The Aotearoa Circle

Mā te Kaitiakitanga ko te Tōnuitanga
Prosperity Through Guardianship

Transport Sector
Climate Change Scenarios

Foreword

As the cliché goes, Aotearoa is a nation of travellers. It is part of our identity – all our ancestors travelled to be here. Our association with travel is forged from necessity and geography. We are a long country, a series of islands with a sparse and widely distributed population. We are a trading nation that is a long way from our markets.

So transportation is key to both our wellbeing and sustainable prosperity. It is a requirement for migration, for community cohesion, for food distribution and for the provision of other essential goods and services.

We have had many reminders of our dependencies and vulnerabilities in recent years. Floods, cyclones and geopolitical factors such as the price of oil have helped reveal the weaknesses in our transportation systems. We already bemoan the state of Auckland traffic, the cancelled inter-island ferries or the rising costs of flying. It is not hard to see how much worse things can be if we are hit by more extreme weather, greater population pressures, the rising cost of resources and lack of access to insurance or capital.

This report lays out several possible futures for our transport sector. Some of the scenarios you will read here are challenging. Some may contain elements which seem hard to believe at first, but all are based in a rigorous process of exploration, consideration and discovery, driven by a thoughtful team at KMPG and with contributions from a variety of thought-leaders in the varying parts of our transport sector.

Challenge is important. If we do not consider the worst case scenario, how can we prepare to avoid it or brace ourselves for its impacts? As KPMG Partner Alec Tang says, when you read this report “suspend your disbelief. Challenge your assumptions and your mental models that have largely been shaped by a world that no longer exists.”

I want to thank the KPMG team and everyone who contributed so substantially to this report. We hope its division into two parts will make it useful to all. For sustainability professionals, finance teams and other technical experts who need to understand and use the scenarios, the second part of this report has a level of detail which will assist you to develop your own work and approaches in your climate reporting. These detailed scenarios will help ensure that your strategy and business models are adequately tested for resilience, as per the XRB guidance.

> “Suspend your disbelief. Challenge your assumptions and your mental models that have largely been shaped by a world that no longer exists.”
>
> **Alec Tang,** KPMG

For executive teams and others in leadership roles who simply want to understand the future of transport in Aotearoa New Zealand, the scenarios, data and assessments in the front section will give you much to think about.

And everyone who reads it, my request to you is that you treat it as a call to action. Only by acting now can we attain true resilience as a nation and ensure sustainable prosperity for Aotearoa.

Vicki Watson
CEO, The Aotearoa Circle

Contents and navigation

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This report is split into two sections with different users in mind. Section 1 is intended as a quick reference for decision-makers within the transport sector, containing an introduction and context for the work, as well as an abbreviated overview of the scenarios. Section 2 contains longer, in-depth scenario narratives across different sub-sector elements, and is designed for Climate Reporting Entities (CREs) to use as a tool for their External Reporting Board (XRB) Climate Standard aligned entity-level scenario analysis.

Table of figures

Acronyms and abbreviations

AI	Artificial Intelligence
AR	Augmented Reality
CCC	He Pou a Rangi Climate Change Commission (Aotearoa New Zealand)
CO_2	Carbon Dioxide
CRE	Climate Reporting Entity
ETS	Emissions Trading Scheme
EV	Electric Vehicle
(e)VTOL	(Electric) Vertical Take-Off and Landing craft
GDP	Gross Domestic Product
ICE	Internal Combustion Engine
IEA	International Energy Agency
IMO	International Maritime Organization
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISSB	International Sustainability Standards Board

MfE	Ministry for the Environment Manatū Mō Te Taiao (Aotearoa New Zealand)
NGFS	Network for Greening the Financial System
NGO	Non-Governmental Organisation
NIWA	National Institute of Water and Atmospheric Research Taihoro Nukurangi (Aotearoa New Zealand)
NZ CS 1	New Zealand Climate Standard 1
OECD	Organization for Economic Cooperation and Development
RCP	Representative Concentration Pathway
R&D	Research and Development
SAF	Sustainable Aviation Fuel
SSP	Shared Socio-economic Pathway
TCFD	Taskforce on Climate-Related Disclosures
tCO_2e	Tonnes of Carbon Dioxide Equivalent
XRB	Te Kāwai Ārahi Pūrongo Mōwaho External Reporting Board (Aotearoa New Zealand)
3D/4D	Three-dimensional/Four-dimensional

SECTION 1

Scenarios overview

Introduction

Context and objectives

Background

This work was commissioned by The Aotearoa Circle with the primary objective of developing a set of sector-level climate scenarios that individual climate reporting entities (CREs) operating within and adjacent to the transport sector could draw from to inform their scenario-based risk and opportunity analysis.

As such, the scenarios set out in this report explore how climate change, and our choices on how and when to take action on reducing emissions and adapting to climate impacts, might impact the transport sector in Aotearoa New Zealand. They are not predictions nor should they be interpreted as recommended policy, decarbonisation and/or adaptation pathways. They are intended to provide a broad perspective on what the future might hold, to enable businesses to identify climate-related risks and opportunities, and to test the resilience of the business models.

It is however recognised that the outputs of the work could also be of value to a broader range of audiences, beyond those seeking to comply with mandatory reporting requirements, such as policy makers, industry bodies, strategic decision makers, and local communities. The primary purpose of the scenarios, as a tool to inform scenario-based risk and opportunity analysis, should however be kept front of mind when reading, reflecting on, and applying these scenarios.

Aims and objectives

These scenarios have been co-developed in workshops by people representing many different parts of the transport sector. They reflect the collective imagination and knowledge shared by participants, not individual views or beliefs. The development of these scenarios have required participants to look beyond the confines of business-as-usual thinking and challenge the assumptions that underpin their own, and our collective, mental models.

Our shared aims were:

- To develop a common vision of what the transport sector in Aotearoa New Zealand could look like under different climate change futures.
- To develop a set of sector climate scenarios aligned with External Reporting Board (XRB) Climate Standards, that may be used as a tool for producing the entity-level scenario analysis for mandatory or voluntary disclosures, as well as for broader climate risk assessment and planning.
- To translate global and national meta-level scenarios and pathways into locally-relevant, qualitative outcomes for the transport sector.
- To provide participants with the knowledge and skills to engage with their own organisations and stakeholders on the critical decisions that are needed for a resilient and sustainable future.

Overview of climate-related scenarios

Scenarios enable organisations to explore hypothetical and plausible futures across a range of uncertain outcomes. They can help organisations make decisions about how to influence the best and prepare for the worst of those potential outcomes.

The XRB defines a climate-related scenario as:

> "A plausible, challenging description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces and relationships covering both physical and transition risks in an integrated manner." [1]

Climate-related scenarios are not predictions or forecasts, but a storyline of how the future might evolve to reach a particular temperature outcome. Scenarios explore the potential changes to our climate and natural hazards, and the changes to greenhouse gas emissions, regulation, technology, and social norms that might be a part of the mix required to reach a temperature outcome.

To align with XRB requirements, the scenarios used explore futures including:

- a +1.5˚C warming climate-scenario;
- a +3.0˚C warming climate-scenario; and
- a third climate-related scenario[1].

These scenarios are designed to be challenging

The Financial Markets Authority[2] note that: "To be challenging, assumptions should confront conventional wisdom and simplistic understandings of today's environment. When thinking about the major sources of uncertainty, scenarios should explore assumptions that will significantly alter the basis for business-as-usual thinking. Scenarios should consider exploring the upper bounds of what is plausible within the architecture of each climate-related scenario by exploring more severe or confronting potential events that could play out in the future" (for example exploring a +1.5˚C scenario, despite the real-world misalignment to this goal currently). The XRB note that the implications of scenario analysis for entities' business models and strategies should be "profound and of critical strategic relevance to the entity"[1]. This challenge is especially important given that climate science may be moving more slowly than climate change, with the real world impacts of even the current +1.5˚C warming more severe than anticipated[3].

What these scenarios are not

- These scenarios are not rigid predictions, nor do they assume greater likelihood of any one outcome. They are designed to prompt thought and conversation about how climate change could affect our future.
- These scenarios are not a roadmap for transition or adaptation for the sector, nor are they intended as recommendations for action for any individual entity.
- They are not policy recommendations for central, regional or local government, or for regulators.
- They are not scenarios for the infrastructure or energy sectors, although they should interface and seek to promote alignment within these sectors due to the extensive interdependencies.

See the Technical Guide for more detail on process, design decisions, participants, limitations and sources.

[1] *XRB, 2023. Aotearoa New Zealand Climate Standard 1 (NZ CS 1). [Online] Available at: https://www.xrb.govt.nz/dmsdocument/4770 (Accessed May 2024)*
[2] *Financial Markets Authority, 2023. Information sheet: Climate-related Disclosures – Scenario analysis. [Online] Available at: https://www.fma.govt.nz/assets/Guidance/Climate-Related-Disclosure-Scenario-analysis-information-sheet.pdf (Accessed May 2024)*
[3] *IPCC, 2023. AR6 Synthesis Report: Climate Change 2023. [Online] Available at: https://www.ipcc.ch/report/sixth-assessment-report-cycle/ (Accessed June 2024)*

Considerations and inherent limitations

Climate scenarios have inherent limitations, such as:

- **Uncertainty:** Scenarios are based on assumptions about the future, and the future is intrinsically uncertain. Moreover, the speed at which climate-related impacts are evolving is unprecedented and little reliance can be placed on historical experience to assess their magnitude, timing, or how different climate-related forces might interact. This gives rise to a higher level of uncertainty. If warming-related 'tipping points' in the Earth system are reached (i.e. small changes create reinforcing loops that 'tip' a system from one stable state into a profoundly different state), certainty in assumptions falls, and it is likely that physical risk predictions become 'best case' scenarios longer term.
- **Simplification:** Even the most complex scenarios are highly simplified representations of profoundly complex systems. They cannot capture all the nuances and interdependencies of the real world, and they may overlook important forces that can have a significant impact on the future.
- **Bias:** Scenarios are influenced by the assumptions and biases of the people that develop them. Different participants may develop different scenarios based on their own perspectives and assumptions.
- **Over-reliance:** Scenarios are useful tools for exploring different futures, but they should not be over-relied upon. They are just one of many tools that can help inform decision-making, and they should be used in conjunction with other methods and sources of information.

In addition to these inherent limitations, the nature of these sector-level climate scenarios, which are designed to help inform the entity-level scenarios that organisations might use to identify climate-related risks and opportunities, as well as the project scope, timing, and availability of participants, create additional considerations and limitations for readers and users of these scenarios, including:

- **Downscaling:** These sector scenarios are based upon information from existing global and Aotearoa New Zealand-specific climate-related scenarios and models, that have been explored in a qualitative way at the national level. These sector scenarios have not been 'built from the ground up' using entity or asset level data or insights. The global and Aotearoa New Zealand-specific climate-related scenarios were chosen because as a set, they broadly cover the spectrum of physical and transitional climate impacts that the transport sector might plausibly face under different future pathways. The actual pathway that emerges will likely be much more complex than the sector scenarios are able to convey.
- **Source Information:** Climate science and modelling is continuously evolving, and there is ongoing work to downscale global data to an Aotearoa New Zealand context. As such, it is recognised that there are data currency limitations in these scenarios. In order to support the accessibility and utility of these scenarios to a broad range of users, a reliance has been placed on publicly-available datasets that are coherent with the scenario architectures, even where more up-to-date, but potentially less coherent, data is know to be available or imminent. The data set out within these sector scenarios, and the associated assumptions, should be used as an input to developing credible, hypothetical scenarios and not as projections or forecasts. *For detailed descriptions of these data limitations, see Appendices E, F and G.*
- **Sector representation:** These scenarios reflect the cumulative efforts of a diverse group of participants brought together for this work. However, the timeframes and requirements of the project meant that not all parts of the sector were able to be involved in the scenarios' development, which has influenced the depth of narratives for some aspects relative to others. It is however broadly recognised that the tailoring of sector-level scenarios to the entity level requires the addition of more granular, entity-relevant information which can supplement any such imbalances.
- **Māori:** Engagement with Māori organisations, individuals or use of te ao Māori concepts or Mātauranga Māori was limited. As such, we chose to not attempt to integrate te ao Māori concepts into this report, as we felt doing so in the absence of broad and genuine engagement would not have been authentic or appropriate.
- **Rural communities:** Whilst the project process included a specific workshop focused on future pathways and outcomes for rural transport, there was limited representation from local government in rural regions within the project participants, and no direct engagement with rural or remote community groups throughout this process.
- **Granularity of analysis:** Participants in this process covered a wide range of land, air, and sea-based modalities. However, given the complexity of the transport system, and scope of this project, our report is focused on providing a high level overview of potential key trends across the transport sector, rather than a detailed analysis of specific aspects, such as mode, vehicle, fuel types, resource availability, or location-specific physical risks impacts (which will vary considerably across Aotearoa New Zealand).
- **Detailed impact and outcome analysis:** Sector scenarios explore how high level, exogenous driving forces could plausibly shape the sector under distinct climate futures. This report is not intended to identify specific risks, opportunities and/or outcomes for organisations, communities or individuals in their engagement with the transport sector. The next step for entities using these scenarios for either XRB-aligned analysis, or as a strategic tool, is to tailor the scenarios to their particular needs, and then explore detailed, relevant risks, opportunities and/or outcomes.

Developing these scenarios

How these scenarios were developed

Aotearoa New Zealand's transport sector climate scenarios were convened by The Aotearoa Circle with KPMG New Zealand acting as the Secretariat. The project was led by representatives from 15 organisations covering various elements of the transport sector who formed the 'Working Group'.

Scenario design decisions and narrative developments took place during a series of workshops from August 2023 to May 2024 with this group. Outputs were socialised with a 'Wider Interest Group' of around 19 organisations from various sectors for input. Finally, a series of workshops were used to gather input from distinct groups both within and outside of the transport sector, such as ports, airports, and participants in the parallel energy sector scenario development process.

Transport sector climate scenarios Working Group members:

Aaron Saunders
Chief Financial Officer, Turners Automotive Group

Abbie Bull
Head of Sustainability and Community, Z Energy

Alex Baker
Director Sustainability, Kāinga Ora – Homes and Communities

Billie Moore
Chief Executive Officer, New Zealand Airports Association

Dawn Baggaley
Group Sustainability Manager, New Zealand Post

Juhi Shareef
Chief Responsibility Officer, Tourism Holdings Limited

June Gibbons
Group Manager, People Process and Technology, Colonial Motor Group

Lucy Hawcroft
Sustainability Manager (acting), Kiwirail

Moana Mackey
Chief City Planner, Wellington City Council

Rebecca Dearden
Sustainability Lead, MOVE Logistics

Stephen Deschamps
Chief Financial Officer, Freightways

Waning Chua
Director, Sustainability and Climate Change, Aurecon

A number of staff from the following organisations also contributed to the Working Group:

Te Kāwai Ārahi Pūrongo Mōwaho External Reporting Board (XRB)

Te Manatū Waka Ministry of Transport (MoT)

NZ Transport Agency Waka Kotahi (NZTA)

A full list of participants in the Working Group and Wider Interest Group can be found in Appendix I.

Sector scope – *defining our boundaries*

The complexity of the transport system, with its many actors, modes, and dependencies on aspects such as spatial planning, infrastructure, and energy, made detailed exploration of all elements within its 'value chain' impractical.

For the purposes of these scenarios, a simplified model of the transport system was used to focus discussion. This was based on four major components: System Managers and Shapers; Users; Operators and Suppliers; and the Physical System. Inputs to the system were assessed, such as workforce, and resources. Then, the impact that climate change may have on the transport sector's ability to directly or indirectly influence socio-economic and environmental outcomes was explored.

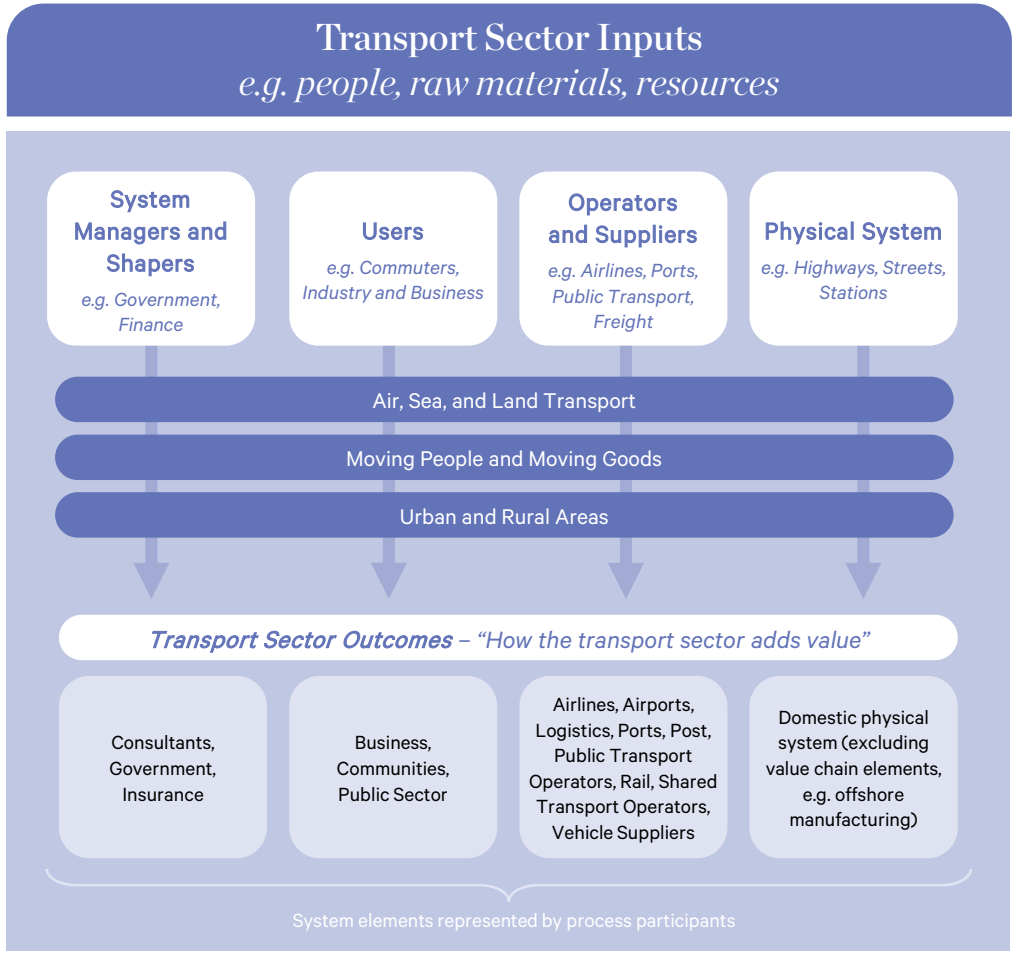
Adjacent Sectors

Adjacent sector dependencies such as infrastructure and urban development were discussed. For scope reasons, the project made assumptions about their impact on the transport sector rather than scrutinising these issues in depth. Where available and relevant, existing sector scenarios were used to inform these assumptions. Where there were gaps, logical assumptions were made. As the transport and energy sector climate scenarios were developed during the same time period, both working groups collaborated at multiple points to align key assumptions and keep the narratives materially consistent where possible.

Figure 1: Scope of transport sector climate scenarios

In scope

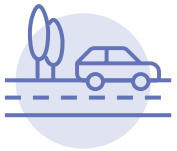
Direct exploration through scenario process



Out of scope

Assumptions made about impact on transport

Transport sector subsystems



Land

Covers public and private road, pavement, and rail-based passenger and freight transport and mobility. This includes the light fleet (e.g. cars), light commercial vehicles (e.g. vans), heavy fleet (e.g. trucks), public transport (e.g. buses), on-demand and ride-sharing platforms, active mobility (e.g. walking), enhanced and micromobility (e.g. e-bikes).
Does not include off-road vehicles.

Air

Covers passenger and freight aviation across domestic and international routes. The main focus is on commercial aviation, covering short- and long-haul international flights and regional air travel across Aotearoa New Zealand, with a lesser focus on general aviation.
Does not include military aviation.

Sea

Covers international and domestic shipping of goods, as well as domestic passenger services like ferries. The focus is on export and import shipping, but includes domestic coastal shipping.
Does not include international passenger shipping.

To provide some structure to the scenarios, focus narratives, and guide readers, the transport sector was divided into basic subsystem elements.

While there are multiple grouping options, these subsystems were formed based on their 'nature of movement' in terms of both distance, duration and frequency. Given the purpose of these scenarios is to provide a high level overview of key pathways and outcomes across the entire transport sector, the granularity in narratives for each element is fairly low. This detail and specificity can be developed when the sector scenarios are 'tailored' to support entity-level scenario analysis. These subsystems provide rough guides, and the descriptions are not intended as an exhaustive list.

Moving People

The movement of people across the land-, sea-, and air-based public and private transport sectors, as well as personal mobility options. Includes 'virtual' modes that may alter traditional concepts of mobility (e.g. metaverse)

Moving Goods

The movement of goods by the freight sector across land, sea, and air, and the inter-modal connections between these network elements. Includes 'virtual freight' technologies (e.g. 3D and 4D printing).

Urban

Includes public, private, and personal mobility, as well as freight movement, within Aotearoa New Zealand's metropolitan areas (e.g. Auckland, Christchurch, Wellington, Hamilton, Tauranga, and Dunedin), and large regional centres (e.g. New Plymouth, Palmerston North).

Regional, Rural and International

Includes public, private, and personal mobility, as well as freight movement, within medium regional centres (e.g. Queenstown, Taupō), rural and isolated communities. Also includes interregional and rural trips across Aotearoa New Zealand and international travel and freight to and from Aotearoa New Zealand.

Scenario narrative process

Developing qualitative scenarios

Aligned with guidance from the Taskforce on Climate-Related Financial Disclosures (TCFD) and the XRB, these scenarios are qualitative and explore complex system dynamics in an accessible way, underpinned by globally recognised quantitative climate models. The XRB state:

> "It is important to first prepare a qualitative narrative reflecting a sector's common understanding of the risks and opportunities." [1]

The XRB emphasise taking an exploratory mindset[2] to scenario analysis given the uncertainty posed by climate change. These scenarios used a clear evidence base to explore 'driving forces', which the XRB defines as:

> "broad scale external factors which influence the direction of future change." [1]

XRB guidance notes that "understanding which driving forces will have the greatest influence in shaping outcomes for the sector and related entities is an essential step in creating climate-related scenarios"[1]. Participants explored which driving forces had the greatest influence on the transport sector, and were most affected by climate change in uncertain ways under different scenario assumptions.

Driving forces are the external factors through which change happens, and are themselves neutral. The change they create can result in risks and/or opportunities for organisations within the sector, based on their unique business models and strategies.

More information on the scenario development process and driving forces can be found in the Technical Appendix.

[1]XRB, 2023. Staff Guidance Sector scenario development. [Online] Available at: https://www.xrb.govt.nz/dmsdocument/4532/ (Accessed May 2024)
[2]XRB, 2023. Aotearoa New Zealand Climate Standard 1 (NZ CS 1). [Online] Available at: https://www.xrb.govt.nz/dmsdocument/4770 (Accessed May 2024)
[3]IFRS, 2023. S2 Climate-related Disclosures. [Online] Available at: https://www.ifrs.org
[4]IFRS, 2023. Basis for Conclusions on Climate-related Disclosures. [Online] Available at: https://www.ifrs.org

Transport sector driving forces

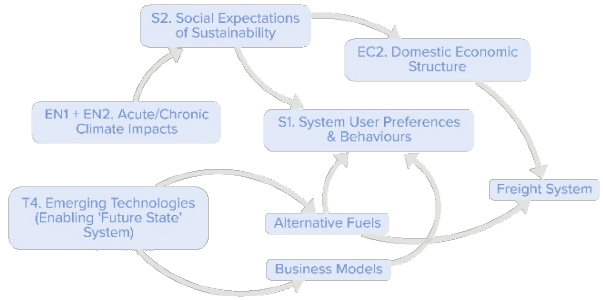
The driving forces were grouped using the PESTLE Framework. The below drivers represent the 'critical uncertainties' that were explored to create the scenario narratives (other more certain 'baseline forces' were also used).

Figure 2: List of drivers classified as 'critical uncertainties'

Political *How domestic and international political policy, sentiment, and future relations affect or may affect policy and legislation for the transport sector.*	P1. Domestic political leadership and ambition P2. Government funding and investment P4. Carbon taxes/markets (domestic and international) P5. Transport-specific legislation P6. Sector-adjacent legislation P7. International ambition
Environmental *How climate-related acute and chronic impacts affect the transport sector both directly and indirectly.*	EN1. Chronic climate impacts EN2. Acute climate impacts EN3. Natural resources
Social *How demographic and political trends, as well as beliefs or values, change over time/geographies and affect transport choices.*	S1. System user preferences and behaviours S2. Social expectations of sustainability S3. Demographics S6. Social expectations of health and wellbeing
Technological *How new and emerging technologies can affect transport business models, strategies, and value chains.*	T1. Availability and accessibility of new technology T2. Enabling ecosystem for technology T4. Emerging technologies
Legal *How laws, regulations, and legal systems can affect the transport sector.*	L1. Government action on climate laws
Economic *How macro and micro-economic conditions, trend, and actors can affect the transport sector and its operating environment.*	EC2. Domestic economic structure EC3. Commodity prices EC4. Access to finance EC6. Global macroeconomic conditions EC7. Global market alignment

Driver impact pathways

During workshops, participants explored how these 'critical uncertainties' might plausibly evolve under each scenario, and how they might impact upon the transport sector and one another to create outcomes. These logical cause-and-effect interactions are the 'impact pathways' that form the basis of the scenario narratives, for example:



Qualitative vs quantitative scenarios

Some readers may be more familiar with quantitative climate scenarios, which try and model anticipated financial or economic impacts. Whilst the transport sector climate scenarios include quantified information, and all driver pathways were founded on research, the XRB encourage "starting out qualitatively and building quantification and sophistication over time on scenario analysis". The International Sustainability Standards Board (ISSB) state that whilst "quantitative information will often enable an entity to carry out a more robust assessment of its climate resilience... qualitative information (including scenario narratives), either alone or combined with quantitative data, can also provide a reasonable and supportable basis for the entity's resilience assessment"[3], and that an entity is "required to use an approach to climate-related scenario analysis that is commensurate with its circumstances."[4] The scenario architecture and quantitative data used in these scenarios enables organisations to integrate them with scenario analysis under an alternative reporting regime like ISSB.

Overview of scenarios

Introducing our scenarios

This scenario set is intended to explore the potential range of physical and transition impacts that the transport system could face under different futures.

- The first – **Bypass to Breakdown** – is designed to explore how Aotearoa New Zealand and the transport sector might take an adaptation-focused strategy, and the subsequent resilience of the system to high physical climate risks in the long term (2041-2050) as emissions reduction efforts falter globally. The extension of this scenario takes the time horizon from 2051-2100.
- The second – **Short Detour** – is designed to explore the impact of a delayed, rapid, but less aligned transition that is highly disruptive in the medium term (2031-2040).
- The third – **Fully Charged** – explores the transport system's readiness to globally-aligned, swift, but still disruptive, decarbonisation starting in the short term (2025-2030).

Bypass to Breakdown extension scenario

An extension scenario was developed to extrapolate the Bypass to Breakdown scenario beyond the 'long term' 2050 time horizon used across other scenarios. This scenario was selected for extension out to 2100 in order to explore the physical climate risk factors that are particularly pertinent to long-lived transport assets (e.g. roads, ports) and are prevalent under higher temperature outcomes, but which are only really distinct from the other scenarios after 2050.

	GLOBAL TEMPERATURE RISE BY 2100[1]
SCENARIO 1 **Bypass to Breakdown** *Aotearoa New Zealand prioritises an adaptation strategy to build climate resilience. Global emissions reduction policies and investment falter, and current socio-economic trends continue, resulting in +2.1°C global warming by 2050 and more than +3.9°C by 2100 in a 'hot house world'.*	+3.9°C
Extension *Explores the physical climate impacts in the Bypass to Breakdown scenario from 2051-2100. Temperatures reach +3.9°C, and 'tipping points' in the Earth climate and ecological systems are breached.*	
SCENARIO 2 **Short Detour** *Meaningful global action on decarbonisation is delayed until the early 2030s, followed by a sudden and globally uncoordinated economic transformation. Extensive and stringent government intervention both in Aotearoa New Zealand and overseas limits global warming to +1.7°C by 2100, but with higher socio-economic costs.*	+1.7°C
SCENARIO 3 **Fully Charged** *An ambitious and globally coordinated transition to a low emissions future accelerates through the 2020s. Strong climate policies, innovation, targeted investment, and social change cause disruption, but limit global warming to a temporary overshoot of +1.6°C by 2050, with carbon capture used to dial temperatures back to +1.4°C by 2100.*	+1.4°C

[1] IPCC, 2021. Summary for Policy Makers. [Online] Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf [Accessed March 2024].

Key scenario characteristics

Climate scenarios explore integrated physical and transition climate-related impacts.

Physical impacts include the changing frequency and intensity of acute events (e.g. cyclones, floods, wildfires), and longer term chronic changes in the Earth system (e.g. sea level rise, changing precipitation patterns). Transition impacts are those arising from the shift to a low carbon, climate resilient economy, such as policy changes.

Figure 3 represents the integrated physical and transition climate-related impacts the transport system may face under each scenario. The physical impact profiles of our three scenarios are relatively similar out to 2050. Each scenario has the following impact pathway profile:

- **Bypass to Breakdown** – whilst transition impacts rise slowly, physical impacts steadily grow and then increase after 2050 as temperature rises accelerate due to unabated emissions. 'Tipping points' are reached in the Earth system, locking in change, and physical impacts rise exponentially out to 2100. A late panic and drive for decarbonisation mid-century creates high transition impacts. This scenario has the highest overall exposure to climate-related disruption.
- **Short Detour** – transition impacts are very high in the 2030-40s as society rushes to decarbonise. These impacts are compounded by transitioning during a decade when physical impacts are greater than in the 2020s, creating higher exposure compared to the Fully Charged scenario.
- **Fully Charged** – transition impacts are high in the short term (2025-2030) causing disruption, but the early action means society and the economy adjust during the mid to late 2030s and 2040s, with physical impacts declining in the long term. This scenario has the lowest exposure to disruption.

Figure 3: Integrated physical and transition climate-related impacts across scenarios and time horizons

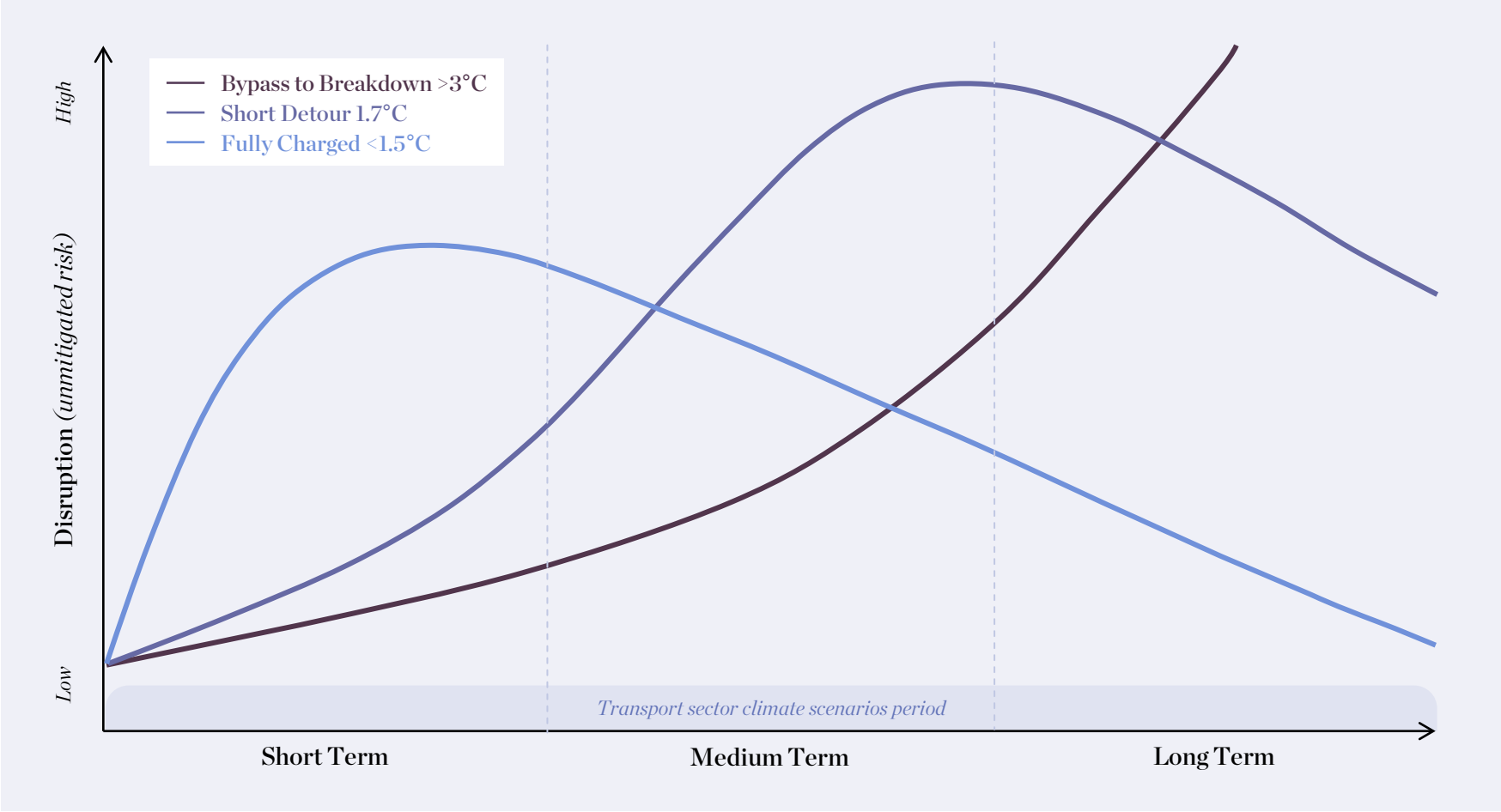


Figure 4: Key scenario characteristics

Scenario	Bypass to Breakdown	Short Detour	Fully Charged
Temperature increase by 2100 *Global avg, vs pre-industrial baseline*	3.9°C	1.7°C	1.4°C
Severity of physical climate impacts	Highest – 'tipping points' in the Earth climate and ecological systems breached	Low to moderate	Lowest
Severity of transition-related impacts	Lowest (steadily increasing, but also giving businesses more time to adapt)	Highest (greatest in medium term)	Moderate (greatest in short term)
Global Policy reaction	Insufficient	Delayed	Immediate and smooth
Domestic Policy reaction	Adaptation focused policy	Delayed, more stringent, and more varied mitigation policy	Coordinated, planned and strong mitigation policy
Speed of technology change	Slow adoption of low carbon fleet and fuel, but faster adoption of other technology (e.g. AI, 3D and 4D printing)	Slow, then fast with less variation in low carbon fuel and fleet options	Fast, but with higher variation in fuel and fleet options
Energy Profile	Slow development of domestic renewable supply. Reliance on increasingly expensive and unstable fossil fuel imports.	Delayed increase in renewable energy, with more decentralised production. More reliance on imported low carbon alternative fuels, and some continued use of highly expensive fossil fuels.	Early increase in renewable energy capacity, and more domestic production of low carbon alternative fuels reduces exposure to volatile global fuel markets.
MOVING PEOPLE			
Urban Mobility	Investment in roading-focused transport network and lack of upzoning means private vehicle use remains the norm in cities, leading to higher levels of congestion and worse social outcomes. Public and shared mobility are less affordable or desirable, and unevenly distributed. Technology is deployed for adaptation to extreme weather events. Urban land use is a mix of high and low density.	Public, shared, and active transport investment is initially slow, then accelerates. Lower urban density and less integrated land use-transport planning requires more stringent interventions to reduce private vehicle use and emissions, creating difficult social outcomes and a less equitable mobility system. There is lower levels of active mobility, but the urban light vehicle fleet has mostly electrified.	There is significant early investment in, and use of, public, shared and active mobility options. Higher urban density and integrated land use-transport planning see short to medium urban trips in private vehicles notably decline. Urban vehicles are electric, smaller, and highly utilised. There is widespread use of active mobility, with more equal transport-related social outcomes.
Regional, Rural and International Mobility	Focus on adaptation of road network slows deployment of Electric Vehicle (EV) infrastructure. Light fleet decarbonises slowly, with internal combustion engine (ICE) vehicles becoming progressively more expensive due to insecure supply chains. Road network maintenance eventually experiences regressive financial outcomes, leading to further retreat and connectivity issues.	Delayed, more stringent decarbonisation of the light fleet and high carbon prices increases costs of travel and creates connectivity issues for some communities who lack access to EVs, chargers, or reliable energy supplies. There is more reliance on decentralised energy generation to support rural and interregional transport. Passenger rail electrification and rail network upgrades are delayed, limiting volume growth and reducing multi-modal options for those without private vehicles.	Social support and early investment in the enabling ecosystem for EVs, such as chargers, workforce, and reliable energy supply, accelerates adoption. EVs are seen as viable options even for remote groups. Resource constraints and behavioural change mean the light vehicle fleet is smaller. Investment in passenger rail, rapid ocean-based modes, and vehicle sharing models, mean personal mobility is less reliant on private vehicle ownership, and more affordable.
	Aviation decarbonises slowly and is increasingly impacted by physical risks domestically and overseas, as well as rising fuel costs. Aviation still plays a key role in domestic connectivity with increasing road network impairment, but small airports are commercially unviable.	Aviation experiences shocks to demand from high global carbon prices and social expectations, becoming more reliant on expensive imported sustainable aviation fuel (SAF) which creates higher costs. Domestic air travel remains more expensive for longer as local SAF production belatedly establishes.	Aviation decarbonises effectively, with domestic SAF and alternative fuel production and bunkering, enabling affordable connectivity. Zero-carbon domestic aviation reinvigorates smaller airports and nearby communities.
MOVING GOODS			
Land Freight	Freight is slow to decarbonise, with minimal mode-shift to rail or coastal shipping. Advanced technology is deployed to mitigate physical risks to road networks and disrupted supply chains. Fuel becomes highly expensive longer term.	Rapid decarbonisation leads to high costs and consolidation in the sector. More focus on electrification creates grid capacity issues. Less shift to rail and coastal shipping creates more reliance on road transport. Changing technology and markets disrupt business models, with greater reliance on costly and scarce imported technology, talent, and resources.	Early demand signals and government support enable efficient transition of the heavy fleet, helping to maintain access to carbon-focused export markets. Domestic production of a variety of alternative fuels is established. Higher mode-shift to rail and coastal shipping lowers carbon and builds resilience. Fast changes to technology and markets are met by innovative Kiwi companies who are proactively supported, helping retain talent and technology onshore.
Air and Sea Freight	Air and sea freight is slow to decarbonise, with prolonged reliance on fossil fuels which eventually become highly expensive. Longer term, high temperatures trigger very high physical (and associated economic, political and social) risks globally, causing severe disruption at foreign and even domestic (air)ports, eventually breaching asset and supply chains' adaptive capacity, steeply inflating costs.	Disorderly transition causes high pressure and risks to fuel supply for ports and shipping, with low carbon cargo ships dropping some port calls in Aotearoa due to inability to refuel. Some smaller ports consolidate, focussing physical risks on select locations. Air freight hit hard by carbon prices in 2030s and slow to decarbonise due to costly fuel and fleet.	Early investment in domestic SAF and alternative fuel production reduces longer term exposure to price and supply risks. Higher collaboration between transport, energy, and other sectors around alternative fuels helps maintain access to rapidly decarbonising global export markets.

Transport and energy linkages

Cross-sector collaboration

The Aotearoa Circle commissioned the development of these transport sector climate scenarios at the same time as initiating the development of climate scenarios for the energy 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.

**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 International Institute for Applied Systems Analysis SSP Database, used for inputs, diagnostics and calibration of global climate models. The transport sector climate scenarios draw temperature values from the IPCC's Sixth Assessment Report Working Group I 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.*

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 energy 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 (SSP-RCPs) or global temperature outcomes, there are common themes in scenario narratives in terms of Aotearoa 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.

Figure 5: 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*

Figure 6: 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 and Slow Followers:** Delayed and less well planned transition, greater reliance on imported fuel, equity challenges more pronounced in remote regions. **Short Detour and 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
Domestic 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 risk.	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.
Domestic 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 the short to medium term. Growing uptake of EVs and smart grid solutions. Diverse energy mix.
Domestic low emissions technology and alternative fuel access and use	Less cross-sector collaboration or research and development (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 to 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.
Domestic 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 to 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. internal combustion engine (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.

Bypass to Breakdown

Aotearoa New Zealand prioritises an adaptation strategy to build climate resilience. Global emissions reduction policies and investment falter, and current socio-economic trends continue, resulting in +2.1°C global warming by 2050 and more than +3.9°C by 2100 in a ‘hot house world’.

Overview

Global action on climate change mitigation falters. Despite vocal support and some progress in the 2020s, rising geopolitical conflict and dampened social support see major economies retreat back into economic growth imperatives. The world is heading to over +2.0°C of warming.

Our World

Throughout the 2020s and 2030s, there is heightened geopolitical strain and less collaboration between major economies. Countries increasingly compete to gain geostrategic access to precious resources that are placed under increasing pressure.

Decarbonisation does still occur. However, the pace is slow, and it is mainly as a by-product of national security and resilience concerns. No country wants to commit resources to emission reduction when they are facing climate impacts alongside other economic disruption. Despite rapid technology innovation, large-scale, long term carbon sequestration is still unviable.

Our Home

Aotearoa New Zealand doesn't feel it can take the risk of decarbonising ahead of major markets. Persistent cost of living pressures temper the social and political will to pay the high price of transition.

Reduced international collaboration makes access to climate-related finance, technology, and workforce increasingly expensive for Aotearoa New Zealand.

Instead, society and government focus on climate adaptation strategies, driven primarily by protecting existing assets and economic structures from the physical impacts of climate change. However, as this becomes increasingly unaffordable hard decisions are made, often in the context of emergency recovery.

Transport by 2050

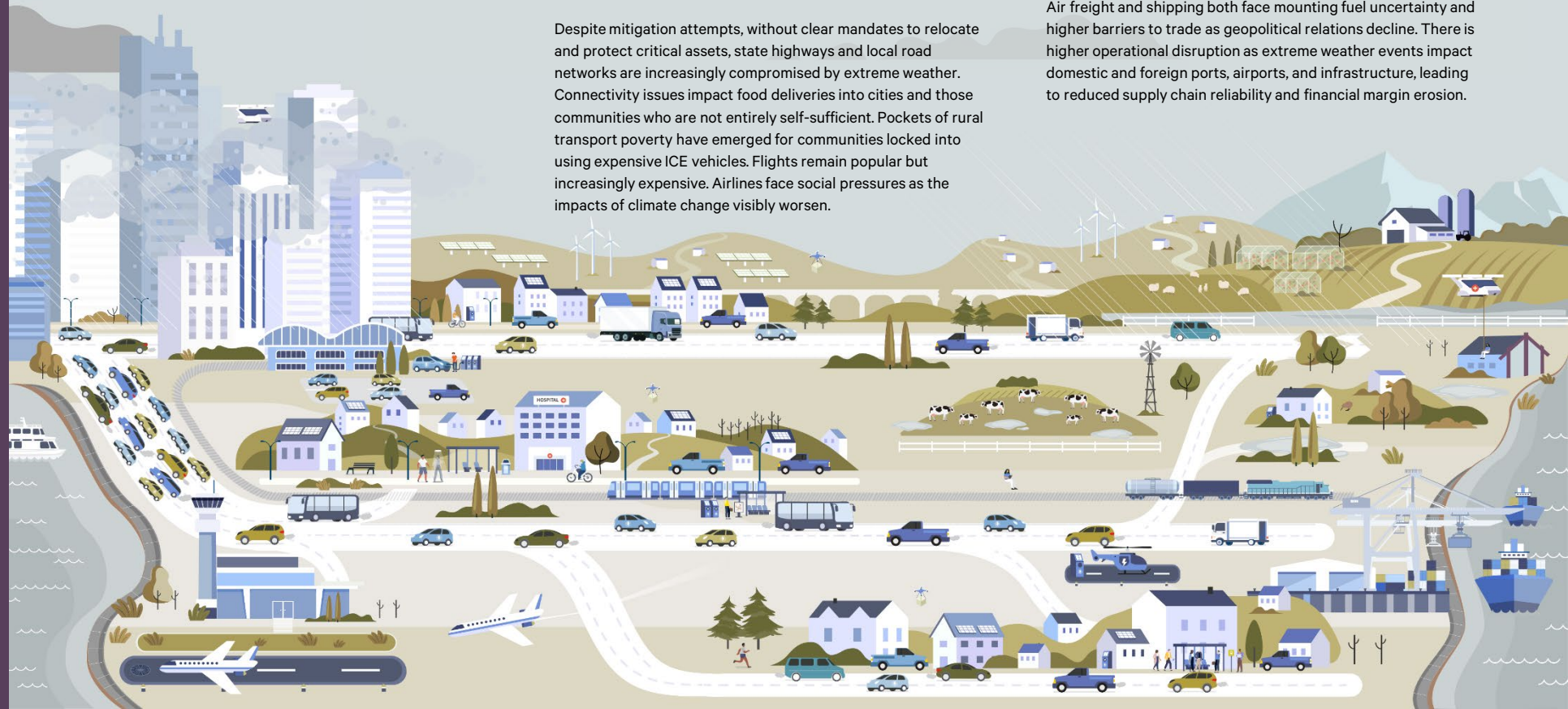
Transport decarbonises slowly, as the focus centres on adaptation and developing climate resilience across the network. Whilst this has reduced transition costs, the system is facing escalating physical climate hazards, such as sea level rise, cyclones, and drought. This causes direct damage to transport assets and services, and influences social and political instability, with growing concerns over food and energy security in a destabilised world.

Moving People. Urban areas are a broad mix of high and low density, with growing populations bolstered by climate migrants. EV uptake has occurred, but many remain reliant on private ICE vehicles and the road network when they need to travel, despite the availability of technology enabled climate-friendly options. Congestion and pollution are growing problems, and disproportionately impact those communities that contribute least to the problem. Investment in infrastructure climate resilience has locked in traditional modes of travel.

Despite mitigation attempts, without clear mandates to relocate and protect critical assets, state highways and local road networks are increasingly compromised by extreme weather. Connectivity issues impact food deliveries into cities and those communities who are not entirely self-sufficient. Pockets of rural transport poverty have emerged for communities locked into using expensive ICE vehicles. Flights remain popular but increasingly expensive. Airlines face social pressures as the impacts of climate change visibly worsen.

Moving goods. The freight network has not fully decarbonised, but has deployed advanced technology to support system efficiency and resilience to physical risks. Preventative drone-based infrastructure maintenance, digital twins, and precise weather forecasting all play a role in a mostly AI-orchestrated network. Freight logistics are increasingly impacted by road and asset damage from extreme weather. Service speed is reducing while prices are increasing in line with rising fuel costs.

Air freight and shipping both face mounting fuel uncertainty and higher barriers to trade as geopolitical relations decline. There is higher operational disruption as extreme weather events impact domestic and foreign ports, airports, and infrastructure, leading to reduced supply chain reliability and financial margin erosion.



Key Indicators – *Bypass to Breakdown*

All figures for Aotearoa New Zealand in 2050 unless otherwise stated

Physical Parameters

Global Temp Change
Average annual temperature vs. pre-industrial baseline

2.1°C

Extreme Heat
Average number of days exceeding 25°C annually

30 days

Extreme Rainfall
% change in depth of 1 in 100 year, 1 hour rainfall event

22%

Sea Level Rise
Average increase in metres from baseline

0.24m

Transport Parameters

Household Person kms Travelled by Mode (%)
● Active ● Public ○ Private

2 | 6 | 92

Freight Mode Shares (%)
● Rail ● Shipping ○ Road

13 | 12 | 75

Road Vehicle kms Travelled by EVs (%)

75%

Domestic Transport Emissions
(Annual $ktCO_2e$)

6,012

Socio-economic Parameters

Renewable Energy Share of Total Final Consumption (%)
Including international transport

39%

Carbon Price
Energy (real NZ$/$tCO_2e$)

$206

Oil Price Increase
% difference, US$ per barrel vs baseline

N/A

GDP
% difference, 2009 prices; local currency vs baseline

-2.7%

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Moving People in 2050, *Bypass to Breakdown*

What does **urban** mobility look like?

Populous, unplanned, and high-tech

Rural-urban and climate-linked migration accelerates into cities as climate impacts displace communities and industries across Aotearoa New Zealand and overseas, especially from the Pacific. Urban form is a haphazard mix of sprawl, some upzoning, and small areas of integrated land use-transport planning, which has made transport emissions reduction harder. Whilst there are developments in more advanced transport technologies like autonomous vehicles and zero carbon, public, and shared modes of transport, these have developed slowly, and are far less utilised than in other scenarios.

Mostly single mode

Private vehicle use is standard. Many are EVs, and trends are for larger cars due to anxieties about climate impacts. The focus on private vehicle use and infrastructure has limited the uptake of public or shared modes in many urban areas, with private ride sharing displacing many public services which struggled to meet social needs. Cycling is still seen as dangerous in many areas due to lack of designated routes. Urban sprawl, and the lack of integrated infrastructure planning and central government funding, mean the costs of developing mode-shifting infrastructure are now prohibitively high for local government. Younger people are adopting more shared-mobility, and new aerial forms of mobility, that enable fast, direct routes above the traffic, prove highly popular for those who can afford it.

Adaptation focus

Cities have developed climate resilience through grey and green infrastructure and by retreating where necessary. Critical infrastructure has been protected against extreme rainfall and heat, often using nature-based solutions, and network AI uses IoT sensors to help re-route demand flows during extreme weather events. New technology that removes the need for physical travel like hologram, virtual robotics, and metaverse technology is now hyper-realistic, and a popular option to avoid extreme weather and congestion. Electric vertical take off and landing (eVTOL) technology is launched in major cities. Despite this, population increases and worsening physical risks strain the system, with successive or extreme events overwhelming the adaptive capacity of local networks, creating delays, expensive repairs, and stress for communities.

Transport inequality

Some communities remain reliant on ICE vehicles that are expensive to maintain and fuel. Congestion, pollution, and space given over to roads and car parks leads to worsening health outcomes, especially for less affluent, inner city neighbourhoods. Crime and disorder, including fuel theft, increasingly hamper transport operators and their workforces. Affluent groups prefer private and often autonomous travel, avoiding public transport.

Moving People in 2050, *Bypass to Breakdown*

What does **regional, rural and international** mobility look like?

Disruption to road network

Despite an organised and well funded adaptation programme, and rerouting away from high risk locations, the mounting physical impacts of climate place high strain on the road network. Escalating costs and weather impacts mean many coastal and local roads are designed to accommodate periodic temporary flooding and slips. Where even this level of resilience isn't feasible, a new 'remote' classification means existing infrastructure will not be maintained or reinstated following an event.

Adaption through tech-adoption

Private vehicle use remains the norm for regional travel, with larger vehicles preferred due to climate anxiety. EVs are increasingly popular, influenced by rising oil prices and government drive for energy and resource security, which has seen markets and consumers reward vehicles that support a circular economy. Land-based regional travel beyond the main centres becomes less frequent, slower, and people tend to carry more belongings and supplies. Technologies like Augmented Reality (AR) and metaverse become increasingly popular for longer-distance connection.

Impaired national connectivity

Weather related damage to roads and other transport assets creates connectivity issues. Many rural groups still use ICE vehicles through choice, as they see them as more resilient to extreme weather, or necessity, due to upfront EV costs or unreliable electricity supplies. These groups face escalating fuel costs and insurance retreat. Some self-reliant groups are able to adapt and thrive. But, with funding generally funnelled into high population areas, rural communities with lower adaptive capacity struggle. Trends towards self-sufficiency and decentralisation accelerate, creating issues for both rural and urban groups.

Aviation increasingly disrupted

Relatively low carbon prices have kept flying affordable and, despite some protests, it has retained its licence to operate as a vital means of connectivity for New Zealanders. However, international tourism has declined as people worry about 'climate-stranding' in foreign countries during extreme weather and climate-related pandemics. Worsening geopolitical relations and supply chain disruption mean oil prices are now rising fast, and the ongoing visible impacts of climate have shocked society into a late, but stringent, push for decarbonisation, with aviation facing mounting pressure.

Air and sea play key role in adaptation

Despite the challenges, aviation is vital for domestic connectivity with increasing road network impairment. Regional battery electric aircraft, seaplanes, and eVTOL craft support access to remote communities, especially during post-crisis responses, whilst seagliders and high speed, low carbon vessels provide a time efficient ocean-based option between major urban areas.

What does **land** freight look like?

Supporting resource security

Mounting pressure on natural resources, people, and supply chains is driving global fluctuations in supply and the price of commodities like fuel and food. Government is promoting hard-line policies on national energy, food, and resource security. Some export products are rerouted for domestic supply and there are mandates on resource circularity and fuel efficiency impacting the freight sector. There is a rush to fully decarbonise to ensure reliable fuel supply.

Handling high physical risks

Worsening physical risks are causing damage to the road network and freight infrastructure from extreme weather and creating less predictability in demand and supply – from crop failure undermining seasonal forecasts, to cancelled shipments due to foreign port flooding. Chronic changes are shifting where commodities are produced and sent to. Workers are exposed to risks like road slips and extreme heat more often. The sector deploys advanced technology to mitigate these risks, from using drones for preventative maintenance, or real-time weather forecasts for route scheduling, vehicle utilisation, and delivery timings across global supply chains. Local production and consumption and technologies like 3D and 4D printing have become increasingly popular to reduce reliance on the physical system.

Serving a divided society

Freight is slower and more expensive, with consumers valuing reliability. In an increasingly uneven society facing high cost of living pressures, the market is bifurcated between quickly transporting low-volume, high-value products to the wealthy, and slower, low value, high volume supplies of basic necessities. Workforces are increasingly strained by social cohesion issues, with clear splits between highly-paid, highly-skilled tech-focused talent, and lower paid workers. Some freight companies now require heightened security due to attacks on trucks carrying valuable commodities.

Urban-rural connectivity issues

Infrastructure serving cities is resilient, and freight companies' main issue is increasing congestion. Roads connecting rural and isolated areas are increasingly compromised by physical hazards. This not only leads to some communities becoming increasingly difficult and expensive to service, with insurance not covering delivery on some roads, but also challenges getting food out of rural areas and into cities. The sector is socially expected to play a role in post-event disaster response to these more isolated regions, and looks to deploy drones and eVTOL craft to overcome damaged roads.

Moving Goods in 2050, *Bypass to Breakdown*

What does **air and sea** freight look like?

Shifting to domestic fuel production

Both aviation and shipping are reliant on a mixture of legacy fossil fuels and steadily increasing use of SAF or near and zero carbon alternatives. However, global fuel supply chains are increasingly geopolitically and physically insecure, and prices are escalating fast. As part of a government drive to achieve energy security, both sectors are now beginning to accelerate the transition towards domestically produced alternative fuels.

Disrupted global supply chains

Both sectors face increasing operational and supply chain disruption from physical climate impacts. Global shipping reliability is declining as ports are flooded and major canals sometimes impassable. Sea level rise, coastal flooding, and extreme weather-related damage cause logistical issues as well as escalating financial costs of repair and maintenance, with some domestic ports' adaptive capacity limits tested by successive events. Whilst domestic airports are generally well adapted, flooding, extreme heat, and water shortages all create intermittent disruption. Some overseas airports have periods of extended blackouts due to major damage or civic unrest. Both sectors have adapted their operations and use predictive AI for network scheduling to mitigate risks. There is high dependence on close relationships with value-chain partners, finance, and insurance.

Demand profiles are shifting

There is notable change in demand. Whilst expensive, air freight is used for high-value export commodities, or imports of national strategic significance. The sector diversifies into drone and eVTOL-based deliveries to support isolated and rural communities, especially in the aftermath of an acute emergency. Most consumers value reliability over speed in shipping. The decline in volume and predictability of Aotearoa New Zealand's export economy, coupled with a pivot to more domestic production and consumption, has made some shipping routes uneconomical, especially for commodities reliant on return-trip shipping. Smaller and more vulnerable ports face the realisation they may have to cease operations due to a decline in trade of their primary commodities, or mounting physical hazards. Some ports experience flooding by unprecedented coastal storms, and sea level rise projections begin to exceed the levels some ports can afford to adapt to.

Moving Goods in 2050, *Bypass to Breakdown*

Bypass to Breakdown: Extension (2051-2100)

Explores the physical climate impacts in the Bypass to Breakdown scenario from 2051-2100. Temperatures reach +3.9°C, and 'tipping points' in the Earth climate and ecological systems are breached. This causes worsening physical acute and chronic climate impacts across every inhabitable region of the planet, with severe implications for humanity. Sea level rise of up to 10m is locked-in, many Pacific countries disappear, and others are at breaking point.

Overview

Global temperatures increase to nearly +4ºC of warming by 2100. The climate crisis is now severely impacting every inhabited part of the planet. Chronic impacts include extensive desertification and drastic impairment of nature and biodiversity. Ocean ecosystems are collapsing, and regions made unliveable due to the 'wet-bulb' overheating effect. Acute impacts include more frequent and intense cyclones, larger wildfires, and prolonged freshwater shortages.

Tipping points have been reached in the Earth system. These self-sustaining, irreversible shifts catapult the Earth into a new climate system that will guarantee continued temperature increases, and sea level rise of up to 10m over the coming centuries, even if emissions were to stop abruptly.

Our World

Natural ecosystem collapse, supply chain disruption, and prolonged food, energy, and water scarcity have destabilised geopolitics and the global economy, with entire countries rendered uninhabitable. Hundreds of millions of climate migrants have been displaced from their homes and even countries. Developed nations retreat into protectionism, and use advanced technology to meet resource needs. Less developed countries grapple with meeting their basic requirements, with conflict widespread.

Our Home

Despite being previously sheltered, Aotearoa New Zealand now faces more frequent and severe cyclones, wildfires, droughts, and extreme heat. Native flora and fauna are collapsing, some agriculture is unviable, and coastal flooding is regular. A fractured society receives an influx of climate migrants, and priorities shift to resource security.

Key outcomes for the sector from 2051-2100

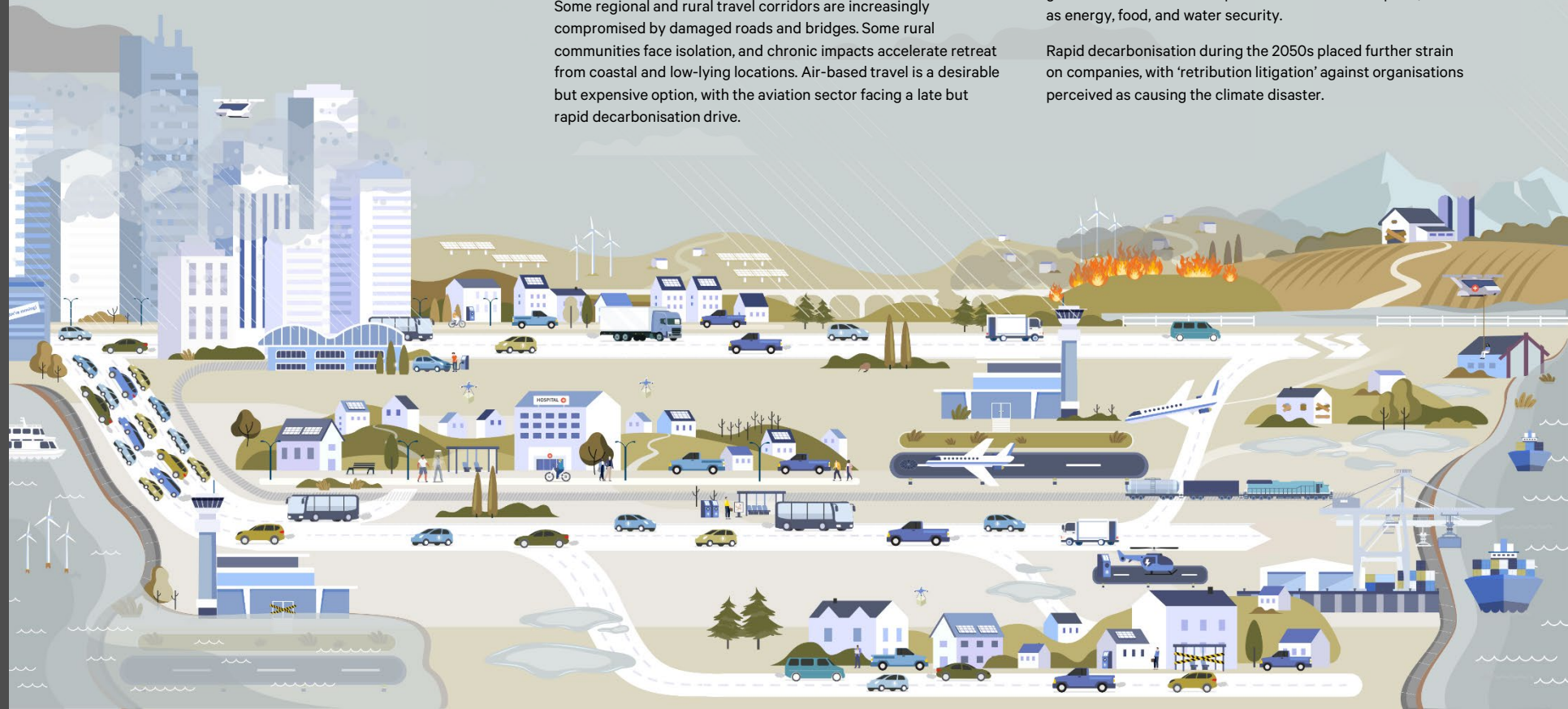
Climate impacts overwhelm the adaptive capacity of the transport network, with regressive financial outcomes for asset maintenance. The sector is impacted directly, with damage to infrastructure from more frequent and severe cyclones, flooding, and wild fires, and indirectly through high commodity prices, and the severe social impacts of heat stress or freshwater shortages on workforces, customers, and communities. Chronic impacts like sea level rise see some major assets like airports facing relocation.

Moving People. Urban mobility is low carbon, digitally-integrated and often autonomous, with an efficient, climate-adapted system having served major cities well for many decades. However, a wave of increased climate migration has increased pressure on transport and social cohesion in cities, with frequent extreme weather and cost inflation for asset maintenance all making the delivery of a comprehensive, reliable, and equitable system challenging. Many people pull back into 'digital lives' for connection.

Some regional and rural travel corridors are increasingly compromised by damaged roads and bridges. Some rural communities face isolation, and chronic impacts accelerate retreat from coastal and low-lying locations. Air-based travel is a desirable but expensive option, with the aviation sector facing a late but rapid decarbonisation drive.

Moving Goods. Despite system adaptation, the freight network faces mounting supply chain challenges from acute impacts and the severe social disruption caused by resource scarcity. People increasingly value reliability, safety, and consistency over speed, with supply chains for basic necessities now at risk. The freight sector is now perceived as mainly catering to 'needs' not 'wants', and is tasked by government with solving critical supply issues into a struggling society. There is a greater focus on domestic production and consumption, as well as energy, food, and water security.

Rapid decarbonisation during the 2050s placed further strain on companies, with 'retribution litigation' against organisations perceived as causing the climate disaster.



Key Indicators – *Bypass to Breakdown Extension*

All figures for Aotearoa New Zealand in 2100 unless otherwise stated

Physical Parameters

Global Temp Change

Average annual temperature vs. pre-industrial baseline

3.9°C

Extreme Heat

Average number of days exceeding 25°C annually

63 days

Extreme Rainfall

% change in depth of 1 in 100 year, 1 hour rainfall event

35%

Sea Level Rise

Average increase in metres from baseline

0.74m

Local Temp Change

Average annual temperature vs. pre-industrial baseline

3.0°C

Tropical Cyclone Damage

Annual expected damage (% at median line compared to the reference year 2015)

+66%

River Flood Damage

Annual expected damage (% at median line compared to the reference year 2015)

+29%

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Moving People in 2100, *Extension*

What does **urban** mobility look like?

Technology has changed 'mobility'

Technology has changed concepts of what 'transport' or 'mobility' is. Developments in multi-sensory AR and metaverse create lifelike interactions in personally curated virtual worlds. People have non-verbal conversations across cities using neuralink technology, and food can be printed at-home using captured carbon. With these digital forms of connection, many people elect to retreat from the difficult and complex 'physical' world.

Autonomous, on-demand, and shared transport

The physical world still matters, especially for those who cannot afford the privilege of these new inventions. By 2060 most urban transport is zero carbon, and digitally integrated into a single AI-orchestrated system. A focus on safety, efficiency, and climate resilience has been built into the network, laws, and people's daily routines. On-demand autonomous vehicles become the norm in centres, with shared assets replacing some private ownership as people enjoy 'stop-free-travel' whilst conducting other activities like work or leisure within vehicles. Active mobility becomes more popular again in certain neighbourhoods, and enhanced mobility develops to include personal aerial mobility.

Transport inequality

Aotearoa New Zealand is forced by geoeconomic partners to accept a high number of global climate migrants and refugees in order to maintain trade access to major markets. Alongside growing health, financial, education, and technology inequalities, this contributes to challenges for transport, society and the economy – with deep social issues seeing increases in crime and deprivation across the decades. In a city where transport segregation means some people can fly private eVTOL craft to protected 'urban islands', and climate refugees can struggle with getting into the central city because of damaged roads or inconsistent transport service level, class conflict can become violent.

Climate resilience is overwhelmed

Extreme weather events become more severe and frequent, with successive events (e.g. a period of water shortage followed by a category 5 cyclone) pushing cities past their adaptive capacities, and leading to social unrest. With global relations and supply chains collapsing, materials for repairs are expensive or unavailable, and local authorities soon face regressive financial outcomes, and the inability to fund proper maintenance or recovery.

Cities forced to move location

By 2070, the news is announced that sea level rise of at least 10 meters is locked-in. The realisation that many parts of cities like Auckland or Wellington will have to be moved or abandoned stuns the country, and becomes the new context for all transport-related decisions.

Moving People in 2100, *Extension*

What does **regional, rural and international** mobility look like?

Regressive financial outcomes

Despite adaptation and retreat, the scale and frequency of climate impacts materially impairs much of the road network. Whilst most national and some arterial roads are secured, a number of key routes are blocked by flooding, damaged bridges, or landslips, with some areas like the West Coast almost entirely abandoned. Even with advanced technology and high road user charges, repairs become unaffordable due to a faltering economy and expensive resources. This creates regressive financial outcomes, with many 'non-critical' parts of the network left in a state of disrepair.

Slower, riskier rural travel

Interregional travel becomes less frequent, riskier, and slower, with people tending to travel for longer, and carrying more in larger vehicles. Whilst most vehicles are now autonomous for highways, manual driving remains a cultural norm on rural roads. Many routes close, or are classified via a government risk rating. Travelling on these roads invalidates most insurance provision.

Rural localisation versus isolation

Some communities who can afford it and have decentralised energy as well as localised food production accept almost full 'physical localisation'. They maintain immersive, lifelike digital connections for work, drone deliveries, 3D and 4D printing for essentials, and eVTOL craft for trips. However, for many lower income communities reliant on roads and local industries for employment or supplies, climate impacts result in physical isolation, deprivation, and risks. Deaths on roads due to road slips or flash flooding are more common, and 'rural' communities can become isolated overnight with bridges or roads swept away.

International aviation uncertain

The 2050s saw aviation hit by carbon pricing and 'retribution litigation' for its perceived role in the crisis. It evolves into a high-tech, zero carbon sector. However, demand for international trips gradually declines. Fractured geopolitics means routes are restricted to trading allies, many New Zealanders are hesitant to risk being marooned abroad, and a series of global pandemics curtail the sector as Aotearoa enacts incredibly strict biosecurity laws. Hyper-realistic virtual 'travel' in sensory stimulation suits replicate trips abroad at a fraction of the cost or risk. By 2070, some airports are forced to move due to sea level rise.

Air and sea travel key to rural access

Despite physical risks to airports and mid-air operations, domestic aviation options like seaplanes, electric and eVTOL craft, play a major role in rural and isolated community accessibility and disaster response. For coastal communities, high speed ferries, seagliders, and sea planes provide a greater variety of resilient options if road networks are compromised.

What does **land** freight look like?

Transition and legal risk

Publicly available emissions records, advanced attribution science, and a society reeling from the social costs of a 'hot house world' sees a spike in 'retribution litigation' against freight companies in the 2050s and 60s. The sector faced rapid pressure to decarbonise as developed countries tried to limit the damage. Land freight become zero carbon by 2060, and highly technologically advanced, with AI scheduling most of the automated network.

Severe physical disruption

The freight sector experiences an increasingly challenging operating environment. Foreign trade of crucial commodities is hampered as shipping reliability collapses, and some ports are forced to close due to sea level rise. Land-based freight is impacted not only directly by severe damage to infrastructure, like road closures, or warping of rail lines in heatwaves, but by secondary impacts such as energy supply failures, the social effects of droughts, cyclones, or heatwaves, as well as declining social cohesion and mental health impacting staff. During difficult periods, freight vehicles can be attacked for their contents, leading to a rise in private security and armoured fleet. Insurance is linked to having the latest adaptation-related protocols or technology.

Changing expectations

Society increasingly demands reliability, safety, and consistency over speed, with supply chains for basic necessities now at risk. 'Just in time' delivery vanishes, stockpiling rises, and goods are mainly ambient instead of fresh. Products are a mix of high volume, low value staples, and high-end consumer goods. The freight sector is now perceived as catering to 'needs' not 'wants', and is tasked with solving critical supply issues into a struggling society. In a resource-scare world, there are high financial and legal penalties for letting food spoil, and periods of nationalisation when governments take control of parts of the sector to ensure continued supply of food and fuel.

Decentralised and virtual footprint

Adaptation needs see a move to a more decentralised network across fuelling/charging stations, distribution centres, and delivery points, and a revival of mode-shift to coastal shipping, some rail routes, and higher collaboration with aviation to access hard-to-reach remote communities. Legacy primary industries become hyper-efficient and adopt new business models, such as vertical, underground, and lab-based farming springing up near cities, and 3D and 4D printing becoming highly popular in Aotearoa due to supply chain efficiency benefits.

Moving Goods in 2100, *Extension*

What does **air and sea** freight look like?

Transition and legal risk

Aviation and shipping both faced steep costs mid-century to rapidly decarbonise in line with social expectations, and 'retribution litigation' for their perceived contribution to the climate catastrophe. Both sectors eventually deploy advanced, often autonomous fleets which run off zero carbon fuels, and use predictive AI scheduling and routing to mitigate climate impacts. Both sectors invest heavily in adaptation – from improving drainage, to cooled storage space to handle goods during delays, and even moving entire assets away from compromised locations

Foreign supply chain collapse

Despite technology and adaptation, the scale of simultaneous climate impacts to the freight value chain eventually overcomes schedule reliability for many routes. Major foreign airports and ports are hampered by a concoction of sea level rise, extreme weather, and unprecedented climate-linked refugees. Ships have to adapt to greater wave height in the Pacific, and disease pandemics become more common, grounding air freight for extended periods. Major routes like the Suez Canal are eventually compromised due to sea level rise, with alternative modes like rail a necessity. Extreme social unrest, drought, and hunger in some countries sees high operational disruption and even attacks on cargo ships or freight planes out of desperation. This all drives huge inflation on imports for Aotearoa New Zealand, and reinforces the move towards domestic resource security and circularity.

(Air)ports need to move

Many ports and airports have to close or move due to sea level rise later in the decade. Knowledge that longer term sea level rise of at least 10m is locked in due to the passing of the Earth system tipping points means all ports have to either invest in hugely expensive sea walls, or also plan for long term retreat over the coming century.

Air freight plays a key role

Air freight becomes a crucial mode between ally countries for rapid and more climate-secure transport of key resources. Domestically, air freight across light planes, seaplanes, and eVTOL craft becomes far more popular and important to support the new decentralised, localised lifestyles of rural New Zealanders, as well as providing vital services during extreme weather events when the road network is impaired.

Moving Goods in 2100, *Extension*

Short Detour

Meaningful global action on decarbonisation is delayed until the early 2030s, followed by a sudden and globally uncoordinated economic transformation. Extensive and stringent government intervention both in Aotearoa New Zealand and overseas limits global warming to +1.7°C by 2100, but with higher socio-economic costs.

Overview

Decisive global action on climate change is delayed until the 2030s. Extreme weather events and sudden decarbonisation of major markets triggers panic globally. There is less time to reduce more emissions and limit warming to +1.5°C this century. A faster, less organised transition deeply destabilises social and economic structures. Action keeps warming to +1.6° by 2100, but with higher social costs.

Our World

Countries shift late and abruptly to sustainable development pathways. There is a surge in green energy policies and investment in increasingly advanced technology. Carbon prices and border adjustments surge in major export markets. However, less coordination and time pressures reduce alignment on technology choices, finance, and labour, increasing the costs of transition. Developed nations move faster, whilst smaller markets are takers of carbon prices and technology choices. Whilst society shifts to more conscious consumption, the transition exacerbates existing inequalities in the medium term.

Our Home

Aotearoa New Zealand is slow to decarbonise its economy in the 2020s. Then it has to move fast in the early 2030s to keep up with major economies and retain access to export markets. Decarbonisation of major sectors is driven by central government using more stringent and blunt policy tools. There is less alignment across levels of government or sectors. Carbon reduction becomes a more singular focus, with less consideration for an equitable transition. Many innovative, low carbon Kiwi companies leave Aotearoa New Zealand, increasing its reliance on imported technology, labour, resources, and finance.

Transport by 2050

Transport is mostly low carbon, although many co-benefits of the transition have been unrealised. There was greater reliance on domestic and foreign carbon offsets. The transition was hard and fast, with stringent government policies and a more singular focus on carbon reduction. Despite more clarity on technology pathways, the late move saw transport more reliant on costly international fuels, technologies, and finance. Many businesses and communities are only just recovering from a very difficult period of disruption where travel and freight costs spiked.

Moving People. Like the Fully Charged scenario, cities have high-tech, low carbon transport systems integrated across on-demand, micro, and public mobility. However, another decade of sprawl and road building means urban form is less compact, infrastructure transition costs were higher, and the public sector still carries high debt. There is greater reliance on private vehicles, and less even distribution of affordable, reliable public or shared mobility options across lower income areas. There are pockets of transport poverty, and cities are less healthy or attractive places to live than in Fully Charged.

The supporting ecosystem for EVs is less mature, with fewer rural chargers, variable grid capacity, and less skilled workforce. Some rural communities are thriving, whilst others are underemployed and disenfranchised, with the rapid transition locking them into increasingly expensive ICE vehicle use at a time when the road network and fuel supply are more frequently impaired by severe weather events.

Moving Goods. Freight is now a high-tech, mostly low carbon sector using digital system planning for efficiency and climate resilience. Although the delay in transition until the 2030s made viable technology pathways clearer, the speed of change, greater reliance on overseas low carbon fuels and technologies, and resource costs created huge disruption and resulted in consolidation of the sector with more advanced foreign entrants. There has been less mode-shift to rail and coastal shipping, creating reliance on a road network now more vulnerable to extreme weather impacts, with managed retreat happening from many locations.

Aviation and shipping are still decarbonising, with both sectors hit harder by higher carbon prices, and dependence on more expensive, foreign low carbon fuel supply. Some smaller ports or air fields became uneconomical and closed.

Key Indicators - *Short Detour*

All figures for Aotearoa New Zealand in 2050 unless otherwise stated

Physical Parameters

Global Temp Change
Average annual temperature vs. pre-industrial baseline

1.7°C

Extreme Heat
Average number of days exceeding 25°C annually

15 days

Extreme Rainfall
% change in depth of 1 in 100 year, 1 hour rainfall event

15%

Sea Level Rise
Average increase in metres from baseline

0.20m

Transport Parameters

Household Person kms Travelled by Mode (%)
Active Public Private

Freight Mode Shares (%)
Rail Shipping Road

Road Vehicle kms Travelled by EVs (%)

89%

Domestic Transport Emissions
(Annual $ktCO_2e$)

3,004

Socio-economic Parameters

Renewable Energy Share of Total Final Consumption (%)
Including international transport

63%

Carbon Price
Energy (real NZ$/$tCO_2e$)

$411

Oil Price Increase
% difference, US$ per barrel vs baseline

839%

GDP
% difference, 2009 prices; local currency vs baseline

-1.5%

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Moving People in 2050, *Short Detour*

What does **urban** mobility look like?

Populous, high-tech, but less compact

As in the Fully Charged scenario, urban mobility options for many of the rising urban population include a mixture of public, on-demand, shared, and active transport that is digitally-enabled through IoT, AI, and automation. However, cities are less compact due to delayed land use planning reforms, with more sprawl and unequal distribution of public or shared transport service coverage or quality in some areas. However, some technologies like autonomous vehicles and eVTOL craft are more embedded into urban form, as the delay in infrastructure investment until the mid-2030s enabled re-design and funding to be centred around nascent technologies.

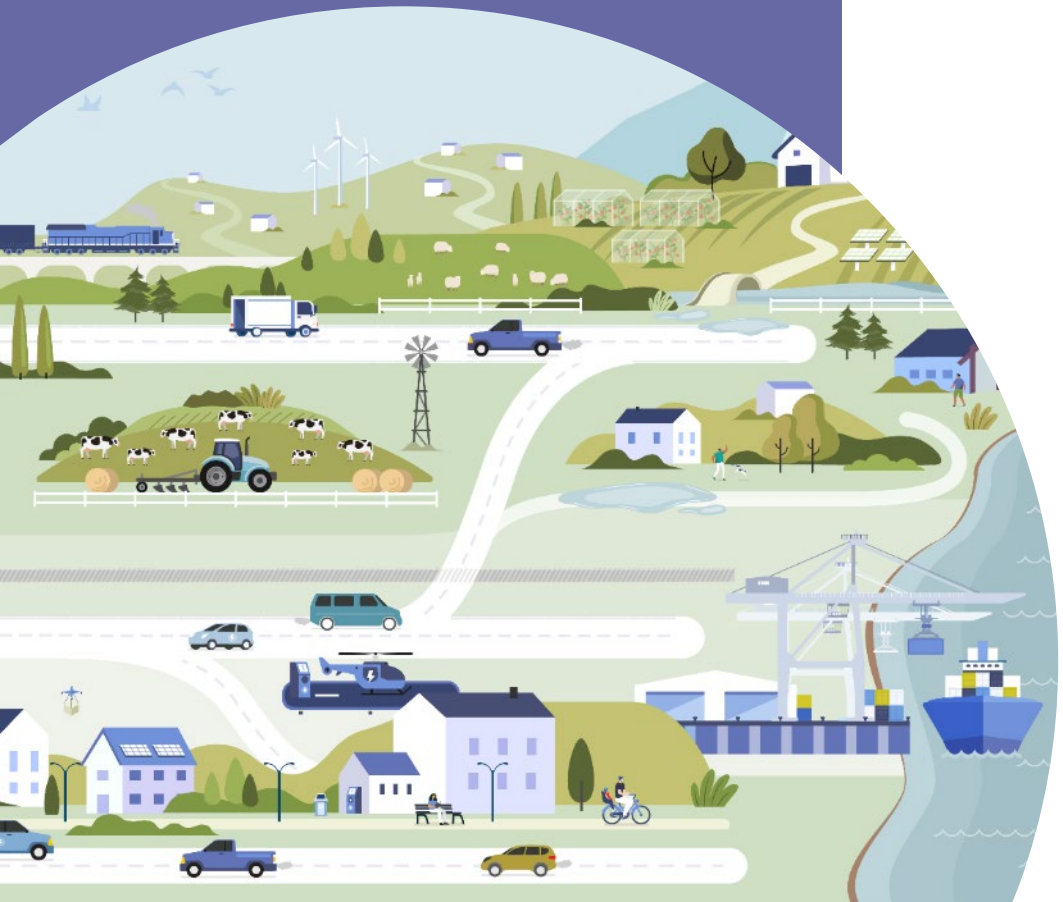
Mid-way through costly transition

The development of integrated land use-transport planning and infrastructure benefits are only just being realised, with some projects still underway. The shift away from private vehicle use and towards public and shared modes is ongoing, and there is notably less active mobility due to reduced development of integrated active mobility networks. The required changes to infrastructure had to contend with another decade of locked-in development, climate-related resource cost spikes, and more social disruption. This means local authorities have higher debt levels, and public transport is more expensive.

Varying social outcomes

There are less equitable outcomes from the transition. Economic conditions are more difficult for low income groups in this scenario. Hard adjustments like removal of parking space, congestion charging, and zones banning single occupancy vehicles were often introduced without some areas being provided with reliable or affordable public, shared, or active mobility alternative options. On top of the social scars from transition, this sees pockets of urban communities (including climate refugees) locked into increasingly expensive and impractical private vehicle use for key trips (e.g. commuting). This reduces options for groups who can't drive, and often makes having a drivers licence a necessity. The lack of active mobility curtails the option for healthy, low cost travel for many areas, and there are higher rates of pollution and congestion, contributing to worse health outcomes.

Moving People in 2050, *Short Detour*



What does **regional, rural and international** mobility look like?

Variable EV ecosystem

EVs displaced ICE vehicles in the 2040s as the most popular mode across regional and rural areas. However, the supporting ecosystem is less consistent and higher cost. With a large electric fleet, grid capacity sometimes struggles with demand, and many who can afford it have turned to decentralised energy generation. A more limited skilled servicing workforce makes repair and maintenance of chargers more difficult in some remote areas. Lack of planning for a circular economy in previous decades means Aotearoa New Zealand has a growing waste problem with retired ICE vehicles and EV batteries.

Rural transport issues and climate risk

Many rural and especially low income and isolated communities faced high barriers to EV adoption. The speed and cost of transition meant governments supplied less financial support for vehicles, charger installations, or home batteries. These areas also faced disproportionate issues around servicing workforce and energy supply reliability, which meant they didn't see EVs as reliable or resilient. The physical impacts of climate change (e.g. extreme weather damaging roads and energy infrastructure) exacerbate barriers to adoption. This means pockets of rural and isolated communities remain locked-in to ICE vehicles which are becoming prohibitively expensive due to increasing carbon prices.

Aviation recovering slowly

Aviation remains in the middle of an expensive and slow transition to alternative fuels and fleet, with international passenger numbers recovering slowly after a sharp decline. Despite lowering emissions intensity, many people are still uncertain about their personal reputation if seen flying. International trips use mostly imported and domestically produced SAF, with some zero carbon options, and jet fuel used in emergencies. High carbon and SAF prices make pricing, social acceptance, and operations hard to juggle for carriers and airports operating multi-model and multi-fuel fleets. Domestic zero carbon and electric flights are available, but are mostly the preserve of the affluent. There are intermittent supply problems because of competition with the land fleet and variable electricity supply.

What does **land** freight look like?

High-tech, more electric, and mostly low carbon

The sudden decarbonisation of major export markets, associated carbon prices and border adjustment mechanisms, as well as expectations from finance providers and customers for transparent reporting placed high pressure on freight to reduce emissions in the 2030s. By 2050, whilst light commercial vehicles are electrified, the delayed and disorganised transition means that although much of the heavy fleet uses zero carbon alternative fuels, a proportion still use interim drop-in biofuels, and even some fossil fuels. There has been greater use of electrification than in the Fully Charged scenario. The same advanced technology is deployed across an integrated network, with shifts in operating and business models caused by advances like digital twins, 3D and 4D printing, smart packaging and AI-linked 'freight-as-a-service'.

Less mode-shift

There has been less mode-shift to rail, coastal shipping, or air-based options. This has placed more pressure on the heavy fleet to reduce emissions intensity, and accentuated the sector's vulnerability to an unreliable road network being impacted by physical risks.

Supply chain issues and higher costs

The speed of transition meant less system coordination with sectors like education or energy on development of domestic alternative fuel infrastructure or related skilled workforce. Aotearoa New Zealand is more reliant on costly foreign imports for materials, fuel, and high-tech skills. There remain logistical issues around new fuel supply chains – from evolving standards, to competition with aviation and shipping for limited supply. These issues are often compounded by physical climate impacts domestically or abroad, leading to semi-regular periods of operational suspension due to delays in key resources. This makes freight less reliable and more expensive.

Consolidated sector

The speed and cost of transition and faster shift in Aotearoa New Zealand's economic base saw unprepared companies struggle with failed technology bets, stranded assets, and expensive or unattainable finance. There were clear winners and losers. The sector is now more consolidated, with higher proportion of foreign companies who had the capital, technology, and business models to seize market share.

Social issues affecting operations

The stringent and fast transition saw a period of social disruption and rapid job erosion which has left lasting psychological and financial scars. Companies try to balance employing high skilled technology workers and a digital 'AI workforce', whilst supporting the retraining and livelihoods of more 'manual' employees who have experienced hardship. With rural and coastal roads more hampered by extreme weather, and delayed use of nature-based interventions, there is greater social pressure to maintain service levels to low income rural and isolated communities who experienced industrial decline and deprivation.

Moving Goods in 2050, *Short Detour*

What does **air and sea** freight look like?

High-tech but mid-transition

Both air freight and shipping are high-tech – deploying automation, predictive analytics, and digital twins to increase global operational efficiency. They account for higher relative proportions of global transport emissions due to land fleet transition. Investment delays, long asset replacement lifecycles, and slow global growth of alternative fuels mean both sectors are still mid-way through an expensive decarbonisation pathway. Whilst ports and airports are electrified and mostly automated, the majority of shipping fleet remains dual-engine across bio and some fossil fuels, whilst aircraft mostly uses SAF to varying levels.

Foreign fuel and offset reliance

Whilst Aotearoa New Zealand is scaling generation of alternative fuel production, the lack of coordination across sectors like agriculture and energy in the 2030s means carriers are still mainly reliant on international supply. Slow global ramp-up and high competition, both globally and from the domestic heavy land fleet, means prices are higher for both sectors. New protocols, standards, and operations are also still being developed, creating operational disruption. There is a continued reliance on high quality offsets.

New demand profiles

Both sectors are adapting to lower carbon, shorter supply chains, with more domestic production and consumption. There have been huge shifts in the location, volume, and type of economic activity impacting imports and exports. Some smaller ports closed during the transition due to local industrial decline, or lack of alternative fuel bunkering seeing them dropped off port calls. SAF scale-up means air freight is slowly recovering from the spike in export market carbon prices and negative social sentiment, and carries low carbon, high-value exports to global markets. Technologies like 3D and 4D printing has increased efficiency and reduced the need for some trips, eVTOL has opened up new air freight business models, and ports are looking to capitalise on a late move towards more coastal shipping, including rapid delivery models via seagliders.

Climate risk is exacerbated by transition

Both sectors are especially vulnerable to climate hazards given their global supply chains. As in Fully Charged, cyclones, flooding, or regional drought are now likely impacting at least one foreign port or airport at any given time, with Kiwi infrastructure also at higher risk. But, these impacts are compounded by the current logistical issues with alternative fuels, and consolidation of the ports sector. Mandated ‘slow-shipping’ means major international canal closures cause longer delays. Missed imports of alternative fuel can see periods of operational shutdown, and weather-related delays to export cargo can cause excessive demands on ‘spillover space’ in city-based ports, with sector consolidation meaning closure of roads into these ports has greater economic impact.

Moving Goods in 2050, *Short Detour*

Fully Charged

An ambitious and globally coordinated transition to a low emissions future accelerates through the 2020s. Strong climate policies, innovation, targeted investment, and social change cause disruption, but limit global warming to a temporary overshoot of +1.6°C by 2050, with carbon capture used to dial temperatures back to +1.4°C by 2100.

Overview

Ambitious and coordinated international action in the 2020s led to an immediate and relatively smooth transition to a low carbon global economy that operated within planetary boundaries. Greenhouse gas emissions were reducing by 2030, and reach net zero by 2050.

Our World

Major economies invested early and heavily in transitioning to renewable and low carbon energy and technologies. There was high collaboration on policy settings to limit warming to 1.5°C by end-century. Management of the global commons rapidly improved, and the global economy shifted towards a broader emphasis on human wellbeing.

Our Home

Aotearoa New Zealand understood the economic, geostrategic, and social opportunities of transitioning to a low carbon, climate resilient economy, and keeping up expectations of major export markets who were rapidly decarbonising. Climate became a centreground issue, with strong government leadership and longer term policy settings giving local authorities, business, and investors the confidence to take decisive action.

Decarbonisation was challenging, with high financial and social costs. However, a focus on supporting communities facing extreme economic and social impacts ensured that there were fewer groups of highly disaffected people as part of the overall transition in Aotearoa New Zealand.

A systems approach and strong cross-sector collaboration, planning, and R&D investment helped Aotearoa New Zealand secure domestic energy security, attract overseas talent, and build a low carbon, high-tech, and more equitable economy.

Transport by 2050

A planned decarbonisation of the transport has unlocked more than just emissions reduction. By 2050, the sector is low carbon, lower cost, and higher-tech. It plays a strategic role in national energy and resource security, and enables a broad range of equitable social and economic outcomes. While coordinated global emissions reduction has helped mitigate the worst physical climate impacts to the system, transport has still had to adapt to a new climate and the reality of increasingly unpredictable and more extreme weather.

Moving People. Urban mobility is cheaper, safer, and healthier than in other scenarios. Travel is more accessible for a diverse range of people. Denser cities with integrated land use-transport planning have enabled zero carbon mass-transit. Active mobility is popular, and private vehicle ownership has been in part replaced by a sharing economy. People seamlessly flow between on-demand, public, and micromobility options on a single payment contract. AI efficiently orchestrates the network, and vehicle utilisation rates have shot up, freeing up public space for nature, communities and commerce. Mode-shift has built climate resilience, including new aerial mobility.

For regional and rural travel, EVs dominate the light fleet, with many people choosing the easy-access vehicle sharing options with high national coverage. Aviation is almost entirely zero carbon where aircrafts have been replaced by new technology, and domestic passenger numbers are increasing on smaller, more frequent flights. Electric aviation has opened up new airfields, revitalised communities, and supports resilience.

Moving Goods. The freight sector is low carbon, high-tech, and more efficient. Strong market signals and green finance in the 2020s helped import low carbon heavy fleet. Cross-sector collaboration and investment in the domestic production and use of a variety of alternative fuels helped retain innovative Kiwi start-ups, and support exporters' continued access to rapidly decarbonising global markets. The sector has adapted to a radically different economy, with more domestic production and consumption. Technologies like 3D and 4D printing has changed business models. AI platforms conduct much of the increasingly autonomous network. Multi-modal options enabled both emissions cuts and climate resilience.

Sea and air freight are now scaling up use of zero carbon fleet, having spent the past two decades eagerly increasing use of low carbon alternative fuels, interim biofuels, and SAF.

Key Indicators - *Fully Charged*

All figures for Aotearoa New Zealand in 2050 unless otherwise stated

Physical Parameters

Global Temp Change
Average annual temperature vs. pre-industrial baseline

1.6°C

Extreme Heat
Average number of days exceeding 25°C annually

15 days

Extreme Rainfall
% change in depth of 1 in 100 year, 1 hour rainfall event

15%

Sea Level Rise
Average increase in metres from baseline

0.19m

Transport Parameters

Household Person kms Travelled by Mode (%)
Active Public Private

10	17	73

Freight Mode Shares (%)
Rail Shipping Road

21	20	59

Road Vehicle kms Travelled by EVs (%)

96%

Domestic Transport Emissions
(Annual $ktCO_2e$)

1,022

Socio-economic Parameters

Renewable Energy Share of Total Final Consumption (%)
Including international transport

79%

Carbon Price
Energy (real NZ$/$tCO_2e$)

$309

Oil Price Increase
% difference, US$ per barrel vs baseline

625%

GDP
% difference, 2009 prices; local currency vs baseline

+0.1%

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Moving People in 2050, *Fully Charged*

What does **urban** mobility look like?

Populous, compact and connected

Urban centres have become more compact and populous with younger, more diverse demographics, and some climate migrants. Integrated land use-transport planning has enabled upzoning, and hubs are well connected by mobility options. Infrastructure spend focuses on reducing embodied carbon and cost, using nature-based options, and repurposing existing assets.

Fewer private vehicle trips

The dominance of private vehicle use for short and cross-town trips has been mostly replaced by public, shared, and active mobility. Rapid mass-transit corridors carry people on regular, reliable, and zero carbon options between key hubs. Most suburbs are served by on-demand options or active mobility routes connecting people to spokes. Many inner city options are now autonomous. Private vehicles remain present, but are reserved for longer and interregional trips. Those used in suburbs are typically smaller and electric.

Active mobility

Active mobility is very popular. Cities are connected by designated, safe, and nature-lined active mobility corridors which merge into a single network. Thousands of families, commuters, and leisure-seekers enjoy fast, cheap, and healthy cross-city travel.

Sharing economy

Sharing transport assets is a social norm. A booming on-demand shared mobility economy encompasses flexible vehicle-hiring, digital ride hailing, eVTOL taxis, and a multitude of enhanced mobility options from e-bikes to hoverboards. There are fewer vehicles which have far higher utilisation rates, meaning space is given back to nature, businesses, and communities, not roads and car parks, which has boosted city economies.

Integrated digital mobility

Technology like remote-operated surgery, AR meetings, and metaverse offices mean many ‘trips’ have been replaced. However, physical transport remains important. Almost all mobility is electric, and digitally connected via IoT technology. People move seamlessly across multiple modes on a single integrated digital mobility contract, meaning the lines between public and private mobility are now blurred. AI orchestrates the system flow through pricing, flexible route optimisation, and predictive demand management, with data shared both across the transport system and across other sectors.

Equitable outcomes

More lower income communities benefit financially and socially from better access to low cost, no-ownership mobility than in other scenarios. The shift to electric and active, public, and shared mobility means fewer private vehicles and less congestion and pollution. Space has been reclaimed from roads and car parks, and nature is embedded in urban form, which provides low cost climate adaptation. These changes have markedly improved health, wellbeing, and social outcomes, as well as developed climate resilience.

Moving People in 2050, *Fully Charged*

What does **regional, rural and international** mobility look like?

Tech-enabled models

Technology has changed the concept of 'mobility'. Holograms, metaverse and AR have replaced many trips. Intelligent integrated systems across multiple modes means local, regional, and international travel is all connected. You can reserve a trip including a local taxi, regional air travel, and a train to your destination on a single booking. Each mode communicates with one another on timing, and AI mitigates weather-related risk in real-time, providing alternate routes and ensuring there are limited delays or wait times.

Electrified society

Although the light fleet has been shrinking in size since 2030, EVs are popular for regional and rural travel. Charging infrastructure is embedded into the social fabric – from new builds and libraries, to schools. EV uptake has gone hand-in-hand with the development of a resilient, affordable, and low carbon central energy grid, although decentralised energy models also play a key role in society – with location-based smart charging for grid management, and active buying or selling of energy across communities using vehicles, solar panels, and home batteries. Early national investment in education means there is a skilled workforce to support servicing, repairs, and software updates. Circularity is embedded into vehicle lifecycles, with consumers and investors attuned to the 'upcycling' value of EV batteries and parts once assets are retired or traded.

Multiple options

Affordable electrified passenger rail connects urban areas in the upper and lower North Island, and seagliders offer fast inter-city sea-based travel. Electrified rail routes on select inter-urban lines provide popular options with younger people who don't own a driving licence, and migrants accustomed to rail travel. On-demand and sharing platforms with national coverage means vehicle ownership no longer precludes cross-country travel. People hire vehicles flexibly, reliably, and affordably for road trips, business meetings, and visiting relatives.

Resilient rural areas

Physical climate risk has seen steady managed retreat from many locations. The road network is intermittently impacted, with some roads now 'high risk' and not covered by vehicle insurance. However, the delivery of a comprehensive EV ecosystem and targeted support for rural or isolated communities means EVs are seen as a climate resilient option for most communities, with local energy production and charging enabling maintained connectivity. Prevention of the worst climate impacts means regional road-based travel remains popular.

Aerially connected

Domestically produced and bunkered SAF made international flying more socially acceptable and affordable earlier than in other scenarios, rekindling tourism markets. Aviation remains vulnerable to climate-related impacts like extreme weather disruption to foreign airports, increased disease events, or extreme turbulence. Domestic aviation is low and often zero carbon, with reliable domestic alternative fuel or energy supply. Electrified regional air mobility including eVTOL technology has reinvigorated smaller airfields and communities, opening up new business models. Aviation plays a key role in disaster response, and providing reliable national travel when the road network is impaired by extreme weather.

What does **land** freight look like?

Low carbon and circular

Proactive investment in the 2020s meant freight helped maintain Aotearoa New Zealand's access to rapidly decarbonising export markets which had deployed high carbon prices and border adjustment mechanisms. Clear demand signals and government R&D support helped retain innovative Kiwi low carbon fuel and vehicle companies onshore, reducing reliance on expensive technology or workforce imports. Only zero carbon trucks have entered the market since 2035. The heavy fleet uses mostly domestically sourced alternative fuels, with hyper-efficient battery electric trucks becoming more popular due to synergies with the wider economy and low cost electrified grid. The sector is expected to be low waste and contribute to a circular economy by consumers and government as part of an efficiency and resource security drive.

Multi-modal system

The system-level freight strategy deployed in the 2020s means that the sector is now truly multi-modal across road, rail, coastal shipping, and air. Land freight operates as a single, digitally connected network that efficiently moves goods across modes, assets, and even providers in a flexible way. Investment in rail network electrification and adaptation alongside coastal shipping routes has reduced system emissions, increased efficiency, and improved resilience to the climate impacts on the road network.

Digitally integrated

Technology has transformed the sector. 3D and 4D printing means many 'freight' companies now send code not products. Real-time data-sharing and IoT technology deployed on products, smart packaging, vehicles, roads, and distribution points has created a digitally connected network. The system is now mostly orchestrated by AI across multiple carriers and modes. Traditional 'owner-carrier' business models have been replaced by 'freight-as-a-service' AI platforms, alongside asset owners. These platforms interface in real-time across multiple data points from supply and demand data, geospatial data on road integrity, and predictive weather forecasting, that not only optimise vehicle utilisation and fill rates, but increases network resilience to extreme weather events or supply and demand spikes.

New demand patterns

The demand profile for freight is completely different from the 2020s. Consumer demand is less materially intense, and some high carbon industries have declined, whereas new models like near-urban vertical farming have increased. Consumers value low carbon, reliable freight, meaning supply chains are shorter and often slower, with more domestic production and consumption. 3D and 4D printing has decentralised some manufacturing, locating it closer to demand – enabling space efficient transit of raw, lightweight additive materials instead of end-products. The circular economy has created opportunities for companies to flow valuable secondary materials across closed-loop systems, and high urbanisation means 'last mile' urban deliveries are a big focus.

Physical risk adaptation

Freight protocols, workforce, and logistics have had to adapt to extreme weather intermittently cutting off roads and communities, or damaging infrastructure. There is a late push for enhanced adaptation investment, with the sector moving to a more decentralised model to build resilience. Freight is expected to protect workers, and plays a key role in disaster response, ensuring vulnerable groups receive vital goods.

Moving Goods in 2050, *Fully Charged*

What does **air and sea** freight look like?

Low carbon and efficient

Despite a period of disruption in the 2020s and 2030s, the early investment in domestic alternative fuel production means aviation and shipping fleets in Aotearoa New Zealand are now mostly low or even zero carbon, ensuring longer term commercial access to carbon-sensitive foreign markets. Both sectors now account for higher proportions of overall transport emissions, so public scrutiny is high. Zero carbon cargo ships have started making port calls to Aotearoa New Zealand. The first long-distance zero carbon aircraft have been demonstrated overseas, and are due to enter major markets. Airports, ports, and near-port operations are all electrified and highly efficient with automation and AI deeply ingrained. Operations are expected to be highly circular and low waste.

Integrated mode-shift

Both sectors are now deeply digitally integrated into the land freight sector both domestically and abroad, with automation, AI, and IoT technology optimising global networks in real-time, and shippers able to select their cost-time trade-off across multiple options. There has been an increasing demand for coastal shipping, and ports have developed stronger connections with the rail network. Air freight has diversified and now supports the land freight sector with cost-effective domestic delivery via drones and eVTOL craft, especially to isolated or hard-to-reach communities. Electric regional air mobility has created affordable national courier services at rapid speed.

Physical risks and response

Although the worst effects of climate change have been avoided, international aviation and shipping are more vulnerable to acute climate impacts. Foreign ports, airports, and other infrastructure are more frequently disrupted by flooding, droughts, and disease – increasing unpredictability and cost in supply chains. To mitigate this, both sectors deploy AI and predictive analytics using globally shared risk data to optimise factors like routes, flight altitude, fuel volumes, and speed in relation to external hazards. With ‘slow-shipping’ still an operational requirement for many ships, successive or compounding climate events (e.g. low water making the Panama Canal impassable combined with a major cyclone at a Chinese port) can create high delays and shortages. Air freight is seen as a faster, more reliable and climate secure mode, with shipping comparatively more impacted by risks.

New demand patterns

Similar to land freight, the demand profile for both sectors is very different to the 2020s. Despite higher populations, a reduction in material consumption, more circular domestic economy, and a reduction in many exports like timber and beef, or fossil fuel imports, has seen a decline in shipping volumes. Air freight is used for high-value exports. New modes like drones and eVTOL craft mean the sector is seen as a vital mode for serving isolated rural communities, especially during emergency response to extreme weather events.

Moving Goods in 2050, *Fully Charged*

SECTION 2

Scenario narratives

Section navigation

This section is designed for CREs to use as a tool in their XRB-aligned scenario analysis.

Technical Guide

Pg 50

Overview of the key design decisions in the scenario process, which can be used for entity-level analysis.

Reading Time: *Short*

Navigating these scenarios

Pg 57

Overview of the structure of the narratives and how to navigate through them effectively.

Reading Time: *Short*

SCENARIO

Bypass to Breakdown

Pg 59

SHORT TERM Pg 64

MEDIUM TERM Pg 68

LONG TERM Pg 72

EXTENSION Pg 77

Reading Time: *Long*

SCENARIO

Short Detour

Pg 87

SHORT TERM Pg 92

MEDIUM TERM Pg 95

LONG TERM Pg 101

Reading Time: *Long*

SCENARIO

Fully Charged

Pg 105

SHORT TERM Pg 110

MEDIUM TERM Pg 117

LONG TERM Pg 123

Reading Time: *Long*

Technical guide for Climate Reporting Entities (CREs)

Climate–related scenario analysis

The anticipated impacts of climate change are deeply uncertain due to the indeterminacy of future greenhouse gas emissions, ambiguity of decarbonisation pathways, complexity of the Earth system, unpredictability of socio-political choices, and limited historical data. Scenario analysis helps us understand and make decisions about how best to prepare for the impacts of climate change despite such deep and dynamic uncertainty.

Scenario analysis is a common tool for organisations to explore the limits of 'what could happen?' in order to be better prepared for whatever does happen. In the context of climate change, scenario analysis involves:

1. Creating different scenarios based on factors such as greenhouse gas emissions, temperature increases, sea level rise, extreme weather events, policy-response, and socio-economic consequences.
2. Analysing how resilient an organisation's current business model and strategy are to these scenarios.

In order to be useful, scenarios must confront commonly held expectations about the future. However, this is not a license for the imagination to run wild. The TCFD[1] suggest characteristics of good scenarios include them being:

- *Distinctive* (i.e. narratives should include a unique combination of key factors and provide differentiated messages).
- *Plausible* (i.e. narratives should describe credible, possible, and believable futures).
- *Consistent* (i.e. narratives should exhibit a strong internal logic, with interactions between factors, actions, and reactions having logical explanations).
- *Challenging* (i.e. narratives should confront business-as-usual assumptions).
- *Relevant* to decision-makers (i.e. narratives should enable dynamic risk management and strategic planning)[1].

XRB climate-related disclosures

Aotearoa New Zealand's Financial Sector (Climate-related Disclosures and Other Matters) Amendment Act 2021 introduced mandatory climate-related disclosure (CRD) requirements for approximately 200 of Aotearoa New Zealand's largest businesses[2,3]. While aligning with the TCFD recommended framework, the XRB has developed Aotearoa New Zealand-specific disclosure standards and guidance[1].

The aim of Aotearoa New Zealand's CRD regime is to provide markets with the information required to understand how large organisations are managing their climate-related risks. Towards this end, the XRB's New Zealand Climate Standard 1 (NZ CS 1) requires covered entities to undertake scenario analysis and disclose how the process was conducted. To support this disclosure, paragraph 13 of NZ CS 1 states:

> "An entity must describe the scenario analysis it has undertaken to help identify its climate-related risks and opportunities and better understand the resilience of its business model and strategy. This must include a description of how an entity has analysed, at a minimum, a 1.5 degrees Celsius climate-related scenario, a 3 degrees Celsius or greater climate-related scenario and a third climate-related scenario.[2]"

The XRB recommends that sectors collaborate to develop shared, qualitative scenarios as a foundation for analysing, improving, and reporting on the resilience of their respective organisations. This collaborative approach to scenario development offers several advantages, including more rigorous, coherent, and comparable analysis, cost savings, and the potential to significantly accelerate sectors' adaptation to climate change.

Shared scenarios for Aotearoa New Zealand's transport sector

The purpose of these sector scenarios is to support high quality, consistent, and comparable entity-level scenario analysis across transport sector CREs.

Integrated scenarios are projections of future climate conditions that take into account various factors relevant to Aotearoa New Zealand such as greenhouse gas emissions, regulatory change, land use change, population growth, technological advancements, and evolving mental modals. This approach considers the physical and societal impacts of climate change, as well as how diverse factors might interact with each other to trigger a cascade of compounding risks … or unlock new opportunities for value creation.

The scenarios differentiate between Moving People and Moving Goods, and the Air, Land, and Sea sub-sectors of transport. Though informed by a wide range of publicly available data, it is important to note that the future is highly unpredictable and is unlikely to unfold exactly as described by any single scenario. The scenarios have, therefore, been developed as a complementary set wherein:

- The first – **Bypass to Breakdown** – is designed to explore how Aotearoa New Zealand and the transport sector might adopt an adaptation strategy, and the subsequent resilience of the system to high physical climate risks in the long term (2040-2100).
- The second – **Short Detour** – is designed to explore the impact of a later, faster and less aligned transition that is highly disruptive in the medium term (2031-2040).
- The third – **Fully Charged** – explores the transport system's readiness to globally aligned, swift, but still disruptive decarbonisation, starting in the short term (2025-2030).

[1] *TCFD, 2016. Technical Supplement: The use of scenario analysis in disclosure of climate-related risks and opportunities. [Online] Available at: https://www.fsb.org/wp-content/uploads/Recommendations-of-the-Task-Force-on-Climate-related-Financial-Disclosures-Supplement.pdf#page=5 [Accessed March 2024].*
[2] *XRB, 2022. Aotearoa New Zealand Climate Standard 1. [Online] Available at: https://www.xrb.govt.nz/dmsdocument/4770 [Accessed March 2024].*
[3] *XRB, 2023. Scenario analysis and climate-related disclosures. [Online] Available at: https://www.xrb.govt.nz/standards/climate-related-disclosures/resources/scenario-analysis-and-climate-related-disclosures/ [Accessed March 2024].*

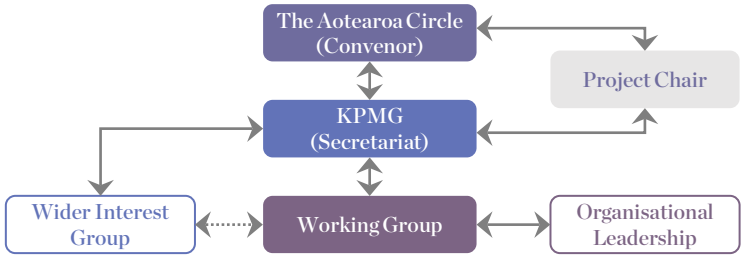
Scenario design

Scenario design includes the technical decisions made by participants during the kick-off workshop to ensure the scenarios were high quality and robust. It includes decisions around project governance and process, and also around framework architecture (underlying pathway assumptions), parameters (quantitative and qualitative variables for assumptions), scope (relevant value chain elements), boundaries (geographical scope), and granularity (level of detail of parameters). This scenarios process was also designed to align with the XRB's requirements for climate-reporting entities to describe how they have analysed, at a minimum, a 1.5 degrees Celsius climate-related scenario, a 3 degrees Celsius or greater climate-related scenario, and a third climate-related scenario.

Project governance

Aotearoa New Zealand's transport sector climate scenarios were convened by The Aotearoa Circle with KPMG New Zealand acting as the Secretariat. The project was led by representatives from 15 organisations representing various elements of the transport sector who formed the 'Working Group'. Outputs were socialised with a larger group of stakeholders for feedback, who formed the 'Wider Interest Group'. All material decisions about scenario design and content were made by agreement between Working Group participants and The Aotearoa Circle, with technical advice provided by KPMG New Zealand.

Figure 7: Summary of project governance



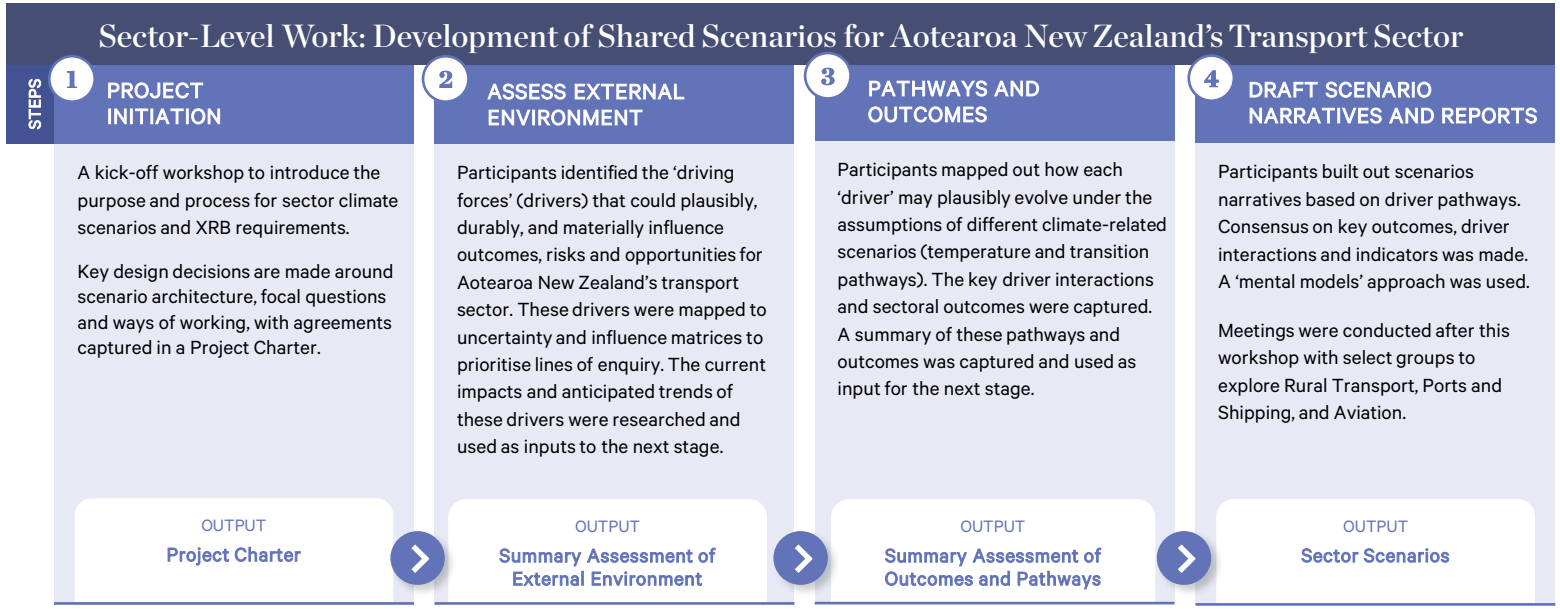
Focal question

A focal question guides a project or a process by providing clarity, direction, and boundaries. It should be specific, short, precise, and reflect the desired outcome and the domain of the project. The focal question guiding this scenario process was: '*How could climate change plausibly affect the transport sector in Aotearoa New Zealand, and when?*'.

Project process

The sector-level scenarios in this report were developed through the process summarised in Figure 8. Steps 1 through 4 were conducted between July 2023 and March 2024.

Figure 8: Summary of scenario analysis processes



Scenario design

Scope

The scope of the scenario analysis is bounded by the focal question, however key decisions were made around the geographic scope, time horizons, framework architecture, system model and parameters that were used.

The complexity of the transport system, with its many actors, modes, and dependencies on sectors like urban planning, broader infrastructure, and energy, made detailed exploration of all elements within its 'value chain' beyond the scope of this work.

For the purpose of these scenarios, a simplified model of the transport system was used to focus discussion. This was based on four major components: System Managers and Shapers; Users; Operators and Suppliers; and the Physical System. Inputs to the system were assessed, such as workforce, and resources.

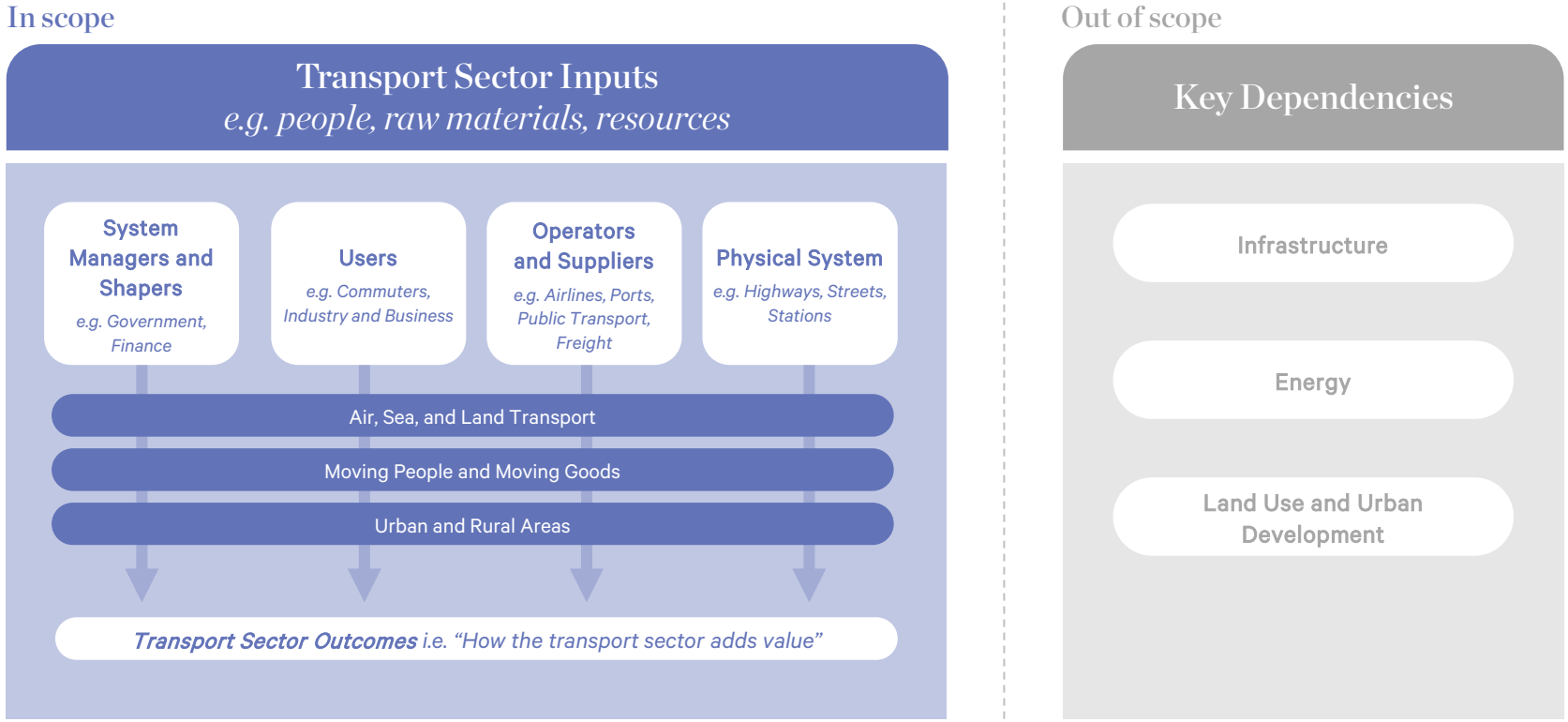
Lastly, the impacts that climate change may have on the transport sectors ability to directly or indirectly produce 'outcomes' for people and the planet were explored.

Adjacent sector dependencies such as infrastructure and urban development were discussed. For scope reasons, the project made assumptions about their impact on the transport sector rather than scrutinising these issues in depth. Where available and relevant, existing sector scenarios were used to inform these assumptions. Where there were gaps, logical assumptions were made. As the transport and energy sector scenarios were developed during the same time period, both working groups collaborated at multiple points to align key assumptions and keep the narratives materially consistent where possible.

Boundaries

The geographical scope of the scenarios was limited to Aotearoa New Zealand's national boundaries. However, consideration of international factors and their potential trends through the time horizons was made, especially in reference to international air travel and shipping.

Figure 9: Simplified transport model and elements that were in and out of scope for this scenario analysis



Scenario design

Framework architecture

The 'framework architecture' of the Bypass to Breakdown, Short Detour, and Fully Charged scenario set was chosen as it aligned with the XRB requirements for "a 1.5 degrees Celsius climate-related scenario, a 3 degrees Celsius or greater climate-related scenario, and a third climate-related scenario"[1]. The architecture consists of an internally coherent set of temperature outcomes, socio-economic assumptions, decarbonisation pathways, and climate change projections. Following XRB guidance, this architecture combines distinctive and diverse higher level, publicly available scenarios and projections to provide broad guide rails.

Figure 10: Scenario framework architecture – integration with higher-level, publicly available scenarios and projections

	Transport sector climate scenarios	Bypass to Breakdown	Short Detour	Fully Charged
Publicly available scenarios	**Network for Greening the Financial System (NGFS) scenarios**	'Current Policies' scenario*, Hot house category	'Delayed Transition' scenario, Disorderly category	'Net Zero 2050' scenario, Orderly category
	UN Intergovernmental Panel on Climate Change (IPCC) scenarios	Shared socio-economic Pathway (SSP) SSP3-7.0	SSP1-2.6	SSP1-1.9
	New Zealand Climate Change Commission (CCC) scenarios	'Current Policy Reference'*	'Headwinds'	'Tailwinds'
	International Energy Agency (IEA) scenarios	'Stated Policies Scenario' (STEPS)	'Sustainable Development Scenario' (SDS)	'Net Zero Emissions by 2050' (NZE)

The transport sector climate scenarios and narratives in this report are best aligned to the framework shown above. In some cases, parameters data does not fit with this framework. Deviations from this are outlined in Appendix E.

Choice of high-end outcomes

Two >3.0°C SSP-RCP pairs were considered to help define the transport sector's 'high-end' Bypass to Breakdown Scenario that satisfied the XRB's requirements for a 3 degrees Celsius or greater climate-related scenario: SSP3-7.0 and SSP5-8.5.

SSP3-7.0 was selected because it accounts for milestone international agreements and mounting progress towards mitigation goals.

In contrast, SSP5-8.5 is a so-called 'baseline' scenario that does not include any specific emissions reduction target, assumes limited international cooperation on climate change, and assumes that policies to address climate change are not a priority amongst governments.

Under this scenario, greenhouse gas emissions continue to increase, leading to a radiative forcing of 8.5 W/m^2 by 2100. This scenario's failure to account for progress at the international level (e.g. the 2019 Paris Agreement), national level (e.g. Nationally Determined Contributions and associated legislation, including Aotearoa New Zealand's 2019 Climate Change Response Act (Zero Carbon) Amendment), coordinated efforts by the private sector, or positive tipping points such as the public access to/demand for electric cars (e.g. in 2023, the EV market share for new car registrations (including plug-in hybrids) in Aotearoa New Zealand was over 27%, significantly up from 1% in 2018[2]) or the phase-out in coal-powered electricity in the United States over the past decade (generation is down to 16.2% of the country's electricity, half of what it was a decade ago[3]) , limits the relevance of SSP5-8.5 to real world decision-makers in the transport sector.

**Please note, 'Current Policies' is the name of an NGFS climate scenario, and not associated with the current state of Aotearoa New Zealand politics and existing or planned policy. The CCC's "Current Policy Reference" scenario also does not reflect current policies as of June 2024.*

[1] *XRB, 2022. Aotearoa New Zealand Climate Standard 1. [Online] Available at: https://www.xrb.govt.nz/dmsdocument/4770 [Accessed March 2024].*
[2] *EVDB, 2024. EV Market Stats 2024. [Online] Available at: https://evdb.nz/ev-stats*
[3] *Inside Climate News, 2024. Coal Power Plunged Again in 2023 and Is Fading Away in the U.S. So What Replaces It? [Online] Available at: https://insideclimatenews.org/news/14032024/inside-clean-energy-coal-power-decline/*

Scenario design

Parameters

'Parameters' refer to the detailed (often, but not always, quantitative) physical climate or socio-economic variables that help define and distinguish scenarios. These data points and assumptions are critical to analysing and eventually quantifying related risks and opportunities. The below parameters were selected to frame the scenarios.

Further detail on parameters can be found in Appendix D.

Figure 11: Scenario parameters

Parameters		
Physical	• Mean Annual Temperature Change • Extreme Heat • Extreme Rainfall • Median Sea Level Rise • Extreme Wind Speed	• Annual Expected Damage from Tropical Cyclones • Annual Expected Damage from River Floods
Socio-economic	• Population • Gross Domestic Product (GDP) • Inflation Rate • Long term Interest Rate	• Carbon Price • Oil Demand • Oil Price Increase
Transport	• Total Transport Carbon Dioxide (CO_2) Emissions • Road Vehicle Kilometres Travelled by Vehicle/Engine Type	• Household Person Kilometres Travelled by Mode • Total Number of Vehicles in Fleet • Freight Mode Share
Energy	• Total Primary Energy Supply – Renewables • Percentage of Electricity Generation from Renewables • Renewable Energy Share of Total Final Consumption (including international transport)	• Breakdown of Transport's Total Final Energy Consumption by Mode • Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption

Granularity

Granularity refers to the level of spatial resolution wherein qualitative and quantitative analysis takes place (e.g. local, place-based, regional, and national levels). In regard to climate change parameters, country-level figures in many cases is all that is currently available for Aotearoa New Zealand. While regional-level data would provide grater granularity, these figures provide an adequate starting point for Aotearoa New Zealand's transport sector participants to assess implications on their operational and market footprints.

Time horizons

Participants agreed to three time horizons which are relevant to transport's strategic planning horizons and capital deployment plans, wherein:

- 'Short term' refers to the 2024-2030 period;
- 'Medium term' refers to the 2031-2040 period;
- 'Long term' refers to the 2041-2050 period; and
- 'Extension Scenario' for Bypass to Breakdown refers to 2051-2100*.

**It was recognised that a longer time horizon would be beneficial in exploring the escalating physical risks under a higher emissions scenario, in order to understand the resilience of system design decisions taken earlier in the century. As such, an 'extension' to the Bypass to Breakdown scenario was also added, spanning from 2051-2100.*

Driving forces

The XRB define 'driving forces' (sometimes referred to as 'drivers' of change) as "broad scale, external factors that may affect the outcomes of the focal question(s)"[1].

Drivers are external factors that influence the events, trends, and patterns determining the direction of change, and thus the 'outcomes' in the sector's environment. For example, the factors dictating how climate change impacts the transport sector's ability to create value for Aotearoa New Zealand.

To be considered a driving force, the XRB say external factors need to:

- Be continuous over a period of time; and
- Influence the outcomes of the focal question durably and consistently.

Through the scenario analysis process, participants in the working group identified a series of key drivers of change that may materially affect Aotearoa New Zealand's transport sector in the future. These drivers of change were grouped using the PESTLE Framework categories:

- Political;
- Environmental;
- Social;
- Technological;
- Legal; and
- Economic.

See the next page for an overview of the driving forces explored in these scenarios.

[1] *XRB, 2022. Aotearoa New Zealand Climate Standard 1. [Online] Available at: https://www.xrb.govt.nz/dmsdocument/4770 [Accessed March 2024].*

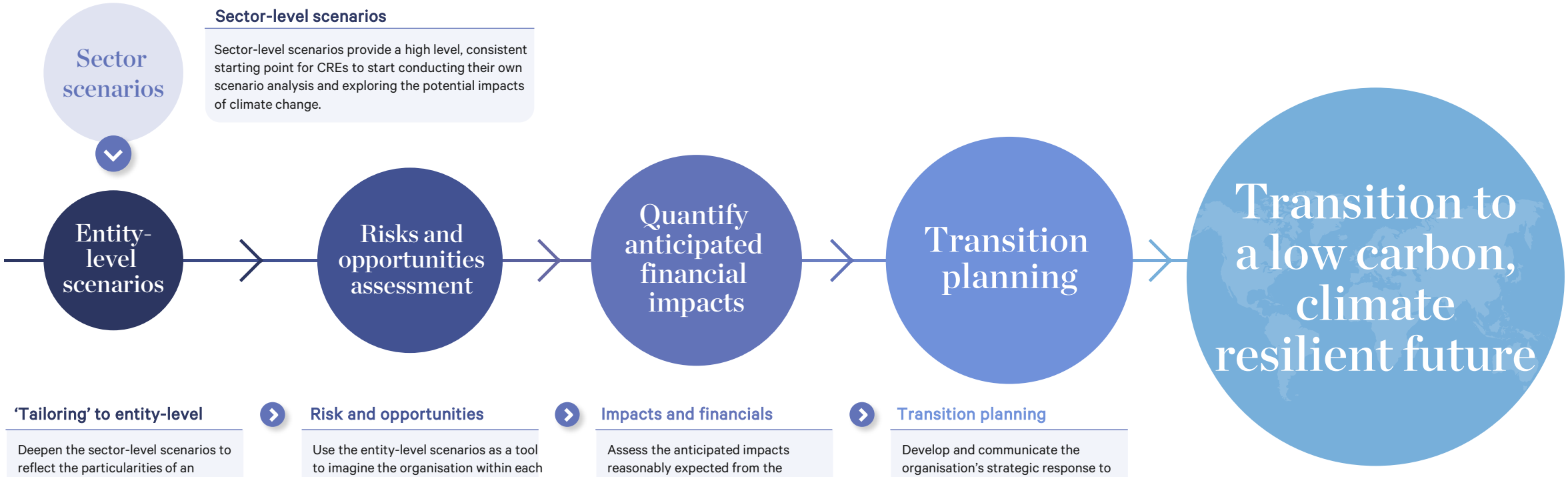
Scenario design

Figure 12: Overview of driving forces identified and using during the scenarios process

Political	Environmental	Social	Technological	Legal	Economic
How domestic and international political policy, sentiment, and future relations affect or may affect policy and legislation for the transport sector.	*How climate-related acute and chronic impacts affect the transport sector both directly and indirectly.*	*How demographic and political trends, as well as beliefs or values, change over time/geographies and affect transport choices.*	*How new and emerging technologies can affect transport business models, strategies, and value chains.*	*How laws, regulations, and legal systems can affect the transport sector.*	*How macro and micro-economic conditions, trend, and actors can affect the transport sector and its operating environment.*
P1. Domestic political leadership and ambition	EN1. Chronic climate impacts	S1. System user preferences and behaviours	T1. Availability and accessibility of new technology	L1. Government action on climate laws	EC1. Domestic macroeconomic conditions
P2. Government funding and investment	EN2. Acute climate impacts	S2. Social expectations of sustainability	T2. Enabling ecosystem for technology	L2. Exposure to public action on climate	EC2. Domestic economic structure
P3. Te ao Māori/Te Tiriti	EN3. Natural resources	S3. Demographics	T3. Existing technologies (impacting 'current state' system)	L3. Directors and officers' liabilities	EC3. Commodity prices
P4. Carbon taxes/markets (domestic and international)		S4. Urbanisation	T4. Emerging technologies (enabling 'future state' system)		EC4. Access to finance
P5. Transport-specific legislation		S5. Social cohesion, equity and equality			EC5. Consumer financial strain and equality
P6. Sector-adjacent legislation		S6. Social expectations of health and wellbeing			EC6. Global macroeconomic conditions
P7. International ambition					EC7. Global market alignment
P8. International geopolitical stability					

See Appendix H for descriptions of these driving forces

Using these sector-level scenarios



Sector-level scenarios

Sector-level scenarios provide a high level, consistent starting point for CREs to start conducting their own scenario analysis and exploring the potential impacts of climate change.

'Tailoring' to entity-level

Deepen the sector-level scenarios to reflect the particularities of an organisation's business model, strategy, and value chain.

This may include exploring certain driving forces in more detail, bringing in location-specific physical risk data, or expanding analysis to an overseas location.

Risk and opportunities

Use the entity-level scenarios as a tool to imagine the organisation within each scenario and identify climate-related risks and opportunities across each time horizon.

How resilient is the organisation's business model, strategy, and value chain under each scenario?

Impacts and financials

Assess the anticipated impacts reasonably expected from the identified risks and opportunities. Financially quantify these impacts based on how they affect financial performance, position, or cash flow.

Consider the capital expenditure, financing, or investment that will need to be deployed towards these risks and opportunities.

Transition planning

Develop and communicate the organisation's strategic response to the climate-related risks and opportunities.

Transition plans describe the aspects of an organisation's overall strategy that will enable its transition to a low carbon, climate resilient future, including interim targets, actions, and financial implications (separate to quantifying other impacts).

Navigating these scenario narratives

Transport is a large complex sector. Whilst users of these scenarios may choose to read through and utilise all narratives, they may also wish to just focus on the elements most relevant to them.

The scenario narratives are consistently structured using the following elements:

Scenarios

Bypass to Breakdown | Extension | Short Detour | Fully Charged

Time Horizons

Short Term (2024-2030)	Medium Term (2031-2040)	Long Term (2041-2050)	Extension (2051-2100)

Look for these symbols throughout the narratives to help navigate the document and find sections most relevant to you. For a refresh on the scope of these subsystems click here.

What if?

Keep an eye out for these 'What if?' boxes, which provide a snapshot into what might be happening in an area of the transport sector at a point in time.

Driver impact pathways

These graphics map out elements of the complex interactions between driving forces that happen throughout the scenarios, and form the basis of the narratives.

The scenarios have a consistent structure, with an overview section (1 and 2), and then detail on specific time horizons (3 to 6).

1 Scenario overview

Outlines the broader assumptions for the world and Aotearoa New Zealand behind each scenario, and the wider contexts within which the sector scenarios are situated. Outlines key temperature pathways and outcomes, risk and rate of change, and the trends that shape our world and home, for example consumption, policies, and trade.

2 Parameters

This section highlights changes in time across key scenario assumptions including physical, socio-economic, transport, and energy related parameters. Whilst these provide a comparable insight between scenarios, these are only indicative projections based on many specific assumptions. They should not be treated with certainty, rather used as a rough guide.

3 Prominent themes for the time horizon

Major themes shaping Aotearoa New Zealand's transport sector under each scenario and time horizon.

4 Sector wide trends

Narratives for the driver pathways and outcomes that impact all system elements. A driver impact map is also included showing the complex system interactions.

5 Moving people

5.1 Urban

Covers urban mobility across air, land, and sea modes in one narrative.

5.2 Regional, Rural and International

Split between:

- Land-based regional and rural mobility.
- Air-based regional and international mobility.

6 Moving goods

6.1 Land

Covers land freight modes across urban, regional, and rural areas.

6.2 Air and Sea

Covers air and sea freight across urban, regional, rural and international routes.

Full scenario narratives

Bypass to Breakdown

Short term 2024-2030
MOVING PEOPLE
MOVING GOODS

Medium term 2031-2040
MOVING PEOPLE
MOVING GOODS

Long term 2041-2050
MOVING PEOPLE
MOVING GOODS

Bypass to Breakdown Scenario

Scenario Overview

This is a divided world that refuses to cooperate and confront the non-negotiable realities of planetary boundaries. Instead, countries focus on their short term domestic best interests, resulting in persistent and worsening inequality and environmental degradation. International and domestic policy settings result in well over 3.0°C warming by end-century.

The physical impacts of climate change are substantial by mid-century. However, from 2050 onwards, their scope, scale, and ferocity accelerate. We have almost certainly surpassed tipping points in the Earth climate system, beyond which greenhouse gas emissions lead to a shutdown of large ocean circulation systems and massive permafrost melting. Under this scenario, the world is most likely to have warmed by roughly 3.9°C (potential range of 2.8°C to 4.6°C) at end-century, with global average sea levels having risen by 46 to 74 centimetres – with materially more locked-in if Greenland and Antarctic ice sheets destabilise.

+3.0°C Policy Ambition*:

** The temperature outcome aligned with global policy settings and ambitions under this scenario[3].*

Severity of physical risk	*High*
Severity of transition risk	*Low*
Policy reaction to climate change	*Insufficient*
Regional policy variation	*Low variation*
Technology change	*Slow change*
Carbon dioxide removal	*Low use*

Global [1]

Warming at 2050

2.1°C

Warming at 2100

3.9°C

Aotearoa New Zealand [2]

1.6°C

NIWA 2031-2050 estimate

4.3°C

NIWA 2081-2100 estimate

[1] *IPCC, 2021. Summary for Policy Makers. [Online] Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf (Accessed March 2024).*
[2] *MfE, 2018. Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition. Wellington: Ministry for the Environment.*
[3] *NGFS, 2024. NGFS Scenarios Portal. [Online] Available at: https://www.ngfs.net/ngfs-scenarios-portal/explore/ (Accessed May 2024).*

Our World

A series of global conflicts and economic instability give rise to a world characterised by resurgent nationalism and driven by short term economic competitiveness and security goals. Conflicts have spread and geopolitical tensions grown, preventing effective global action on climate change. Most governments are preoccupied with achieving energy and food security goals at the expense of broader-based development. Countries' capacity to adapt to the physical impacts of climate change is relatively low as a result of worsening inequality, widespread environmental degradation, lack of cooperation, and slow technology development.

- **Consumption:** Continues along current trends, remaining material-intensive. A growing percentage of the population aims to align consumption with planetary boundaries, but most people's choices are driven by consideration of cost and/or the social status they associate with particular goods, services, and/or brands.
- **Society:** Inequalities persist or worsen over time.
- **Education and Health:** Population growth is low in industrialised and high in developing countries. Public investment in education and health declines.
- **Economy and Trade:** Economic growth is based on material-intensive production and consumption patterns. The physical impacts of climate change are affecting the economy through multiple pathways, including lost labour productivity, lost productive land, damaged capital, increased incidence of disease and mortality, lost tourism, and reduced agricultural yields. By 2050, the physical impacts of climate change have cost the world 11-14% of global GDP, with the degradation of nature generating additional economic headwinds.
- **Land Use and Nature:** Addressing environmental concerns is a low priority, leading to strong environmental degradation in some regions.
- **Technology:** The absence of strict climate policies means that energy supply is dominated by the economics of energy resource availability and energy conversion technologies. The development and uptake of technologies is relatively slow.
- **Energy:** The global energy system continues to decarbonise, and whilst the close historical relationship between growth in GDP and growth in emissions is broken, decarbonisation happens far more slowly - driven by slower electrification of light transport in developing nations, slower reduction in coal and oil, and less behavioural change. Renewables account for only 30% of global total primary energy supply by 2050, with 70% of global electricity generation from (non-nuclear) renewable sources. There are only small increases in the use of low carbon and hydrogen-based fuels to 2030 or biofuels.
- **Transport and Energy:** By 2030, only around 35% of all new car sales are electric, although this is mainly in developed nations. Global gasoline demand continues to rise out to the mid-2030s, driven mainly by emerging markets and developing nations (excluding China), where ICE vehicles maintain a dominant share of sales. Aviation and shipping see their total energy consumption continue to rise, with constrained supply of SAF available to major airlines in the United States and Europe, and limited ability of operators in Aotearoa New Zealand to access supply. This leaves few cost-effective, low-emissions alternatives beyond improving efficiency available out to 2030. By 2050, 78% of final transport energy consumption remains from oil, only 11% from electricity, and with minimal contributions from biofuels (6%) and hydrogen (1%).

Our Home

Aotearoa New Zealand lags behind its OECD peers in mitigating climate change. Government, business, and society do not think the country can afford to 'decarbonise alone' ahead of major economies. Instead, Aotearoa New Zealand chooses to take an adaptation approach, investing in resilience to acute and chronic physical climate impacts to protect communities and businesses, while ensuring continued economic viability and retaining competitive advantages. Emissions reduction investment is deprioritised, and is typically a by-product of indirect efficiency gains. In recognition of the significant challenges, infrastructure investment, technology, and especially AI and digital information systems are widely adopted to boost resilience.

- **Policy:** Government's approach to curbing emissions continues relies on the Emissions Trading Scheme (ETS) in a manner which sees companies pay to continue emitting rather than invest in decarbonisation. A national adaptation programme is launched, prioritising policies around hardening infrastructure, facilitating managed retreat from certain locations, and preparing the economy for a warmer, less stable, climate. Attention, financial support, resources and technology required for the transition to greener alternatives are not prioritised. Focus is instead directed towards preserving economic output. Adaptation policies and funding do attempt to protect vulnerable populations, at least until climate severely impacts public fiscal balances.
- **Trade:** Strong regional migration based on maximising labour supply, which results in strong regional competition to attract business. There is limited demand for clean, green products.
- **Behaviour:** People and businesses continue to engage in materially intensive consumption and high emitting activities, and are less inclined to adopt low emissions technologies unless there is a compelling economic or commercial rationale.
- **Natural resources:** Aotearoa New Zealand exploits its natural resources to maximise economic returns in the short to medium term and leverage competitive advantages. Freshwater resources are provided with limited protection. High discount rates are a major driver for government expenditure, and environmental conservation is a lower government priority.

Bypass to Breakdown Parameters

Bypass to Breakdown physical parameters

PHYSICAL VARIABLE	LOCATION	2030	2040	2050
Mean Annual Temperature Change *(°C, average annual temperature vs pre-industrial baseline)*	Global	1.5°C	1.8°C	2.1°C
	NZ	*2031-2050 Figure*: 1.6°C		
Extreme Heat *(Average number of days exceeding 25.0°C annually)*	NZ	*2031-2050 Figure*: 30 Days		
Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	NZ	*2031-2050 Figure*: 22%		
Median Sea Level Rise *(Increase in metres)*	NZ	0.11	0.16	0.24
Extreme Wind Speed *(Estimates from NIWA visuals)*	NZ	*2031-2050 Estimate*: Approx. 5-10% increase in parts of the country (Mostly southern half of North Island, and South Island)		
Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NZ	-16	-23	-33
Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NZ	31	31	16

Bypass to Breakdown socio-economic parameters

SOCIO-ECONOMIC VARIABLE	LOCATION	2030	2040	2050
Population *(Million)*	Global	8,565.8	9,361.0	10,093.4
	NZ	5.8	6.4	6.9
GDP *(% difference, 2009 prices; local currency vs baseline)*	NZ	-0.7	-1.7	-2.7
Inflation Rate *(Absolute difference % vs baseline)*	NZ	0.04	0.10	0.17
Long Term Interest Rate *(Absolute difference % vs baseline)*	NZ	-	-	-
Carbon Price *Energy (real NZ$/tCO$_2$e)*	NZ	114	153	206
Oil Demand *(Million barrels per day)*	Global	101.5	-	97.4
Oil Price Increase *(% difference, US$ per barrel vs baseline)*	NZ	-	-	-

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Bypass to Breakdown Parameters

Bypass to Breakdown transport parameters

TRANSPORT VARIABLE	LOCATION	MODE	2030	2040	2050
Total Transport CO_2 Emissions *(Global = $MtCO_2e$) (NZ/Domestic = $ktCO_2e$)*	Global	-	8,282	7,954	8,060
	NZ	-	15,204	11,760	6,012
Road Vehicle Kilometres Travelled by Vehicle/Engine Type *(Total = billion kilometres) (Type = % share)*	NZ	Total	58	63	67
		ICE Vehicle	92	64	25
		EV	4	36	75
Household Person Kilometres Travelled by Mode *(Million kilometres)*	NZ	Active Transport	1,381	1,454	1,502
		Public Transport	3,268	3,916	4,538
		Private Transport	60,550	63,630	65,597
Total Number of Vehicles in Fleet *(Thousands)*	NZ	-	5,350	5,592	5,700
Freight Mode Shares *(% share)*	NZ	Rail	13	13	13
		Costal Shipping	12	12	12
		Road	75	75	75

Bypass to Breakdown energy parameters

ENERGY VARIABLE	LOCATION	MODE	2030	2040	2050
Total Primary Energy Supply – Renewables *(% share)*	Global	-	18	-	31
	NZ	-	46	53	62
Percentage of Electricity Generation from Renewables *(% share)*	Global	-	47	-	70
	NZ	-	90	90	92
Renewable Energy Share of Total Final Consumption (including international transport) *(% share)*	NZ	-	27	31	39
Breakdown of Transport's Total Final Energy Consumption by Mode *(% share of total)*	Global	Road	73	-	68
		Aviation	13	-	17
		Shipping	10	-	11
Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption *(% share)*	Global	Biofuels	5	-	6
		Hydrogen	0	-	1
		Electricity	4	-	11

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Bypass to Breakdown

Prominent themes for 2024-2030

Limitations to climate action

Policy makers face significant geopolitical and economic challenges to decarbonisation. Rising nationalism and economic protectionism impair the import of critical resources needed for the transition of the transport sector, including financing, labour, and technology. There is less global collaboration on targets, standards, or policies. Government, business, and most of society do not think Aotearoa New Zealand can afford to move first or alone.

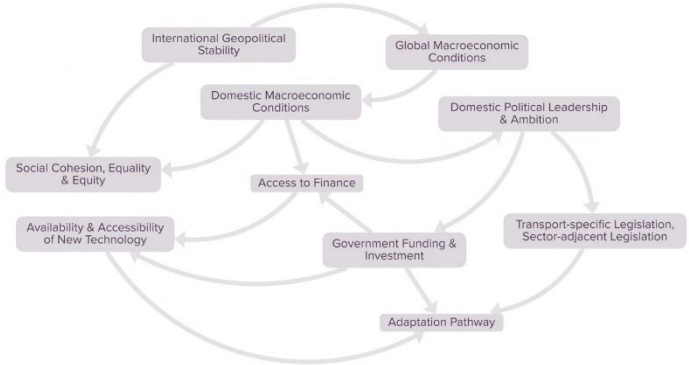
Focus on adaptation and short term economic growth

Government focus is on resilience and adaptation as a prerequisite for economic stability, with less emphasis on greenhouse gas emissions reduction initiatives. Existing transport infrastructure is expanded and hardened rather than a shift towards low carbon fleet or modes. The high cost of EVs and slow progress in low emissions infrastructure encourages continued reliance on private vehicles and road construction.

Social divisions and inequity

Less focus on providing equitable access to transport, limited climate mitigation action, and growing economic inequalities all see social polarisation steadily worsen out to 2030.

Driver Impact Map



Sector-Wide Trends

Geopolitical relations deteriorate following a series of conflicts and a faltering global economy. Resurgent nationalism pushes countries to focus policy on national or, at most, regional security issues, with a focus on domestic energy and food security instead of broader-based development. A lack of focus on addressing environmental concerns limits the flows of finance, labour and resources. The development and supply of compatible technologies required for a global transition is disrupted, whilst the rising cost of living dampens social support for climate mitigation.

In response, there is a resurgence in the view that “Aotearoa New Zealand's emissions are insignificant” and that the country cannot afford to take the lead or act alone. Focus shifts to short term GDP growth. A 30-year ‘Strategy for a Resilient Aotearoa New Zealand’ is launched and backed by substantial long term funding. It establishes a national consensus on the need for adaptation action and confidence that government will support people and businesses affected.

Transportation plays a central role in this strategy, with adaptation integrated into planning, investment, and decision-making across the sector. Risks to critical infrastructure are identified, and a comprehensive plan to reinforce or relocate infrastructure in priority areas is established.

Funding focuses on enhancing road and rail transport connections to critical facilities like ports and hospitals to improve resilience. While this investment creates jobs and increases GDP, the extensive construction works temporarily disrupt logistics and freight at the local level.

Policies and incentives are developed to encourage resilient development in designated low risk areas. Cost-effective nature-based solutions are prioritised, such as restoring catchment areas near highways, or using trees in cities for temperature regulation. A centralised climate risk data programme and investment in advanced monitoring and early warning technologies help manage climate risks. The transport and energy sectors work together to assess network resilience and create a joint plan. These programmes are also set up with bipartisan and long term commitment, creating economic certainty limited only by availability of resources and capabilities.

Hazard Advisory

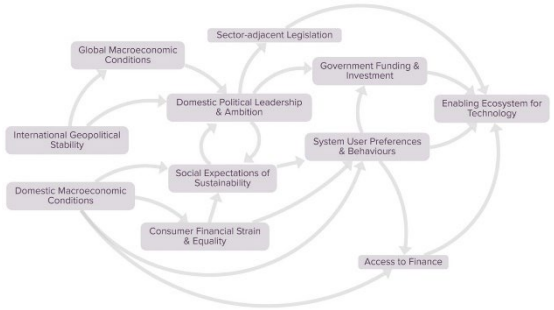
A new national advisory entity is established as a multidisciplinary hub coordinating information of hazards and understanding vulnerabilities of communities and local economies. This information is then fed back into the national adaptation masterplan to adjust priorities.

Despite a strong youth voice advocating for climate action in the early 2020s, emissions reduction is deprioritised as Aotearoa New Zealand focuses on economic growth, benefitting from its relatively climate-secure geographical location. The ETS and market forces are relied on to set the pace of mitigation, but a lack of investor encouragement leads to private sector transport operators postponing investments.

While there is widespread support for this strategy, some groups protest against it due to concerns about social outcomes. Activists fear that the approach maintains 'business as usual'. Although many communities, particularly those in coastal and lowland areas, welcome the allocation of dedicated funding and support for adaptation, other groups protest the lack of emissions reduction and the perceived long term implications for their communities and the environment in Aotearoa New Zealand.

Moving People

SHORT TERM (2024-2030) **MEDIUM TERM** (2031-2040) **LONG TERM** (2041-2050)



Urban

Projects, funding, and building standards focus on climate resilience of existing road and rail infrastructure, with renewal programmes focused on reducing vulnerability, primarily through better stormwater management. Projects designed to enable public transport or walking and cycling are mothballed unless there is an underpinning resilience business case (such as the Te Ara Tupua connection between Wellington and Lower Hutt).

New development is only allowed in areas where climate risk is deemed acceptable. In some areas this forces densification as no low risk land is available, and in others it encourages sprawl, particularly in areas where population is increasing rapidly.

Vehicle ownership remains a cultural symbol of independence in Aotearoa New Zealand and private vehicle use remains high. More roads are built to meet rising demand in key areas where congestion is a fact of life. There is a lack of support for any policies that increase the cost of vehicle use or ownership, and the vehicle sharing market stagnates outside main urban centres.

Those who can afford to not use public transport choose not to due to concerns of reliability or coverage, and increasing crime. Privately organised car sharing starts to displace struggling publicly provided services which aren't meeting needs. Micromobility rises in popularity, although the lack of dedicated infrastructure sees increasing conflicts with pedestrians and car users. Those who can afford home-charging and EVs switch for the return on cheaper electricity.

There are rising pockets of transport poverty. Young people, elderly, poorer communities and some Māori and Pasifika groups complain that the approach just "locks in the status quo" and perpetuates existing transport and social inequalities. Towards 2030, larger cities are experiencing worsening congestion because of a growing light fleet and extensive adaptation works underway. Cities lag further behind global peers on transport-related liveability indexes.

Less Active Mobility

Active mobility routes appear, but fall short of producing a connected, safe network that encourages a diverse group of people to adopt new practices. Cycling is felt to be unsafe or inefficient in many areas due to rising traffic, and fewer low speed zones.

Regional, Rural & International

Global EV prices remain high in an uncertain market, and the domestic enabling ecosystem needed to address range anxiety is slow to roll out. Although successive governments have removed barriers to charging infrastructure in certain locations, the lack of targeted consumer finance, workforce development, or consumer education all mean that EV uptake is slow. Many rural or isolated areas do not have EV chargers or maintenance support. By 2030, EVs account for less than 5% of all vehicle kilometres travelled.

Government plans for road network adaptation centre on the use of nationally consistent climate data and conducting a comprehensive assessment of asset and network criticality. Collaboration with local government helps identify 'single points of failure', like bridges in remote areas that support both the transport and energy networks. Technologies like digital twins and predictive AI are deployed to model and plan for the impact of extreme weather events on critical infrastructure. Major works are carried out on key assets to reshape or reinforce them against impacts of flooding, landslides, or heatwaves.

Community-led retreat becomes a centreground topic. Decisions are made to reduce or cease the repair and remediation of many at-risk roads in coastal and remote areas. Whilst this causes some local outcry from affected communities, there is social and financial support to help people migrate to more resilient locations. As several notable extreme weather events hamper movement in coastal areas, some communities find themselves increasingly disconnected from the main transport network, as both insurers and service providers retreat from high risk areas.

Communities start stockpiling food and fuel, or set up local 'Climate Resilience Hubs' where disaster response plans are made, including maintaining vital road access.

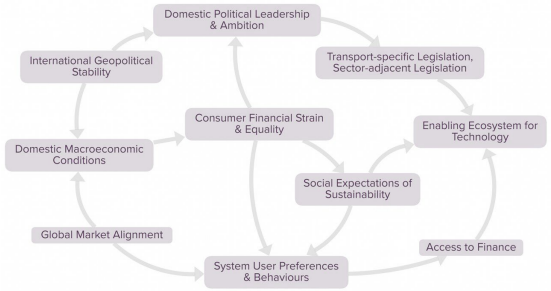
Critical Road Network

Nearly 20% of the state highway network and critical local roads require works, many of which will also directly affect the communities on and around those routes. Announcements are received with uproar and demands for funding of property and commercial buyouts. Court cases accuse the government of wiping out property values.

Limited global collaboration on SAF production or standards limits development, with little ambition for domestic investment in production or storage. Pilots of green hydrogen and electric aviation are conducted, but struggle to compete commercially with legacy jet fuels. Carriers struggle to pass on emissions-related costs via consumer pricing, limiting the ability to shift fuel type or practices. Despite some protest from activist groups, most consumers remain focused on cost-effective travel and connectivity. The sector implements AI and predictive weather analytics to improve operational efficiency and reduce fuel wastage, with carbon intensity reductions a by-product. Protecting airport infrastructure against extreme weather events is a key priority.

Moving Goods

SHORT TERM (2024-2030) **MEDIUM TERM** (2031-2040) **LONG TERM** (2041-2050)



Land

With domestic consumers and global export markets less sensitive to Scope 3 emissions, and lack of long term government policy on emissions reduction, freight businesses hold off major investment in low emissions alternative fuels or vehicles. Lack of global collaboration increases the financial, technological, and workforce barriers to adopting low emissions fuel or vehicles.

There is limited cross-sector collaboration or R&D support from government on scaling the development of interim drop-in biofuels or alternatives like green hydrogen. Many innovative low emissions fuel or fleet companies relocate overseas to more progressive markets. This entrenches Aotearoa New Zealand's reliance on fuel imports. With finance and insurance agnostic to emissions intensity, the freight sector only decarbonises where they see low carbon modes offering other commercial opportunities, but most don't.

Exploring new routes

With the Panama Canal already experiencing access issues due to drought-induced low water levels, and forecasts predicting more disruption, a group of shippers strike a long term deal with a Mexican railway provider for faster, more reliable carrying of goods between Pacific Ocean and Gulf of Mexico ports, boosting access to the United States and Europe.

Government rolls out a freight strategy that looks to increase system resilience to climate impacts and maximise efficiency in the current freight system. Funding and policy is directed at road and rail improvements and adaptation. Rail network maintenance and repair is prioritised to boost overall land transport network resilience to extreme weather. Freight businesses lobby for reinforcing or developing climate resilient infrastructure at key points of criticality in the network, such as access to ports. Government encourages use of standard climate risk assessments frameworks and data-sharing across the freight sector.

The sector is an early adopter of AI and automation in network planning to deliver cost and time efficiencies and also protect key assets. Digital twins and spatial modelling predict potential impacts of extreme weather. IoT and automated damage detection sensors support a more proactive approach to maintenance and ensure critical resources are properly distributed across the system in preparation for events.

Local government engages with the sector on plans to service at-risk locations, with a more decentralised approach encouraged. Freight operators are generally expected to collaborate to support vulnerable communities during extreme weather events. Companies who are seen as profiting from climate-related incidents quickly lose public favour.

Aotearoa New Zealand's export industries perform well. Whilst there is some planned retreat from certain locations or production methods, the goods needing physical transfer remain relatively consistent. This reinforces the need for adaptation investment into existing infrastructure. Rising populations and congestion in urban areas make 'last mile' deliveries more challenging for urban locations.

Isolated Communities

In 2027 and 2028, there are two Category 5 cyclones which cause extensive road damage around the Gisborne region. Some isolated communities become increasingly difficult and costly to serve, although planned retreat pre-empts most of the critical incidents.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

Air and Sea

Similar to passenger aviation, air freight faces a wide range of challenges in increasing the use of SAF. These include insufficient global cooperation, inconsistent domestic standards, uncertain regulations, and inadequate cross-sector involvement with energy, ports, and local government.

Global shipping falls short of converting climate commitment into action. The International Maritime Organization (IMO) fails to enforce 'Annual Efficiency Ratio' regulations as cost of living pressures dilute political support for scrapping ships. Lack of sensitivity to Scope 3 emissions mean major shippers remain unwilling to pay a premium for alternative fuels and fleets. Global mitigation regulatory standards remain inconsistent.

Growing demand

As the global economy recovers, and with limited focus on carbon intensity, Aotearoa New Zealand's export markets perform well, boosting demand for air freight and shipping. A combination of the country's relatively climate position sees strong foreign direct investment into land and primary industries as climate risk data shifts global supply chains.

There is lack of financing towards global alternative fuel or low emissions ships. The focus remains on speed and reliability over emissions reduction. Shipping remains high carbon, although data-sharing has improved operating efficiencies, with port operators in Aotearoa New Zealand leading on many 'time-at-port' metrics.

Canal Disruptions

Even during the 2020s, global shipping faces increasing operational impacts from social unrest in key regions like the Red Sea, and a series of highly disruptive climate-related events. Globally, major canals are disrupted and a couple of major ports are shutdown for periods due to flooding. Aotearoa New Zealand is disproportionately affected, and a system response includes stockpiling key resources.

Both sectors make investments in data-sharing and AI-enabled system efficiency, and adaptation measures like refitting cargo holds to handle heatwaves, or adapting key airport infrastructure. The IMO does provide strong leadership in developing a global adaptation plan. Funding and technology flow towards making critical infrastructure like major foreign canals or ports more resilient to climate impacts. Instead of port electrification or developing alternative fuel bunkering, ports across Aotearoa New Zealand prioritise investment in infrastructure adaptation to ensure they can accommodate extreme weather. Ports cooperate with the road and rail land freight sectors and local government on the shared climate data, plans, and investments needed to ensure continued access for exports and imports, and to deal with sea level rise and the heightened risk of storm flooding.

Bypass to Breakdown

Prominent themes for 2031-2040

Tech-enabled adaptation

Although Aotearoa New Zealand falls behind its emissions targets, adaptation and technology investments accelerate. Standard climate risk data is made readily available and key transport corridors are hardened against physical risks. Digital twins, drone-based infrastructure maintenance, and AI predictive network management are all deployed to counter the less predictable, more intense acute impacts of climate and boost network resilience.

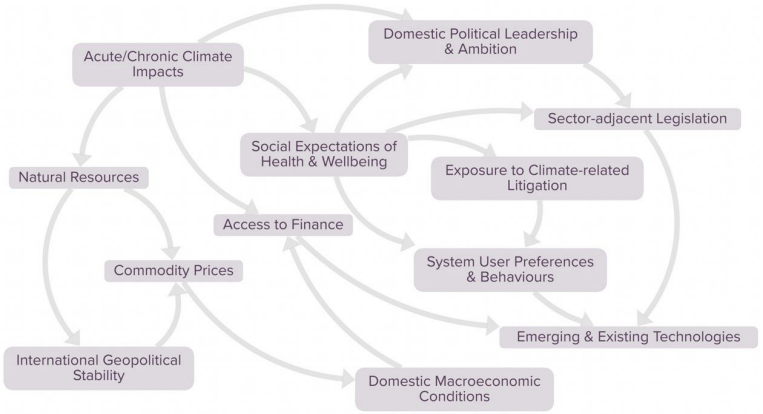
Managed retreat continues

Managed retreat from some locations or industries continues as the acute and chronic impacts of climate change begin to worsen. Certain transport infrastructure becomes unsupported for maintenance as better climate data emerges, and insurance retreat occurs. Government still supports most communities well with relocation, although it is a disruptive period.

Rising costs and inequality

Less global collaboration combined with steadily worsening physical impacts to global supply chains triggers cost of living spikes. Socio-economic inequality and polarisation worsens, threatening the long term welfare of communities like Māori, Pasifika, migrants, the elderly, and poorer rural groups who have experienced historic transport inequities from the private vehicle-based system.

Driver Impact Map



Sector-Wide Trends

Climate-linked pressure on critical resources like water and declining geopolitical collaboration sees increases in economic protectionism and trading blocs, with Aotearoa New Zealand more reliant on Australia and struggling to maintain relationships with China due to pressure from the United States. Carbon markets are failing, and there is reduced commitment to greenhouse gas emissions reduction targets. Decarbonisation occurs as a by-product of national energy security efforts. This inflates technology prices as countries serve internal markets first. Government is struggling to mobilise mitigation plans and is falling behind on greenhouse gas emissions reduction targets.

Advances in attribution science have now communicated the role of anthropogenic climate change in extreme weather events. As in all scenarios, climate impacts are disrupting supply chains, increasing costs, and driving inflation. This increases social demand for adaptation. Policy, finance, and adaptation focused technology are directed at sustaining economic activity for GDP growth.

Significant improvement in climate and geographic information system (GIS) models, digital twins, and AI all support adaptation planning and response, prioritising the resilience and vulnerability issues that need proactive attention. Predictive analytics, miniaturised IoT sensors, and drone-led infrastructure maintenance all enable preventative and cost-effective asset management and renewals. Transport collaborates with other sectors like energy and agriculture to build resilience of key commercial assets like bridges, railways, vulnerable roads, and key distribution hubs.

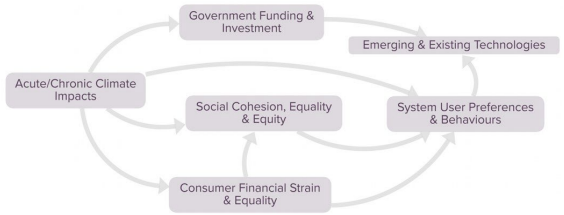
As a comparatively climate-sheltered location with a growing population, partly due to climate migrants, Aotearoa New Zealand performs well economically. Adaptation investments mitigate the worst impacts of climate, although successive or compounding extreme events still cause high disruption to peoples' lives.

However, early in the decade, improved climate science reveals the insurance sector has underestimated the true implications of the temperature pathway the world is on course for. This triggers rapid retreat from insuring certain locations or asset types due to 'locked-in' physical risk. This impacts finance flows, infrastructure investment viability, and fiscal headroom. Government is forced to reconsider the approach of trying to repair and maintain all current infrastructure, including a sprawling road network. This sees a policy of increased retreat of maintenance for certain coastal or at-risk infrastructure that is often misaligned across central and local governments, resulting in some communities being isolated from main networks.

Disproportionate impacts are felt by isolated or vulnerable communities, including climate migrants, the elderly, and Māori. On top of cost of living pressures, this drives a decline in social cohesion and societal mental wellbeing in an increasingly unequal economic system. These divisions progressively impact transport operators' workforces and operations, for example through higher interpersonal conflict and crime. Some younger citizens, Māori, and climate-impacted cohorts begin greater legal challenge to government and high emitting businesses, but momentum struggles to build.

Moving People

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)



Urban

Increasingly reliable and efficient public transport options are deployed in city centres and along select mass-transit corridors. Advanced AI, IoT, and digital twins technology provide effective traffic management and network communications safely integrated into individual and commercial logistics. People receive predictive messaging on traffic demand and are recommended to alter travel time, and there is flexible pricing for delivery times based on forecast congestion.

However, private vehicle ownership remains the most popular mode of urban travel outside these routes, with people buying larger private vehicles due to climate hazards.

Many public transport services struggle for patronage and revenue, competing with private car sharing. Declines in social cohesion mean public transport is increasingly seen as 'unsafe' by many people, creating a negative cycle. This means many communities are not serviced by low emissions public transport options. There are growing congestion issues at peak times along main routes which worsens air quality and reduces public transport reliability. Vehicle utilisation statistics remain low as the sharing economy struggles to develop.

The number of 'manual' human drivers slows deployment of autonomous vehicles in locations outside of controlled central city lanes where driverless shuttles carry people between key transport hubs. On demand transport is increasingly used as society becomes more digitally connected, however the sector contends against congestion on busy roads.

Climate-linked urban migration from rural areas and overseas means cities are seeing high population growth, which is driving further urban sprawl onto greenfield sites and creating more low to medium urban density in areas. Funding remains locked into preserving a road-based and private vehicle-centric system, and 'anti-car' policies are unpopular, especially in the context of extreme weather events when people want to have personal mobility options. EVs become more popular as costs fall, and those who can afford home charging make the switch.

PPPs for adaptation

With many projects underway, focus shifts to the personal scale. Public-private partnerships (PPPs) are established to help small businesses and homeowners plan and develop in low risk zones and incentivise the migration away from current high risk properties. Transport leads the way on this with integrated transport and logistics hubs being the first steps in the planning and design process.

Space in cities remains reserved for private vehicles – from expanding highway lanes to car parks. Local governments struggle to incentivise behavioural change. There is continued uptake in more advanced forms of micromobility, however infrastructure does not encourage safe or longer-distance travel by active modes like cycling as routes are often patchwork and not dedicated. Later in the decade, rising fuel and vehicle ownership costs, poor affordable public transport coverage, and extreme weather impacts accentuate transport poverty within marginalised groups who feel disillusioned with local transport decision-making, creating protest and disruption for operators.

Technology like remote-operated robotics and metaverse-related solutions do reduce the need for some trips, but typically for higher income groups. Extreme weather events are increasingly frequent and disrupt the network through both primary (e.g. damage to infrastructure) and secondary (e.g. delayed workforce issues as communities recover) impacts. Local governments develop system resilience through infrastructure adaptation or opening alternative routes where possible.

Regional, Rural & International

Although EV production and batteries become more efficient as global adoption rises, mounting supply chain challenges due to geopolitical conflict and chronic climate impacts on resource scarcity keep prices out of reach of many people. Government does not prioritise supporting EV roll-out, and the lack of battery storage capacity for commercial or personal use remains a barrier, with grid supply limitations dampening many consumers' confidence.

Moving People

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)

Most rural and isolated communities stick with ICE vehicles as EV charging infrastructure is unreliable. Those who can afford EVs alongside domestic energy production and storage switch to enjoy the payback from lower operating costs. Many consumers trend towards larger, more robust ICE vehicles as a form of personal climate resilience, despite vulnerability to spikes in oil price due to geopolitical conflict. High levels of individual consumption and vehicle car ownership contribute to the burgeoning waste problem, leading to belated government investment in circular economy initiatives.

The road network has been hardened in key areas, and nature-based solutions are used wherever possible to improve resilience, with strict policies around land use near state highways and key nodes.

Technology Affordability

Disparity in affordability of new technology like EVs drives worsening social cohesion. Some groups feel 'left behind' by advances. A cultural trend begins on social media of ICE vehicles being seen as 'the people's choice' and linked to ideas of personal freedom.

Extreme and less predictable weather events do impact the road network; however the adaptation investment mitigates the worst of the damage. Drainage is effective, roadside trees support stormwater management, and when isolated coastal roads are cut off, it is typically after communities have been relocated, or the remaining community sees itself as self-sufficient. The development of seagliders and other ocean-based modes is providing resilience to some regional inter-urban connections and coastal communities.

Climate data is now embedded into people's decision-making, with a risk rating attached to regional journeys and routes. Although some locations are rendered inaccessible, there is generally limited impact on regional travel for leisure, tourism or business, as main routes remain climate resilient. The extent of the public works investment has resulted in rapidly increasing GDP but also significantly increased cost of living, with the cost of transport creating disparity between regions and communities.

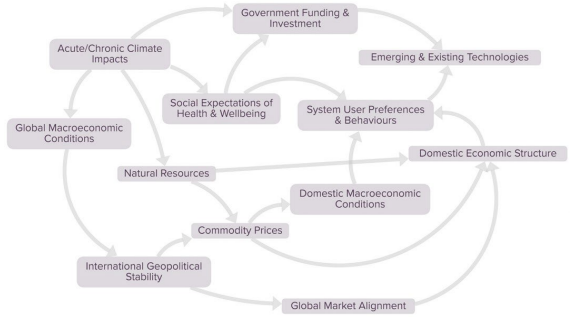
Aviation remains popular and decarbonises slowly, with alternative fuels struggling to reduce their cost premium against fossil fuels. Connectivity remains a priority over emissions reduction for most people, although pockets of climate protest against airlines periodically disrupt operations. Domestic aviation is increasingly popular as the road network undergoes periods of adaptation-linked work. The sector plays a role in disaster response to isolated communities, and invests in eVTOL technology.

The sector deploys advanced predictive AI to mitigate travel disruption, and uses real-time communication with passengers to prevent inefficient 'wasted-trips' if there is forecasted extreme weather, or social disruption, at the destination airport. The decline in geopolitical relations means some international routes are closed during the decade, and traffic starts to align more with geoeconomic trading-bloc allies.

Some destinations or lay-over locations are already feeling the pressure of water or food shortages, with social unrest creating less predictable or secure travel. The sector starts to see passengers hesitant to fly to some higher risk locations for fear of being stuck there due to extreme weather events, or social unrest.

Moving Goods

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)



Land

The land freight sector remains carbon intensive as alternative fuels struggle to reach commercial thresholds for sector-wide adoption. Lack of supporting carbon price or regulation mean providers running dual-fuel fleets struggle with higher operational costs. High global material consumption continues to drive demand for physical goods across both the import and export markets, with Aotearoa New Zealand's economic structure remaining relatively consistent. Urbanisation means cities are now key focus areas, but congestion is making 'last mile' deliveries increasingly difficult. Some high-end providers now specialise in drone-based deliveries and micromobility solutions.

The physical impacts of climate and worsening geopolitics are making longer global supply chains less reliable, encouraging a growth in domestic consumption, and the adoption of technologies like 3D and 4D printing which enable more efficient freight handling. Sectors like agriculture shift to new heat or flooding resistant crops and climate secure production methods, changing freight demand profiles.

Many retailers start holding greater inventory, and there is growing pressure on freight for reliable supply of essential products.

Smart Packaging

Shippers and carriers closely communicate through 'Smart Packaging' that provides real-time data on shipment status. Many shippers are upgrading vehicles to handle 'Active Packaging' which predicts conditions in response to outside stimulus like temperature changes and helps with delays.

Leading carriers must use digital technology to forecast delays and impacts. The sector now deploys advanced IoT, predictive AI and digital-twin technology in combination with geophysical data to make informed decisions on network optimisation, and mitigate both weather-related risks, and the increasing fluctuation of demand and supply of goods which is now more prevalent due to eschewed growing seasons, or seasonal weather variation changing retail demand last-minute.

This advance in technology means freight-as-a-service providers rise in popularity, and autonomous vehicles are trialled for controlled routes. This shift to being a high-tech sector places pressure on talent attraction and retention, with companies struggling to attract highly skilled international talent due to tighter labour markets. Declining social cohesion due to economic inequalities strains workforce relations.

As in other scenarios, more extreme weather events cause intermittent disruption to land freight operations. Risk management and efficient resource allocation are now vital for remaining competitive. Preventative asset maintenance using drones and automated damage detection systems, fast disaster-recovery, and intelligent network optimisation are all key to managing costs.

However, adaptation investments mean critical road, rail, and freight infrastructure remains generally intact, supporting a strong export economy from a comparatively climate-sheltered Aotearoa New Zealand. Whilst rail and coastal shipping volumes do not increase their proportionate share of freight versus road-based options, rail adaptation and inter-modal investment is prioritised with track and asset hardening, maintenance, and repair to maintain capacity due to rail's role in wider network resilience. However, the missed opportunity for greater mode-shift has reduced the adaptive capacity of the overall system.

Policies see a retreat from managing infrastructure in some locations. This either precludes or increases the cost-to-serve for rural and isolated communities, with carriers needing special insurance given the prevalence of climate risk data. This sees an increase in underserved communities and exacerbates the rising cost of living, impairing economic and social outcomes.

Nature-based adaptation

Nature-based solutions are a key intervention for cost-effective adaptation of transport assets. Replanting of native forests in catchment areas is mitigating flood risk for major travel corridors like state highways, railways, or coastal roads, improving freight reliability and coverage.

Air and Sea

Air and sea freight see steadily rising demand alongside population growth. Issues like the slow global development of alternative fuels, the lack of a supporting regulatory environment, and limited development of domestic electricity capacity, means both sectors have made slow progress on decarbonisation despite action from individual operators. Globally rising commodity prices place high pressure on keeping costs down, with customers valuing reliability and price over reduced emissions.

Both sectors have taken advantage of global adaptation finance and made operational and infrastructure adaptation investments to deal with the rising physical impacts of climate. For example, airports have invested heavily in drainage, whilst ports have introduced flood defences, and have new protocols for climate-related weather risk (e.g. cargo container stacking heights). Insurance premiums are beginning to rise.

Despite a challenging operational context globally, there is an increasing focus and expectation on how Aotearoa New Zealand's sea and air freight providers can support the Pacific as climate change begins to materially impact livelihoods on many islands. With uncertain projections over physical impacts, ports are finding funding for expansion plans limited and expensive. Insurance retreat is starting to occur too, despite adaptation investment.

As the decade progresses, both sectors begin to see worsening supply chain disruption from either deteriorating geopolitical relationships or physical climate hazards. Trade embargos from foreign countries can cancel routes overnight, or social unrest after a cyclone can close a major port for months. This changes key routes and means both sectors have to build in logistical resilience to either delays or cancellations. Predictive AI is used to mitigate physical impacts and predict market demand fluctuations, and data is shared across other freight providers to boost network optimisation.

Bypass to Breakdown

Prominent themes for 2041-2050

Rising physical impacts and response

Global failure to curb emissions worsens domestic and international impacts of climate change. Supply chain disruptions raise freight and resource costs, while more frequent and severe extreme weather events damage infrastructure and test adaptive capacity. Sea level rise forecasts prompt retreat from some locations, and infrastructure maintenance is reconsidered or abandoned in areas due to underestimated climate implications and financial impacts. Government financial support is stretched, leading to isolation, economic disparity, and increased transport poverty in vulnerable communities.

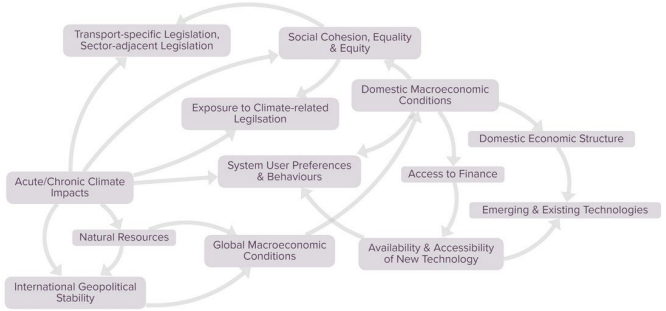
Resource security

The focus shifts to securing domestic energy, food, and resources, while global supply chains and trading relationships are strained. There is an emphasis on domestic production and low waste, efficient transport. The heavy fleet, aviation, and shipping subsectors transition to low carbon alternative fuels to reduce reliance on high risk supplies.

Unequal technology gains

eVTOL, 3D and 4D printing, as well as metaverses are mainstreamed and used for climate adaptation. The cost of electrified mobility decreases, with EVs surpassing ICE vehicles in the light fleet. Technology is unevenly distributed, with affluent people enjoying high-tech, climate-secure lifestyles, which remain out of reach for those experiencing rising costs of living, especially if still using ICE vehicles.

Driver Impact Map



Sector-Wide Trends

Physical climate impacts begin to materially worsen compared to other scenarios. Extreme weather, less predictable rainfall, flooding, sea level rise, biodiversity loss and drought are affecting every country in some way, causing food and water shortages, and geopolitical disruption. These impacts steadily erode global GDP, raise interest and inflation rates, and cause key commodity prices to rise. There are now millions of climate migrants leaving their homes and migrating internally or abroad. Many vulnerable countries are in critical condition, whilst developed nations double-down on adaptation and food, energy, and key resource security, forming crucial trade links with other countries where needed.

Aotearoa New Zealand's location makes it especially vulnerable to supply chain disruption. GDP growth is being materially impaired, with high inflation driven by volatile supply chains, and rapidly increasing prices for even basic commodities. This drives cost of living pressures, and high inflation and interest rates. There is an inflow of climate migrants and refugees, especially from the Pacific.

Severe weather events are noticeably more frequent, as are chronic changes to sea level and agricultural production. Some beaches are disappearing at high tide, and certain crops grow further south. Increasing hot days, extreme rainfall, and drought are all annual occurrences across Aotearoa New Zealand, hindering the transport sector both directly and indirectly – from heat stress impacts on railway tracks, to the lasting psychological impacts of extreme events impacting workforce wellbeing.

The export economy is hampered by its distance from markets, and consumer shift towards low cost and reliable products. The focus turns to prioritising domestic needs, with the transport sector asked to ensure safe, reliable, and cost-effective transit of goods around the country. Government is pressured into a strategy centred around energy and food security, strategic resource circularity, and further adaptation of key sectors. High levels of consumption in preceding decades see Aotearoa New Zealand's waste management systems struggling to cope. Alongside rising commodity prices, government enacts strong circular waste recovery legislation to ensure critical resources for transport and energy security stay in country.

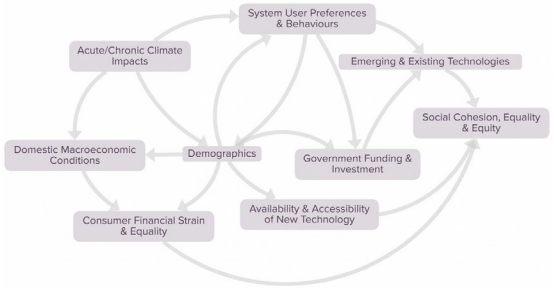
Adaptation planning is constantly reassessed and adjusted. However, work done over the last 15 years has limited loss of lives and assets. Planning is now fully integrated with climate risk assessments, and technology has advanced hugely since the 2020s. AI, IoT and open-source climate data has led to high effective adaptation-linked management of asset networks, with digital twins and predictive maintenance and servicing now commonplace. 3D and 4D printing is used to produce local replacements for transport infrastructure from overseas suppliers. Towards 2050, innovation and scale have overcome supply chain issues to make low emissions vehicles affordable, and an important part of achieving energy sovereignty and reducing dependence on unstable global oil markets. Technology is unevenly and inequitably distributed – whilst the rich having tech-enabled, climate-secure lifestyles, many struggle with the day-to-day physical impacts.

Despite adaptation, as the decade progresses, temperature rises see more frequent and severe weather, and more sea level rise impacts than in other scenarios. The costs to maintain, repair, and adapt transport infrastructure begin to inexorably rise across the network. Whilst many rail routes have been maintained, the lack of extra demand being shifted to road-alternative modes like rail or coastal shipping earlier in the scenario compounds disruption and costs as the road network is more frequently damaged or inundated each year. Government funnels significant fiscal spend into maintaining core assets and raises taxes.

Cost of living and a deteriorating climate causes widespread social upset and worsens civic cohesion, leading to a highly politically and economically divided Aotearoa New Zealand across geographic, ethnic, and cultural lines. Transport operators face an increasingly difficult operating environment for their workforce due to social issues. The impending realisation that government and companies will miss 2050 climate targets causes a wave of anger, and many individuals and non-governmental organisations (NGOs) raise lawsuits against the transport sector which they perceive as a leading culprit of climate change.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Urban

Urban migration accelerates, as climate impacts displace communities and industries across Aotearoa New Zealand and overseas, especially from the Pacific. This boosts patronage and revenues for a public transport system that is increasingly efficient, zero carbon, and climate resilient. Although the line between public and private transport is less defined, with deployment or public funding of on-demand light fleet options that blur into the private fleet, mass-transit options do establish themselves alongside rising populations. Autonomous vehicles are common in central city areas which have reduced private vehicle use, and developed integrated walking, cycling, and public transport options, with the network optimised by AI. High-tech on-demand platforms have seen an increase in shared mobility amongst some younger generations who don't own private vehicles in central locations.

Cities are mostly well adapted to the frequent extreme weather events such as cyclones or extreme heat. Critical infrastructure has been adapted, although temporary weather-related closures are becoming more common again. Thanks to early warning systems, injury and loss of life is rare as people receive localised warnings about upcoming floods or heatwaves, and it is common, for workers who can, to work from home when this occurs.

Remote Drivers

Some affluent individuals have moved away from fully autonomous vehicles. They don't trust the software, or that the vehicle can react to increasing incidences of social unrest. They employ real drivers often located overseas who drive the vehicles remotely via neuralink.

Home working is also a mechanism that local government encourages to minimise congestion, especially during high smog risk days.

Private vehicles remain the primary mode of travel for most use-cases outside of the central city. Although the proportion of EVs has doubled since 2040, population increases, combined with the general acceptance of private vehicle use, means some corridors struggle with severe congestion. Urban sprawl and lack of integrated planning mean the costs of developing mode-shifting infrastructure are now prohibitively high for local government. Outside of select zones, cycling is seen as dangerous due to the lack of designated lanes, and most cities have failed to encourage higher adoption. The comparative lack of easy public mobility connections, high congestion rates, air pollution, and the high proportion of public space given over to roads, are driving some businesses to consider relocating out to greenfield sites to attract the skills they need. Qualified people find remote work for overseas businesses enables a higher standard of wellbeing, hampering Aotearoa New Zealand's economic growth.

Both public and on-demand mobility service quality and reliability are varied across different neighbourhoods, with many locations remaining underserved by public transport.

This generates pockets of increased transport poverty, often in areas where adaptation investment has not taken place and low quality housing remains. High in-migration and cost of living pressures see declining social cohesion in many areas, with transport operators and workforce dealing with more regularly impacted by crime and social health issues.

Hologram and metaverse technology is now hyper-realistic. Many office workers work 'in person from home', and doctors perform operations from their local surgery, instead of travelling to the hospital, with virtual work especially popular during cyclone season. Although eVTOL technology is launched in major cities, only the affluent can afford to use the service, reflecting the increasingly divided society, with Aotearoa New Zealand now a climate refuge for the uber rich, but also home to severe social inequalities.

Those who can afford to use private or autonomous travel (including aerial options) do so between gated enclaves in affluent neighbourhoods, and typically avoid public transport options. At the other end, lower income families find themselves still without regular local bus services, locked into owning increasingly expensive vehicles, and facing hours of commuting just to get to work across town.

Adaptation Reassessment

Research indicates that it's likely we have already breached tipping points which results in a reassessment of the 'AdaptAotearoa' masterplan and identifies additional adaptation challenges for our main urban centres.

Regional, Rural & International

EV adoption accelerates during the 2040s as technology advancement and mass-market adoption in developed countries reduces costs. High quality rapid charging infrastructure, servicing workforce, and local energy production encourage adoption. The exposure to volatile global oil markets and price spikes means many people now see EVs as more cost effective. Climate anxiety increases people's desire for personal mobility and self-preservation. People tend to buy larger private vehicles to deal with climate risks, but also expect models to be circular economy-enabled, and retain value on re-sale or battery replacement. The energy sector invests in renewables capacity buildout to deal with this forecast demand.

Physical impacts to the transport system are beginning to materially impact connectivity for rural and remote areas. Despite deployment of nature-based solutions across many critical corridors, road slips, fallen trees, and flooding are occurring more frequently across the national road network. Before commencing regional trips, people assess the risk rating using national climate data – this affects their insurance premium and cover if travelling on certain routes. On top of replacement technologies like AR, this sees regional travel by roads begin to decline, with people travelling more slowly and taking more supplies with them.

Many rural communities have adapted to connectivity issues and become mostly self-sufficient with local food and energy production and retreat to secure locations where needed. Multi-mode options including seagliders provide connectivity when the road network is impaired, although costs are high.

However, as impacts worsen, some local governments or communities find their adaptive capacity overwhelmed. There are examples of coastal residents cut off from power, medical, and food deliveries for extended periods.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) **LONG TERM** (2041-2050)

Extensive response operations involve coastal shipping and drone deliveries to provide basic supplies.

With escalating road maintenance costs across the sprawling network and record public debt levels, some rural regions are given a new 'remote' classification that means existing infrastructure will not be maintained. People experience difficulties with vehicle insurance, rising freight costs, and the life changing impacts of a sudden loss in housing value. There is government pull-back from the more generous social support provided in the 2020s and 2030s. Those who rely on connectivity with other areas for critical supplies live with the day-to-day fear of being 'cut off', and poorer groups remain stuck using ICE vehicles are exposed to fuel price spikes.

Communities who once saw themselves as relatively well-connected can find themselves isolated overnight, for example after an unprecedented flood sweeps away a bridge that had been hardened against such an event. Many critical national corridors are maintained, although impacts to certain collector or minor arterial roads sees issues with getting food supplies out of agricultural regions into urban areas, causing intermittent food shortages and highlighting the dependence of connectivity between cities and rural areas.

Aviation has scaled the use of biofuels to reduce costs, although remains dependent on international oil supplies as domestic food security concerns reprioritise land use for food. There are models of zero carbon planes operating on select international routes, with increasing numbers of international routes serviced by aircrafts with 80% SAF, and some electric flights domestically. Climate impacts create worsening shocks to supply chains, leading to periods of fuel rationing to ensure supply for land transport.

By mid-decade, the sector is looking to accelerate transition to avoid price spikes or supply shortages, and is mindful of social perceptions as 2050 emissions targets loom.

Climate marooned!

A news story runs of a group of New Zealanders 'stuck abroad' in India due to a freak cyclone incapacitating the local transport system and grounding all flights. Polls suggest New Zealanders are increasingly concerned about the risks of being 'climate marooned' aboard, and are reducing trips to high risk countries.

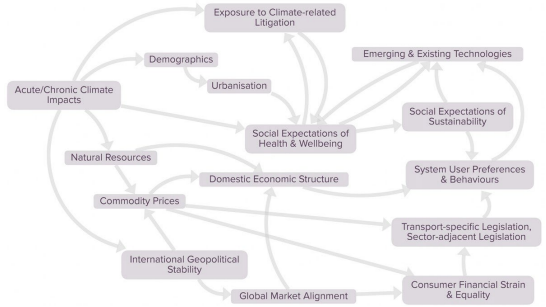
International aviation has seen a large reduction in viable routes due to geopolitical and actual conflict between countries. Climate-related zoonotic disease pandemics have caused periodic shutdown of global travel. The sector plays a key role in bringing climate migrants or refugees to Aotearoa New Zealand, with added operational challenges. The sector aims to maintain air access to the Pacific as a matter of national importance. However, there has been a noticeable drop-off in non-essential travel, in particular for families, as people are concerned about climate risks at destinations that may maroon them. Tourist numbers to Aotearoa New Zealand decline, with people typically coming for longer.

Domestic aviation remains an expensive but popular option to avoid the road network. Carriers and airports face more frequent delays to service, and use integrated communications and predictive weather technology to give live updates to passengers to prevent them leaving their homes unnecessarily, as well as increasing 'wait space' and facilities in airports. Society has adapted to flights being flexibly rescheduled for free.

Aviation now plays a critical role in disaster response with use of eVTOL and drone technologies to get people or goods into or out of crisis areas.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) **LONG TERM** (2041-2050)



Land

As low emissions technology and vehicle cost curves reduced, the land freight sector has steadily decarbonised the heavy fleet. Many operators run dual-fuel networks, but remain dependent on fossil fuels. The drive for national food, energy and resource sovereignty from government, and price pressures from consumers see freight forced to become highly resource efficient and use circular economy models across asset lifecycle management and fuel use. Carriers also plan to reduce reliance on the unstable global fossil fuel industry, with the transport and energy sectors accelerating alternative fuel production. Cancelled inbound shipments of fossil fuels have already created periods of operational blackouts. AI and automation are employed to ensure high levels of utilisation and reduce unnecessary or inefficient trips.

Many owner-carriers have been replaced by AI-enabled platform companies who orchestrate the network, allowing 'bidding' for space on freight, and connecting with asset owners that provide the vehicles.

Technologies like 3D and 4D printing have decentralised some manufacturing, locating it closer to demand. This also enables space-efficient transit of raw, lightweight additive materials instead of bulky end-products, which affects freight demand and vehicle profiles.

Extreme weather events create rising variability and less predictability in freight system demand and supply. This ranges from crop failure undermining seasonal forecasts, to cancelled foreign shipments due to port flooding, and road damage cutting off access to major clients in rural areas. Chronic impacts shift growing ranges and viable production locations, altering the nature of 'criticality' in the road and rail network and forcing adaptation funding and freight supply to move with it. The freight system increasingly adopts a decentralised model to reduce single points of failure and support domestic and export markets. Workers are exposed to weather-related hazards such as heat stress, or extreme rainfall on roads, requiring more investment in health and safety, and changing operating protocols. Some routes are no longer approved by insurers, reducing services to remote and high risk locations.

These factors cumulate in an increasingly expensive and often slower freight network, especially to and from rural and isolated areas on access or collector roads, creating semi-regular issues transporting food into urban areas. Consumers pay a high premium for speed and reliability. Those that can't pay accept that imports and even domestic products take longer to arrive, cost more, and semi-regular shortages become normal. Communities use technology to collectively 'batch ordered' goods to reduce per person costs. If successive events such as cancelled shipments combine with track or road damage, this can lead to prolonged shortages for some areas, with protests popping up around the country against freight providers.

In some areas freight companies now require heightened security as attacks on trucks carrying valuable commodities start to occur. The sector is targeted by angry climate activists and faces ongoing legal challenges for its perceived role in the climate crisis, and the failure to meet 2050 targets.

Freight companies respond to logistics risks by continuing to deploy ever more advanced versions of the AI-enabled predictive and planning technology introduced in earlier decades, as well as physically resilient fleet and infrastructure. The network becomes highly optimised. New technologies like eVTOL craft that are low emissions by default become part of the arsenal of many freight companies to serve hard-to-reach areas. The carrier market is bifurcated between high-value, advanced tech-enabled products, and low value, high volume supplies of basic necessities. There is a reinvigoration of discussions about shifting greater volume to alternative modes like rail and coastal shipping routes to improve resilience and alleviate pressure on the impaired road network, although funding is becoming more limited.

Urban Food Connectivity

As extreme weather continues to degrade the road network and rural-urban connections, cities with growing populations struggle to maintain adequate food supply, especially of fresh produce, as farmers and rural communities struggle to distribute their goods.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

Air and Sea

Slow asset replacement cycles see both shipping and aviation continue to decarbonise slowly. The majority of ships are now dual-fuel globally, and there has been some progress in domestic bunkering of alternative drop-in biofuels. The decline in volume and predictability of Aotearoa New Zealand's export economy, together with a pivot to more domestic production and consumption, has made some shipping routes uneconomical and seen a reduction in trade volumes, especially for those commodities reliant on return-trip shipping. The majority of global shipping is now experiencing operational disruption from physical climate risks – from major ports being flooded to impassable canals adding weeks to travel times. The network uses AI to try and predict and schedule the network as effectively as possible, and relies heavily on close relationships with value-chain partners, finance, and insurance. Climate-related health and safety of the workforce has become paramount, with new safety protocols in place for operating equipment in high winds or rain.

Aotearoa New Zealand's location means that some carriers no longer ship to the country as the risk and cost is higher than the reward, and government subsidies are required to keep crucial resources like fossil fuel shipments arriving into port. There is a balance between Aotearoa New Zealand being a comparatively productive and climate-sheltered producer of primary products like food, and its distance to market becoming more of an issue due to supply chain insecurity. Sea level rise, coastal flooding, and extreme weather-related damage cause major operational issues and financial costs of repair and maintenance, with some ports' adaptive capacity pushed to the limit by successive events. Smaller and more vulnerable ports face the realisation they may have to cease operations due to decline in trade of their primary commodities or mounting physical hazards, with sea level rise projections now higher than ports' ability to respond.

Air freight remains popular for sending high-value products to geopolitical allies. It also becomes crucial for moving goods around the country after extreme weather events incapacitate parts of the road network. New technologies like drone deliveries or eVTOL craft are popular for rural deliveries and event-response.

However, there is growing public sentiment and examples of activism against the sector as the visible impacts of climate shock people, and 2050 emissions commitments are clearly going to be missed. Fuel strategy is increasingly important as geopolitical instability and supply disruption see fossil fuel prices increasing, with a late push for domestic renewable energy sources emerging towards 2050. Whilst domestic airports are generally well adapted, flooding, extreme heat, and water shortages all create intermittent disruption, whilst some foreign airports have periods of extended blackouts due to major damage or civic unrest.

Canal Closures

Panama City reaches breaking point. An unprecedented earthquake incapacitates the main desalination plant following a period of severe drought. Water riots ensue, and the Panama Canal Authority is forced to supply water to the population. Without enough water to operate the locks, the canal closes for two months, critically impairing global shipping.

As both sectors juggle various demands for resource efficiency with uncertain social and weather patterns, government increasingly mandates export bans to focus on domestic food security, rapidly shifting freight demand profiles. This places commercial pressure on some parts of the rail network, but the decision is made to maintain most routes for wider resilience.

Bypass to Breakdown: Extension (2051-2100)

EXTENSION 2051-2100

MOVING PEOPLE | MOVING GOODS

Bypass to Breakdown - Extension

‘Hot house world’ – Overview of Physical Impacts

Overview of the main Earth system dynamics, including ‘tipping points’, during the 50 year period, and their impact on global society and economy.

Temperatures increase throughout the second part of the century, reaching nearly 4°C of warming globally by 2100. The climate crisis is now severely impacting every inhabited part of the planet, with some countries devastated and largely uninhabitable.

Chronic impacts include extensive desertification, melting glaciers and permafrost contributing to alarming sea level rise, drastic impairment of nature and biodiversity due to thermal range shift and invasive species, and increasingly unliveable regions due to the ‘wet-bulb’ overheating effect and prolonged drought.

Extreme weather events include more frequent and intense storms and cyclones which inundate coastal regions. Drought, large wildfires, and freshwater shortages are commonplace in many regions. Ocean ecosystems are collapsing due to temperature and ocean acidity wiping out coral reefs and fish populations.

Whilst relatively sheltered in the previous half of the century, Aotearoa New Zealand is now frequently impacted by higher volume extreme rainfall, and severe extratropical cyclones and storm tracks which push further south than before, with associated coastal and river flooding. Sea level rise and associated storm surge cause severe issues for low-lying agricultural land that is spoilt by salination, whilst saltwater intrusion into freshwater aquifers contaminates drinking water. Wildfires, droughts, and extreme heat are commonplace, with a systematic collapse of the country’s native flora and fauna, and regular water shortages in some regions causing high social unrest.

Much legacy agriculture is unviable, Aotearoa New Zealand’s glaciers have all-but disappeared, and over 70cm of sea level rise has seen large tracts of beaches, land, and low-lying islands and atolls lost to the sea by 2100.

Crucially, the Earth system has reached ‘tipping points’. The Greenland ice sheet and Arctic sea ice are set to melt. Permafrost thaw is set to release methane into the atmosphere and the Amazon rainforest and boreal forests are tipped into a pathway towards becoming deserts, switching from net carbon sinks to emitters. These self-sustaining, irreversible shifts catapult the Earth into a new climate system that will guarantee continued temperature increases, and sea level rise of up to 10m over the coming centuries, even if emissions were to stop abruptly. The world watches this slow-onset disaster unfold.

For Aotearoa New Zealand and the transport sector, this means there is a realisation that sea level rise, which will cover large areas of Auckland, Wellington, and other major low-level urban locations, is locked-in. There will have to be a full-scale system retreat at some point in the future. This knowledge becomes the background context to all political, financial, and economic decisions.

These extreme weather events have many direct and indirect implications for the transport sector in the 2050-2100 time horizon.

Bypass to Breakdown Extension – Parameters

Bypass to Breakdown Extension physical parameters

PHYSICAL VARIABLE		LOCATION	2100
	Mean Annual Temperature Change *(°C, average annual temperature vs pre-industrial baseline)*	Global	3.9°C
		NZ	*2081-2100 Figure:* 3.6°C *2101-2120 Figure:* 4.3°C
25°C	**Extreme Heat** *(Average number of days exceeding 25.0°C annually)*	NZ	*2081-2100 Figure:* 63 days
	Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	NZ	*2081-2100 Figure:* 35%
	Median Sea Level Rise *(Increase in metres)*	NZ	0.74
	Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NZ	-66
	Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NZ	29
	Population *(Million)*	NZ	8.3

Considerations for long term parameters

'Tipping points' in the Earth system make long term projections highly uncertain

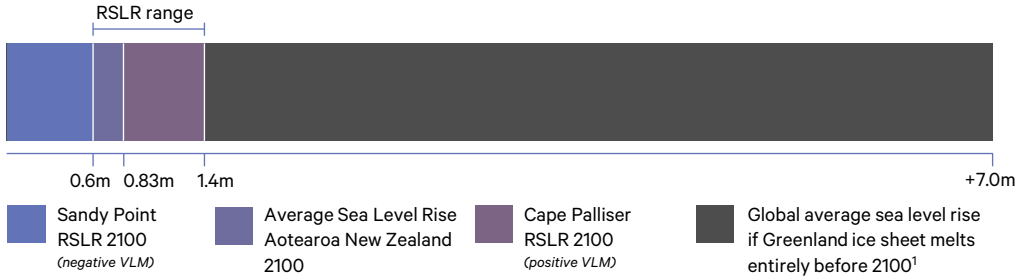
Longer term climate projections are highly uncertain, with wide possible ranges for chronic and acute impacts. Tipping points are thresholds in the Earth system that, if breached, have the capacity to cause unexpected and irreversible changes, locking in temperature changes and a new climatic system. If we pass tipping points, the parameters displayed for this time horizon may be significantly different, as they do not currently factor in these events. As such, these figures may reflect a 'best case' scenario for this emissions and temperature pathway. For example, if the point is reached where the melting of the Greenland ice sheet is irreversible, and it melts entirely, global sea levels could rise by around seven metres[1]. The latest figures[2] present a range of projections for average sea level rise in Aotearoa New Zealand under the SSP3-7.0 scenario by 2100 from 0.6m to 1m, and under a worst-case emissions scenario (SSP5-8.5), sea level rise projections range from 5.3m to 15.9m by 2300.

Sea level rise vs relative sea level rise

The sea level rise data used throughout this report does not include rates of Vertical Land Movement (VLM). Aotearoa New Zealand is a highly tectonically-active country, where some parts of the coastline are subsiding (or rising) at different rates, as measured by VLM. This can compound the impacts of climate-related sea level rise. Accounting for VLM on top of climate-related sea level rise provides a Relative Sea level Rise (RSLR) figure for the actual water level rise an area will experience. For example, while national sea level rise at 2100 is estimated at 0.74m in this scenario, the RSLR could range widely between specific locations, e.g. with Cape Palliser (Wellington - site 2453) reaching 1.4m of RSLR by 2100 due to negative VLM, as opposed to Sandy Point (Invercargill - site 5041) reaching 0.6m of RSLR by 2100 due to positive VLM. See NZ SeaRise[2] to explore individual sites across the country and factor in rates of future projected VLM.

Indicative examples of different rates of sea level rise

The chart below shows median potential sea level rise in 2100 for 2 illustrative locations as well as the average for Aotearoa New Zealand. It also shows the additional potential impact if the Greenland ice sheet tipping point is exceeded and rapid melting occurs.



[1] American Geophysical Union, 2023. [Online] Available at: https://www.sciencedaily.com/releases/2023/03/230327163212.htm [Accessed May 2024]
[2] NZ SeaRise, 2024. [Online] Available at: https://www.searise.nz/maps-2 [Accessed May 2024]

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Bypass to Breakdown - Extension

Prominent themes from 2051-2100

Physical risks breach adaptive capacity, causing regressive financial outcomes

The frequency and intensity of extreme weather events, wildfires, and prolonged heat will severely damage transport infrastructure, making maintenance increasingly costly and complex. Sea level rise, which could necessitate a significant retreat from many coastal areas, would likewise deeply affect the location and functionality of transport services.

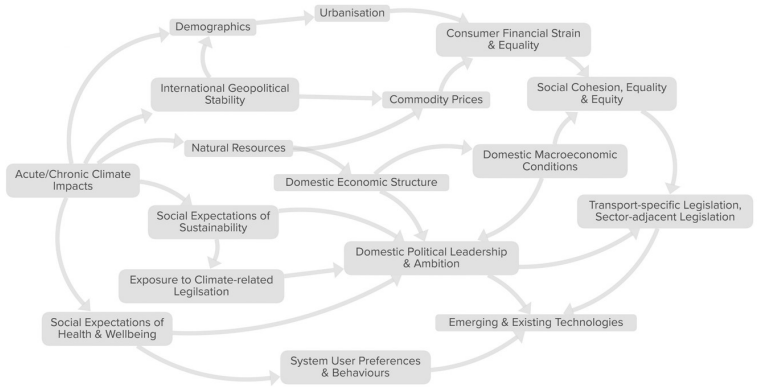
Decarbonisation pressure

With global temperatures projected to continue rising, the transport sector faces mounting pressure to eliminate emissions in the 2050s while providing resilient services. This rapid decarbonisation will not only be costly but could also potentially cause some businesses to collapse if they fail to meet rapidly set targets or fail to protect workers from climate-related harms.

Policy and legal challenges

Governments and policymakers must grapple with the impact of climate change as they develop decisions and strategies for the transport sector. This would include managing lawsuits or 'retribution litigation' from communities affected by climate change, adapting taxation and regulation policies to attract financing for adaptation and resilience programmes, and addressing social and economic disparities caused by climate change.

Driver Impact Map



Sector-Wide Trends

During the period, the physical impacts of climate change see entire countries' economies collapse due to sea level rise or social unrest arising from lack of food and housing, coupled with unprecedented levels of migration as people retreat from land that can no longer support crops. Global GDP becomes meaningless, and geopolitics retrench into trade protectionism and economic or actual conflict. The world is split into trading blocs, with smaller countries like Aotearoa New Zealand highly dependent on partnering with regional powers, like Australia and Indonesia. Remaining developing countries become subject to a new wave of economic colonialism as they are targeted for rare mineral production capability.

Resource scarcity and trade barriers increase the price, supply volatility, and accessibility issues of key commodities, finance and technology imports for Aotearoa New Zealand. This drives cost of living pressure, interest and inflation rise, and makes longer term funding harder.

Government increases taxation and limits public services to fund the ongoing adaptation and resilience programmes needed to respond to the latest projections of sea level rise now that tipping points for Greenland have followed the West Antarctic ice sheet into history. Consumption is increasingly divided between high-tech lifestyle products for the rich and basic necessities for the poor – with stark differences in social outcomes for mental health and wellbeing which impact transport's workforce and consumer profile.

Hundreds of millions of people are displaced over the period due to their homes, or countries, becoming uninhabitable. What started as an acceleration of economic migrants evolves into a refugee crisis on a scale never witnessed. Aotearoa New Zealand sets up strong policies to support refugees, but the speed of population growth leads to overwhelming demand on housing, resources, and public services, including transport. During flashpoints of resource scarcity, tensions boil over into ethnic, cultural, and class-based street level and political conflict.

Extreme weather events, sea level rise, and heat stress cause frequent damage to large parts of the transport infrastructure network – from roads, to rail tracks, and runways. Transport disruption is either direct (e.g. roads and bridges swept away on the West Coast), or indirect (e.g. energy and water utilities damaged, leading to impossible demands on transport). Aotearoa New Zealand's early adoption of adaptation measures means for a few decades, many elements of the system are well prepared with protection and accommodation measures, and AI-enabled preventative and early warning maintenance systems.

However, the combination of the scale of damage across the road and infrastructure network, frequency and intensity of extreme events, and high prices for imported materials eventually overwhelm the financial system. A growing fiscal deficit means government struggles to fund the required works, leading to social dissatisfaction with the standards of infrastructure which creates economic hardship, leading to further managed retreat of rural communities who have lost their adaptive capacity, resulting in increased levels of physical isolation for some rural groups (despite digital connection now being ever-present). This perpetuates inequality, and disproportionately impacts coastal and Māori communities who are forced to retreat.

All politics becomes 'climate politics' with a 'wartime' feel to the management of resources. Governments frequently enact emergency powers and central planning, reaching further into people's lives to maintain order and stability in the face of extreme events or supply shocks. There is increased financial strain on local and regional governments who all seek funding to protect their section of the transport network. Transport has a vital role in society, helping secure energy and food security and sovereignty through embedding efficiency and circularity. More localised systems of energy and resource production, storage, and consumption create local resilience and change transport demand.

Climate crimes

The UN establishes a new criminal court specifically to address retrospective and current climate crimes at the global level.

Shock at the impacts of climate at home and abroad leads to a late global drive for real carbon reduction and the alternatives needed for energy security. The transport sector is placed under high pressure to remove remaining emissions, whilst also providing resilience to a fractured Aotearoa New Zealand. Excess carbon, sequestered through direct air capture technology is used to make a wide range of long-life infrastructure.

Technology advances in AR, AI and holographics, along with the ability to establish a direct neural interface, have removed many reasons to travel. Local 3D and 4D printing technologies have enabled local production of most low-tech items. These tech advances mean predicting and meeting transport needs becomes highly complex as light vehicle travel declines.

Climate migration

International agreements on mass climate migration see Aotearoa New Zealand forced to agree to provide refuge to high numbers of migrants, especially from the Pacific, if it is to maintain trade rights.

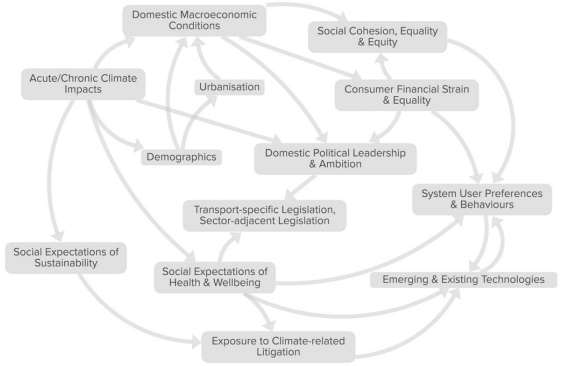
Missed climate targets and the human impacts of climate change trigger a huge spike in climate litigation and local rebellion. As well as successful cases against organisations who missed net zero 2050 targets, company directors and officers and government are increasingly sued for either failing to provide adequate adaptation or protection to transport workers from climate-related harms, or missing the rapid decarbonisation targets established in the mid-2060s.

Rapid advances in technology and climate reporting mean transparency is very high. Combined with maturing attribution science, while some suggest there was ample time for affected communities to relocate, there is an accelerating trend for 'retribution litigation' from displaced, impacted, and angry communities who demand those who were in positions of authority in companies or government during the 2020s to 2050s are brought to trial for negligence and perceived 'climate crimes'.

Augmented reality

Face to face meetings, GP visits and events of all sizes take place in AR. The look, feel and even taste of many products is neural interface enabled, meaning the item itself can be optimised for minimal environmental impact through the lifecycle - without packaging, hydration, or extras that add to transport emissions.

Moving People



Urban

Technology trends accelerate despite, and also because of, a challenging global economy. Developments in AR, lifelike interactions in personally-curated virtual worlds, and person-to-person non-verbal virtual communication via neuralink technology see many people choose to retreat from the difficult and complex 'physical' world. Although a lot of human connection and 'mobility' now happen virtually across digital landscapes, the physical world still matters hugely, especially for those who cannot afford the privilege or security of these new inventions.

'Physical transport' also sees huge technological changes, although political, trade, and financial barriers mean there are limits on what Aotearoa New Zealand can afford access to. The late and expensive drive for climate mitigation and strict government policies means most urban transport is entirely zero carbon by 2060.

Operators or individuals still using ICE vehicles found costs become prohibitive, with a period of high social disruption as vehicles were phased out over the decade.

Over the same period, urban mobility transitions to being digitally connected, with IoT technology linking public and private infrastructure and vehicles into a single, efficient network that reduces waste and improves climate resilience. Some new mode-shifting infrastructure like light rail is embedded in major cities as populations rise. Mobility becomes integrated into a single system, with most people moving between multiple modes seamlessly using integrated payment systems.

Public, private, and on-demand autonomous vehicles become the norm for many, with designated lanes providing hyper-efficient, 'traffic free travel' whilst people conduct other activities like work or leisure within vehicles. Automation means that for many, shared assets become the sensible option and private vehicle ownership or use is limited to those with exceptional security requirements or unlimited funds. High volume autonomous vehicles carry people along mass-transit corridors, and local flexible shuttles replace local fixed-route buses. As private vehicle use reduces, active mobility becomes more popular again in certain neighbourhoods, and enhanced mobility options develop to include personal aerial mobility for rapid and efficient access.

Sea level rise sees cities losing land to the ocean, and many areas become regularly inundated by storms. However, the connected network has learnt to deal well with climate impacts. Adaptation and land use planning has changed assets, ensured housing is not located in high risk areas, and people are used to the early warning systems and adapt their schedules and mobility accordingly. However, the wider challenges of scarce resources mean the physical or social resilience of cities is sometimes pushed to the limit, or past breaking point.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050) EXTENSION (2051-2100)

Water riots

A period of severe water shortage in Auckland followed by a Category 5 cyclone which damaged roads and the warehouse where freshwater delivery drones were stored creates localised riots as communities run out of drinking water.

People demand protection from climate impacts when using public transport, which requires adapting vehicles to both extreme heat, rainfall, and flooding, as well as complex insurance provisions.

Over time, growing health, financial, employment, education, and technology inequalities create challenges for transport in a strained society and economy. The increase of climate refugees from rural areas and overseas to cities and large towns alongside economic pressure creates deep social problems that government funding fails to address. Many climate refugees from the Pacific struggle to manifest their national identities and mourn the loss of their islands. Young people struggle with the lack of opportunity as Aotearoa New Zealand's export market continues to shrink. There are growing levels of crime and deprivation. Across a sprawling road network, this makes maintaining infrastructure and delivering a safe, reliable public transport service difficult and expensive.

The wealthy pull back from 'public' life and retreat to affluent virtual or real enclaves with high levels of security both for their homes and for their transport options.

Those who can afford it own vehicles that can be driven autonomously, or using mind control via personal neuralink technology. There is a focus on security from both extreme weather but also people. In a city where transport segregation means some people can fly private eVTOL craft to protected 'urban islands', and climate refugees can struggle with getting into the central city because of damaged roads, class conflict often becomes violent.

By 2070, the news is announced that sea level rise of at least 10 metres is locked-in. The realisation that many parts of cities like Auckland, Wellington and Christchurch will have to be abandoned and moved stuns New Zealanders, and becomes the new context for all transport policy and investment.

Climate protocols

Extreme weather events have standard protocols. Workers stay home, pay for frontline workers is risk-adjusted, and some workers are paid more to sleep near the office to ensure they are not cut off from their work location.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050) EXTENSION (2051-2100)

Regional, Rural & International

Physical impacts accelerate retreat from many locations that become unviable, and sea level rise means entire towns or communities cease to exist by 2100. The frequency of extreme events means the system of preventative maintenance and repair on the national road network eventually fails under regressive financial outcomes. Many people do still travel rurally and regionally via on-demand and shared EVs and new forms of fuelled vehicles, although the electrification of the rail network due to rapidly reducing costs provides a time-efficient and climate resilient alternative. Alternative technologies like immersive digital communications. 3D and 4D printing alleviate the need for many trips. Most vehicles are now autonomous for highways and main roads, but manual driving remains the norm on many parts of the rural road network because of the high risk. Interregional travel becomes less frequent, riskier, and slower, with people tending to travel for longer, and carrying more in larger vehicles. Road user charges are high to cover repairs and maintenance of critical corridors.

Self-sufficient life

Self-sufficient communities emerge in hard to access locations. These locations have their own system of rules and allocation of resources and increasingly seek to conceal themselves from the world to reduce risk of attack. The best equipped of these maintain their own energy production and aerial vehicles, coordinating with other communities for local exchange of goods and services.

Road access

Many rural roads are now closed, or classified via a government risk rating that links in to real-time climate and weather data. Travelling on these roads invalidates most forms of insurance.

Some rural repopulation occurs for those who can afford to leave cities with social cohesion and safety declining. Decentralised and local energy and food production and storage systems become increasingly important to rural or isolated communities' lives and their transport options. Many parts of Aotearoa New Zealand shift to systems of self-sustaining local production and consumption, with domestic renewable energy production used to charge vehicles for access to the main network. Some communities who can afford it accept almost full 'physical' isolation, as they can maintain immersive, lifelike digital connections for work, and can rely on drone-based deliveries or 3D and 4D printing of essentials.

However, for many lower income communities reliant on local industries for employment, the impacts of climate change result in physical isolation and travel risks which perpetuate social inequalities. Whilst they have local food production, connectivity issues hamper their access to commodities like medicines, technology, or imports. News reports of deaths on roads due to road slips or flash flooding become more common despite the early-warning systems. The rapid decarbonisation in the 2050s created huge social issues for remote or isolated communities still reliant on ICE vehicles as oil imports to Aotearoa New Zealand practically ended.

The aviation sector was hit hard by rapid decarbonisation in the 2050s, and only begins to recover midway through the 2060s. During this period, fuel rationing was enacted, with SAF on average making up only 40 to 50 percent of an aircraft's fuel, leaving it subject to demand sanctions. Aviation became a political example for government to demonstrate its commitment to reducing the damage of climate change. Trips became prohibitively expensive, and only 'essential' travel was permitted, with social outcry if affluent individuals took trips for leisure. During the 2070s, new evidence on sea level rise means the majority of the country's international airports have to relocate or build significant flood banks, causing huge disruption and deployment of emergency measures by government to maintain connectivity.

Digital beaches

Beaches and many towns are disappearing as sea levels rise. There is a national movement to document the best spots using digital twins before they disappear, so future generations can enjoy them digitally.

By the mid-2060s, domestic aviation has adopted new, zero carbon technologies alongside its advanced, AI-driven operating systems that connect carriers and airports globally to real-time climate and social risk data. Late investment in scaling domestic alternative fuel production and renewable electricity capacity sees affordable domestic zero carbon aviation become a reality.

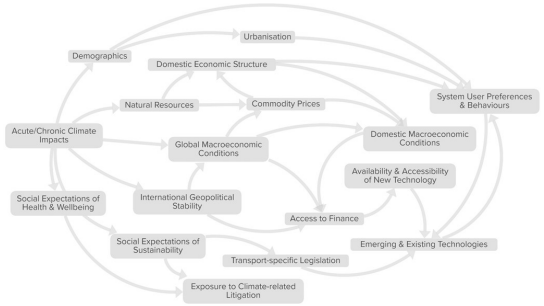
The sector becomes a national priority to maintain connection both within Aotearoa New Zealand and overseas. The new market in regional air mobility alongside technologies like eVTOL craft and seaplanes sees the sector play a vital role in stimulating otherwise unreachable local economies, and playing a key role in disaster response.

International aviation recovers from the 2050s to become a zero carbon and highly advanced sector. New models revolutionise the speed and efficiency of flights, with lightweight battery electric 'blended wing body' aircraft that easily make cross-ocean trips. However, demand for international trips gradually declines. The movement of people via the climate refugee crisis and expanding thermal vector ranges see global zoonotic disease pandemics become more common. Aotearoa New Zealand enacts hyper stringent biosecurity protocols to protect food security, grounding fleets for extended periods. Hyper-realistic virtual 'travel' in sensory stimulation suits replicate trips abroad at a fraction of the cost or risk. A fractured geopolitical landscape restricts routes to trading allies, and the huge level of social and physical climate disruption globally have made many New Zealanders hesitant to risk being marooned abroad.

Zoonotic disease

Climate change has seen an explosion of novel zoonotic disease pandemics as thermal ranges shift. International aviation has been bought to standstill multiple times. Preserving local food production leads to incredibly strict biosecurity protocols with mandated biosecurity scans and quarantining.

Moving Goods



Land

As part of the late push for climate mitigation and energy security, government introduces stringent policies around resource circularity and decarbonisation for the land freight sector in the 2050s, resulting in a period of compounding costs as the physical impacts of climate change drive inflationary pressure through supply chains. With technological advances, the sector manages to reach net zero and become low waste and mostly reliant on domestically produced electricity or alternative fuel sources by 2065. However, the rise in 'retribution litigation' across society particularly impacts freight companies who are perceived as having had a leading role in causing climate change. Businesses that can't demonstrate that 'they tried' or 'are trying' are subject to devastating class action lawsuits. Some businesses are broken by the costs of these lawsuits.

The freight sector experiences an increasingly challenging operating environment. Foreign trade of crucial commodities is hampered as shipping reliability collapses and costs increase due to climate-linked supply chain disruption.

Land-based freight is increasingly impacted not only directly by increasing damages to infrastructure like road closures, but by secondary impacts such as energy supply failures, the corollary social effects of droughts, cyclones, or heatwaves, and declining social cohesion and mental health impacting frontline staff.

This results in increasing social demand for reliability, safety, and consistency over speed, with supply chains for basic necessities now at risk. 'Just in time' delivery vanishes, stockpiling rises, and goods are mainly ambient instead of fresh. Products are a mix of high volume, low value staples, and high-end consumer goods. The freight sector is now perceived as mostly catering to 'needs' not 'wants', and is tasked with solving critical supply issues into a struggling society. During difficult periods, freight vehicles are sometimes attacked for their valuable contents, leading to a rise in private security and armoured vehicles. There are high financial and even legal penalties for letting food spoil, and insurance is linked to having the latest adaptation-related protocols or technology. There are periods of nationalisation when government takes control of parts of the sector to ensure continued supply of food and fuel.

Urban deliveries become increasingly important, and the sector adapts to a shift towards decentralised food and energy production and consumption across rural Aotearoa New Zealand. Ensuring connectivity for food supply is a priority. Legacy primary industries become hyper-efficient, with vertical farms springing up near cities, and food made from 3D and 4D printed captured carbon contributing to changing freight demand profiles.

Some critical export products like food are rerouted, with the local market taking priority. The sector is mainly run using AI which is integrated into demand and supply data across other sectors, as well as vehicles and 'smart packaging'.

With the sector highly optimised, profit margins are found in having better data and software, or gambling on greater climate-related risks.

Adaptation investments include decentralising the network of fuelling stations, distribution centres, and delivery points. With a move away from a centralised system, freight increases across some rail, coastal shipping, and drone-based delivery routes.

The retreat from some locations, move to domestic consumption, or spiralling repair and maintenance costs, sees some assets designated as uneconomical to maintain in the face of physical climate impacts. Some parts of the rail network are closed as they become uneconomical, and demand is focused on a smaller number of key lines for priority export or import goods.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050) EXTENSION (2051-2100)

Air and Sea

Ports and shipping remain a crucial lifeline for critical imports for Aotearoa New Zealand. Despite deployment of advanced predictive AI and operational automation to increase port efficiency and port call optimisation, the scale of simultaneous climate-related impacts to the shipping value chain eventually overcome efforts and impact shipping schedule reliability. Of those countries Aotearoa New Zealand still trades with, major ports are often damaged, and some are forced to move due to sea level rise, causing periods of disorder. Coastal port cities abroad have been some of the worst hit by a concoction of sea level rise, and extreme weather, and unprecedented climate-linked migration, putting them on the brink of social and economic collapse. Ships have to adapt to greater wave height in the Pacific, and worsening storms. Key routes become impassable, with the Suez Canal eventually compromised due to sea level rise, and extreme social unrest in some countries sees pirate attacks become commonplace.

State collapse

By 2073, state collapse and conflict around the Red Sea has now made the Suez Canal impassable. Pirate attack risk is now spreading further down the West African coastline, with resource scarcity in Mozambique seeing attacks on ships navigating around the Cape of Good Hope now hampering global shipping.

Some domestic ports close due to a decline in foreign trade of the commodities they handle, or because of physical impacts like persistent storm surge flooding. There is consolidation with larger ports, with knock-on effects for railway lines.

Autonomous ships

Ships are mostly autonomous and have onboard renewable energy generation, but have to deploy expensive security measures for fear of pirate attacks, as well as adaptation measures like the ability to keep goods temperature-regulated for far longer periods in case of delays.

Those ports that survive through to later in the century see many operations become almost entirely automated and integrated digitally with the land freight and other sectors. They also adapt to dealing with high levels of physical risk, from storms surges to high winds, as well as the unpredictability of demand due to more frequent and intense extreme weather events across the global shipping network. Many have opened large areas for temperature-controlled storage of goods to provide overspill during delays from either side of the supply chain, with rail and coastal shipping also adapting to new requirements.

International air freight gradually reduces in cost as renewable energy capacity is developed, and is used to carry high-value goods between developed ally nations that can guarantee airport security from physical risks or social disorder. Resource shortages in some countries see examples of air freight being attacked by locals out of desperation. Domestically, light planes, seaplanes, and eVTOL craft become far more popular to support the new decentralised, localised lifestyles of rural New Zealanders, as well as providing vital services during extreme weather events when the road network is impaired. As with passenger aviation, the sector faces high risks from zoonotic diseases or biosecurity hazards, even with enhanced detection and mitigation protocols.

Short Detour

Short term 2024-2030
MOVING PEOPLE | MOVING GOODS

Medium term 2031-2040
MOVING PEOPLE | MOVING GOODS

Long term 2041-2050
MOVING PEOPLE | MOVING GOODS

Short Detour Scenario

Scenario Overview

International and domestic policy settings aim to limit total warming to less than 1.5°C this century. However, decisive action is delayed. Global emissions peak in 2030, then drop sharply. As a result of delayed action, deeply destabilising policies are required to keep total warming below potentially catastrophic levels.

Negative emissions (i.e. more greenhouse gases captured and stored than emitted) are necessary in the second half of this century. Low to medium deployment of carbon removal solutions dials the heat back to 1.6°C of warming by end-century. Accordingly, the physical impacts of climate change are more likely than not to be limited and affordable. It is also more likely than not that we have avoided a tipping point in our climate system, beyond which greenhouse gas emissions would lead to a shutdown of large ocean circulation systems and massive permafrost melting.

1.6°C Policy Ambition*:

** The temperature outcome aligned with global policy settings and ambitions under this scenario[3].*

Severity of physical risk	*Low to moderate*
Severity of transition risk	*High*
Policy reaction to climate change	*Delayed*
Regional policy variation	*High variation*
Technology change	*Slow, then fast*
Carbon dioxide removal	*Low to medium use*

Global [1]

Warming at 2050

1.7°C

Warming at 2100

1.7°C

Aotearoa New Zealand [2]

Warming at 2050

1.3°C

NIWA 2031-2050 estimate

Warming at 2100

1.3°C

NIWA 2081-2100 estimate

[1] *IPCC, 2021. Summary for Policy Makers. [Online] Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf (Accessed March 2024).*
[2] *MfE, 2018. Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition. Wellington: Ministry for the Environment.*
[3] *NGFS, 2024. NGFS Scenarios Portal. [Online] Available at: https://www.ngfs.net/ngfs-scenarios-portal/explore/ (Accessed May 2024).*

Our World

The world shifts late and abruptly to a more inclusive and sustainable development pathway that respects planetary boundaries. Management of the global commons eventually improves but needs to make up for (yet another) 'lost decade'. The global economy begins to adapt to encompass a broader focus on human wellbeing.

- **Consumption:** Re-orients belatedly and suddenly toward low material growth, lower resource use, and lower energy intensity.
- **Society:** Rapid changes to reduce emissions initially impact negatively on the most disadvantaged, but an increasing commitment to achieving overdue development goals ensures inequality is eventually reduced both across and within countries.
- **Economy and Trade:** By 2050, the physical impacts of climate change are impairing global GDP. Transition-related macroprudential risks peak in the 2030s, higher and later than under a Fully Charged scenario. A 'green wave' of growth is set to add trillions in net present value to key economies by 2070, with growth in the Asia Pacific region eclipsing growth in Europe and the Americas. Major markets impose additional costs on trade from countries failing to do 'their fair share' in the transition to a sustainable future.
- **Land use and nature**: Historical trends are eventually reversed, including a gradual, global-scale, and pervasive expansion of forests and other natural habitats. Forests become a net carbon sink. Our increasingly circular economy, the efficient use of natural resources, and investment in productive landscapes, is transforming the vitality of terrestrial and marine ecosystems.
- **Technology:** The uptake of carbon reducing technologies (e.g. renewables, carbon capture and storage), as well as technologies to better manage climate-related risks, is slow to 2030 then extremely fast.
- **Energy:** The global energy system decarbonises, but progress is uneven and mainly led by developed economies, who reach net zero emissions by 2050, with China around 2060, and all other countries by 2070 at the latest. There is a surge in clean energy policies and investment, especially from 2030s, that puts the energy system on track for key UN Sustainable Development Goals. The world transitions to a global total primary energy supply from (non-nuclear) renewable energy of 24% by 2030, but more than doubles this by 2050 to 55%. The use of alternative fuels including hydrogen and biofuel develops belatedly under policy guidance. By 2030, 53% of global electricity generation is from renewable sources. This rises to 84% by 2050.
- **Transport and Energy:** Transport is slower to decarbonise initially, hampered by lower EV uptake in the 2020s in developing economies and slow decarbonisation of heavy fleet, aviation, and shipping. By 2030, only 5% of transport's final energy consumption is electric. This begins to improve in the middle of the 2030s, and by 2050, 25% of global transport final energy consumption is electricity, with biofuels accounting for 17%, and 7% hydrogen. Aviation and shipping account for 36% of global transport emissions (up from 20% in 2020), although there is a scale-up of biofuels to meet emissions targets, and both sectors do decarbonise from the mid-2030s.

Our Home

Aotearoa New Zealand's climate change response is characterised by ambitious commitments but poor follow-through and minimum improvements in land use until panic begins to spread amongst the general population and businesses in the late 2020s/early2030s. Aotearoa New Zealand belatedly invests in transformational mitigation and adaptation measures, with innovation playing an important role. Our response to the climate challenge is recognised by the international community, including major trade partners. As a result, Aotearoa New Zealand gains secure access to critical markets. However, its lack of early vision means that, by 2050, Aotearoa New Zealand's society and economy are less prepared for the future than many of its OECD peers.

- Policy: Central and local government policy settings were inconsistently aligned with the global goal of limiting total warming to no more than 1.5°C until 2030. Stringent domestic policies then drove transformational decarbonisation and meaningful adaptation.
- Trade: Carbon-related trade barriers spike in the 2030s. The Pacific participates in a global trade regime through a growing service industry and niche products. There is market demand for Aotearoa New Zealand's 'green' primary products and services.
- Behaviour: Commitment to low emissions activities and practices, as well as the uptake of low emissions technologies, follows current trends until the late 2020s/early 2030s, then grows dramatically.
- Labour: Immigration is part of a regional system taking into account refugees as well as voluntary migrants, with consideration of labour force development and addressing demographic bottlenecks.
- Land use and nature: Aotearoa New Zealand is preserving, and has begun restoring, its fragile ecosystems and limited natural resource base. As a result of successive resource management planning reforms, degraded hillsides are returning to native forest and coastal ecosystems are being re-established throughout their range.

Short Detour Parameters

Short Detour physical parameters

PHYSICAL VARIABLE	LOCATION	2030	2040	2050
Mean Annual Temperature Change *(°C, average annual temperature vs pre-industrial baseline)*	Global	1.5°C	1.6°C	1.7°C
	NZ	*2031-2050 Figure*: 0.7°C		
Extreme Heat *(Average number of days exceeding 25.0°C annually)*	NZ	*2031-2050 Figure*: 15 Days		
Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	NZ	*2031-2050 Figure*: 15%		
Median Sea Level Rise *(Increase in metres)*	NZ	0.11	0.15	0.20
Extreme Wind Speed *(Estimates from NIWA visuals)*	NZ	*2031-2050 Estimate*: Approx. <5% increase in parts of the country (Mostly southern half of North Island, and South Island)		
Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NZ	-16	-23	-23
Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NZ	31	31	31

Short Detour socio-economic parameters

SOCIO-ECONOMIC VARIABLE	LOCATION	2030	2040	2050
Population *(Million)*	Global	8,413.3	8,854.5	9,136.9
	NZ	5.7	6.1	6.5
GDP *(% difference, 2009 prices; local currency vs baseline)*	NZ	-0.7	-2.6	-1.5
Inflation Rate *(Absolute difference % vs baseline)*	NZ	-0.13	0.17	-0.11
Long Term Interest Rate *(Absolute difference % vs baseline)*	NZ	0.07	0.78	0.54
Carbon Price *Energy (real NZ$/tCO$_2$e)*	NZ	114	306	411
Oil Demand *(Million barrels per day)*	Global	87.6	-	47
Oil Price Increase *(% difference, US$ per barrel vs baseline)*	NZ	15	441	839

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Short Detour Parameters

Short Detour transport parameters

TRANSPORT VARIABLE	LOCATION	MODE	2030	2040	2050
Total Transport CO_2 Emissions *(Global = $MtCO_2e$) (NZ/Domestic = $ktCO_2e$)*	Global	-	7,348	5,112	3,239
	NZ	-	15,426	8,404	3,004
Road Vehicle Kilometres Travelled by Vehicle/Engine Type *(Total = billion kilometres) (Type = % share)*	NZ	Total	56	58	60
		ICE Vehicle	91	46	11
		EV	9	54	89
Household Person Kilometres Travelled by Mode *(Million kilometres)*	NZ	Active Transport	1,626	2,083	2,268
		Public Transport	3,938	5,826	7,121
		Private Transport	57,550	55,798	55,800
Total Number of Vehicles in Fleet *(Thousands)*	NZ	-	4,912	4,792	4,780
Freight Mode Shares *(% share)*	NZ	Rail	14	15	15
		Costal Shipping	13	14	14
		Road	73	71	70

Short Detour energy parameters

ENERGY VARIABLE	LOCATION	MODE	2030	2040	2050
Total Primary Energy Supply – Renewables *(% share)*	Global	-	24	-	55
	NZ	-	49	62	78
Percentage of Electricity Generation from Renewables *(% share)*	Global	-	53	-	84
	NZ	-	92	94	96
Renewable Energy Share of Total Final Consumption (including international transport) *(% share)*	NZ	-	31	44	63
Breakdown of Transport's Total Final Energy Consumption by Mode *(% share of total)*	Global	Road	73	-	65
		Aviation	13	-	20
		Shipping	9	-	10
Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption *(% share)*	Global	Biofuels	9	-	17
		Hydrogen	0	-	7
		Electricity	5	-	25

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Short Detour

Prominent themes for 2024-2030

Uncertain Geopolitical and Macroeconomic Environment

The combined impact of lingering COVID-19 effects, geopolitical conflicts, and post-Covid economic conditions leads to an uncertain policy environment and a hesitant financial space that restricts the flow of green finance and hinders the acceleration of mitigation actions.

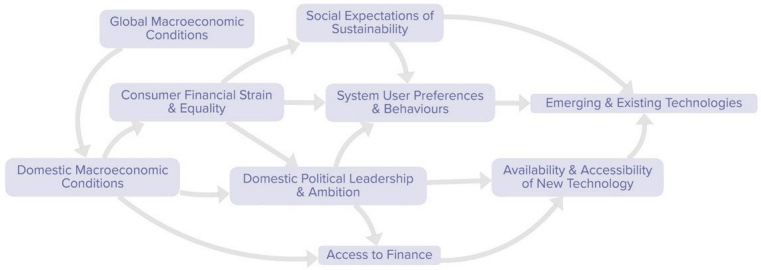
Lack of Long Term Planning and Policy Shifts

Governments are more focused on addressing short term pressures including managing post-Covid debt levels and dealing with national security concerns. This leads to the marginalisation of climate change issues amidst other policy priorities and inhibits much-needed strategic planning and the systemic overhaul of sectors such as transport.

Consumer Distrust and Slow Uptake of Green Alternatives

The lack of clear, integrated planning between transport and energy systems has resulted in consumer distrust for EVs. There is a slow uptake of green alternatives due to persisting high production costs, lack of government incentives, and inadequate consumer education.

Driver Impact Map



Sector-Wide Trends

Ongoing conflict zones and the post-Covid economic hangover create a challenging and uncertain geopolitical and macroeconomic environment. Whilst there is ongoing public reaffirmation of commitments to 2030 and 2050 targets, government focus is swayed by voters' concerns about the cost of living, the perceived expense of climate mitigation, rising crime levels, and other 'contentious' social issues, furthering social polarisation. Global misalignment in climate action, particularly driven by food security concerns, means Aotearoa New Zealand's high emissions economy performs well, driving volume through the transport system and income growth.

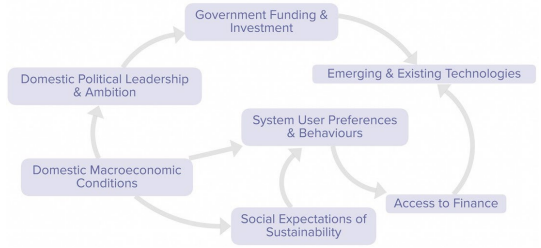
This leads to political indecision which prevents longer term planning or policy, and inhibits commitment from green finance and business to invest in the transition with persistently high interest rates increasing the cost of borrowing above the carbon 'pay-off'. There is little step-change in transport appetite, policy, or funding beyond the ETS to reduce private vehicle ownership, fund mode-shifting public infrastructure, or invest in meaningful alternative fuel R&D.

Segments of the population become increasingly frustrated by the lack of government action and growing transport inequality, threatening social cohesion further. There is little systemic, comprehensive planning for a socially responsible transition in the transport sector, embedding nature fully into climate action, or integrating te ao Māori or other diverse worldviews into decision-making.

Regulations and disclosures are initially ahead of public opinion, meaning climate litigation occurs mainly from activist NGOs or legal groups, with relatively limited reputational or financial impacts. However, company directors and officers become increasingly aware of their liabilities, leading to some prescient companies proactively managing their climate risk and exposure.

Moving People

SHORT TERM (2024-2030) **MEDIUM TERM** (2031-2040) **LONG TERM** (2041-2050)



Urban

Despite growing demand, there is disagreement over the best approach to sustainable urban mobility. Less joined-up thinking, policy, and funding across national, regional and local government reduces long term commitment by the public or private sectors to fund or finance net zero infrastructure. Although some higher density developments are completed, government fails to enact expedited consenting processes or reform of the Resource Management Act instead yielding to vocal 'not in my back yard' protests against land use changes. The result is less upzoning and a lack of integrated transport. Government focuses on the expanding the road network, resulting in further urban sprawl and degradation of greenfield and native flora and fauna habitats.

Public transport reliability and capacity steadily improves, with more zero or low emissions vehicles. But the lack of wider incentives to leave private vehicles at home means patronage levels remain low compared with international comparators. Enhanced mobility options like e-scooters rise in popularity but there is limited planning or development of comprehensive active mobility networks.

The culture of private vehicle use remains dominant, and whilst many imported vehicles are electric, a lack of financial incentives mean it is typically affluent consumers who can afford home-charging infrastructure and upfront costs. As urban populations and private vehicle numbers rise, cities and large towns increasingly struggle with congestion and fail to build momentum for the expansion of urban greenspaces and active transport corridors.

Barriers to active mobility

Despite demand from many demographics, safety and accessibility concerns - such as the lack of protected infrastructure or low speed zones - are significant obstacles to greater uptake of active and micromobility modes, such as e-bikes, for meaningful mode-shift.

Regional, Rural & International

Government leaves EV adoption to market forces, with no targeted financial or policy support, or phase out date for ICE vehicle imports. Slow uptake in markets like Japan stymies the second-hand market. There is also a delay in delivering the ecosystem needed for mass-market EV adoption, from skilled mechanics to standardised chargers, or coordinated engagement with local institutions to enable key locations to become charging hubs

Most people remain unconvinced by the financial or practical reality of EVs, and see the perceived or real barriers as too high a hurdle. Especially in rural and isolated areas, people worry about the reliability of electricity distribution and the lack of public chargers or mechanics. Electricity is not a resilient option for most communities who already experience intermittent power cuts. The lack of financial support in the form of grants, rebates, and reduced road charges, and limited social education for communities about EVs leads to uneven uptake, perpetuating class divides in EV ownership and energy economics. While fossil fuel prices remain relatively cheap, most trips around towns, rural areas and across country remain in private ICE vehicles.

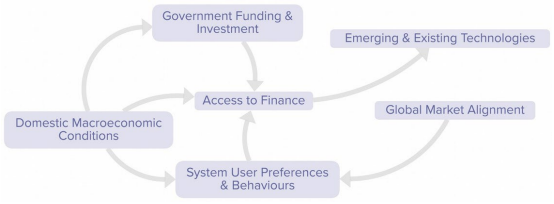
Domestic and international aviation remain relatively costly but popular. International development of SAF is hampered by a lack of fair markets, consistent standards, or bilateral deals. Smaller countries with limited buying power, like Aotearoa New Zealand, feel there is a lack of fair representation in global markets. The sector struggles to build momentum in developing low emissions infrastructure, with misaligned regulation and incentives, dampened green finance and lack of collaboration with the energy sector and local government. Despite transparent pricing, consumers reject sustainable surcharging with high price elasticity. Despite some pilots of low emissions test flights, an uncertain environment sees many innovative companies pull back from investing in Aotearoa New Zealand, and there is limited development of the workforce or technology planning needed to scale SAF or alternatives at speed when the time comes.

Rural affluent adopt EVs

More affluent rural residents who can afford EVs alongside domestic energy production and storage systems readily adopt them. Individuals in rural and regional areas typically drive further, so receive a faster payback from lower operating costs compared to ICE models.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Land

Lack of long term clarity on decarbonisation targets from government and discrepancies in policy targets, legislation, and actual investments means the freight sector struggles to make the business case for 'big ticket' investments in mode-shift, fleet replacement, or alternative fuel infrastructure. With the domestic export market performing well, and consumers seemingly not willing to pay a 'sustainability premium', few companies commit to perceived risky investments. Heavy emitters are targeted by NGOs and activists through legal and media channels, but with limited effect.

R&D projects for alternative heavy fleet fuels, such as battery electric, hydrogen, or biofuel are still far from reaching a level that could accelerate the decarbonisation of the sector. The initiatives are hindered by misaligned targets, superficial cross-sector collaborations, and generally low conviction in the urgency of these investments. Whilst there are pockets of progress, start-ups in the space generally struggle to compete commercially with the entrenched fuel ecosystem, and many leave Aotearoa New Zealand for more progressive markets.

Lack of demand for mitigation of heavy freight transport emissions means there is limited planned mode-shift to rail, and a period of low investment and managed decline in the late 2020s. Some parts of the network are not considered economical to repair after extreme weather events, and are closed or mothballed. There is limited investment in adaptation or resilience of the network, exposing it to future physical risks.

Efficiency and cost reduction

Government supports a National Freight Strategy. However, priority export markets (including China) are yet to fully price in carbon emissions, so efficiency and cost reduction remain the driving economic imperatives, with carbon-reduction a by-product. The strategy does result in improved sector data-sharing and collaboration, which lays the groundwork for later efforts on emissions reduction.

Air and Sea

As with passenger aviation, air freight struggles to accelerate SAF infrastructure development or supply due to a lack of international collaboration, misaligned domestic standards and uncertain regulatory forecasts, as well as limited cross-sector engagement with key adjacent sectors like energy, ports, or local government. With carbon prices relatively low and export market consumer demand not sensitive to emissions, the sector continues to carry high-value, time-sensitive exports to key foreign markets.

The IMO fails to provide strong leadership for 2030 targets. There is a high degree of uncertainty in the sector about alternative fuel pathways. More ships are commissioned with dual engines for marine diesel and drop-in biofuels. But there is less sector-wide investment because ship builders, carriers, and investors remain uncertain about timeframes for emissions targets and which fuel types will prove most commercially viable.

Limited progress in 'book and claim' models limits carriers' and ports' access to emerging overseas low emissions technology. With the domestic supporting ecosystem for biofuel or zero carbon fuels like green hydrogen or ammonia uncertain, ports hold back from making large investments into infrastructure. Progress on operational decarbonisation levers like 'slow-shipping' or port electrification are patchy and run up against market pressures for speed and cost-reduction from carriers and consumers.

Short Detour

Prominent themes for 2031-2040

Rapid policy shift and poor planning

Extreme weather events, rising social pressure, and rapid shifts in export market demands force government to hastily enact policies to reduce carbon emissions. A central command-and-control approach is adopted. The pace of change results in misalignments in infrastructure investments and policy, causing contention, escalating costs, and greater socio-economic disruption.

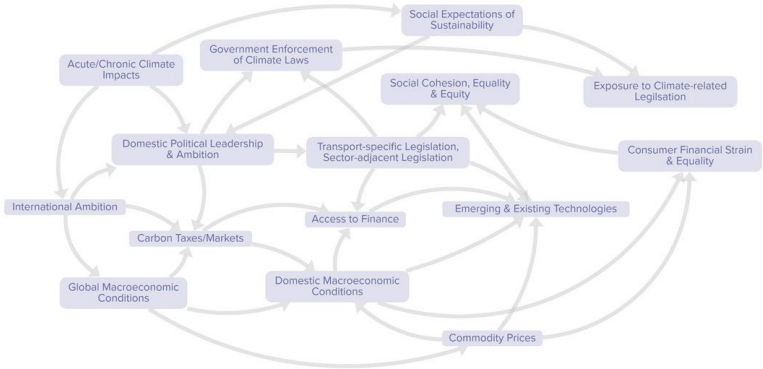
Socio-economic disparity and affordability

There is less funding or policy to support an equitable transition. The rapid move away from traditional fuels disproportionately impacts certain sectors or demographics, leading to increased living costs, particularly among lower income populations. Lack of government support for adopting EVs, less mode-shift to active mobility, and extended reliance on expensive private ICE vehicles worsens social inequality. Some rural or isolated communities face additional challenges due to inconsistent access to EV charging infrastructure.

Expensive and misaligned transition

Although technology pathways are clearer than in the Fully Charged Scenario, the transition is disproportionately more expensive for Aotearoa New Zealand. Mismatches in supply and demand for low carbon fleet, resources, labour, and finance create high competition and costs. Organisations struggle to compete on the global market due to location and buying power. This supply/demand inconsistency is particularly evident in the heavy fleet, sea and air transport sectors, which struggle for access to imported sustainable fuels and low emissions technologies. There is consolidation of the freight sector with foreign entrants.

Driver Impact Map



Sector-Wide Trends

In the early 2030s, a series of extreme weather events shock the globe, and energy economics swings decisively in favour of renewable energy from both a consumer price and geostrategic perspective. Major economies take the world by surprise, announcing unprecedented financial and policy interventions and entering a 'race to net zero'.

Aotearoa New Zealand suddenly faces the economic reality of spiralling fuel costs and being cut-off from major global export markets. Government is forced to respond rapidly, enacting Covid-style central command-and-control delivery of emissions reduction. Carbon credit prices skyrocket to meet global rates, causing a sudden economic jolt across every sector.

Transport is targeted for rapid emission cuts. Regulations and policies are quickly enacted, often without thorough consultation, leading to misaligned responses across national, regional, and local levels both within and across sectors. Transport and energy fail to collaborate effectively on key targets, demand forecasting, or fuel pathways, leading to electricity supply issues and higher infrastructure development costs.

A seemingly singular policy focus on emissions undermines efforts for an equitable transition, or achieving broader co-benefits from a decarbonised transport system. There is limited social license and high levels of social discontent, with many examples of aggressive protests from all sides of the political spectrum. Cost of living pressures increase social divisions, with increased crime, deprivation, and social polarisation, especially among young and marginalised communities. This social unease negatively impacts on the workforces and operations of transport providers.

Developed countries rush to secure the scarce technology, resources and workforce needed for the transition, leading to disproportionately higher costs for Aotearoa New Zealand as its lack of buying power and remote location see it fall down the pecking order. There are inflationary and cost of living pressures through society. Lead times on imports are high, there is frequent disruption and cancellation of imports as global supply chains grapple with rapid transition, and the country is forced to partner with Australia to access transition-related technology and crucial imports.

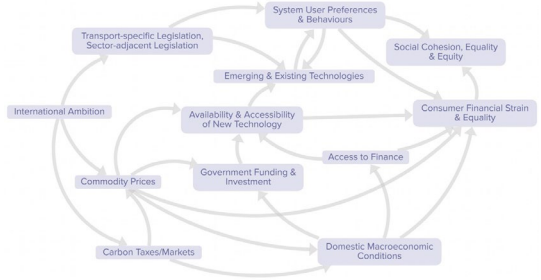
Fuel raids and petrol crimes

Covid-style homebased schooling rules come into force in many parts of the country while schools wait in line for access to electric buses. Emergency vehicles are exempt, leading to 'fuel raids' on fire and ambulance stations around the country. People buy kits to remove the petrol from their private vehicles overnight and leave signs on their car telling would-be thieves: "no petrol here".

Communities are strained by fear of continued climate warming, significant financial pressure, and having to adapt their work, travel patterns, and livelihoods around emissions reduction. Because of this pressure, transport companies are targeted by all sides for rising prices, inconsistent service levels, or insufficient progress on emissions reduction. Companies face climate-related court cases and litigation, with now radically transparent public data on emissions focusing anger on the worst performers.

Moving People

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)



Urban

Local governments make hard, fast decisions to decarbonise transport systems and reduce private vehicle use, often before the enabling work, like infrastructure development or workforce planning, is in place. Policy and legislation that requires low emissions infrastructure and repeals land use planning and policy constraints is rushed through to increase urban density. However, another 'lost decade' of urban sprawl and road building means cost-effective decarbonisation options like active mobility networks are less viable. The speed of change means there is less alignment across central and local government, with more variation in technology, policies, and infrastructure investments. The transition is more expensive and disruptive, leading to comparably higher social costs.

Policy instruments like congestion charging, rate hikes, and road user charging, are used to target low occupancy private vehicles and fund infrastructure changes. The scale and speed of change means many communities are not consulted, informed, or prepared. Instead, they find their traditional transport options either removed or made prohibitively expensive before alternative modes are made available.

Urban form and ways of living have further entrenched private vehicle use on a sprawling road network, meaning many people cling to their vehicles for day-to-day use.

The costs of transport rise for almost all users. Certain groups protest the introduction of cycle lanes, commuters complain that their commute now takes twice as long, and freight companies bemoan the sudden lack of access to some commercial areas.

Low emissions travel

low emission zones ban older ICE vehicles, and some councils mandate that private companies have at least two days a week where office workers work from home. Highways close lanes or designate them for buses only. Many parts of the network are filled with road works and construction, causing high disruption to businesses and communities. There are regular public transport service outages and workforce supply problems, and it will be several years before many areas are serviced by affordable, reliable public transport.

EVs and grid power are both expensive due to supply chain issues linked to physical and transition impacts – from global demand-driven shortages of resources like skilled labour and precious metals, to extreme weather-related operational disruption for imports.

High grid energy prices mean those who can afford it move to decentralised power. People without access to reliable, affordable public or shared mobility options, and who cannot afford EVs, experience spiralling fuel costs and the inability to travel to their places of work.

This transport poverty leads to huge financial strain, job losses, increased financial poverty and social inequality. Transport providers find themselves trying to transform their services during a period when rising social polarisation and crime are hampering workforce and operations.

There are clashes between affected consumer and community groups as emotions run high. Over the decade, protests subside into a sense of collective social sacrifice and private ICE vehicle use in urban centres is increasingly viewed as selfish and unacceptable. Being a low emissions individual becomes something to be celebrated, as well as being more cost effective, helping increase public transport and active mode use. Towards the end of the decade, new urban transport models are being adopted, with advanced on-demand technology and AI planning creating highly efficient urban mobility for some communities.

Social polarisation

A strong anti-emission sentiment creates social polarisation. People who are perceived as able to afford transition to EVs but have chosen not to are the target of broader angst and frustration.

Moving People

Regional, Rural & International

ICE vehicle imports (of all types, new and used) are banned from the mid-2030s, strict emissions standards are introduced, and policy shifts to strongly favouring EVs. Carbon prices trigger a huge spike in fuel costs, and ICE vehicles are targeted with higher road user charges and restricted access to certain town centres and parking spots. The rapid transition catches many New Zealanders off-guard causing social and financial distress - with EV, fuel, and energy costs high due to global competition, strained resources (like rare earth minerals), and climate-related supply chain disruption.

Having not previously invested in the necessary ecosystem to overcome barriers to EV adoption, government hastily rolls out charging infrastructure, with the blanket costs borne by private businesses and society in a disproportionate way. Lack of institutional collaboration and planning sees many rural and isolated communities miss out. Lack of workforce planning for maintenance and repair of chargers or EVs leaves many in remote areas with faulty chargers, or long distances and costs to access servicing.

Uncoordinated managed retreat causes problems with the EV charger rollout. Some charging companies rapidly pull back from planned developments as new guidance is released about which roads or coastal infrastructure will not be maintained. Those who can't afford home charging in towns experience queues for public stations as local government make expensive infrastructure upgrades. Slow grid capacity upgrades see the land fleet, aviation, and ports all competing for affordable or reliable energy supply, with extended power outages and periods when isolated communities cannot recharge.

Global competition means EV costs are far higher, and the Japanese second-hand market is smaller.

More affluent regional or rural residents who can afford decentralised domestic energy solutions and the upfront cost of EVs enjoy cheaper operating expenses and quick payback. Lack of financial support for poorer communities, especially in areas experiencing rapid climate-linked industrial change, means EVs are prohibitively expensive, or require expensive financing.

Despite willingness to adopt, supply and financial barriers see many rural and isolated groups remain locked into ICE vehicles which experience escalating fuel costs, insurance retreat, and a shrinking refuelling market. There are protests across the country as connectivity becomes more expensive, impacting poorer and younger people especially. Some areas see rising theft of fuel, or community fuel stockpiling, whilst others refuse to move away from ICE vehicles and there are frequent incidents of chargers being vandalised. Some remote communities who can't afford local energy production, but have attempted to switch to EVs, find themselves cut off from the grid during extreme weather events. Many rural communities adapt fast to increasing fuel costs and the logistical needs of fuel storage or local power generation. However, growing transport poverty results in some isolated communities being largely abandoned by residents who move closer to towns.

No to forced EVs!

The "Save Our Freedom: No to Forced EVs!" campaign has become very popular. Many towns now have anti-government control placards and protests, and charging stations have even been vandalised. The campaign has been divisive.

Moving People

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)

For a period, there is a noticeable reduction in regional travel for tourism, leisure, and business. Regional rail routes are playing catch-up on electrification plans, with delivery times pushed out to the early 2040s. However, huge advances in battery electric technology mean lines can be feasibly made low emissions.

Towards the end of the decade, strong global demand and a rapidly scaling supply chain sees marginal costs of EVs and chargers begin to plummet in price, with over half of light fleet vehicle kilometres travelled in Aotearoa New Zealand made by EVs by 2040.

Price of fuel impacts

In some rural towns, the price of fuel means the school buses have stopped running, and digital home schooling is used. People are frightened by energy prices, and there are reports of solar panels being stolen off roofs.

Aviation is hit by a sudden spike in global carbon price,. At the same time, domestic and consumer demand steeply declines due to price elasticity and shifting social perception of emissions. The sector must navigate rapidly deployed but highly variable standards around fuel types, flight operations, and carbon pricing. The delay in action and Aotearoa New Zealand's location and lack of buying power means everything about aviation's transition costs disproportionately more. A lack of domestic SAF bunkering exposes the sector to highly expensive foreign SAF prices or carbon offsets, and some airlines simply stop flying here.

Development of alternative fuel infrastructure is expensive and slow, with high costs of finance, commodity price spikes, and reliance on importing in-demand workforce and technology.

There is less time to collaborate and coordinate with the energy sector, ports, or local government, leading to faster decisions and some misplaced bets. Some smaller airports struggle with reduced demand and shifts from historic production sectors and locations. Whilst battery electric flight technology is available, the competition for electricity sees them prohibitively expensive to deploy at scale, and operationally inconsistent.

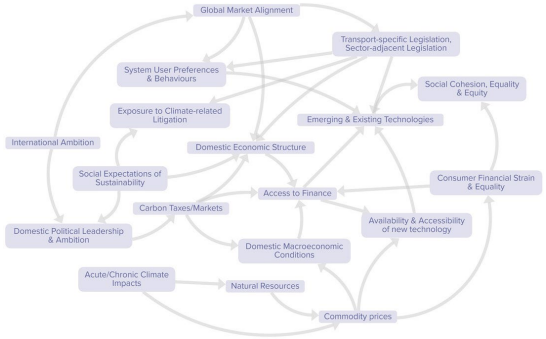
The aviation sector retains its licence to operate for connectivity reasons, but faces pressure. With mainly the affluent being able to afford air travel, punitive and income-based flight shaming becomes common for a period. With many families unable to afford land-based regional travel as often, frequent flyers try and disguise their use of domestic aviation. Foreign airports are increasingly disrupted by supply issues and extreme weather damage. New technology like eVTOL is expensive but prioritised for government funding for its role in reaching isolated communities during emergencies.

Fair access to flying

Mid-decade, social pressure mounted on government to make access to flying more equitable and curb 'affluent frequent flyers' who shrugged off price rises. For a period, trips domestically or overseas are regulated and approved by government under an 'essential travel' list, and offsets are mandated as carbon capture, or the highest quality credits.

Moving Goods

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)



Land

Major trading blocs become highly sensitive to Scope 3 emissions. With exporters facing exclusion from key markets, Exporters from Aotearoa New Zealand place huge pressure on the freight sector to rapidly decarbonise as an economic necessity. As people endure the costs of 'carbon austerity', there is limited social acceptance for high emitters or greenwashing. Radical transparency of corporate emissions has focused media, investor, and NGO attention, with a slew of legal cases against climate laggards.

With less time to deliver mode-shift, government targets the road-based heavy fleet by banning heavy ICE vehicle imports from the mid-2030s and bringing forward strict emissions and operating efficiency standards. Having missed the window for early R&D or investment into alternative fuel capacity or heavy fleet, many carriers are more reliant on competing for hugely expensive imports of materials, technology, and workforce. However, another decade has provided more clarity on alternative fuel pathways, with some short term transition fuels (like hydrogen) leapfrogged in commercially viability and operational performance, and electrification more prevalent.

Despite carriers across Aotearoa New Zealand knowing what they need, they just can't access it. Capital is expensive, and rushed coordination across sectors like energy, shipping, and local government leads to misalignment and unreliable electricity or fuel supply for zero carbon trucks. A national biofuel strategy is pushed through, but results in clashes during food shortages as crops are prioritised for food and sustaining the population rather than creating fuel.

There is still an emphasis on mode-shift to rail and coastal shipping to lower heavy freight emissions. However, underinvestment in the 2020s and closure of some routes makes transition more expensive and limited. Key lines are re-prioritised for adaptation, maintenance, and repair in the 2030s, but works are more difficult and expensive, with higher physical risks, less funding, and more expensive capital. These commercial challenges mean lower volumes of mode-shift are achieved than in the Fully Charged scenario.

New H&S protocols

Amidst a rapid global adoption of alternative fuels, a tragic tunnel fire in Europe caused by a green hydrogen truck has led to panic. Updated international hydrogen tunnel safety standards are rolled out. The retrofitting of tunnels with new systems takes time, and freight fleets are unable to move between some routes in Aotearoa New Zealand.

The operating environment becomes challenging. Operators run dual-fuel fleets across legacy, interim, and zero carbon options, and wider variation in infrastructure, and regulatory decisions creates a confusing, inefficient mix of standards and protocols at ports or with suppliers. Many customers refuse to work with carriers who cannot provide low emissions freight, and the insurance sector quickly pulls back from insuring high emission fleets.

Failed deliveries of foreign fuel due to price spikes or extreme weather events result in operational shutdowns, with the domestic electricity supply still not able to fully cater to heavy fleet demands directly (e.g. electric trucks), or indirectly (e.g. green hydrogen production).

High social pressure

'Carbon austerity' has placed huge pressure on society. There is high social stigma around any form of greenwashing. An exposé on a freight company who massaged the figures sees their share price tank, and protestors target their trucks by spraying them green.

Physical climate impacts create unpredictable demand patterns, and semi-regular disruption to infrastructure and operations. Freight activity shifts quickly alongside a changing economy. Some locations and sectors become uneconomical due to extreme weather, carbon intensity, or shifts in land use to forestry carbon sequestration instead of food production, whilst others flourish. There is reduced 'return-trip' shipping from China, and many people and businesses choose domestic production and consumption patterns to cut down on emissions.

Demand from cities rises, but freight companies bemoan how difficult some 'last mile' deliveries are as roads are pedestrianised or made multi-purpose. In an economy where emissions, efficiency, and reducing waste become paramount, the sector invests in new technology like drone delivery, IoT and predictive AI, and is increasingly orchestrated by 'freight-as-a-service' providers who optimise utilisation and fill rates.

Workforce management becomes difficult. There is a drive to attract a high skill workforce to manage the increasingly digital network.

Other employees experience high financial and social strain, especially those who see their local area's economic base collapse as exports rapidly move away from high emissions products.

Rural service issues

A major freight company has been forced to backtrack publicly after announcing it can no longer afford to serve some rural and isolated communities.

Carbon prices, failed technology bets, stranded assets, and expensive finance mean the sector has a high cost base which is passed onto disgruntled consumers. This not only erodes corporate margins but drives inflation and cost of living pressures for financially vulnerable groups, leading to public protests against the cost of food and basic goods. There are clear winners and losers by the end of the decade, with many carriers who were not prepared for transition failing, leading to consolidation in the sector, and entry of larger, more prepared international competitors.

Biofuel shortage

Storm damage to a foreign port means a major shipment of imported biofuel is delayed, creating a national shortage. Exporters complain – they are struggling with fine margins on many products, and the added Scope 3 emissions of using diesel trucks and cargo ships makes their goods uneconomical.

Moving Goods

Air and Sea

The aviation and shipping freight sectors face high carbon prices and social pressure to rapidly decarbonise. Stringent international targets and standards on emissions and alternative fuels are set by the IMO and global governments. However, these lack coordination and lead to a challenging operating environment. As markets price in Scope 3 emissions, and social sentiment shifts to low emissions and local consumption, operators in Aotearoa New Zealand find themselves vulnerable due to their remote location and limited buying power. The uncoordinated nature of previous R&D or infrastructure development into alternative fuels puts both aviation and shipping freight sectors at the mercy of expensive and competitive global markets for materials, skilled labour, and technology. This makes the transition slower, more reliant on overseas offsets and imports, and disproportionately expensive compared to international benchmarks.

Changing fuel preference

Whilst another decade passing has provided some clarity over alternative fuel pathways, the lack of global or national alignment and limited timeframes mean some ports make investments in a particular fuel type which is then superseded as the global fuel of choice before infrastructure completion, creating stranded assets.

Dropped port calls

By mid-decade, ships are dropping calls to ports that do not have the required alternative fuel infrastructure or guaranteed fuel supply. This results in several port closures and sector consolidation, causing high levels of social and economic disruption in local communities. The shifting network demand and risk of alternative fuel supply means the rail sector struggles to predict which ports to invest in mode-shifting infrastructure.

Having failed to deploy the more gradual approach to progressively increasing carbon price over time under World Shipping Council's 'Green Balance Mechanism' in the 2020s, a blanket greenhouse gas emissions value is introduced by the IMO in the early 2030s. This causes financial distress across the sector and makes many shipping routes to Aotearoa New Zealand uneconomical. With lack of domestic alternative fuel, value chain partners fund expensive offshore projects via the IMO's offset programme.

Traditional high carbon export sectors decline rapidly, and even low emissions products become unviable for long-distance shipping to price sensitive markets. This sees many ports, and especially smaller ones who don't service container ships, experience a drop-off in demand and utilisation, which in turn increases shipped cargo's Scope 3 emissions intensity and marginal per-unit carbon price in a negative feedback loop. The loss of revenue leads to job cuts and social issues in some areas. There are frequent periods of high disruption at ports as operators are confused by the latest government policies and guidance on the kinds of products that are permitted for freighting.

Extreme weather events cause periodic damage to port and land freight network infrastructure, compounding issues.

Ports belatedly begin or accelerate infrastructure investments for shore-to-ship electrification and alternative fuel bunkering. Capital is expensive, and there is confusion across ports, energy, local government and shipping companies over who is funding these expensive works. Ports encounter a period of high cost and operational disruption as they retrofit renewable energy systems. Dual-engine ships emerge, but domestic drop-in biofuel production is stretched across the heavy land fleet and aviation, with a reliance on imports.

As with passenger aviation, air freight faces huge social and cost pressure, and the prospect of having to rapidly accelerate SAF and alternative fuel capacity in an expensive and disorganised economy. Government mandates mean that only pre-defined 'priority' goods can be exported or imported by air. The global spike in carbon price sees many exporters pull back from air freight in favour of shipping, with supply chains having to reconfigure to slower delivery times. Public examples of goods being delivered for affluent individuals by air creates social outcry and protest. As with shipping, expensive capital and misalignment with the energy sector and local government creates costly and slower transition through the decade. Airports are deprioritised for electrification in favour of ports, and there is fierce competition with the land fleet for biofuels and green hydrogen supplies.

As physical impacts intensify, air freight does become a more reliable mode for critical resources, either domestically or internationally. Predictive AI technology is deployed in tandem with the land freight sector to optimise logistics efficiency and to reduce fuel burn, and there is government-backed investment in eVTOL technology to support delivery of goods to disaster-hit isolated communities.

Short Detour

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) **LONG TERM (2041-2050)**

Prominent themes for 2041-2050

Expensive and slow transition

Aotearoa New Zealand remains part way through an expensive and costly transition with persistently high inflation and slow GDP growth. Offsets are required to meet 2050 targets. The heavy fleet, aviation, and shipping are undergoing fleet renewal and remain partly reliant on overseas imports of alternative fuels. Technology advances are reducing marginal costs of low carbon options.

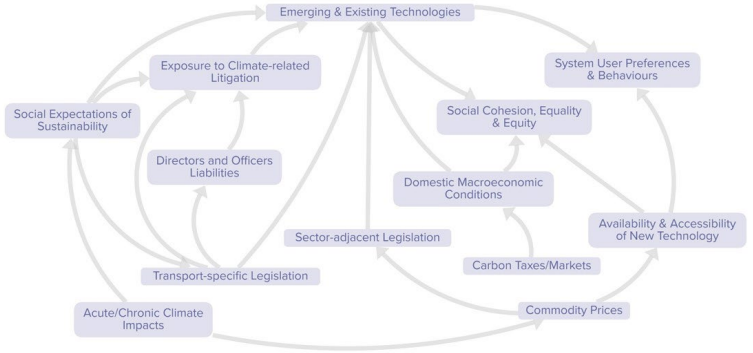
Transport inequalities

The almost singular focus on emissions and rapid switch to low carbon fleet and mobility options means some communities remain reliant on highly expensive ICE vehicles, or do not have access to affordable public or shared mobility options. Pockets of lower socio-economic urban areas, or some isolated rural communities face rising transport costs. The visible impacts of climate and 'social sacrifice' of transition have created high social and legal risks for companies.

Compounding physical and transition impacts

Physical climate impacts like flooding and extreme heat impact the sector as it transitions. This affects operational productivity and increases social demand for decarbonisation. A sense of 'collective sacrifice' at the social and economic costs means social expectations are very high. More stringent emissions regulations pose legal risks to the sector. Less investment in adaptation means extreme weather events more adversely impact infrastructure, and especially the road network, with further insurance, maintenance, and service retreat in some areas.

Driver Impact Map



Sector-Wide Trends

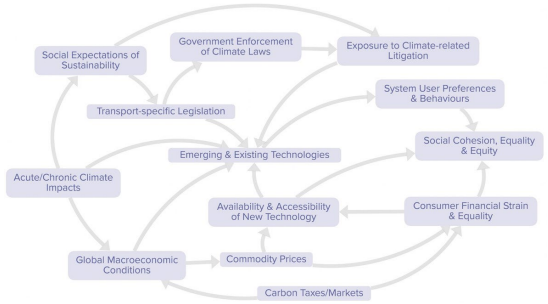
Economies of scale, technology innovation, and global collaboration on renewable energy means most developed economies' transport systems are becoming low or zero carbon by the early 2040s. In Aotearoa New Zealand, electricity becomes the most popular fuel for final energy consumption in transport, EV ownership surges to dominate the private vehicle market, and peak land fleet size is reached. Whilst most of the heavy land fleet is decarbonised, aviation and shipping are still part way through an expensive transition. Global critical resource shortages see a strong government drive for energy and resource sovereignty. Transport is expected to facilitate and contribute to a circular economy that is low waste and keeps resources in country.

Although some countries see post-transition economic growth, Aotearoa New Zealand has experienced an expensive transition with heavy socio-economic costs. Whilst advances in automation and AI are driving down prices, transport remains comparatively expensive, and there remain pockets of transport poverty across urban and rural areas. Although the economy begins to recover, the social scars of 'carbon austerity' affect communities and workforces across the country, with transport operators dealing with lasting inequality and social cohesion challenges.

Whilst the worst effects of climate change have been avoided, the emotional reaction to the visible impacts on communities like flooding, water shortages, or extreme heat are combined with the collective feeling of 'social sacrifice' made for the transition. This has created very high legal and social risks for companies found to be greenwashing or in non-compliance with standards or emissions budgets. With radical tech-enabled transparency, transport providers are forced to keep pace with decarbonisation targets. However, Aotearoa New Zealand is aligned with international company directors and officers responsibilities and fiduciary duties, re-cementing Aotearoa New Zealand's reputation as an attractive, competitive location for top talent.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Urban

City populations rise, including climate migrants from the Pacific and wealthier developed nations. As in the Fully Charged scenario, the transition to a low emissions, digitally-enabled transport system has enabled affordable and time-efficient mobility for many urban dwellers. Electrified rapid transit networks carry commuters from modern high-rise residential areas to key employment hubs. Advanced technology like AR robot-assisted surgery, eVTOL craft, and autonomous vehicles are equally advanced and changing traditional transport demand.

However, infrastructure upgrades are still being completed. The investments and fiscal costs borne by local government during the disorderly transition mean council rates, road user charges, and public transport costs remain expensive. Active mobility networks are less developed, with the health and social benefits dampened. People prefer to use enhanced mobility options from e-bikes to modern hoverboards.

Anti-social ICE use

Strong social aversion to emissions and awareness of the health implications of exhaust fumes means unnecessary ICE vehicle use by affluent individuals who can afford both EV's and the carbon price is now seen as anti-social.

More people still rely on private vehicle use (although they are typically electric and smaller). However, this habit is shifting as digital platforms make shared and on-demand options simple and readily available, blurring the line between public and private mobility. Space is still being reclaimed from roads and private vehicle parking, Auckland and Wellington are rising back up the 'liveability' rankings having dropped off for a decade.

The lack of early integrated land use-transport planning, or development of truly integrated active mobility networks, means that many areas, especially in the sprawling suburbs, are under-served by reliable public transport or private on-demand mobility providers. Many communities remain locked-in to private light electric vehicle use, with some stuck with expensive legacy ICE vehicles. The number of drivers on the road means congestion is still an issue, and many areas have long trips to reach rapid transit hubs. Whilst for many residents, mobility has never been easier, there remain a substantial portion of communities that still experience transport inequality and poverty.

Regional, Rural & International

Most rural and regional travel is now done by EVs. Falling production costs and a healthy second-hand market all accelerate uptake. Charging infrastructure and grid capacity upgrades across the country see range anxiety disappear for most, with decentralised energy production a highly popular solution. Electrification has seen fuel costs plummet, which has opened affordable regional travel again for business, tourism, and leisure. The shared and on-demand transport market is booming.

Rising commodity prices and climate-related supply chain disruption mean government is focused on enabling reduction in fleet size and private vehicle dependence. Pressure to reduce virgin mining and resource use means vehicle manufacturers are expected to build circularity into vehicle design. A new electric passenger rail line is opened between Auckland and Tauranga, and cross-country shared mobility platform providers scale up, both proving popular with younger demographics.

Petrol range anxiety

In a mirror of the 2020s, it is now more difficult to find a reliable petrol or diesel fuel station than it is to charge an EV across most of the country. Some communities who use diesel or petrol vehicles face huge challenges and rely on local fuel storage solutions.

Growing populations and insufficient mode-shift away from private vehicles has increased demands on the network from an energy, resource, and time perspective. Whilst many rural communities have built local resilience with decentralised energy production and storage, those groups who remain reliant on the central system experience energy blackouts when local grid capacity is overwhelmed, or extreme weather damages infrastructure.

National shortages in skilled workforce means charger or EV maintenance remains an issue in remote areas. A number of these groups still don't see EVs as practical or climate resilient. For others, the lack of upfront financial support means EVs remain too expensive, and some people have simply refused to adopt for political reasons.

This has created pockets of rural or isolated communities that remain locked into ICE vehicles which are now extremely expensive and logistically difficult to use. With economic and managed retreat in many locations and sectors, connectivity issues resulting from escalating transport costs accentuate social issues and rural deprivation in some parts.

Moving People

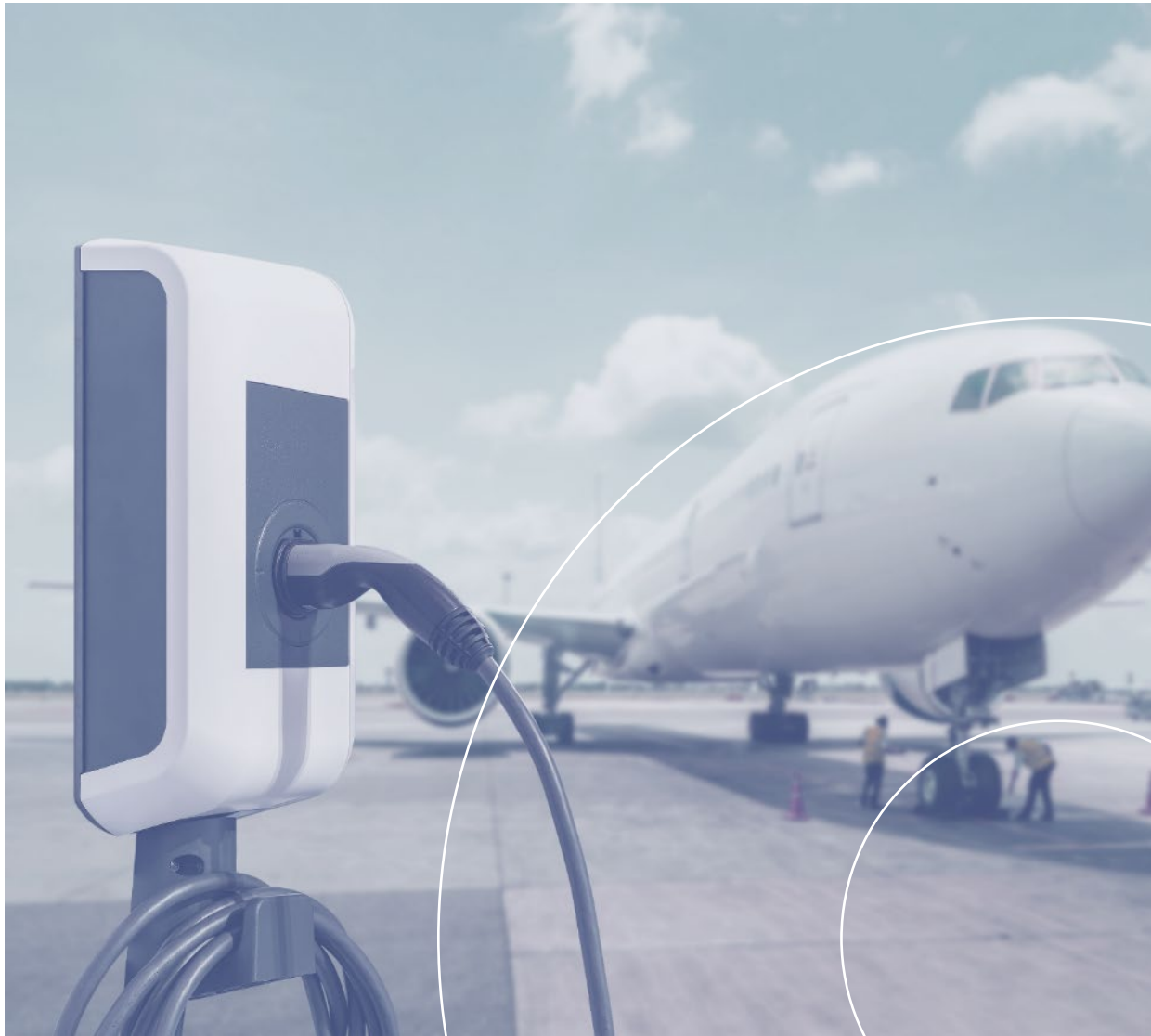
Aviation remains in the middle of an expensive and slow transition to alternative fuels and fleet. Despite lowering emissions intensity, the sector is under high social and legal scrutiny. Many people remain uncertain about their personal reputation if seen flying unnecessarily. The sector is handling zero carbon, SAF, and legacy jet fuel options. With high carbon and SAF prices, this makes pricing, social acceptance, and operations hard to juggle for carriers and airports who are operating multi-model and multi-fuel fleets.

International electric flights

Demonstration of a trans-Atlantic battery electric passenger flight introduces a mixture of excitement and uncertainty to the green hydrogen fleet. Many countries are now moving towards full electrification.

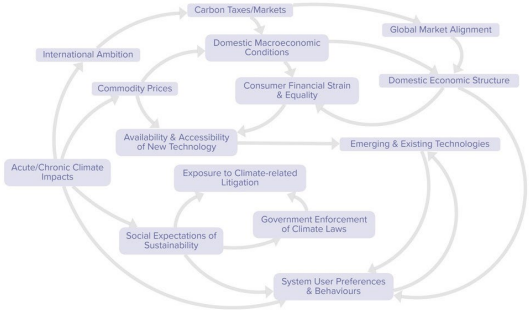
The sector competes with ports and the heavy land fleet for SAF inputs and alternatives like green hydrogen. Domestic SAF production is still being scaled for international flights. Greater reliance on overseas capital, technology and value chain partners, mean margins are lower across the sector. International passenger numbers steadily recover in line with reducing emissions intensity throughout the decade. Long-distance zero carbon fuels and aircraft are demonstrated in the decade, but remain commercially unviable for smaller markets like Aotearoa New Zealand.

Domestic zero carbon flights become more prevalent from early in the decade, reinvigorating local demand as people feel they can travel 'guilt-free' again, although electric flights remain reliant on intermittent grid capacity. AI and predictive technology embedded into operations and wider transport systems across departure and arrival destinations creates time and carbon-efficient journeys. Towards the end of the decade flying is increasingly lower or zero carbon, and regaining its former social acceptance and popularity. Rising physical impacts have seen the sector become increasingly important and popular as the road network is hampered.



Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Land

After a decade of disruption, by the mid-2040s most of the land-based heavy fleet is decarbonised, and almost all light commercial vehicles are electric. Some use-cases remain dependent on hugely expensive ICE vehicles. Aotearoa New Zealand has retained competitive access to export markets. But the rapid transition to alternative fuels, fleet, and infrastructure, alongside the shift of freight demand from traditional exports towards low emissions, circular, and domestic production and consumption patterns, has created high financial and operational costs that the sector is still recovering from.

Freight is comparatively expensive and still struggles with logistical issues around new fuel supply chains. Evolving standards and competition with aviation and shipping for limited supply see semi-regular operational suspensions as vehicles wait for fuel. The resources and workforce needed for asset and infrastructure maintenance and repair remain expensive and reliant on imports.

Technology advancements like drones or 3D and 4D printing have changed demand, whilst AI has enabled the rise of new business models. The sector is more digitally integrated across providers and sectors like shipping. Urbanisation has driven more demand for 'last mile deliveries', but more private vehicles and congestion creates challenges. AI integration across the transport network means many carriers partner with on-demand transport providers who offer combined personal mobility and last mile delivery solutions in a cost-effective way. New Zealanders value low emissions, reliable, and affordable freight. Government pressures the sector into becoming more circular and to reduce resource usage and waste.

As the physical impacts of climate worsen, the prioritisation of investment in climate mitigation instead of adaptation means effects are more acutely felt across transport assets like railways or roads. Delayed resilience investment into rail until the 2030s means maintenance and repair costs are higher, but still only enables a smaller volume of mode-shift versus the Fully Charged scenario. This comparatively lower mode-shift to rail or coastal shipping accentuates exposure to a vulnerable road network. Road slips, flooding, and damage to rail tracks all cause delays and risks to workforces.

System-level data-sharing, digital twins, and AI decision-making are commonly employed to keep things moving. Some rural and isolated communities are increasingly difficult and costly to serve, with operators having to set up specific legal and insurance contracts for driving into certain locations. The communities that are often hardest to serve are those who have experienced the greatest cost from the transition and the decline in legacy industries. Freight is targeted for protest by some groups for its perceived role in perpetuating cost of living issues, with delivery of essential goods seen as a public right.

Air and Sea

Aviation and shipping face public and economic pressure to decarbonise as their share of transport's overall emissions increases. 2050 emissions targets force both sectors to accelerate transition to alternative fuels and fleet. Both sectors have adapted to the lower carbon, more circular, and shorter supply chains that Aotearoa New Zealand now operates, with huge shifts in the location of economic activity and the types of imports and exports.

Given asset renewal timeframes, shipping is in the middle of slowly phasing out legacy fuel models, with increasing proportions of dual-engine ships and a growing number of zero carbon models now visiting Aotearoa New Zealand. Whilst most port electrification work has been completed, many ports are still developing alternative fuel bunkering capacity. The disruption of changing fuel and export economics in the 2030s means a number of smaller ports close during the decade, and are consolidated with larger ones. This affects rail lines, and causes high socio-economic problems for local communities. Whilst supporting efficiency in some ways, consolidation increases supply chain risks. Extreme weather or delays to shipments leaving remaining ports can cause excessive demands on 'spill over space' for ports in and around urban centres. The closure of roads or rail leading into these ports now has even greater economic impact.

New operating standards and alternative fuel production issues lead to continued disruption at ports through to 2050. Despite the introduction of predictive AI, and use of advanced technology like digital twins to model infrastructure and route integrity, there has been less global investment in adaptation. The rising impacts of climate change mean semi-regular disruption to the global shipping network, which disproportionately impacts Aotearoa New Zealand and freight partners like rail.

In this scenario, the delay in decarbonisation means there are greater occurrences of physical risks compounding transition risks, and vice versa. From impassable canals to freak storms shutting down major ports, the sector adapts to a 'new normal'. With fewer zero carbon ships operating due to a delayed transition, 'slow-shipping' mandates remain common. This means the coincidence of a missed shipment due to insufficient alternative fuel bunker supply and a missed shipment due to physical impacts creates longer delays, and high supply chain and operational costs, with consumers feeling the impact.

The arrival of SAF and alternative fuels means air freight becomes a more socially accepted mode again. However, prices are high and it remains reserved for high-value, priority exports or imports. As the physical impacts of climate on coastlines, ports and canals worsen both domestically and abroad, the aviation sector becomes an attractive mode for time-efficiency and reliability. Although many consumers are now less sensitive to time-based deliveries, this plays an important role during crisis response, or to mitigate the semi-regular supply chain shortages. Airports remain generally more resilient to physical risks than ports, but with global warming projected to decline there is limited need for moving locations of either sector's fixed assets.

Fully Charged

Short term 2024-2030
MOVING PEOPLE
MOVING GOODS

Medium term 2031-2040
MOVING PEOPLE
MOVING GOODS

Long term 2041-2050
MOVING PEOPLE
MOVING GOODS

Fully Charged Scenario

Scenario Overview

International and domestic policy settings aim to limit total warming by end-century to less than 1.5°C, and reaching net zero emissions around 2050.

Though ambitious, these targets are insufficient to avoid crossing the Paris Agreement's 1.5°C threshold by mid-century. There is a temporary overshoot, and medium to high deployment of carbon removal solutions is used to dial the heat back to 1.4°C warming by end-century.

Accordingly, the physical impacts of climate change are limited and affordable. We have avoided major tipping points in our ecological and climate systems.

1.4°C Policy Ambition*:

** The temperature outcome aligned with global policy settings and ambitions under this scenario[3].*

Severity of physical risk	*Low*
Severity of transition risk	*Moderate*
Policy reaction to climate change	*Immediate and smooth*
Regional policy variation	*Medium*
Technology change	*Fast*
Carbon dioxide removal	*Medium to high use*

Global [1]

Warming at 2050

1.6°C

Warming at 2100

1.4°C

Aotearoa New Zealand [2]

1.3°C

NIWA 2031-2050 estimate

1.3°C

NIWA 2081-2100 estimate

[1] IPCC, 2021. Summary for Policy Makers. [Online] Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf (Accessed March 2024).
[2] MfE, 2018. Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition. Wellington: Ministry for the Environment.
[3] NGFS, 2024. NGFS Scenarios Portal. [Online] Available at: https://www.ngfs.net/ngfs-scenarios-portal/explore/ (Accessed May 2024).

Our World

The world shifts *immediately* and *smoothly* toward a more sustainable path, emphasising more inclusive development that respects recognised planetary boundaries. Management of the global commons rapidly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts to a broader emphasis on human well-being.

- **Consumption**: Oriented toward low material growth and lower resource and energy intensity. Consumers are increasingly committed to sustainable lifestyles.
- **Society**: Driven by an increasing commitment to the UN Sustainable Development Goals, inequality is reduced both across and within countries.
- **Economy and trade**: By 2050, the physical impacts of climate change have shaved roughly 5% off global GDP. However, transition-related macroprudential risks peak in the 2020s and a 'green wave' of growth is set to add US$43 trillion, or approximately 3.8%, in net present value to key economies by 2070 (with growth in the Asia Pacific region eclipsing growth in Europe and the Americas). Major markets impose additional costs on trade for countries failing to do 'their fair share' in the transition to a sustainable future.
- **Land use and nature**: Historical trends are reversed, including a gradual, global-scale, and pervasive expansion of forests and other natural habitats. Forests become a net sink by mid-century. An increasingly circular economy, efficient use of natural resources, and investment in productive landscapes has transformed the vitality of terrestrial and marine ecosystems.
- **Technology**: The uptake of carbon reducing technologies (e.g. renewables, carbon capture and storage), as well as technologies to better manage climate-related risks, is fast.
- **Energy sector**: The global energy system rapidly decarbonises with development and deployment of solar, wind, and batteries alongside substantial behavioural change, achieving around a 35% reduction in CO_2 emissions by 2030 and net zero emissions by 2050 (with carbon capture and storage employed for residual emissions). Unabated coal use for electricity ends by 2040 globally. Rapid upscaling of generative capacity leads to an increase in global total primary energy supply from renewables rising from 29% in 2030, to 71% by 2050. Electricity dominates the system, with 89% of global electricity generation from (non-nuclear) renewable sources by 2050. Hydrogen production increases fivefold from today by 2050, and biofuels increase two and a half times.
- **Transport and energy**: Global transport emissions fall 24% by 2030, thanks to electrification, efficiency improvements and behavioural change. By 2030, almost 60% of all new car sales are electric, and by 2050, electricity accounts for 51% of transport's final energy consumption. Ships, planes, and heavy trucks make up around 85% of transport non-electricity demand in 2050. However, the blending and direct use of low-emissions alternative fuels such as biofuels and hydrogen-based fuels increases significantly, especially in aviation and shipping, and for long-haul road freight. By 2050, hydrogen accounts for 14% of global transport energy consumption, and biofuels for 11%.

Our Home

Aotearoa New Zealand invests in strategic, transformational mitigation measures with innovation playing an important part. Aotearoa New Zealand's response to the climate challenge is recognised and respected by the international community, including major trade partners. As a result, it still has secured access to critical markets.

- **Policy:** Central and local government policy settings align with the global goal of limiting total warming to no more than 1.5°C. Domestic policies support swift and efficient decarbonisation. Policies ensure the protection of vulnerable populations during the transition to a low emissions, climate resilient future. This allows the country to maintain a relatively high degree of social cohesion.
- **Trade**: The Pacific participates in an effective global trade regime through a growing service industry and niche products. There is strong market demand for Aotearoa New Zealand's 'green' primary products and services.
- **Behaviour**: Changes in people's and businesses' preferences encourage more behaviour shifts away from high emitting activities and practices. People and businesses want to adopt existing low emissions technologies, business models, and lifestyles.
- **Land Use and Nature:** Aotearoa New Zealand is effectively preserving, and even beginning to restore, its fragile ecosystems and limited natural resource base. As a result of strong, successive resource management planning reforms, degraded hillsides return to native forest, coastal ecosystems are re-established throughout their range, and Aotearoa New Zealand's air and waterways are renowned for their ecosystem services.

Fully Charged Parameters

Fully Charged physical parameters

PHYSICAL VARIABLE	LOCATION	2030	2040	2050
Mean Annual Temperature Change *(°C, average annual temperature vs pre-industrial baseline)*	Global	1.4°C	1.6°C	1.6°C
	NZ	*2031-2050 Figure*: 1.3°C		
Extreme Heat *(Average number of days exceeding 25.0°C annually)*	NZ	*2031-2050 Figure*: 15 Days		
Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	NZ	*2031-2050 Figure*: 15%		
Median Sea Level Rise *(Increase in metres)*	NZ	0.12	0.15	0.19
Extreme Wind Speed *(Estimates from NIWA visuals)*	NZ	*2031-2050 Estimate*: Approx. <5% increase in parts of the country (Mostly southern half of North Island, and South Island)		
Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NZ	-16	-19	-16
Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NZ	31	34	31

Fully Charged socio-economic parameters

SOCIO-ECONOMIC VARIABLE	LOCATION	2030	2040	2050
Population *(Million)*	Global	8,413.3	8,854.5	9,136.9
	NZ	5.6	5.9	6.2
GDP *(% difference, 2009 prices; local currency vs baseline)*	NZ	-1.1	-0.2	0.1
Inflation Rate *(Absolute difference % vs baseline)*	NZ	0.13	-0.22	-0.03
Long Term Interest Rate *(Absolute difference % vs baseline)*	NZ	0.78	0.54	0.39
Carbon Price *Energy (real NZ$/tCO$_2$e)*	NZ	1711	230	309
Oil Demand *(Million barrels per day)*	Global	77.5	-	24.3
Oil Price Increase *(% difference, US$ per barrel vs baseline)*	NZ	158	371	625

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Fully Charged Parameters

Fully Charged transport parameters

TRANSPORT VARIABLE	LOCATION	MODE	2030	2040	2050
Total Transport CO_2 Emissions *(Global = $MtCO_2e$) (NZ/Domestic = $ktCO_2e$)*	Global	-	5,992	2,430	578
	NZ	-	12,258	4,503	1,022
Road Vehicle Kilometres Travelled by Vehicle/Engine Type *(Total = billion kilometres) (Type = % share)*	NZ	Total	52	49	50
		ICE Vehicle	73	24	4
		EV	27	76	96
Household Person Kilometres Travelled by Mode *(Million kilometres)*	NZ	Active Transport	2,436	4,949	5,982
		Public Transport	5,552	8,115	9,854
		Private Transport	53,073	45,503	43,112
Total Number of Vehicles in Fleet *(Thousands)*	NZ	-	4,602	4,119	4,010
Freight Mode Shares *(% share)*	NZ	Rail	16	21	21
		Coastal Shipping	14	19	20
		Road	70	60	59

Fully Charged energy parameters

ENERGY VARIABLE	LOCATION	MODE	2030	2040	2050
Total Primary Energy Supply – Renewables *(% share)*	Global	-	29	-	71
	NZ	-	54	76	89
Percentage of Electricity Generation from Renewables *(% share)*	Global	-	59	-	89
	NZ	-	93	95	98
Renewable Energy Share of Total Final Consumption (including international transport) *(% share)*	NZ	-	37	61	79
Breakdown of Transport's Total Final Energy Consumption by Mode *(% share of total)*	Global	Road	71	-	62
		Aviation	14	-	20
		Shipping	11	-	13
Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption *(% share)*	Global	Biofuels	10	-	11
		Hydrogen	1	-	14
		Electricity	8	-	51

See Appendix D for detailed parameter references.
See Appendices E-G for rationale, considerations, and limitations of data sources.

Fully Charged

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

Prominent themes for 2024-2030

Proactive low carbon, high-tech transition

The country proactively steps into transition with bipartisan, long term government climate leadership. Electrification, alternative fuels, and technology like AI and IoT all accelerate the move to more energy efficient, lower carbon transport. There is a shift away from inefficient private vehicle usage for some use-cases and towards public modes. EV adoption trends in the private and public fleets accelerates through large-scale investments in new technologies, workforce, infrastructure, and focused behavioural shifts.

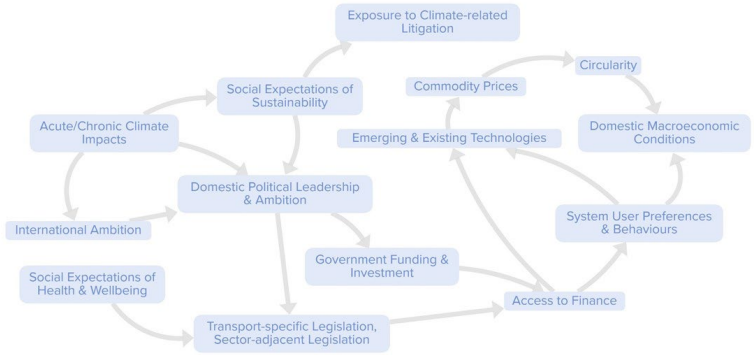
Economic and social impact

Whilst proactive investment saves the country money in the long term, ensures domestic fuel sovereignty, and society is supportive, the short term cost of transition to a low emissions economy causes financial instability among businesses and individuals. Ongoing high inflation leads to cost of living pressures, reduced spending, and significant social impact.

Decarbonisation increases costs

Land, air, and sea freight all face common challenges – the requirement for high financial investment, technical limitations in transitioning fuel types and models, rising operational costs due to carbon pricing, changing network demand, and high political and social pressure. However, carbon prices make inaction equally costly. There is greater variation in alternative fuel types across modes due to uncertainty in pathways.

Driver Impact Map



Sector-Wide Trends

By the end of 2025, global economic and geopolitical stability improve. There are two significant milestones in western economies. First is a critical mass in public awareness of climate impact and loss of nature, leading to a demand for action. Second is a dramatic move of early actors that trigger a vast retreat from insurance, indicating a highly inaccessible insurance environment in a world heated beyond 2°C.

There is a step-change in global decarbonisation investment, primarily spurred by the United States and China engaging in an 'arms race' towards net zero greenhouse gas emissions, and acknowledging the financial, geostrategic, and national security benefits of swift greenhouse gas emissions reduction strategies. There is widespread understanding that targeting 1.5°C of warming wasn't an arbitrary number, but significantly reduced the risk of tipping points in the Earth system.

Aotearoa New Zealand, realising the imperative of not being left behind or excluded by financial, market, and technological global forces, brings forward investment timeframes, and proactively ramps up action to curb climate change. Climate returns to a centreground issue, with bipartisan consensus on evidence, measurement, and appropriate action.

Government provides strong leadership, renews commitments to 2030 and 2050 emission targets, and recognises the limitations of relying solely on the ETS price signal to drive change. There is bipartisan support for long term climate action. The role of transport and urban form are recognised as vital to achieving these targets, and there is acceptance that widespread, rapid investment is needed.

There is strong co-ordination between central, regional and local government across policy, and more streamlined transport infrastructure planning, consenting and long term funding processes. Policy direction is aimed towards unlocking the co-benefits of a decarbonised transport system, ensuring the transition addresses existing and consequential social inequalities, as well as the Crown's obligations under Te Tiriti.

Global carbon tax

COP29 has dramatic consequences, with policymakers agreeing a global carbon tax based on per capita emissions. With 38th highest per capita emissions globally, and fourth highest in the OECD, this has an immediate impact with new legislation limiting domestic and imported emissions, emissions labelling requirements, and a new domestic carbon tax. Introduction is staggered over five years but the effects on transport are immediate, with conventional fuel almost costs doubling overnight.

Aotearoa New Zealand strengthens the alignment of transport and energy sectors, aiming to increase electricity generation to meet transport electrification demands, and focuses on workforce re-skilling and mitigating transport poverty risks.

Innovation in renewables and clean energy, catalysed by policy backing and production advancements, makes low emissions options more energy- and cost-efficient than traditional energy sources. This leads to substantial green finance flows and accelerates electrification and energy security processes in major economies. Aotearoa New Zealand sets its sights on energy sovereignty. There is rapid buildout of new generation.

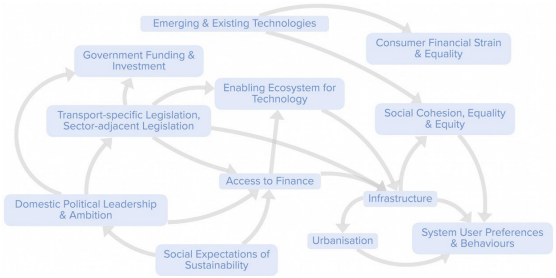
Bioeconomy boom

A group of leading agriculture, transport and energy organisations sign a landmark deal on scaling biofuels in the Waikato region. This prompts an explosion of similar bioeconomy deals across Aotearoa New Zealand.

Despite planning, this rapid pivot creates high socio-economic costs. There are high inflationary and cost of living pressures across Aotearoa New Zealand. Governments, public transport providers, and freight companies face increasing social, political, and legal pressure to decarbonise their operations as climate litigation becomes a media favourite. People are highly concerned about job losses and many groups push back firmly against this 'carbon austerity', leading to fractious social interactions. Many private businesses struggle, while insurance and markets retreat from certain sectors as the reality of climate action becomes more accepted.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Urban

Government understands the step-change that is required in urban transport and that 2050 targets will only be met with significant mode-shift and reduction in private vehicle use. Policy is aimed at reducing car-dependency by developing reliable and safe public, shared, and especially active modes like cycling and walking, alongside shifts in urban land use and community consensus-building. Enhanced mobility like e-bikes are supported and brought into the funding and planning framework, with global companies attracted to set up pilots and business in major urban centres.

Funding frameworks and priorities are aligned across national, regional, and local governments for enhanced investment in green infrastructure. Urban densification and upzoning is prioritised through resource management, land use, and housing standard reform. Accelerated consenting processes for evidence-based, low emissions developments are passed, and there is genuine integration between land use and transport planning.

There is a clear move away from building more roads, and a nationally coordinated infrastructure approach focuses on reducing funding needs and embodied carbon by prioritising the repurposing of existing assets. Funding frameworks are revisited with greater application of innovative mechanisms and user pays models.

Barriers to human-centric mobility are targeted, with priority given to 'quick wins' and interventions that yield high rates of decarbonisation on a 'per dollar expended' basis e.g. protected cycle lane networks, bus rapid transit, and 'complete roads' (prioritised active and public transport corridors) for walking, cycling, public transport and some private vehicles. Public transport electrifies and focuses on reliability and safety, and government supports access for EVs through subsidies and policies to support a comprehensive charging infrastructure.

Government actively engages with communities through clear public messaging on the broad health, wellbeing, cost and environmental benefits of moving to a low emissions model and actively engages in more deliberative methods for decision making.

Carbon protests

A procession of vehicles slow drive over Auckland Harbour bridge in protest against the new congestion charging. An interview with a young family who now can't afford to drive to work and have no alternative goes viral and fuels the anti -'carbon austerity' campaign.

Lower socio-economic neighbourhoods are prioritised for investment in developing safe, flexible, and reliable active, public, and shared transport options as well as low cost EV options. The rapid built out of energy generation creates affordable and resilient grid power. This supports EV adoption, although does reduce incentives for households to adopt decentralised energy production. This makes urban grid management through initiatives like smart charging more important at peak times.

Mini-Amsterdam!

The booming demand for bikes and e-bikes across the country has led to a resurgence in domestic bike manufacturing with the latest factory opening in Manukau. A government partnership with Strava gives real-time updates on how many people are cycling at any one time.

There is a boom in cycling, companies are eagerly partnering with ride-sharing apps, and rapid uptake of public transportation use increases as efficiencies grow across the network. Many people passionately embrace the change, as evidenced by greater diversity in walking and cycling and public transport. All modes are used for a wider array of uses with options like e-cargo bikes and light rail connections becoming more accessible and integrated.

However, the period is also highly disruptive. Despite trying to sequence events so that supply of public and active mobility options precedes the disincentivising of private vehicle use, those without alternative options find themselves burdened with high levels of financial cost and disruption. Unreliable nascent bus routes, skyrocketing fuel prices, congestion charging, and seemingly never-ending roadworks all increase time and cost of travel. Poorer neighbourhoods and those unable to afford EVs are disproportionately impacted, with rising costs of travel, and people even having to change or lose their jobs because of high commuting expenses. There are several protests against the speed of the change, and transport providers find themselves increasingly open to public legal challenge.

Adjusting to change

Many people are having to readjust their lives as new bus lanes and cycle paths start impacting their commutes and normal journey times. There are clashes between cyclist and drivers on the new 'right of way' signs at most inner city junctions.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

Regional, Rural & International

Private vehicles remain a necessity for rural and regional travel, with electrification of the light fleet a major priority for government. Aligning with major market timelines, a 2030 new and second-hand ICE vehicle import phase-out date is set. This strong market signal, booming global EV production, and strong flow of second-hand vehicles from Japan sees EV adoption accelerate in Aotearoa New Zealand. Government focuses on ensuring the supporting ecosystem for EVs is an enabler, not a blocker, from rolling-out a comprehensive public charging network to local authority procurement support, partnerships with education institutions for workforce training, attractive EV rebates, and grants for battery recycling R&D.

Tough decisions

A particularly bad storm sees 400 people forced to abandon their homes on the West Coast. Government support is limited leading to mass outrage online. Ministers have to remind people of the need to focus on mitigation, and that less funding is available for adaption.

The transport and energy sectors collaborate on both boosting electricity grid transmission capacity and supply ahead of forecast transition-related demand, whilst also managing system demand. Retailers provide incentives for off-peak EV charging, and invest in AI for future system load management and smart charging.

This collaboration encourages longer term plans for the development of affordable interregional electric passenger rail within the Upper and Lower North Island, integrated with housing densification plans and mobility corridors. This focus on rail necessitates proactive investment in adaptation and resilience to deal with the future locked-in impacts of current climate warming.

Whilst grid power becomes low carbon, affordable, and resilient for many, this also means fewer people adopt decentralised generation. This exposes more households and communities to power outages during extreme events when infrastructure is damaged, or when national grid capacity is breached, with consequences for EV drivers' ability to charge.

There is a strong push for more equitable access to low emissions vehicles. Government addresses upfront cost barriers through targeted capital cost subsidies, rebates, and promotes new ownership models like social leasing and car-sharing. Innovative finance companies collaborate with manufacturers, dealers, fleet operators, and e-commerce companies to reduce the barriers to EV adoption for lower income groups, from providing affordable finance, to building spare battery stocks onshore for rapid replacement. There is broad engagement with communities, as well as social campaigns to educate and empower communities around EV adoption. Local authorities are empowered to strategically locate chargers in high demand areas like schools, and encouraged to prioritise community access.

Media channels hum with lively discussion on the positive 'price parity' and 'payback time' time for EVs, especially for those who live in towns or rurally and spend more time behind the wheel, and 'New Zealand's Favourite Charging Stations' becomes a popular (if tongue-in-cheek) annual competition. More affluent early adopters read the tea leaves and double down on the self-sufficient lifestyle of EV, home battery and solar power. As petrol prices rise and social sentiment shifts behind emissions reduction, EV adoption accelerates.

Electric education

The University of Auckland partners with an engineering firm and Google to roll out a national apprenticeship for EV servicing and digital skills in all major regions, proving highly successful.

Although the majority of rural communities support the transition, some find it hard to make the switch, and there is some social discord between urban and rural groups as new laws and policies impact each differently. Despite government support, many people can't justify the upfront cost of EVs. For others, local charging infrastructure never materialises, with EV drivers facing long trips and queues to access public charging sites. Some isolated communities don't see EVs as climate resilient or practical in places where grid reliability is low, chargers are sparse, and extreme weather events can damage energy or road infrastructure.

Fuel problems

A broken charging station near Tikitiki left some families stranded, and refuelled the debate about EVs being practical in rural areas. An underground market in biofuels has developed because of the price of petrol.

Stricter emissions standards and rising diesel and petrol prices means travel becomes more expensive with ICE vehicles, with longer cross-country trips noticeably declining. There are local protests against perceived top-down Government intervention, and some communities collectively push back on 'forced' EV adoption. There is stockpiling of legacy fuels, and cases of EVs or chargers being vandalised. Many isolated communities strongly criticise the lack of adaptation funding.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

The aviation sector experiences a turbulent period of investment and disruption. Robust but fair global carbon markets and expensive SAF see costs increase, but not as sharply as could have been expected due to early investment in supplies. Despite communication with customers about the pass-on costs of developing low emissions infrastructure, demand elasticity sees a notable drop off in domestic passenger volumes. Investment from corporate firms into SAF supply increases as they look to continue to travel internationally whilst scrambling to meet imminent 2030 emissions targets, and there is strong social outcry that interregional air travel is now purely for the rich.

Scrutiny on flying

Social scrutiny on frequent flyers under government's new 'essential travel' programme is high. Airline executives are grilled on live TV about what the term 'essential' means, and why so many business customers continue to fly weekly.

Society demand that offsets are high quality, and preferably carbon capture. International travel to Aotearoa New Zealand becomes more expensive, impacting the number of global visitors. Whilst polls suggest most New Zealanders see the option to fly as essential for maintaining connectivity and national mental health, there is a rise in 'flight shaming' and scrutiny of those who do not support the SAF industry, both at home and abroad as 'per capita' emissions become the yardstick, and the media and NGOs call out the worst offenders for 'frequent flying'.

Despite a challenging environment, the aviation sector is backed by government as a national security imperative, and there is strong collaboration with the energy, agriculture and local authority sectors, and a buoyant global green finance market.

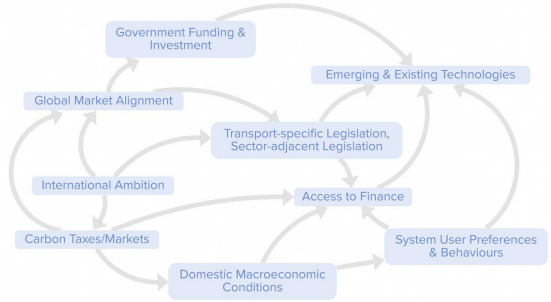
Government policy is aligned across multiple objectives (e.g. decarbonisation as well as consumer cost regulation). SAF is initially imported from a global pool, or procured virtually via 'book and claim' models which allow airlines to purchase offsets from overseas SAF production. Planning and execution begins on the future workforce, infrastructure and technology needed to adopt zero carbon fuels, supported by government R&D. Local government and marine ports collaborate through joint-ventures to fund investment in infrastructure for multi-fuel provisioning.

The aviation sector is globally aligned and supportive, with alignment on SAF regulatory standards, a Trans-Tasman memorandum of understanding on aviation decarbonisation, and development of 'green aviation' lanes to Australia and Pacific countries. Fleet renewal plans are made with confidence in long term direction of travel. R&D accelerates into developing domestic SAF supply and storage using drop-in biofuels. New Zealanders watch with excitement as Aotearoa New Zealand is a pioneer in piloting green hydrogen and battery electric planes, and deploying advanced AI-linked operational efficiency measures across airports and flights.

Green aviation!

In 2028 there is cause for national celebration as the first successful commercial green hydrogen plane touches down in Queenstown, documented by international media.

Moving Goods



Land

As major markets accelerate towards a preference for low emissions products and high carbon border adjustments, Aotearoa New Zealand's location places it at a disadvantage, and export industries find themselves in a race to remain competitive. The land freight sector is responsible for maintaining export access to these markets by rapidly cutting its emissions intensity. It also plays a key role in delivering renewable technology and resources to enable the transition.

Through the National Freight Strategy, government and the freight system begin planning for a higher volume yet lower carbon sector operating in a decarbonised economy. Government sets out a clear direction and policy certainty around freight sector gross emission targets and sets a mandate for 30% of heavy vehicle fleet purchased to be zero emissions by 2030 and 100% by 2040.

Despite continued uncertainty on alternative fuel pathways, government supports an enabling environment for the sector through legislation and R&D investment. There is high collaboration with manufacturers.

Changing demand

Agriculture plans to reduce its reliance on animal products and shift to a more diversified system of plant-based, cellular, and precision fermentation methods. Freight executives enter proactive dialogue with farmers and banks about what the future demand profile looks like, where to target services, and how to set up effective new export models.

This sends a clear demand signal for import of zero carbon fleet and encourages private investment into local pilots for a range of alternative fuels and solutions, meaning many innovative start-ups stay in Aotearoa New Zealand as they see a clear trajectory for product development and growth.

Additionally, the energy, agriculture and transport sectors collaborate to boost alternative fuel supply, such as drop-in biofuels. By 2030, biofuel is powering some heavy fleet, and there are pilots of zero carbon alternatives like green hydrogen or electric trucks. Aotearoa New Zealand's strategy of domestic development of alternative fuels reduces forecast reliance on imports for the heavy fleet. However, the lack of certainty in future fuel pathways means there is a higher mix of fuels invested in across the country.

There is also a focus on mode-shift to rail and coastal shipping for emission reduction and to mitigate climate-related risks to the road network. Green finance supports the optimising, repurposing, or upgrading of infrastructure for new inter-modal hubs at key logistics 'nodes' in the system. The commitment to increasing rail and coastal shipping volumes necessitates investments in adaptation and resilience of key assets.

This includes a focus on maintenance and repair to deal with the locked-in impacts of climate changes later in the decades.

Plans are made for future workforce skills in a high-tech, high-value economy, and data platforms are used to improve network decision making. AI is deployed to achieve high levels of utilisation and fill rates to reduce product level Scope 3 emissions. Social stigma around 'wasted carbon' means activists call for companies to disclose how many 'empty truck' trips they make. Demand patterns shift steadily away from high carbon sectors.

The transition period is marked by high social and political pressure, substantial financial investment, and operational complications due to setting up and running a parallel networks of fuel types. Some operators experience financial strain, leading to a rise in costs that are often passed onto consumers. Consumers mostly accept slower and costlier deliveries as the price of transition. Changes to urban form and repurposing of inner city roads make some 'last mile' deliveries challenging, with access issues present where localised distribution hubs are absent.

Some rural and isolated communities struggle with rising prices of basic goods that can't be sourced locally. A few companies are targeted by groups protesting the cost of living impacts of 'carbon austerity' measures. Despite these challenges, the sector recognises the necessity for transition to continue to compete in a rapidly changing global market.

Biofuel growth

The R&D market for alternative fuels has boomed, with freight companies, banks and energy providers all jostling to gain access to best start-ups. Biofuel stations are popping up everywhere as farmers spot an opportunity.

Moving Goods

Air and Sea

International freight providers also grapple with pressures from markets and importers demanding reduced emissions. Air freight sees its market share moving to providers with access to SAF where businesses can claim sustainability credit for their product supply chain. Regulatory action by the IMO and major markets like Europe drives progress to meet interim emissions reduction targets through a mix of operational efficiency measures (e.g. time at ports, speed of sailing), dual-fuel ship commissioning, and investment in scaling alternative fuels like biofuels. Given its location and lack of alternative fuel bunkering, Aotearoa New Zealand faces steadily but materially rising shipping costs, with a short period to act to remain commercially competitive before carbon prices rise too far. Changes to Scope 3 emissions requirements from regulation and financiers, and a shift of focus from 'tank-to-wake' emissions (downstream emissions from ship tank to exhaust) towards full lifecycle 'well-to-wake' emissions (production to ship exhaust) places pressure on ships and shippers to use alternative fuels with low lifecycle emissions.

Border issues

Borders experience intermittent chaos as the raft of new rules make it unclear whether ships currently docked can be unloaded or if containers at port can be transferred to destinations. At the same time, new stringent air quality regulation puts pressure on shore power electrification.

Green fuel growth

The World Shipping Council and IMO launch the 'Green Balance Mechanism' in 2027, a maritime greenhouse gas emissions pricing mechanism which levels the price of near or zero carbon green shipping fuels with fossil and other bunker fuels. This changes fuel economics projections almost overnight, driving green finance and R&D towards low or zero-emission ships and fuels.

Many of the cargo ships that visit Aotearoa New Zealand, and ports' fossil fuel infrastructure, have long asset renewal lifecycles, so whilst some ports begin scaling biofuel or ammonia bunkering, many enter a process of experimentation and global cooperation to identify viable longer term fuel pathways and investment points aligned with the IMO. All ports begin work to electrify their land-based operations and develop charging sources for cargo ships. There is a national strategy for Aotearoa New Zealand to have domestic alternative fuel production and bunkering, and position itself as a future green fuel service centre for the Pacific. Many ports begin preparing for dual-engine ships that can use biofuels or liquid natural gas.

As with passenger aviation, air freight begins investment in developing domestic SAF production. The land freight sector, ports and airports collaborate to start developing charging and alternative fuel bunkering for the heavy fleet. Mode-shift towards rail and coastal shipping encourages optimisation of ports' spatial connectivity to help strengthen critical freight corridors, with alternative port models appearing. It also requires a diversity of future fuels for long and short haul trips.

New financing models like 'book and claim' become popular, allowing the heavy freight sector across air, land, and sea to contribute to, and benefit from, the scaling of alternative fuel solutions in different geographies when domestic options are unavailable.

Rising costs

The sharp rise in carbon pricing makes some air freight and shipping routes unviable. The kit required to mix alternative fuels is difficult and expensive to source. There are job losses. Many people use a government sponsored 'Green Jobs' platform to identify new transition-related roles or training programmes to get back into employment.

Value-chain collaboration and co-investment intensify to making new technology and solutions commercially viable. Domestic shippers and ports send clear signals to global green carriers that they will be ready for alternative fuel demand when the current fleet are renewed.

Nevertheless, a combination of high carbon prices, capital investment, rapidly changing policy and operational protocols, and misplacement of technology or fuel 'bets' sees costs rise sharply throughout the shipping and aviation freight sectors, which are passed onto consumers. Although many accept slower, more expensive freight as a cost to pay for decarbonisation, there are flashpoints of public outcry when critical shipments are delayed, with examples of misalignment of global supply and demand of low emissions fuels seeing port calls and shipments cancelled as some ports lack refuelling capacity.

Although many consumers adjust to slower, more expensive shipping, ports face periods of extreme pressure as backlogs, workforce issues and public scrutiny all mount. Many ports publicly complain about lack of adaptation funding.

Fully Charged

Prominent themes for 2031-2040

Increased pressure on electricity supply

With the widespread transition to renewable energy and the rise of EVs, there's a significant surge in electricity demand. This is putting pressure on grid capacity, prompting the need for investments in domestic battery storage solutions, smart-charging, and integrated energy-transport planning to ensure sufficient charging capacity.

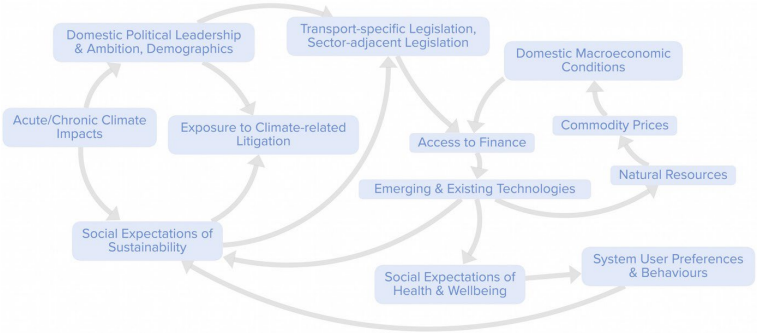
Equitable transition

While the principles of an equitable transition are part of decision making, efforts to bring about a fair and equitable distribution of resources are confronted with hurdles. The shift towards public over private transport and the consequent changes in urban spaces still face resistance from sections of the population more comfortable with the status quo. Problems such as costly interregional travel for ICE vehicle users and the threat of isolation for some communities persist. Investing in infrastructure aimed to enhance connectivity and inclusivity are key to ensuring transport options are affordable and accessible.

Technological advancement

Technologies like AI, metaverse, 3D and 4D printing and autonomous vehicles begin to scale, radically shifting some transport models. Society explores the barriers to integration and administration of such technologies such as privacy and data security concerns, potential job displacement, ethical issues related to AI and autonomous systems, and the substantial financial investments.

Driver Impact Map



Sector-Wide Trends

After a political shift in the 2020s, the global community has returned to a multilateral approach in the 2030s, with climate change becoming a priority on both social-political and economic fronts. Renewable energy is now the primary energy supply and is more cost-efficient than fossil fuels. Carbon taxes and rising oil prices have made low emissions transport options more attractive, and GDP and inflation are stabilising by mid-decade. Technology like AI, IoT, and metaverses are transforming people's understanding of 'mobility'. A younger generation coming into power reinforces support for climate action, with principles of an equitable transition now embedded in decision making.

However, the full weight of carbon austerity is now in effect, and supply of new vehicles and sustainable fuels is still a major barrier to a return to 'normality' in the transport sector.

Lack of investment directed to social services and healthcare is rapidly increasing inequality in urban areas. Critical infrastructure is provided additional CO_2 emission allowances for maintenance and repair, but this does not include most local roads and so regional allowances are used up rapidly each year. Extreme weather events cause some areas to be abandoned as policies don't allow for reconstruction of emissions-intensive or low priority areas. Affordable nature-based solutions are deployed as the main source of adaptation, with carbon-offsetting co-benefits.

Societal changes in Aotearoa New Zealand have seen a shift towards more diverse and integrated worldviews incorporating te ao Māori principles. This shift has supported a more equitable distribution of resources, fostering social cohesion and care for nature. A decrease in material consumption has also led to societal acceptance of slower delivery times and the popularity of 'slow-travel' concepts.

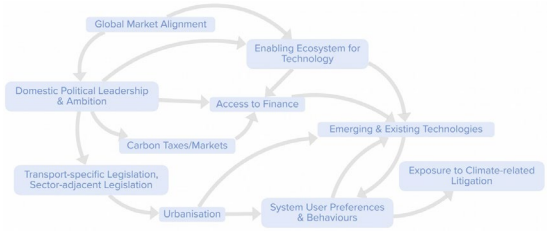
Transport and energy sectors have become more integrated as the electricity demand surge placed pressure on grid capacity. Measures like domestic battery storage solutions become popular to ensure charging capacity and earn income from the grid.

Impact attribution

Advances in climate attribution science combined with radical AI-driven emissions transparency means people can link causality between extreme weather and organisations' carbon output. This places high scrutiny on poor performers, and leads to the strict enforcement of climate laws and disclosures by company directors and officers who actively drive emissions reduction to avoid litigation, and loss of finance or reputation.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Urban

Urban populations are rapidly adjusting to low emissions mobility. After a decade of profound change, new infrastructure is fully operational and prices for public and shared modes of transport are cooling as renewable energy provides cheap grid electricity. The investments in urban densification and public, shared, and active modes in the 2020s start to pay off, with continued shift towards more sustainable, integrated, and equitable transport solutions that are coping with population growth and climate-linked migration.

eVTOL arrives!

Excited crowds gathering to watch demonstrations of an electric vertical take-off and landing (eVTOL) craft carry two All Blacks across Auckland Harbour. Aerial mobility has arrived!

Commuters are carried on reliable, rapid transit electric buses from high-rise developments to city centre jobs, while autonomous vehicles efficiently shuttle people across central transport hubs, and electric ferries roam waterways. People are typically never more than 10 minutes walk from a regular bus route. Younger generations now eagerly embrace the booming 'sharing economy', with many choosing to not have a driving licence or own private vehicles, but use the mobility-as-a-service platforms that seamlessly integrate journeys across public transit, ride-sharing, and micromobility options into one system. The lines between public and private transport are blurred.

Changing norms

There is social stigma against high carbon activities, and some central roads have banned single occupancy vehicles, with fines if caught on camera. This results in a market for highly realistic dummy passengers.

The public transport network comprises regular routes that extend across the majority of neighbourhoods with increasing use of local on-demand shuttles for journeys. A noticeable change is the network of safe, tree-lined active mobility corridors which are woven across cities, carrying a high number of cyclists and a growing range of micromobility solutions – from segways to prototype hoverboards. With significant changes to transport modes on commutes, school runs and other journeys, many streets are unrecognisable.

By mid-decade, private vehicle use in city centres has flipped from completely normal to social faux pas. Not only is it expensive to drive into the city, but there is strong social judgement against doing so as people feel collective investment in the net zero journey. This reduction in private vehicle use opens urban space to residential and social uses – car parks are converted into apartment blocks or markets, and nature is embedded in urban form for both wellbeing, but also as tactical, low cost shields against rising climate impacts. City centres have become more liveable and healthier. This attracts younger people from home and abroad to live in Aotearoa New Zealand's cities, helping the country compete for talented migrants. Their arrival accelerates new technology adoption, expectations, and change.

Private vehicle use remains practical and popular for more suburban trips, but they are typically smaller and electric. The transition towards EVs led to increased pressure on electricity supply, necessitating investments in grid demand management, and some domestic battery storage solutions to ensure charging capacity. Petrol prices and the closure of many fuel stations in cities has made owning an ICE car both expensive and difficult, particularly for people in poorer suburban communities.

Adjusting to change

In a period of collective social adjustment and sacrifice during 'carbon austerity', driving an ICE vehicle has become socially unacceptable. There is public outcry at affluent people justifying continued use of large vehicles via expensive offsets, with regular viral exposés on social media.

Moving People

Regional, Rural & International

Rural and regional travel is well on its way to electrification. 100% of private vehicles entering Aotearoa New Zealand are now EV, all new housing has EV charging built-in, and the supporting ecosystem of battery replacement, servicing workforce, and circular waste management is strong. Economics now heavily favour smaller EVs versus larger ICE engines across lifecycle costs, creating a virtuous spiral of adoption. Despite the economic strain of the past ten years, many consumers are now enjoying the lower operating costs of their vehicles.

Despite integrated energy-transport planning, the electricity demand pressurises grid capacity, and there is strain on global resources like rare earth minerals from the transition. This re-emphasises the need for reducing private vehicle use and domestic fleet size. Domestic battery storage solutions are increasingly popular with rural and isolated groups for ensuring charging capacity, whilst those in urban areas use them to earn revenue from the grid. The transport and energy sectors are increasingly integrated, with smart-charging and innovative grid demand management models expected. The shift of electricity supply to households sees many New Zealanders participating in (local) energy markets, partly through their vehicles.

New legislation requires councils to actively manage emissions for equity across their region, but an urban-rural divide is still present, exacerbated by the increasing infrastructure deficit arising from cuts to investment in projects with embodied carbon. Isolated communities who cannot afford EV infrastructure face rising travel costs and logistical difficulties. This encourages some young people to leave rural areas earlier due to cost of living, a situation compounded by managed retreat from locations or sectors.

Tipping points

In 2031, tipping points are reached in the affordability and practicality of ICE vehicles. Both lifetime and upfront costs for EVs are now lower. Drivers in some rural areas struggle to find fuel stations. Oil prices are high and weather-related shipping delays sees some communities go for weeks without local supplies. This leads to fuel stockpiling, and the need for increased security on fuel.

Adaptation spend is more limited and focused on national critical infrastructure and corridors. This means some rural and especially coastal areas see infrastructure fall into disrepair, reducing access to and from these areas. Whilst some communities are mostly self-sufficient, others experience hardship.

Electrified interregional rail is proving a popular option for many people moving between Auckland, Hamilton and Tauranga. The ease of getting to train stations without a car is a decisive factor. Physical risks to the network do cause occasional delays, but early commitment to adaptation investment mitigates the worst effects. The sharing economy spills out of cities, with popular on-demand and car-share platforms meaning many companies and even people make their vehicles available to others for low hassle regional travel. A few coastal ferry 'slow-travel' pilot routes emerge which prove popular with tourists, whilst seagliders offer rapid, low carbon journeys between major urban centres.

The need for global connectivity for trade, mental wellbeing, international relations, and security have maintained the relevance of air travel. Domestic SAF plants are located tactically near ports and inter-modal transport hubs, and SAF production starts to scale. This steadily reduces reliance on temperamental imports, and offsets carbon prices. There are difficult supply chain issues, for example episodes where extreme weather-linked crop failure for biofuel inputs sees flashpoints in the media about 'food not fuel'. Huge advances in the weight and power of battery electric technology mean a number of smaller routes are now mostly electric (when grid capacity allows). This opens up smaller, remote airstrips and communities to new tourism and business opportunities. The sector is increasingly recognised for its vital role national adaptation plans and provision of post-disaster support to isolated communities who are cut-off by the fragile road network.

Electric airways

Electric aviation has proven hugely popular. Guest houses open up near remote airstrips for city break weekends, and agricultural consultants fly to local farms to advise on climate resilient crops.

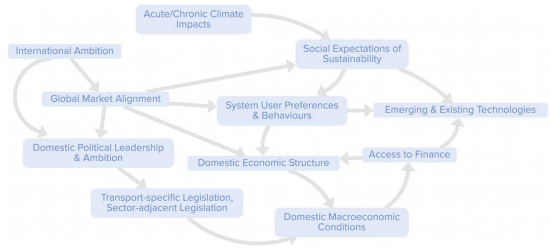
However, both domestic and international aviation remain prohibitively expensive for most, with new immersive hologram-based technology replacing some domestic trips. A decarbonising land transport sector sees aviation's share of global transport emissions rising, placing pressure on the sector to 'keep up'.

NGOs publish regular league tables of airlines on metrics like 'fuel burn per passenger kilometre', with laggards losing consumer preference. Investment in AI that predicts and manages responses to extreme weather events, adjusts cruising altitudes, or pinpoints fuel levels based on conditions has helped reduce unnecessary fuel emissions, prevent flight disruptions and optimised airport operations.

Whilst it retains its social licence to operate, the aviation sector struggles to shake persistent 'flight shaming' rhetoric against its mostly wealthy clientele, and there is little public acceptance of greenwashing or missed interim targets. Consumers have become more discerning about when air travel is appropriate. The sector faces a decade of frequent disruptions from running multi-fuel fleets and new airport safety protocols to extreme weather and a period of extensive fleet renewal. On top of global economic strain, this sees international tourism numbers remain flat, with people typically coming for longer periods. Costs of SAF and technology development begin to fall towards the end of the decade.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Land

The full weight of carbon austerity is now in effect, and the limited supply of low carbon heavy fleet vehicles and sustainable fuels is still a major barrier to a return to 'normality' in the transport sector. Freight carriers race to keep up with consumer and market expectations. Climate mitigation and adaptation have become tightly aligned to financial decisions and outcomes in the sector.

Clarity from government on long term ambition and support for R&D sees the energy, agriculture, and transport sectors scale drop-in biofuels and zero carbon alternatives. However, the shift towards a low emissions system continues to cause upheaval. Rising carbon and fossil fuel prices and continued operational disruption from asset renewal and running dual-fuel fleets see costs remain high for shippers and consumers during the decade across both urban and rural communities, with remote groups seeing more disruption. Tensions bubble over during extreme weather events, leading to social protests at companies for disrupted supplies.

'Code not product'

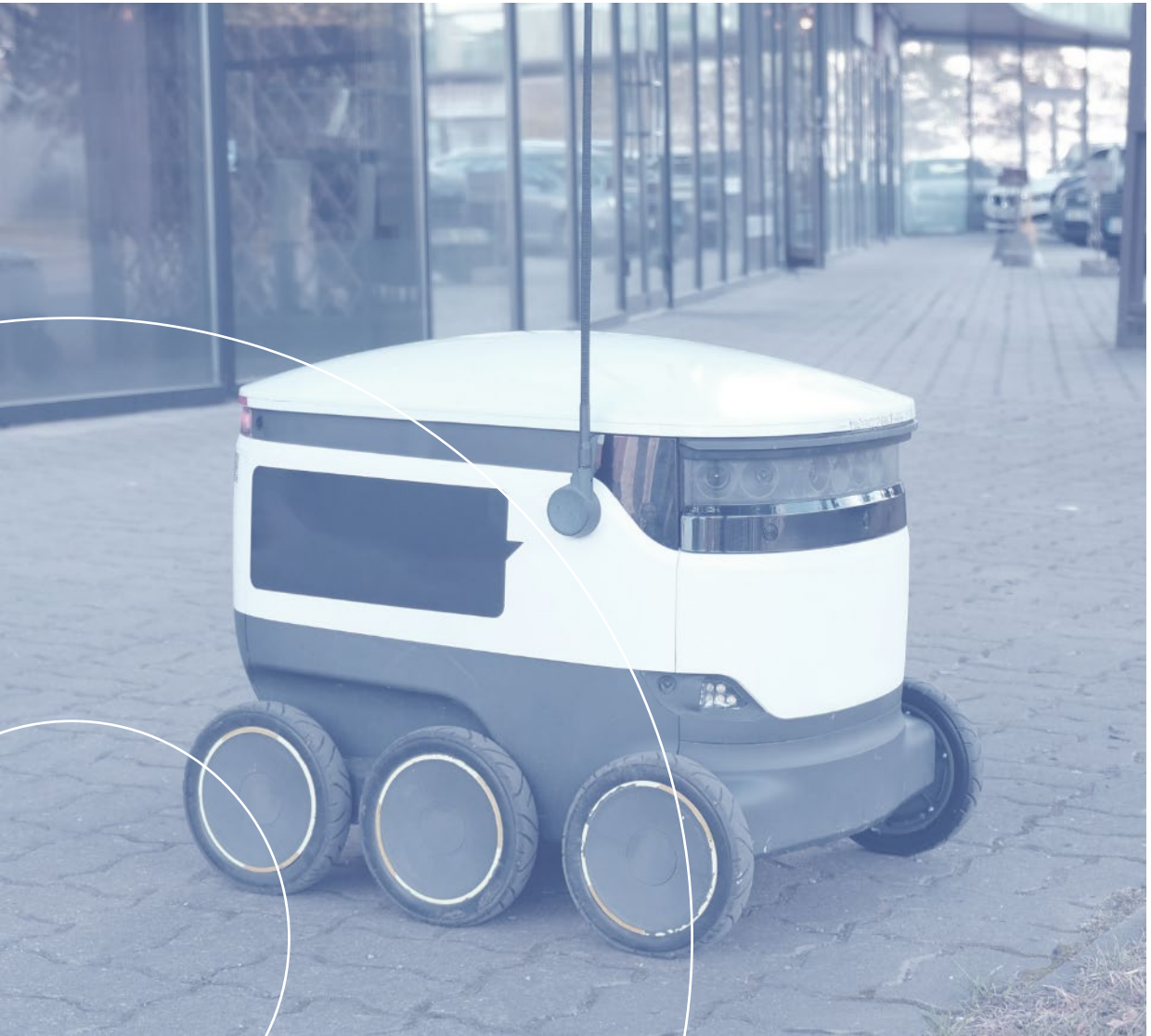
Some companies now send 'code not product' and maintain a network of 3D and 4D printers. Intelligent energy management is now a competitive necessity. Carriers operate with minimal operating expense by timing freight activity, and selling electrons back to the grid.

Whilst fleet imports remain challenging and slow to scale, a mix of energy economics, green finance and consumer preferences see a tipping point in commercial viability of legacy fuel types. With a clear direction of travel and the market settling on viable technology and fuel pathways, there are clear winners and losers. Freight companies without robust transition plans go out of business as zero carbon fleet and fuels scale during the 2030s. There are also examples of 'first mover disadvantage' as some early adopters find their fuel choices superseded by more advanced or popular technologies later in the decade.

A 'National Freight Strategy' has seen the system become more efficient, connected, and resilient thanks to collaboration around system planning, data, and policy. Aotearoa New Zealand invests heavily in education, retraining, and workforce attraction to operate the high-tech sector and support transitioning workers. Increasing mode-shift to rail and coastal shipping alongside proactive adaptation investment in these modes has reduced system emissions, and supported resilience to extreme weather impacts by providing alternatives to the road network.

Moving Goods

SHORT TERM (2024-2030) **MEDIUM TERM (2031-2040)** LONG TERM (2041-2050)



The system adapts to a rapidly changing economy. Major export markets impose heavy tariffs and penalties on Scope 3 emissions and there is a shift away from traditional high carbon sectors and locations, whilst new industries emerge, such as cloud-based services and data centres exploiting the low emissions grid.

Overall, consumers' material consumption reduces. The 'buy local' trend and climate risk management see many supply chains shorten, while rising commodity prices and resource security concerns see a shift to circular economy principles. The freight sector facilitates circular flows of valuable materials around society. Urbanisation and densification see 'last mile' logistics become a key battleground for efficient, low emissions deliveries, with companies finding innovative ways to overcome the reduction in road access through drones or micromobility. Consumers increasingly accept slower deliveries and value reliability. Managed retreat continues and makes some remote areas difficult to serve.

Driver-free on SH1

Autonomous freight vehicles now operate for short shuttle trips in controlled local areas. Many cities now have automated freight shuttles in the central city, and there is a successful pilot for long-distance driver-free trucking along State Highway 1.

Technology advancement is redefining the sector. AI now orchestrates large sections of the system, using IoT technology across fleet, 'smart packaging', and infrastructure assets to optimise the network with high utilisation and efficiency rates – crucial in this waste and carbon conscious world.

Security needs

Social unrest has stabilised at a higher level than in the early 2020's, with private security and police force presence much more visible near locations where high carbon activity is centred, such as refuelling stations.

Owner-operator models are being replaced by freight-as-a-service models where platforms use AI to allocate load across multiple carriers, with shippers bidding for space on trucks, ships, and planes at their accepted cost level, creating new methods of tactical competition.

3D and 4D printing has been eagerly adopted in Aotearoa New Zealand, and drones are used to conduct remote infrastructure repair and maintenance. The sector balances an increasingly diverse workforce, where legacy manual roles like drivers work alongside data scientists and 'AI employees'.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

Air and Sea

Sea and air freight make significant evolutions towards climate-conscious policies and practices. Both sectors see rapidly shifting energy economics in favour of lower carbon fuels and experience a decade of disruption.

Global shipping works to meet IMO targets and standards. The World Shipping Council's 'Green Balance Mechanism' has facilitated high amounts of capital to be deployed in R&D into near or zero carbon fuels and ships. This results in fleet renewal to new generations of efficient, dual-engines ships entering the sector, and some zero carbon prototypes. Multiple alternative fuels are experimented with across global routes, from green methanol and ammonia to green hydrogen and hybrid-battery electric. The scaling of green fuels under the Green Balance Mechanism makes fossil fuels more expensive, and raises the financial pressure on ports in Aotearoa New Zealand to have alternative fuel bunkering. There is concern across the whole freight sector that ports need to make the right decisions on which alternative fuel bunkering and capacity they develop – a wrong move could see costs skyrocket, and prevent ships from refuelling at ports in Aotearoa New Zealand.

Value chain co-investment and green finance is used to de-risk decisions and ensure proactive dialogue, whilst 'book and claim' models help shippers access offshore technology. Aotearoa New Zealand opens a 'Green Shipping Lane' with Singapore and Australia, and government supports R&D across shipping, freight, energy and agriculture to develop domestic biofuels and other zero carbon alternatives. Towards the end of the decade, technology development and economic momentum mean there appear to be clear winners globally for international shipping alternative fuels, with Aotearoa New Zealand now scaling some production, and mothballing other investments.

These investments occur during a period where there is an increase in operational interventions like new import product inspection standards, more 'slow-shipping', greater mode-shift to rail, and electrified near-port operations for ships.

New fuel issues

In 2031, a tragic ammonia spillage kills 400 people overseas. This prompts global outcry at bunkering of the fuel. Many development projects, including in Aotearoa New Zealand, are axed half way through, leading to huge costs for some ports who now have to play catch-up.

Extreme weather disruption increasingly causes time delays and cost spikes. Key trading routes like the Suez Canal are rendered inaccessible for periods every couple of years, and social disruption in countries hampers shipping. Ports in Aotearoa New Zealand are vulnerable to increasingly frequent cyclones. Despite deployment of hyper-efficient AI logistics planning and predictive weather analytics, successive compounding events such as fuel supply issues combined with weather-related infrastructure damage cause major disruption.

Consumers adjust to longer shipping times, and value reliability over speed. This shifts logistics across the whole freight system, businesses, and society. Managing an increasingly diverse workforce during this period becomes crucial, especially as rural transport costs rise and communities continue to feel cost of living pressures.

Port executives try and plan for a tumultuous period in terms of demand economics. Whilst Aotearoa New Zealand's population steadily rises, per capita commodity consumption is decreasing and becomes more local. Some exports fall, and imports of fossil fuels decline. On the flipside, the sector is responsible for delivering net-zero infrastructure and technology across the country.

Air freight steadily increases the proportion of SAF, helping the industry in the face of high carbon and oil prices, as well as rising social expectations. Shipping by aviation remains highly expensive and is used for high-value exports or vital inbound supplies of national significance. The sector does benefit from increasing physical risks in the global maritime system, and provides a comparatively more reliable and faster mode than shipping. As with other sectors, predictive analytics and AI operational optimisation have become second nature.

Airports' new role

Many airports and ports are morphing into 'energy companies' as they partner with local government and freight carriers to develop green hydrogen production and storage near their operations.

Fully Charged

Prominent themes for 2041-2050

Net zero becomes mainstream

A collective focus on meeting 2050 emissions targets sees low carbon transport becomes the norm across society. Climate and financial outcomes are now aligned. There is notable mode-shift to shared, public, and active modes. The heavy fleet has mostly transitioned, whilst aviation and shipping scale zero carbon fleet options.

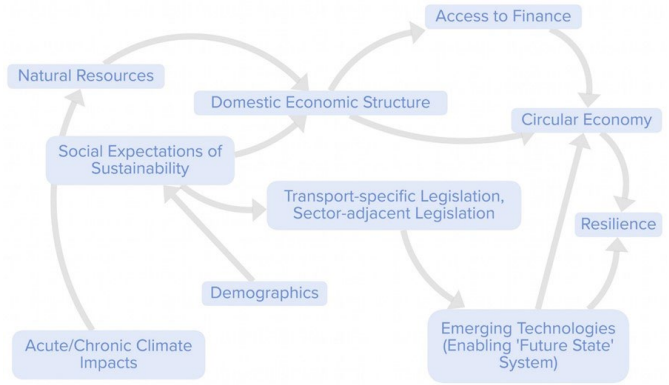
Technological advancement

Accelerating regulatory and social acceptance of technologies like drone deliveries, automation, AI orchestration of networks, 3D and 4D printing and AR change the concept of 'mobility', enhance 'physical' transport and transform peoples' lives, choices, and travel decisions. Some groups still face cultural, habitual, or perception-related barriers, requiring a strong focus on ensuring equitable access to these tools and services across society, including to rural and remote areas.

Adaptation challenges

With the early decision to focus on mitigation not adaptation, there is a growing need to ensure that the transport system is resilient and adaptable as climate impacts intensify. This includes maintaining critical supply routes and providing safe mobility options. There is a greater focus on resource efficiency, circularity, and local production and consumption. Developing and implementing such strategies in the face of increasing extreme weather events are a challenge given limited budgets.

Driver Impact Map



Sector-Wide Trends

The world is making its final collective decarbonisation push to meet 1.5°C targets. In the 2040s, a new, younger and more diverse generation of political leaders is prioritising inclusive policies that enhance community wellbeing and actively regenerate, not just protect, nature. Leadership at all levels is more informed by diverse worldviews including te ao Māori principles. Transition towards net zero has positively impacted global GDP, resulting in a shift in economic activities away from consumerism, and driving tech-enabled efficiencies and health outcomes.

Technology has transformed many elements of peoples' lives, choices, and travel decisions. Hyperconnectivity and technological advancements such as holograms, neural implants, AR integrated with metaverse, remote-operated robotics, as well as 3D and 4D printing have redefined the 'transport' sector.

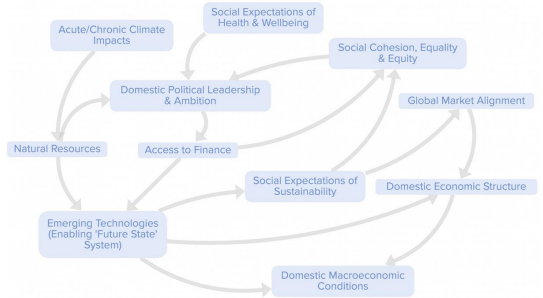
Whilst the worst physical impacts of climate change and tipping points in the Earth system were avoided, physical risks like extreme weather, drought, and wildfires do occur more frequently than in the 2020s, and impact the transport sector directly (e.g. storm damage to infrastructure) and indirectly (e.g. water scarcity causing unpredictability of agricultural yield). Aotearoa New Zealand is particularly exposed to supply chain impacts, due to its location, and shifts focus to adaptation and ensuring critical supply routes remain operational. Aotearoa New Zealand looks to secure its energy and resource independence, driving towards a highly circular, waste and pollution free economy that focuses more on the booming domestic production and consumption market. Measures are implemented to ensure the transport sector provides equitable access to safe, climate-adapted mobility options, focusing on system resilience and making the most of multi-modal options.

Impact attribution

Emissions data and league tables are regularly shown in the media and are a cultural norm. There are public holidays in countries as their 'net zero' status is achieved and validated, and almost real-time country and region emissions level data available anytime.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Urban

Cities are increasingly compact, populous, and connected – both physically and digitally. Metaverse, AR and remote robotics have removed the need for many trips. Mobility is now logging into a hyper-realistic, virtual office, or using IoT and robotics to remotely operate machinery. When 'traditional' transport is needed, it is almost entirely zero carbon and digitally integrated across micro, enhanced, shared, public and on-demand service providers – blurring the lines between public and private transport. Autonomous vehicles are common on many roads.

Seamless travel

Physical payment methods are redundant these days – technology keeps track in the background. Autonomous vehicles are now common in city centres, where new 'charging roads' are enabling a 24/7 continuous service.

Mass-transit corridors carry people between high density housing and commercial centres, with flexible on-demand transport and active mobility networks providing effective coverage across the majority of urban areas. Thousands of people commute, travel, and enjoy leisure time on bicycles, segways and hoverboards on safe, designated pathways that cross cities. eVTOL options have become more affordable, and dart across the skyline. They are especially handy when bad weather hits, when they are prioritised by law for emergency response.

Highly utilised

It is rare to see a parked vehicle these days in the city centre and some suburbs. Vehicles are almost always on the move. Most streets in the central city are pedestrianised, with access channels for small autonomous delivery vehicles.

AI and IoT technology regulate large portions of the network. Vehicle trip requests alter traffic light patterns to manage flow. Intelligent public transport networks pre-emptively react to extreme weather events. Almost everything is connected in a highly regulated and efficient network that prioritises public, active, and shared transport options.

This is the sharing economy in the truest form – people happily move between public, ride-share and on-demand chauffeur or private vehicle rental options.

Integrated mobility-as-a-service platforms are now common across mode types and providers, letting people choose their time-cost trade-off, and jump from e-scooter, to bus, to train all in one journey. Private vehicle use has all but disappeared in these areas. This has made travel safer, healthier, and freed up public space for new uses and enabled upzoning of housing.

In suburban areas, designated roads have driver-free, low cost shuttles scurrying around collecting people on-demand. Private vehicle use is almost entirely electric, and it has become possible to live without owning a vehicle in most areas thanks to the low cost of renewable energy and ubiquity of on-demand options. Large finance flows have focused on alleviating transport inequality and poverty, leading to GDP growth in many districts as people participate more freely in the economy.

Flexible mobility

Flexible local shuttles have brought easy mobility to the vast majority of suburbs. People request pick-up and often have to wait less than 15 minutes before being taken to transport hubs or local destinations. Local authority subsidies make these very affordable.

Moving People

Regional, Rural & International

EV costs have plummeted in upfront and operating terms, and they dominate regional mobility within and between towns, rural, and isolated areas. Precious metal resource limits mean there is a drive for fewer vehicles per capita. Original equipment manufacturers prioritise 'circularity-by-design' and there is a strong second-hand market. A combination of the comprehensive charging network, a skilled servicing workforce, and huge advances in battery technology have seen the term 'range anxiety' disappear. Cross-sector collaboration with the energy industry has helped provide reliable central electricity supply. EV owners use flexible smart charging to balance energy grid demand and participate actively in local energy markets. Some isolated areas have set up decentralised energy production, enabling local energy self-sufficiency which has supported climate resilience and new business opportunities for rural communities. Remaining ICE vehicles are prohibitively expensive to drive, and either belong to 'classic car' owners who pay heavy offset fees, groups whose usage is government-subsidised due to genuine operational complications with EVs, or pockets of those refusing to switch.

New lifestyles

There are many different lifestyles in Aotearoa New Zealand these days. Immersive virtual schooling can be done from home, and local rural hubs offer advanced virtual robotic surgery, performed from the other side of the country or abroad. This is all changing how and why people need the transport system.

EVs embedded

EV battery technology advances meant by 2035, new vehicles had a range of over a thousand kilometres on a single charge. With charging embedded across society in homes, schools, and offices, many charging stations begin to be replaced with other uses. Some legacy petrol stations have been converted into accommodation for road-trippers, filled with paraphernalia on ICE vehicles. It is difficult to run out of charge these days, but some tourists manage it on isolated roads. Luckily 'battery drones' offer emergency (if expensive) remote charging service.

The on-demand and sharing economy has become digitally integrated across most of the country. Car ownership is no longer necessary for on-demand cross-country travel, and people hire vehicles flexibly, reliably, and affordably to move between cities, towns, and even villages. Road trips, business journeys, and visits to relatives can all be done without asset ownership.

Affordable, electrified rail routes now connect dense population hubs in the upper and lower North Island, and seagliders provide zero carbon, rapid ocean-based travel between urban centres. These modes are highly popular with younger and international demographics and provide time-effective travel and resilience during extreme weather events when the road network is compromised. The global mitigation of the worst physical risks, and continued investment in the network, means the adaptive capacity of rail is rarely breached on key lines.

Moving People

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)

Extreme weather events continue to impact the road network. Managed retreat accelerates, and there are 'high risk' roads where insurers no longer cover drivers. Insurance retreat also impacts the energy sector, with areas unable to maintain certain transmission lines. Whilst many rural communities have adapted well and are thriving, some isolated groups without localised energy production experience intermittent connectivity issues if transmission lines are damaged by the more frequent extreme weather, even if road access remains open. Locked-in late-century sea level rise will see further retreat out to 2100.

The domestic aviation sector has successfully pivoted to zero carbon fuels, including green hydrogen, and the use of small, lightweight battery electric options is also disrupting the market. Air-based mobility now reaps the benefits of cheap renewable energy and offers a cost-competitive and reliable alternative to the road network. Electric planes zip between smaller airfields which now have thriving local economies, and there is a return to more air-based inter-city travel like in the pre-Covid era. Both eVTOL craft and seaplanes are used to reach isolated communities and play a vital role in disaster response.

eVTOL gives options

eVTOL technology has completely changed some locations. Whilst some road access is needed, many who can afford it can now live 'off-grid' and don't need to worry about the road network being down.

International aviation uses SAF with high quality carbon capture offsets and there are increasing zero carbon options like green hydrogen flights. Blended wing body and autonomous planes capture the public imagination, and the first long-distance battery electric flight is piloted across the Atlantic.

Flexible pricing

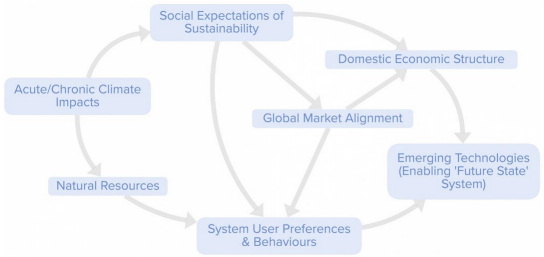
Flight pricing is linked to weather conditions. If weather is forecast to be worse, people pay more. Some people make money by hedging climate data and re-selling tickets.

As costs and carbon emissions reduce, aviation becomes a more affordable and socially accepted again, seeing passengers to Aotearoa New Zealand steadily rise as key tourism sites have been protected from more extreme levels of global warming. Improving geopolitical relations mean more routes remain open to Aotearoa New Zealand, and national carriers play a key role in supporting climate migrants.

Extreme weather events are more common, disrupting domestic and foreign airports and flights, often in severe ways. As with other sectors, predictive AI is deployed to optimise operations and logistics. Passengers receive live communications in the days leading up to travel about how weather events across the trip will affect journeys. Passengers have the option to adjust when and by what route they fly, feeding into the fuelling and flight altitude decisions made by AI and reviewed by pilots.

Moving Goods

SHORT TERM (2024-2030) MEDIUM TERM (2031-2040) LONG TERM (2041-2050)



Land

The freight network uses almost entirely low or zero carbon fuels across the heavy and light commercial fleets. Favourable energy economics from domestic renewable supply see costs reducing for users, but also increased reliance on the local energy sector. The system includes road, rail, and coastal shipping, and is flexible to real-time demand and climate-related hazards. The sector strategy has been reshaped by technology and changing demand.

Technology has revolutionised how freight operates. Many 'freight' companies now send code, not products, and focus entirely on the booming 3D and 4D printing markets (including bioprinting of food), which has been eagerly adopted in Aotearoa New Zealand as consumers and government prefer shorter, more circular supply chains. Autonomous vehicles are deployed for many basic use-cases, and have been rolled out on major state highways. The sector thinks and operates as a single, digitally integrated system. Most 'owner-carrier' freight companies have been replaced by a combination of asset owners, who own and maintain advanced vehicles and infrastructure, and the freight-as-a-service AI platforms who orchestrate end-to-end shipments across multiple modes based on shippers' preferred time-cost-risk trade-off.

Freight depends on attracting and retaining a talented workforce and the latest AI software to regulate and improve the network and mitigate physical climate disruption.

Consumer demand is less materially intense, with more local production and consumption of energy, food, and goods, and a booming circular economy opening up new opportunities for freight. Shippers are used to freight taking longer, but do expect real-time information on location, weather conditions and risk factors. There is more focus on 'last mile' deliveries to densely populated urban centres. There has been a managed retreat from many sectors or locations at risk of climate hazards. Legacy export industries have changed dramatically since the 2020s, with some traditional agriculture and timber sectors now lower volume and higher priced. There is a focus on exporting high-tech and premium products, and physical products cater more to domestic markets.

Electrified freight

With an abundance of cheap electricity, most freight companies are now looking to purchase the latest electric trucks which have ranges of well over a thousand kilometres. Increased energy efficiency and the ability to recharge quickly whilst unloading (and even on the move with some 'charging roads') has made the difference.

The decision to focus funding on mitigation has meant less investment in adaptation (outside of priority projects, such as interventions enabling mode-shift to rail). This has implications with the road and rail networks, as well as other infrastructure assets more vulnerable to extreme weather events. Whilst less acute than in the other scenarios, these impacts are still noticeably higher than the 2020s.

Blurred lines

Autonomous micro-freight options have blurred lines between personal and freight mobility. On-demand vehicles now carry goods, or people, or both, for a fraction of the cost of legacy freight.

Further mode-shift and decentralisation of freight infrastructure is now a government priority for resilience, as adaptation funds can only afford to harden critical national corridors like state highways. Exporters from some locations lose out in markets as their goods don't even make it to the state highway due to compromised roads. Some locations, especially coastal, are now no longer served by land-based freight due to inaccessibility or insurance risk, with drone delivery used to reach isolated communities.

Moving Goods

Air and Sea

Shipping and aviation freight become highly digitally integrated into the land-based system. As the last transport modes to decarbonise, the global spotlight is on both sectors' emissions. Both sectors have developed good domestic production and bunkering of alternative fuels, and marginal costs are steadily reducing. Globally, zero carbon models of cargo ships become more prevalent, with some visiting Aotearoa New Zealand, and long-distance zero carbon aircraft enter the market.

Technology like 3D and 4D printing or remote-operated robotics has reduced the need for some freight. Automation is deployed across ports and airports – from automated gantry cranes to human-free baggage handling. Despite higher populations, reducing material consumption, a local circular economy, and a retraction in 'physical' economic exports has seen a decline in shipping volumes.

Globally, physical climate risks are causing semi-regular disruption to both sectors. Major canals are comprised by drought, and planes are grounded by major storms at airports. With less global investment in adaptation of infrastructure, both sectors deploy increasingly advanced predictive weather and AI-based operational management systems to mitigate impacts. Departure timing, routes, and dispatch of stock from distribution centres is all automatically dictated by forecasts of route conditions.

Despite this, vital supply routes are sometimes compromised, and domestic consumers and businesses adapt to more frequent shipping delays. Port operators find themselves juggling the implications of 'slow-shipping', a reduced number of return-trip shipments from exports, and lingering dependency on price-volatile bio or fossil fuels. At the same time, weather-related disruption can shutdown major global ports overnight. This creates periods of delays and stock shortages.

Mode-shift has connected rail and ports more closely than ever, and many ports now support coastal shipping to reduce emission and improve climate resilience. Local sea-based deliveries as well as eVTOL and drone technology are now essential to serve many isolated coastal communities during extreme weather events when the road network is impaired.

As SAF usage rises, air freight sees a resurgence in commercial and social viability and is used to carry high-value exports overseas in a more climate resilient way. Internationally, airports are more frequently hampered by climate hazards, and a few have had to move location.

Whilst Aotearoa New Zealand is not the first market to purchase or utilise long-distance zero carbon ships or aircraft, the arrival of these technologies around 2050 creates strong commercial opportunities to boost competitive advantage versus other markets that are closer to demand centres, given that high carbon prices still impact margins even on lower carbon fuels.

Globally connected

Supply chains are now fully integrated, even across countries. If it looks like a cyclone will affect a foreign port, or drought is likely to cause delays at an airport, AI will co-ordinate to hold stock back at distribution centres, or bid for space at an intermediary location. Retailers and consumers are automatically updated, and all value chain participants can vote on their risk appetite for sending products.

Technical appendices

Appendix guide

Appendix A: Glossary

TERM	DEFINITION
Adaptation	The process of adjusting practices, systems and structures to moderate potential damage and cope with the consequences of natural and climate-related hazards. This includes adjusting socio-economic and environmental practices to limit damage.
AR	Augmented Reality – technology that superimposes a computer-generated image on a user's view of the real world, providing a composite view.
Cash Flows	An entity's actual cash flows as reflected in its statement of cash flows or potential cash flows under different climate-related scenarios.
Climate Change	Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.
Climate Migrant	Someone who decides to move to a new country or area (permanently or temporarily) because climate change has made it very difficult for them to continue to live or work where they are.
Climate Refugee	Someone who is forced to leave their home country or area because climate change has made it impossible for them to continue to live or work there.
Climate-related Scenario	A plausible, challenging description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces and relationships covering both physical and transition risks in an integrated manner. Note that climate-related scenarios are not intended to be probabilistic or predictive, or to identify the 'most likely' outcomes of climate change.
Climate-related Risks	Refers to the potential negative impacts of climate change on an organisation. Physical risks emanating from climate change can be event-driven ('acute') such as increased severity of extreme weather events (e.g. cyclones). They can also relate to longer term shifts ('chronic') in precipitation and temperature and increased variability in weather patterns (e.g. sea level rise). Climate-related risks can also be associated with the transition to a lower carbon global economy, the most common of which relate to policy and legal actions, technology changes, market responses, reputational considerations, and access to capital.

TERM	DEFINITION
Critical Uncertainties	The driving forces that are most influential and most uncertain. These will define the range of scenarios required to explore the potential futures.
Driving Forces	Broad scale, external factors that may affect the outcomes of the focal question(s), also known as 'drivers'.
Feedback Loop	An interaction in which a perturbation in one climate quantity causes a change in a second and the which ultimately leads to an additional change in the first. A negative feedback is one in which the initial perturbation is weakened by the changes it causes; a positive feedback is one in which the initial perturbation is enhanced. The initial perturbation can either be externally forced or arise as part of internal variability.
Impacts	The effects of climate-related risks and opportunities materialising on an entity, which will in turn depend on the impacts of climate change on the broader socio-economic and ecological systems the entity operates within. These impacts are driven by the specific climate-related risks and opportunities to which an entity is exposed, and its strategic and risk management decisions on seizing those opportunities and managing those risks.
Just Transition	Refers to a framework for managing the shift towards a low carbon economy in a way that is fair and equitable for workers and communities impacted by the transition. The International Labour Organization defines it as "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".
Maladaptation	Actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Narratives	Qualitative descriptions of plausible future world evolution, describing the characteristics, general logic, and developments underlying a particular quantitative set of scenarios.

Appendix A: Glossary

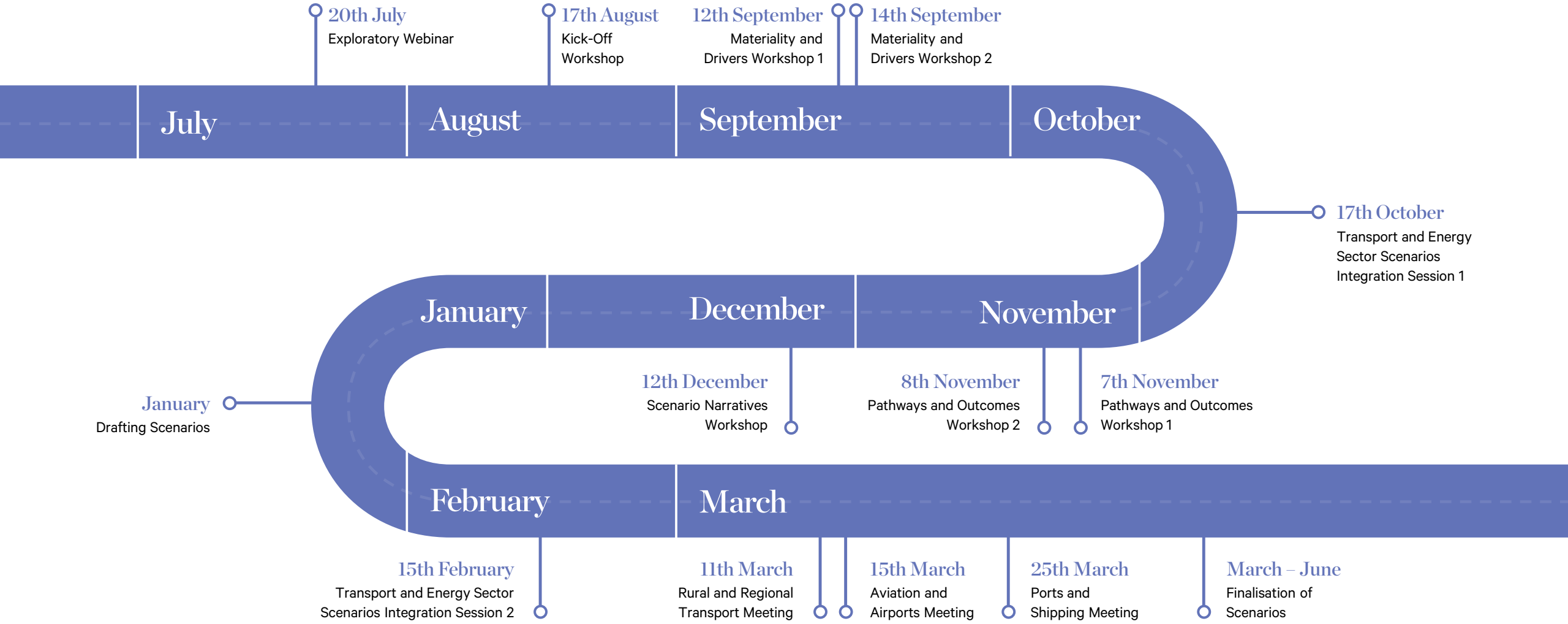
TERM	DEFINITION
Natural Hazard	A hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Climate change is considered an underlying driver of risk for meteorological, hydrological and environmental hazards and can exacerbate the impacts of these hazards as well as those which are geological / geophysical. Climate change is altering the frequency and intensity of hazard events, affecting vulnerability, and changing exposure patterns.
Pathways	The temporal evolution of natural and/or human systems toward a future state. Pathway concepts range from sets of quantitative and qualitative scenarios or narratives of potential futures, to solution-oriented decision-making processes to achieve desirable societal goals. Pathway approaches typically focus on biophysical, techno-economic, and/or socio-behavioural trajectories and involve various dynamics, goals, and actors across different scales.
Physical Risk	Risks related to the physical impacts of climate change. Physical risks emanating from climate change can be event-driven (acute) such as increased severity of extreme weather events. They can also relate to longer term shifts (chronic) in precipitation and temperature and increased variability in weather patterns, such as sea level rise.
Qualitative Scenario Analysis	Analysis that focuses on the identification of trends and on the overarching narratives of the scenarios, often providing insight into less quantifiable company characteristics such as strategy, agility, philosophy, vision, and culture. This kind of analysis can weave together multiple trends of various scales and complexity into a narrative to provide context relevant to a company's strategy.
Reporting	The methods for measuring, monitoring, evaluating and reporting the outcomes and impact of the adaptation and resilience financing, including the indicators used.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

TERM	DEFINITION
Scenario Analysis	A process for systematically exploring the potential impacts, affecting the entity, of the range of plausible futures described under the climate-related scenarios. While acknowledging the uncertainty of these futures, this process allows entities to better understand how climate-related risks and opportunities may impact their strategy and business model over time.
Scenario Category	NGFS-sourced scenarios 'Fully Charged ', 'Short Detour ' and 'Bypass to Breakdown World' are termed the 'scenario category' in this report. Under each scenario category, validated selections have been made of representative scenarios from NGFS, 2020.
Scenario 'Framework Architecture'	The combinations of SSPs (Shared Socio-economic Pathways), RCPs (Representative Concentration Pathways), NGFS (Network for Greening the Financial System) representative scenarios, modified SPANZ (Shared Policy Assumptions for New Zealand) selections and CCC (Climate Change Commission) reference scenarios that comprise each scenario.
Scenario Narrative	A plausible propagation of natural, macroeconomic, socio-economic and political factors occurring during each time frame of each scenario.
Scenario Pathway	The political, technological, and economic developments and associated risk drivers (e.g. which sectors and regions bear the most emissions reductions, or which energy technologies win out in different economies) that lead to a particular scenario outcome; there can be distinctively different pathways leading to the same outcome. Also see Pathways.
Scenario Storyline	A narrative description of a scenario (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces, and the dynamics of their evolution. Also referred to as "narratives" in the scenario literature.
Sharing Economy	Within the context of this report, the sharing economy involves short term transactions to share the use of idle assets and services or to facilitate collaboration. The sharing economy often involves some type of online platform that connects buyers and sellers. In a sharing economy, idle assets such as parked cars, spare bedrooms, tools, or clothing can be rented out when not in use. In this way, physical assets are shared as services.
Tipping Points	'Positive tipping points' refer to the moment at which low carbon technologies become more affordable, attractive and/or accessible than high carbon alternatives. 'Negative tipping points' refer to a situation where a small change in the Earth climate system triggers a larger and more permanent change.

Appendix A: Glossary

TERM	DEFINITION
Transition Risk	Risks related to the transition to a low emissions, climate resilient global and domestic economy, such as policy, legal, technology, market and reputation changes associated with the mitigation and adaptation requirements relating to climate change.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g. a probability density function) or by qualitative statements (e.g. reflecting the judgment of a team of experts)
Value Chain	The upstream and downstream life cycle of a product, process, or service, including material sourcing, production, consumption, and disposal/recycling. Upstream activities include operations that relate to the initial stages of producing a good or service (e.g. material sourcing, material processing, supplier activities). Downstream activities include operations that relate to processing the materials into a finished product and delivering it to the end user (e.g. transportation, distribution, and consumption).
Vulnerability	Refers to the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Wet-bulb effect	A threshold where the combination of high temperature and humidity makes it impossible for sweat to evaporate, preventing the human body from effectively cooling itself. In the context of climate change, global warming may increase occurrences of such extreme conditions, posing a serious risk to human health and survival in affected areas.

Appendix B: Project timeline



Appendix C: Scenario architecture narratives

Element	Overview of Source	Bypass to Breakdown	Short Detour	Fully Charged
IPCC SSPs (and RCPs)	The UN Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing climate change science. In March 2023, they released the synthesis report for their Sixth Assessment Report (AR6) which provides policymakers with the most up-to-date projections of future climate change, its impacts and risks, and options for mitigation and adaptation (IPCC, 2023a). Shared Socio-economic Pathways (SSPs) present five routes that span a range of possible future developments of anthropogenic drivers of climate change which influence mitigation and adaptation. SSPs combine socio-economic assumptions (like demographic shifts, or technology uptake), levels of climate mitigation, land use and air pollution controls, and can be used in climate scenarios to inform future exposure, risk, vulnerability, and challenges to adaptation (IPCC, 2023b). Representative Concentration Pathways (RCPs) describe different levels (or scenarios) of greenhouse gasses and other factors that can alter the amount of the sun's energy that could be 'trapped' by the Earth's atmosphere. This trapping of heat is known as 'radiative forcing', and is measured in 'Watts per m^2' (i.e. RCP 1.9 is 1.9W/m^2 of atmospheric warming). Some RCPs are complementary to SSPs. SSPs, and their socio-economic activity projections, determine the level of greenhouse gas emissions, which in turn determines the radiative forcing effect, which eventually influence surface air temperatures (van Vuuren, et al., 2011).	**SSP3 Regional Rivalry – A Rocky Road** A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions. (Riahi, et al., 2017). RCP Scenario: SSP3-7.0 = 7.0W/m^2 radiative forcing.	**SSP1 Sustainability – Taking the Green Road** *See: SSP1 Sustainability, but in this scenario, major policy, behavioural, and technological changes are delayed until the 2030s, realising higher RCP.* RCP Scenario: SSP1-2.6 = 2.6W/m^2 radiative forcing.	**SSP1 Sustainability – Taking the Green Road** The world shifts gradually, but pervasively, toward a more sustainable path, emphasising more inclusive development that respects perceived planetary boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity (Riahi, et al., 2017). RCP Scenario: SSP1-1.9 = 1.9W/m^2 radiative forcing.

Appendix C: Scenario architecture narratives

Element	Overview of Source	Bypass to Breakdown	Short Detour	Fully Charged
NGFS	The Network for Greening the Financial System (NGFS) is a series of climate scenarios, produced by central banks and experts, that provides a globally consistent set of plausible, coherent scenarios, with a database of associated parameters for numerous countries (NGFS, n.d).	**Current Policies** Current Policies assumes that only currently implemented (2023) global policies are preserved, leading to high physical risks. Emissions grow until 2080 leading to over 3°C of warming and severe physical risks. This includes irreversible changes like higher sea level rise. This scenario can help central banks and supervisors consider the long term physical risks to the economy and financial system if we continue on our current path to a 'hot house world' (NGFS, n.d).	**Delayed Transition** This scenario assumes global annual emissions do not decrease until 2030 and that new climate policies are not introduced until this time. Strong policies are then needed to limit warming to below 2°C, but the level of action differs across countries and regions. The availability of carbon dioxide removal technologies is assumed to be low, pushing carbon prices higher than in Net Zero 2050. As a result, emissions exceed the carbon budget temporarily, yet decline to ensure a 67% chance of limiting global warming to below 2°C. This leads to both higher transition and physical risks than the Net Zero 2050 scenario (NGFS, n.d).	**Net Zero 2050** An ambitious scenario that limits global warming to 1.5°C through stringent and immediate climate policies and innovation. Carbon dioxide removal technologies are used to accelerate the decarbonisation but kept to the minimum possible and broadly in line with sustainable levels of bioenergy production. Emissions reach net zero around 2050, giving at least a 50% chance of limiting global warming to below 1.5°C by end-century, with no or low overshoot (< 0.1°C) of 1.5°C in earlier years. Physical risks are relatively low but transition risks are high (NGFS, n.d).
CCC	The Climate Change Commission (CCC) is an independent Crown Entity which delivers evidence-based advice to guide climate change action for Aotearoa New Zealand. They present four scenarios which explore the uncertainty around how technologies and social factors may develop in the future and how this may impact individual mitigation options to reduce emissions and set actions towards Aotearoa New Zealand's 2050 target in the Climate Change Response Act (CCC, 2021a).	**Current Policy Reference** This scenario examines the impact that current policies (based on advice to the 2021 government) would have on emissions in Aotearoa New Zealand over time. It allows the CCC to assess whether current policies put Aotearoa New Zealand on track to meeting their targets. Under current policies, long lived greenhouse gas emissions are projected to fall however will be insufficient to meet 2030 and 2050 targets (CCC, 2021b).	**Headwinds** This scenario examines what could happen if there were higher barriers to uptake of technology across all sectors, and modest behavioural change among people and businesses. Net zero long-lived greenhouse gases would still be achieved by 2048, with a greater reliance on carbon removals by forests (CCC, 2021b).	**Tailwinds** The CCC's most optimistic scenario that examines a future where there are fewer barriers to technology and major behavioural changes, allowing Aotearoa New Zealand to reach net zero long-lived greenhouse gases by 2040 (CCC, 2021b).

Appendix C: Scenario architecture narratives

Element	Overview of Source	Bypass to Breakdown	Short Detour	Fully Charged
IEA	The International Energy Agency (IEA) scenarios examine future energy trends relying on the Global Energy and Climate model. This model explores various scenarios, each of which is built on a different set of underlying assumptions about how the energy system might respond to the current global energy crisis and evolve thereafter. These scenarios were created with the aim to enable readers to compare possible versions of the future and the levers and actions that produce them (IEA, 2022).	**STEPS (Stated Policies Scenario)** STEPS provides a more conservative benchmark for the future, taking a more granular, sector-by-sector look at policies that have been put in place, and those currently under development, to reach government goals and other energy-related objectives internationally. STEPS therefore explores where the energy system might go without a major additional steer from policy makers (IEA, 2022).	**SDS (Sustainable Development Scenario)** SDS describes the broad evolution of the energy sector that would be required to reach the key energy-related goals of the UN, including the climate goal of the Paris Agreement (Sustainable Development Goal (SDG) 13), universal access to modern energy by 2030 (SDG 7), and a dramatic reduction in energy-related air pollution and the associated impacts on public health (SDG target 3.9). This scenario limits global temperature rise to 1.8°C if greenhouse gas emissions remain at net zero after 2070, with the likelihood of reaching 1.5°C by end-century (IEA, 2020).	**NZE (Net Zero Emissions by 2050 Scenario)** NZE shows a pathway for the global energy sector to achieve net zero emissions by 2050, with advanced economies reaching net zero emissions in advance of others. This scenario limits global temperature rise to 1.5°C with no or limited temperature overshoot, and meets key energy-related UN SDG's, in particular by achieving universal energy access by 2030 and major improvements in air quality (IEA, 2022).

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van Vuuren, D. P. et al., 2011. The representative concentration pathways: an overview. Climatic Change, Volume 109, pp. 5-31.

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.	2030	2040	2050		
Bypass to Breakdown	*Physical*	**Mean Annual Temperature Change** *(°C, Global: Average annual temperature vs pre-industrial baseline)* *(°C, NZ: Projected annual mean temperature change from 1986-2005 baseline)*	SSP3-7.0	GLBL	1.5	1.8	2.1	IPCC	https://dx.doi.org/10.5285/98af2184e13e4b91893ab72f301790db
			RCP5-8.5	NZ	*2031-2050 Figure*: 1.6			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=38 *(Value is 'Seven station average')*
		Extreme Heat *(Average number of 'hot days' exceeding 25.0°C annually)*	RCP5-8.5	NZ	*2031-2050 Figure*: 30			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=68 *(Value calculated across average of 15 New Zealand locations)*
		Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	RCP5-8.5	NZ	*2031-2050 Figure*: 12			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=100 *(Value calculated by multiplying average increase in rainfall depth by associated RCP estimated temperature change)*
		Median Sea Level Rise *(Representative 'medium confidence' projection for national increase in metres)*	RCP3-7.0	NZ	0.11	0.16	0.24	NZ SeaRise	https://searise.takiwa.co/map/6233f47872b8190018373db9/embed *(Site 7067, tip of West Head, Marlborough, excluding VLM)*
		Extreme Wind Speed *(Change in the magnitude of the 99th percentile of daily-mean wind speed, relative to 1986-2005 baseline)*	RCP5-8.5	NZ	*2031-2050 Estimate*: Approx. 5-10% increase in parts of the country (Mostly southern half of North Island, and South Island)			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=106 (Approximate estimates interpreted from visuals)
		Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NGFS Current Policies	NZ	-16	-23	-33	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from Tropical Cyclones Scenario: NGFS Current Policies
		Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NGFS Current Policies	NZ	31	31	16	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from River Floods Scenario: NGFS Current Policies
	Socio-economic	**Population** *(Million)*	SSP3	GLBL	8,565.8	9,361.0	10,093.4	SSP Database	Scenario: IIASA-WiC POP 2023 | SSP3 (https://data.ece.iiasa.ac.at/ssp/) Data Selection: Population (Total) Region: World
			95th Percentile	NZ	5.8	6.4	6.9	Stats NZ	https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.stats.govt.nz%2Fassets%2FUploads%2Fnational-population-projections-2022base-2073.xlsx&wdOrigin=BROWSELINK (95th percentile - Figures taken from 2033, 2043, 2053 columns)
		GDP *(% difference, 2009 prices; local currency vs baseline)*	NGFS Current Policies	NZ	-0.73	-1.70	-2.74	NGFS Database	Scenario: Current Policies (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM Gross Domestic Product (GDP)| Combined Region: New Zealand (NiGEM NGFS v1.22)
		Inflation Rate *(Absolute difference % vs baseline)*	NGFS Current Policies	NZ	0.04	0.10	0.17	NGFS Database	Scenario: Current Policies (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Inflation rate; %|Combined Region: New Zealand (NiGEM NGFS v1.22)

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.		2030	2040	2050	
Bypass to Breakdown	*Socio-economic*	Long Term Interest Rate *(Absolute difference % vs baseline)*	NGFS Current Policies	NZ		-	-	-	NGFS Database	Scenario: Current Policies (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Long term interest rate; %|Combined Region: New Zealand (NiGEM NGFS v1.22)
		Carbon Price *Energy (real NZ$/tCO$_2$e)*	Low	NZ		114	153	206	New Zealand Treasury	https://www.treasury.govt.nz/sites/default/files/2023-12/cbax-tool-climate-environmental-impacts.pdf#page=3
		Oil Demand *(Million barrels per day)*	STEPS	GLBL		101.5	-	97.4	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
		Oil Price Increase *New Zealand (% difference, US$ per barrel vs baseline)*	NGFS Current Policies	NZ		-	-	-	NGFS Database	Scenario: Current Policies (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Oil price| Combined Region: New Zealand (NiGEM NGFS v1.22)
	Transport	Total Transport CO_2 Emissions *(Global = MtCO$_2$e) (NZ/Domestic = ktCO$_2$e)*	STEPS	GLBL		8,282	7,954	8,060	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
			Current Policy Reference	NZ		15,204	11,760	6,012	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
		Road Vehicle Kilometres Travelled by Vehicle/Engine Type *(Total = billion kilometres) (Type = % share)*	Current Policy Reference	NZ	Total	58	63	67	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
					ICE	92	64	25		
					EV	4	36	75		
		Household Person Kilometres Travelled by Mode *(Million kilometres)*	Current Policy Reference	NZ	Active	1,381	1,454	1,502	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
					Public	3,268	3,916	4,538		
					Private	60,550	63,630	65,597		
		Total Number of Vehicles in Fleet *(Thousands)*	Current Policy Reference	NZ		5,350	5,592	5,700	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
		Freight Mode Shares *(% share)*	Current Policy Reference	NZ	Rail	13	13	13	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
					Coastal	12	12	12		
					Road	75	75	75		

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.		2030	2040	2050	
Bypass to Breakdown	*Energy*	Total Primary Energy Supply – Renewables *(% share)*	STEPS	GLBL		18	-	31	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
			Current Policy Reference	NZ		46	53	62	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
		Percentage of Electricity Generation from Renewables *(% share)*	STEPS	GLBL		47	-	70	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
			Current Policy Reference	NZ		90	90	92	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx
		Renewable Energy Share of Total Final Consumption (including international transport) *(% share)*	Current Policy Reference	NZ		27	31	39	CCC	https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/supporting-documents/ERP2-supporting-spreadsheet-Updated-demonstration-path-and-CPR-2022.xlsx *(Figures converted to percentages to align with other scenarios from older CCC source)*
		Breakdown of Transport's Total Final Energy Consumption by Mode *(% share of total)*	STEPS	GLBL	Road	73	-	68	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
					Aviation	13	-	17		
					Shipping	10	-	11		
		Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption *(% share)*	STEPS	GLBL	Biofuels	5	-	6	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
					Hydrogen	0	-	1		
					Electricity	4	-	11		

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter		Source	Data Access Methodology
				Loc.	2100		
Bypass to Breakdown - Extension	*Physical*	**Mean Annual Temperature Change** *(°C, Global: Average annual temperature vs pre-industrial baseline) (°C, NZ: Projected annual mean temperature change from 1986-2005 baseline)*	SSP3-7.0	GLBL	3.9	IPCC	https://dx.doi.org/10.5285/98af2184e13e4b91893ab72f301790db
			RCP5-8.5	NZ	*2081-2100 Figure*: 3.6 *2101-2120 Figure*: 4.3	MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=38 *(Value is 'Seven station average')*
		Extreme Heat *(Average number of 'hot days' exceeding 25.0°C annually)*	RCP5-8.5	NZ	*2081-2100 Figure*: 63	MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=68 *(Value calculated across average of 15 New Zealand locations)*
		Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	RCP5-8.5	NZ	*2081-2100 Figure*: 35	MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=100 *(Value calculated by multiplying average increase in rainfall depth by associated RCP estimated temperature change)*
		Median Sea Level Rise *(Representative 'medium confidence' projection for national increase in metres)*	RCP3-7.0	NZ	0.74	NZ SeaRise	https://searise.takiwa.co/map/6233f47872b8190018373db9/embed *(Site 7067, tip of West Head, Marlborough, excluding VLM)*
		Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NGFS Current Policies	NZ	-66	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from Tropical Cyclones Scenario: NGFS Current Policies
		Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NGFS Current Policies	NZ	29	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from River Floods Scenario: NGFS Current Policies
	Socio-Economic	**Population** *(Million)*	Very High Migration Scenario	NZ	8.3	Stats NZ	https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.stats.govt.nz%2Fassets%2FUploads%2Fnational-population-projections-2022base-2073.xlsx&wdOrigin=BROWSELINK (Very high migration scenario - Figure taken from 2073 column)

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.	2030	2040	2050		
Short Detour	*Physical*	**Mean Annual Temperature Change** *(°C, Global: Average annual temperature vs pre-industrial baseline)* *(°C, NZ: Projected annual mean temperature change from 1986-2005 baseline)*	SSP1-2.6	GLBL	1.5	1.6	1.7	IPCC	https://dx.doi.org/10.5285/98af2184e13e4b91893ab72f301790db
			RCP1-2.6	NZ	*2031-2050 Figure*: 1.3			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=38 *(Value is 'Seven station average')*
		Extreme Heat *(Average number of 'hot days' exceeding 25.0°C annually)*	RCP1-2.6	NZ	*2031-2050 Figure*: 15			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=68 *(Value calculated across average of 15 New Zealand locations)*
		Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	RCP1-2.6	NZ	*2031-2050 Figure*: 8			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=100 *(Value calculated by multiplying average increase in rainfall depth by associated RCP estimated temperature change)*
		Median Sea Level Rise *(Representative 'medium confidence' projection for national increase in metres)*	RCP1-2.6	NZ	0.11	0.15	0.20	NZ SeaRise	https://searise.takiwa.co/map/6233f47872b8190018373db9/embed *(Site 7067, tip of West Head, Marlborough, excluding VLM)*
		Extreme Wind Speed *(Change in the magnitude of the 99th percentile of daily-mean wind speed, relative to 1986-2005 baseline)*	RCP1-2.6	NZ	*2031-2050 Figure*: Approx. <5% increase in parts of the country (Mostly southern half of North Island, and throughout South Island)			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=106 (Approximate estimates interpreted from visuals)
		Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NGFS Delayed Transition	NZ	-16	-23	-23	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from Tropical Cyclones Scenario: NGFS Delayed Transition
		Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NGFS Delayed Transition	NZ	31	31	31	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from River Floods Scenario: NGFS Delayed Transition
	Socio-economic	**Population** *(Million)*	SSP1	GLBL	8,413.3	8,854.5	9,136.9	SSP Database	Scenario: IIASA-WiC POP 2023 | SSP1 (https://data.ece.iiasa.ac.at/ssp/) Data Selection: Population (Total) Region: World
			75th Percentile	NZ	5.7	6.1	6.5	Stats NZ	https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.stats.govt.nz%2Fassets%2FUploads%2Fnational-population-projections-2022base-2073.xlsx&wdOrigin=BROWSELINK (75th percentile - Figures taken from 2033, 2043, 2053 columns)
		GDP *(% difference, 2009 prices; local currency vs baseline)*	NGFS Delayed Transition	NZ	-0.7	-2.6	-1.5	NGFS Database	Scenario: Delayed Transition (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM Gross Domestic Product (GDP)| Combined Region: New Zealand (NiGEM NGFS v1.22)
		Inflation Rate *(Absolute difference % vs baseline)*	NGFS Delayed Transition	NZ	-0.13	0.17	-0.11	NGFS Database	Scenario: Delayed Transition (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Inflation rate; %|Combined Region: New Zealand (NiGEM NGFS v1.22)

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.		2030	2040	2050	
Short Detour	*Socio-economic*	**Long Term Interest Rate** *(Absolute difference % vs baseline)*	NGFS Delayed Transition	NZ		0.07	0.78	0.54	NGFS Database	Scenario: Delayed Transition (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Long term interest rate; %|Combined Region: New Zealand (NiGEM NGFS v1.22)
		Carbon Price *Energy (real NZ$/tCO$_2$e)*	Low/High	NZ		114	306	411	New Zealand Treasury	https://www.treasury.govt.nz/sites/default/files/2023-12/cbax-tool-climate-environmental-impacts.pdf#page=3
		Oil Demand *(Million barrels per day)*	SDS	GLBL		87.6	-	47.0	IEA	https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf#page=305
		Oil Price Increase *New Zealand (% difference, US$ per barrel vs baseline)*	NGFS Delayed Transition	NZ		15	441	839	NGFS Database	Scenario: Delayed Transition (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Oil price| Combined Region: New Zealand (NiGEM NGFS v1.22)
	Transport	**Total Transport CO_2 Emissions** *(Global = MtCO$_2$e)* *(NZ/Domestic = ktCO$_2$e)*	SDS	GLBL		7,348	5,112	3,239	IEA	https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf#page=305
			Headwinds	NZ		15,426	8,404	3,004	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Road Vehicle Kilometres Travelled by Vehicle/Engine Type *(Total = billion kilometres)* *(Type = % share)*	Headwinds	NZ	Total	56	58	60	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
					ICE	91	46	11		
					EV	9	54	89		
		Household Person Kilometres Travelled by Mode *(Million kilometres)*	Headwinds	NZ	Active	1,626	2,083	2,268	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
					Public	3,938	5,826	7,121		
					Private	57,550	55,798	55,800		
		Total Number of Vehicles in Fleet *(Thousands)*	Headwinds	NZ		4,912	4,792	4,780	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Freight Mode Shares *(% share)*	Headwinds	NZ	Rail	14	15	15	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
					Coastal	13	14	14		
					Road	73	71	70		

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.		2030	2040	2050	
Short Detour	*Energy*	Total Primary Energy Supply – Renewables *(% share)*	SDS	GLBL		24	-	55	IEA	https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf#page=305
			Headwinds	NZ		49	62	78	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Percentage of Electricity Generation from Renewables *(% share)*	SDS	GLBL		53	-	84	IEA	https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf#page=305
			Headwinds	NZ		92	94	96	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Renewable Energy Share of Total Final Consumption (including international transport) *(% share)*	Headwinds	NZ		31	44	63	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Breakdown of Transport's Total Final Energy Consumption by Mode *(% share of total)*	SDS	GLBL	Road	73	-	65	IEA	https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf#page=305
					Aviation	13	-	20		
					Shipping	9	-	10		
		Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption *(% share)*	SDS	GLBL	Biofuels	9	-	17	IEA	https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf#page=305
					Hydrogen	0	-	7		
					Electricity	5	-	25		

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.	2030	2040	2050		
Fully Charged	*Physical*	**Mean Annual Temperature Change** *(°C, Global: Average annual temperature vs pre-industrial baseline)* *(°C, NZ: Projected annual mean temperature change from 1986-2005 baseline)*	SSP1-1.9	GLBL	1.4	1.6	1.6	IPCC	https://dx.doi.org/10.5285/98af2184e13e4b91893ab72f301790db
			RCP1-2.6	NZ	*2031-2050 Figure*: 1.3			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=38 *(Value is 'Seven station average')*
		Extreme Heat *(Average number of 'hot days' exceeding 25.0°C annually)*	RCP1-2.6	NZ	*2031-2050 Figure*: 15			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=68 *(Value calculated across average of 15 New Zealand locations)*
		Extreme Rainfall *(% change in depth of 1 in 100 year 1 hour rainfall event)*	RCP1-2.6	NZ	*2031-2050 Figure*: 8			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=100 *(Value calculated by multiplying average increase in rainfall depth by associated RCP estimated temperature change)*
		Median Sea Level Rise *(Representative 'medium confidence' projection for national increase in metres)*	RCP1-1.9	NZ	0.12	0.15	0.19	NZ SeaRise	https://searise.takiwa.co/map/6233f47872b8190018373db9/embed *(Site 7067, tip of West Head, Marlborough, excluding VLM)*
		Extreme Wind Speed *(Change in the magnitude of the 99th percentile of daily-mean wind speed, relative to 1986-2005 baseline)*	RCP1-2.6	NZ	*2031-2050 Figure*: Approx. <5% increase in parts of the country (Mostly southern half of North Island, and throughout South Island)			MfE (NIWA)	https://environment.govt.nz/assets/Publications/Files/Climate-change-projections-2nd-edition-final.pdf#page=106 (Approximate estimates interpreted from visuals)
		Annual Expected Damage from Tropical Cyclones *(% at median line compared to the reference year 2015)*	NGFS Net Zero	NZ	-16	-19	-16	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from Tropical Cyclones Scenario: NGFS Net Zero 2050
		Annual Expected Damage from River Floods *(% at median line compared to the reference year 2015)*	NGFS Net Zero	NZ	31	34	31	Climate Impact Explorer (CLIMADA)	Country: New Zealand (https://climate-impact-explorer.climateanalytics.org/) Indicator: Annual Expected Damage from River Floods Scenario: NGFS Net Zero 2050
	Socio-economic	**Population** *(Million)*	SSP1	GLBL	8,413.3	8,854.5	9,136.9	SSP Database	Scenario: IIASA-WiC POP 2023 | SSP1 (https://data.ece.iiasa.ac.at/ssp/) Data Selection: Population (Total) Region: World
			Median	NZ	5.6	5.9	6.2	Stats NZ	https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.stats.govt.nz%2Fassets%2FUploads%2Fnational-population-projections-2022base-2073.xlsx&wdOrigin=BROWSELINK (50th percentile - Figures taken from 2033, 2043, 2053 columns)
		GDP *(% difference, 2009 prices; local currency vs baseline)*	NGFS Net Zero	NZ	-1.1	-0.2	0.1	NGFS Database	Scenario: Net Zero 2050 (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM Gross Domestic Product (GDP)| Combined Region: New Zealand (NiGEM NGFS v1.22)
		Inflation Rate *(Absolute difference % vs baseline)*	NGFS Net Zero	NZ	0.13	-0.22	-0.03	NGFS Database	Scenario: Net Zero 2050 (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Inflation rate; %|Combined Region: New Zealand (NiGEM NGFS v1.22)

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.		2030	2040	2050	
Fully Charged	*Socio-economic*	**Long Term Interest Rate** *(Absolute difference % vs baseline)*	NGFS Net Zero	NZ		0.78	0.54	0.39	NGFS Database	Scenario: Net Zero 2050 (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Long term interest rate; %|Combined Region: New Zealand (NiGEM NGFS v1.22)
		Carbon Price *Energy (real NZ$/tCO$_2$e)*	Central	NZ		171	230	309	New Zealand Treasury	https://www.treasury.govt.nz/sites/default/files/2023-12/cbax-tool-climate-environmental-impacts.pdf#page=3
		Oil Demand *(Million barrels per day)*	NZE	GLBL		77.5	-	24.3	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
		Oil Price Increase *New Zealand (% difference, US$ per barrel vs baseline)*	NGFS Net Zero	NZ		158	371	625	NGFS Database	Scenario: Net Zero 2050 (https://data.ene.iiasa.ac.at/ngfs/#/login?redirect=%2Fworkspaces) Model:NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] Timeseries Variable: NiGEM| Oil price| Combined Region: New Zealand (NiGEM NGFS v1.22)
	Transport	**Total Transport CO_2 Emissions** *(Global = $MtCO_2e$)* *(NZ/Domestic = $ktCO_2e$)*	NZE	GLBL		5,992	2,430	578	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
			Tailwinds	NZ		12,258	4,503	1,022	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Road Vehicle Kilometres Travelled by Vehicle/Engine Type *(Total = billion kilometres)* *(Type = % share)*	Tailwinds	NZ	Total	52	49.1	50.4	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
					ICE	73	24	4		
					EV	27	76	96		
		Household Person Kilometres Travelled by Mode *(Million kilometres)*	Tailwinds	NZ	Active	2,436	4,949	5,982	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
					Public	5,552	8,115	9,854		
					Private	53,073	45,503	43,112		
		Total Number of Vehicles in Fleet *(Thousands)*	Tailwinds	NZ		4,602	4,119	4,010	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Freight Mode Shares *(% share)*	Tailwinds	NZ	Rail	16	21	21	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
					Coastal	14	19	20		
					Road	70	60	59		

Appendix D: Detailed climate scenario parameters

	Cat.	Parameter	Scenario	Summary of Parameter				Source	Data Access Methodology
				Loc.		2030	2040	2050	
Fully Charged	*Energy*	Total Primary Energy Supply – Renewables *(% share)*	NZE	GLBL		29	-	71	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
			Tailwinds	NZ		54	76	89	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Percentage of Electricity Generation from Renewables *(% share)*	NZE	GLBL		59	-	89	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
			Tailwinds	NZ		93	95	98	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Renewable Energy Share of Total Final Consumption (including international transport) *(% share)*	Tailwinds	NZ		37	61	79	CCC	https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Modelling-files/Scenarios-dataset-2021-final-advice.xlsx
		Breakdown of Transport's Total Final Energy Consumption by Mode *(% share of total)*	NZE	GLBL	Road	71	-	62	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
					Aviation	14	-	20		
					Shipping	11	-	13		
		Breakdown of Select Fuels' Contribution to Transport's Total Final Energy Consumption *(% share)*	NZE	GLBL	Biofuels	10	-	11	IEA	https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf#page=276
					Hydrogen	1	-	14		
					Electricity	8	-	51		

Appendix E: Parameter source rationale and considerations

Source	Rationale	Considerations
SSP Database	The Shared Socio-economic Pathways (SSP) database aims at the documentation of quantitative projections of the SSPs and related Integrated Assessment scenarios. The framework is built around a matrix that combines climate forcing on one axis and socio-economic conditions on the other. Together, these two axes describe situations in which mitigation, adaptation and residual climate damage can be evaluated. They served as the starting point for the identification of internally consistent assumptions for the quantification of SSP elements. A range of different modelling tools were used to develop quantifications of these storylines, including factors like population, economic development, land use, and energy use.	The data in this report is based on preliminary data made publicly available as part of an ongoing peer review process of the SSP Database published in March 2024. While the data is accurate at the time, this may change in the future. SSP data modelled for the three scenarios and time horizons in this report remain similar under both SSP1 (Fully Charged and Short Detour) and SSP3 (Bypass to Breakdown), and only start to diverge notably beyond 2060.
NGFS Database	The Network for Greening the Financial System (NGFS) provides a global, harmonised set of transition pathways, physical climate change impacts and economic indicators. NGFS is widely used for scenario analysis, provides a common starting point to analyse climate risks, and improves the comparability of scenario parameters and associated narratives. See Appendix F for more detail on the NGFS framework and models used.	The parameters used in this report are drawn from NGFS Phase 3 data. The database has since been updated to reflect the latest climate science. To keep the parameters in line with the scenario architecture used in this report, this Phase 3 data has not been updated. It is important to note that the selected integrated assessment model used for this report did not model current policies data for both the long term interest rates, and oil price parameters so there is a gap in this data.
New Zealand Treasury	New Zealand Treasury shadow carbon prices were used as indicative carbon price pathways under three different hypothetical pathways. These three pathways are not forecasts of carbon pricing, or ETS, and are not modelled in alignment with SSPs or other socio-economic pathways, but are Aotearoa New Zealand-specific.	New Zealand Treasury's recommended shadow carbon prices differ across their 'low', 'central' and 'high' scenarios. To align with the scenario architecture of this report, the Short Detour scenario uses the 'low' pathway figures (the same as Bypass to Breakdown) up to 2030, and then the 'high' pathway figures from 2030 onwards, to reflect the anticipated steep rise in carbon price. Shadow emissions values are different from forecast prices in the ETS. ETS prices are highly uncertain, and not something this report seeks to predict. ETS price paths for analytical purposes are however available on request from cipa@mfe.govt.nz.
CCC	The data from Aotearoa New Zealand's Climate Change Commission (CCC) was sourced from their ENZ (Energy and Emissions in New Zealand) model used to understand the scale of the emissions reductions that are achievable in each sector over time – including energy, industry and transport. This data also formed the basis for the Commission's guidance to the Government on the country's first Emissions Reduction Plan. CCC data is a reliable, relevant source of future parameters for Aotearoa New Zealand as they are based on distinct climate scenarios that have been developed specifically for Aotearoa New Zealand by the CCC.	CCC data for the Fully Charged (tailwinds) and Short Detour (headwinds) scenarios are from their 2021 guidance to the Government, while the Bypass to Breakdown (current policy reference) data was recently updated as part of the Commissions 2023 guidance for the country's second Emissions Reduction Plan.
IEA	The IEA (International Energy Agency) publish yearly 'Global Energy Outlooks' that utilise the latest data for energy markets, policies and technologies to provide insights on global energy issues including supply and demand, renewable technologies, energy efficiency, and market access. While the data is not Aotearoa New Zealand specific, it provides a comparison point for some of the local CCC data.	IEA data for the Fully Charged (NZE) and Bypass to Breakdown (STEPS) scenarios are from the 2023 Global Energy Outlook. The Short Detour (SDS) data however, is from the 2021 Global Energy Outlook as data for this scenario has not been updated since this report. Multiple parameters in the IEA Global Energy Outlooks do not provide figures for 2040, hence gaps in some of the data.

Appendix E: Parameter source rationale and considerations

Source	Rationale	Considerations
IPCC	The UN Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) summarises the state of global knowledge on climate change, spanning it's impacts, risks, and adaptation challenges. The data it features is based on peer-reviewed, scientific, technical, and socio-economic literature, and incorporates the increasing diversity of global climate action.	This data is aligned to the newest SSP/RCP (Representative Concentration Pathway) combinations. Unfortunately, many of the other sources used in this report, particularly those for Aotearoa New Zealand specific data, are yet to be updated to align with these, including NIWA's data for extreme heat and rainfall. As such, this IPCC data is one of the only parameters which fits the scenario architecture outlined in this report.
MfE/NIWA	Aotearoa New Zealand's Ministry for the Environment (MfE)'s Climate Change Projections for New Zealand (2nd Edition) provide data that is both downscaled from the IPCC's Fifth Assessment Report (AR5) global climate predictions and CMIP5 (Coupled Model Intercomparison Project Phase 5), and the National Institute of Water and Atmospheric Research (NIWA)'s New Zealand regional climate model. At the time of the report's publication, this provided an unprecedented level of detail and robustness for Aotearoa New Zealand specific data and remains the most recent document of its kind despite changes in global climate modelling.	Since this source's publication in 2018, the IPCC has released its Sixth Assessment Report (AR6) which has revised modelling and SSP/RCP couplings. MfE/NIWA are yet to publish a new set of climate change projections for Aotearoa New Zealand aligned to this and the CMIP6 (Coupled Model Intercomparison Project Phase 6) modelling, however it is expected this will happen in 2024. As this report is not aligned with the latest AR6 SSP couplings, SSP1-2.6 was used in place of SSP1-1.9, and SSP5-8.5 in place of SSP3-7.0. MfE (NIWA) temperature increase data for Aotearoa New Zealand was adjusted to align with commonly used pre-industrial warming figures from AR5, estimating global temperature rise between the period of 1985-2005 was +0.6°C.
NZ SeaRise	NZ SeaRise provides an interactive map with hundreds of individual coastal sites across Aotearoa New Zealand. This database shows sea level rise and vertical land movement under potential climate change scenarios using the latest SSP-RCP pairings. This source is used by national agencies such as NIWA and MfE to model their statistics on sea level rise, however it is updated more frequently.	NZ SeaRise does not provide a national average sea level rise estimate. Site 7067 (Approximate location is the tip of West Head, Marlborough) has been used as a central location to be representative for an Aotearoa New Zealand average. The figures used also do not incorporate vertical land movement. NZ SeaRise projections use a baseline of 1995-2014, with a mid-point (zero) at ~2005. Further details can be explored using the interactive map from the source. To note: this source is frequently updated, and the data in this report has recently been superseded (with no material impact on the narratives in this report).
Climate Impact Explorer (CLIMADA)	The parameters sourced from the Climate Impact Explorer are built from the CLIMADA (Climate Mapping and Damage Assessment) model which is a global state-of-the-art probabilistic model which provides data on climate risks, and provides robust analysis of the cost-benefits of adaptation measures. CLIMADA constitutes a platform to analyse risks of different hazard types (floods, tropical cyclones, droughts, etc.) in a globally, regionally, and locally consistent fashion at different resolution levels, at scales from multiple kilometres down to metres, depending on the purpose.	*No baseline values:* Due to the quality of historical records, bias adjustment and validation of the absolute values simulated by the models used for this indicator have not been completed for all locations. Therefore, we don't provide its baseline absolute values over the reference period 1986-2006. *Relative Changes (Flood Damage):* Due to the rare occurrence of flood events over some grid cells, projected relative changes result in extremely high values over some of these grid cells as soon as they start occurring due to global warming. Relative changes are therefore not displayed explicitly for each grid point. *Uncertain Projections (Cyclone Damage):* The projected changes in damages from tropical cyclones presented here are derived from the CLIMADA model, calibrated on the results from Knutson et al. (2015). Although their analysis is based on several climate models, more recent publications question their results in some parts of the world, including New Zealand, in particular relating to future increases in damages from cyclones.
Statistics New Zealand	In the absence of nationally generated, SSP-RCP aligned population projections, Statistics New Zealand national population projections were used to indicate the future population of Aotearoa New Zealand. The varying population projections were aligned with the corresponding global trends in the SSPs. This source presents a number of probable population outcomes which incorporate a range of fertility, mortality, and migration assumptions.	Statistics New Zealand data is not SSP-RCP aligned. The figures used in this report are taken from the "national population projections: 2022(base) – 2073" document, using the projected probability distribution percentiles, with the 50th percentile taking place of SSP1-1.9, the 75th percentile representing SSP1-2.6, and the 95th percentile modelling SSP3-7.0. The very high migration scenario was also used to provide a population estimate for the extension scenario, taking the figure from 2073 as this modelling does not extend to 2100. Stats NZ's time horizons do not perfectly align with those in this report, using 2033, 2043, and 2053 in place of the usual 2030, 2040, and 2050.

Appendix F: NGFS framework and models

The Network for Greening the Financial System (NGFS) scenario framework and economic models are far from perfect. For example, defining assumptions about fossil fuel investment levels and the roll-out of carbon capture and storage technologies may be fundamentally out of alignment with science-based pathways to a 1.5°C world. Meanwhile, the current generation of NGFS Integrated Assessment Models (IAMs) fails to account for tail risks, second-order effects, potential non-linearities in climate-related risks (e.g. tipping points), and other potentially large sources of risk (e.g. an abrupt correction in asset prices when transition shocks result in the fire sale of assets in exposed sectors). Despite such significant shortcomings, the scenarios in this report are rooted in the NGFS framework and macroeconomic models because they:

- Are widely used by key partners in the transport sector value chain;
- Provide relatively wide variable coverage, geography-specific granularity and a dataset that allows comparison across different climate models;
- Represent the most comprehensive global macroeconomic, land and energy models currently available; and
- Are regularly updated and improved.

Choice of Integrated Assessment Model

The NGFS has used three IAMs to explore future macroeconomic conditions. All NGFS macroeconomic data included in this report has been extracted from the REMIND-MAgPIE 3.0-4.4 IAM (and NiGEM REMIND-MAgPIE 3.0-4.4) (Hilaire and Bertram, 2020).

- MAgPIE (Model of Agricultural Production and its Impacts on the Environment) is a global, multi-regional economic land use optimisation model designed for scenario analysis up to the year 2100. It focuses on the fulfilment of agricultural demand for ten world regions at minimum global costs under consideration of biophysical and socio-economic constraints.
- REMIND (Regional Model of Investment and Development) is a global multiregional model incorporating the economy, the climate system, and a detailed representation of the energy sector. REMIND enables analyses of technology options and policy proposals for climate change mitigation. The latest version includes a detailed representation of the transport sector with an explicit separation into freight and passenger transport for short-to-medium and long distances respectively.
- REMIND-MAgPIE is a 'comprehensive' IAM framework that simulates, in a forward-looking fashion, the dynamics within and between energy, land use, water, air pollution and health, economy and climate systems up to 2100. It is the only NGFS IAM that generates Aotearoa New Zealand (regional) tailored data.

NiGEM overlay

The Scenarios also utilise the NGFS NiGEM v1.22 overlay for REMIND-MAgPIE. NiGEM (National institute Global Econometric Model) is the leading global macroeconomic model, relied upon by policymakers and private sector organisations around the world for economic forecasting, scenario building and stress testing.

It consists of individual country models for major economies which are linked together through trade in goods and services and integrated capital markets.

A key feature of the model is its flexibility which allows users to define the scenario space, including policy regimes, expectation formation by consumers, firms, wage setters or financial markets, and other assumptions and judgements. The IAM's reference scenario GDP pathway is a counterfactual long term asymptotic GDP pathway that would emerge in the absence of either physical or transition shocks. NiGEM replicates the long term, reference GDP pathways produced by the three IAMs, as well as the associated population and primary energy consumption pathways.

NiGEM overlays physical and transition 'shocks' under each temperature and policy profile. NiGEM transition scenario inputs are based on change in energy consumption type and emissions, 'useful energy' (the actual level of energy service (e.g. passenger-kilometre, tonne-kilometre) which can be satisfied by various technologies with different energy efficiency and carbon intensity)), and carbon tax revenue. Transition shocks are focused on: prices (carbon pricing raising prices of energy, and reduction in fossil fuel usage deflating prices); taxation (carbon pricing an additional tax cost and revenue, and increasing costs of production); and demand (decline in volume of demand for fossil fuels).

Simplified representations of acute physical risks (i.e. risks driven by the occurrence of extreme climatic events as a macroeconomic shock) have been included in the NiGEM model. The purpose of this is to complement the existing estimate of chronic physical risk estimates in the IAMs and capture the highly disruptive economic impacts of extreme events. It should be noted that 'regions' (such as Aotearoa New Zealand) in NiGEM consist of several countries, all with a differing frequency and severity of acute climate effects, so a weighted average approach to GDP impacts of historic damage is used.

Appendix G: Limitations and mitigation measures

Limitations and reflections

An earlier section of this report outlined some high level limitations of this scenarios process, namely in regard to the scope of work. This limited the number of contributors to the scenario narratives, particularly in the areas of Māori engagement, rural community involvement, and detailed mode analysis. Generic inherent limitations of scenario analysis are discussed below:

Inherent limitations

Climate change scenarios have inherent limitations, including:

- *Uncertainty:* Scenarios are based on assumptions about the future, and the future is intrinsically uncertain. Moreover, the speed at which climate-related impacts are evolving is unprecedented and little reliance can be placed on historical experience to assess their magnitude, timing, or how different climate-related forces might interact. This gives rise to a higher level of uncertainty.
- *Simplification:* Even the most complex scenarios are highly simplified representations of profoundly complex systems. They cannot capture all the nuances and interdependencies of the real world, and they may overlook important forces that can have a significant impact on the future.
- *Bias:* Scenarios are influenced by the assumptions and biases of the people that develop them. Different participants may develop different scenarios based on their own perspectives and assumptions.
- *Over-reliance:* Scenarios are useful tools for exploring different futures, but they should not be over-relied upon. They are just one of many tools that can help inform decision-making, and they should be used in conjunction with other methods and sources of information.

SSP-RCP limitations

The UN Intergovernmental Panel on Climate Change (IPCC) Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs) contributing to the scenarios in this report are widely used but do have methodological limitations. The most significant of these limitations include:

- *Uncertainty:* SSP-RCP pairs are based on a range of uncertain factors, such as future greenhouse gas emissions and the effectiveness of climate policies.
- *Simplified assumptions:* SSPs and RCPs are based on simplified assumptions about the future, such as demographic trends, economic growth, and technological development. These assumptions may not accurately reflect the complexities of real-world social, economic, and technological systems.
- *Lack of integration:* SSP-RCP pairs do not fully integrate political, economic, social, technological, and environmental factors.
- *Inflexibility:* SSP-RCP pairs are static and do not consider physical or socio-economic feedback loops or tipping points.

This last point is particularly important.

Combining higher-level, publicly available scenarios

The sector-specific scenarios in this report blend Network for Greening the Financial System (NGFS), IPCC, and Climate Change Commission (CCC) 'backbone' (i.e. high level, sector-agnostic) scenarios, allowing for greater granularity and breadth of decision-relevant insights. However, this approach comes at a cost, especially:

- ***Friction:*** NGFS, IPCC, and CCC scenarios were not designed to be integrated. They have been developed using different methodologies, assumptions, and models, which makes it difficult to blend them in 'frictionless' narratives. Apparent inconsistencies and/or contradictions can undermine credibility in the eyes of end-users.
- ***Complexity:*** Blending multiple scenarios increases the complexity of analysis, which can make interpretation and communication more difficult.

Overall, blending well-recognised backbone scenarios can be useful for exploring the potential impacts of climate change and making well-informed decisions.

Socio-economic parameters

The socio-economic projections in this report have been drawn from:

- The Integrated Assessment Model (IAM) Regionalised Model of Investments and Development-Model of Agricultural Production and its Impact on the Environment (REMIND-MAgPIE) 3.0-4.4 accessed via NGFS Scenario Explorer
- The Climate Mapping and Damage Assessment (CLIMADA) model accessed via the Climate Analytics Climate Impact Explorer
- The International Institute for Applied Systems Analysis (IIASA) Shared socio-economic Pathways (SSP) Database
- Aotearoa New Zealand's Climate Change Commission's 'Ināia tonu nei: a low emissions future for Aotearoa' dataset
- New Zealand Treasury's Recommended Shadow Emission Values.

REMIND-MAgPIE combines the MAgPIE model of the global economy with the REMIND model of regional energy systems to (a) explore the relationships between climate change, greenhouse gas emissions, and socio-economic factors and (b) assess the impacts of climate change mitigation policies. Meanwhile, the CLIMADA model simulates the potential impacts of climate change on a range of sectors using climate projections, socio-economic data, and environmental data.

The REMIND-MAgPIE and CLIMADA models have undergone extensive peer review and are widely used. However, like all models, they are subject to limitations and uncertainties, particularly with regards to capturing the full complexity of the systems they seek to model. Ongoing efforts to improve the accuracy and usefulness of these models through better data sources and modelling techniques are important for enhancing their value to decision-makers in transport and other sectors.

Appendix G: Limitations and mitigation measures

Tipping points and the precautionary principle

Tipping points in the Earth system can have a significant impact on the reliability of SSP-RCP scenarios. These scenarios are based on assumptions about the future, including greenhouse gas emissions, land use, and other factors that influence climate change. However, tipping points in the Earth system (e.g. Greenland ice sheet melting) are thresholds that, if breached, can cause unexpected and irreversible changes to the Earth system which may induce further temperature rise, and lock us into a new climatic system. As such, if we were to reach tipping points, it would make the physical impact assumptions under the SSP-RCPs used in these scenarios 'best case'.

For example, if a tipping point is reached in the Arctic, where melting permafrost releases large amounts of methane, it could significantly increase greenhouse gas emissions beyond what is predicted in the SSP-RCP scenarios. This could lead to more severe and rapid climate change impacts than what is anticipated in the scenarios.

Similarly, tipping points in the ocean, such as the collapse of the Atlantic Meridional Overturning Circulation, could also have significant impacts on climate change. This could cause a rapid cooling of the North Atlantic, which is not accounted for in the SSP-RCP scenarios. This could have significant impacts on the reliability of the scenarios, as they may not accurately predict the future impacts of climate change if these tipping points are reached.

Overall, tipping points in the Earth system highlight the limitations of the SSP-RCP scenarios and the need for continued research and monitoring to better understand and account for these potential impacts.

Of note, all NGFS models are currently based on the use of IPCC SSP2, in combination with the previous generation of IPCC RCPs, both of which have been superseded by the latest generation of IPCC SSPs used elsewhere in this report. For more information about the state of NGFS IAMs, the rationale for specific socio-economic models used in this report, and their inherent limitations see Appendices E and F.

Mitigation measures

In order to help address known risks and limitations, the project:

- Developed challenging scenarios that capture a wide range of possible outcomes
- Incorporated feedback loops and non-linearities in socio-economic and Earth systems
- Employed a collaborative process leveraging a range of professional disciplines, experiences, and perspectives across the transport sector value chain
- Sought to expose implicit assumptions and potential biases through consulting a wider interest group and various transport experts (see Appendix I for list of those involved).

A final word of caution

Climate *science* may be moving more slowly than climate *change*, and the projections in this report may significantly underestimate the extent and/or timing of physical impacts. As such, users should apply the precautionary principle when making material decisions in the face of deep and dynamic uncertainty.

Appendix H: Drivers and descriptions

The list of climate-related drivers and their descriptions across the PESTLE (political, environmental, social, technological, legal, and economic) categories. These were identified by participants of the sector scenarios during the workshop process.

	Drivers	Descriptions
Political	**P1** - Domestic Political Leadership and Ambition	The level and consistency of domestic political ambition and leadership on climate change, including: level of consistency between successive governments, degree to which climate is politicised, balance of mitigation vs adaptation, long term vs short term planning, prioritisation of (sub)sectors vs transport, and national vs local projects.
	P2 - Government Funding and Investment	How, when, and where large scale transport investment is made (primarily in infrastructure), and how climate-related investments are prioritised by the Government across mitigation vs adaptation, across sectors (e.g. agriculture vs transport), within sectors (e.g. hydrogen for air vs land), and across national vs regional locales.
	P3 - Te ao Māori/Te Tiriti	Evolving judicial perspectives on Tiriti obligation in climate adaptation outpacing Central Government understanding and developing policy responses.
	P4 - Carbon Taxes/Markets (Domestic and International)	How Aotearoa New Zealand and international governments approach using carbon taxes / pricing e.g. ETS prioritisation and pricing, international carbon border taxes and carbon credit regimes (e.g. Article 6 Paris Agreement) and sector schemes (e.g. CORSIA, Carbon Offsetting and Reduction Scheme for International Aviation).
	P5 - Transport-specific Legislation	The timing, speed, and level of climate-related and other legislation passed by the Government, and specific, targeted examples impacting each transport sub-sector across air/sea/land, e.g. mandates on ICE vehicles, emissions standards, circular economy requirements.
	P6 - Sector-Adjacent Legislation	Climate-related and other legislation passed on adjacent sectors such as urban planning, infrastructure, renewable energy and building design requirements that influence the transport sector and its ability to respond to climate change.
	P7 - International Ambition	The scale and speed of climate action in large markets (e.g. the United States, China, Australia) and transnational organisations (e.g. IMO) impacting Aotearoa New Zealand's import/export markets, supply chains, and global political positioning.
	P8 – International Geopolitical Stability	The levels of geopolitical collaboration, competition, protectionism, and national political stability across global geopolitics impacting trade, labour flows, resource availability and finance/technology flows etc.
Environmental	**EN1** - Acute Climate Impacts	Short term changes in the climate, particularly around the frequency and severity of 'event-based' impacts on direct transport operations and indirect sector adjacencies e.g. cyclones, heavy rainfall.
	EN2 - Chronic Climate Impacts	Longer term changes in the Earth system driven by climate change, e.g. sea level rise, average temperatures.
	EN3 - Natural resources	Availability, cost, and quality of natural resources both domestically (e.g. crop yields) and internationally (e.g. petroleum).

Appendix H: Drivers and descriptions

	Drivers	Descriptions
Social	**S1** - System User preferences and behaviours	Changing system user expectations/norms around how and why people engage with the transport system and the factors that influence decision making such as values (e.g. demand for low carbon travel), consumption patterns (e.g. changing product consumption volumes, shared ownership, 'just-in-time' delivery), mobility patterns (e.g. reduced commuting), and mode-shift (e.g. autonomous vehicles). Includes 'induced' demand (greater uptake in private vehicle use when road lanes expanded), 'direct' trends (demand for low carbon transport), and 'indirect' trends (changing demand for material goods).
	S2 - Social Expectations of Sustainability	Wider societal expectations of transport organisations to reduce emissions and contribute to adaptation, and expectations over managed retreat. Degree of influence of te ao Māori world view on social norms.
	S3 - Demographics	Demographic shifts such as population, age, international immigration/emigration, social trends, education levels within Aotearoa New Zealand.
	S4 – Urbanisation	The level, rate, and timing of urbanisation patterns within Aotearoa New Zealand, and subsequent demand for transportation systems and urban planning.
	S5 – Social Cohesion, Equality and Equity	The level of social cohesion, inequality, and polarisation around climate change. The levels of expected equity in a transition to a low carbon economy.
	S6 – Social Expectations of Health and Wellbeing	Social expectations around the public and private sectors' roles in promoting levels of physical, mental, and social health and wellbeing in the context of physical climate change and economic developments.
Technological	**T1** - Availability and Accessibility of New Technology	The speed and scale to which organisations in Aotearoa New Zealand can feasibly attract and/or develop, access, and utilise affordable new climate-related technologies in a meaningful way (not the existence of the technology itself).
	T2 - Enabling ecosystem for technology	The level to which the financial, political, and cross-sector ecosystem enables the development and/or deployment of (new) technology to flourish in Aotearoa New Zealand, e.g. energy system, data/AI systems, downstream waste management, infrastructure etc.
	T3 - Existing Technologies (Impacting 'Current State' System)	The level of deployment and adoption of proven, existing (but still developing) technologies that enable low carbon, resilient operations and products that are more effective, efficient and/or economical (within the 'current state' transport system, i.e. current modes and usage patterns), e.g. EVs, SAF, hydrogen fuel cells, e-scooters.
	T4 - Emerging Technologies (Enabling 'Future State' System)	Emerging, disruptive, and speculative technology which enables radically new business models, shifts transport modes, and enables new conceptions of 'mobility' (e.g. delivery drones, eVTOL craft, domestic 3D and 4D printing, 3D hologram technology, metaverse).
Legal	**L1** - Government Enforcement of Climate Laws	The frequency and intensity in which the Government takes action against organisations or individuals for breaching climate-related legislation, laws, mandates etc.
	L2 - Exposure to climate-related litigation	Frequency, scale, and success of legal challenges by the public, NGOs, unions, and shareholders against government agencies and industries seen to not be taking sufficient action to deliver against mitigation/adaptation targets.
	L3 - Directors and Officers' Liabilities	The level of risks that director and officers face from climate-related litigation, and the behaviours and risk appetite this generates, i.e. level of ambition vs conservativeness.

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	Drivers	Descriptions
Economic	**EC1** - Domestic macroeconomic conditions	Domestic levels of inflation, interest rates, unemployment, and GDP growth.
	EC2 - Domestic economic structure	The shape, structure, and interactions of Aotearoa New Zealand's economy and sectors within it, e.g. size/shape of the timber, tourism, or agriculture sector, and balance of exports vs domestic consumption or imports.
	EC3 - Commodity prices	Price of domestically produced and imported commodities, e.g. fuel, precious metals, food etc.
	EC4 - Access to Finance	Access to and cost of debt and equity finance and insurance for net zero transition and other purposes.
	EC5 - Consumer financial strain and Equality	Financial strain on end-consumers and social/political sentiments towards this.
	EC6 - Global macroeconomic conditions	Global levels of inflation, interest rates unemployment and GDP growth.
	EC7 - Global market alignment	Degree to which Aotearoa New Zealand is aligned to primary global import/export markets and international corporations on climate-related standards, trade rules, taxes, tariffs, targets, accepted emissions levels, etc.

Appendix I: Acknowledgements

While convened by The Aotearoa Circle, Aotearoa New Zealand's transport sector climate change scenarios were created with the help of a wide range of individuals across the Working Group, the Wider Interest Group, and the Secretariat. We would like to thank each individual for their contribution to this project.

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Mā te Kaitiakitanga ko te Tōnuitanga
Prosperity Through Guardianship