FROM FOSSIL FUELS TO LOCAL RENEWABLES

A research framework to address Aotearoa New Zealand's energy GHGs

Bio oil from pine:Scion

NERI

National Energy Research Institute

This document may be cited as:

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National Energy Research Institute, 2023

The National Energy Research Institute (NERI) is a Charitable Trust incorporated in Aotearoa New Zealand (NZ). Its primary purpose is to enhance NZ's sustainability and to benefit the NZ community by stimulating, promoting, co-ordinating and supporting high-quality energy research and education within NZ.

Its research members are GNS Science, Scion, University of Canterbury, University of Otago and the Western Institute of Technology at Taranaki, and its industry association members are the Bioenergy Association of NZ, BusinessNZ Energy Council, the Carbon and Energy Professionals New Zealand, the New Zealand Geothermal Association, the New Zealand Wind Energy Association, Ia Ara Aotearoa Transporting New Zealand, and Tourism Industry Aotearoa.

The publication has been developed in conjunction with the membership and with representatives of energy researchers, sector organisations and government agencies, and EECA kindly contributed to the cost of final editing, design, and production, but the final document does not necessarily represent any of their individual views.

The document is available on the NERI website www.neri.org.nz.

FOREWORD

Aotearoa New Zealand (NZ) has set a target of zero net Greenhouse Gas emissions by 2050 (excluding methane from agriculture) and faces further targets for international transport. Overall, the energy sector emits around two thirds of these emissions, almost exclusively from fossil fuels that are largely imported.

To eliminate these emissions, we will need to address this fossil fuel use by substituting renewables, cutting back demand, or sequestering the emissions.

As a measure of the task, fossil fuels supply nearly 70% of our energy. Addressing this will make dramatic changes, bringing significant uncertainty, costs, and disruption, going well beyond the energy sector.

But it will also bring opportunities.

The move to renewables should increase local control over energy supply and bring greater stability and resilience. It will mean increased local employment, investment, and demand for renewable resources. The latter will increase the role of Māori and help bring a more holistic approach to the sector – an opportunity to be built upon.

Further, the rest of the world will be facing the same issues and NZ has competitive advantages: e.g., our existing ~80% renewable electricity system, our temperate growing conditions, and land availability. This will mean a comparatively lower-cost transition to renewables, along with global opportunities to expand industries based on our competitive clean energy.

But we will need to address comparative disadvantages, for example our relative isolation and the difficulty in abating long-haul transport emissions, particularly aviation.

Much is already being done to address our emissions. The Emissions Trading Scheme (ETS) provides the underpinning policy, and the 2022 *Te hau mārohi ki anamata Aotearoa New Zealand's First Emissions Reduction Plan* (ERP) seeks to accelerate the pace of the ETS and address social and environmental impacts not able to be addressed by it, including empowering Māori knowledge and resources.

But the ERP's focus is primarily short term.

There remain a set of issues that are intractable and uncertain in the medium-term. These will require medium-term applied research to address, and while the ERP recognises this, it provides limited guidance on priorities for investment.

To take this the next step we have developed priority areas requiring uniquely NZ energy research investments. This provides mission-led energy research priorities as foreshadowed in *Te Ara Paerangi Future Pathways White Paper 2022*.

This Framework sets out these priority areas along with their rationale.

AT A GLANCE

Fossil fuels supply 70% of our energy (including international transport), but generate virtually all of the sector's GHGs and two thirds of NZ's total non-biogenic net GHGs.

Thus, our target of net zero GHG emissions by 2050[1] means we have to address this energy sector fossil fuel use, along with any future growth.

This Framework sets out the areas of medium-term applied research needed to achieve this, to maximise opportunities, and to minimise negative impacts.

IMPACTS OF NET ZERO EMISSIONS

We have three ways to address our fossil fuel emissions: adopt clean substitute fuels, cut fossil fuel demand, or directly sequester the GHGs.

We will need to address all three. In doing so we will completely reshape our energy supply chains and our energy intensive sectors. We will shift from importing energy to local production.

This means major changes over the next thirty years. They will touch us all, our economy, our people, and our natural and physical environment. Māori will be significantly impacted having tino rangatiratanga over key resources and taonga.

Managing this transformation will require innovative approaches and significant long-term investment in a very uncertain environment. Achieving this will be enhanced by te ao Māori.

CHALLENGES & OPPORTUNITIES

The Challenge then is to achieve the required emissions reductions while minimising the adverse impacts and exploiting the positive ones.

The Emissions Trading Scheme (ETS) should ensure the target will be met, but not guarantee the lowest impact pathway to it is found. Well-designed and informed public policy can help us do better, while poor policy can make things worse.

Accordingly, there is extensive study required into the challenges that lie ahead, how best to respond, and the interventions that might assist.

The Opportunities are less often discussed, but the rest of the developed world will be facing similar or even more drastic change. In many areas we will be comparatively better off.

This will produce new competitive advantages for us to exploit.

ROLE OF R&D

Targeted medium-term R&D and mātauranga Māori are needed to underpin this policy work, as well as to inform businesses, government, iwi, and our communities as they adapt.

This will involve researching energy, fuels and their supply, and the impacts of change. It will inevitably be more applied than our current public good energy RS&I investments and sits in an investment gap acknowledged by the Government[2].

Many of the technologies needed will come from overseas, with the local effort focusing on adaption and application.

But some technologies will need to be developed here to meet unique or priority local needs, and many of the impacts on our energy sector and society will be unique. Local applied research will be needed here. Mātauranga Māori has unrealised contributions to make, particularly on sustainability.

This Framework prioritises the difficult areas, where the impact or change will be significant, and unique local R&D is required.

OUR FOSSIL FUEL SECTOR

Medium-term research will take until the 2030s to have major impacts. This, and the general uncertainty, argues for focusing on areas of significant fossil fuel use.

A small number of sectors account for ~85% of our fossil fuel use[3]: Transport, 54% (282PJ); Industry, 22% (113PJ); and Electricity, 10% (55PJ).[4]

Within these sectors the main drivers are Road Transport, Aviation, the Food and Chemical Industries, and Electricity Generation.[5]

These are the key targets for this Framework.

OUR SITUATION

Several strategic supply and demand issues influence our ability to address these targets:

Clean fuel supply

- The proportion of our electricity that is clean is high internationally. But above 95% renewable, electricity becomes increasingly expensive.
- This aside we have reasonably affordable ways to expand clean electricity generation, displacing fossil fuels in industry and short haul transport. Our hydro reduces the impact of intermittency.
- We also have a significant supply of biomass that already underpins thermal loads in industry, and this too can be grown affordably.
- Clean fuels for long-haul transport are typically 2-3 times more expensive than fossil fuels at today's prices. The best options are unclear.
- Drop-in fuels, e.g., biofuels, are the likely, if more expensive, solution for long-haul planes and ships, at least through the 2030s.

Fossil fuel demand reduction

- Transport demand reduction from vehicle efficiency gains and better infrastructure will be on-going, encouraged by the ETS and shorter-term initiatives. Public transport and urban form help achieve other goals but are limited in their impact on fossil fuel use on these timescales.
- More significant medium-term reductions in longer-haul transport will come from improving our relatively inefficient logistics, intelligent vehicles, and the use of virtual interactions. NZ is strong in key relevant capabilities.
- Global preferences for clean products and services will shift our industrial investments towards clean energy use, exploiting our relatively low-cost clean electricity and biomass.
- The additional costs of clean international transport and our isolation puts us at a relative disadvantage in trade in goods. Weightless value chains (services) will be attractive.

THE CONSEQUENT RESEARCH THEMES

This then translates into key challenges for our medium-term applied energy research:

Develop the supply of clean fuels where significant increase in demand is anticipated

De-risk the scale up of:

- *Clean electricity supply for short-haul transport and industry. The key issues are electricity system stability and expanding lower cost supply from geothermal and offshore wind.*
- *Biofuel supply for industry, long-haul marine, and aviation. A key issue is growing a new industry converting biomass to both gaseous and liquid fuels while reducing costs.*

Opportunities: NZ's comparative advantage in clean electricity; early availability of near 100% clean electricity; growing geothermal; and a new bioenergy industry. A resilient clean energy supply.

Clarify the fuel options for long-haul land transport and their implementation in NZ

Increase our fuel options and de-risk their uptake: i.e., better batteries and charging; electro-fuels (e.g., hydrogen); biofuels; hybrids; and fossil fuels with Carbon Capture, Use, or Storage (CCUS).

Reduce the demand for long-haul transport

Apply emerging technologies and behaviour changes to target demand, develop weightless alternatives, and improve the efficiency of logistics.

Opportunity: To exploit these advances internationally, e.g., low-cost virtual tourism.

Develop clean/low energy industries

Support shifts to industries that have low energy intensity or add significant value to clean energy.

Opportunity: To grow our economy and trade.

Address the major wider impacts

Identify and address the major cumulative wider economic, work force, social, cultural, and environmental impacts of cutting fossil fuels.

Empower te ao Māori in addressing energy GHGs

Enable the contribution of Māori knowledge, resources, and people to research that addresses sustainability and economic opportunities to Māori.

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1. INTRODUCTION

This Framework sets out the medium-term, public good, energy research investments needed to help NZ achieve its target of zero net emissions of GHGs by 2050.

It sits alongside NERI's 2017 Energy Research Strategy for New Zealand: The Key Issues[6] but goes into much greater detail on GHG emissions.

Table 1: Fossil Fuel Use in NZ 2019 PJ

Sector	Domestic	International	Total	
Industrial	113		113	22%
Transport	212	70	282	54%
– petrol	98		98	19%
– diesel	95	2	97	19%
– fuel oil	4	12	16	3%
– aviation	15	57	71	14%
Primary	23		23	4%
Commercial	20		20	4%
Residential	27		27	5%
Electricity	55		55	10%
Total Fossil Fuel	**450**	**70**	**520**	**100%**

ENERGY GHG EMISSIONS

In 2019 the energy sector produced two thirds of New Zealand's net emissions[7 8].

While our need is to cut emissions, fossil fuel use[9] generates 98% of energy GHGs[10 11], is better understood, and can be more directly managed.

We therefore focus on fossil fuel use in the balance of this Framework.

Table 1[12] highlights the significant users[13]. **Transport** dominates (54%), followed by **Industry** (22%), and **Electricity** (10%). The Primary, Commercial and Residential sectors' fossil fuel use is relatively minor.

Within these main sectors there are seven subsectors that dominate: **Cars/SUVs** (20%); **Utes/Van**s (8%); **Trucks** (10%); **Aviation** (14%); **Food processing** (8%); **Chemicals** (8%); and, as noted, **Electricity** (10%)[14].

IMPACT OF EXISTING POLICY

We have three ways to reduce these emissions: adopt clean substitute fuels; cut fossil fuel demand; or directly manage the emissions.

New Zealand's main tool for encouraging these is the Emissions Trading Scheme (ETS)[15]. Capped tradable rights to emit are used to progressively reduce emissions to net zero.

As the cap is lowered the cost of emitting increases, making alternatives more attractive. This encourages emitters to find the least cost way to reduce the country's exposure to fossil fuels.

But other initiatives are needed to secure equitable outcomes, overcome barriers to change, and encourage longer-term innovation.

The Government's Emissions Budget to 2025[16], and the supporting Emissions Reduction Plan (ERP)[17] set out its initial additional policy package to help achieve net zero by 2050.

The next chapter expands on this policy work to put this Framework in the wider New Zealand context.

What it shows is the current policy focus is on achieving an immediate, 2020s, impact. This leaves persistently hard-to-abate uses.

We need to identify these uses to establish where to invest to address the 2030s and beyond.

THE HARD-TO-ABATE USES

A number of studies estimate the fossil fuel use likely to be remaining in the 2030s and beyond. Two that go into the necessary detail are:

TIMES-BEC[18] that projects NZ's fossil fuel use and emissions on two sets of assumptions. Using the average of its two scenarios this shows fossil fuel use by mid-2030:

- In transport dropping 9% overall, but with aviation growing 35% and the balance falling more significantly.

- Reducing to zero in dairy, but with other food production not changing. Use in methanol production depends on plant closing dates.
- In electricity generation dropping 75%.

A Ministry for the Environment study on estimated 2030 GHG abatement costs[19]. Using greater than $100/tCO2-e in 2030 as a guide to the difficult-to-abate uses, this study:

- Confirms short-haul land transport is able to be addressed, but long-haul land transport, marine and aviation remain difficult.
- Suggests all food processing emissions can be abated, but methanol and urea depend upon plant closures.
- Anticipates only ~4% of electricity generation remaining as fossil fuels.

These results lead to the broad conclusion that longer-haul transport is the major issue.

In addition, targeted R&D will be required to address:

- How to significantly increase the supply of affordable clean fuels.
- Areas where demand management might contribute.
- Managing the impacts of change and developing the contribution from Māori.

There will also be opportunities that arise for New Zealand from these changes, and these will require R&D support.

BALANCE OF FRAMEWORK

Chapter 2 looks at the policy context, and building on that, chapter 3 the role of te ao Māori in unlocking the potential contribution of Māori knowledge, resources, and people.

Chapter 4 expands on the research needed to ensure an affordable supply of clean fuels, with the transport and industrial sectors particularly in mind.

Chapter 5 focuses on the most intractable sub-sector – long-haul transport – understanding the clean fuel options, and opportunities for demand reduction.

Chapter 6 looks at the issues for the key industries and the wider opportunities that arise.

Finally, chapter 7 addresses three of the key economic, work force, social, and environmental impacts from the transition.

CLEAN FUELS VS REDUCING DEMAND

In what follows we will look at clean fuels and demand reduction somewhat separately, but both can address the emissions from the same source. To find the optimum solution they need to be considered together.

An example that shows the risks in not doing this is emissions from short-haul trips. These can be reduced by switching to clean fuels (EVs) or by changing land use/urban form.

The ERP focuses on the latter despite the evidence that this will be expensive and take time, while switching to EVs will address the same emissions more quickly and at lower cost[20 21].

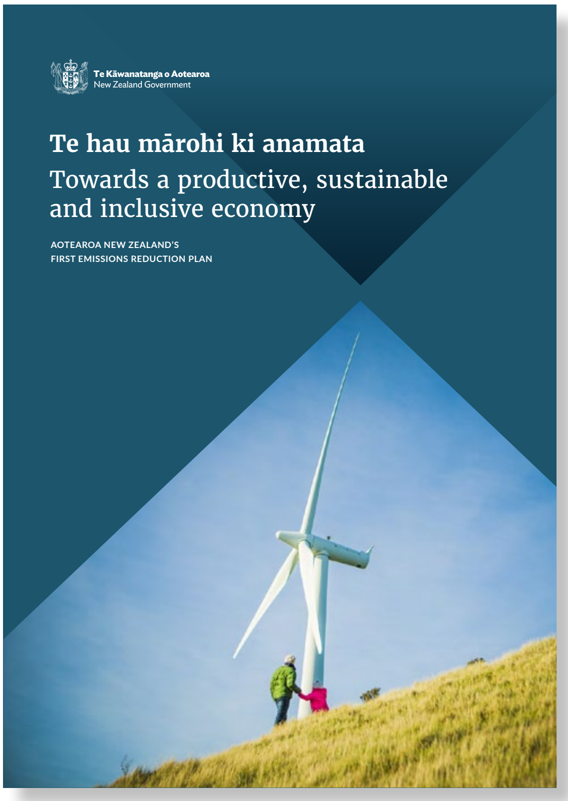
The cost effectiveness of all the options for addressing any particular source of emissions should be integral to any research.

2. THE POLICY CONTEXT

The core of the policy response to fossil fuel emissions is the ETS. Its simplicity is attractive but other concerns remain.

"Additional policies are needed to secure equitable outcomes, overcome barriers to change … and coordinate research and investment at the frontier of innovation"[22]. Thus, other initiatives are needed, but not so they compromise the strengths of the ETS[23].

The ERP provides the immediate framework for those initiatives.



THE EMISSIONS REDUCTION PLAN

Underpinning the ERP is a large and growing body of reports, with the Climate Change Commission being a major contributor[24 25]. Many directly address energy[26].

However, the need for the ERP to address the 2025 timescale means its emphasis is on policies able to be quickly adopted with immediate impact. This has favoured direct regulation targeting specific energy resources and energy users.

But as the ERP headlines *"Research, science, innovation and technology make a low-emissions future possible"* adding the *"Climate Change Commission … identified innovation as one of three key pillars for reducing emissions and highlighted the importance of prioritising low-emissions research, science and innovation to our transition. [It] recommended the development of a number of longer-term research related actions to support emissions reductions"*.

It committed to two actions – to develop climate innovation platforms and to reorient existing programmes to address climate change.

It is, however, light on specific R&D priorities, appropriately noting these will need to derive from the particular sectors' needs and challenges, i.e., sector strategies[27].

The ERP does include the following targets for action that implicitly will require research:

- Heavy transport and freight emissions;
- Decarbonising aviation and marine transport;
- Ensuring the electricity system is future proof;
- Developing low emissions fuels, particularly biofuels and hydrogen.

Strategy development is a theme of the ERP. Those that are energy related include:

- A Māori climate strategy and action plan;
- An equitable transitions strategy;
- Circular economy and bioeconomy strategy, and a new waste strategy;
- Transport strategies for public transport, EV charging, and for freight and supply chain;

- An Energy Strategy and a renewed NZ Energy Efficiency and Conservation Strategy.

Some of these strategies are well described in the ERP, but others, particularly the Energy Strategy, are just beginning. Its Terms of Reference have been released[28] but its timeline runs through to 2024. Initial work suggests a scenarios/pathways approach is being followed, but this will tend to mask the uncertainties and risks that are central to identifying research needs.

Energy related subsector strategy work is being produced, e.g., Offshore Wind, Hydrogen[29], Biofuels[30], infrastructure requirements (e.g., the NZ battery project[31], work by the Infrastructure Commission[32]), Freight[33], and Digital Technologies[34].

But any such work needs to be within a framework that covers overall fuel demand, alternatives, and the risks and uncertainties. This is needed to properly address the full range of options and establish relative priorities for action.

RESEARCH STRATEGIES

Even less common is work on the R&D required to underpin these strategies, such as Scion's biofuels research roadmap[35] and NERI's 2017 Energy Research Strategy for New Zealand: The Key Issues[36].

The Government's White Paper Te Ara Paerangi – Future Pathways 2022[37] identifies the weakness in energy research funding, commits to addressing that, but most important in the context of this Framework, identifies the need for mission-led research priorities to inform that investment.

This Framework directly supports the White Paper by addressing what it identifies as one of the likely priorities, *GHG reductions*. Further, it has involved the key stakeholders in its development and seeks to establish processes to develop Māori priorities and the role of mātauranga Māori.

We have identified the key areas to target – transport, industry, and electricity supply.

We address the major drivers of intractable fossil fuel demand, the implications for fuels and energy resources, the opportunities, and then the wider economic, social, cultural, and environmental impacts.

In particular we address the issue of te ao Māori in the next chapter and identify where Māori interests are significant throughout the balance.

The Framework will provide the basis for NZ to address the more difficult medium-term issues in moving to a low GHG energy sector.

3. TE AO MĀORI

Mai i te kore, ki te ao mārama

From potential to the world of understanding

As kaitiaki, knowledge holders, knowledge creators, resource owners and investors, Māori will play a significant role in reducing GHGs from energy.

Because Māori are more reliant on natural resources than many others, they will also be more exposed to this transition (both positive and negative).

OUR UNIQUE FRAMEWORK

Te taiao

Through whakapapa, whānau, hapū and iwi connect to land and resources. Historic and local knowledge assist in understanding the cultural and spiritual connections of people and the land. Through this intimate and long-term connection with natural resources, sustainable and successful use and innovation has occurred.

Any innovation therefore requires working closely alongside mana whenua, recognising the knowledge held by communities who are connected to our energy resources.

Oranga whenua, oranga tinana describes the interconnected relationship between the natural environment and people's health. Te taiao reflects the waterways, forests, biodiversity, native species, ecosystems, and the connection of these elements to the health of people.

Ensuring the health of these connections is our responsibility as kaitiaki and custodians, and ensuring energy research supports the health of te taiao will underpin this.

Mātauranga Māori

Mātauranga Māori helps create options to realise new ways to harness our natural resources. It also provides cultural innovation through the design of mauri models and frameworks that guide how to sustainably manage resources[38].

Mātauranga Māori can enrich research by acknowledging a systems-wide view that recognises the interconnection between the physical, spiritual, and social realms that Māori have with the natural environment. This incorporates a wide range of concepts founded on traditional knowledge.

Thus, empowering Mātauranga Māori has become a cornerstone consideration for future research within Te hau mārohi ki anamata (the emissions reduction plan). This extends to this longer-term energy research Framework to address GHG emissions.

By Māori, For Māori, With Māori

Investing to support Māori trained researchers can empower a co-innovation approach. Building Māori capacity within energy research enhances Māori as the beneficiaries of research, using a "By Māori, For Māori approach". Māori research capacity supports iwi, hapū and whānau as knowledge holders, policymakers, and enablers of collective and environmental wellbeing.

Integrated knowledge systems

The Research, Science, and Innovation (RSI) system has increasingly recognised mātauranga Māori. The growth of the Māori economy, the assertion of rights and interests in natural resources and an increased presence in education and research have led to more partnered approaches between tāngata whenua and the RSI system, with social, ecological, and economic benefits to Aotearoa.

Among other benefits, a partnered approach with iwi/Māori enables the evolution of new frameworks for scientists, researchers, other interested groups, and Māori to work together.

Developing these frameworks and incorporating mātauranga Māori into research programmes are key goals. The partnership approach presented in Figure 1 will help achieve this.

The approach recognises the relationships that Māori have with their natural environment. It positions the ecosystem as a co-design tool for future research design.

Solutions will balance the various components of the partnership approach to ensure that mutually beneficial outcomes are derived from the research programmes.

PARTNERSHIP APPROACH

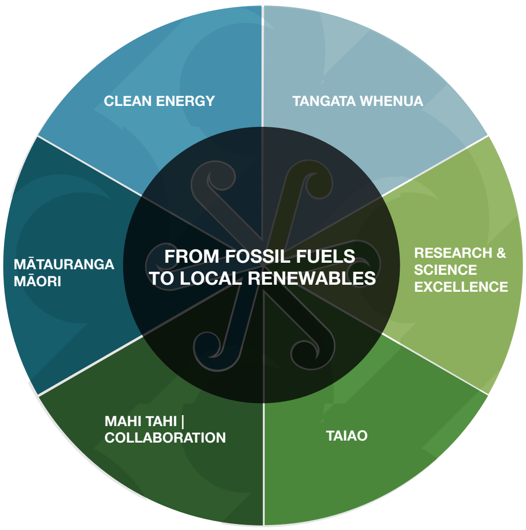


Figure 1: Partnership with Māori

The objectives for each of the components are:

Component	Objectives
Mātauranga Māori	Unlocking the potential of Māori knowledge, resources, and people by putting tikanga as a foundation for the future circular economy.
Research & Science Excellence	Ensure the research, science, and innovation sector continues to build its reputation as leaders in renewable industry science and innovation
Tangata Whenua	Recognising the role of tangata whenua as having kaitiakitanga obligations over their land and natural resources, and that a partnered approach empowers tangata whenua to exercise this.
Mahi Tahi | Collaboration	Giving effect to a relationship-based approach to work with other organisations, including science services/providers and commercial partners to serve the interests of both parties; and assist in the building of critical capabilities.
Taiao	Protection and enhancement of the natural and built environment and ensure the resilience of ecosystems, people, and communities
Clean Energy	Transitioning from fossil fuels to local renewables to produce economic and social wellbeing while minimising negative environmental impacts.

CRITICAL CAPABILITIES

To achieve this, we will need to continue to build the capabilities in mātauranga Māori and te ao Māori in NZ's energy researchers and lift the numbers of Māori scientists in the RSI system.

Creating a talent pipeline will ensure a strong contingent of Māori scientists to lead the long-term aspirations of the Māori and science ecosystem to address the changes in the energy system.

There are significant resources and assets owned, managed, and protected by Māori, or resources in which Māori have an interest. These may be managed by an entity, controlled by one or more iwi, hapū, or whānau, or managed or protected by a non-business entity of the iwi or hapū.

These resources will become increasingly important as we transition to local renewable energy, often presenting significant opportunities. Māori are already actively partnering and investing alongside universities, research institutes and commercial partners in relevant programmes, and this will need to increase.

There will also be the unique needs of iwi, hapū, or whānau when faced by the changes in the energy system. Māori organisations will need to be empowered to gain access to research to support this transition.

Strong and enduring relationships founded on mutual partnership objectives with Māori will allow future opportunities and research agendas to be co-developed.

PRIORITIES

Priorities will be determined by whānau, hapū, iwi and Māori landowners. Kaupapa Māori research and research methodologies will enable Māori research priorities and outcomes to be embedded in broader research agendas.

We have identified where the key targets for research developed in this Framework have a particular strong Māori emphasis, and some more specific key priorities for Māori may include:

- *Build capacity for Māori participation in the energy sector at all levels;*
- *Enable iwi/Māori communities to identify and provide for their own energy needs;*
- *Recognise the importance of relationships between Māori, government and industry*
- *Collect high-quality information to better inform Māori policy and research and focus on broader outcomes; and*
- *Foster and support Māori energy workforce development.*

SUMMARY THEME

Te ao Māori

Enable the contribution of Māori knowledge, resources, and people to research that addresses sustainability and economic opportunities to Māori.

4. THE SUPPLY OF CLEAN ENERGY

The clean energy available to supply the Transport and Industrial sectors are: bioliquids, clean gases, electricity, direct use of geothermal, and biosolids (Figure 1).

These fuels by-and-large require biomass, hydro, solar, wind, and geothermal as feedstocks. Significantly increasing their availability at relatively low cost is fundamental to displacing NZ's fossil fuel use.

Coupled with this will be the need for efficient technologies to convert these feedstocks to clean fuels, and address fuel storage, distribution, and use.

FUELLING THE 2030S AND BEYOND

NZ will require a significant increase in the volume of clean fuels, both to get to the 2030s and to address what might be needed beyond.

On the face of it we might need to triple our clean energy production to replace current fossil fuel use. But electricity supply chains can be significantly more efficient than fossil fuels – e.g., more than two times in EVs[39], so actual demand will be significantly less than this.

Some fuels will be able to be imported, but by and large we are contemplating a major shift to domestic production[40].

The ERP sets a target for 50% of total final energy consumption to come from renewable sources by 2035. The most aggressive TIMES-BEC scenario is at 43%, but the marginal abatement cost analysis suggests the ERP target should be achievable.

This suggests our research investments today should be looking beyond the ERP, either to accelerate its achievement, reduce its cost, or de-risking what comes next.

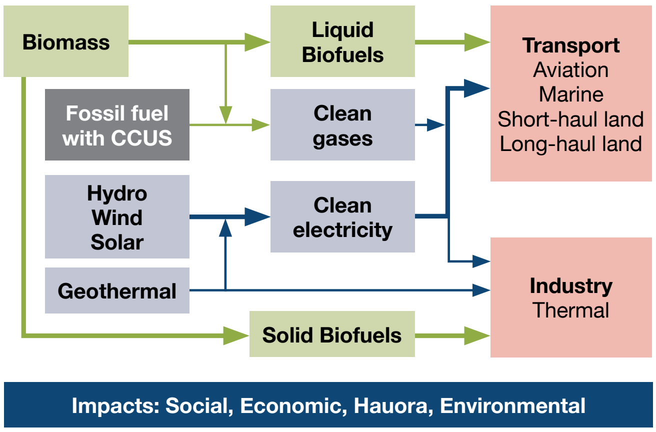
In what follows we look at how to increase the supply of the key clean fuels for the Transport and Industrial sectors[41].

ELECTRICITY

Electricity is one of NZ's most important clean fuels and will need to grow significantly both to cover growth in demand and to replace fossil fuel, primarily in transport (EVs).

NZ's relatively unique mix of hydro, solar, wind, and geothermal should meet the projected growth in demand, and most fossil fuel generation can be replaced reasonably cost competitively under BAU (but getting completely to zero is projected to be very expensive[42]).

Figure 2: Potential clean energy value chains



In this, NZ has a significant advantage over most other countries that lack renewable base load (geothermal) and seasonal storage (hydro). Grid stability will be much more of a problem for them.

By 2035 on the average of the TIMES-BEC scenarios demand for electricity grows ~130% from 150 PJ. Fossil fuel use drops to ~3% of electricity generation.

Transpower's modelling suggest a slower increase in demand, but unlike the Kea TIMES-BEC scenarios has Tiwai Point closing[43].

Scoping the implications of this and subsequent growth is the subject of ongoing work, e.g., by Transpower[44] and others, but new, "smart", technologies, and the relative uniqueness of the NZ system raises issues that will still need beyond-BAU research. Some of this is underway[45].

*Ongoing research is needed into the impacts of demand growth, new technologies, and alternative fuels on NZ's **electricity system**.*

Examples, reflected in the ERP, include the stability and reliability of the overall system; its performance as it grows; the impacts of increasing distributed resources including generation and storage; and the use of alternative fuels.

On the various current projections geothermal and hydro generation are not projected to grow, but wind grows significantly off a low base of 10% to a third of the generation, and solar grows but still remains under ~1% of generation.

Research investments need to target ways to affordably increase the use of all these resources at lower cost and/or impact than is currently being assumed in these projections.

Hydro

Hydro is a valuable resource particularly for seasonal storage. While there have been reports looking at the potential to grow hydro generation the general conclusion has been that any significant opportunities for growth are limited in the medium-term by location, land use considerations, and competitiveness[46].

Consequently, at this stage there is limited need for significant additional uniquely NZ research into the potential for hydro growth.

However, the hydrological cycle brings a dry year risk with hydro use. This is currently serviced by fossil fuels. The difficulty in finding an alternative low-cost renewable solution is one example why complete elimination of fossil fuels is so expensive[47].

The direct contribution to GHG reductions of replacing this last fossil fuel use in electricity generation will be small. But stable growth of the electricity supply, including greater intermittency, does need to be addressed.

Long-term storage is one option and pumped hydro can provide this, particularly if it can bring other benefits to help reduce its cost. One major option, Onslow, is the subject of significant policy work as of today, and this work includes other hydro and non-hydro fuelled alternatives[48].

Some of these alternatives will require beyond-BAU research, e.g. fossil fuels with CCUS, biofuels[49] with or without Bio-energy CCUS (BECCUS)[50], and managed load shedding or flexible demand, and these are discussed elsewhere in this chapter.

Solar

Technology improvements have been reducing the cost of utility solar faster than large scale wind[51], although both are levelling off[52].

The TIMES-BEC scenarios show Solar making limited contribution by the mid-2030s but growing rapidly after that. Transpower projects even more significant growth in Solar, and emerging commercial interest has been higher still, although the extent to which that will emerge has been questioned[53].

Notwithstanding Solar faces no obvious barriers that require uniquely NZ research, apart from the issue of integrating this increase into the grid and some possible land use issues that might arise.

There are potential developments that could change the possible applications of PV, and with that lead to novel impacts in NZ[54]. This should be monitored and may eventually lead to research into their application in NZ.

Wind

Wind is a strength in NZ given our high capacity-factor. It is seen as the significant contributor to servicing the growth in electricity demand in both TIMES-BEC and Transpower scenarios.

Onshore wind is well understood, but offshore wind is a potential option[55] with investors locally studying feasibility at the scale of 1 GW[56].

*Research is needed into the **deployment of wind in NZ's offshore environment**, the impacts, and its integration into NZ's energy system.*

Examples include the geotechnical suitability of the seabed, the use of the sea and seabed and, the relationship with Māori interests, detailed wind modelling, and transmission issues.

Geothermal

NZ is one of a relatively small group of countries using geothermal at scale, and our resource has unique characteristics. Any developments apart from the technology for final thermal electricity generation will likely require NZ based research.

Geothermal is not seen as having a significant role in electricity generation growth in the TIMES-BEC scenarios. This is due, as Transpower notes, to its relatively high cost and GHGs emissions, notwithstanding its high availability factor (~90%) versus wind (~40%) and solar (~20%).

However, Transpower further observes this is not consistent with the ongoing commercial interest being shown in investment[57].

Transpower suggests this is because the costs are overstated for a number of reasons: geothermal plants have twice the lifetime of wind and solar; the potential to continue to use the heat elsewhere after it is no longer useful for generation is not being recognised; nor is the potential to cost effectively avoid CO2-e costs by reinjection[58].

The last is supported by the Ministry for the Environment's marginal abatement analysis.

Addressing these problems will lower the cost of NZ's clean electricity supply, help improve system stability, and with that getting to net zero.

The use of geothermal energy outside electricity generation is more limited and this declines in the scenarios. This is also for these cost reasons, and opportunities in direct thermal uses should therefore also be in scope.

*Research is needed into lowering the cost of **developing existing geothermal resources and expanding the available resource base**, and the wider impacts and opportunities for growth.*

Examples include difficult to access resources, making use of supercritical resources, use where base load demand is at a premium, and lower temperature geothermal.

Māori have a unique relationship with geothermal systems, including ownership of resources. These will need to be included.

BIOFUELS

Biofuels are the other major group of clean fuels[59], and can be solid, liquid[60], or gaseous.

These are produced from sustainable biological feedstocks, predominantly: wood and wood processing wastes; energy crops including algae, agricultural wastes[61]; and biogenic solid wastes including manure and sewage.

They are converted to energy through four basic processes:

- direct combustion to heat;
- thermochemical to the full range of fuels e.g., pyrolysis, hydrothermal, thermal gasification;
- chemical, e.g., transesterification of fats and oils, largely to biodiesel; and
- biological, e.g., fermentation to ethanol, and anaerobic to biogas.

These core processes generally require preparation of the raw material and typically the crude products need subsequent upgrading[62].

The most relevant to NZ's resources are:

Direct combustion

Direct combustion of waste wood is a mature technology and is used as the primary fuel in the wood processing sector. As such, it supplies close to a quarter of all NZ's industrial energy use.

TIMES-BEC shows 30% growth to 2030 reflecting its BAU expansion for low and medium-grade process heat, e.g., in the food industry.

The MfE marginal abatement analysis confirms a significant role for biomass in industrial heat alongside electrification.

Subsidised conversions of industrial boilers to biomass are already occurring. Breakeven for replacing end-of-life assets with biomass is expected in a few years[63].

The need for NZ specific beyond-BAU research is limited, although there are applications that can require specialist products from biomass[64].

Biological conversions

Biogas, predominantly from anaerobic digestion of organic wastes is a mature technology in NZ with capacity for modest but useful expansion under BAU[65,66].

New opportunities to add value to the platform of NZ's existing agricultural and food industries may emerge, and these warrant monitoring.

Chemical conversions

Transesterification has been used to produce biodiesel from tallow in NZ. But in the face of international competition and the price of tallow, the plant was hibernated and recently closed[67].

A risk with these feedstocks is demonstrating that their use is not competing with food production. This limits significant growth in their use[68].

Thermochemical conversion

The limitations on organic wastes and fats and oils as feedstocks points to the need for much higher volume feedstocks to address NZ's energy GHGs.

Wood waste and energy crops, possibly supplemented by algae, are much less constrained feedstocks in NZ[69], and internationally thermochemical processes are the most mature approaches to converting these to fuels in volume.

As the IEA notes[70]:

- Fast pyrolysis is proven at commercial scale with worldwide capacity expanding while hydrothermal liquefaction is just emerging at commercial scale[71]. The outstanding issue is pre-treating the biocrudes to produce finished fuels from existing refineries[72].
- Thermal gasification of coal is a mature technology for the production of hydrogen and finished fuels. Its application to biomass is still at the demonstration stage, but there are several commercial scale projects internationally in the pipeline.
- While the average cost of these biofuels is 2-3 times that of fossil fuels, this could decline up to 30% over the next decade.

Thermochemical conversions can produce high volumes of near drop-in replacements for fossil fuels. This means they may work with existing vehicles and fuel distribution systems.

This advantage is significant for long-haul aviation and marine, and possibly long-haul land, making them the least-cost clean fuels through to the mid-2030s at least[73].

However, **they will still be more expensive than fossil fuels at recent prices**. But if fossil fuels remain at existing prices, CO2-e prices continue to rise, and expected reductions in the cost of thermochemical biofuels occur, the latter will be competitive in these markets over the next decade. Forecasts suggest this outcome will occur[74].

Regulation is mandating biofuel use regardless of price, e.g., NZ's deferred Sustainable Biofuels and the Sustainable Aviation Fuel (SAF) Obligations, international efforts by ICAO and IMO, along with other initiatives[75].

This uncertainty in demand, our options, and how to manage them are matters for ongoing research. But regardless it is likely thermochemical biofuels will be significant in NZ's future clean fuel mix[76].

This implies the likelihood of significant growth in the demand for suitable feedstocks and fuels coming off a zero base.

The increasing use of waste wood for industrial heat loads will add to this demand, as will the likely expansion of demand for biochemicals and industrial feedstocks from similar processes[77].

This demand will translate into demand for land and related resources. This is an area of significant importance and opportunity for Māori.

NZ's particular exposure to long-haul transport (see chapter 4), the availability of suitable land[78], and a temperate climate means that NZ has reason to be at least a "fast follower" internationally, if not a leader, when it comes to liquid biofuels.

> *Research is needed into **biofuels from thermochemical conversions**, including the potential demand; feedstocks; barriers to significant sustainable growth; and reducing costs.*

Examples include using thermochemical processes with NZ's feedstocks, making the fuels fit-for-purpose and competitive, and optimising supply chains from feedstocks through to fuels.

Māori have a unique relationship with these resources, including extensive ownership. Again, addressing these interests will be essential.

This R&D will support the ERP initiatives to investigate low-emissions energy supply options from bioenergy.

CLEAN GASES

Clean gases can be derived from biomass, electricity, and fossil fuels with CCUS. For example, clean hydrogen can be produced from all these sources.

Clean gases barely feature in either of the TIMES-BEC or the Vivid projections[79], even out to 2050[80]*. This reflects the assumptions these* studies made on their limited use in industry (particularly high-grade heat), and longer-haul transport.

These assumptions are uncertain, and the potential fuels are not just limited to hydrogen. Beyond-BAU research is needed into their potential in NZ, particularly in comparison with other clean fuels.

> Research is needed into the ***options for clean gas production*** (e.g., ammonia, hydrogen, biomethane), including access to affordable feedstocks, their potential to grow, and conversion technologies.

Examples include using NZ's resources e.g., renewable electricity, gasification of NZ's forest residuals; improving conversion technologies; and their competitiveness.

Again, this will be informed by the ERP's initiatives on clean gases, including the roadmap for hydrogen.

BECCUS AND CCUS

Mitigating GHG emissions by using BECCUS and CCUS opens up a wider range of potential feedstocks for clean fuels and can lower the cost[81]. The options for doing this can be country specific.

Near commercial technologies favour processing concentrated GHGs and doing this at scale. They therefore work best for large-scale operations, e.g., industrial fossil fuel users or users of biomass (creating a GHG credit); or converters of dirty feedstocks to clean fuels.

The NZ geothermal industry routinely uses reinjection to achieve Carbon Capture and Storage (CCS) and has the ability to increase this with rising CO2-e prices. Geothermal fields have been suggested as a potential BECCUS sink when biomass is used to enhance geothermal generation.[82]

There are other CCS developments in NZ, e.g., using our rich sources of magnesium silicate that could potentially assist this effort.[83]

Ara Ake has published a recent review of the need for CCS in NZ and possible future applications[84] and includes a discussion of the impact on Te Ao Māori.

This review goes beyond energy use into wider industrial processes (e.g., where fossil fuels are used as a reductant in iron sand and aluminium smelting). The MfE marginal abatement study shows there are just a small number of these, but they have high costs of abatement, the emissions are significant[85], and similar technologies are needed for CCUS.

Therefore, we should extend consideration of CCUS in energy use to include these industrial processes.

Internationally there are reviews identifying the potential research challenges in CCUS, and these coupled with the Ara Ake review define a beyond-BAU research programme for NZ.

> *Research is needed to **extend CCUS in NZ** to more widespread use in geothermal extraction, and to its potential in large-scale BECCUS and industrial processes, thereby helping to reduce a barrier to emissions reductions.*

Examples include extending CCUS to wider and novel uses in geothermal, our mineral endowments as sinks, and the potential for BECCUS in our wood processing industries.

OPPORTUNITIES

Clean electricity

NZ has comparative advantage in the developed world in its percentage of renewable electricity[86], and in expanding this at relatively low cost[87].

Because we will be very early to a nearly 100% renewable electricity system, NZ will build up knowledge that can be exploited internationally. This extends into the design and operation of new types of users e.g., EVs (see chapter 4).

A further opportunity is trade in clean electricity-intensive goods and services. This is being considered[88] but more in the context of electricity surpluses created by possible shorter-term industry closures.

Looking beyond that there may be systemic advantages for NZ in a world where a premium is placed on products and services that have a low emissions profile. This is discussed further in chapter 5.

> *Research is needed to better understand where the opportunities lie from our potential advantages in producing clean electricity, and the risks.*

The priority here is research into the relative value of direct export of clean fuels compared with adding value to it in NZ before export.

Geothermal

NZ is one of a small number of countries with experience in geothermal energy, and this has already led to international commercial opportunities[89]. With wider international interest in this source of energy, these opportunities are likely to expand, supported by the research into expanding low-cost supply in NZ.

Biofuels

While NZ's temperate climate will give some advantages in the production of biofuel feedstocks, these are unlikely to offer more than a lower cost pathway to supplying our domestic demand for clean transport fuels. This is discussed further in chapter 6.

However, we will be seeing the emergence of a new biofuels (and biochemicals) industry over the next decade, substituting for imported fossil fuels.

This will mean significant opportunities for resource development, employment, skills development, capital inflows, investment in infrastructure and secondary industries. It will also have environmental and social impacts.

Much will be undertaken by private interests, but public investment in research will be needed to scope the opportunities and ensure the necessary resources are available and appropriately developed.

This industry offers significant opportunities for Māori interests. Māori currently own nearly 40% of the commercial forestry plantations and hold large areas of other potentially suitable land for feedstocks. Iwi also bring access to capital to help develop the infrastructure, so that Māori are well positioned to build this new industry.

To achieve this will require relevant research, including the application of mātauranga Māori to help ensure the long-term social and environmental sustainability of the rohe.

Research is needed to de-risk the development of a new biofuels industry, better understanding where the opportunities lie, and the risks. Māori interests will need targeted relevant research.

An early example of the research required is the extension of the work already underway on the "The Forestry and Wood Processing Industry Transformation Plan"[90] into bioenergy.

Resilience

The shift to more distributed energy production, both electricity and biofuels, and the reduced dependence on international sources of energy, over time will make the NZ system more resilient to shocks.

Research is needed to ensure a more resilient energy sector is achieved, and the resilience benefits are captured.

Examples will be ensuring local supplies of electricity can be decoupled from the wider distribution system in the event of a breakdown in the grid, and fit-for-purpose biofuels can be produced locally.

SUMMARY THEMES

Develop the supply of clean fuels where significant increase in demand is anticipated.

De-risk the scale up of:

- *Clean electricity supply for short-haul transport and industry. The key issues are electricity system stability and expanding lower cost supply from geothermal and offshore wind.*
- *Biofuel supply for industry, long-haul marine, and aviation. A key issue is growing a new industry converting biomass to both gaseous and liquid fuels while reducing costs.*

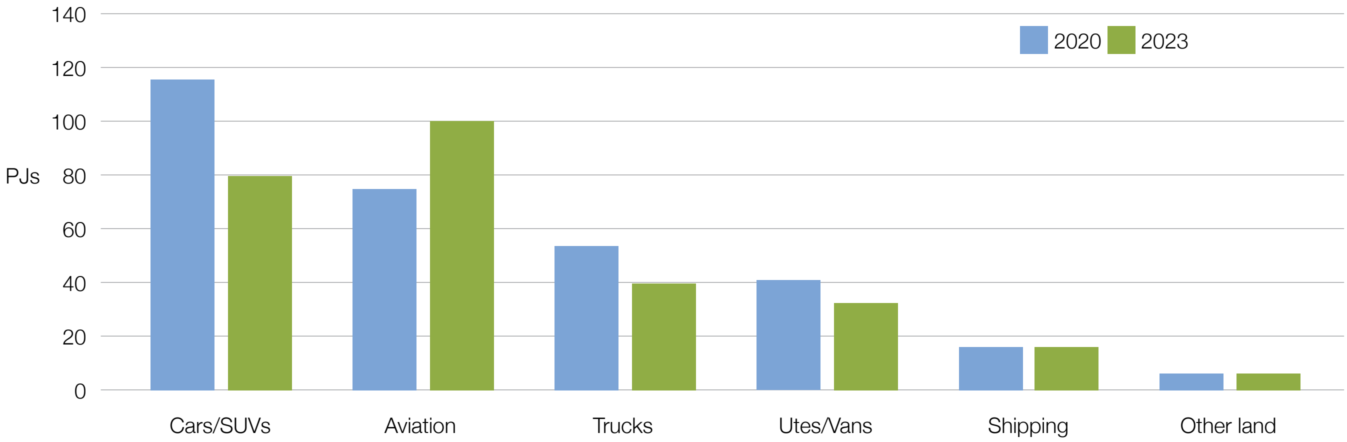
Opportunities: NZ's comparative advantage in clean electricity; early availability of near 100% clean electricity; growing geothermal; and a new bioenergy industry. A resilient clean energy supply.

5. LONG HAUL TRANSPORT

Transport's almost exclusive reliance on fossil fuels creates over half of NZ's energy GHG emissions.

Its fossil fuel use amounts to around 300 PJ in 2030 falling to ~270PJ by 2035 on the average of the TIMES-BEC scenarios[91]. Graph 2 breaks this down into the main components[92].[93]

Graph 2: Changes in BAU Transport Fossil Fuel use 2020-2035



DRIVERS OF GHGS

Car/SUV vehicle-kilometres are projected by TIMES-BEC to increase ~120% while Van/Utes grow slightly more (~130%) and Trucks slightly less (~110%).

However, road transport fossil fuel use declines 25%. This reflects the assumed uptake of electric vehicles/hybrids, particularly by *Cars/SUVs*[94].

Further, despite the increase in vehicle-kilometres travelled, total energy use by road transport declines 18%. This reflects the relative much greater energy efficiency of EVs.

On the other hand, there is no fuels substitution assumed in *Aviation or Shipping*, so their fossil fuel use follows assumed growth in demand.

While this is only one set of forecasts, other NZ scenario work points to similar conclusions[95]. BAU will deliver gains primarily from the use of electricity in shorter haul transport, but with some contribution from ongoing improvements in fuel efficiency and fleet utilisation.

This is reflected in the emphasis in the ERP that targets accelerating the uptake of EVs, shifts to public transport, and discourages the use of fossil fuels.

Medium-term applied research will be required in the areas that remain unaddressed.

Vehicle and engine technologies will overwhelmingly be sourced from overseas, but the supply of clean transport fuels will increasingly be a matter for NZ. Similarly, our demand for transport, and the impacts of the changes will be unique to NZ[96].

So local research will be needed to address the difficult, unique-to-NZ issues in introducing alternative clean transport fuels and reducing demand for fossil fuelled transport.

ALTERNATIVE CLEAN FUELS

Alternative clean transport fuels face barriers to their introduction. They need a complete package of competitive and mature solutions, at scale, that address their supply, distribution, use in vehicles, not to mention their wider support industries.

EVs for shorter-haul transport in NZ has by and large overcome these barriers, but other fuels still face issues of feedstock availability, mature competitive supply and distribution, and vehicles.

Car/SUV and Utes/Van

In the case of electric vehicles, the NZ electricity supply chain can be developed incrementally on the back of existing infrastructure, and NZ's electricity is predominantly clean[97] and getting increasingly so.

Apart from the medium-term system growth and dry year issues discussed in chapter 2, we assume that under BAU[98] there is a plentiful supply of relatively affordable clean electricity (if not a significant surplus[99]).

By the 2030s the EV supply constraints are expected to be overcome for *Car/SUV* and *Utes/Van* categories, and their Total Cost of Ownership (TCO) should be lower than for internal combustion engines (ICEs)[100].

On this basis the constraints to uptake look likely to be limited to the speed at which the existing fleet of ICE vehicles can affordably be replaced.

Therefore, electric vehicles should replace fossil fuels for shorter-haul road transport, and the supply of the EVs and the necessary electricity are matters for policy, and not major priority targets for medium-term applied research.

Rail

Short-haul passenger rail is predominantly electrified, as is the Palmerston North to Te Rapa section of the North Island main trunk line.

Overall future investment in clean fuel options for rail are being considered under BAU by the government and KiwiRail[101], and the GHGs involved are not large in relationship to trucking.

Again, this is therefore not a major priority target for research.

Long-haul trucks

Ara Ake have published a Long-Distance Heavy Freight Total Cost of Ownership Comparison Tool[102] that compares the TCO per t/km for various hydrogen, BEV, biodiesel, and diesel fuelling.

At the time of writing full comparisons are only available for the largest 50MAX B-train[103] and then at a specific kilometrage. Two observations come from the modelling:

- There is considerable uncertainty in the parameters, particularly in the NZ context and this requires further research, and
- For the lighter trucks up to 26t there are credible sets of assumptions from the MfE abatement study that have the BEV reaching a lower TCO by the mid-2020s.

*Comparative research into the clean fuel options for NZ's **heavy land transport** is needed, including future duty cycles, vehicle technologies, fuels, and their supply chains.*

The significant gap here is systematic comparative research into the fuel options and how they might evolve. The emphasis to date has been on proving particular solutions rather than assessing options.

Various short-term policy initiatives[104] may influence how these options develop in the medium-term and these will need to be considered.

Photo: supplied by Fonterra

Shipping

There is considerable activity underway in NZ looking at clean alternative fuel options for smaller vessels, particularly electricity[105].

However, the dominant sources of emissions are from coastal (4.5 PJ), and international shipping (12 PJ)[106] NZ will be influenced by what happens internationally, particularly for the latter.

Around a third of coastal fuel use is on the Cook Strait. The balance is bulk coastal freight and general cargo, along with the fishing fleet.

NZ's coastal fleet has considerable investment in the current propulsion technology, and they have significant life left in them. Even KiwiRail, when investing in the new Interislander ferries, has settled on a hybrid diesel-electric configuration.

While these marine diesel ICE engines remain in use, drop-in biofuels are most likely to meet the need. Their adoption will be assisted by the ability of these engines to use lower-cost, less processed fuels[107].

The longer-term options remain unclear[108], and these need to be explored[109,110]

*Research into the clean fuel options for NZ's **coastal and international shipping**, both medium and long-term is needed. This will need to include engines, fuels, and their supply chains.*

An example would be developing lower cost, less processed biofuels for the coastal fleet, and reviewing options for the fishing fleet.

Aviation

Short-haul aviation operators are investigating alternative fuels, particularly all-electric short flights[111] and a range of propulsion systems for larger domestic flights[112].

However, for longer-haul regional and international flights existing gas turbine engines are likely to be still in use through to the 2030s. Therefore, clean drop-in fuels will be the only option.

The government has setup a partnership with Air New Zealand to look into the feasibility of establishing a commercial-scale Sustainable Aviation Fuels (SAF) pilot plant in New Zealand[113]. The ERP adds weight to this and foreshadows a sustainable aviation fuel mandate.

> *Research into the clean fuel options for NZ's regional and international **aviation industry** is needed. This should include aircraft technologies, fuels, and their supply chains.*

An early target should be to help reduce uncertainties and de-risk investment options for operators that service the NZ market.

Mitigating GHGs

Fossil fuels can be cleaned up by the use of CCUS. However, the opportunities in transport fuels are limited because existing near-commercial CCUS technologies require scale to be economic.

Thus, by-and-large the viable approaches to cleaning up transport fossil fuels involve centralised conversion to a clean fuel (discussed in chapter 3). However, ships could accommodate the equipment necessary to directly capture GHG from exhausts, and this is being considered[114].

REDUCING DEMAND

Clean fuel options will be slow to deliver climate change targets. A shift to reducing the demand for transport fossil fuels will also be required[115].

Two alternatives are to make better use of existing trips or to develop clean alternatives to substitute for the demand.

Better use of trips

There are rapid advances occurring in technologies that will improve the fuel efficiency of logistics and passenger movements.

Examples include: real-time mobile tracking, Internet of Things; big data, machine learning, Artificial Intelligence, systems' optimisation; e-commerce and procurement; supply chain integration; and drones, eVTOL, autonomous vehicles[116], "transport as a service", that all help address the "first and last kilometre" problem[117].

More flexible and distributed production (Manufacturing 4.0), and the growth in services[118], also give opportunities to reduce the GHG impacts of supply chains.

All these technologies are particularly important for NZ, given our long skinny geography and remoteness from international markets.

Bigger companies will pick up these technologies under BAU. However, many of these industries rely upon small owner operators, and some of these developments look likely to be disruptive of larger firms and their business models.

Research is needed to establish how these technologies might develop in NZ and where they might have a material impact on GHGs. The outcomes are by no means certain, and even apparently clear-cut technologies, e.g., autonomous shared vehicles, can have equivocal results[119 120].

> *Research into **technologies that improve logistics and passenger movements** is needed, to establish those that could have a material impact on NZ's hard-to-abate transport emissions, and to de-risk the rapid uptake of positive developments.*

An example would be opportunities to use AI tools to better optimise logistics.

Better understanding the various technologies would support the ERP's proposed national freight and supply chain strategy.

Alternatives to trips

The increasing use of virtual communications and e-commerce, encouraged by COVID, has broken down the historic barriers to the use of virtual interactions[121]. This particularly suits NZ with its isolation and heavy reliance on international travel.

Equally the COVID experience has bought into focus the limitations of current technologies, and the problems that can arise from lack of physical interactions. Addressing these has significant potential to reduce difficult-to-abate travel internationally and within NZ.

However, particular care will need to be taken to manage the potential adverse impacts on our tourism businesses, and on our social relationships and whanaungatanga.

> *Research into using **virtual interactions to reduce the demand for mobility**, including the various impacts, is needed.*

An early example woul be a scoping study of the significant opporunities and risks from emerging technologies for virtual interactions and developing a research investment plan to address these. Māori will have significant input, e.g., in tourism and logistics.

OPPORTUNITIES

Because NZ has comparative advantage in the generation of renewable electricity, the early adoption of EVs in a near 100% renewable system will offer international opportunities.

For NZ, these are most likely to be electricity system technologies and services, rather than in the EVs themselves, although a role as a test bed could be possible.

This links into the opportunities raised in chapter 3 that arise from NZ's comparative advantages in supplying clean electricity.

Wider opportunities will arise in addressing the more difficult transport GHG emissions. These include opportunities from NZ firms having access to:

- Cleaner and more efficient logistics and passenger movements;
- Virtual/AR interactions and their application in NZ, e.g., tourism and international business.

> *Research into **cleaner, more efficient land transport** and **using virtual interactions** needs to address the **wider commercial opportunities that arise**.*

These themes are picked up in the next chapter (Industry).

SUMMARY THEMES

Clarify the fuel options for long-haul land transport and their implementation in NZ

Increase our fuel options, i.e., better batteries and charging, electro-fuels (e.g., hydrogen), biofuels, hybrids, and fossil fuels with CCUS, and de-risk their implementation.

Reduce the demand for long-haul transport

Apply emerging technologies and behaviour changes to target demand, develop weightless alternatives, and improve the efficiency of logistics.

Opportunity: To exploit these advances internationally, e.g., low-cost virtual tourism.

6. INDUSTRY

Industrial users of fossil fuels create 20% of NZ's energy GHG emissions.

Total fossil fuel use amounts to around 110PJ, with Food Processing Industries using 40PJ and Chemical Industries, 35PJ. The balance is used in the Energy Industries[122].

The average of the TIMES-BEC scenarios has Industry's use of fossil fuels declining by 14% by 2035, but this is very sensitive to the assumptions about the closing of key industries, e.g., the Kea scenario has it dropping by 40%.

This is a reminder that industrial fossil fuel use is predominantly the result of a relatively small number of large industrial sites.

In these circumstances, much of the research required to address fossil fuels will be undertaken directly by the relevant industries under BAU.

DRIVERS OF GHGS

Unlike Transport, clean fuels are already supply around half the energy used by industry. Biomass (wood processing) and electricity (aluminium smelting, food processing and wood processing) each supply about a quarter.

Fonterra Te Awamutu Wood Pellet Conversion

Fossil fuels provide the remaining 50%, with process heat being the dominant use. The relatively small amount used for motive power (10 PJ) will be addressed by the initiatives discussed in chapter 4.

The MfE marginal abatement cost curves show that within the range of the expected medium-term CO2-e prices:

- Low and medium grade industrial heat demand (e.g., food processing) should be able to be met by electricity and/or biomass[123];
- Urea production can be addressed, but high-grade heat in methanol, steel, and cement production would remain problems.

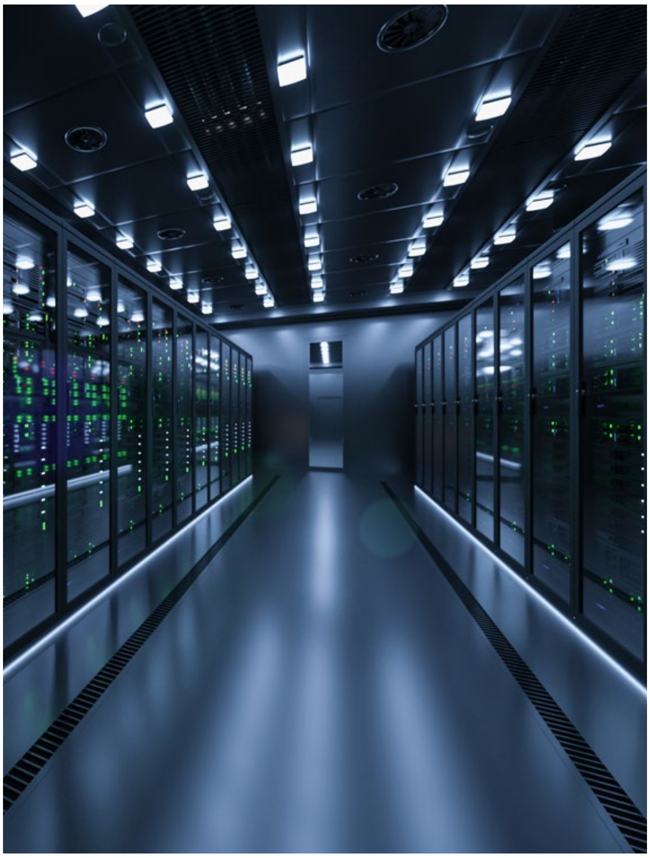
As noted, it is anticipated that alternatives for the high-grade heat users will be addressed by the companies involved and, in some cases, this may mean closures. This shift in NZ's industrial base will have wider impacts that will require research, and these are addressed in chapter 6.

While thermal loads from the remainder of our industry base can be addressed, the MfE report does draw attention to the supply of biomass being a potential constraint.

Addressing this has been discussed in chapter 3, but in addition, high temperature industrial heat pumps are an emerging technology that would allow electricity use to expand to higher temperature thermal loads for example[124]. These would suit NZ's particular industrial needs, and possible applications are beginning to be addressed[125] [126].

Beyond the specialist needs of individual companies, the main need for medium-term research on reducing fossil fuel use in Industry is around medium temperature process heat and the use of heat pumps.

An example could include the use of advanced thermodynamics to improve the performance of high temperature heat pumps.



Māori have significant interests in the industries that use fossil fuels (e.g., food processing) and deliver potential alternatives (e.g., forestry).

OPPORTUNITIES

It is likely that NZ will have access to significant quantities of clean electricity that will be internationally competitive[127].

But to export electricity energy it needs to be efficiently converted into a form that can be safely and easily stored and transported, i.e., desirably it should have both a high energy density and specific energy.

Using electrolysis to convert electricity to hydrogen is one option being considered as an export[128], along with further conversion to ammonia that, among other things, is easier to ship. But competition from hydrogen from fossil fuels with CCUS will constrain margins in international markets in the medium-term[129].

This suggests the opportunity for NZ is to develop industries that use renewable electricity locally to produce high-value products and services, particularly consumer products, that are electricity intense and relatively easy to ship.

NZ already has a significant entertainment industry that falls into this category. Other emerging examples are data centres[130], and Industry 4.0 that has much greater emphasis on electricity-rich technologies, e.g., ICT, AI, VR/AR[131].

*Research to maximise the **value of NZ's potential surplus clean electricity supply** is needed.*

Examples would start with a stocktake of the potential of this endowment in NZ industries.

SUMMARY THEME

Develop clean/low energy industries

Support shifts to industries that have low energy intensity or add significant value to clean energy.

7. WIDER IMPACTS

Shifting from fossil fuels to local renewables will have wider social, economic, cultural, and environmental impacts on NZ.

Many will be gradual and be able to be managed under BAU, but some will be disruptive and will call for directed research to help facilitate the change and reduce the risks.

THE MAJOR TRENDS

As of today, we can anticipate at least three trends that could cumulate into significant or disruptive change. Aspects of each of these have been mentioned but they each also warrant R&D into their wider potential impacts:

1. Increasing energy costs for households, particularly if switching fuels.
2. The cumulative impacts of addressing difficult-to-abate fossil fuels.
3. The impacts on natural and physical resources and our skill requirements from shifting to clean energy.

Other significant or disruptive changes will emerge over time, and monitoring for these will also be a role for the research community.

AFFORDABILITY

While the cost of expanding the renewable electricity system will increase in real terms[132], this should be gradual enough to be addressed using existing social assistance and some targeted extensions.

However, affordability issues will arise from the high price increases expected for clean liquid fuels, and with that the need to buy new vehicles, appliances, and equipment in order to switch fuels.

The latter can be seen today in the cost of conversions to EVs and heat pumps. This has led to government programmes to support these transitions[133].

The price increases will also impact fossil fuel intensive goods and services, e.g., travel and freight.

The impacts will be uneven across society, with those with inadequate housing and energy services being particularly affected.

Research is needed to help address long-term affordability issues faced by the household sector.

Examples might commence with baseline studies to ensure these stresses can be recognised and interventions evaluated over time, and R&D on community development to support better locally those in need.

DIFFICULT-TO-ABATE FOSSIL FUELS

Business users of difficult-to-abate fossil fuel will face increasing costs (including regulation) and this may threaten the viability of these activities.

In the extreme, businesses may decide to discontinue the activity or to completely change their business (e.g., virtual tourism). Examples are discussed in chapters 4 and 5.

Regardless, over time these kinds of activities will just attract less investment and be run down, and our economy will grow in areas less exposed.

Chapter 5 has discussed the opportunities for using renewable electricity. More generally, services that can be delivered weightlessly are an area where NZ is seen as having competitive advantages and have been slated as a growth sector[134].

The overall change to our economy from this shift is likely to be significant, particularly as many export and import industries are particularly exposed.

There will be flow on effects into our community as businesses decline and grow.

The Just Transitions Unit in MBIE[135] has been set up to help regions adjust to specific changes, e.g., in Taranaki [136] and Southland (pending the closure of the smelter)[137]. Work has been done by others on the impacts of regulations, e.g., the impact of the oil and gas ban[138].

The MBIE's separate Transitions Strategy Unit is considering the overall Government response to the changes, but systematic medium-term research into these is still lacking.

> *Research is needed into the cumulative medium-term impacts on NZ from addressing difficult-to-abate fossil fuels.*

Developing a high-level assessment of the areas where significant change might occur by the mid to late 2030s, and the direction of that change, would be a useful starting point.

RESOURCES

The additional natural and physical resources likely to be required to grow our renewable energy has been considered in chapter 3, but together they will represent a significant demand particularly for soil and land, i.e., from bioenergy, solar, wind, and electricity infrastructure.

Other resources will also be required, such as water, e.g., bioenergy, geothermal, electro-fuels, and hydro should the need arise, and the oceans, e.g., wind and possibly biomass/algae.

Māori have significant interests in these resources.

The growth in demand for renewable energy over a relatively short period of time will also create growth in demand for physical infrastructure. As noted this is already the subject of work by the Infrastructure Commission[139] and any work on the natural resources will need to coordinate with this.

This demand for resources and infrastructure will potentially compete with other sources of growth, e.g., biomass and biochemicals.

Meanwhile greater emphasis is being placed upon ensuring the sustainability of natural resources, and our responsibilities through Kaitiakitanga. Mātauranga Māori will help inform the balance required going forward.

> *Research into the cumulative medium-term impacts of growing renewable energy supply on our natural resources and their sustainability is needed. Māori will be essential partners along with coordination with the work the Infrastructure Commission is doing on energy infrastructure.*

A review of the likely medium-term impacts, drawing together the various pieces of work already undertaken would be a useful starting point.

PEOPLE

The clean fuel industries and those industries that have relied heavily on fossil fuels, will both face significant changes to their work forces and skills needs. The communities heavily involved with these industries will also face change.

We have noted the role and work of the MBIE Just Transitions Unit, and they have established Regional Skills Leadership Groups for all regions[140] to help address these issues.

The impact of the close down of the fossil fuel supply industry is already being seen with the offshore oil and gas exploration ban impacting Taranaki, and the closing of the Marsden Point refinery impacting Northland.

Some work has been undertaken in response[141].

Less has been done on the requirements from the industries that are expected to grow significantly: electricity, particularly wind (but see[142]), geothermal, and system management, electro/syn-fuels, and bioenergy/chemicals.

Addressing their needs out to the 2030s is an area calling for research.

Some work is underway on the wider sector skill requirements, e.g. on the forestry and wood processing work force[143]. The Workforce Development Councils[144] can be expected to address their industries' needs but they lack an overarching view of the energy sector.

The International Energy Association (IEA) has published an overview of the global energy sector's workforce needs[145] and a NZ version could provide context for the various agencies considering these issues.

> *Research is needed into the impacts on work forces and their communities from industry moving to clean energy, the opportunities, and the risks.*

An initial task could be to develop a report similar to the IEA overview, specific to NZ. NERI is looking to contribute to assist this, building on its tertiary education and business organisation memberships.

OTHER

Monitoring for additional areas of potential disruption will need to be ongoing.

SUMMARY THEME

> **Address the major wider impacts**
>
> *Identify and address the major cumulative wider economic, work force, social, cultural, and environmental impacts of cutting fossil fuels.*

8. CONCLUSION

The NZ energy sector emits around two thirds of our non-biogenic GHG emissions, almost exclusively coming from fossil fuels. These supply nearly 70% of our energy.

To reach Net-Zero we need to shift to local renewable fuels and otherwise cut the demand for fossil fuels. Much of this is underway but there remain a set of issues that are significantly uncertain and otherwise intractable.

MEDIUM-TERM APPLIED R&D

This shift will require dramatic changes to parts of our energy sector, bringing further uncertainty, costs, and disruption.

They will create economic, social, and environmental challenges, but opportunities will also emerge. Māori will face their own unique problems and opportunities.

NZ will require investment in medium-term applied research to help understand the challenges and opportunities, and to de-risk the options we face.

To assist this, we have developed a framework for the uniquely NZ applied research required, and the high-level priorities for investment.

Because we are addressing major medium-term issues, the focus is on our best assessments of what will be the remaining unresolved drivers of energy GHGs by the 2030s.

THE TARGET AREAS

The main sectors using fossil fuel in NZ are Transport (54% of energy fossil fuel use), Industry (22%) and Electricity (10%). Even within those, significant areas will be addressed under business as usual. Short haul transport converting to EVs is the most obvious example.

Looking beyond these, we have identified the following key themes:

- Develop the supply of clean fuels (electricity and biofuels) to meet the anticipated increases in demand;
- Clarify the fuel options for long-haul land transport and support their implementation;
- Reduce the demand for long-haul transport (land, air and marine);
- Develop clean/low energy industries;
- Address the major NZ-wide impacts from these changes; and
- Empower te ao Māori to contribute to these challenges and opportunities.

NEXT STEPS

GHG reductions are one of a number of strategic issues NZ is facing that call for significant investment in medium-term applied R&D. These fit within the structure of Te Ara Paerangi Future Pathways White Paper 2022[146].

Because the drivers of energy sector GHGs are quite distinct from those for biogenic GHGs, the energy GHGs warrant separate attention within that structure. This Framework provides the next level of detail below this.

We therefore see this Framework informing the *Te Ara Paerangi* process going forward and, in the interim, providing a touch stone for those seeking to address the difficult issues involved in cutting energy GHG emissions.

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