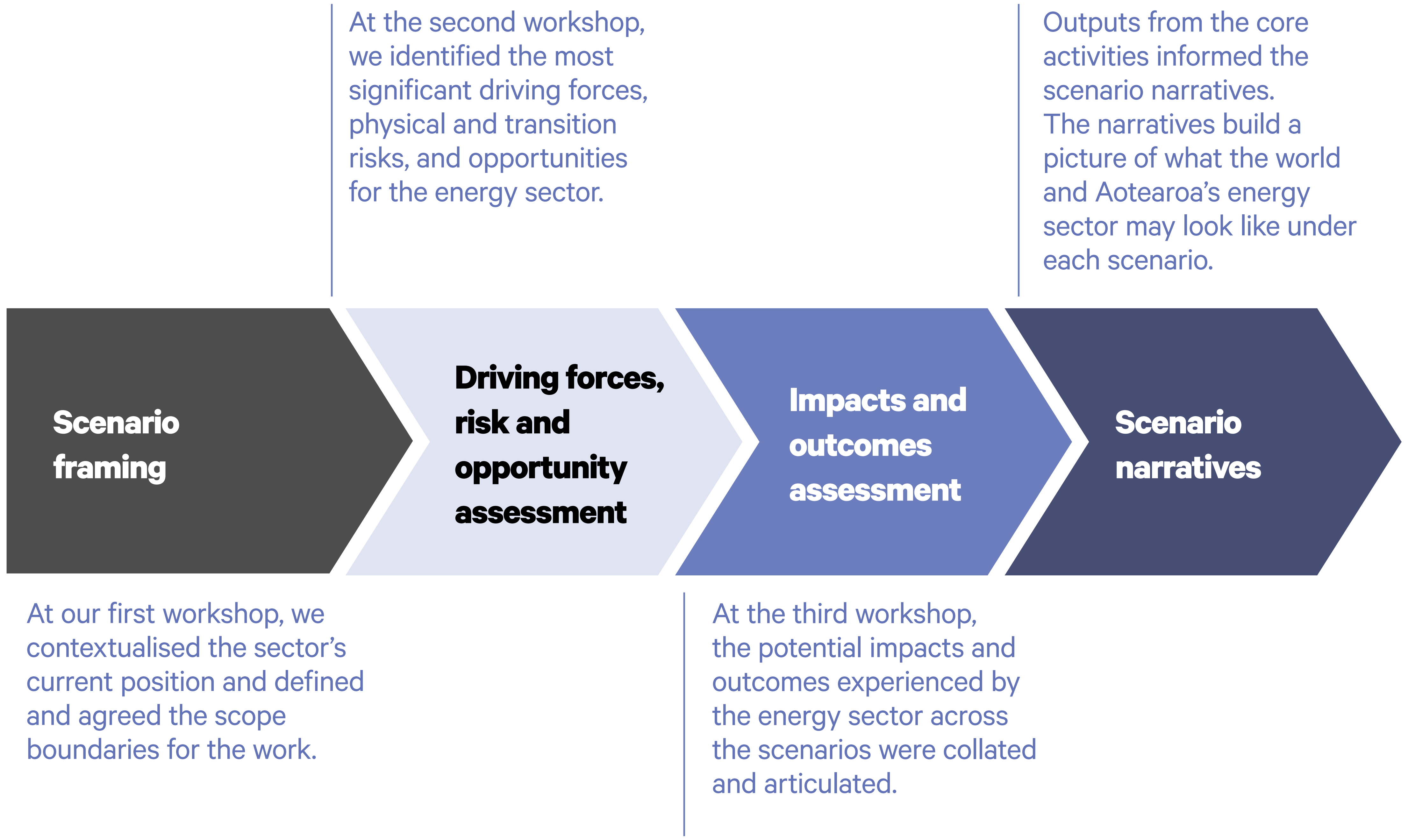
The scenarios in this sector-level report are intended to inform entity-level scenario analysis and provide a common ground for aligning reporting within and across the energy sector. They do not need to be adopted in full for entity-level reporting. Many energy sector entities have already constructed entity-level scenarios and this sector-level analysis can be an additional resource for future analysis and reporting. Elements of the scenarios, such as the identified risks, can be included, excluded, combined, adjusted, or augmented to suit each organisation's needs. Identifying the deviations from the sector-level scenarios and explaining the reasoning for doing so will aid primary users in interpreting an entity's disclosures. This report could also benefit organisations considering adopting the reporting framework as a tool for internal capability building and knowledge sharing.

Scenario development process

The scenarios detailed in this report were developed across three workshops with the Working Group (WG), followed by review and input at Leadership Group (LG) meetings. Each workshop built on the previous one, allowing for the development of scenario narratives that are relevant for input into strategic decision-making.

The energy and transport sectors simultaneously developed sector-level climate change scenarios. Given the interdependencies and reliance of these sectors on one another, the participants from each group came together for two joint working sessions. These sessions covered discussions to ensure the development of credible scenarios for each sector, such as the key linkages between the future pathways. Please see the energy and transport sector section for more information.

Figure 3: The scenario development process



17 External Reporting Board. (2023). Staff guidance: *Entity scenario development.*

Climate-related risk and opportunity assessment

The most significant climate-related risks and opportunities identified for the sector are presented in the tables. Please see the appendix for the long list of climate-related risks and opportunities. Please note these **do not represent the view of any individual organisation or the energy sector as a whole**.

Identifying climate-related risks and opportunities is key to understanding the exposure the sector has to climate change. With this understanding, scenario analysis can be developed to better test points of challenge and opportunity, with consideration of how risks and opportunities manifest differently across the scenarios to a long-term horizon of 2080.

Definitions of climate-related risk and opportunity

Physical risks are risks arising as a result of chronic changes to the climate such as rising sea levels and warming temperatures, in addition to increased frequency and severity of acute and extreme weather events such as droughts or flooding.

Transition risks are risks arising from the process of adjusting to a low-carbon economy or adapting to the impacts of climate change.

Climate-related opportunities are potential benefits or co-benefits arising from the impacts of or responses to climate change. Opportunities can be categorised into resource efficiency, energy source, products and services, markets, and resilience.

Each of these climate-related risks and opportunities are present under all four of the scenarios. The level of significance of each will vary depending on the conditions of the scenario. It's important to note that physical climate risks are present under all scenarios, however, how they manifest will vary.

Table 1: The most significant climate-related physical risks for the energy sector

Physical risks	
P1	Increased damage and loss of access to key energy system assets (lines, pipelines) and supporting infrastructure (bridges, telecommunications) as a result of increased frequency and severity of extreme acute weather events.
P2	Increased ongoing maintenance requirements and reduced ability to effectively maintain key infrastructure as a result of systemic loss of access and key asset damage due to increased frequency and severity of extreme acute weather events.
P3	Increased international supply-chain constraints and continuity of supply disruptions across key energy system components and inputs as a result of increased frequency and severity of extreme weather events.
P4	Increased volatility of electricity production and supply as a result of increased variability of weather events and changing regional seasonality (e.g. hot days, rainfall, wind patterns).
P5	Increased asset vulnerability and damage as a result of chronic climate change, such as rising temperatures, sea level rise and erosion.

Table 2: The most significant climate-related transitions risks for the energy sector

Transition risks	
T1	Failure to adequately build, upgrade, and maintain long term infrastructure to handle the energy transition.
T2	Inability of the sector to efficiently manage electrification transition and stability of supply leading to increased peak loads, outages, and network costs.
T3	Ineffective climate adaptation due to a lack of whole-system coordination across the sector.
T4	Inability of the sector to affordably access financial services, including insurance and debt markets.
T5	Politicisation of the energy transition, competing regulation, and limited political stability for prioritisation of investment across the sector.
T6	Increased volatility and/or cost of carbon as a result of regulatory intervention such as changes to the Emissions Trading Scheme (ETS) or inclusion of NZ Emissions-Intensive Trade Exposed Industries (EITEs) in the ETS.
T7	Supply chain and labour market constraints in a highly competitive global market are a barrier for the transition to low-carbon energy.
T8	Inability to afford and/or access new technology and components essential to the transition to a low-carbon economy.
T9	Inability to manage increased inequity and impacts on community well-being associated with cost and access to low-carbon energy.
T10	Increased stranded assets and asset write downs as a result of rapid decarbonisation, regulatory change, increased lower carbon alternatives etc.

Table 3: The most significant climate-related opportunities for the energy sector

Climate-related opportunities	
O1	Increased adoption and implementation of new monitoring and management technologies grow a more flexible and resilient energy market, enabling more efficient distribution of energy.
O2	As technology continues to evolve, there is increased opportunity to provide further energy storage solutions at a residential, commercial and industrial scale.
O3	Increased digitisation of energy platforms and adoption of 'smart tech' to assist more effective distribution of energy and management of energy consumption for some consumers.
O4	Investors are able to make attractive investments that have co-benefits with Te Taiao, the natural world, and sustainable, intergenerational prosperity (mana whanake).
O5	New employment opportunities for some regional communities to support the transformation of assets and infrastructure as the energy sector continues to decarbonise and emerging uses come online.
O6	New markets, such as solar, wind and hydrogen-based products like ammonia, aviation fuel, marine fuels, will enable increased diversification and decentralisation of energy mix, increased resilience of energy supply, and reduced dependence on imported liquid fuels.

Driving forces

Driving forces (also known as 'drivers') are large-scale external factors or influences that affect how the energy sector operates. They are the critical trends which will shape the future and impact the manifestation of climate-related risks and opportunities. Driving forces are a critical input into the development of climate change scenarios, as the evolutions and interactions between them create the foundation for the scenario narratives. The driving forces are all dynamic in nature and will change over time. Some will evolve fairly predictably, while others will be highly uncertain. Driving forces have been mapped using the STEEP framework categories, social, technological, environmental, economic, and political. The key driving forces are the most influential and uncertain, known as the 'critical uncertainties'. Please see the appendix for the long list of driving forces and their definitions.

Table 4: Critical uncertainties for the energy sector

STEEP category	Driving force	Definition
Technological	**Technological advancements**	The degree of research and development enabling new emerging and disruptive technologies, which impact the wider energy system.
Environmental	**Severe acute weather events**	Frequency and severity of climate-driven acute weather events.
Political	**Domestic regulatory changes**	The timing, speed and level of climate-related and other legislation passed by government in New Zealand, including resource consenting and specific examples targeting the energy system e.g. emissions standards, mandates on ICE vehicles, product stewardship requirements, renewable energy targets, biofuel requirements, fossil fuel bans/restrictions, etc.
Social	**Social preferences and behaviour**	Changing expectations and norms around climate change/sustainability and the demand from customers, shareholders, employees and investors for balancing energy security, sustainability, and affordability. Influenced by socioeconomic factors including equity, tangata whenua relationships and priorities, demographics, values, and consumption patterns.
Social	**Changes to customer base**	Breakdown of energy system users by residential/commercial/industrial categories, as well as the type of industrial users. User base is also influenced by patterns of urbanisation and emergence of low-emissions technologies.
Political	**Domestic government priorities and attitudes**	The level and consistency of New Zealand governments ambition and leadership on climate change mitigation and adaptation. Also includes the degree to which climate action is politicised, the scale and timing of investment and funding for climate-related issues/infrastructure, and governments perspectives on Te Tiriti obligations.
Economic	**Access to finance and insurance**	Access to and cost of debt, equity finance and insurance for net-zero transition and other purposes. Includes the Māori economy and funding for iwi-led investment.
Economic	**Availability and cost of fossil fuels**	Availability, cost, and quality of fossil fuels from international markets.
Political	**International policy**	The timing, speed and level of climate-related and other legislation passed by governments outside of New Zealand (e.g. USA, China, Australia) and level of climate action in large markets.

Scenario architecture

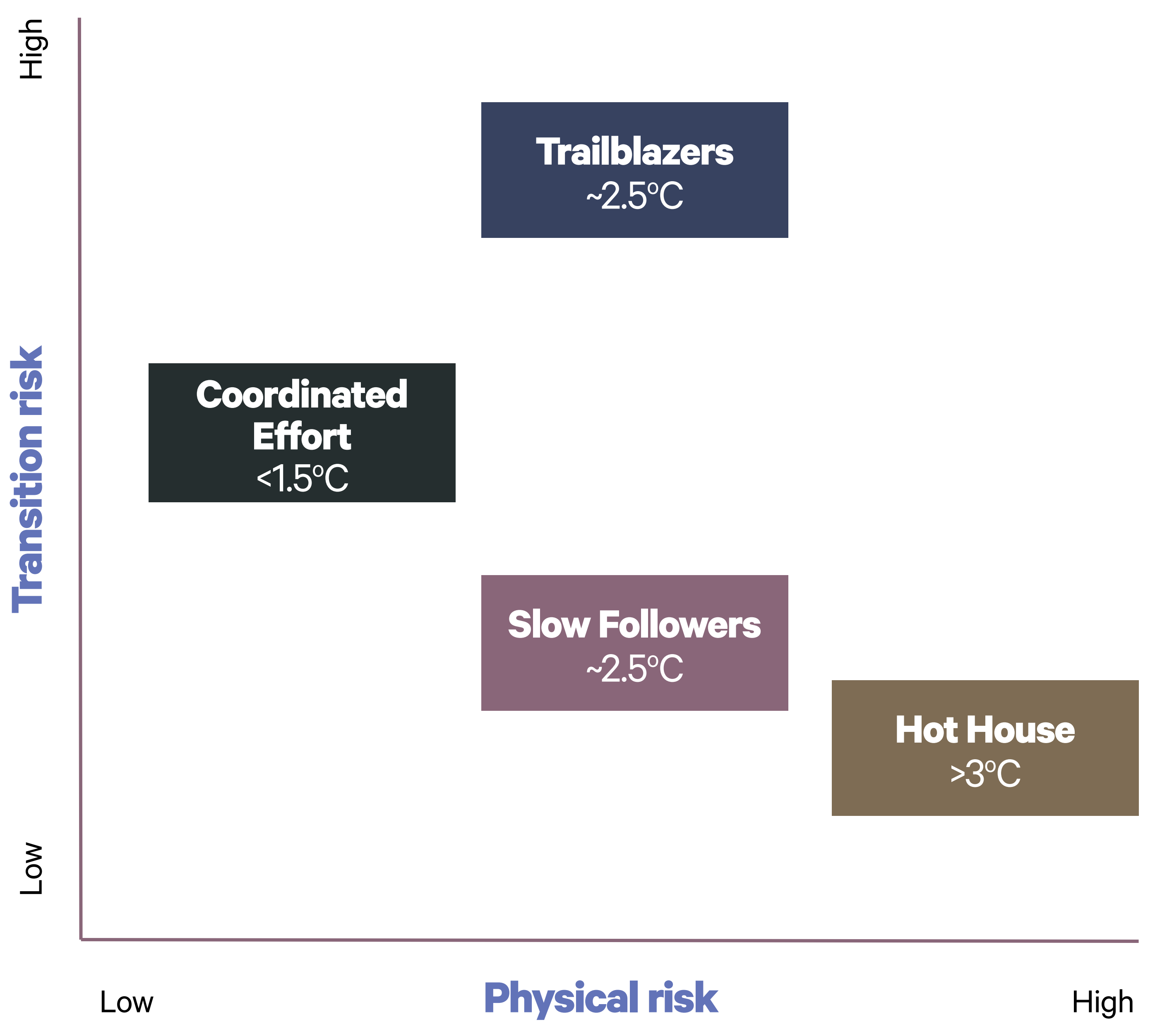
The XRB recommends using scenario axes to provide the high-level logic for how the scenarios compare to one another. This helps set the direction for identifying how driving forces evolve under each scenario. The Energy Sector Climate Change Scenarios use the axes of transition and physical risk as shown on the scenario matrix. The four scenarios span a broad range of plausible outcomes for the identified physical and transition risks.

Each scenario is also characterised by how rapid and ambitious the response to climate change is in Aotearoa New Zealand versus the rest of the world. New Zealand takes strong action under Coordinated Effort and Trailblazers but lags under Slow Followers and Hot House. Global ambition is high under Coordinated Effort, moderate and differentiated under Trailblazers and Slow Followers, and low under Hot House.

Transition risks are lower under Slow Followers than Trailblazers as New Zealand takes more of a free-rider approach to climate action. While this places less pressure on organisations to change operating practices in the short term, it introduces risks to New Zealand's international reputation and our ability to access finance and resources. A transition to a low-emissions economy still occurs under the Slow Followers scenario, albeit later on, catching out organisations that have failed to plan ahead.

Figure 4: Energy sector climate change scenario matrix

The temperature indicators below are high-level to show alignment with XRB requirements reflecting approximate global warming by the year 2100.



Hot House

Global warming at 2050

2.2°C

Global warming at 2080

3.3°C

Hot House represents a world where minimal and fragmented efforts towards climate change mitigation have resulted in severely increased physical impacts. Emissions continue to rise unabated and there is continued reliance on fossil fuels across the energy sector. Global warming hits 3.3°C and is still rising by 2080. Countries pursue individualised responses to climate change and poorer countries experience the brunt of physical impacts, but no nation is unscathed. Tipping points are crossed in the Earth's systems, locking in ecological destruction for decades to come. The Hot House scenario assumes low transition risks in the short term that grow towards the middle of the century, relating to high costs of adaptation and recovery from climate-related disasters.

Key assumptions

Severity of physical risk	Extreme
Severity of transition risk	Low - Moderate
Global policy ambition	Low
NZ policy ambition	Limited
Technology change	Slow
NZ behaviour change	Slow
Global emissions and temperature	Continue to grow through the century (in line with SSP3-7.0)

Note: The above high-level descriptions are relative to the other scenarios.

Reference scenarios

SSP3-7.0 | RCP8.5 | NGFS Current Policies | CCC Current Policy Reference | BCG Business-as-usual | Transpower Business as Usual

Table 5: Key climate-related risks and opportunities under Hot House

The energy sector climate-related risks and opportunities are present across all scenarios. The table holds those identified as most significant for the Hot House scenario. This scenario provides the conditions for these risks to be most challenging. Physical climate risks are present under all scenarios and will vary in severity.

P1	Increased damage and loss of access to key energy system assets (lines, pipelines) and supporting infrastructure (bridges, telecommunications) as a result of increased frequency and severity of extreme acute weather events.
P2	Increased ongoing maintenance requirements and reduced ability to effectively maintain key infrastructure as a result of systemic loss of access and key asset damage due to increased frequency and severity of extreme acute weather events.
P3	Increased international supply-chain constraints and continuity of supply disruptions across key energy system components and inputs as a result of increased frequency and severity of extreme weather events.
P4	Increased volatility of electricity production and supply as a result of increased variability of weather events and changing regional seasonality (e.g. hot days, rainfall, wind patterns).
P5	Increased asset vulnerability and damage as a result of chronic climate change, such as rising temperatures, sea level rise and erosion.
T3	Ineffective climate adaptation due to a lack of whole-system coordination across the sector.
T4	Inability of the sector to affordably access financial services, including insurance and debt markets.

Global situation at 2050

A lack of coordinated policy to support a net-zero transition means countries focus on short-term interests and energy security, continuing to exploit fossil fuel resources. Conflicts and geopolitical tension are on the rise, and insufficiently few countries cooperate on addressing climate change. By 2050, Paris Agreement targets have been largely abandoned. Managed retreat is common, with many communities and businesses around the world unable to withstand the physical and economic impacts of climate change. Energy sector supply chains suffer disruption and insurance is hard to come by due to climate-related risks. Where possible countries, including New Zealand, invest instead in reactive and incremental adaptation measures and domestic energy security.

Environment

Temperatures have soared by 2.2°C by 2050 and are on track to reach over 4.0°C of warming by 2100. The world is facing irreversible and devastating impacts of climate change. Tipping points in the Earth system have been surpassed, leading to massive disruptions of ocean currents and significant permafrost melting. In the long term, the Greenland and West Antarctic ice sheets are confirmed to be heading towards collapse, locking in metres of sea level rise over the coming century.

Society

There is unrealistic optimism amongst developed countries in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary. Consumers and industrial users demand resilient energy systems that can withstand extreme weather events and disruptions, and fossil fuels are perceived as essential. Social unrest rises as inequalities are exacerbated and crop failures proliferate. Climate refugees become more common and there are increased levels of geopolitical instability and conflict.

Economy

The cost of dealing with climate change puts a strain on national budgets and hinders global economic growth. The unequal distribution of resources and adaptation capabilities furthers economic disparities between countries. Major parts of some countries most vulnerable to physical impacts, such as Pacific nations, become effectively uninhabitable, leading to a rise in displacement of people.

Technology

Due to a lack of government support and investment in technology, there are no major improvements in energy efficiency or breakthroughs in emerging technologies. Energy security concerns, armed conflict and high fossil fuel prices in the medium to long term drive a combination of behind-the-meter generation, or energy systems located on the customer's side of the utility meter, such as solar panels, and battery installation by a range of critical sectors and industrial users, such as hospitals, water treatment, food production, as well as affluent residential users.

Policy

Rising geopolitical unrest and supply chain disruptions are common, resulting in high costs and key product shortages. Increased international tensions lead to greater nationalist and protectionist policies, including border controls, trade barriers and conflicts, affecting energy supply chains. International institutional agreements collapse, worsening the lack of trust between countries. Due to lack of government support, public and private climate-related funding mechanisms that target emissions reduction cease to exist.

Global scenario indicators

Figure 5: Hot House global CO_2 emissions trajectory[18]
(Gt CO_2/year)

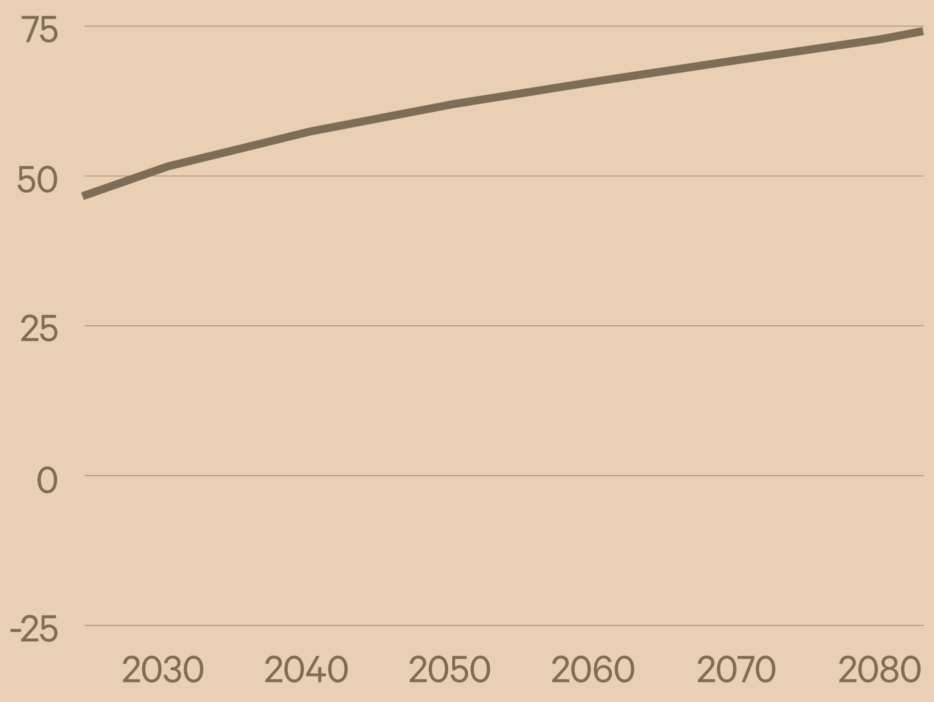
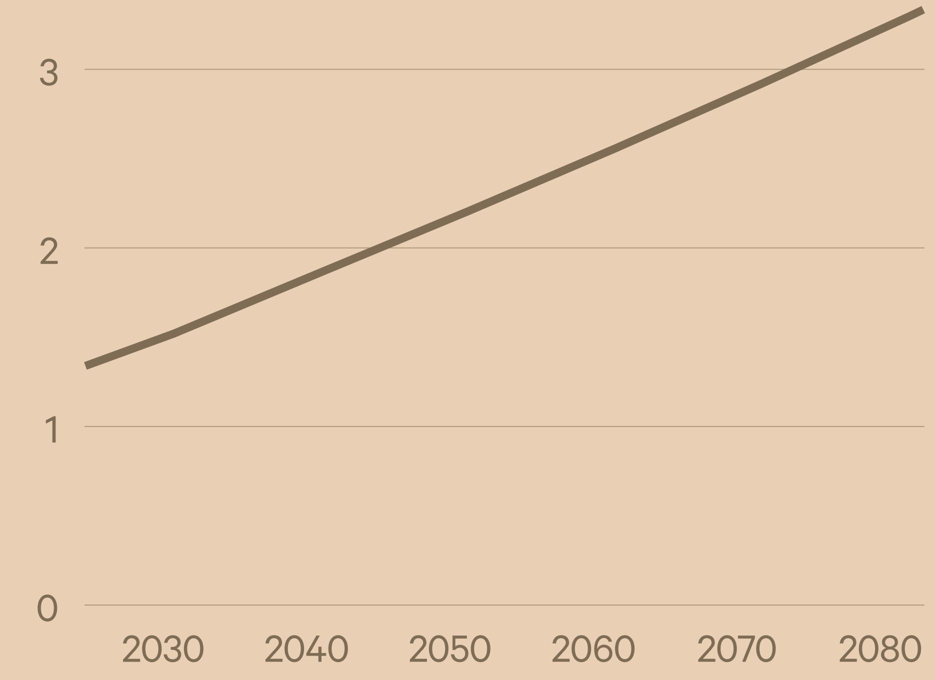


Figure 5: Hot House global temperature rise trajectory[18]
(°C)



18 IIASA SSP Database. (Version 2.0). SSP3-7.0.

Aotearoa New Zealand situation at 2050

By 2050, the physical impacts of climate change on the New Zealand energy sector are glaringly evident. Rising sea levels, warming temperatures, and extreme weather events pose risks to infrastructure and operations. The energy sector is grappling with the need to enhance climate resilience and adapt to changing conditions.

National adaptation investment is highly reactive. The Government struggles to get ahead and truly adapt to an ever-changing 'new normal'. Prioritisation of domestic energy security leads to consideration of increased offshore oil and gas drilling. During the 2040s, fast tracking consent for adaptation is prioritised. Political attitudes and actions respond to this dynamic context with changes in environmental regulations, a government-led approach to managed retreat, reframing of resource management policies, and a shift towards prioritising energy security.

In response to energy security and resilience concerns and weather risks for large scale infrastructure and generation, there is a rise of decentralised energy systems and more use of LPG. These systems enable localised energy generation, storage, and distribution, enhancing energy resilience and reducing reliance on the grid. However, the costs of procuring equipment from international suppliers continue to grow due to significant global demand for energy components, making scaling these solutions difficult. Additionally, new natural gas fields have been developed.

2050 and beyond

Emissions continue to grow throughout the century, exacerbating the global climate crisis. The environmental state of the world significantly worsens, resources are being depleted at a rate greater than ever before, and in turn, energy prices begin to soar. Supply chain disruptions increase cost volatility as well as rising geopolitical and trade constraints, putting pressure on all of society. A lack of global collaboration adds to degrading social cohesion, with conflict and unrest becoming increasingly common.

Solar cells are more commonly used off-grid by security-conscious consumers, rather than for grid-scale generation. The energy sector faces infrastructure deterioration and there is a continuation of using traditional sources of energy, such as coal, wood, oil and gas. With an increasing number of climate refugees, New Zealand struggles to deliver essential services in areas that are no longer supported by energy infrastructure and services.

New Zealand scenario indicators

Figure 7: Hot House NZ CO_2 emissions trajectory[19]
(Mt CO_2/year)

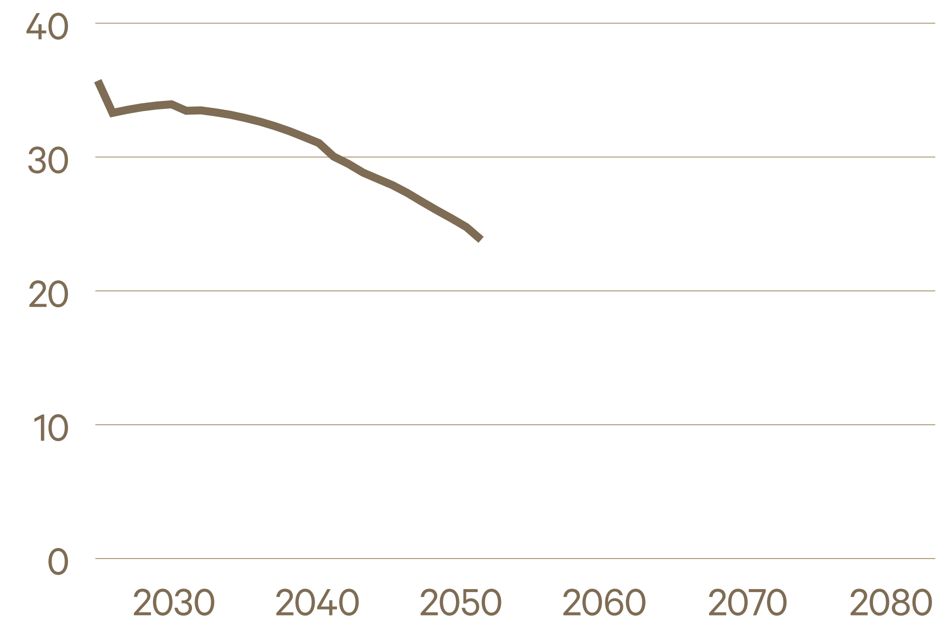
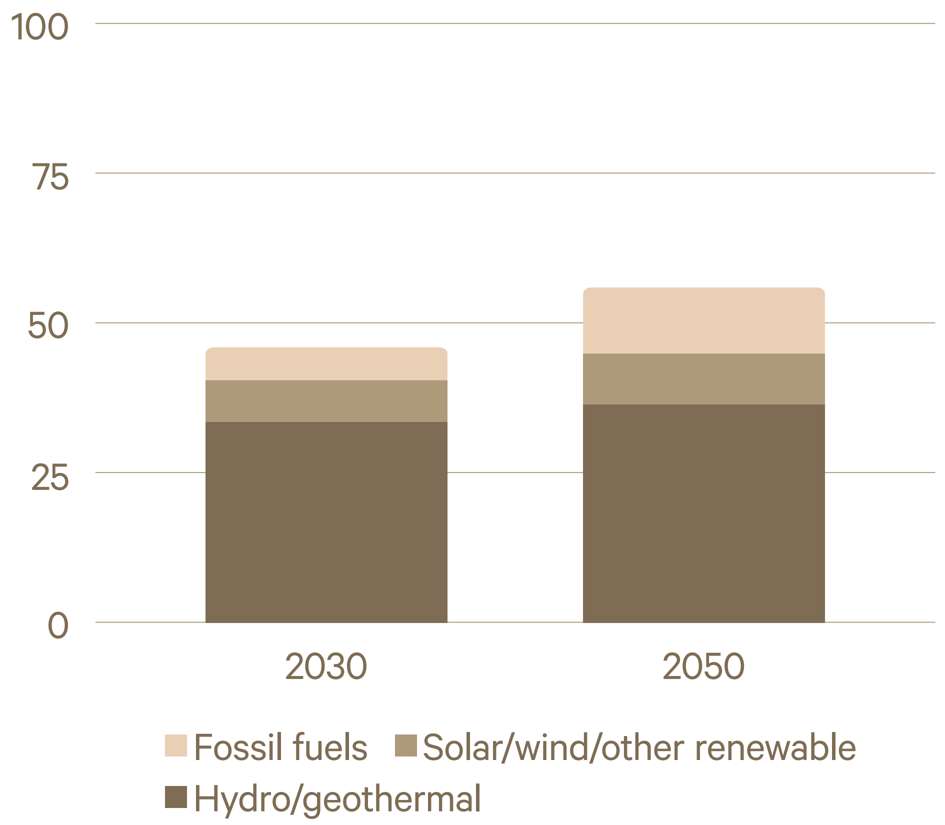


Figure 8: Hot House NZ electricity generation by source[20]
(TWh)



NZ renewable energy
46%
share of total final consumption in 2050[21]

NZ carbon price
$35
in 2050 (NZ/tCO_2$e)[21]

NZ population
6.9m
in 2053[22]

NZ sea level rise
+0.24m
in 2050[23]

NZ hot days >25°C
+66.6%
in 2050[24]

NZ rainfall intensity
+8.3%
in 2050[24]

EV uptake

Grid reliability

Transmission & distribution costs

Notes

- As the quantitative data for this scenario are drawn from a variety of reference scenarios, the metrics may not align perfectly. Providing useful points of comparison across scenarios and aligning with the scenario narrative has been prioritised over perfect alignment across metrics.
- The amounts of electricity generation by source were generated by grouping the sources, averaging the percentage of grid generation across three projections and using the results to inform selection of round numbers that align with the scenario narratives. "Solar/wind/other renewable" includes all scales and locations of these technologies.
- The scaled scores for EV uptake, grid reliability, and transmission & distribution costs are qualitative indicators based on the scenario narratives and are relative to conditions across all scenarios and timeframes.
- Please refer to Appendix Six for more detailed information on the scenario data.

19 Climate Change Commission. (2021). *Current policy reference.*
20 Climate Change Commission. (2021). *Current policy reference.* BCG. (2022). *Business-as-usual.* Transpower. (2020). *Business as Usual.*
21 Climate Change Commission. (2021). *Current policy reference.*
22 Stats NZ. (2022). *National population projections: 2022(base)–2073.*
23 NZ Sea Rise Programme. (2023). *Maps.* Ministry for the Environment. (2024). *Coastal hazards and climate change guidance.*
24 Ministry for the Environment. (2018). *Climate change projections for New Zealand.*

Changes across the STEEP drivers show how Aotearoa New Zealand has evolved under the Hot House scenario

Social

In the short term, sustainability is not a priority for the majority of consumers in their energy choices. There is a lack of demand for renewable energy sources and low uptake of energy-efficient technologies. As the impacts of climate change become undeniable, consumer and government priorities lie in ensuring energy security for households. Vulnerable communities in New Zealand, including low-income households, bear a disproportionate burden of the negative effects, exacerbating social inequities. Over time, worsening physical impacts raise costs across the board, such as for insurance and housing, and household budgets take a hit. People struggle to pay their bills, including energy, and some are forced into unmanaged retreat, relocating from vulnerable coastal areas or regions prone to extreme weather events. Energy infrastructure in these areas is increasingly abandoned, putting lives at risk.

Rising temperatures and severe weather events result in prolonged blackouts and loss of access to energy services and infrastructure. Load shedding, a controlled shutdown of power supply to certain areas, as a method to prevent grid failure has become a common practice in developed countries, including New Zealand. Living off the grid also becomes a more frequent occurrence in society, including through the use of diesel backup generators. Warming temperatures and a more volatile climate have led to increased energy use to mitigate the impacts, such as through air conditioning, heating, and irrigation, affecting peak demands.

By 2050, social cohesion has degraded across the country. Activism has been fuelled by New Zealand's lack of sustainable action, as people demand more effective measures to address the crisis. Criticism is directed towards the Government and other stakeholders, including the energy sector, for their perceived contribution or lack of action. Attracting labour into the energy sector is challenging, as field service crew well-being is put at risk due to physical climate impacts. In the 2030s, frequent extreme weather events cause widespread community disruption, hospitalisation and some deaths. Energy sector workers responding to increased infrastructure repair and maintenance requirements are disproportionately affected. As temperatures continue to rise later in the century, heat-related illnesses become more prevalent, and locally contracted cases of dengue, malaria, and other mosquito-borne diseases start to occur in the upper North Island.

National population growth is at the higher end of projections, driven largely by net migration. New Zealand is still seen as a relatively safe place by international standards, which helps in attracting skilled workers, but the growing number of climate refugees globally means that immigration is a highly charged topic, politically and socially. The inequitable impacts of climate change worsen socioeconomic divides around the world and within New Zealand.

Technological

The lack of international coordination to address climate change drives the energy sector to prioritise security first and foremost. A lack of international investment in developing new technologies leads New Zealand to rely more on domestic funding, but capacity for innovation is hindered by skills shortages. Energy infrastructure has not been designed to withstand the extremes of climate change and is crumbling under the pressure of extreme heat, also causing derating of networks due to higher operating temperatures, floods and wildfires. Domestically produced natural gas is relied upon more and more, with the use of new peaker plants considered to run when there is high demand for electricity. Some new renewable projects are built in the short term, but securing funding for large projects with long payback periods becomes a major challenge in this volatile climate.

Beyond 2030, disrupted supply chains and dysfunctional global markets mean New Zealand must increasingly go it alone when it comes to providing energy to the country. Building new generation infrastructure and investing in research and development becomes more and more expensive, meanwhile repairs and maintenance take up a growing share of budgets. Ageing plants and transmission and distribution assets are kept in service well beyond their designed lifespan, while sourcing replacement parts becomes increasingly difficult. Fault-driven blackouts become more common, driving many critical sectors to install off-grid generation and storage. This takes the form of solar panels, batteries, diesel generators, wood burners, and others, whatever is cheap and reliable. Coal mining is expanded, and it continues to be used for electricity generation and process heat, or the application of heat during industrial processes.

In the long term, unreliable rainfall creates more variability for the operation of hydroelectric schemes, particularly in dry years. New schemes in the South Island that had previously been proposed are re-investigated, but construction costs are by now extremely high. Warming temperatures result in rising demand for freshwater across the country. River health is under pressure, with conditions more conducive to weed and algae growth. The increasing frequency of damaging weather events diverts more and more of the sector's funds to repairs and maintenance, hindering its ability to invest in expanding generation. Compounding pressures force a focus on survival, maintaining existing assets, simply doing whatever it takes to keep the lights on as much as possible.

Economic

Economic growth is based on resource-intensive production and consumption. Investors, while aware of the environmental damage of fossil-fuel businesses, maintain access to capital due to strong returns in the short term. By the 2030s, as the worsening impacts of climate change continue to be understood, costs of capital rise to meet heightened risk and scrutiny on energy sector operators. In the long term, access to capital is determined more by the physical risks that organisations are exposed to, with investment prioritised on a resilience basis.

Insurance prices continue to rise throughout the 2020s as the frequency and severity of weather events and chronic changes in the climate escalates. For some areas, insurance is not available at all. Self-insurance, or funding buffers, becomes common for many operators in the energy sector, where immobile and highly vulnerable assets have low adaptive capacity. Pressure mounts on the government to step in as the insurer of last resort, but politicians are wary of setting unaffordable precedents. Greater operating costs are passed along to consumers with higher energy prices, adding to pressures on low-income families. By the 2050s, insurance is hard to come by and very expensive for many.

There is greater difficulty for the energy sector to effectively maintain key infrastructure and assets due to continual damage. Supporting infrastructure, such as roads and ports, face the same challenges, increasing supply chain constraints both domestically and internationally. The sector receives increasing backlash for failing to adapt sufficiently. Energy sector operators begin to face amplified litigation for failing to take effective action, with director and executive liability also becoming increasingly scrutinised.

Environmental

Extreme weather events have become more frequent and compounding. On extreme hot days, outside labour is restricted due to the health and safety risks posed by high temperatures. The workers building and maintaining energy infrastructure are particularly at risk. The need to protect workers from heat-related illnesses and ensure their well-being becomes a priority, leading to adjustments in work schedules and practices.

The sea level is rising at an accelerating rate, posing significant challenges for coastal regions and infrastructure. Low-lying areas are increasingly vulnerable to flooding and erosion. While some regions of the West Coast experience increased rainfall and the potential for more frequent and intense storms, other areas, including the North Island's east coast, have drier conditions and more drought. Weather patterns are less predictable making it difficult to forecast the impact on energy sector operations. Heatwaves and prolonged periods of high temperatures have led to enlarged energy demand for cooling, putting strain on the energy grid.

In the long term, the warming climate leads to changes in rainfall patterns and increasing droughts that affect the operation of hydroelectric dams. Over the South Island schemes' catchments, more rain falls in winter than used to, which helps alleviate the winter peak in demand. Winters are warmer overall reducing the seasonal demand peak, but cold snaps are still severe, so daily spikes in demand are not alleviated. The shifts in rainfall are not all positive, though, as less rain is falling in summers right at the same time as warmer temperatures are increasing the demand for cooling.

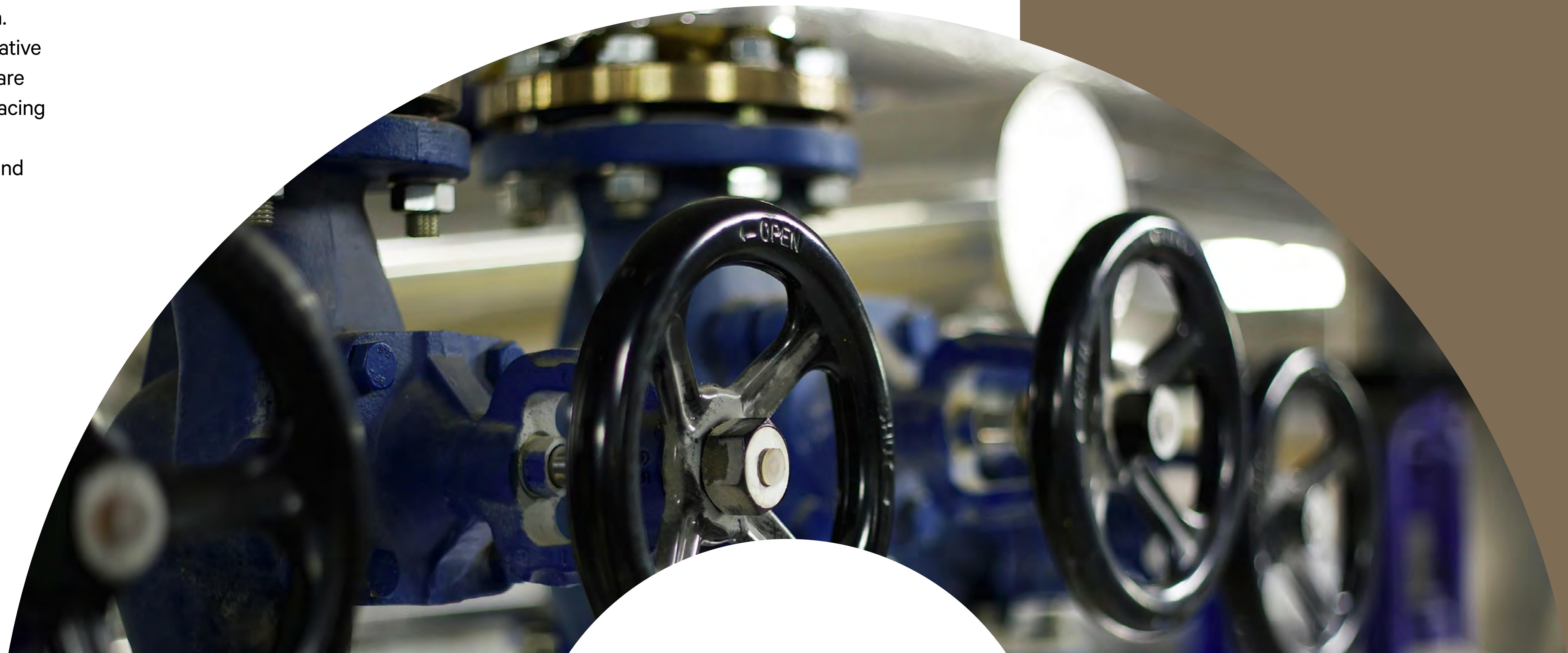
By 2050, there are grave concerns regarding the risks that climate change poses to endemic biodiversity. Changes in temperature and precipitation patterns have influenced species distribution, and the timing of biological events such as flowering and migration. This has had cascading impacts on the functioning of ecosystems and the survival of native species, raising concerns that ecosystems are nearing collapsing tipping points. There are growing incidences of pests, such as termites and fungal growth on electricity poles, placing additional stress on maintenance across the sector. The impacts on ecosystems have far-reaching consequences across the globe, including reduced access to food, water, and other natural resources.

Political

By 2030, environmental regulations are lifted, allowing a wider supply of domestic natural resources, including coal. Changes in policies are focused on energy security, alongside improved government spending on national security. The Resource Management Act is reframed to reduce barriers to agriculture, technology, and land use and fuel taxes are removed. The ETS survives in a modified form and is maintained as a revenue generation tool, but it is not effective in incentivising emissions reductions.

As the severity of climate change events are felt, the Government takes action to transition communities and assets through managed retreat. However, adaptation measures remain reactive, focusing on increased maintenance and fixing things as a result of weather events. There is a lack of systems thinking and cross-sector partnership for adaptation. Partnership is also limited in other areas, such as with local communities and iwi/Māori in strategic planning and consenting processes.

In the early 2030s, rising international tensions led to greater border controls and trade barriers. Many multinational companies struggle to operate effectively. Widespread regional and international conflicts over immigration, water availability, and resources flare up often and with little warning. Trade wars impact energy supply chains and consequently many emissions-intensive energy sources are susceptible to fluctuations in commodity prices. Importing liquid fuels comes at a high cost to New Zealand's economy, prompting increased domestic refining.



The physical impacts of climate change bring unprecedented challenges to the energy sector

Due to a lack of global climate policy and continued reliance on fossil fuels, the world is facing a future where no country is safe from the physical impacts of climate change.

The energy sector faces growing challenges to ensure energy security and experiences high costs, particularly in the long term. Transnational collaboration erodes and countries become more inward-looking, focusing on domestic energy security to maximise their own resources.

Slow Followers

Global warming at 2050

2.0°C

Global warming at 2080

2.5°C

Key assumptions

Severity of physical risk	Moderate
Severity of transition risk	Low - Moderate
Global policy ambition	Moderate overall, highly differentiated
NZ policy ambition	Slow and lagging globally
Technology change	Moderate
NZ behaviour change	Slow - Moderate
Global emissions and temperature	Peak around 2040, nearly reaching net zero by 2100 (in line with SSP2-4.5)

Note: The above high-level descriptions are relative to the other scenarios.

Reference scenarios

SSP2-4.5 | RCP4.5 | NGFS Fragmented World | IEA Stated Policies Scenario (STEPS) | CCC Current Policy Reference | BCG Business-as-usual | Transpower Measured Action

Slow Followers represents a divided world where New Zealand takes a 'bare minimum' approach towards achieving net zero, in comparison to the ambition of most other developed countries. This scenario assumes that nations around the world make efforts to decarbonise, but with varying levels of ambition. Collectively, the global rate of emissions reduction is not enough to limit global warming to 1.5°C. Global average temperature rise is on track to exceed 2.5°C by the end of the century and the impacts of climate change are significant. The energy sector must navigate the tension of minimal domestic political support for decarbonisation, against growing sustainability-conscious consumer attitudes and international trends. This scenario assumes international progress on low-carbon technologies, while slower than in other scenarios, does lead to these out-competing fossil-fuel alternatives. New Zealand's transition away from fossil fuels in the medium term is ultimately driven by economics, presenting transition risks for organisations.

Table 6: Key climate-related risks and opportunities under Slow Followers

The energy sector climate-related risks and opportunities are present across all scenarios. The table holds those identified as most significant for the Slow Followers scenario. This scenario provides the conditions for these risks to be most challenging, and for these opportunities to be most successful. Physical climate risks are present under all scenarios and will vary in severity.

T1	Failure to adequately build, upgrade, and maintain long term infrastructure to handle the energy transition.
T4	Inability of the sector to affordably access financial services, including insurance and debt markets.
T5	Politicisation of the energy transition, competing regulation, and limited political stability for prioritisation of investment across the sector.
T6	Increased volatility and/or cost of carbon as a result of regulatory intervention such as changes to the Emissions Trading Scheme (ETS) or inclusion of NZ Emissions-Intensive Trade Exposed Industries (EITEs) in the ETS.
T7	Supply chain and labour market constraints in a highly competitive global market are a barrier for the transition to low-carbon energy.
T9	Inability to manage increased inequity and impacts on community wellbeing associated with cost and access to low-carbon energy.

Global situation at 2050

There is moderate ambition to decarbonise globally, with emissions peaking around 2040. The world is not quite on track to reach net zero this century and many countries remain reliant on fossil fuels to power their development. Some countries take a more ambitious approach to reducing emissions through policy and regulatory settings, driving technological developments. New Zealand prioritises energy security and short-term cost savings, no longer being seen as a sustainable leader, and is increasingly excluded from collaboration and trade with other countries, weakening our economy in the longer term. The physical impacts of climate change cause disruption and damage to ecosystems, businesses, and communities worldwide.

Environment

The global average temperature has risen by 2.0°C by 2050, relative to pre-industrial levels. Weather and seasonal patterns are less predictable, with some countries experiencing intense rainfall and others experiencing prolonged droughts. Heatwaves, storms, and heavy rainfall events have become more frequent and severe, increasing supply chain disruption globally and frequently damaging energy sector assets.

Society

Consumer preferences in New Zealand prioritise access, affordability and security of energy supply, particularly as climate change risks become evident. There is building activism against countries, including New Zealand, that are seen to be falling behind on sustainable action.

Economy

Sustainable investors shift away from markets that are struggling to demonstrate progress towards decarbonisation and are falling behind the rest of the western world, such as New Zealand. Fuel costs begin to increase at a global level as suppliers begin to reduce exports and international carbon prices soar in major economies.

Technology

Low-carbon technologies are expensive in the short term and uptake is slow. Countries who are committed to the transition lead the development of generation and storage technologies, with emerging technologies becoming viable and existing technologies becoming cheaper. Energy efficiency gradually improves as technological developments in energy are pushed forward.

Policy

Fair trade agreements are established between countries that are committed to transitioning to low-carbon economies and trade relationships are dominated by power blocs. Those who fail to meet sustainability requirements lose out.

Global scenario indicators

Figure 9: Slow Followers global CO_2 emissions trajectory[25]
(Gt CO_2/year)

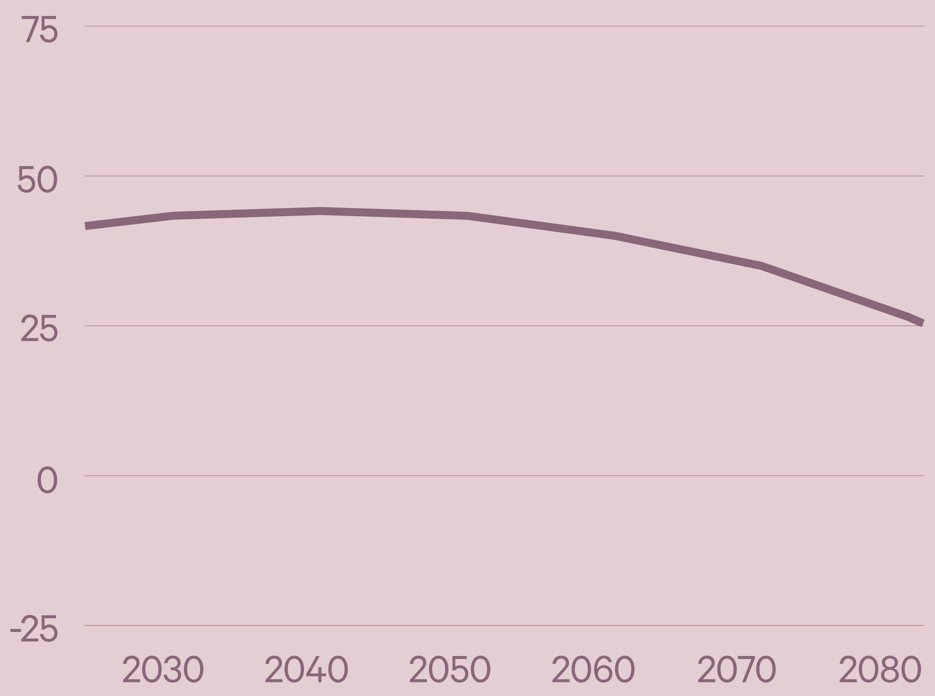
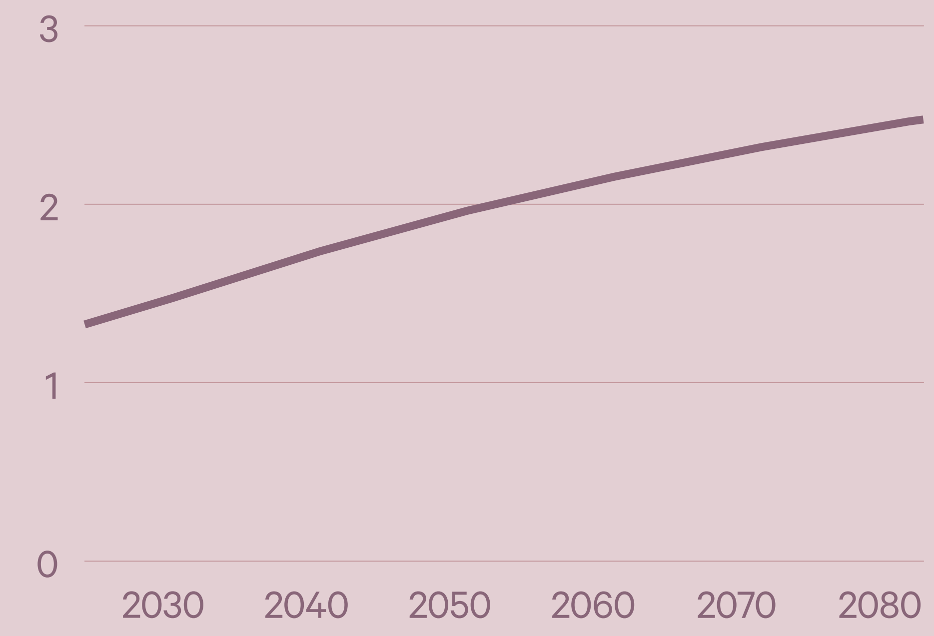


Figure 10: Slow Followers global temperature rise trajectory[25]
(°C)



25 IIASA SSP Database. (Version 2.0). *SSP2-4.5.*

Aotearoa New Zealand situation at 2050

New Zealand fails to meet its climate goals and neglects to implement policies and regulations that support a smooth transition to net zero. As a result, the country is perceived as a slow follower in the global fight against climate change, leading to reputational damage on the international stage. There is building activism against companies and the Government, due to their lack of transformative action, both from within and outside the country.

Domestic policy is focused on compliance with international requirements, while accepting that long-term prosperity lies in adaptation. There is a growing gap between rhetoric and action when it comes to addressing climate change and there are no forward-thinking strategies, such as investments into smart energy infrastructure, or regulatory changes to enable a low-carbon energy system. International capital and favourable free trade agreements are lost, due to failure to meet sustainability requirements. Export markets and tourism are affected, damaging the economy and reputation as 'off brand' unsustainable action hampers investment and New Zealand's energy sector struggles to attract the talent it needs..

Some forward-thinking organisations continue to pursue low-carbon technologies and energy pathways, recognising the urgency of the climate crisis and the long-term benefits of transitioning to sustainable practices. They invest in renewable energy sources, energy efficiency measures, and innovative technologies, however, this is done at a high upfront cost. Companies still heavily reliant on fossil fuels, without a transition plan, find themselves caught off guard in the 2030s. By this time, low-carbon technologies have become affordable because of global economies of scale and are increasingly adopted in New Zealand. In some parts of the market, consumers switching to alternatives drives up costs for the remaining users, spurring more to switch and speeding up the transition in a feedback loop that will hit lower-income consumers the hardest if not well managed with government and company policies.

The reputational damage suffered by New Zealand as a slow follower in climate action exacerbates difficulty for companies that are not prepared to transition. They find it harder to attract investment, secure partnerships, and maintain their market share. Their lack of foresight and failure to embrace the transition to a low-carbon economy ultimately hampers their long-term viability.

2050 and beyond

New Zealand finds itself in a challenging position as it undertakes a delayed transition to a low-carbon economy. The international pressure to address climate change, coupled with the availability and reduced costs of viable technology and resources, finally pushes New Zealand towards embracing sustainable practices. While the Government aimed to keep costs low by limiting intervention and maintaining the status quo in the first half of the century, global fossil fuel prices are now significantly higher.

The consequences of missed climate goals and delayed policy implementation become increasingly apparent as the impacts of global warming intensify. Rising sea levels, extreme weather events, and disruptions to ecosystems put immense pressure on the energy sector to transition quickly. Increasing maintenance costs and volatile fossil fuel prices raise energy costs, pushing many into energy poverty. Access to insurance internationally becomes difficult and costly.

New Zealand is compelled to reevaluate its energy infrastructure. Energy security remains a priority throughout this scenario, with both grid-scale and residential-scale storage being steadily deployed, driven primarily by economics.

New Zealand scenario indicators

Figure 11: Slow Followers NZ CO_2 emissions trajectory[26]
(Mt CO_2/year)

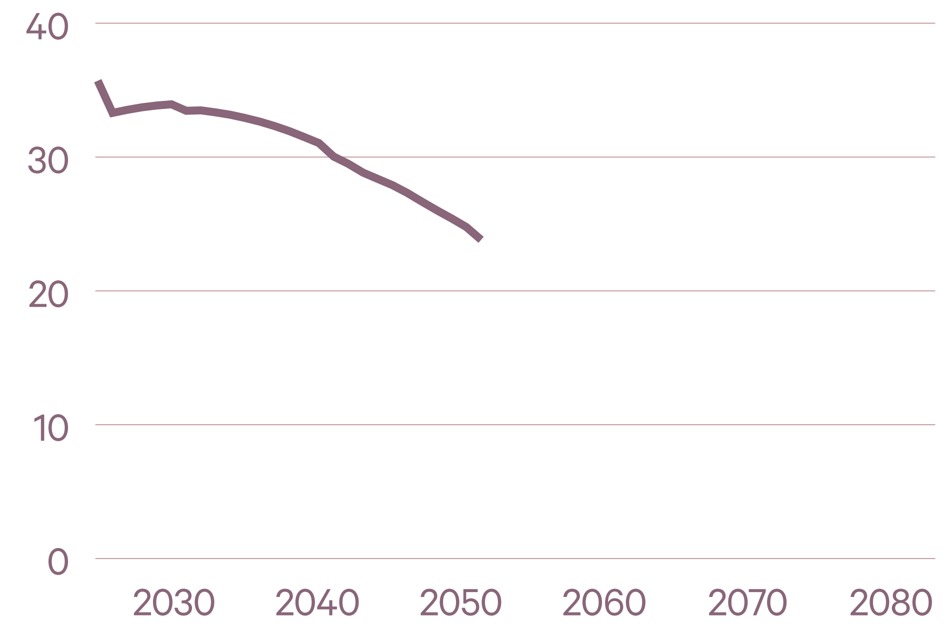
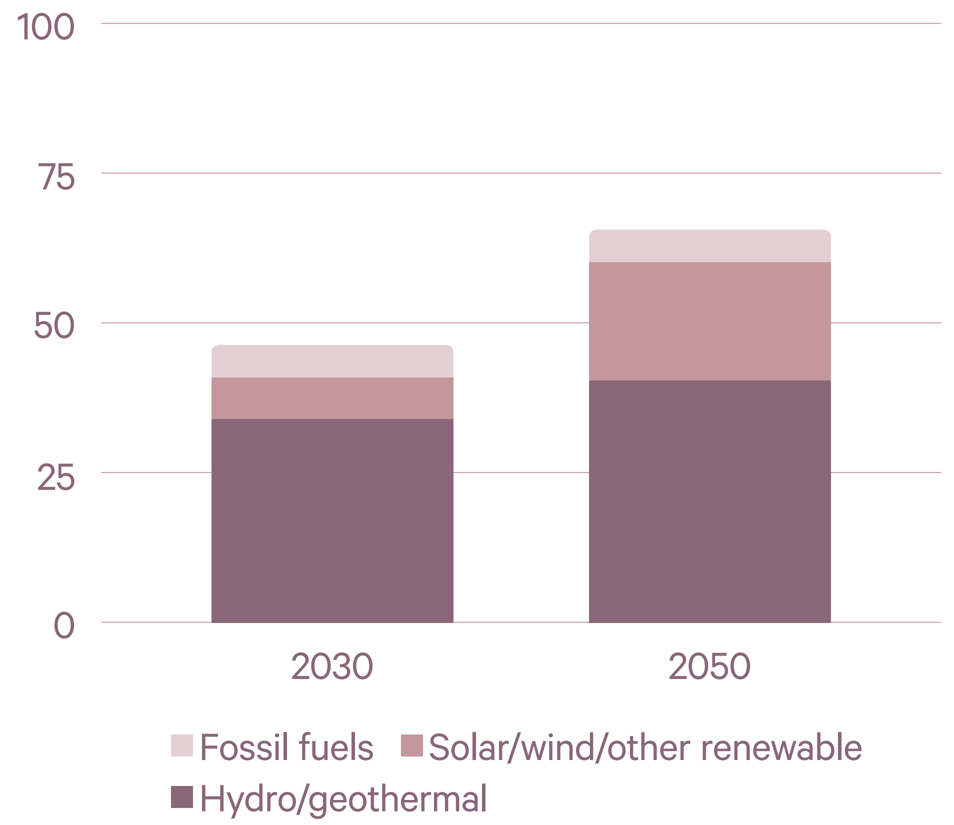


Figure 12: Slow Followers NZ electricity generation by source[27]
(TWh)



NZ renewable energy
46%
share of total final consumption in 2050[28]

NZ carbon price
$35
in 2050 (NZ/tCO_2$e)[28]

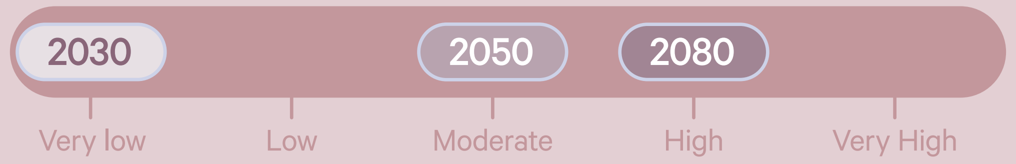
NZ population
6.2m
in 2053[29]

NZ sea level rise
+0.22m
in 2050[30]

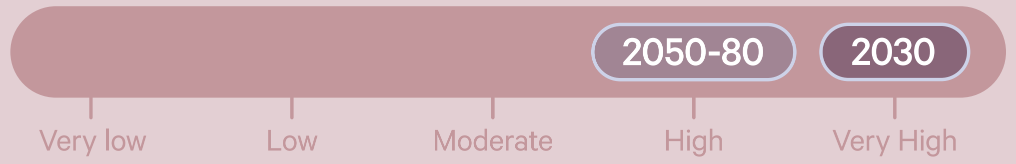
NZ hot days >25°C
+53.7%
in 2050[31]

NZ rainfall intensity
+7.2%
in 2050[31]

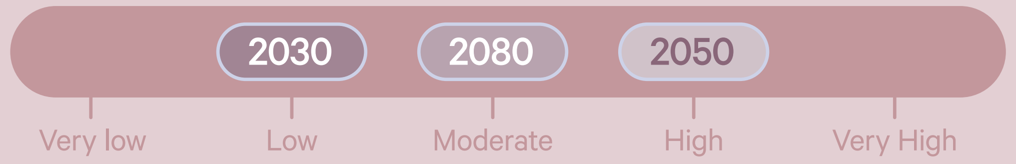
EV uptake



Grid reliability



Transmission & distribution costs



Notes

- As the quantitative data for this scenario are drawn from a variety of reference scenarios, the metrics may not align perfectly. Providing useful points of comparison across scenarios and aligning with the scenario narrative has been prioritised over perfect alignment across metrics.
- The amounts of electricity generation by source were generated by grouping the sources, averaging the percentage of grid generation across three projections and using the results to inform selection of round numbers that align with the scenario narratives. "Solar/wind/other renewable" includes all scales and locations of these technologies.
- The scaled scores for EV uptake, grid reliability, and transmission & distribution costs are qualitative indicators based on the scenario narratives and are relative to conditions across all scenarios and timeframes.
- Please refer to Appendix Six for more detailed information on the scenario data.

26 Climate Change Commission. (2021). *Current policy reference.*
27 Climate Change Commission. (2021). *Current policy reference.* BCG. (2022). *Business-as-usual.* Transpower. (2020). *Measured Action.*
28 Climate Change Commission. (2021). *Current policy reference.*
29 Stats NZ. (2022). *National population projections: 2022(base)–2073.*
30 NZ Sea Rise Programme. (2023). *Maps.* Ministry for the Environment. (2024). *Coastal hazards and climate change guidance.*
31 Ministry for the Environment. (2018). *Climate change projections for New Zealand.*

Changes across the STEEP drivers show how Aotearoa New Zealand has evolved under the Slow Followers scenario

Social

Society continues to focus on status-quo material consumption. Electric vehicle (EV) adoption and electrification of heating are slow and there is an increasing division between those who can afford versus those who cannot. Without a coordinated plan for adjusting to the added load and stress on the grid that electrification brings, electricity prices rise, slowing the rate of change and increasing the risk of people entering energy poverty. Activism builds over time and there are incidents of drastic action causing disruption to business. The energy industry struggles to hire skilled workers as it is seen as a less admirable place to work, compared to more sustainable industries internationally. Net migration is moderate, leading to slow growth in national population, but attracting the talent needed to transform the economy remains a major challenge.

Security, access, and affordability of supply are prioritised in the short-term, but longer-term investments in the resilience of the network to increasing physical hazards are insufficient. As extreme weather events become more frequent and severe under warming, social inequities are exacerbated due to the resulting increases in power outages, rising costs of energy and difficulty accessing insurance. There are growing concerns regarding the resilience of the energy network. Households increasingly rely on traditional fossil fuels, including diesel generators, LPG and coal as a low-cost and accessible backup, as fuel taxes remain low. In the long term, warming temperatures and increased air conditioning use drives a 'second peak' in the afternoons.

Technological

Natural gas is maintained in the short term for both domestic and industrial use. Additional gas-fired peaker plants, or power plants run only when there is high demand, are built to bolster the grid. The use of imported coal is phased out as global prices rise, replaced with biomass. Buildout of new renewable generation is more gradual, partly due to phase-out plans for thermal assets being pushed out indefinitely. Investor funding and government support for emerging renewable technologies is also very limited, not helped by a lack of confidence in the direction of carbon prices. Initially, low energy costs and a lack of subsidies see minimal uptake of rooftop solar and other decentralised generation. There are also no technological investments into smart energy solutions

By the 2040s, progress internationally has led to low-emissions technologies eclipsing their traditional alternatives in both cost and performance. EVs now have a cheaper drive-away cost than equivalent internal combustion (ICE) vehicles, heat pumps and induction stoves are cheaper upfront than gas units, and industrial-scale electrical heat processes have vastly improved. Globally, oil prices rise as production ramps down. The transition starts to happen organically as cost-conscious consumers replace older equipment. In some sectors, this transition happens rapidly as people exiting the market raises costs for the remainders, accelerating the shift in a feedback loop. This presents significant challenges to any industry players that have not adequately prepared, and creates equity issues in the form of higher prices potentially being faced by those unable to afford to switch. Gas-fired power plants remain in use as the preferred way to manage peak demand due to an absence in demand-side innovation, fed by domestically extracted natural gas. New renewable generation is built gradually to meet growing demand, favouring technologies with shorter payback periods.

In the long term, decarbonisation of the energy sector occurs, driven by a combination of consumer choices, international pressure in the form of climate-targeted tariffs and trade barriers, and fossil fuels being out-competed on price. The limited availability of skilled workers within New Zealand, however, hampers the ability of the sector to transition, locking in higher-cost legacy sources for longer than is optimal.

Economic

Sustainable investors shift away from New Zealand's energy sector from the 2030s as it is perceived to be falling behind in lowering emissions compared to the rest of the developed world. The energy sector struggles to access and afford international capital as a result. New Zealand also faces costs of not meeting climate reduction commitments, such as through restrictions on exports.

The energy sector's failure to provide adequate levels of adaptation and mitigation also makes it more difficult and costly to access international insurance. Self-insurance becomes more of necessity as access reduces. This escalation in cost for the energy sector is often passed along to consumers, with electricity prices becoming more volatile in the 2030s. From the late 2030s, depletion of resources nationally and stricter regulations globally lead the cost of non-renewable energy sources to rise. Lack of investment for resilience results in managed decline and an increase in stranded assets in the long term.

With security as a priority for energy policy, fossil fuels are still a key input in the energy market, with fuel costs beginning to rise at a global level as suppliers begin to reduce exports of fuel. Carbon prices have soared globally, and thus carbon suppliers are now charging those still reliant on fossil fuels ever-growing prices in order to remain profitable. Leaders globally shift away from the practice of carbon offsets from the mid 2030s and certain offsetting methods are seen as greenwashing.

Environmental

By 2050, average temperatures are noticeably higher with growing heat stress risks for the sector. Seasonal weather patterns have become more unpredictable since the 2030s, particularly in the eastern North Island, which has experienced multiple severe drought events.

Extreme weather events and intense rainfall events are common, particularly in the west and south of the country. Storm events have resulted in flooding and landslides consequently damaging infrastructure, impacting transportation networks, and disrupting communities, with localised blackouts becoming more common. Severe weather events also cause disruption to global supply chains.

More permissive regulatory conditions exist for energy generation and environmental conservation is a low priority. In the short term, competition ramps up globally to access environmental resources necessary for the energy transition. New Zealand's climate position relative to some trading partners hinders access to favourable trade agreements for key minerals and inputs.

Political

Without political and regulatory changes to enable an orderly, decarbonised energy transition, policy decisions focus on short term economic gain. Fuel taxes are reduced to prioritise consumer affordability over long-term sustainability and hinders the transition to renewable energy sources. Consenting becomes more permissive for both renewable and fossil fuel energy projects in an attempt to lower costs and increase investor confidence. However, the lack of government support for renewables development leads global suppliers to prioritise other markets. For fossil fuels, a focus on short-term returns and international movement towards decarbonisation leads to hesitancy to invest in more field development, instead favouring the importing of LNG and coal.

New Zealand's reputation as a sustainable leader is diminished, resulting in exclusion from international collaborations and free trade agreements. New Zealand struggles to attract and retain skilled workers, especially from Pacific countries, which are growing in size and market influence and place climate action at the top of their agenda. The reliance on emissions-intensive energy sources exposes the country to fluctuations in commodity prices and geopolitical tensions.

New Zealand does not update existing energy regulation policy. Adaptation climate policy is incremental and reactive and managed retreat policies are introduced to address challenges such as coastal erosion and flooding. However, tensions arise in the medium term due to the way these are implemented, leading to reduced insurance supplements and the removal of payouts for affected assets. As a result, the burden of replacing assets falls on consumers. Additionally, in response to the impacts of physical climate change, infrastructure design life cycle periods are shortened, reflecting the need for more frequent updates and modifications.

Inability to keep up with global movement sees the energy sector face the challenges of lagging behind

New Zealand fails to meet its climate goals and neglects to implement policies that would support a smooth transition towards a low-carbon future. As a result, the country is perceived as a slow follower in the global fight against climate change, leading to reputational damage on the international stage.

Players in the Aotearoa energy sector are divided in their approach to transition to a low-carbon economy. Gas-fired power plants remain in use into the medium term as the preferred way to manage peak demand, fed by domestically extracted natural gas. By 2040, the sector is challenged as low-carbon technologies become economically preferable, pressuring organisations that have not adequately prepared to transition.

Trailblazers

Global warming at 2050

1.9°C

Global warming at 2080

2.2°C

Key assumptions

Severity of physical risk	Moderate
Severity of transition risk	High
Global policy ambition	Moderate overall, highly differentiated
NZ policy ambition	Immediate and bold
Technology change	Moderate
NZ behaviour change	Fast
Global emissions and temperature	Peak in the 2030s, reaching net zero by the 2080s (broadly in line with SSP4-3.4)

Note: The above high-level descriptions are relative to the other scenarios.

Reference scenarios

SSP4-3.4 | RCP4.5 | NGFS NDCs | IEA Announced Pledges Scenario (APS) | CCC Headwinds | BEC TIMES Tui | BCG Renewable Energy Pioneer | Transpower Mobilise to Decarbonise

Trailblazers represents a world where the level of international cooperation varies across countries, resulting in a fragmented response to climate change. A handful of affluent countries, New Zealand and several others, have decarbonised faster compared to poorer countries, reflecting disparities in resources and capabilities. Global warming is limited to less than 2.5°C by 2100. The Trailblazers scenario assumes technological development has occurred at a slower pace due to less conducive international conditions. Fossil fuel consumption has been largely phased out in those countries leading the climate movement. There is a focus on decarbonising the energy sector, with a heavy emphasis on electrification. Global greenhouse gas emissions have peaked in the 2030s and are declining.

Table 7: Key climate-related risks and opportunities under Trailblazers

The energy sector climate-related risks and opportunities are present across all scenarios. The table holds those identified as most significant for the Trailblazers scenario. This scenario provides the conditions for these risks to be most challenging, and for these opportunities to be most successful. Physical climate risks are present under all scenarios and will vary in severity.

T1	Failure to adequately build, upgrade, and maintain long term infrastructure to handle the energy transition.
T2	Inability of the sector to efficiently manage the electrification transition and stability of supply leading to increased peak loads, outages, and network costs.
T5	Politicisation of the energy transition, competing regulation, and limited political stability for prioritisation of investment across the sector.
T6	Increased volatility and/or cost of carbon as a result of regulatory intervention such as changes to the Emissions Trading Scheme (ETS) or inclusion of NZ Emissions-Intensive Trade Exposed Industries (EITEs) in the ETS.
T8	Inability to afford and/or access new technology and components essential to the transition to a low-carbon economy.
T9	Inability to manage increased inequity and impacts on community well-being associated with cost and access to low-carbon energy.
T10	Increased stranded assets and asset write downs as a result of rapid decarbonisation, regulatory change, increased lower carbon alternatives etc.
O4	Investors are able to make attractive investments that have co-benefits with Te Taiao, the natural world, and sustainable, intergenerational prosperity (mana whanake).
O5	New employment opportunities for some regional communities to support the transformation of assets and infrastructure as the energy sector continues to decarbonise and emerging uses come online.

Global situation at 2050

A lack of unified action resulted in slower advancements in transitioning to a low-carbon economy. Without a cohesive global approach, some countries have pursued their own individual strategies, leading to disparities in ambition and action. Wealthier nations, with greater resources and capabilities, were able to decarbonise faster, while poorer countries continue to face challenges due to limited capacity and competing development priorities. Over time, a gap has widened between an internationally connected society that contributes to knowledge and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labour intensive, low-technology economy.

Environment

The global average temperature has exceeded the 1.5°C Paris Agreement target, reaching a 1.9°C increase by 2050. The global environmental picture is similar to the Slow Followers scenario, but with slightly lower climate-related physical hazards due to lower emissions.

Society

As a result of divided global policy to address climate change, social views are varied regarding sustainability. In countries that are committed to decarbonisation, there are increasing public awareness campaigns to influence stakeholder preferences.

Economy

Access to sustainable finance increases for countries committed to decarbonisation, such as New Zealand, seen as a safe and progressive place to invest. Household energy prices rise initially as low-carbon energy is prioritised, exacerbating social strain until prices stabilise due to buildout of renewable generation.

Technology

Emerging technologies take a long time to overcome technical, cost, and supply-chain hurdles. This leads the decarbonisation effort to rely primarily on existing, proven technologies to electrify transport and industry. These technologies are less resilient to the increasingly disruptive physical climate than a more diverse energy portfolio would be.

Policy

International policy reflects the divide between nations. Disparities between these nations persist, resulting in unequal access to resources and support for sustainable development. To incentivise climate-positive trading amongst countries leading the transition, strengthened tariffs on imports, such as oil, are implemented.

Global scenario indicators

Figure 13: Trailblazers global CO_2 emissions trajectory[32]
(Gt CO_2/year)

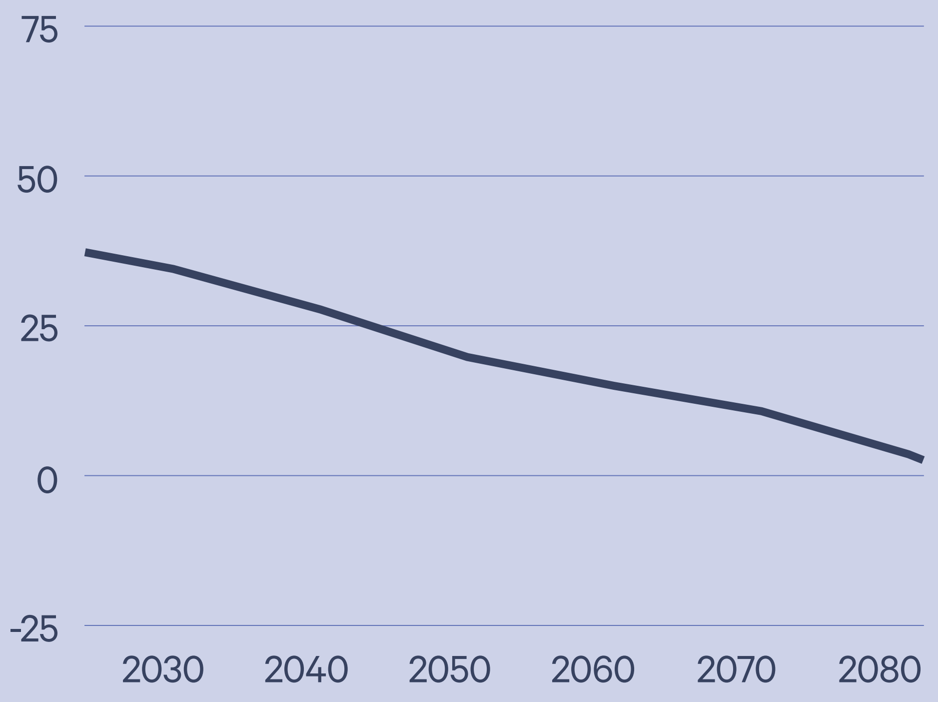
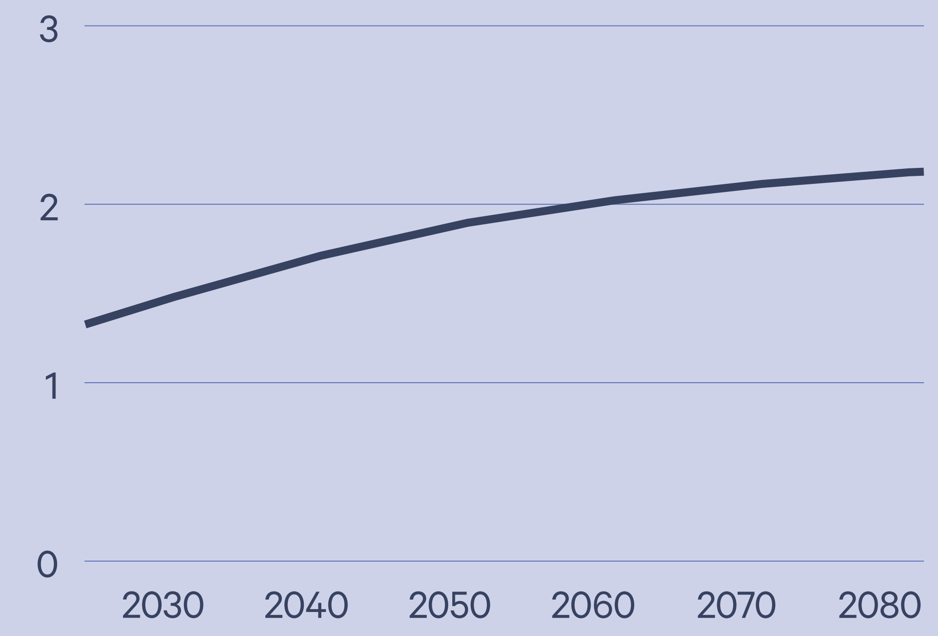


Figure 14: Trailblazers global temperature rise trajectory[32]
(°C)



32 IIASA SSP Database. (Version 2.0). *SSP4-3.4*.

Aotearoa New Zealand situation at 2050

By 2050, New Zealand has emerged as a leader in the sustainable transition, actively driving efforts towards a low-carbon future to secure its international reputation. Political parties have reached strong consensus and bipartisan agreement in tackling climate change, recognising the urgency of addressing this challenge and being part of the 'leading pack' of the global economic transition. This unity in political approach ensures long term planning and commitment to decarbonising the energy sector, largely through electrification.

Decarbonisation is achieved primarily through electrifying transport and industry, while building out renewable electricity generation and phasing out fossil fuels. Policies that target fossil fuel use, such as a ban on imports for ICE vehicles, have been enacted. New Zealand decarbonises in line with a 1.5°C trajectory, but at a high cost to the energy sector as international conditions and technological developments are not so conducive to rapid change. The energy sector faces major challenges in aligning with industry and consumers to enact efficient demand-side management, as well as working with regulators to develop policy to coordinate a smart energy transition. In the short term, this means the sector struggles to efficiently manage the electrification transition and stability of supply, leading to increased peak load and network costs. Technical and economic hurdles are not overcome for many emerging technologies in the short term, creating investor wariness. Reliance on solar, hydro, geothermal, and onshore and offshore wind electricity for total power delivery grows. Distributed generation, such as rooftop solar, becomes widespread in New Zealand in the lead-up to 2050 in the face of high market prices and increasing severe weather events that threaten energy security.

While New Zealand is seen as an attractive place to invest, this scenario does not reflect a socially just transition. The public is generally onboard with the goal of decarbonising, but most are not prepared to make large lifestyle changes. In the short term, there was a large movement of activism against the transition in New Zealand because of rising costs. Rising costs have pushed vulnerable people into energy poverty and hardship, requiring targeted support.

2050 and beyond

Aotearoa New Zealand is recognised globally as a sustainable energy market leader. Domestically, businesses must show adaptation and mitigation measures to access insurance. Climate risk exposure becomes a greater factor to determine accessibility and price of insurance globally.

Steady population, energy efficiency improvements, and adoption of decentralised generation help manage growing peak demands. Solar helps to relieve changing demand. Global warming reaches around 2.2°C by 2080, but the rate of increase has slowed dramatically. This is more than enough warming to see a marked heighten in severe weather events felt across the world. Globally, inequalities and energy poverty are increasing. An increase in environmental refugees to New Zealand sees the development of an agreement with Pacific nations to assist.

The energy sector invests in renewable infrastructure, replaced with various technologies and increased efficiency. By this time, even hard to abate sectors like aviation have low-emissions solutions that allow them to transition, and high carbon prices are in place to achieve cost parity.

New Zealand scenario indicators

Figure 15: Trailblazers NZ CO_2 emissions trajectory[33]
(Mt CO_2/year)

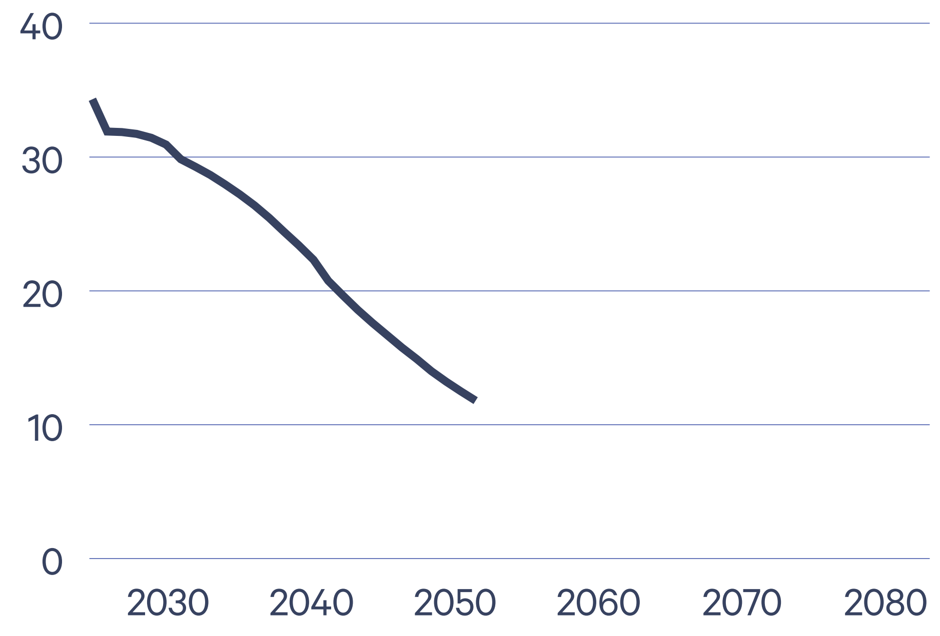
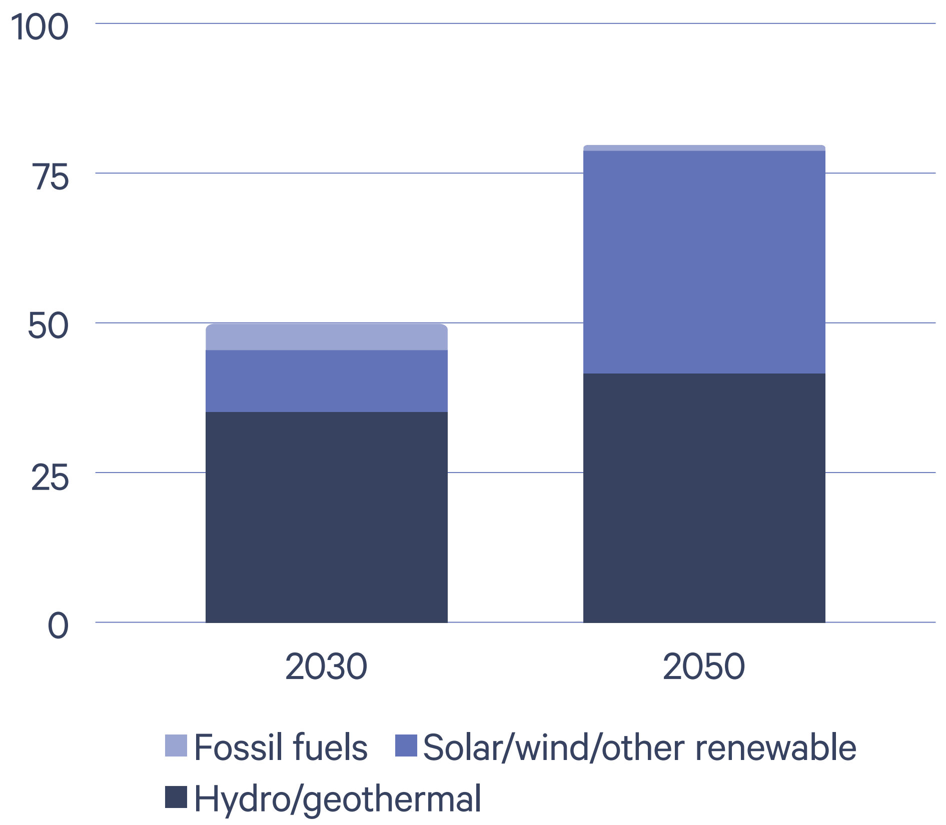
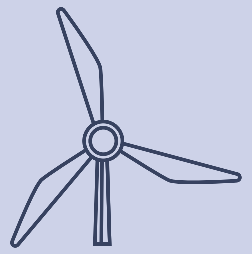
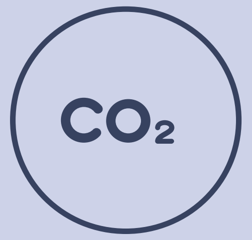


Figure 16: Trailblazers NZ electricity generation by source[34]
(TWh)



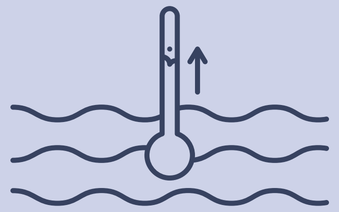


NZ renewable energy
74%
share of total final consumption in 2050[35]



NZ carbon price
$411
in 2050 (NZ/tCO_2$e)[36]

NZ population
6.5m
in 2053[37]



NZ sea level rise
+0.22m
in 2050[38]

NZ hot days >25°C
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in 2050[39]

NZ rainfall intensity
+7.2%
in 2050[39]

EV uptake

Grid reliability

Transmission & distribution costs

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33 Climate Change Commission. (2021). *Headwinds.*
34 Climate Change Commission. (2021). *Headwinds.* BCG. (2022). *Renewable Energy Pioneer.* Transpower. (2020). *Mobilise to Decarbonise.*
35 Climate Change Commission. (2021). *Headwinds.*
36 Treasury New Zealand. (2023). *Assessing climate change and environmental impacts in the CBAx tool.*
37 Stats NZ. (2022). *National population projections: 2022(base)–2073.*
38 NZ Sea Rise Programme. (2023). *Maps.* Ministry for the Environment. (2024). *Coastal hazards and climate change guidance.*
39 Ministry for the Environment. (2018). *Climate change projections for New Zealand.*

Changes across the STEEP drivers show how Aotearoa New Zealand has evolved under the Trailblazers scenario

Social

Initially, the public are generally onboard with the goal for New Zealand to achieve net zero and strengthen its clean, green international reputation, however many are not prepared or able to make large lifestyle changes. The division in mindset sees building activism from consumers and industry lobby groups against the high costs of taking action, as energy poverty and hardship continues to be a growing issue through to the 2030s. The inequitable impacts of more expensive energy pose multiple risks to the sector, including reputational damage, cost increases having to be internalised, and government intervention, all of which require careful management.

In the short term, uptake of EVs and electrification without sufficient battery infrastructure or demand side management systems sees ineffective load management occurring, with customers bearing the cost, such as community blackouts at peak times. Gas remains an option for meeting peak demand, but a high carbon price makes this expensive, resulting in a wind-down of the gas distribution/transmission and production businesses. This then contributes to concerns over energy security which rise further from 2040 with increasing severe weather events. During dry years, demand side management that targets consumers becomes necessary. Despite some success with energy efficiency improvements, demand continues to grow due to widespread electrification of transport and heating.

In the short term, demand for skilled workers in the energy sector outstrips supply, causing significant issues. Over time, though, our leading reputation, relatively mild climate, strong project pipeline, and ability to attract international investment leads New Zealand to be seen as an attractive place to work. As the demand for technology and energy continues to grow, New Zealand can draw in international talent. Higher net migration than expected leads to population growth towards the higher end of projections.

As the impacts of climate change become clearer in the medium and long term, attitudes start to shift in a way that prioritises decarbonisation even over other environmental concerns. Proposed hydroelectric dams are viewed more favourably than in decades past. Following advancements in nuclear energy that see significant improvements to costs and safety, the New Zealand public sees other jurisdictions across the globe deploying these technologies, prompting local public discussion about potential use here.

Technological

Global demand for renewable energy technology through the 2020s waxes and wanes, leading to investor wariness and economies of scale not being achieved for some otherwise promising technologies. The rapid drops in price for technologies like solar photovoltaics and wind turbines during the 2010s do not continue at the same rate. New Zealand pushes ahead with a continued buildout of renewable generation and storage, including geothermal, onshore and offshore wind, and solar, but at costs towards the upper end of projections. Old plans for new hydroelectric schemes of varying sizes are dusted off and revisited in the now more supportive political climate. The lack of signal for a global green hydrogen market means that investment into this technology is held back. Coal use is phased out through mandates, initially in the electricity sector, with industrial uses not far behind. Some users are able to transition coal furnaces to run on biomass, but securing a reliable fuel supply becomes a challenge for slow movers due to the relatively sudden spike in demand.

Low- and zero-carbon fuels, such as hydrogen, biofuels, and biomass remain expensive into the medium term as they see a lack of international investment. New Zealand's public and private sectors thus increasingly rely on electrification of transport and industry to achieve their emissions goals. Shrinking demand, a rising carbon price, and a lack of viable substitutes present significant challenges to the domestic natural gas industry. Grid demand continues to grow, particularly as the use of EVs and electric industrial heating accelerates. Demand-side management becomes critical for managing peaks. This ranges from large industrial users cutting production to individual homeowners being offered lower rates to cut power to their smart appliances and selling back power from their connected EV batteries. The rollout of demand-side management (DSM) technology and distribution infrastructure to support this approach requires significant investment. The rising cost of energy drives more and more homeowners and businesses to invest in distributed generation and storage, typically solar panels with battery packs.

In the long term, some hard-to-abate sectors, such as aviation, finally see low-carbon alternatives become cost-effective due to international investment in and support for decarbonisation. Domestic energy prices overall become more affordable, benefitting from the investment of decades past. The buildout of variable renewables, mainly solar and onshore and offshore wind, means that hydropower can be used in a more peaker-like fashion to meet shortfalls, while geothermal plays an important role for baseload generation. There is a diverse mix of grid-scale, community-scale, and building-scale storage available, using a variety of technologies. The focus on reducing emissions as New Zealand's primary environmental goal grants more flexibility in operations. However, increasingly unreliable rainfall in the North Island challenges the viability of some of the smaller hydro dams.

Economic

Domestic banks make sustainability linked loans mainstream from the late 2020s, and access to capital for the energy sector escalates. In the short term, energy prices rise as fossil fuel assets are wound down, creating a shortfall of energy supply. Strong domestic regulation leads to a large increase in the price of fossil fuels. In the 2030s, reticulated natural gas enters a period where heightened carbon price and exit of many consumers drives the distribution, transmission and production companies into unprofitability. Energy prices from 2030 stabilise due to strong domestic advancements in renewables.

Insurance prices continue to grow as the effects of climate change intensify. In the long term, businesses must show domestic adaptation and mitigation measures to access insurance. Self-insurance becomes more common. Local organisations fare better than international peers due to moving early to manage climate impacts and investment in infrastructure pays off.

The rapid transition places pressure on household energy prices as the operation of low-carbon energy sources is prioritised over cost. This places strain on communities as energy poverty rises and social disparities become more apparent between those that can afford energy and those who cannot. Some consumers are able to have greater control over their energy security, with investment in decentralised grids. Isolated areas, including Māori communities, are disproportionately affected by high prices coupled with increased extreme weather events and become early adopters of decentralised grids. Government support is required to assist households, until long term expansion of renewable generation stabilises and lowers energy prices from the 2040s.

Environmental

By 2050, average temperatures are noticeably higher across the nation. New Zealand experiences similar environmental challenges as the *Slow Followers* scenario, as a result of extreme weather events, such as heat waves, storms, drought, and wildfires, hindering the energy sector's ability to operate effectively.

Species migration and distribution have been altered, affecting ecosystem services and ecological balance. Decarbonisation is prioritised over ecological concerns in consenting decisions. In the long term, as the focus shifts towards more than decarbonisation, resource management policy begins to integrate with te ao Māori values and with a focus on conserving biodiversity, supporting greater strategic protection of natural resources.

In the short term, a few key minerals and energy inputs remain highly constrained and expensive, but New Zealand can trade on favourable terms due to its climate position. Over time, international markets mature and are reasonably resilient to shocks, but some key environmental resources remain expensive.

Political

New Zealand's political consensus to tackle climate change and position the country as a leader in the low-carbon economy results in transition risks for the energy sector. Increased cost of carbon because of changes to the ETS settings are ultimately placed on energy consumers. New Zealand introduces stronger import and export ETS legislation which challenges international trade relationships. New Zealand pushes for domestic control of supply chains but remains vulnerable to international players, such as when importing solar panels. Disparities between richer and poorer nations are keenly felt. Oil imports have intensified tariffs. Disparities between economic communities raises tension domestically. While there is bipartisan political consensus to decarbonise, discontent in some parts of society risks fringe voices using the energy transition as a political wedge issue.

Top-down policy of adapting to climate change is seen as key to New Zealand's well-being, which includes adaptation and mitigation to secure its international reputation and fulfil its moral obligations. Fast-track consenting is supported by a strong partnership model with the energy sector and government. Technological solutions, such as offshore wind farms, are the primary targets of this strategy. Decarbonisation is often prioritised over other ecological concerns in consenting decisions. New Zealand makes moderate changes to existing energy regulation policy to help facilitate decarbonisation.

The Government provides financial incentives and subsidies to promote the adoption of renewable energy sources. This helps level the playing field by making cleaner alternatives more economically viable for consumers and businesses. The Commerce Commission regulates funding for renewable investment.

New Zealand takes a lead role in global decarbonisation, but this comes at a high cost

New Zealand takes a strong stance towards net zero, led by the electrification of transport and industry and a strong buildout of renewables. However, without coordination across the private and public sectors or other nations accelerating decarbonisation, all of this comes at a high cost. The actions of a handful of leading countries are not sufficient to ensure a just transition.

Coordinated Effort

Global warming at 2050

1.6°C

Global warming at 2080

1.5°C

Coordinated Effort represents a world defined by a rapid global push to decarbonise in the 2020s, achieving net-zero emissions by 2050. International trends in technology and geopolitics move in sync to ensure global warming is limited to 1.5°C by 2100 with limited overshoot. Rigorous climate regulations and policies are enacted rapidly across the world. This scenario assumes decarbonisation is achieved through a wide range of renewable energy sources and energy efficiency measures, reducing energy demand and improving overall energy productivity. Tipping points in the earth system have largely been avoided, however, the world still faces increased physical impacts of climate change. Achieving net zero by 2050 reflects a highly ambitious mitigation scenario and the pace of change threatens those organisations that fail to keep up.

Key assumptions

Severity of physical risk	Lower
Severity of transition risk	Moderate - High
Global policy ambition	Highly ambitious and coordinated
NZ policy ambition	Immediate and coordinated globally
Technology change	Fast
NZ behaviour change	Fast
Global emissions and temperature	Peak in the 2020s and then decline, reaching net zero by the 2050s (broadly in line with SSP1-1.9)

Note: The above high-level descriptions are relative to the other scenarios.

Reference scenarios

SSP1-1.9 | RCP2.6 | NGFS Net Zero 2050 | IEA Net Zero Emissions by 2050 (NZE) | CCC Tailwinds | BEC TIMES Kea | BCG P2 Smart System Evolution (short term), P5 Green Export Powerhouse (medium-long term) | Transpower Accelerated Electrification

Table 8: Key climate-related risks and opportunities under Coordinated Effort

The energy sector climate-related risks and opportunities are present across all scenarios. The table holds those identified as most significant for the Coordinated Effort scenario. This scenario provides the conditions for these risks to be most challenging, and for these opportunities to be most successful. Physical climate risks are present under all scenarios and will vary in severity.

T6	Increased volatility and/or cost of carbon as a result of regulatory intervention such as changes to the Emissions Trading Scheme (ETS) or inclusion of NZ Emissions-Intensive Trade Exposed Industries (EITEs) in the ETS.
T7	Supply chain and labour market constraints in a highly competitive global market are a barrier for the transition to low-carbon energy.
O1	Increased adoption and implementation of new monitoring and management technologies grow a more flexible and resilient energy market, enabling more efficient distribution of energy.
O2	As technology continues to evolve, there is increased opportunity to provide further energy storage solutions at a residential, commercial and industrial scale.
O3	Increased digitisation of energy platforms and adoption of 'smart tech' to assist more effective distribution of energy and management of energy consumption for some consumers.
O4	Investors are able to make attractive investments that have co-benefits with the natural world (Te Taiao) and sustainable, intergenerational prosperity (mana whanake).
O5	New employment opportunities for some regional communities to support the transformation of assets and infrastructure as the energy sector continues to decarbonise and emerging uses come online.
O6	New markets, such as solar, wind and hydrogen-based products like ammonia, aviation fuel, marine fuels, will enable increased diversification and decentralisation of energy mix, increased resilience of energy supply, and reduced dependence on imported liquid fuels.

Global situation at 2050

A global commitment to combat climate change saw robust policies that prioritise public awareness on sustainable development and environmental protection being swiftly implemented. Net zero 2050 decarbonisation regulatory changes are aligned with market drivers to redirect society towards growth that is decoupled from depletion of natural resources. Countries have invested in collaborative research and development for innovative clean energy technologies, energy storage solutions, and grid integration to support the transition to a low-carbon energy system.

Environment

By 2050, the world has warmed 1.6°C above pre-industrial levels. Although emissions have been tracking down since the 2020s, historic emissions continue to warm the world. Weather patterns are increasingly unpredictable and extreme due to the acute and chronic manifestations of climate change. Ecosystems are disrupted with vulnerable species facing challenges in adapting to changing conditions.

Society

Strong change in consumer and business attitudes increased competitiveness of low emissions technologies, intensifying the 'green race' in the 2020s. There is an increased focus on societal health and wellbeing, including the appreciation for nature underpinning human well-being and people are empowered to transform their lifestyles.

Economy

A gradual re-prioritisation of economic goals has occurred so that focus has shifted to broader human and planetary well-being, including social, environmental and cultural indicators. The physical impacts of climate change have been detrimental to global GDP, but a new wave of green growth boosts the economy in the long term.

Technology

As many new sustainable technologies came to market, uptake was fast and costs dropped across the board after initial supply-chain constraints were overcome. The energy sector has become more diverse, with a range of energy generation and storage solutions available. Collaboration internationally has played a key role, ensuring technologies, ideas and projects are shared to gain mutual benefits.

Policy

Synchronised international policy helped to facilitate technological developments and phase out the use of fossil fuels. Many countries implemented carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, to incentivise emission reductions and promote the transition to a low-carbon economy.

Global scenario indicators

Figure 17: Coordinated Effort global CO_2 emissions trajectory[40]
($Gt\ CO_2$/year)

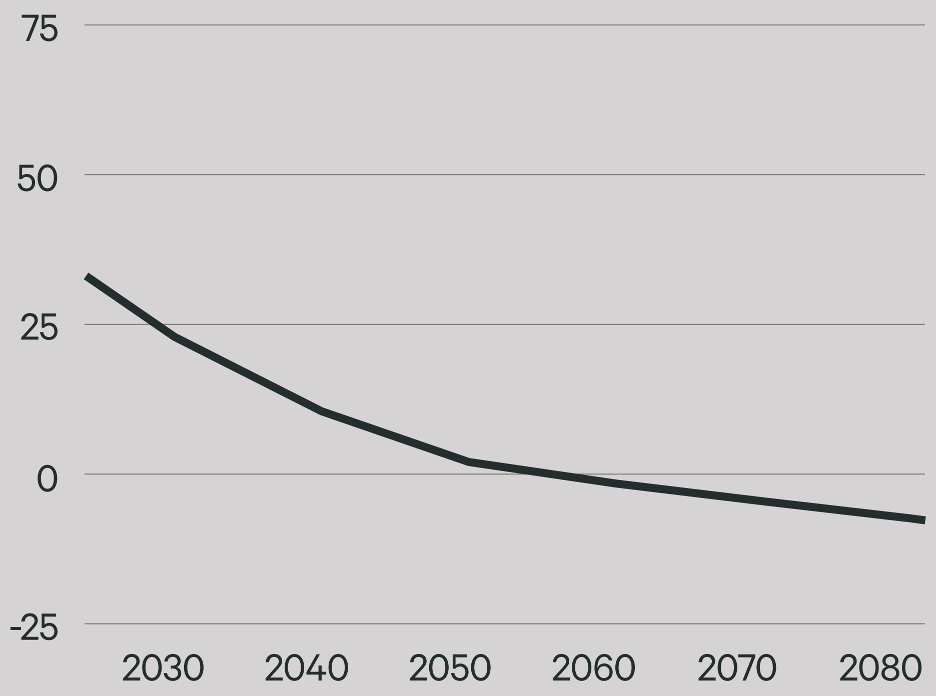
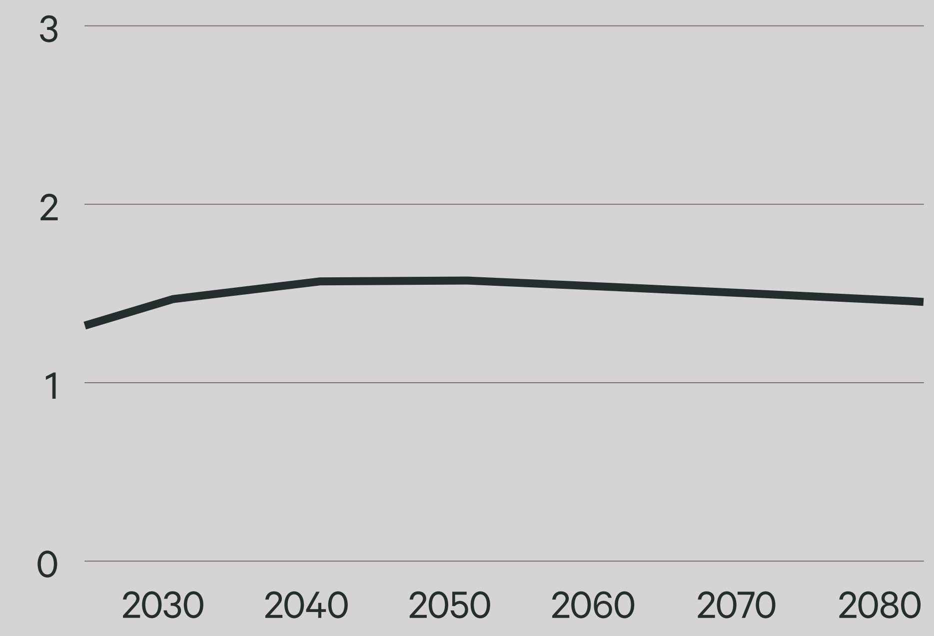


Figure 18: Coordinated Effort global temperature rise trajectory[40]
(°C)



40 IIASA SSP Database. (Version 2.0). *SSP1-1.9.*

Aotearoa New Zealand situation at 2050

New Zealand successfully embarked on a transformational decarbonisation journey aligned with the 1.5°C pathway following international agreement for immediate action in the mid 2020s. The level of change is highly disruptive to all industries, especially the energy sector, requiring a staggering rate of decarbonisation year-on-year. Some organisations are unable to survive the revolutionary transformation required to reach net zero. Political parties demonstrated a remarkable consensus in tackling climate change, recognising the urgency it required.

Domestic policy settings support meaningful adaptation and decarbonisation. The energy sector has prioritised the development of resilient and flexible grid infrastructure, with integration of intermittent renewable energy sources, such as solar and onshore and offshore wind, ensuring a stable and reliable power supply. Energy efficiency measures have been implemented across various sectors including infrastructure, where new builds have improved insulation, smart energy management systems and appliances. Industries have adopted energy-efficient technologies and processes, reducing overall energy consumption and emissions. A domestic low-emissions fuel industry, including exported green hydrogen, has emerged, driving a large increase in total electricity generation, with all additional capacity coming from new renewables.

ICE vehicles have been phased out and EVs are the norm, with charging infrastructure being well-developed across the country. Mode shift and public transport use also increases, reducing network load. The uptake of electrification and battery infrastructure has seen gas generation called on to avoid community blackouts at peak times. Additionally, distributed energy generation and mixed energy solutions, such as the use of biogas and solar, increase resilience in times of need. Energy affordability was initially negatively affected by high demand and high prices, particularly impacting vulnerable populations. Energy poverty has improved over time due to low-emissions energy becoming affordable, alongside a shift towards more social collaboration and redistribution of resources.

2050 and beyond

Domestic buildout of renewable energy generation and storage catches up with growing demand. Excess capacity, new storage technology and biogas use means peak demand can be consistently met. The extra capacity in the energy sector is utilised for hydrogen electrolysis, supercomputing, and other time-flexible industrial processes.

Policy measures are in place to support a carbon negative economy, including investment in carbon capture technologies. Transparent and inclusive decision-making processes promote environmental justice and addressing social and economic disparities. Nationwide resource management policy is fully integrated with te ao Māori values, enhancing biodiversity protection and climate resilience. Companies that have not embraced the transition to a low-carbon energy system are no longer in business.

New Zealand scenario indicators

Figure 19: Coordinated Effort NZ CO_2 emissions trajectory[41]
(Mt CO_2/year)

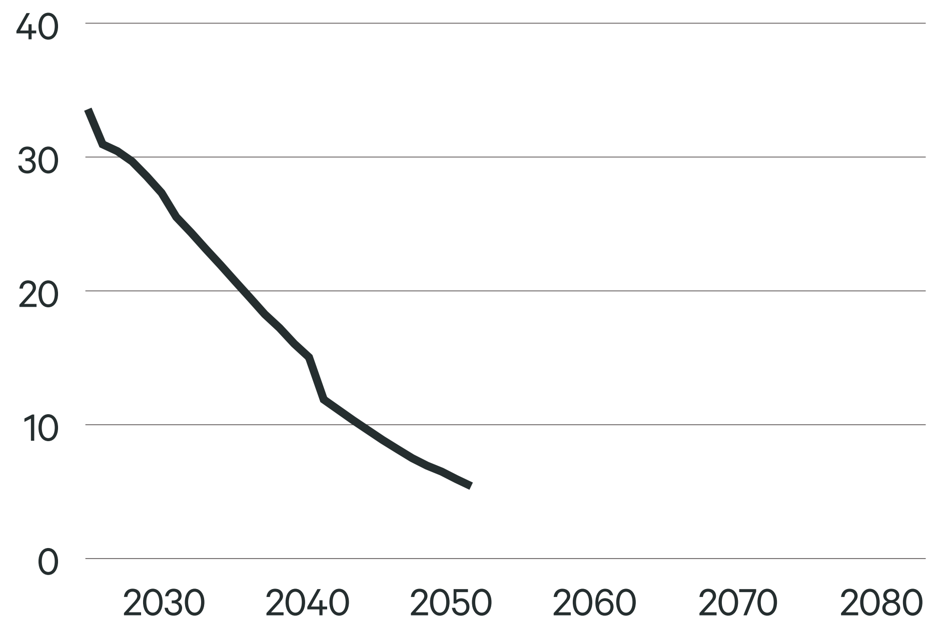
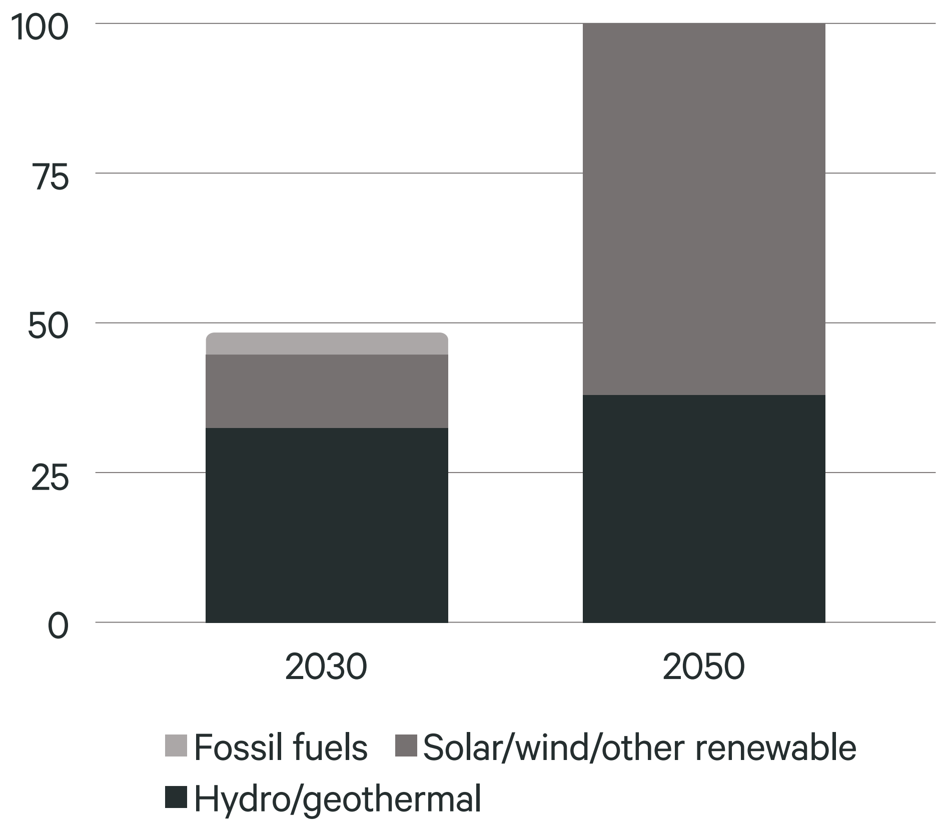


Figure 20: Coordinated Effort NZ electricity generation by source[42]
(TWh)



NZ renewable energy
89%
share of total final consumption in 2050[43]

NZ carbon price
$309
in 2050 (NZ/tCO_2$e)[44]

NZ population
6.2m
in 2053[45]

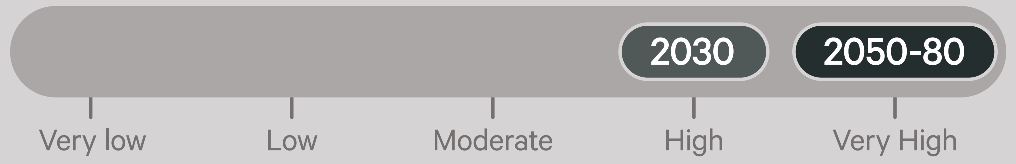
NZ sea level rise
+0.19m
in 2050[46]

NZ hot days >25°C
+42.6%
in 2050[47]

NZ rainfall intensity
+5.7%
in 2050[47]

EV uptake

Grid reliability



Transmission & distribution costs

Notes

- As the quantitative data for this scenario are drawn from a variety of reference scenarios, the metrics may not align perfectly. Providing useful points of comparison across scenarios and aligning with the scenario narrative has been prioritised over perfect alignment across metrics.
- The amounts of electricity generation by source were generated by grouping the sources, averaging the percentage of grid generation across three projections and using the results to inform selection of round numbers that align with the scenario narratives. “Solar/wind/other renewable” includes all scales and locations of these technologies.
- The scaled scores for EV uptake, grid reliability, and transmission & distribution costs are qualitative indicators based on the scenario narratives and are relative to conditions across all scenarios and timeframes.
- Please refer to Appendix Six for more detailed information on the scenario data.

41 Climate Change Commission. (2021). *Tailwinds*
42 Climate Change Commission. (2021). *Tailwinds*. BCG. (2022). *P2 Smart System Evolution (short term), P5 Green Export Powerhouse (medium-long term)*. Transpower. (2020). *Accelerated Electrification.*
43 Climate Change Commission. (2021). *Tailwinds.*
44 Treasury New Zealand. (2023). *Assessing climate change and environmental impacts in the CBAx tool.*
45 Stats NZ. (2022). *National population projections: 2022(base)–2073.*
46 NZ Sea Rise Programme. (2023). *Maps.* Ministry for the Environment. (2024). *Coastal hazards and climate change guidance.*
47 Ministry for the Environment. (2018). *Climate change projections for New Zealand.*

Changes across the STEEP drivers show how Aotearoa New Zealand has evolved under the Coordinated Effort scenario

Social

Education schemes and public awareness campaigns played a pivotal role in driving public support for the transition to a sustainable energy system. Stakeholders and consumers prioritise renewable energy and low-carbon options, influencing market trends and driving businesses to embrace the transition. Pressure is placed on the energy sector to become an agent of change, demanding the movement away from fossil fuels. During the mid 2020s to 2050, reputational and greenwashing risks for organisations that are seen to be lagging are high. In the long term, sustainability becomes the norm and companies that did not transition are no longer in business.

Workforce demand for skilled energy and technology-based roles increases due to the electrification revolution and decarbonisation. In the short term, demand outstrips supply of skilled workers, but over time sustainability skill sets become common in the market. Industries perceived as being linked to environmental degradation, such as oil and gas, experience greater job vulnerability. Where organisations and industries fail to implement a just transition, job losses are pronounced. In areas where single employers provide a significant proportion of employment, this deindustrialisation risks major social upheaval to the region.

In New Zealand, there is an increasing prevalence of te ao Māori worldviews in expectations for addressing nature and climate issues. The Government navigated tensions between decarbonisation and nature preservation policies and fast-track consenting is supported by a strong partnership model between iwi/Māori, the energy sector, and government. Forums are created to foster cross-sector collaboration towards the shared goal of decarbonisation. The international push to address climate change leads to growth in job opportunities and a greater feeling of security across the globe, which tempers climate and economic-driven migration. National net migration is moderate, and the population grows roughly in line with projections.

Technological

R&D investment in low-emissions energy technologies is ramped up around the world. This drives down the cost of emerging technologies for energy generation and storage. However, as countries race to decarbonise, competition is high in the short term before markets can respond. New Zealand embarks on an ambitious buildout of grid-scale renewable generation in many forms. Strong demand signals both nationally and globally lead New Zealand to invest in domestic green hydrogen production, with large-scale production requiring building new large-scale renewable generation assets. This and other local production of low-emissions fuels leads to large increases in total electricity generation.

In the medium term, many of the technological and cost hurdles facing low-emissions fuels, such as hydrogen, biogas, and e-fuels, as well as carbon capture and storage (CCS) technologies are steadily overcome. The domestic fuel industry transitions to produce these locally. Transport operators and industrial users currently heavily reliant on fossil fuels are thus presented with multiple options for decarbonising. As the carbon price rises concurrently, the point of price parity is reached sooner than expected, though still at a premium compared to today's relatively cheap fossil fuels. Coordination is a major challenge for the sector as organisations are driven to adopt different, incompatible technologies, potentially undermining the ability to share infrastructure and costs. Coal use is phased out as alternatives rapidly become more affordable and the carbon price rises.

Energy efficiency and smart grid management similarly see significant innovation and investment. EV uptake is rapid and sustained. When coupled with smart home chargers and customer incentives, such as discounts or payouts, this presents a large and growing distributed energy storage resource. These changes exacerbate the skills shortage faced by the industry, as specialist expertise is in high demand. Peak demand is managed through a combination of batteries and demand side management. There is also a role for flexible large scale energy conversion technologies such as pumped hydro and green hydrogen that divert renewable electricity generation to the wider grid. Novel technologies, such as supercritical geothermal and efficient wave/tidal generators become viable in the late 2030s.

In the long term, the sector settles into a more stable regime. Slower population growth, improved efficiency, and the benefits of widespread capacity building through to the 2040s helped to reduce the pressure on increasing capacity. Some early investments in alternative generation and storage technologies are left stranded as lower-cost options become dominant. The increasing focus on biodiversity and ecological health places more scrutiny on the impacts of hydroelectric dams, posing challenges for reconsenting their operation.

Economic

There is a push to increase access to international and domestic capital to fund energy decarbonisation investments. Sustainability linked loans become mainstream in New Zealand from the late 2020s and high-emitting organisations find it increasingly difficult to affordably access capital. In the long term, sustainability becomes the norm and New Zealand is seen as an attractive place to invest.

However, New Zealand is not immune to the rising physical impacts of climate change, with insurance prices rising to reflect the risk and uncertainty facing organisations. Self-insurance becomes more prevalent in the energy sector. By the 2050s, access to insurance is almost impossible for high emitters. Many organisations look to invest in nature-based solutions to reduce exposure to risks and increase resilience of assets and systems.

The cost of carbon and fossil fuels rises steeply to incentivise the transition. This speeds up the decarbonisation of emissions-intensive production, a critical step for domestic export businesses to avoid falling behind other markets with lower transport-related emissions. By 2050, carbon offsets are used on exception as most businesses have pivoted to lower emissions. Slow-moving organisations are dismantled as their core business model and strategy becomes incompatible with the market.

The rapid transition places pressure on energy prices as use of fossil fuels diminishes. This shortfall in supply worsens prices for households, only stabilising and becoming more affordable in the late 2030s. In the short term, there is an increasing divide between those who can afford energy and those who cannot. Government incentives and redistribution policies are introduced to combat social disparities and energy poverty.

Environmental

The physical impacts of climate change significantly affect the energy sector, though they are not as severe as in the Hot House, Slow Followers, and Trailblazers scenarios. Temperatures are noticeably higher than present day, but largely manageable due to adaptive responses.

Droughts have worsened and intense rainfall and storm events on the scale of Cyclone Gabrielle occur multiple times every decade, causing damage to energy infrastructure. Sea level rise and storm surges also escalates the risk of flooding and landslides, disrupting supply chains, transportation networks, and communities across New Zealand. In the long term, the climate stabilises around this new normal, with warmer temperatures overall.

Access to environmental resources to support the energy transition, such as key minerals, is competitive. By 2050, a diverse market, combined with technology and recycling developments, reduced competition for critical resources by providing alternatives.

Biodiversity continues to decline in the short term, but this is reversed in the long term through robust interventions to restore and conserve natural ecosystems. Businesses within the New Zealand energy sector are driven to become 'nature positive', emphasising protection of land, water and environmental ecosystems in their business model.

Political

Increasing climate weather events and understanding of the need for urgent action to address climate change leads to tipping points in the socio-political system being crossed. Global collaboration drives New Zealand political consensus on tackling climate change beyond government cycles, enabling the implementation of comprehensive policies and regulations that support the energy transition. Existing energy regulation policy is updated to enable a decarbonised future.

In the 2020s, greater emissions taxes are introduced, such as on diesel and ICE vehicles. Policymakers increase sustainable actions that highlight locality and spatial aspects of decarbonisation interventions, including a ban on combustion vehicle imports in the early 2030s. Consumer incentives for low-carbon energy options are introduced alongside education programs, such as low-carbon technology subsidies. Governments gradually remove free ETS allocation for high emission industries, redirecting those funds toward supporting renewable energy initiatives.

Governments and private entities continue to allocate funds to research and development initiatives focused on advancing clean energy technologies. This helps make cleaner alternatives more economically viable for consumers and businesses. The Commerce Commission regulates funding for renewable investment. Resource management policy nationwide is fully integrated with te ao Māori values and with a focus on protecting biodiversity.

In the short to medium term, trade policies and carbon border adjustment mechanisms (CBAMs) are increasingly used internationally, and New Zealand must comply. This places export companies that have largely decarbonised at a competitive advantage, and spurs investment in low-emissions fuels for aviation and shipping. The Pacific is part of an effective global trade regime through a growing service industry, and niche products that support the sustainable use of local resources. New Zealand supports climate refugees from Pacific nations. New Zealand policies promote a just transition and ensure meaningful participation of communities, especially those disproportionately affected by emissions-intensive activities, in decision-making processes.

Collaborative effort propels climate action with the energy sector playing a pivotal role in the net zero transition

The New Zealand energy sector undergoes a significant transformation, reducing its reliance on fossil fuels and shifting to a more diversified, renewable, low-carbon energy system. The sector plays an influential role in New Zealand meeting successive emission budgets and achieving net zero in the 2050s, alongside many other nations. Ambitious mitigation efforts and rapid decarbonisation measures have been implemented, ensuring that global warming was limited to 1.5°C.

A balance has been struck between decarbonisation and nature preservation policies. Climate and energy use data has improved and become easily accessible for the sector. Businesses can understand their climate risks, build resilience, and provide flexible energy solutions to manage peak loads, with a range of energy generation and storage solutions available.

He Ara Waiora Framework

In developing these scenarios, we have sought to consider the ways in which te ao Māori impacts and is impacted by the changing climate, as an important perspective when thinking about the future of Aotearoa New Zealand's energy system.

To guide our thinking, we reflected on He Ara Waiora, a framework centred on a te ao Māori view of waiora (wellbeing). The framework outlines a holistic and intergenerational approach, highlighting the interconnected nature of waiora. It focuses on the 'means' or principles and approaches for creating waiora, and the 'ends' or outcomes, key to wellbeing.

The He Ara Waiora framework has been used by Te Tai Ōhanga, The Treasury and He Pou a Rangi, The Climate Change Commission. This framework was also key to The Aotearoa Circle's Low Carbon Energy Roadmap, guiding the roadmap actions to ensure the energy sector achieves the desired outcome of maximising wellbeing for New Zealand. We acknowledge the work done by others to develop this framework.

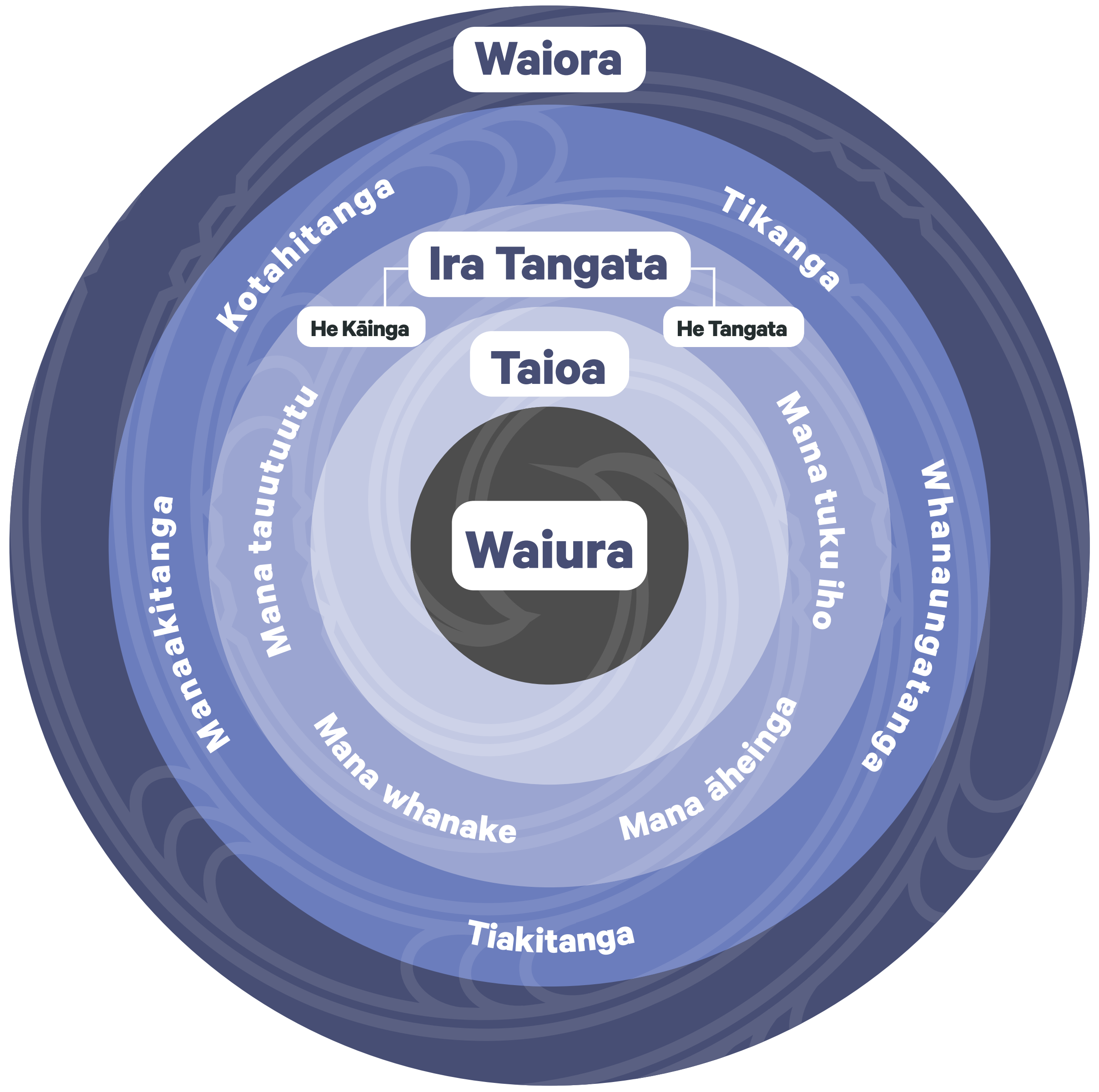
The framework was not used to describe the outcomes under each scenario, but can be used as a way to inform organisational decision-making in response to the risks and opportunities each scenario presents. Organisations' responses will shape how the changing climate may impact waiora across te taiao (the natural world), ira tangata (the human domain) and wairua (spirit).

During our workshops, we discussed what a successful application of a te ao Māori framework could look like for the energy sector. The following themes emerged across these discussions:

- Kotahitanga, working with alignment and coordination, could be exercised locally through developing national energy strategies and objectives, cross-sectoral forums and discussions to foster collaboration, as well as globally through participation in an international carbon market.
- Paying heed to whanaungatanga means genuine engagement with a broad section of stakeholders as decisions are made.
- Manaakitanga, an ethic of care, is manifest in energy organisations that take society-wide considerations into their work, which provides a fundamental human need. Organisations that do this well adopt values of care and protect vulnerable communities.
- Tiakitanga is achieved when organisations take long-term viewpoints in their investment and decision-making processes. Organisations that recognise the centrality of te taiao to our wellbeing will then consider the impacts of energy generation, transmission, distribution, and use on the natural environment.
- A lack of principles (means) leads to a loss of values (ends), particularly in the short-term thinking and lack of regard for the natural environment that characterises the Hot House scenario.

He Ara Waiora can be seen as an example of a useful and actionable framework for organisations to take forward as they use these climate change scenarios to inform strategic thinking. Many organisations will have their own strategies to identify opportunities for achieving the best outcomes for the waiora of Aotearoa and our energy system, whatever scenario may come.

Figure 21: He Ara Waiora framework



- **Wairua** (spirit) is at the centre as the source of wellbeing.
- **Te Taiao** (the natural world) is paramount and interconnected with human wellbeing.
- **Ira tangata** (the human domain) reflects human activities and relationships.
  - Mana tuku iho - identity.
  - Mana tauutuutu - community belonging and and cohesion.
  - Mana āheinga - aspiration and capability.
  - Mana whanake - prosperity.
- These **principles** underpin the approach for **creation** of waiora (wellbeing).
  - Kotahitanga - working with alignment and coordination.
  - Tikanga - right decision-making processes.
  - Whanaungatanga - relationships and kinship.
  - Manaakitanga - ethic of care.
  - Tiakitanga - guardianship and stewardship.

Transport and Energy Linkages

Transport and Energy Linkages

Cross-sector collaboration

The Aotearoa Circle commissioned the development of these energy sector climate scenarios at the same time as initiating the development of climate scenarios for the transport sector through a separate, but parallel process. In recognition of the interdependencies and reliance of these sectors on one another, the two project secretariat brought together participants from both scenario working groups to discuss insights, linkages, and dependencies between the sector scenarios. This was conducted across two joint working sessions where discussion focused on intersection points of the two sectors through the future scenario pathways. Themes discussed and developed through these workshops have been integrated within the scenario narratives of both sectors.

The collaboration between the transport and energy sectors for these climate scenarios not only underscored the need to consider interdependence and interactions outside of industry sectors when considering potential future pathways, but also the opportunity and need for cross-sector, integrated solutions to address the challenges posed by climate change.

The shift towards a low-carbon economy and the mitigation of climate change necessitates the combined efforts of multiple stakeholders. By working together, we can build a more resilient and sustainable future for generations to come.

Comparing scenarios

Scenario users may want to explore potential impacts and outcomes across both sectors. This section outlines key assumptions underpinning the transport and energy sector-level scenarios, highlighting areas of alignment and distinction. Please refer to the transport sector scenarios for more sector-specific information.

The table below shows high-level alignment in the scenario architecture and assumptions between the transport and energy sector climate scenarios. Whilst these scenarios were produced by different groups and have variations in specific parameters and narratives, the transition and physical risk pathways for aligned scenarios are broadly comparable.

Whilst the central scenarios ('Trailblazers', 'Slow Followers', 'Short Detour') are not strictly aligned on reference scenarios (SSPs) or global temperature outcome, there are common themes in scenario narratives in terms of New Zealand's response to climate change.

For those looking to construct entity-level scenarios, see the next page for an overview of key themes across the scenarios.

Table 9: Alignment across transport and energy sector climate scenarios

Energy scenarios	Transport scenarios	SSP	Temperature outcome (2100)
Hot House	Bypass to Breakdown	SSP3-7.0	3.9 - 4.1 °C*
Slow Followers	-	SSP2-4.5	2.6°C
Trailblazers	-	SSP4-3.4	2.2°C
-	Short Detour	SSP1-2.6	1.7°C
Coordinated Effort	Fully Charged	SSP1-1.9	1.3 - 1.4°C*

* There are minor differences in global temperatures between scenarios in both sector-level reports that are based on the same reference scenarios. This is due to methodological choices in the datasets used. The energy sector scenarios draw temperature values from the IIASA SSP Database, used for inputs, diagnostics and calibration of global climate models. The transport sector climate scenarios draw temperature values from the IPCC's AR6 WGI Summary for Policymakers, which includes adjustments based on additional supporting evidence. Both datasets are technically robust, publicly available, and widely used in the scientific community.

Table 10: Key scenario characteristics: Transport and energy interdependencies and alignment

	>3 °C SCENARIOS	CENTRAL SCENARIOS			<1.5 °C SCENARIOS
Scenario	Hot House & Bypass to Breakdown (SSP3-7.0)	Slow Followers (SSP2-4.5)	Trailblazers (SSP4-3.4)	Short Detour (SSP1-2.6)	Coordinated Effort & Fully Charged (SSP1-1.9)
Key assumption variations	**'Bypass to Breakdown' explores Aotearoa New Zealand taking a proactive adaptation policy response, whereas 'Hot House' assumes a more reactive response that struggles to meet the challenges faced.**	**Despite using different SSPs, these three central scenarios connect across select themes impacting both sectors:** **Short Detour & Slow Followers:** Delayed and less well planned transition, greater reliance on imported fuel, equity challenges more pronounced in remote regions. **Short Detour & Trailblazers:** Less well planned transition, greater reliance on transport electrification, more decentralised energy generation and storage.			**No areas of material misalignment. Exact narratives vary.**
Global temperature outcome (2100)	3.9 - 4.1°C	2.6°C	2.2°C	1.7°C	1.3 - 1.4°C
NZ policy and economic environment	Little to no new decarbonisation policy introduced. Slow development of carbon price. Significant physical climate–related economic disruption in longer term.	Energy security and affordability prioritised over decarbonisation. A disruptive transition occurs, albeit later on, primarily market-driven due to international efforts lowering costs.	Immediate ambition to decarbonise led by stringent policies despite poor coordination and a largely unsupportive global environment, leading to high costs.	Delay then act rapidly. Carbon price spikes in 2030s alongside stringent and regionally varied government mitigation policies, creating high pressure to decarbonise.	Emissions reduction is an economic imperative. Long-term policy clarity and enabling environment for development of low-carbon technologies.
Cross-sector collaboration	Lower collaboration on decarbonisation, more on energy/fuel security in longer term.	Generally low. Some ad-hoc, organisation-level collaboration across sectors.	High, but less inclusive, leaving some organisations more exposed to transition risks.	High, but delayed and less coordinated on policies, targets, or investments.	High, with early, strong coordination on supply and demand planning, including with other sectors and government.
NZ energy sector development and electrification	Renewable capacity or demand slow to scale. Decentralised energy adopted for security reasons at high cost. Supply issues make energy sovereignty a priority in long term.	Differentiated approach across organisations, with a mix of new renewables and fossil fuel projects.	Strong buildout of new renewable generation at relatively high cost. High adoption of decentralised energy generation and storage technologies.	Grid and renewables upgrades delayed and more expensive due to high global competition. Transport electrification demand spike in 2030s disrupts supply. EV system investment is more reactive. Greater use of decentralised generation and storage.	Proactive development of energy grid and supporting ecosystem to enable transport electrification. Renewable costs fall in short-medium term. Growing uptake of EVs and smart grid solutions. Diverse energy mix.
NZ low-emissions technology and alternative fuel access and use	Less cross-sector collaboration or R&D support from government on scaling alternative zero, low-carbon, or interim drop-in fuels. Technology adoption focused on efficiency gains, with emissions reduction a by-product.	Little to no investment in local production of alternative fuels or new infrastructure for low-emissions technologies until the medium-long term, when these become consistently cheaper than fossil fuels.	Alternative fuels remain prohibitively expensive in the short-medium term, so the decarbonisation effort is achieved through electrification of transport and industry using existing technologies. High EV uptake.	More reliance on imported technology, skills, and fuel during period of high competition and disrupted supply chains. Lack of coordination domestically leads to competition for limited fuels. Some alternative fuels leapfrogged, with electrification more prevalent.	Early action and long-term planning creates positive R&D environment and leads to domestic production of low and zero carbon alternative fuels and interim drop-in biofuels, and associated technology and infrastructure. Higher energy sovereignty and lower costs by long term.
NZ fossil fuel access and use	Fossil fuel prices low in the short term, but becoming volatile and then very high in the long-term due to supply chain disruption.	Fossil fuel use remains widespread in the short-medium term but prices rise over time due to international policies and reductions in production.	Rapid phase-out of fossil fuels through combination of carbon pricing and targeted policies (e.g. ICE vehicle ban).	Fossil fuel costs spike in 2030s. Slower decarbonisation sees parts of land, sea, and air transportation more reliant on very expensive imported fuels for longer.	Fossil fuels systematically phased out from 2020s and replaced by domestic production, enabling higher energy sovereignty and resilience.
Physical impacts	Longer term, very high and rising acute and chronic impacts to infrastructure, assets, and supply chains.	Moderate, continuing to rise into the long term.	Moderate, continuing to rise into the long term.	Moderate. Acute impacts occur mid-transition, creating compound events for both sectors.	Lowest, with worst impacts happening post-transition.
Challenges to equity	High costs for those reliant on fossil fuels in the longer term. Infrastructure damage leads to transport/energy isolation and inflation.	Differentiated across regions due to rising physical hazards and existential challenges to highly exposed industries.	High transition costs in the short term risk being passed onto vulnerable end users.	Higher inflation and cost of living for medium to long term. Higher transition costs for some more remote users and ICE vehicle owners.	Short to medium term inflation and cost of living pressure. Longer term, social equity challenges are lower.

Appendices

APPENDIX ONE: Our approach

Workshops

Kick-off Workshop: 27th September 2023
The kick-off hui brought together participants across the Working Group (WG) and Leadership Group (LG) with the PwC New Zealand Secretariat team. This hui confirmed the objectives and structure for the project and covered a number of key decisions for the scenario framing, including the scope boundaries, focal question, and time horizons for the analysis.

WG Risk and Opportunities Identification Workshop: 2nd November 2023
LG Meeting- Risk and Opportunities: 21st November 2023
The Secretariat facilitated a climate-related risk and opportunities identification workshop with the WG. This workshop identified the top physical and transition climate-related risks and opportunities for the sector. Additionally, the most significant driving forces for the sector were prioritised based on their influence and uncertainty and possible scenario pathways were discussed. Workshop outputs were taken to the LG meeting for review and feedback.

WG Impact Assessment Workshop: 13th February 2024
LG Meeting - Scenario Impacts: 27th February 2024
This workshop explored how the key driving forces could evolve over time across the four selected scenarios, bringing rise to potential impacts and outcomes. Impacts and outcomes were mapped using the STEEP framework across three time horizons. Workshop outputs were taken to the LG meeting for review and feedback.

Energy and Transport Sectors Climate Scenarios Working Sessions: 17th October 2023 and 15th February 2024
The energy and transport sectors simultaneously developed sector-level climate change scenarios. Given the interdependencies and reliance of these sectors on one another, the participants from each group came together for two joint working sessions. These sessions covered discussions to ensure the development of credible scenarios for each sector, such as the key linkages between the future pathways.

Consultation and review

Following each WG workshop, the LG were consulted on the outcomes. A feedback cycle was followed to allow input from the WG and LG into the final outputs. This report is a result of a collaborative cross-sector approach and the outputs of this project have been developed based on the collective view across participants. Please note the Energy Sector Climate Change Scenarios **do not represent the view of any individual organisation or the energy sector as a whole**.

Scenario development process

PwC New Zealand as Secretariat developed a customised approach for this distinctive piece of work, utilising XRB sector-level scenarios guidance and best practice. This approach allowed for collaboration amongst sector participants to develop a comprehensive understanding of the most significant climate-related risks, opportunities, driving forces, and potential impacts and outcomes for the sector. These elements were critical inputs to the development of the scenario narratives. The steps taken were as follows:

1. Establishment of project scope boundaries
2. Identification of the most significant climate-related physical and transition risks and opportunities.
3. Identification of most significant driving forces and critical uncertainties.
4. Development of scenario architecture.
5. Identification of how driving forces, risks and opportunities materialise as potential impacts and outcomes across the scenarios.
6. Development of scenario narratives.
7. Quality check and review process.

APPENDIX TWO: Long list of climate-related risks and opportunities

Table 10: Physical climate-related risks for the energy sector

Risk No.	Description
P1	Increased damage and loss of access to key energy system assets (lines, pipelines) and supporting infrastructure (bridges, telecommunications) as a result of increased frequency and severity of extreme acute weather events.
P2	Increased ongoing maintenance requirements and reduced ability to effectively maintain key infrastructure as a result of systemic loss of access and key asset damage due to increased frequency and severity of extreme acute weather events.
P3	Increased international supply-chain constraints and continuity of supply disruptions across key energy system components and inputs as a result of increased frequency and severity of extreme weather events.
P4	Increased volatility of electricity production and supply as a result of increased variability of weather events and changing regional seasonality (e.g. hot days, rainfall, wind patterns).
P5	Increased asset vulnerability and damage as a result of chronic climate change, such as rising temperatures, sea level rise and erosion.
P6	Increased ecosystem changes affecting operations e.g. warming changing ecology in water systems.

Risk/opportunity ranking

- Critical (high exposure and vulnerability).
- Important (medium exposure and vulnerability).
- Considered (lower exposure and vulnerability).

Table 11: Transition climate-related risks for the energy sector

Risk No.	Description
T1	Failure to adequately build, upgrade, and maintain long term infrastructure to handle the energy transition.
T2	Inability of the sector to efficiently manage the electrification transition and stability of supply leading to increased peak loads, outages, and network costs.
T3	Ineffective climate adaptation due to a lack of whole-system coordination across the sector.
T4	Inability of the sector to affordably access financial services, including insurance and debt markets.
T5	Politicisation of the energy transition, competing regulation, and limited political stability for prioritisation of investment across the sector.
T6	Increased volatility and/or cost of carbon as a result of regulatory intervention such as changes to the Emissions Trading Scheme (ETS) or inclusion of NZ Emissions-Intensive Trade Exposed Industries (EITEs) in the ETS.
T7	Supply chain and labour market constraints in a highly competitive global market are a barrier for the transition to low-carbon energy.
T8	Inability to afford and/or access new technology and components essential to the transition to a low-carbon economy.
T9	Inability to manage increased inequity and impacts on community wellbeing associated with cost and access to low-carbon energy.
T10	Increased stranded assets and asset write downs as a result of rapid decarbonisation, regulatory change, increased lower carbon alternatives etc.
T11	Increased company, director and executive liability and potential litigation for failing to effectively take action against the impacts of climate change.
T12	Resource consenting process is insufficient in keeping up with demands of the sector.
T13	Lack of local/regional capability or capacity to transition.
T14	Failure to adapt leads to loss of social licence.
T15	Failure to meet and understand changing consumer preference.

Table 12: Climate-related opportunities for the energy sector

Opp. No.	Description
O1	Increased adoption and implementation of new monitoring and management technologies grow a more flexible and resilient energy market, enabling more efficient distribution of energy.
O2	As technology continues to evolve, there is increased opportunity to provide further energy storage solutions at a residential, commercial and industrial scale.
O3	Increased digitisation of energy platforms and adoption of 'smart tech' to assist more effective distribution of energy and management of energy consumption for some consumers.
O4	Investors are able to make attractive investments that have co-benefits with Te Taiao, the natural world, and sustainable, intergenerational prosperity (mana whanake).
O5	New employment opportunities for some regional communities to support the transformation of assets and infrastructure as the energy sector continues to decarbonise and emerging uses come online.
O6	New markets, such as solar, wind and hydrogen-based products like ammonia, aviation fuel, marine fuels, will enable increased diversification and decentralisation of energy mix, increased resilience of energy supply, and reduced dependence on imported liquid fuels.
O7	Sector-wide partnership in alignment with government to accelerate the transition in an equitable and holistic manner, whilst prioritising community wellbeing.
O8	Implementing techniques to make better use of wastes and residues e.g. waste to resource, circular economy.
O9	Increased opportunity to support the UN SDG Goal 7: Affordable and clean energy.
O10	Increased domestic share of energy supply and energy independence.
O11	Increased attractiveness of Aotearoa's exports in international markets, in terms of marketability and relative cost, if we successfully decarbonise our energy system.
O12	Increased innovation and ownership of intellectual property.
O13	Build out of new generation allows for increased opportunities for community and iwi ownership.

APPENDIX THREE: Long list of driving forces

Table 13: Long list of driving forces under the STEEP framework

Social

Driving force	Definition
Social preferences and behaviour	Changing expectations and norms around climate change/ sustainability and the demand from customers, shareholders, employees and investors for balancing energy security, sustainability, and affordability. Influenced by socioeconomic factors including equity, tangata whenua relationships and priorities, demographics, values, and consumption patterns.
Changes to customer base	Breakdown of energy system users by residential/commercial/ industrial categories, as well as the type of industrial users. User base is also influenced by patterns of urbanisation and emergence of low-emissions technologies.
Labour force demand and supply	The availability of employment and skilled labour, and the degree to which the demand and supply is met.
Population, demographics and urbanisation	Demographic changes such as population, age, international immigration/emigration, social trends, and education levels within New Zealand. Includes the distribution of people and their wealth across the country and subsequent demands for energy.

Technological

Driving force	Definition
Technological advancements	The degree of research and development enabling new emerging and disruptive technologies, which impact the wider energy system.
Technological demands and deployment	The degree to which technology demands are able to be met and the speed and scale at which organisations can attract/ develop, access and utilise new climate-related technologies (not the existence of the technology itself), including the ability of infrastructure to meet energy system needs.

Environmental

Driving force	Definition
Severe acute weather events	Frequency and severity of climate-driven acute weather events.
Chronic changes in climate	Longer-term changes in the earth system driven by climate change e.g. sea level rise, average temperatures, sunlight hours, average wind speeds, tropical disease incidence.
Natural resources	Availability, cost and quality of domestic natural resources, including both renewable and non-renewable resources e.g. water, land, biomass, fossil fuels, minerals etc.

Economic

Driving force	Definition
Access to finance and insurance	Access to and cost of debt, equity finance and insurance for net-zero transition and other purposes. Includes the Māori economy and funding for iwi-led investment.
Availability and cost of fossil fuels	Availability, cost, and quality of fossil fuels from international markets.
Carbon price	New Zealand and international government approach to using carbon taxes/pricing e.g. NZ ETS, international carbon border taxes etc.
Macroeconomic conditions	Domestic and international levels of inflation, interest rates, unemployment, and GDP growth.

Political

Driving force	Definition
Domestic government priorities and attitudes	The level and consistency of New Zealand governments ambition and leadership on climate change mitigation and adaptation. Also includes the degree to which climate action is politicised, the scale and timing of investment and funding for climate-related issues/infrastructure, and governments perspectives on Te Tiriti obligations.
Domestic regulatory changes	The timing, speed and level of climate-related and other legislation passed by government in New Zealand, including resource consenting and specific examples targeting the energy system e.g. emissions standards, mandates on ICE vehicles, product stewardship requirements, renewable energy targets, biofuel requirements, fossil fuel bans/restrictions, etc.
International policy	The timing, speed and level of climate-related and other legislation passed by governments outside of New Zealand (e.g. USA, China, Australia) and level of climate action in large markets.
Geopolitical tension	The levels of collaboration, competition, protectionism and political stability across global geopolitics impacting trade, labour flows, finance/technology flows, etc.
Trade barriers	Degree to which global import/export markets and international corporations implement trade barriers, such as climate-related standards, trade rules, taxes, tariffs, accepted emission levels etc.

APPENDIX FOUR: Use of reference scenarios

The scenarios presented in this report are the product of a collaborative effort bringing together experts across the sector. However, establishing the high-level boundary conditions for the scenarios often required selecting information from the range of existing climate scenario frameworks. This process involves reconciling often disparate and inconsistent information across different scenarios. This section outlines the reference scenarios used in this report, what information was taken from them, and the rationale behind those choices. The tables below also outline our assessment of the best alignment between the reference scenarios and the four energy sector scenarios. If entities wish to use more metrics from these references to inform their own scenario analysis, we recommend choosing scenarios in line with the matches presented below. Additional reports and studies that project potential pathways for the development of individual technologies were also referenced to qualitatively inform the scenario narratives. These are listed in the References section. However, the majority of these reports were not designed to explore climate-related risks, nor do they adopt a sector-wide viewpoint. If entities wish to draw on additional reference reports/studies for their own scenario analysis, they will need to assess these for alignment with the assumptions in the scenario narratives.

Shared socioeconomic pathways (SSPs)

SSPs were developed to examine how global society, demographics and economics might change over the next century. SSPs pathways provide a framework for integrating socioeconomic factors, exploring the consequences of different policies and social attitudes and their potential impacts on the environment. There are five SSPs, and a range of concentration pathways that are attached to these for the purposes of climate modelling.[48] The four energy sector scenarios use four different SSPs to inform the global picture of socioeconomic trends and development, and use the results of global climate models using different SSP-concentration pathway pairings to inform the state of the global climate over time.

Scenario	SSP used	Assumptions/Rationale
Coordinated Effort	1-1.9	A scenario in which there is a strong commitment to sustainable development, significant reductions in greenhouse gas emissions, widespread adoption of clean and renewable energy sources, and a high-level of international cooperation to address climate change. This is the SSP-concentration pathway pairing specified to result in less than 1.5°C of global warming, in line with XRB requirements.
Trailblazers	4-3.4	This describes a world of high inequality, divided international cooperation, and fragmented efforts to address climate change, with rapid decarbonisation in much of the developed world. Carbon dioxide emissions peak in the 2020s and reach net-zero in the 2080s, resulting in global warming of around 2.2°C by 2100.
Slow Followers	2-4.5	A 'middle-of-the-road' scenario with moderate economic growth, intermediate population growth, a mix of fossil fuel and renewable energy sources, and some international cooperation, leading to moderate greenhouse gas emissions and limited environmental improvements. Global carbon dioxide emissions peak around 2040 but don't reach net zero this century, resulting in global warming of around 2.6°C by 2100.
Hot House	3-7.0	A scenario where there is limited policy action and international cooperation to address climate change. There is heavy reliance on fossil fuels, with limited efforts to transition to renewable energy sources, leading to high greenhouse gas emissions and continued dependence on coal, oil, and gas. Global carbon dioxide emissions continue to rise through the century, resulting in global warming of around 4.1°C by 2100. This meets the XRB requirement for a scenario with >3°C warming.

Representative concentration pathways (RCPs)

RCPs provide a range of possible future greenhouse gas concentration pathways, which serve as inputs for climate models to project future climate change impacts. These pathways were developed by the MESSAGE modelling team and the IIASA Integrated Assessment Framework at the International Institute for Applied Systems Analysis (IIASA).[49] These were used to determine the physical climate characteristics of each scenario. The numbers relate to the heating effect of emissions on the climate. That is, the higher the RCP, the higher emissions are and the more warming the world experiences. These RCPs have been downscaled to the New Zealand context by NIWA. The New Zealand-specific climate impacts in these scenarios were taken from the downscaled NIWA data.[50]

<table>
<tr><th>Scenario</th><th>RCP used</th><th>Assumptions/Rationale</th></tr>
<tr><td>Coordinated Effort</td><td>2.6</td><td>This scenario represents a future with ambitious climate mitigation efforts, where greenhouse gas emissions peak around 2020 and decline rapidly thereafter. It envisions a world with low greenhouse gas concentrations, limiting global warming to well below 2°C above pre-industrial levels. There is not an RCP1.9 to align with the SSP-concentration pathway chosen for Coordinated Effort, SSP1-1.9.</td></tr>
<tr><td>Trailblazers</td><td>4.5</td><td rowspan="2">This scenario represents a future with moderate climate mitigation efforts, where greenhouse gas emissions peak around 2040 and gradually decline thereafter. It envisions a world with intermediate greenhouse gas concentrations, resulting in a moderate level of global warming. There is not an RCP3.4 to align with the SSP-concentration pathway chosen for Trailblazers, SSP4-3.4.</td></tr>
<tr><td>Slow Followers</td><td>4.5</td></tr>
<tr><td>Hot House</td><td>8.5</td><td>This scenario represents a future with little climate mitigation efforts in which emissions continue to rise, leading to severe physical impacts</td></tr>
</table>

48 Riahi, et al. (2017). The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change.*
49 IIASA. (2023). *Representative concentration pathways database (RCP).*
50 NIWA. (2016). *Our future climate New Zealand.*

Network for Greening the Financial System (NGFS)

The NGFS framework has become a common tool for determining high-level scenario narratives. These transition pathways are differentiated by key design choices relating to long- term policy, short-term policy, and technology availability.[51] Output metrics from NGFS modelling have not been used as direct inputs into the scenarios, but NGFS scenarios were reviewed for alignment. Qualitative aspects, such as trends in GDP and global carbon prices, were used to inform the scenario narratives.

Scenario	NGFS scenario used	Assumptions/Rationale
Coordinated Effort	**Net Zero 2050**	This describes an ambitious scenario that limits global warming to 1.5°C through stringent climate policies and innovation, reaching net zero CO_2 emissions around 2050.
Trailblazers	**Nationally Determined Contributions (NDCs)**	This scenario assumes that the moderate and heterogeneous climate ambition reflected in the conditional NDCs at the beginning of 2021 continues over the 21st century (low transition risks).
Slow Followers	**Fragmented World**	The Fragmented World scenario assumes delayed and divergent climate policy ambition globally, leading to elevated transition risks in some countries and high physical risks everywhere due to the overall ineffectiveness of the transition.
Hot House	**Current Policies**	This scenario assumes that only currently implemented policies are preserved, leading to high physical risks. Emissions grow until 2080 leading to about 3°C of warming and severe physical risks.

He Pou a Rangi: Climate Change Commission (CCC)

The Climate Change Commission is an independent Crown entity that advises the New Zealand Government on climate change policy within the framework of the Climate Change Response Amendment Act. The Climate Change Commission (CCC) in New Zealand has developed a set of scenarios to guide the country's climate change policy and planning. These scenarios explore different pathways for greenhouse gas emissions reduction and the associated impacts.[52] CCC modelling has additionally been used as a data input for New Zealand's economy and emissions across the four energy sector scenarios.

Scenario	CCC scenario used	Assumptions/Rationale
Coordinated Effort	**Tailwinds**	A scenario that meets the 2050 emissions target under relatively low barriers to future behaviour and technology change.
Trailblazers	**Headwinds**	A scenario that meets the 2050 emissions target under relatively high barriers to future behaviour and technology change.
Slow Followers	**Current Policy Reference Case**	A scenario representing the continuation of current policies.
Hot House	**Current Policy Reference Case**	A scenario representing the continuation of current policies.

51 NGFS. (2023). *Scenarios technical documentation.*
52 Climate Change Commission. (2021). *Ināia tonu nei: a low emissions future for Aotearoa.*

International Energy Agency (IEA) scenarios

The IEA scenarios provide valuable insights into the potential future energy landscape, including the role of different energy sources and policy implications.[53] Output metrics from IEA modelling have not been used as direct inputs into the scenarios, but IEA scenarios were reviewed for alignment. Qualitative aspects, such as oil price trends, were used to inform the scenario narratives.

Scenario	IEA scenario used	Assumptions/Rationale
Coordinated Effort	**Net Zero Emissions by 2050 (NZE)**	This scenario considers a combination of ambitious climate policies, technological advancements, and behavioural changes to rapidly decarbonise the energy sector and other sectors of the economy.
Trailblazers	**Announced Pledges Scenario (APS)**	The APS scenario assumes that countries around the world meet their ambitious but differentiated Net Zero targets and their Nationally Determined Contributions under the Paris Agreement in full and on time.
Slow Followers	**Stated Policies Scenario (STEPS)**	The STEPS scenario is based on the existing policies and measures that countries have announced or implemented. It provides a reference point for assessing the potential future energy landscape if no additional policy actions are taken beyond those already in place.
Hot House	**N/A**	There is no IEA scenario that aligns with the continued growth in emissions and resulting temperature pathway of the energy sector Hot House scenario.

Business Energy Council (BEC) scenarios

Produced by the Business Energy New Zealand Council, TIMES-NZ 2.0 is a technology-based optimisation model that represents the entire New Zealand energy system, encompassing energy carriers and processes from primary resources to final energy consumption. The model is based on the International Energy Agency Energy Technology Systems Analysis Program TIMES model. There are two scenarios presented in this work.[54] Output metrics from BEC modelling have not been used as direct inputs into the scenarios, but the scenarios were reviewed for alignment. Qualitative aspects, such as EV uptake trends, were used to inform the scenario narratives.

Scenario	BEC scenario used	Assumptions/Rationale
Coordinated Effort	**Kea**	This represents a scenario where climate change is prioritised as the most pressing issue and New Zealand deliberately pursues cohesive ways to achieve a low-emissions economy.
Trailblazers	**Tui**	This represents a scenario where climate change is an important issue to be addressed as one of many priorities, with most decisions being left up to individuals and market mechanisms.
Slow Followers	**N/A**	There is no BEC scenario that best aligns with the temperature pathway and assumptions of the energy sector Slow Followers scenario.
Hot House	**N/A**	There is no BEC scenario that best aligns with the temperature pathway and assumptions of the energy sector Hot House scenario.

53 International Energy Agency. (2023). *Global energy and climate model.*
54 Business New Zealand Energy Council. (2024). *New Zealand energy scenarios: TIMES-NZ 2.0.*

Boston Consulting Group (BCG) - The Future is Electric

This report forms a decarbonisation roadmap for the New Zealand electricity sector and was prepared by BCG on behalf of several participants, comprising generators, distributors, and retailers. Concept Consulting contributed quantitative modelling. Five pathways are modelled which can be roughly aligned with the scenarios in this report.[55] In developing our four scenarios, we leveraged the modelling results to inform our breakdown of generation by hydropower/geothermal, wind/solar/other renewable, and fossil fuels. Exact quantitative data from the BCG report are not used directly in our four scenarios.

Scenario	BCG scenario used	Assumptions/Rationale
Coordinated Effort	**P2 Smart System Evolution (short term), P5 Green Export Powerhouse (medium-long term)**	The P2 pathway emphasises broad alignment, a whole-of-system approach, and emerging technologies to encourage a smart transition, in line with Coordinated Effort. P5 assumes a large domestic green hydrogen industry. This fits with the longer-term narrative of Coordinated Effort, which assumes a broad range of technological options available for sectors to decarbonise.
Trailblazers	**P3 Renewable Energy Pioneer**	This pathway depicts a mandated target leading to 100% renewable electricity by 2030, in line with the top-down transition described in Trailblazers. The pathway assumes a faster uptake of emerging technologies than projected under Trailblazers, but it does similarly include an uptick in the amount of intermittent generation capacity built.
Slow Followers	**P1 Business-as-usual**	This pathway exhibits continued reliance on fossil fuels for peak demand response. However, it still projects close to 100% renewables by 2030, representing a faster transition than the Slow Followers scenario.
Hot House	**P1 Business-as-usual**	This pathway exhibits continued reliance on fossil fuels for peak demand response. However, it still projects close to 100% renewables by 2030, representing a faster and more complete transition than the Hot House scenario.

Transpower - Whakamana i Te Mauri Hiko

This report explores potential future evolution of the energy sector out to 2050 through analysis and quantitative modelling to provide a basis for stakeholder discussions and planning.[56] Similar to the BCG report, we leveraged the modelling results to inform our breakdown of generation by hydropower/geothermal, wind/solar/other renewable, and fossil fuels. Exact quantitative data from the BCG report are not used directly in our four scenarios.

Scenario	Transpower scenario used	Assumptions/Rationale
Coordinated Effort	**Base case: Accelerated Electrification**	Accelerated Electrification presents a realistic yet aspirational scenario, a large-scale transformation requiring integrated, coordinated planning and action from across the economy and government. It assumes growing political and social pressure to decarbonise, as well as economic, technological and social forces promoting widespread adoption of electric vehicles and electrifying process heat. This scenario assumes increasing energy efficiency, smart demand-side management, and increasing levels of solar and accompanying battery installations. These assumptions align well with Coordinated Effort.
Trailblazers	**Higher electricity demand: 'Mobilise to Decarbonise'**	The Mobilise to Decarbonise scenario includes a higher demand for electricity than the base case. It assumes that the world is slow to act on climate change before eventually taking rapid action. There is also emphasis on reducing high-emitting activities, as opposed to implementing lower-emissions technologies for continuing with current lifestyles. This scenario also notes that New Zealand distinguishes itself as a decarbonisation leader and global 'safe haven'. These assumptions align well with Trailblazers.
Slow Followers	**Slower case: 'Measured Action'**	The Measured Action scenario tests a variant of the base case in which slower electrification of transport is realised. It assumes the same context as the base case with the only difference being electric vehicle adoption occurring more slowly. This represents a different approach to decarbonising than Slow Followers, but the scenario is similar in depicting a slower transition.
Hot House	**Lower case: 'Business as Usual'**	The Business as Usual scenario was developed to test a future in which significant electrification fails to eventuate. Reduced economic and policy incentives to electrify, combined with slower than expected technology development, results in lower levels of electrification of transport and process heat. These assumptions align well with Hot House.

55 Boston Consulting Group. (2022). *Climate change in New Zealand: The future is electric.*
56 Transpower. (2020). *Whakamana i te mauri hiko: Empowering our energy future.*

APPENDIX FIVE: Carbon sequestration and negative emissions assumptions

The XRB climate standards general requirements (NZ CS 3) state that scenario analysis needs to include a description of the various emissions reduction pathways in each scenario and the assumptions underlying pathway development over time, including the scope of operations covered, policy and socioeconomic assumptions, macroeconomic trends, and energy pathways. The following table highlights the carbon sequestration from afforestation, nature-based solutions, and technology assumptions including negative emissions technology for the Energy Sector Climate Change Scenarios. The political and socioeconomic assumptions have been covered in detail in the scenario narratives.

The scenarios are informed by CO_2 concentration pathways from four of the SSPs that are used to coordinate the climate models that inform the IPCC's 6th Assessment Report (AR6). Each SSP makes assumptions about the amount of carbon sequestration from afforestation, nature-based solutions and negative emissions technology at the global level, but the amounts are not reported directly via the International Institute for Applied Systems Analysis (IIASA), which prescribes the SSP data. They are instead aggregated with other emissions sources into two of the reported sector-level emissions levels: Agriculture, Forestry, and Other Land Use (AFOLU) for afforestation; and Energy Sector for negative emissions technology. We also draw on the NZ Climate Change Commission's (CCC) modelling to inform national-level metrics relevant to the scenarios, including afforestation rates as outlined below.

Assumptions	Hot House	Slow Followers	Trailblazers	Coordinated Effort
Afforestation (assumed to follow CCC scenario assumptions)	**Current Policy Reference** Exotic afforestation: 0.96 Mha from 2021-2050 Native afforestation: 0.13 Mha from 2021-2050	**Current Policy Reference** Exotic afforestation: 0.96 Mha from 2021-2050 Native afforestation: 0.13 Mha from 2021-2050	**Headwinds** Exotic afforestation: 0.76Mha from 2021-2050 Native afforestation: 0.44Mha from 2021-2050	**Tailwinds** Exotic afforestation: 0.57Mha from 2021-2050 Native afforestation: 0.67Mha from 2021-2050
Nature-based solutions (NbS)	This scenario assumes limited efforts to mitigate climate change and reduce greenhouse gas emissions, which results in limited emphasis on nature-based solutions. However, some localised NbS initiatives, such as community-based conservation and restoration projects, are still implemented to address local adaptation challenges such as sea level rise particularly in the long-term, particularly in the long-term.	This scenario has limited emphasis on nature-based solutions in New Zealand due to the high reliance on fossil fuels and slower transition to sustainable development. However, some localised NbS initiatives, such as community-based conservation and restoration projects, are still implemented to address local adaptation challenges such as sea level rise, particularly in the long-term.	NbS, such as sustainable agriculture, forest management, and coastal protection, are assumed to be moderately implemented to enhance carbon sequestration, water management, and biodiversity conservation in the medium to long-term.	NbS, such as reforestation, afforestation, and ecosystem restoration, are assumed to be widely implemented to enhance carbon sequestration and biodiversity conservation. Policies and incentives are in place to promote the protection and restoration of natural ecosystems, including forests, wetlands, and coastal areas.
Technology assumptions (negative emissions technology)	There remains low demand for low-carbon or emissions-saving technologies. The cost of Carbon Capture and Storage (CCS) technologies remain relatively high, making their adoption less economically viable.	Globally, CCS technologies are assumed to be moderately deployed, with varying effectiveness in capturing and storing carbon dioxide emissions.	Assumes negative emissions technology remains cost-prohibitive into the medium term.	Assumes rapid development of both CCS technology for point-source emissions capture and Carbon Dioxide Removal (CDR) technology for distributed negative emissions. Also use of low-carbon liquid fuels. Exact levels are not prescribed.

APPENDIX SIX: Detailed climate scenario data

Hot House

Variable/indicator	Values at time horizons			Data source
	2030	2050	2080	
Global warming relative to pre-industrial (°C)	1.52	2.20	3.28	IIASA SSP Database: SSP3-7.0
Global annual CO_2 emissions ($GtCO_2$)	52.85	62.90	73.41	IIASA SSP Database: SSP3-7.0
NZ annual CO_2 emissions ($MtCO_2$)	33.31	23.72	-	NZ Climate Change Commission, 2021: Current policy reference
NZ renewable energy share of total final consumption (%)	31%	46%	-	NZ Climate Change Commission, 2021: Current policy reference
NZ carbon price ($NZD/$tCO_2e$)	$35	$35	-	NZ Climate Change Commission, 2021: Current policy reference
NZ population (million persons)	5.849	6.863	7.860	Stats NZ, 2022: 95th percentile projection Values reported for 2033, 2053, and 2073
NZ sea level rise relative to 2005 (m)	0.11	0.24	0.5	Ministry for the Environment, 2024 NZ Sea Rise Programme, 2023: SSP3-7.0 Vertical land movement excluded. Site 7067 taken as a central location to be representative for New Zealand
Change in NZ average hot days >25°C relative to 1986-2005 (%)	-	66.60%	255.90%	Ministry for the Environment, 2018: RCP8.5 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average
Change in NZ rainfall intensity relative to 1986-2005 (%, 20-year ARI, 12-hour storm)	-	8.3%	25%	Ministry for the Environment, 2018: RCP8.5 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average

Slow Followers

Variable/indicator	Values at time horizons			Data source
	2030	2050	2080	
Global warming relative to pre-industrial (°C)	1.49	1.97	2.46	IIASA SSP Database: SSP2-4.5
Global annual CO_2 emissions ($GtCO_2$)	43.48	43.46	26.84	IIASA SSP Database: SSP2-4.5
NZ annual CO_2 emissions ($MtCO_2$)	33.31	23.72	-	NZ Climate Change Commission, 2021: Current policy reference
NZ renewable energy share of total final consumption (%)	31%	46%	-	NZ Climate Change Commission, 2021: Current policy reference
NZ carbon price ($NZD/$tCO_2e$)	$35	$35	-	NZ Climate Change Commission, 2021: Current policy reference
NZ population (million persons)	5.564	6.209	6.644	Stats NZ, 2022: 50th percentile projection Values reported for 2033, 2053, and 2073
NZ sea level rise relative to 2005 (m)	0.11	0.22	0.42	Ministry for the Environment, 2024 NZ Sea Rise Programme, 2023: SSP2-4.5 Vertical land movement excluded. Site 7067 taken as a central location to be representative for New Zealand
Change in NZ average hot days >25°C relative to 1986-2005 (%)	-	53.7%	96.1%	Ministry for the Environment, 2018: RCP4.5 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average
Change in NZ rainfall intensity relative to 1986-2005 (%, 20-year ARI, 12-hour storm)	-	7.2%	11.7%	Ministry for the Environment, 2018: RCP4.5 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average

Trailblazers

Variable/indicator	Values at time horizons			Data source
	2030	2050	2080	
Global warming relative to pre-industrial (°C)	1.48	1.90	2.17	IIASA SSP Database: SSP4-3.4
Global annual CO_2 emissions ($GtCO_2$)	34.46	19.84	3.71	IIASA SSP Database: SSP4-3.4
NZ annual CO_2 emissions ($MtCO_2$)	29.87	11.82	-	NZ Climate Change Commission, 2021: Headwinds
NZ renewable energy share of total final consumption (%)	36%	74%	-	NZ Climate Change Commission, 2021: Headwinds
NZ carbon price ($NZD/$tCO_2e$)	$228	$411	$1,092	Treasury New Zealand, 2023: High projection For 2080, the 2070 value is taken as representative
NZ population (million persons)	5.679	6.477	7.098	Stats NZ, 2022: 75th percentile projection Values reported for 2033, 2053, and 2073
NZ sea level rise relative to 2005 (m)	0.11	0.22	0.42	Ministry for the Environment, 2024 NZ Sea Rise Programme, 2023: SSP2-4.5 Vertical land movement excluded. Site 7067 taken as a central location to be representative for New Zealand
Change in NZ average hot days >25°C relative to 1986-2005 (%)	-	53.7%	96.1%	Ministry for the Environment, 2018: RCP4.5 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average
Change in NZ rainfall intensity relative to 1986-2005 (%, 20-year ARI, 12-hour storm)	-	7.2%	11.7%	Ministry for the Environment, 2018: RCP4.5 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average

Coordinated Effort

Variable/indicator	Values at time horizons			Data source
	2030	2050	2080	
Global warming relative to pre-industrial (°C)	1.47	1.56	1.46	IIASA SSP Database: SSP1-1.9
Global annual CO_2 emissions ($GtCO_2$)	22.85	2.05	-7.31	IIASA SSP Database: SSP1-1.9
NZ annual CO_2 emissions ($MtCO_2$)	25.53	5.42	-	NZ Climate Change Commission, 2021: Tailwinds
NZ renewable energy share of total final consumption (%)	42%	89%	-	NZ Climate Change Commission, 2021: Tailwinds
NZ carbon price ($NZD/$tCO_2e$)	$171	$309	$557	Treasury New Zealand, 2023: Central projection For 2080, the 2070 value is taken as representative
NZ population (million persons)	5.56	6.21	6.64	Stats NZ, 2022: 50th percentile projection Values reported for 2033, 2053, and 2073
NZ sea level rise relative to 2005 (m)	0.12	0.19	0.30	Ministry for the Environment, 2024 NZ Sea Rise Programme, 2023: SSP1-1.9 Vertical land movement excluded. Site 7067 taken as a central location to be representative for New Zealand
Change in NZ average hot days >25°C relative to 1986-2005 (%)	-	42.6%	38.2%	Ministry for the Environment, 2018: RCP2.6 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average
Change in NZ rainfall intensity relative to 1986-2005 (%, 20-year ARI, 12-hour storm)	-	5.7%	5.7%	Ministry for the Environment, 2018: RCP2.6 2050 value based on 2031-2050 average, 2080 value based on 2081-2100 average

APPENDIX SEVEN: Acknowledgements

The Energy Sector Climate Change Scenarios have been created through the voluntary efforts of the following organisations. We would like to acknowledge each member of the Leadership Group, Working Group, Wider Advisory, and all others involved for their time and effort. Each group consisted of a diverse group of people, including technical specialists, sustainability leads, risk managers, strategy leads, finance and legal representatives.

This report is a result of a collaborative cross-sector approach and the outputs of this project have been developed based on the collective view across participants. Please note the Energy Sector Climate Change Scenarios **do not represent the view of any individual organisation or the energy sector as a whole**.

Leadership Group

- Beca
- BlueFloat Energy and Elemental Group
- Clarus
- Contact Energy
- Genesis Energy
- Mercury
- Meridian Energy
- National Institute of Water and Atmospheric Research (NIWA)
- Orion Group
- Powerco
- Unison Networks
- Vector
- Wellington Electricity

Working Group

- Bioenergy Association of New Zealand
- Beca
- BlueFloat Energy and Elemental Group
- Clarus
- Contact Energy
- Energy Resources Aotearoa
- External Reporting Board (XRB)
- Genesis Energy
- Mercury
- Meridian Energy
- National Institute of Water and Atmospheric Research (NIWA)
- Orion Group
- Powerco
- Scion
- Unison Networks
- Vector
- Wellington Electricity

Wider Advisory

- New Zealand Geothermal Association

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- James Ayling
- Otene Hopa
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- Ethan Kay
- Phoebe McCartie
- Isla Christensen
- Aaron Webb

APPENDIX EIGHT: Project timeline

References

Boston Consulting Group. (2022). *Climate change in New Zealand: The future is electric.* https://www.bcg.com/publications/2022/climate-change-in-new-zealand

Business New Zealand Energy Council. (2024). *New Zealand energy scenarios: TIMES-NZ 2.0.* https://times.bec.org.nz/

Castalia. (2022). *New Zealand hydrogen scenarios and the future of gas.* https://www.mbie.govt.nz/dmsdocument/27266-new-zealand-hydrogen-scenarios-and-the-future-of-gas-september-2022-pdf

Clarke, L., Wei, Y.-M., De La Vega Navarro, A., Garg, A., Hahmann, A.N., Khennas, S., Azevedo, I.M.L., Löschel, A., Singh, A.K., Steg, L., Strbac, G., & Wada, K. (2022). Energy Systems. In IPCC. (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.008

Climate Change Commission. (2021). *Ināia tonu nei: a low emissions future for Aotearoa.* https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa.pdf

Climate Change Commission. (2021). *Scenarios dataset for the Commission's 2021 final advice (output from ENZ model).* https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx

Climate Change Commission. (2021). E*NZ assumptions and inputs for 2021 final advice.* https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/ENZ-assumptions-inputs-2021-final-advice.xlsx

Concept Consulting. (2023). *Potential demand for thermal generation in the transition to a renewables-based electricity system.* https://www.ea.govt.nz/media/documents/Appendix_C_-_Concept_Consulting.pdf

Cook, M. (2023). *The hydrogen opportunity: Ecosystem update 2023.* https://www.gns.cri.nz/our-science/energy-futures/green-hydrogen/the-hydrogen-opportunity-ecosystem-update-2023/

Ebinger, J. & Vergara, W. (2011). *Climate impacts on energy systems: Key issues for energy sector adaptation.* https://doi.org/10.1596/978-0-8213-8697

Energy Efficiency & Conservation Authority. (2022). *The future of energy in New Zealand.* https://www.eeca.govt.nz/insights/energys-role-in-climate-change/the-future-of-energy-in-new-zealand/

Enerlytica. (2023). *LNG import and options to increase indigenous gas market capacity and flexibility in New Zealand.* https://www.mbie.govt.nz/dmsdocument/27262-lng-import-and-options-to-increase-indigenous-gas-market-capacity-and-flexibility-in-new-zealand-march-2023-pdf

External Reporting Board. (2022). *Aotearoa New Zealand climate standard 1: Climate-related disclosures (NZ CS 1).* https://www.xrb.govt.nz/dmsdocument/4770

External Reporting Board. (2022). *Fact sheet: Scenario analysis and climate-related disclosures.* https://www.xrb.govt.nz/dmsdocument/4375

External Reporting Board. (2023). *Staff guidance: Entity scenario development.* https://www.xrb.govt.nz/dmsdocument/4994

External Reporting Board. (2023). *Staff guidance: Sector scenario development.* https://www.xrb.govt.nz/dmsdocument/4532

Frame, B., Lawrence, J., Ausseil, A., Reisinger, A., & Daigneault, A. (2018). Adapting global shared socio-economic pathways for national and local scenarios. *Climate Risk Management, 21, 39-51.* https://doi.org/10.1016/j.crm.2018.05.001

IIASA. (2023). *Representative concentration pathways database (RCP).* https://iiasa.ac.at/models-tools-data/rcp

IIASA SSP Database. (Version 2.0). [SSP1-1.9; SSP4-3.4; SSP2-4.5; SSP3-7.0]. https://tntcat.iiasa.ac.at/SspDb

International Energy Agency. (2023). *Global energy and climate model.* https://iea.blob.core.windows.net/assets/ff3a195d-762d-4284-8bb5-bd062d260cc5/GlobalEnergyandClimateModelDocumentation2023.pdf

International Energy Agency. (2024). *Clean technologies are driving job growth in the energy sector, but skills shortages are an increasing concern.* https://www.iea.org/news/clean-technologies-are-driving-job-growth-in-the-energy-sector-but-skills-shortages-are-an-increasing-concern

International Labour Organization. (2024). *Frequently asked questions on just transition.* https://www.ilo.org/global/topics/green-jobs/WCMS_824102/lang--en/index.htm

Kelly, S. (2023). The *economics of four future electricity system pathways for New Zealand.* https://pce.parliament.nz/media/lnrayjcz/the-economics-of-four-future-electricity-system-pathways-for-new-zealand-kelly.pdf

Luo, T., Cheng, Y., Falzon, J., Kölbel, J., Zhou, L., Wu, Y., & Habchi, A. (2023). A framework to assess multi-hazard physical climate risk for power generation projects from publicly-accessible sources. *Communications Earth & Environment*, 4(1), 117. https://doi.org/10.1038/s43247-023-00782-w

McKinsey. (2023). *Global energy perspective 2023.* https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2023

Miller, A. (2020). *Economics of utility-scale solar in Aotearoa New Zealand.* https://www.mbie.govt.nz/assets/utility-scale-solar-forecast-in-aotearoa-new-zealand-v3.pdf

Ministry for the Environment. (2018). *Climate change projections for New Zealand.* https://environment.govt.nz/publications/climate-change-projections-for-new-zealand/

Ministry for the Environment. (2022). *Aotearoa New Zealand's first emissions reduction plan.* https://environment.govt.nz/assets/publications/Aotearoa-New-Zealands-first-emissions-reduction-plan.pdf

Ministry for the Environment. (2022). *Aotearoa New Zealand's first national adaptation plan.* https://environment.govt.nz/publications/aotearoa-new-zealands-first-national-adaptation-plan/

Ministry for the Environment. (2024). *Coastal hazards and climate change guidance.* https://environment.govt.nz/publications/coastal-hazards-and-climate-change-guidance/

Ministry of Business, Innovation and Employment. (2019). *A vision for hydrogen in New Zealand: Green paper.* https://www.mbie.govt.nz/dmsdocument/6798-a-vision-for-hydrogen-in-new-zealand-green-paper

Ministry of Business, Innovation and Employment. (2023). *Gas transition plan.* https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-strategies-for-new-zealand/gas-transition-plan/

Ministry of Business, Innovation and Employment. (2023). *Strengthening national direction on renewable electricity generation and electricity transmission: Consultation document.* https://www.mbie.govt.nz/dmsdocument/26387-strengthening-national-direction-on-renewable-energy-generation-and-electricity-transmission-consulation-doc-pdf

Ministry of Business, Innovation and Employment. (2024). *Energy in New Zealand.* https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/energy-in-new-zealand/

New Zealand Infrastructure Commission. (2021). *Sector state of play*: Energy. https://tewaihanga.govt.nz/our-work/research-insights/sector-state-of-play-energy

NIWA. (2016). *Our future climate New Zealand.* https://ofcnz.niwa.co.nz/#/localCharts

NGFS. (2023). *Scenarios technical documentation.* V4.1. Network for Greening the Financial System, Paris, France.

NZ Sea Rise Programme. (2023). *Maps.* https://www.searise.nz/maps-2

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok., K., Levy, M., & Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change.* https://doi.org/10.1016/j.gloenvcha.2015.01.004

Purdie, J. (2022). Modelling climate change impacts on inflows, lake storage and spill in snow-fed hydroelectric power catchments, Southern Alps, New Zealand. *Journal of Hydrology (NZ).* 61 (2), 151-178. https://deepsouthchallenge.co.nz/wp-content/uploads/2022/11/623971_ef9aaa8b8f434a0da2bc175892b6c2ec.pdf

PwC UK. (2023). *Net zero economy index 2023.* https://www.pwc.co.uk/services/sustainability-climate-change/insights/net-zero-economy-index.html

PwC Global. (2023). *Why energy companies need to innovate value chains now.* https://www.pwc.com/gx/en/issues/esg/the-energy-transition/why-energy-companies-need-to-innovate-value-chains-now.html

PwC New Zealand. (2024). *National impact study: New Zealand offshore wind industry.* https://www.pwc.co.nz/industry-expertise/energy-and-utilities/new-zealand-offshore-wind-industry-national-impacts-study.html

Reeve, D., Comendant, C., & Stevenson, T. (2020). *Distributed energy resources: Understanding the potential.* https://srgexpert.com/resource/distributed-energy-resources-understanding-the-potential/

Riahi, K., van Vuuren, D.P., Kriegler, E., Edmonds, J., O'Neill, B.C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O., Lutz, W., Popp, A., Cuaresma, J.C., KC, S., Leimbach, M., Jiang, L., Kram, T., Rao, S., Emmerling, J., …& Tavoni, M. (2017). The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change, 42,* 153-168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Stats NZ. (2022). N*ational population projections: 2022(base)-2073.* https://www.stats.govt.nz/assets/Uploads/national-population-projections-2022base-2073.xlsx

Task Force on Climate-Related Financial Disclosures. (2017). *The use of scenario analysis in disclosure of climate-related risks and opportunities.* https://www.fsb-tcfd.org/publications/final-implementing-tcfd-recommendations/

The Aotearoa Circle. (2022). Low *carbon Aotearoa: Energy roadmap to 2030.* https://www.theaotearoacircle.nz/low-carbon-energy-roadmap

Treasury New Zealand. (2023). *He Ara Waiora: Brief overview.* https://www.treasury.govt.nz/node/14759

Treasury New Zealand. (2023). *Assessing climate change and environmental impacts in the CBAx tool.* https://www.treasury.govt.nz/sites/default/files/2023-12/cbax-tool-climate-environmental-impacts.pdf

Transpower. (2020). *Whakamana i te mauri hiko: Empowering our energy future.* https://www.transpower.co.nz/about-us/our-strategy/whakamana-i-te-mauri-hiko-empowering-our-energy-future

Transpower. (2023). *Transmission planning report 2023.* https://www.transpower.co.nz/our-work/industry/transmission-planning

Wiek, A., Keeler, L. W., Schweizer, V. J., & Lang, D. J. (2013). Plausibility indications in future scenarios. *International Journal of Foresight and Innovation Policy, 9*(2/3/4), 133-147. https://doi.org/10.1504/IJFIP.2013.058611

World Energy Council. (2022). *World energy trilemma index 2022.* https://www.worldenergy.org/assets/downloads/World_Energy_Trilemma_Index_2022.pdf?v=1707998024

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