Idea Bank of Pathway Milestones for New Zealand's Low-Emission Future: Work in Progress from Motu's Low-Emission Future Dialogue

First Edition May 2016

Author contact details

Catherine Leining (corresponding author)
Motu Economic and Public Policy Research
catherine.leining@motu.org.nz

Suzi Kerr (corresponding author)
Motu Economic and Public Policy Research
suzi.kerr@motu.org.nz

Other contributing authors from the Low-Emission Future Dialogue: Nathan Argent, Anders Crofoot, David Frame, Adrian Macey, Sarah Meads, Warwick Murray, Simon Ngawhika, Judd Ormsby, Meredith Osmond, Megan Owen, Matt Paterson, Lara Phillips, Geoff Simmons, Duncan Stewart, Gerri Ward, Maree Willetts, and Paul Young.

Acknowledgements
The ideas in this document were developed through, informed or inspired by discussions among Low-Emission Future Dialogue participants which were undertaken in their personal capacity. Additional Dialogue participants not listed above included: Chris Baker, Rick Barber, Alastair Cameron, Sally Garden, David Kidson, and Paul Melville. The Dialogue also benefited from input from the following guest presenters: Corey Allan, David Bibby, Alastair Bisley, John Hancock, Philippa Howden-Chapman, Katie Hsia-Kiung, Adam Jaffe, Roger Lincoln, Erica Morehouse, Tina Porou, Janet Stephenson, Derek Walker, and Nic Williams.

This work was conducted under Motu's programme "Shaping New Zealand's Low-Emission Future." Motu would like to acknowledge with gratitude the support from programme funders: the Aotearoa Foundation, Meridian Energy, Z Energy, Ministry for the Environment, and the Parliamentary Commissioner for the Environment.

These ideas are intended to provoke thought and discussion. They are not intended to be prescriptive or predictive, nor does their inclusion in this document imply any recommendation, consensus or endorsement by Dialogue participants or presenters, their affiliated organisations or the programme funders.

Motu Economic and Public Policy Research

PO Box 24390 Wellington New Zealand
info@motu.org.nz www.motu.org.nz
+64 4 9394250

Introduction

From May 2014 through February 2016, Motu Economic and Public Policy Research convened a group of about 20 cross-sector stakeholders to explore pathways to achieving zero net greenhouse gas (GHG) emissions in New Zealand. Participants engaged in their personal capacity, not as organisational or sector representatives. The Motu Note entitled *New Zealand's Low-Emission Future: Transformational Pathways* presents a synthesis of ideas that emerged during the course of nine meetings of the Low-Emission Future Dialogue. **More detailed ideas that emerged from the process are captured in this "idea bank" document, which is offered in the spirit of sparking discussion, not as recommendations.**

Dialogue participants recognised that other experts were already conducting technical and economic assessment of New Zealand's mitigation options, and sought to complement that effort by exploring what changes across society could help to turn such options into reality. Any number of pathways could deliver a zero-net-emission future for New Zealand. Participants applied a backcasting process to translate a broad **vision** for a thriving zero-net-emission economy into a range of potential **sectoral characteristics** (see Table 1) that would underpin that economy. The adaptive pathway choices made by government, business and civil society in conjunction with external change drivers will determine the balance of characteristics that eventuates. Each of these sector characteristics will require the achievement of **milestones** that can be organised into four categories: technology, policy and regulation, business, and behaviour. In turn, each milestone will be supported by the **actions** of specific sector actors.

This document presents a preliminary "idea bank" of potential pathway milestones (see Table 2) that might help with achieving the sectoral visions for stationary energy, land transport and agriculture. These ideas resulted from a series of creative brainstorming sessions by Dialogue participants with a range of interests and expertise. They have not been listed in chronological order or prioritised. Some may be interdependent and others mutually exclusive. While some may already be underway or show significant potential, others may not be technically, economically, or socially feasible or may be undesirable for other reasons. Some may only be remote possibilities. Individual Dialogue participants may not agree with many of these ideas.

We invite sector experts to work with us to assess these potential milestones, suggest which milestones could be deleted or added, and explore how these milestones could be achieved through practical actions by specific actors. At all stages of this review process, Dialogue members encourage others to take up the most promising ideas and run with them.

Table 1: Possible sector characteristics in a low-emission future

Sector category	Sector characteristics
Stationary energy vision: NZers have access to secure, resilient and affordable zero-net-emission energy to power their homes and businesses.	
Electricity and heat supply	1. Utilities supply (nearly) 100% renewable generation.
	2. Distributed renewable generation (DRG) displaces (some) utility generation.
	3. Heat for industrial production and buildings (primarily) is produced with renewable electricity or other non-fossil fuels.
	4. Emissions from fossil fuel or biomass combustion are removed by CCS.
	5. Disruptive technology transforms the supply of power and/or heat.
Electricity and heat demand	6. Enhanced energy efficiency and conservation generates multiple benefits.
	7. Disruptive technology transforms demand for power and/or heat.
Land transport vision: NZ's land transport system ensures efficient, resilient and affordable zero-net-emission mobility for people and goods.	
Land transport fuel supply	8. Land transport is powered (primarily) by electricity.
	9. Land transport is powered (primarily) by biofuel (e.g. bioethanol, biodiesel, biogas [CBG, LBG]).
	10. Disruptive technology transforms land transport energy supply.
Vehicle fuel demand	11. Vehicle fuel efficiency increases significantly.
Passenger transport demand	12. Private motor vehicle use is heavily displaced by public, other shared or active transport modes.
	13. Private motor vehicle use is significantly reduced by urban planning and/or culture change.
Freight transport demand	14. Freight mode shifts significantly from road to rail and shipping.
	15. Freight transport demand declines significantly due to changes in technology or consumer demand.

Sector category	Sector characteristics
Agriculture vision: NZ operates a highly efficient, ultra-low-emission food production system.	
Food supply	16. NZ operates an ultra-GHG-efficient livestock sector. 17. NZ produces zero-CH4, low-N2O nutrition.
Food demand	18. NZ reduces food waste across the chain of food production and consumption. 19. Consumers demand low-emission food.

Table 2: Possible pathway milestones in a low-emission future

0. Cross-cutting milestones

A. Technology milestones

1. Processes are put in place to support systematic scanning of international developments in technology and best practice.
2. NZ expands local R&D focused on local and globally valuable mitigation options where NZ has comparative research advantage.
3. New funds and technical support networks are established to enable experimentation with emerging technologies and infrastructure in the NZ context.

B. Policy/regulatory milestones

1. The NZ ETS is repositioned within a broader portfolio of policies and regulations supporting low-emission transformation.
2. The NZ ETS is reformed to produce a rising emission price floor that transitions to the social cost of carbon.
3. Financial mechanisms are created to reduce risk from long-term mitigation investments – including forestry.
4. NZ ETS auction revenue is invested directly, and used to leverage private investment, in R&D, technology diffusion, infrastructure improvements, public education and behaviour change on mitigation, and managing distributional effects of mitigation policy.
5. The government issues Green Bonds to help raise funds for major investments in infrastructure and technology.
6. Central/local government consider whether there are climate implications in all decisions and apply a shadow social cost of carbon for all decisions relating to long-term planning and infrastructure with emission implications.

C. Information, education and training

1. Climate change mitigation is integrated into school curricula at all levels.
2. Training in the implementation of emerging technologies is provided across sectors.
3. Information on the performance and cost of emerging mitigation technologies and on the reliability of service providers is made widely available from reliable, independent sources.
4. Public awareness campaigns are used to shift values and social norms.

D. Stakeholder processes

1. Cross-party support for NZ's low-emission development strategy enables policy continuity across election cycles and increases policy certainty for investors.
2. Multiple stakeholder processes operating at the sectoral and cross-sectoral levels support pathway finding, problem solving and collaboration in implementing mitigation solutions.
3. Independent technical advice is provided to government on climate change mitigation targets and policies.
4. The 10 largest companies in each sector collaborate to develop voluntary emission reduction strategies and lead sectoral change.

1. Utilities supply (nearly) 100% renewable generation.

A. Technology milestones

1. Fast-response grid-scale batteries, pumped-hydro energy storage systems and/or electric vehicle batteries can ensure security of supply.
2. Improved transmission/distribution systems reduce losses and increase resilience to natural disasters.
3. Smart grid, smart meter, smart appliance and building monitoring technologies optimise the supply/ demand balance.
4. New renewable fuel sources become viable in New Zealand: ocean/tidal energy, utility-scale solar, hydrogen.

B. Policy and regulatory milestones

1. Increased demand from population growth and electrification of transport and industrial heat is met by renewables.
2. Backstop regulation is used to phase out natural gas (and prevent future coal use) for electricity generation.
3. [What is needed for transmission and distribution?]
4. Government provides funding and infrastructure investment to support diversification of renewable generation for security of supply.
5. Public/private partnerships support generation over-build to cover security of supply.[1]
6. Government stops subsidising mineral and gas exploration under cross-party agreement.
7. Government supports R&D and pilot projects for ocean/tidal energy and utility-scale solar.

C. Business milestones

1. Time-of-day pricing is used to improve peak load management and provide accurate emissions accounting to consumers.
2. Utilities collaborate with other sectors to support electrification of passenger and freight transport and industrial production.
3. [What is needed for transmission and distribution?]
4. New Zealand exports its expertise as a world leader in geothermal energy, ocean/tidal energy and grid management of renewable generation.
5. Green tech innovators/entrepreneurs develop new products and services supported by zero-net-emission electricity.
6. Electricity-intensive businesses move to New Zealand to benefit their carbon footprint.
7. Public/private partnerships are used to commercialise ocean/tidal and utility-scale solar energy.

D. Behavioural milestones

1. In their power bill, consumers receive information about their electricity emissions and their rate of consumption relative to peers.
2. Consumers have price incentives and tools to shift electricity use to off-peak times, reducing peak demand.
3. Where feasible, building systems, appliances and EV charging systems are set by default to use electricity in off-peak times.
4. Communities support siting of new renewable generation.
5. Education and training programmes support the renewable generation industry.

[1] Is this still relevant if technologies provide storage solutions?

2. Distributed renewable generation (DRG) displaces (some) utility generation.

A. Technology milestones

1. Advanced battery technologies ensure security of supply from DRG at the level of communities, facilities and/or buildings.
2. Advanced solar technologies support DRG in the New Zealand context.
3. Advanced DRG technologies become integrated with building design; new buildings generate their own energy as industry standard.
4. On-farm DRG technology supports efficient agriculture systems.
5. Improved metering and transmission/distribution systems ensure secure DRG load management and enable power sell-back to the grid.

B. Policy and regulatory milestones

1. Resource consent requirements are adapted to facilitate experimentation with emerging DRG technologies.
2. DRG is adopted as an enduring policy solution to energy poverty for low-income households.
3. DRG is adopted as an enduring policy solution to improve energy-supply resilience to natural disasters.
4. Government provides financial incentives to accelerate uptake of DRG (e.g. tax breaks, tariffs orsubsidies).
5. Central/local government mandates integration of DRG into government buildings and social housing.
6. Building codes mandate integration of DRG into all new residential and commercial buildings, and guide retrofitting of existing buildings.
7. Under government regulation, utilities must enable consumers to sell surplus DRG back into the grid.
8. Central and local governments collaborate on bulk purchases of DRG technologies at reduced prices.

C. Business milestones

1. Energy performance contracting and financing mechanisms overcome the up-front cost barrier to DRG.
2. Utility, transmission and distribution models change to support community-scale and farm-level DRG.
3. Community ownership models enable local residents to profit from investing in community-scale DRG.
4. Through business partnerships, DRG technologies are adapted and standardised to support EV charging.
5. Utilities provide reliable price incentives to consumers to sell excess generation to the grid.
6. Businesses collaborate on bulk purchases of DRG technologies at reduced prices.
7. New Zealand exports its expertise as a world leader in community-scale DRG and grid integration.

D. Behavioural milestones

1. Consumers value energy independence from utilities and lead the DRG revolution.
2. Under new financing mechanisms, consumers change their focus from up-front costs to life-cycle costs for investment in residential and commercial DRG, and accept a longer return on investment.
3. Consumers can easily access independent information on the cost and reliability of emerging DRG technologies and on the quality of DRG service providers.

3. Heat for industrial production and buildings (primarily) is produced with renewable electricity or other non-fossil fuels.

A. Technology milestones

1. Technology advances enable biomass or other renewable fuels (solar thermal, electric heat pumps, enhanced/low-heat geothermal) to be used for high- and low-temperature industrial heat.
2. Technology advances enable biomass or other renewable fuels (solar thermal, electric heat pumps, geothermal) to be used cost effectively for heat in commercial and residential buildings.
3. Wind generation is used to drive air compressors to generate motive energy.
4. Co-generation of heat and power (CHP) is fuelled by renewable sources (e.g. biomass and geothermal).
5. District heating systems fuelled by renewable energy are introduced in New Zealand.

B. Policy and regulatory milestones

1. Government provides financial incentives to businesses to transition to zero-net-emission industrial heat production (e.g. tax breaks and subsidies).
2. Policies and emissions pricing encourage biomass co-firing with coal as a transitional measure.
3. Regulation imposes a high up-front commissioning fee for new fossil-fuel boilers to factor in the social cost of carbon over the lifetime of the asset.
4. Backstop regulation is used to prohibit industrial heat production with fossil fuels after a specified date.
5. Regulatory efficiency standards are applied to industrial heat production.
6. Under government regulation, CHP generators can sell surplus electricity back into the grid.
7. Government supports R&D for industrial heat production.

C. Business milestones

1. Industries co-locate their production with other energy production to capture waste heat.
2. Industries co-locate their production and supply chains strategically to ensure secure biomass/other fuel supply at acceptable cost (e.g. co-locating biofuel plantations, forest mills and milk driers).
3. Energy- and cost-efficient transport networks deliver fuels to plants.
4. Industry users invest in infrastructure to support biofuel development/transport.
5. Industries factor a shadow price for the social cost of carbon into investment decisions on energy generation assets.
6. Industries use CHP where feasible.
7. Industries report their product emission footprint to consumers and shareholders.
8. Industries require upstream and downstream suppliers to report and improve the emissions intensity of their goods and services.
9. Industries switch to less emissions-intensive production and transportation processes to reduce demand for industrial heat (e.g. for producing milk powder).

D. Behavioural milestones

1. Eco-branding is valued; consumers demand information from producers on the emission footprint of the goods and services they provide, and make purchase decisions accordingly.
2. Consumers substitute less emissions-intensive industrial products for today's standard products.

4. Emissions from fossil fuel or biomass combustion are removed by carbon capture and storage (CCS).

A. Technology milestones

1. Affordable CCS technology enables net-zero-emission fossil generation.
2. Affordable CCS technology enables net-negative-emission biomass energy generation (BECCS).
3. Captured CO_2 can be stored safely in NZ, exported or used as a feedstock for other processes.
4. Affordable CCS technology can be applied at industrial scale for emissions from heat production.

B. Policy and regulatory milestones

1. Residual fossil generation should produce combined heat and power (CHP) where possible.
2. The government signals that once CCS is commercially viable, all fossil fuel generation and industrial heat will be required to use CCS.
3. Policies and emissions pricing encourage biofuel production for BECCS.
4. Government supports R&D and pilot projects for BECCS.
5. Under regulation, any new fossil generation plant or industrial boilers built after 2015 must be CCS-ready.

C. Business milestones

1. Industries are co-located with residual fossil fuel electricity generation to support CHP.
2. New financing and insurance mechanisms support the uptake of CCS and BECCS.
3. Utility and forestry industries develop an accord for secure biomass supply for BECCS.
4. Public/private partnerships are used to commercialise BECCS.
5. New Zealand exports its expertise as a world leader in BECCS.

D. Behavioural milestones

1. Communities support operation of fossil fuel generation or industrial heat with CCS.
2. Communities support storage of recovered CO_2.

5. Disruptive technology transforms supply of power and/or heat.

A. Technology milestones

1. Unexpected advances in technologies (e.g. hydrogen, fusion) fundamentally change the generation of power and/or heat in ways we cannot predict.

B. Policy and regulatory milestones

C. Business milestones

D. Behavioural milestones

6. Energy efficiency and energy conservation are promoted to generate multiple benefits.

A. Technology milestones

1. Improvements in energy-efficiency technologies and practices significantly reduce energy demand per capita and support peak load management while improving health, productivity and quality of life.

B. Policy and regulatory milestones

1. The NZ ETS price signal counteracts the rebound effect, discouraging consumers from increasing energy or other consumption as efficiency improves.
2. More stringent residential and commercial building codes and appliance standards increase energy efficiency.
3. A building warrant-of-fitness programme provides appropriate requirements and incentives for landlords to invest in energy efficiency measures.
4. Central and local governments collaborate on bulk purchases of energy-efficient technologies at reduced prices.
5. Increasing energy efficiency support to low-income households helps to offset the impact of increasing energy prices.
6. Regulations mandate universal insulation in new and existing housing by 2025.

C. Business milestones

1. Utilities and industrial producers invest in energy efficiency improvements in their own operations.
2. Utilities are incentivised to help consumers invest in energy efficiency, smart meters and building monitoring systems to manage peak load and offset rising power costs.
3. Energy performance contracting overcomes the up-front cost barrier to energy efficiency improvements.
4. Online platforms report and rank energy-efficiency performance by commercial buildings and rental properties to incentivise improved performance in the competition for tenants.
5. Businesses collaborate on bulk purchases of energy-efficient technologies at reduced prices.

D. Behavioural milestones

1. Smart meters and building monitoring systems provide real-time information about opportunities to reduce electricity use and resulting cost savings.
2. Households and businesses are educated about the costs and benefits of options for energy efficiency and energy conservation.
3. Under new financing mechanisms, consumers change their focus from up-front costs to life-cycle costs for investment in residential and commercial energy efficiency improvements, and accept a longer return on investment.
4. Efforts by households and businesses to reduce electricity use are reported and good performance is recognised publicly.
5. Nudges support selection of energy-efficient options as the default choice.
6. Consumers can easily access independent information on the cost and reliability of emerging energy-efficient technologies and on the quality of energy-efficiency service providers.

7. Disruptive technology transforms demand for power and/or heat.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
1. Process changes reduce industrial heat needs (e.g. technologies to change drying processes, changes to transit and storage techniques, changes in shipping technologies, increased changed-state products (frozen, molecular, UHT)). 2. Biomass becomes viable for petrochemical feedstocks.[2]		1. Businesses adopt new technologies that transform production processes to reduce demand for power and/or heat.	1. Consumers substitute less emissions-intensive products which reduce demand for power and/or heat.

[2] This may relate more to industrial process emissions but may have energy implications as well. Need more information.

8. Land transport is powered (primarily) by electricity.

A. Technology milestones

1. New Zealand's grid is powered (primarily) by renewable energy (see above).
2. Technology improvements (especially to batteries) lower the cost and raise the performance of EVs.
3. An EV charging network is developed that meets diverse user needs for accessibility and speed.
4. Manufacturers standardise EV batteries to facilitate battery exchange and recharging.
5. Environmentally sound and cost-effective methods for disposing of, or recycling, EV batteries are developed.
6. Affordable electrified light rail is developed for lower-density cities.

B. Policy and regulatory milestones

1. The government funds infrastructure investments for EVs and provides transitional financial incentives for EV purchases (e.g. tax breaks and subsidies).
2. The government guarantees a minimum vehicle resale price for fleet purchasers of EVs.
3. Central government procurement guidelines transparently report the relative life-cycle cost and emissions of EVs.
4. Central and local governments purchase EV fleets to demonstrate the technology and stimulate the second-hand market.
5. Central and local governments support pilot projects for emerging EV technology for heavy vehicles (e.g. public transport, waste collection).
6. Regulations require housing and commercial developments and parking lots to install standardised EV charge points.
7. Central and local governments provide EV incentives such as free or preferential parking, HOV lane access, exemption from road user or congestion charges, reduced vehicle registration fees, etc.
8. Local governments pilot EV car sharing schemes for low-income

C. Business milestones

1. New business models overcome the EV barriers to consumers: up-front cost, range, charge time, fear of reliability/safety.[3]
2. Cottage industry developed in EV conversions.
3. Owners of gas stations, commercial developments and parking lots pilot EV charging stations to attract customers.
4. Time-of-day pricing is used to incentivise EV charging at off-peak times.
5. Bulk fleet purchases across NZ and Australia lower purchase prices and seed a growing second-hand market.
6. Electricity generators, distributors and/or retailers collaborate with EV importers to build the EV market.
7. Markets are developed for recycled materials from scrapped vehicles.
8. Vehicle insurance providers create incentives for EVs.

D. Behavioural milestones

1. The public endorses EVs as a contributor to energy independence from imported fossil fuels as well as climate change mitigation.
2. Reliable independent information is provided to consumers on the lifecycle costs and environmental impacts of EVs.
3. Where feasible, EV charging systems are set by default to use electricity in off-peak times.
4. Community EV car-share programmes are developed to build exposure to EVs and mitigate up-front costs.
5. Public awareness programmes and use of EVs by role models encourage public interest in EVs.

[3] An example is the success of car-share systems that have a much higher uptake of electric vehicles because they address these barriers.

8. Land transport is powered (primarily) by electricity.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
	communities to address transport poverty. 9. Progressive vehicle emission standards are imposed at the point of import. 10. Progressive vehicle fleet portfolio requirements for the share of EVs are imposed at the point of import with a trading system. 11. Differential fees are charged at the point of vehicle import or registration based on GHG emissions intensity. 12. Government scrappage programmes help to accelerate fleet turnover. 13. Rail for freight transport is electrified.		

9. Land transport is powered (primarily) by biofuel (e.g. bioethanol, biodiesel and/or biogas (CBG, LBG)).

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
1. Technology supports the development of cost-effective first- and second-generation biofuels. 2. Viable biofuel feedstocks are diversified (e.g. crops, wood waste, food waste). 3. Viable and scalable biofuel production processes are demonstrated in the NZ context. 4. Biofuel by-products are used as asphalt substitutes, or for other uses (NZ discovery). 5. International vehicle manufacturers produce biofuels-ready models as a	1. Biofuels are identified in policy as a key to transitioning from ICEs to EVs for passenger transport, and a bridge to a renewable-energy future for freight transport. 2. The government develops a value proposition for domestic biofuel production and export (leverage as national advantage). 3. Bio-risks to the fuel supply are assessed and managed. 4. The government funds R&D and infrastructure investments for biofuel development.	1. Through public/private partnerships, the fuel delivery infrastructure is adapted for biofuels. 2. Biofuel development is co-located with plantation forestry, forest processing mills, geothermal energy and/or sources of waste heat. 3. Domestic and international supply chain implications for biofuel development, delivery and use are identified and managed strategically. 4. New Zealand becomes a net exporter of sustainable biofuels.	1. With eco-branding, households and businesses are willing to pay a price premium for biofuels. 2. Households and businesses offset price increases from biofuels through more efficient vehicle use and by reducing VKT. 3. Consumers put pressure on producers to use biofuels in their fleet. 4. Consumers “save the V8” by using biofuels. 5. Car racing using fossil fuels becomes taboo.

9. Land transport is powered (primarily) by biofuel (e.g. bioethanol, biodiesel and/or biogas (CBG, LBG)).

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
standard, and increase the size of vehicles that can use biofuels. 6. Biofuel processing uses geothermal or waste heat where feasible. 7. Specialised biofuels are developed for use in shipping and aviation.	5. Central and local governments collaborate to develop a nationally coordinated, regionally delivered biofuel plan. 6. Policies and emissions pricing encourage forest planting for biofuel production. 7. The government offers loan guarantees for major new capital investments for biofuel production. 8. The government develops purchasing agreements for biofuels for use in government fleets. 9. Government policy ensures domestic and imported biofuels are sustainably sourced, and issues an NPS for biofuel production. 10. Progressive vehicle emission standards are imposed at the point of import. 11. Progressive vehicle fleet portfolio requirements for the share of biofuel vehicles are imposed at the point of import with a trading system. 12. Regulations are developed for introducing biofuels in shipping and aviation. 13. NZ government leads an international accord to facilitate uptake of biofuel for international aviation.	5. New Zealand exports its expertise in developing a biofuel industry. 6. Eco-branding benefits incentivise businesses to use biofuels in their fleet. 7. Biofuel use becomes industry standard for movement of heavy freight. 8. AirNZ leads development of biofuel technology and infrastructure for aviation.	

10. Disruptive technology transforms land transport energy supply.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
1. Unexpected advances in technologies and fuels (e.g. hydrogen) fundamentally change transport in ways we cannot predict.	1. The government invests in infrastructure supporting the integration of renewable hydrogen or other renewable fuels into the transport system, either alongside or in place of electricity or biofuels.		

11. Vehicle fuel efficiency increases significantly.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
1. Improvements in vehicle design significantly reduce fuel demand, both during the phase-out of fossil fuels and use of renewable fuels for transport. 2. Driverless cars are proven effective, improving the efficiency of car operation and road use and reducing congestion in urban areas.	1. Progressive vehicle fuel efficiency standards are imposed at the point of import. 2. Government scrappage programmes help to accelerate fleet turnover. 3. Central and local governments pilot the use of driverless cars	1. Businesses require highly fuel-efficient vehicles in their fleets.	1. Consumers respond positively to vehicle efficiency labelling programmes. 2. People transition to very small vehicles. 3. People transition to highly efficient driverless cars.

12. Private motor vehicle use is heavily displaced by public, other shared or active transport modes.

A. Technology milestones

1. Network management technology improves the delivery of public transport services to increase access and convenience, meet demand and reduce total travel time for users.
2. Public transport vehicles are redesigned to improve the ridership experience.
3. Technology for e-bikes improves performance and lowers cost.
4. Light rail becomes economic in urban areas.

B. Policy and regulatory milestones

1. Road networks are redesigned to favour public, shared and active transport modes.
2. The transport network is designed to facilitate commuter connections between rail, ferries, airports, and public and active transport.
3. The government improves infrastructure for public and active transport.
4. Central and local government change their criteria for evaluating the life-cycle cost and environmental impacts of transport investments to favour public and active transport.
5. Central and local government reforms public transport operating models to improve performance (efficiency, quality and cost), including in rural and low-density communities.
6. Government increases subsidies for public transport to reflect public-good benefits.
7. Congestion pricing and increasing parking fees discourage personal vehicle use.
8. Central and local governments pilot the use of vehicle-share programmes.
9. Government leads better coordination of transport financing across central and local government and business.

C. Business milestones

1. New business models are developed for delivering affordable and high-convenience public transport in both high- and low-density areas.
2. The size of public transport vehicles is matched to demand.
3. New business models are developed for providing safe and reliable vehicle-sharing and shared-ride services.

D. Behavioural milestones

1. Employers offer bikes, e-bikes and bus passes to employees, rather than company cars and parking spaces.
2. Employers and schools organise bike sharing and carpooling programmes.
3. Ferries, rail and buses provide bike racks for commuter use.
4. Schools encourage use of buses and active transport.
5. People join vehicle-share programmes rather than owning multiple vehicles.
6. Vehicle-share systems allow drivers to select the size and type of vehicle to meet their needs on a trip-by-trip basis.
7. People embrace carpooling for routine travel to work, school and social activities.
8. People embrace walking and cycling for recreation, health and fitness.
9. It feels “wrong” to drive in a large car by yourself.

13. Private motor vehicle use is significantly reduced by urban planning and/or culture change.

A. Technology milestones

1. New networking and information sharing technologies better match transport supply with demand.
2. Development of autonomous vehicles enables new solutions to meeting collective transport needs.

B. Policy and regulatory milestones

1. Under improved central and local government planning guidelines, urban infrastructure increasingly supports high density, mixed-use development that reduces transport demand.
2. Reduced transport demand is factored into strategies for provision of affordable housing.
3. Government policy supports new business models for transport service provision that reduce overall demand (e.g. Uber, if this is the case).

C. Business milestones

1. Businesses locate in mixed-use areas to reduce commuting time for employees.
2. New business models support deployment of new transport technologies or services (e.g. autonomous vehicles and car sharing systems)
3. Vehicle insurance providers charge on a per-km rather than per-vehicle basis.
4. Vehicle insurance providers accommodate new business models for transport service delivery (e.g. autonomous vehicles, car sharing)
5. Businesses support telecommuting or development of regional work hubs that reduce commuting demands on employees.

D. Behavioural milestones

1. People demand urban planning that reduces the need for private motor vehicle use.
2. People embrace digital access to employment, social and other opportunities and reduce transport demand.
3. Popular culture marketing campaigns reduce transport demand.
4. The social norm changes from personal vehicle ownership to car sharing or other collective transport solutions.

14. Freight mode shifts significantly from road to rail and shipping.

A. Technology milestones

1. Rail and shipping are powered (primarily) by renewable fuels (see above).

B. Policy and regulatory milestones

1. Government supports upgrades to rail and port infrastructure for freight transport and solves regional access issues.
2. Urban development is coordinated to support access to freight transport by rail and shipping.
3. Government increases road user charges for freight transport.

C. Business milestones

1. Businesses change regional freight delivery networks to allow greater use of rail and shipping.
2. Freight transport is coordinated to maximise loading of rail and shipping.
3. Businesses factor transport emissions into their carbon footprint calculations and publish the results for marketing advantage.

D. Behavioural milestones

1. With eco-branding, consumers reward freight transport by rail and shipping.
2. Consumers accept slower delivery times to reduce freight transport emissions.

15. Freight transport demand declines significantly due to changes in technology or consumer demand

A. Technology milestones

1. Breakthroughs in manufacturing technology (e.g. 3-D printing) reduce demand for freight transport.

B. Policy and regulatory milestones

C. Business milestones

1. New business models support trading of IP rather than trading of manufactured products.
2. Businesses support local manufacture of goods for local consumption.
3. Businesses improve logistics management methods to deliver freight more efficiently.

D. Behavioural milestones

1. People reduce consumption of goods.
2. Through eco-branding, consumers make the effort to “buy local.”

16. NZ operates an ultra-GHG-efficient livestock sector.

A. Technology milestones

1. Real-time measurement tools are available for farmers to see the impact of their decisions on greenhouse gas emissions (and co-benefits).
2. We have credible research on the cost-effectiveness of capping effluent ponds and biodigesters/energy.
3. New feasible and cost-effective mitigation technologies have been found for livestock nitrous oxide and methane.
4. Methane-neutral systems for dairy have been created. Recovered methane is used for energy or flared.

B. Policy and regulatory milestones

1. A pricing mechanism is established to reward efficiency and discourage inefficiencies – poorly performing farmers have incentives to become more efficient.
2. Water use and quality are priced (capture externalities).
3. Regulation on land-use change is built into Council/local government planning, with mitigation considerations for appropriate land use.
4. Regional Councils and Resource Management Act facilitate transition to low-emissions food.
5. An effective rural extension programme is implemented to improve farmer training in ultra-efficient livestock production.
6. New mitigation technologies for livestock nitrous oxide and methane (e.g. inhibitors or vaccines) are approved internationally and in NZ regulations.
7. A methodology has been agreed internationally for GHG measurement on farm – to compare GHG efficiency across countries and farm systems.
8. A metric for comparing nutrition from different sources has been agreed globally.
9. Mandatory farm-level reporting of GHGs has been implemented.
10. Regulation requires specific practices – e.g. farmers have to

C. Business milestones

1. Efficiency across the curve has increased; farmers still producing dairy and sheep/beef are ultra-GHG efficient.
2. An industry group has developed practical and effective tools to measure and verify GHGs on farm.
3. Barriers to take-up of new technologies have been overcome.
4. Precision agriculture tools are widely used.
5. Milk company business models have changed from provider to value-added consumer products (value from quality not quantity).
6. Reform in the sheep-beef sector has improved coordination within supply chains.
7. Traceability mechanisms have been set up to facilitate value from low emissions.
8. Improved supply chain management has created close connections with consumers.
9. New Zealand companies are exporting expertise in low-emission technology.

D. Behavioural milestones

1. Networks and communications channels are fully utilised to share accurate information and debunk myths and misperceptions.
2. Sector conversations are held on efficiency measures and technology uptake.
3. Trust is established between government (central and regional) and the farming community.
4. New mitigation technologies for livestock nitrous oxide and methane (e.g. inhibitors or vaccines) are acceptable to consumers,
5. Consumer demand for low emissions food products (recognition of nutrient density – or other measure of nutrition) makes them profitable.
6. Herd homes are cool looking.
7. A new generation of smart export-focused entrepreneurs and marketers manages livestock value chains.

16. NZ operates an ultra-GHG-efficient livestock sector.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
	capture gas from effluent ponds (to generate energy or just flare). 11. Regulation requires that farms must meet efficiency benchmark X. 12. Regulation limits conversions to high-GHG production or places a moratorium on increasing ruminants.		

17. NZ produces zero-CH_4, low-N_2O nutrition.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
1. Real-time measurement tools are available for farmers to see the impact of their decisions on GHG emissions (and co-benefits). 2. Profitable non-ruminant land use options have been found and tested. (e.g. horticulture; crop production to feed poultry, insects or aquaculture; production of petri-protein). 3. Water quality issues with aquaculture have been solved. 4. New feasible and cost-effective mitigation technologies have been found for fertiliser use and other N_2O emissions from cropping. 5. Biosecurity issues for insect production have been solved.	1. A pricing mechanism is established to reward efficiency and discourage inefficiencies – poorly performing farmers have incentives to become more efficient. 2. Seed money is available to develop and implement alternatives to livestock production and use of nitrogenous fertilisers. 3. A metric for GHG intensity of nutrition is agreed globally. 4. Mandatory farm-level reporting of GHGs is adopted. 5. Regulation requires specific practices – e.g. fertiliser management plans to optimise timing and method of application. 6. Regulation requires that farms must meet efficiency benchmark X. 7. Regulation on land-use change is built into Council/local government planning, with mitigation	1. Efficiency of performance across the curve increases. Use of nitrogenous fertilisers is optimised. Precision agriculture tools are widely used. 2. Traceability mechanisms are set up to facilitate value from low emissions. 3. Barriers to take-up of new products and technologies have been overcome. 4. There is increased use of non-ruminant animals. 5. New industries are established for zero-methane foods (market research, etc.). 6. Improved supply chain management is applied to create close connection with consumers. 7. Capital is mobilised to change land uses. 8. Business models are developed for indigenous plantations.	1. Networks and communications channels are fully utilised to share accurate information and debunk myths and misperceptions. 2. Sector conversations are held on new products. 3. Trust is established between government (central and regional) and farming community. 4. Consumer demand for low-emissions food products (recognition of nutrient density – or other measure of nutrition) makes them profitable. 5. Industry training and universities have transitioned out of training young farmers for ruminant agriculture and into alternatives. 6. We have built capability to grow NZ's economy from primary production to clean tech. 7. Consumer diet has changed (e.g. franchised insect bars; children prefer no-methane food options).

17. NZ produces zero-CH_4, low-N_2O nutrition.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
	considerations for appropriate land use. 8. Regional Councils and the Resource Management Act facilitate the transition to low-emissions food. 9. New structures are set up to support new industries – Producer Boards (legumes, nuts, insects…). 10. National Policy Statement is implemented around bio-diverse plantation forests. 11. An effective rural extension programme is implemented to train farmers in alternative food production.	9. NZ exports expertise in low-emission food products and technologies.	8. Animal rights issues associated with new types of food production are addressed.

18. NZ reduces food waste across the chain of food production and consumption.

A. Technology milestones	B. Policy and regulatory milestones	C. Business milestones	D. Behavioural milestones
1. New technologies improve effectiveness of food preservation/refrigeration/storage. 2. Food waste can be converted into cost-effective biofuels.	1. An accord with supermarket chains is negotiated to reduce food waste.	1. Businesses collaborate to transform food supply chains to improve efficiency, match supply to demand and reduce waste. 2. Supermarkets develop programmes to reduce food waste and distribute surplus food to communities in need. 3. Businesses, schools and institutions match food supply to demand and distribute surplus food to communities in need. 4. On-farm milk waste is reduced. 5. Food waste is collected for biofuel production.	1. Consumers value food more and make an effort not to waste it. 2. Consumers don't expect supermarkets to stock large amounts of perishable foods. 3. Consumers become more willing to substitute canned/refrigerated food for fresh food. 4. Consumers eat more seasonal food which reduces need for storage. 5. Consumers are well informed about the emission impact of wasting food.

19. Consumers demand low-emission food.

A. Technology milestones

1. New technologies for food production and distribution make low-emission food readily available to consumers.

B. Policy and regulatory milestones

1. Government policies support the testing, production and distribution of low-emission food.
2. Government introduces mandatory food emission labelling.
3. Government incorporates low-emission foods into government dietary guidelines.
4. Government introduces low-emission foods into school food services.
5. Emission pricing is extended to biological emissions from food production.

C. Business milestones

1. Businesses respond to domestic and international consumer demand by investing in development and production of low-emission foods.
2. Businesses secure a market premium in NZ and overseas for low-emission foods.
3. Businesses actively promote low-emission foods (e.g. marketing campaigns, low-emission cookbooks and training courses, low-emission recipe competitions).
4. Businesses support food emission labelling.
5. Low-emission foods are affordable to consumers.

D. Behavioural milestones

1. Consumers are educated about the value of low-emission food and the choices available to them.
2. Consumers become more willing to choose lower-emission food alternatives.
3. Consumers respond to emission price incentives applied to food.