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Farming Energy

Opportunities to Help New Zealand Reach Net Zero Carbon 2050

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2019 Nuffield Scholar

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Disclaimer

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Acknowledgments

The Nuffield Scholarship is one of the greatest honours possible in New Zealand agriculture. I feel extremely privileged to be joining an alumni that have shaped the New Zealand agricultural industry into the world leading position we enjoy today. I hope to do my best to contribute to the legacy.

This scholarship pushes you in directions you are never quite ready to discover. The bubble of what I considered 'normal' was quick to burst as I challenged international farmers on their decisions and found I learnt more when they directed the same questioning back at me. Ultimately, we are all proud of what we do and have a strong willingness to share our achievements and knowledge with anyone brave enough to ask.

Leaving family, friends and a business behind for many months is also a big leap that teaches you independence, perseverance and most of all gratitude for the fantastic place we call home, and those we are lucky enough to share it with.

Many thanks to Anne Hindson, Hamish Gow and the New Zealand Rural Leaders Trustees for your backing to take on this experience and support throughout. My fellow 2019 scholars Hamish Murray, Hamish Marr, Corrigan Sowman and Ben Hancock have been a valuable sounding board for ideas and challenges. They are each a credit to the programme, and it has been a privilege to share my travels with you all this past year.

The support of my friends and family has meant I have never felt far from home. The team on farm have been incredible in picking up the extra work in my absence and repeatedly exceeding all expectations to give me piece of mind while I have been away.

Finally to Sarah, who since this Nuffield journey began, I have met, fell in love with, got engaged to, bought a house with and within weeks will share the joy of a little girl together. Thank you for your patience, understanding and unending love and support this past year.

Executive Summary

The New Zealand Net Zero Carbon Act's main objective is that New Zealand contributes no further to global warming by 2050, a target commonly known as 'Net Zero Carbon 2050'. To reach this vision, targets have been set for all greenhouse gas (GHG) emissions in New Zealand. Agriculture, as New Zealand's largest GHG emitting sector, will face pressure on productivity and profitability as it works towards Net Zero carbon. Other sectors will also face pressure, particularly the energy sector which is New Zealand's second largest GHG emitting sector. Forecasts show that not only will the energy sector need to transition to low emission alternatives, but the mix of energy types (electricity, gas, oil etc.) will need to shift to meet new technological innovations and increasing energy demand.

Given this challenge, I believe there are opportunities for the sectors to work together for mutual benefit. My travels and report seek to answer the question:

What energy farming opportunities could New Zealand farmers pursue to help our country reach Net Zero Carbon 2050?

Energy farming is where farms generate a form of energy (electricity, gas, fuel or heat) on farm that can be exported for use elsewhere in the economy. To be successful in helping achieve Net Zero Carbon 2050, the farmed energy must have lower GHG emissions that the fossil fuel alternative it is often replacing, and be technically and economically viable for the farmer.

Energy farming may become vital to future energy generation as forecasts show New Zealand's current energy path, particularly our perceived reliance on hydroelectric power and electric vehicles, will not move the industry far towards Net Zero Carbon 2050.

I set out on my travels to visit a range of energy farming operations in Ireland and California. Both Ireland and California, like New Zealand, have a large and successful agricultural sector and face similar pressure to reduce GHG emissions from all sectors.

Technologically, the range of energy farming options is diverse. Some are already common in New Zealand, like solar and wind power. Others are rare, but innovating rapidly using such technology as Agrovoltaics and anaerobic digestor biogas with refining. Each operation aims to take advantage of local weather conditions or available feedstocks to create a usable energy product. Every energy farming operation in this report could technically work here in New Zealand.

Environmentally, the GHG emissions from each operation was more favourable that the fossil fuel alternative with some even sequestering more carbon than they emit. Consequently, each option would help lower energy GHG emissions in New Zealand.

Economically however, each energy farming operation I examined was influenced heavily by local policy and incentives to make them competitive with cheaper fossil fuel alternatives. The policy and incentives in both California and Ireland were imbedded in their respective government's energy strategies.

To make these technically and environmentally feasible energy farming opportunities profitable to New Zealand farmers, New Zealand needs an energy strategy that is similarly supportive of energy farming. It turns out, we are in the early stages of developing such a strategy in New Zealand, but the agricultural voice is absent.

To resolve this economic roadblock, I recommend three actions:

1. Create a Farming Energy Working Group (FEWG), by pulling in expert knowledge from across the agricultural sector in advocacy, science and development. In addition to agricultural experts, include some external energy advice to create a group uniquely skilled in leading energy farming to New Zealand.
2. The FEWG should enter the New Zealand energy strategy conversation and work alongside the energy sector and government to advocate for, and implement, policy to economically support energy farming. Such polices could include low interest funding of energy farming investments, standards to replace liquid fossil fuel with biofuel alternatives and long term price guarantees for farmed energy.
3. The FEWG should collate local and international knowledge on energy farming to create case studies and systems that can be demonstrated on farm, both to policy makers and farmers, to build confidence in the future of energy farming.

By implimenting these recommendations, every energy farming option outlined in the report, could successfully be pursued by farmers in New Zealand to help the country achieve Net Zero Carbon 2050.

Scholar Biography

I am a 37 year old farmer, engaged to Sarah with a baby girl due in late March 2020. We live in Oxford, North Canterbury.

I own a 700 cow dairy farm five minutes south of Oxford. The dairy unit is accompanied by a 200ha mixed cropping lease farm that provides economic and agronomic diversity while providing opportunities to experiment with land use.

I grew up on a family dairy farm just west of Hamilton, but on leaving home decided to pursue other career interests. In 2004 so completed an honours degree in Mechatronic Engineering and Bachelor of Finance at University of Auckland.

After a year's travel post graduation I began a three-year term with Fonterra working in all aspects of the corporate office including human resources, health and safety and supply chain strategy.

The call of the farm grew stronger, so in 2009 I joined the white gold rush to Canterbury seeking farming opportunities. On arrival, I found Canterbury dairy farms an energetic and exciting place to be. With growth opportunities everywhere so in I 2011 bought and converted a sheep farm in Oxford. Since then the farm has grown to milk 730 cows and more recently shrunk again with dry corners now planted in trees. The lease farm joined the business in 2012.

Since 2011, I have been involved in many facets of the dairy industry. Young Farmers clubs, competitions and committees introduced me to a network of talented young people, who are now all making their mark in New Zealand agriculture. A year employed with DairyNZ as a Developer brought me closer to the industry-good structure and introduced me to meet some talented scientists and researchers who all hold the dairy industry in very high regard. While balancing work and farm life had its challenges, it has always been in my nature to multitask and fill the weekly calendar. I feel fortunate to have worked in all my roles with people who share my vision for the future of our New Zealand dairy space, and to be able to implement their advice on my own farm (and often run an experiment here and there).

Alongside farm duties, I now enjoy working in the representation and policy space as President of North Canterbury Federated Farmers and as Deputy Chair of the Waimakariri Water Zone Committee. Good policy has a growing influence in farmers lives and deserves strong voices to ensure fact wins over perception and that change is truly for the better.

I am passionate about finding better ways to farm more sustainably - environmentally, socially and economically.

Contents

Introduction

The passing of the Zero Carbon Act in 2019 outlines changes required to meet our country's commitment to mitigating climate change. The emissions targets set for agriculture will be challenging and adds another layer of pressure on top of environmental, social and economic challenges farmers already face. Farmers, like myself, understand the need to change, but with the high level of capital investment already made in the land and infrastructure, it is difficult to make any other land practice pay a good return.

In New Zealand, we research our common land uses extensively (dairy, beef, arable etc.), but don't invest in developing alternative land uses that may provide similar financial benefits and better environmental outcomes. I decided to spend my Nuffield year doing just that.

My original interest was in finding alternative uses for the fodderbeet (a variety of sugar beet) that I grow to feed my cows in winter. A few years back, I came across an article about the use of harvested sugar beet to create biofuel. This sparked an interest in growing crops for energy production. Would it be possible to grow energy crops on a portion of my dairy farm that could potentially:

- Cut back my herd size to reduce methane emissions;
- Help the energy sector reduce its emissions by providing a renewable energy source;
- Reduce nutrient leaching;
- Achieve all this profitably; and
- As a bonus, use this change to improve the image of the ag sector and restore some pride in being a farmer?

I had hoped to build a compelling business model, but found out early in my travels that I needed to look at the wider context of the energy sector. The opportunities to generate energy on farm expand beyond biofuels, and they all start with a national strategy on transitioning energy to 'net zero carbon', which is only in its infancy in New Zealand. The policy and incentives that flow from that strategy then form the foundation for the energy farming business case because, unfortunately, fossil fuels are always cheaper. A New Zealand national energy strategy is still in early development, therefore it is important to look at the best and most recent projections of what energy might look like in the future and identify where energy farming opportunities might exist.

My study starts by looking at domestic and international issues influencing energy supply and demand, with a focus on the recent Net Zero Carbon Bill. The analysis will compare two recent energy sector forecast reports. I then look at what change is occurring in the energy sector of two major agricultural markets, Ireland and California, and what opportunities have been created from advances in policy, incentives and technology. Throughout this report I have included case studies of farmers who are actively pursuing these opportunities. I end with an overview of the current state of the New Zealand energy strategy, and answer the question:

What energy farming opportunities could New Zealand farmers pursue to help our country reach net zero carbon?

This report is based on my observations, conversations, and research while travelling in 2019. It is by no means an exhaustive summary of what is a complex and diverse subject. I have also included some related observations (outlined in blue boxes) from my travels that help inform the discussion.

My goal is to introduce a new opportunity to the New Zealand agricultural sector and to encourage further discussion on how agriculture can play a critical role in the nation achieving environmental targets.

The Climate Change Challenge

Before delving into the specifics of farming energy, it is necessary to set the scene and understand the current climate in which we operate. Why is it important to consider farming energy as a potential solution to addressing climate issues and reach emissions targets? What problem am I seeking to solve?

The Climate Change Movement

Climate change sits at the forefront of political and media thought. From the international political discussions at the International Panel on Climate Change (IPCC) to the public protests led by young Swede Greta Thunburg, climate change dominates much of the long-term planning internationally and media cycles.

The perspectives on the effects of climate change are varied. Most focus on the damage and costs that climate change may inflict. From rising sea levels displacing millions, to increasingly extreme weather patterns causing increased flooding, snow, heat waves and storms. The current models paint a grim picture.

There are some who look at the positive effects. In Iowa, we heard about scientists looking at the benefits to plant growth from higher CO2 concentrations and warmer climates in the northern USA. Overall, the international political consensus (bar a few notable exceptions), is that climate change is a threat and must be prevented.

At the 2015 United Nations Climate Change Conference (COP21) in Paris, member states of the IPCC agreed to implement policies with the aim of limiting global warming to well below 2° C this century and to strive to limit the temperature rise to 1.5° C. As part of the Paris Agreement, New Zealand committed to reduce its greenhouse gas (GHG) emissions by 30% from 2005 levels. Despite this target, GHG gas emissions have remained static in New Zealand since the signing of the Agreement.

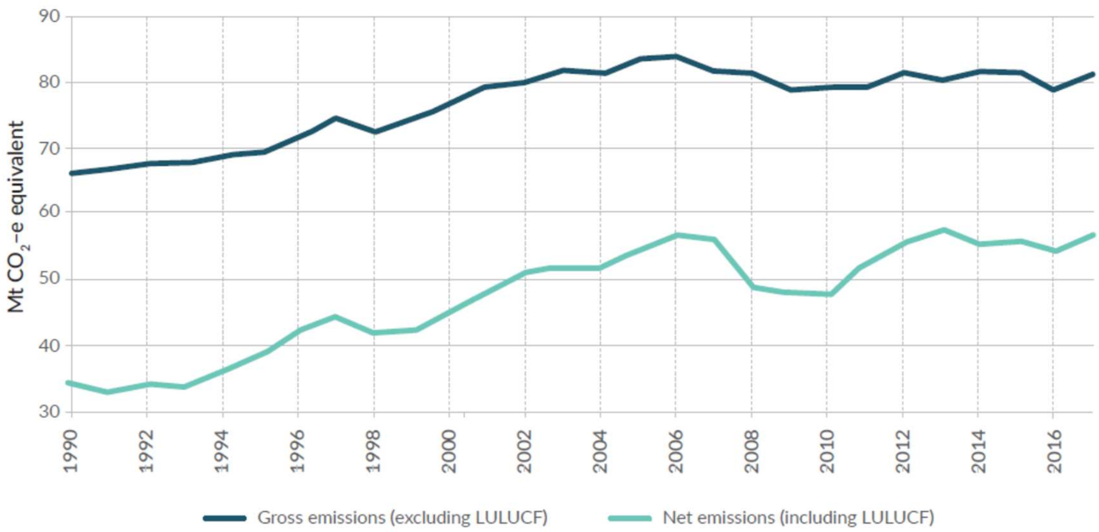

Fig 1. New Zealand GHG emissions 1990 to 2017[1]

[1] NZ Ministry for the Environment, (2019) (p.3)

The targets imposed by the Paris Agreement have sparked further debate about the need to act as, according to the science, any net positive GHG emissions with continue to contribute to global warming.

Prior to the 2016 NZ election, a youth organisation called Generation Zero advocated for a stricter approach to climate change mitigation by proposing New Zealand aim to get to Net Zero emissions. The election resulted in a coalition of the NZ Labour party, NZ First and NZ Green party. Newly elected Prime Minister Jacinda Ardern, went on to call climate change 'My generation's nuclear free moment' and Green party co-leader James Shaw became Minister for Climate Change. Minister Shaw quickly began work on a 'Zero Carbon Bill' with the target of net zero emissions in New Zealand by 2050.

The Minister sought bipartisan support and consulted widely with the public. Over 15,000 submissions were lodged and the complexity of what exactly Net Zero Emissions looks like was hotly debated. As a result, the Zero Carbon Bill was presented to parliament on 9th May 2019

The Zero Carbon Act

The passing of the Zero Carbon Act (officially titled the Climate Change Response (Zero Carbon) Amendment Act) in 2019 set a vision for New Zealand and outlines changes required to meet our country's commitment to mitigating climate change. The overall purpose of the Act is to provide a framework by which New Zealand can develop and implement clear and stable climate change policies that[2]:

- contribute to the global effort under the Paris Agreement to limit the global average temperature increase to 1.5° Celsius above pre-industrial levels; and
- allow New Zealand to prepare for, and adapt to, the effects of climate change

The 2019 Act focused on four key actions:

- Set a new domestic greenhouse gas emissions reduction target for New Zealand to:
  - reduce net emissions of all greenhouse gases (except biogenic methane) to zero by 2050; and
  - reduce emissions of biogenic methane to 24–47 per cent below 2017 levels by 2050, including to 10 per cent below 2017 levels by 2030;
- Establish a system of emissions budgets to act as stepping stones towards the long-term target;
- Require the Government to develop and implement policies for climate change adaptation and mitigation; and
- Establish a new, independent Climate Change Commission to provide expert advice and monitoring to help keep successive governments on track to meeting long-term goals.

The amendments received near unanimous support (119 votes for, 1 against) indicating the legislation is likely to survive beyond the term of the current government[3]. The implication is these long-term targets in the act are likely to guide development in New Zealand for the foreseeable future.

[2] Climate Change Response (Zero Carbon) Amendment Act 2019, s4
[3] Walters, L. (2019)

Agriculture's Reaction

Agricultural industry leaders have expressed concern at the scale of change required to meet the targets in the Net Zero Carbon Act however I believe these comments are based on the current agricultural landscape with little insight into how land use may evolve given these new pressures.

New Zealand agriculture is described as an industry of food and fibre. But what if we look outside these traditional boundaries for other land use options that could help farmers, and New Zealand achieve Net Zero Carbon? The answer may lie in the other major carbon emitter in New Zealand – energy.

The Energy Sector's Slice

GHG emissions in New Zealand form a unique pattern in the developed world. As an agricultural exporter, New Zealand's GHG profile is heavily dominated by agriculture.

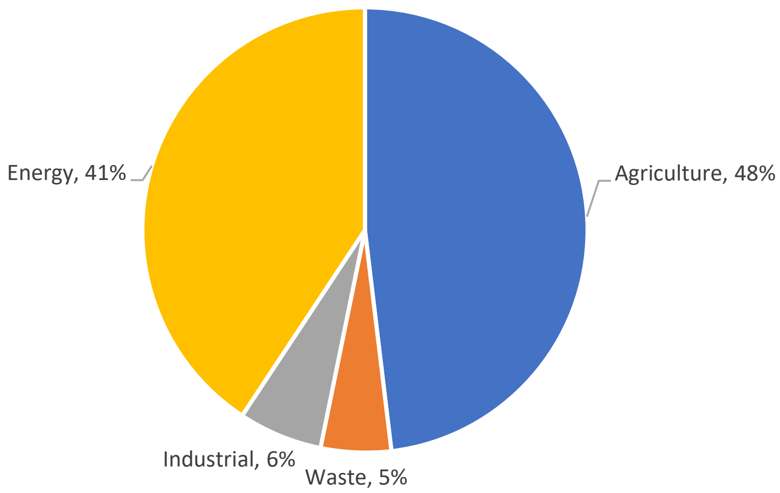

Fig 2. New Zealand 2017 GHG profile[4]

Compare this to GHG profile of the USA and agricultural emissions are heavily shadowed by energy.

[4] Ministry for the Environment, (2019)

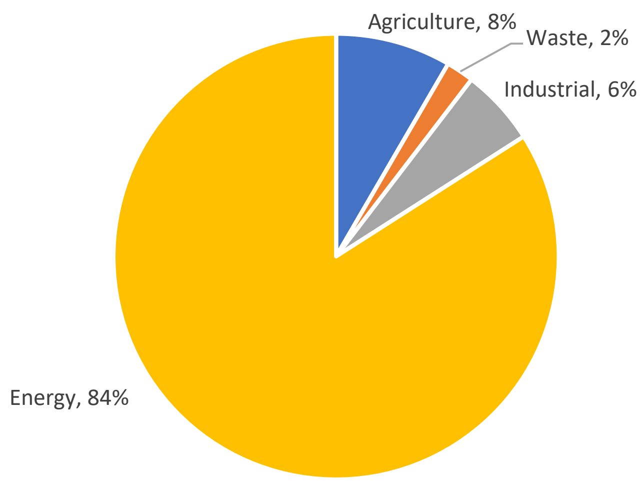

Fig 3. 2017 USA Greenhouse Gas Emissions[5]

The closest related profile to New Zealand is that of Ireland where agricultural emissions make up 33% of total emissions.

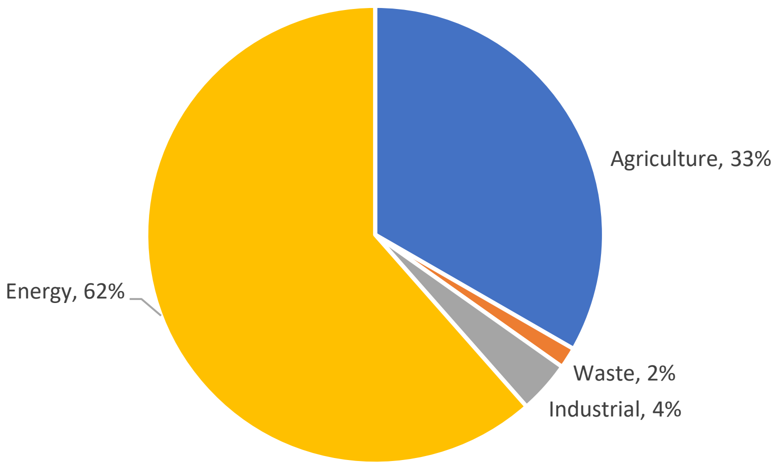

Fig 4. 2017 Ireland Greenhouse Gas Emissions[6]

Consequently, New Zealand agriculture has been in the spotlight for our total emissions, even though on a per unit of agricultural production, many products, particularly dairy, have the lowest carbon intensity in the world[7].

[5] United States Environment Protection Agency, (2019)
[6] Ireland Environmental Protection Agency, (2019)
[7] FAO (2010)

Irish Agriculture Under Fire

During my visit to Ireland in October 2019, the major news item was Ireland missing its national GHG emissions reduction targets. The country as a whole must achieve 20% reduction on 2005 levels by 2020 and a 30% reduction on 2005 by 2030. The targets are set by the EU and could cost the country more than €250m in penalties and carbon credit costs.[8] This is the third year in a row that Ireland has missed its targets and in nearly every article and news program the spotlight was immediately shone on agriculture.

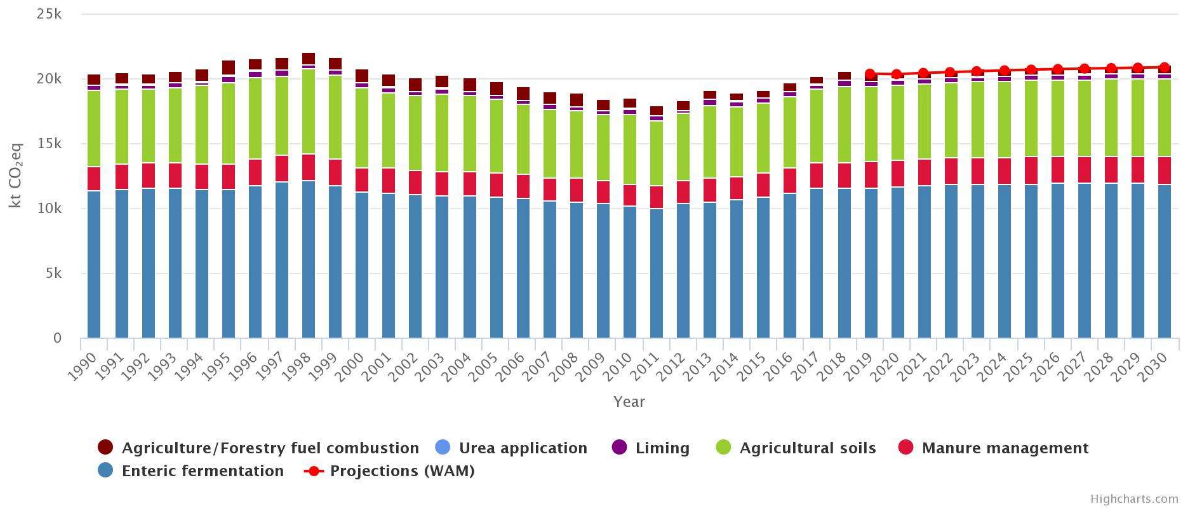

Fig 5. Projected Irish agricultural emissions [9]

Irish agriculture had seen a 20% decline in emissions between 1998 and 2012. In 2012, news broke that EU milk production quotas would be removed from dairy production in 2015 and the national dairy herd began to grow. Since 2012 the national dairy herd has increased 27%, milk production 40% and agricultural emissions have climbed 15%. Despite expectations of a plateau, 2019 saw a further emissions increase of 2% over the previous year[10].

The increased production is in line with Ireland's Foodwise 2025 strategy to grow food related exports by 85% between 2015 and 2025, but is putting pressure on the government's own Climate Action Plan for agriculture.

2017 Provisional Emissions	2030 Projected Emissions based on NDP	2030 Required Emissions Based on MACC
20 Mt CO_2 eq	21 Mt CO_2 eq	17.5 – 19 Mt CO_2 eq

Fig 6. Current, projected and target agricultural emissions, Ireland [11]

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[8] O'Sullivan, K. (2019)
[9] Ireland Environmental Protection Agency (2020)
[10] ibid
[11] O'Donogue, M. (2019)

New Zealand's Energy Supply and Demand

Internationally, it is energy not agriculture that is in the climate change spotlight and feeling the pressure to change to meet climate change targets. When energy is discussed In New Zealand, we often reference our hydro and geothermal schemes making our electricity 80% renewable. But energy encompasses much more than electricity.

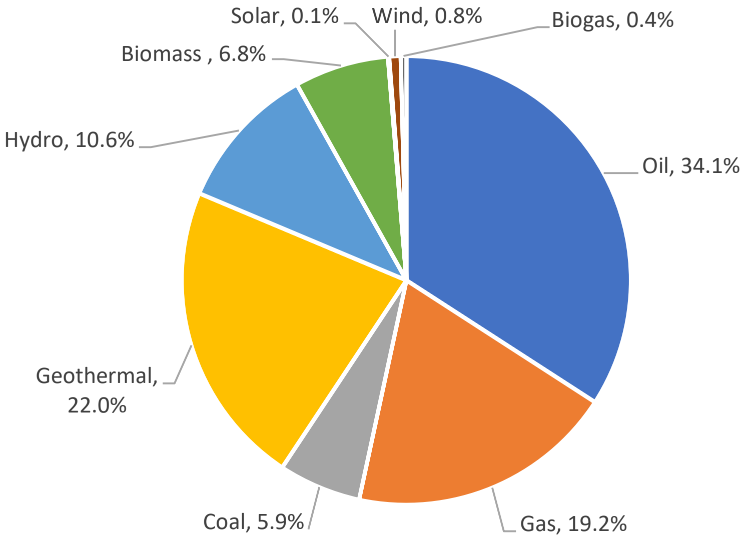

Fig 5. New Zealand Total Primary Energy Supply 2018[12]

The total energy mix in New Zealand includes natural gas, coal and oil based products which together make up 60% of all energy used (see Fig 5). This 60% of non-renewables is responsible for 40% of the our total GHG emissions.

Where does this energy get used? The answer is not surprising given our highly renewable electricity – transport is the largest user of non-renewable energy.

[12] NZ Ministry of Business, Innovation and Employment (2019) *Energy in New Zealand 2019*

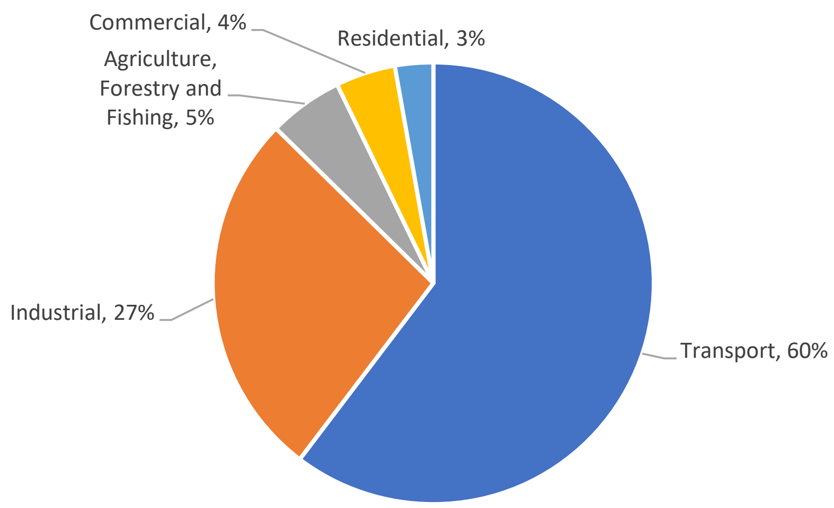

Fig 6. New Zealand Non-Renewable Energy Use by Sector 2017[13]

The challenge is to not only convert current non-renewable energy sources into renewable, but to adapt our energy supply to meet future technological changes (electric vehicles for example) and population growth.

Forecasting the Energy Landscape in Future New Zealand

Forecasting energy demand 20-30 years into the future is difficult. The BusinessNZ Energy Council, in partnership with the World Energy Council, undertakes regular comprehensive modelling exercises looking at all the variables that could impact the New Zealand energy sector of the coming decades. The latest outlook was released in December 2019 and is titled BEC2060 – Navigating our Flight Path to 2060.

The report highlights over 40 issues to consider when forecasting the New Zealand energy sector of the future. BEC2060 plotted them to indicate the level of uncertainty for each issue versus its potential impact on the sector.

[13] NZ Ministry of Business, Innovation and Employment (2019) *Energy in New Zealand 2019*

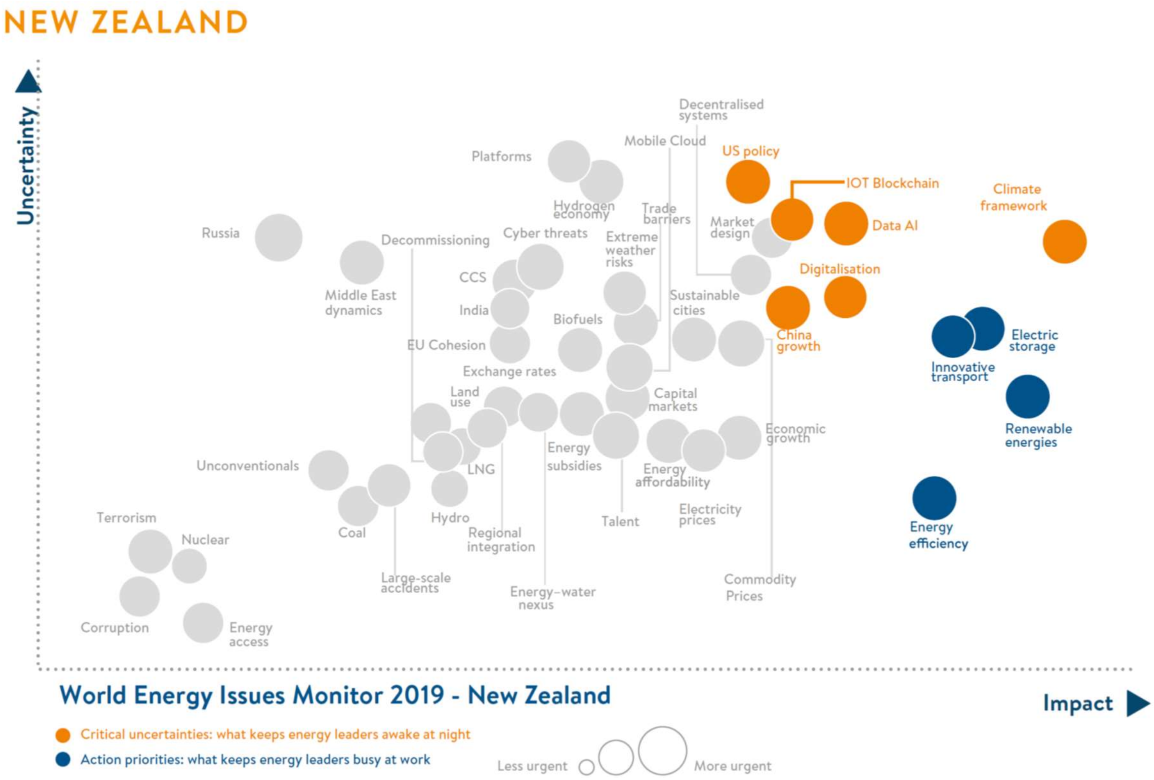

Fig 7. Issues influencing the Energy Sector in NZ 2019[14]

The issues impacting the future of New Zealand energy use and production range from the political decisions of the larger energy consuming countries, to technological innovation, economic cycles and the social pace of change.

With so many factors to forecast over a long timeframe the level of uncertainty is wide. The World Energy Council labelled this "the funnel of uncertainty"[15]. It explains how the range of possible outcomes and uncertainty grows as the time horizon grows. The funnel also gets wider as the range of factors to consider increases.

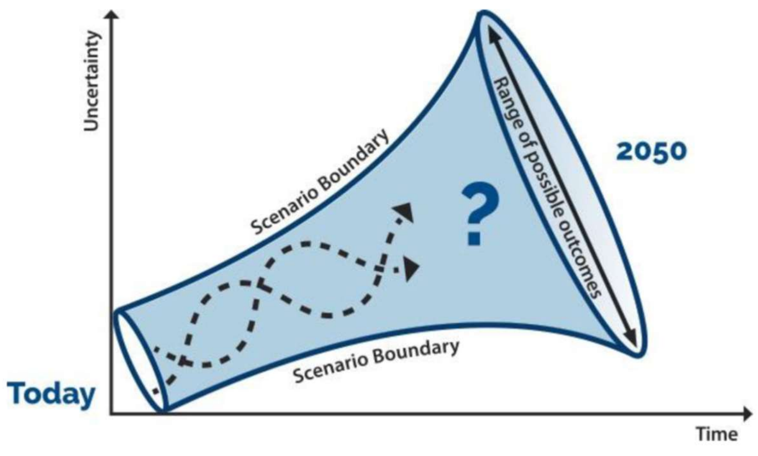

Fig 8. Forecasting funnel of uncertainty[16]

[14] World Energy Council (2019) (p.78)
[15] Business Energy Council NZ (2015)
[16] Ibid (p.28)

The BEC2060 forecasting approach was to narrow the vast range of possibilities into two broad scenarios that between them defined the likely range of outcomes. The first scenario, which the report names "Tui", assumes New Zealand follows the world in addressing climate change. The second scenario, "Kea" assumes New Zealand leads the world on climate change mitigation. To provide greater certainty and more useful scenarios, BEC2060 shortened their forecast time horizon to 2040.

Tui Scenario – New Zealand follows the world

In the Tui scenario, climate change is just one of many important issues in society. New Zealand society does not generally share a common view on what is the most important issue of the day. As a result, governments do what they have to do to meet international emissions commitments but otherwise, New Zealand focuses on delivering economic prosperity and wellbeing by leveraging off our natural resources.

The Tui scenario predicts a 20% increase in total energy use by 2040. Greater electricity use (+100%) and biomass and biofuels (+100%) account for the majority of the increase with oil products declining.

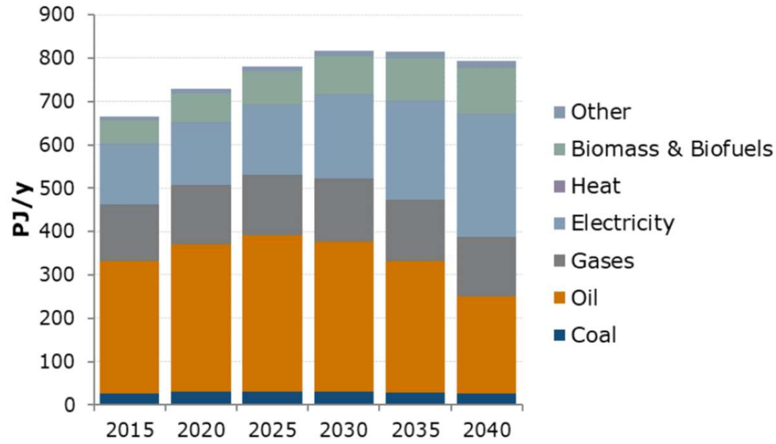

Fig 9. Total energy demand by fuel type – Tui Scenario[17]

The way we generate our electricity is forecast to change too. Hydro power remains static and all future generating capacity is predicted to come from geothermal, wind and solar (fig 10).

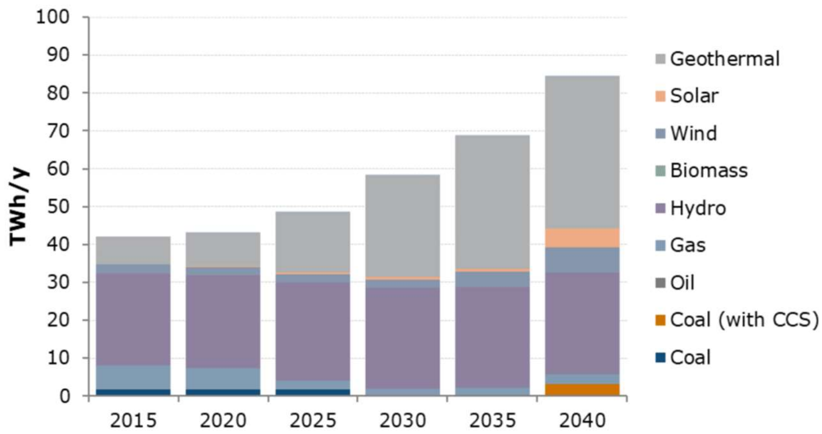

Fig 10. Electricity generation by source – Tui Scenario[18]

[17] Business Energy Council NZ (2019) (p.37)
[18] Ibid (p.39)

It is interesting to note the difference between where our electricity will come from (fig 10) and the total capacity to generate electricity (fig 11). Much our generating capacity may be unreliable, particularly wind and solar. Therefore, we will need extra generating capacity in the network to fill in the gaps and provide a stable electricity supply.

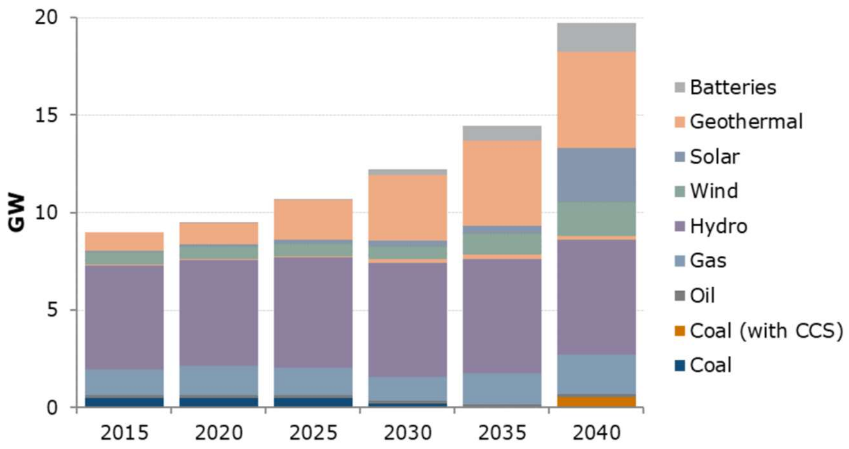

Fig 11. Electricity Generating Capacity – Tui Scenario[19]

Transport fuel is forecast to decline as vehicle efficiency and public transport use increases, but will still heavily dominated by fossil fuel for many decades (fig 12). This highlights that despite the current market enthusiasm for electric and hydrogen vehicles, they will not replace our fossil fuel burning fleet.

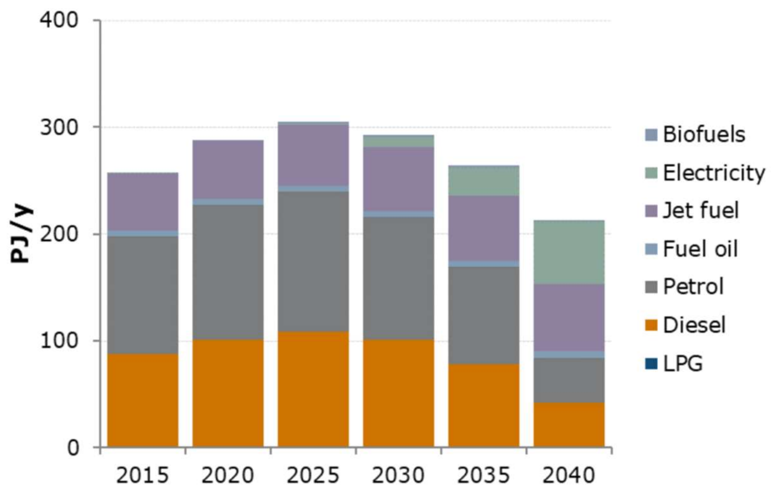

Fig 12. Transport Fuels – Tui Scenario[20]

Overall, total energy sector emissions will decline but only by 30% leaving the sector requiring further change or offsetting to meet Net Zero Cabron 2050 targets.

[19] Business Energy Council NZ (2019) (p.39)
[20] ibid (p.34)

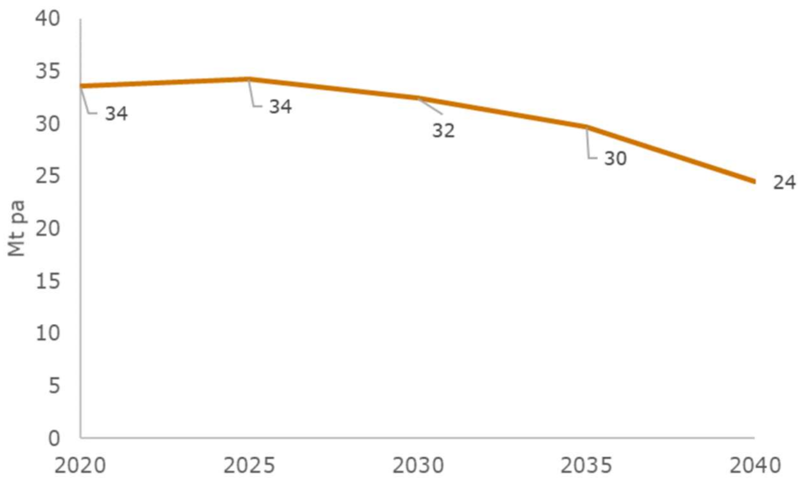

Fig 13. Energy Sector Emissions – Tui Scenario[21]

Kea Scenario – New Zealand leads the world

The second scenario considered by BEC2060 is the Kea scenario. Unlike the Tui scenario, which supposes New Zealand follows the world in addressing climate change, the Kea scenario adopts the position that the New Zealand economy and international brand would ultimately benefit from being an international climate leader. New Zealand must adopt a leadership role in lowering emissions, choosing to undergo an aggressive economic and environmental transformation.

The Decline of Rural NZ

Under the Kea scenario New Zealand economic growth slows dramatically for 20 years. Carbon prices will rise above $200/tonne, population growth has stalled, and rural communities have suffered with some 'declining into non-existence' due to pressure on land use change.

The Kea scenario predicts total energy use declines (-30%) in New Zealand by 2040 despite a slight population increase largely due to greater energy efficiency and conservation. Oil usage declines as electricity use increases (fig 14).

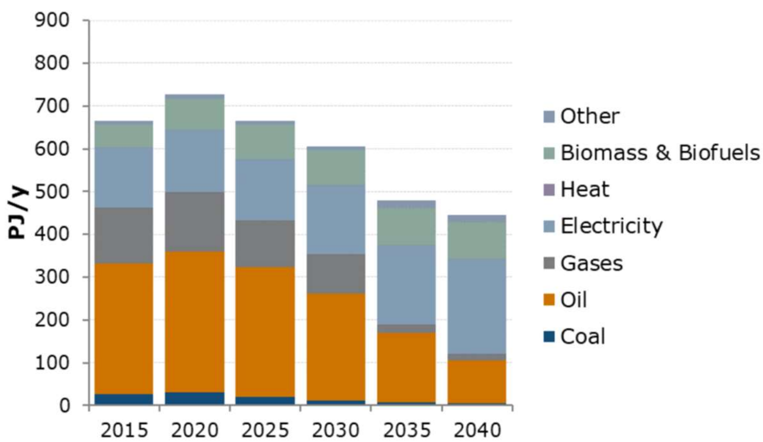

Fig 14. Total energy consumption by source[22]

[21] Business Energy Council NZ (2019) (p.44)
[22] Ibid (p.51)

Electricity from non-renewables is predicted to decline to near zero with wind, hydro, and solar all increasing (fig 15). As with the Tui scenario, extra capacity is built into the generation network to increase energy security with batteries playing a significant role.

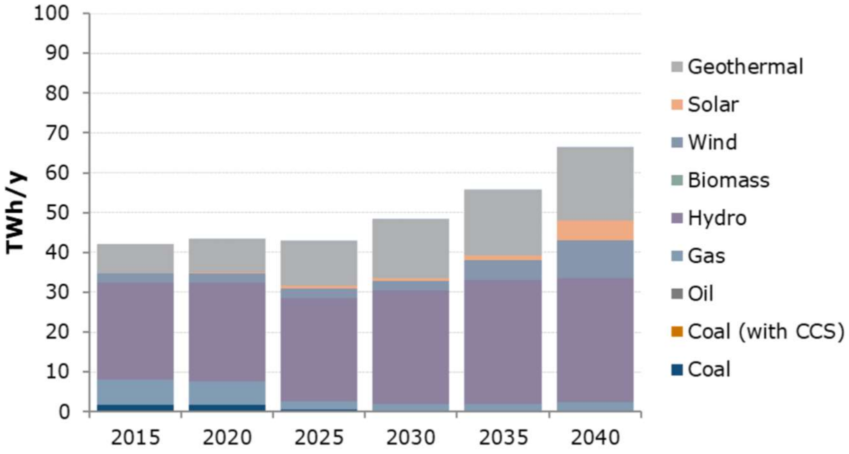

Fig 16. Electricity generation by source – Kea Scenario[23]

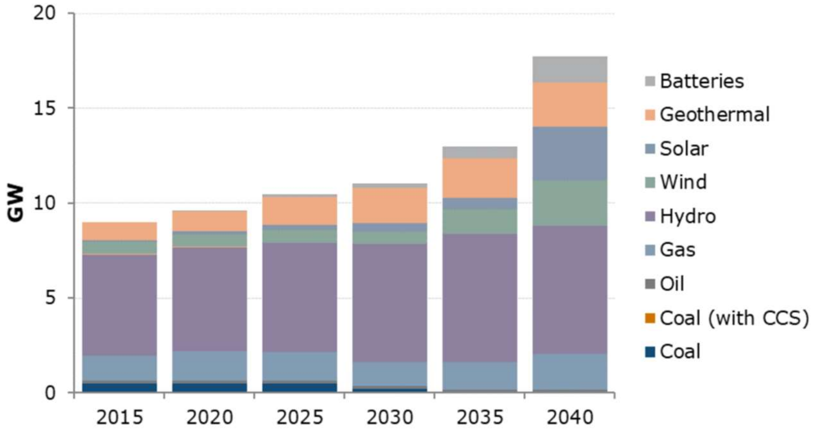

Fig 15. Electricity generating capacity – Kea Scenario[24]

The Kea scenario predicts transport fuel becomes increasingly dominated by electric vehicles, however fossil fuels still makes up half of all fuel use. Importantly the BEC2060 report notes that biofuel and biogas will become common energy supplies on farm.

[23] Business Energy Council NZ (2019) (p.53)
[24] ibid (p.54)

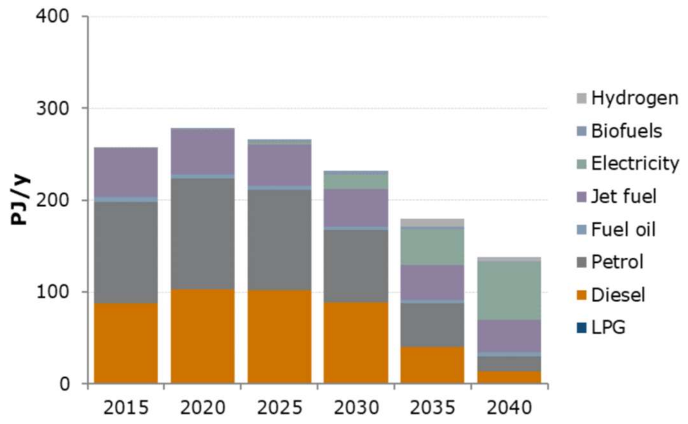

Fig 17. Fuels in Transport – Kea Scenario[25]

Under this aggressive approach, energy GHG emissions in the Kea scenario reduce by 73% by 2040.

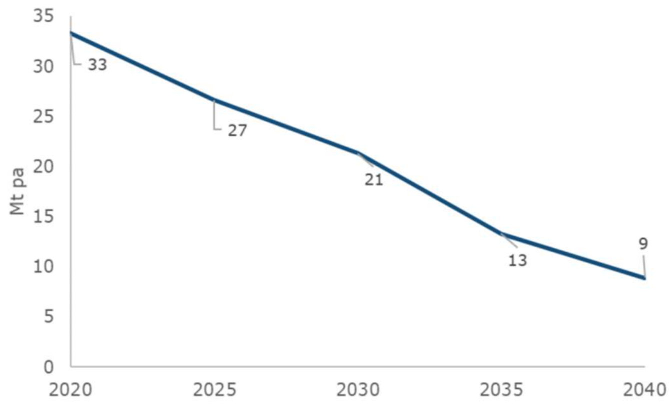

Fig 18. Energy sector CO2 emissions – Kea Scenario[26]

International Energy Forecasts

Looking at international trends, the World Energy Outlook 2019 (WEO2019) from the International Energy Agency (IEA) followed a similar scenario approach to forecasting the world energy landscape in 2040. The WEO2019 report looks at three scenarios:

- Current Policy – The outcome based on current international policy:
- Stated Policy – The outcome is governments effectively implement their policy intentions; and
- Sustainable Development – The scenario required to meet the Paris Agreement

All three scenarios predict a substitution of fossil based fuels with electrical equivalents alongside some energy conservation and efficiencies. Electricity generation is increasingly renewable (from solar and wind) however the report is less optimistic about weaning economies off fossil fuels. Bioenergy are all given greater significance than in the New Zealand scenarios. No scenarios predict a net zero carbon outcome in the given timeline.

[25] Business Energy Council NZ (2019) (p.48)
[26] Ibid (p.60)

	2000	2018	Stated Policies 2030	Stated Policies 2040	Sustainable Development 2030	Sustainable Development 2040	Current Policies 2030	Current Policies 2040
Coal	2 317	3 821	3 848	3 779	2 430	1 470	4 154	4 479
Oil	3 665	4 501	4 872	4 921	3 995	3 041	5 174	5 626
Natural gas	2 083	3 273	3 889	4 445	3 513	3 162	4 070	4 847
Nuclear	675	709	801	906	895	1 149	811	937
Renewables	659	1 391	2 287	3 127	2 776	4 381	2 138	2 741
Hydro	225	361	452	524	489	596	445	509
Modern bioenergy	374	737	1 058	1 282	1 179	1 554	1 013	1 190
Other	60	293	777	1 320	1 109	2 231	681	1 042
Solid biomass	638	620	613	546	140	75	613	546
Total	**10 037**	**14 314**	**16 311**	**17 723**	**13 750**	**13 279**	**16 960**	**19 177**
Fossil fuel share	*80%*	*81%*	*77%*	*74%*	*72%*	*58%*	*79%*	*78%*
CO_2 emissions (Gt)	23.1	33.2	34.9	35.6	25.2	15.8	37.4	41.3

Notes: Mtoe = million tonnes of oil equivalent; Gt = gigatonnes. Other includes wind, solar PV, geothermal, concentrating solar power and marine. Solid biomass includes its traditional use in three-stone fires and in improved cookstoves.

Fig 19. Forecast World Energy Demand by Fuel and Scenario[27]

Implications for Farming Energy

In comparing the scenarios from the BEC2060 and WEO2019 reports, some interesting factors arise that will influence the opportunities to farm energy:

- Electricity demand will rise considerably as technology develops and reliance on fossil fuel declines.
- The majority of the new generating capacity in New Zealand will come from geothermal, wind and solar with some bioenergy. Solar and wind need to be backed up by reliable (likely gas) generation to ensure a stable electricity supply. Internationally, solar and wind will provide the bulk of new generating capacity.
- No scenarios expect the New Zealand or the international energy sectors to achieve net zero emissions by 2040 implying offsets would be required elsewhere in the economy.
- Fossil fuels will still be a dominant vehicle fuel source in 2040, despite new electric vehicle technology. WEO2019 sees a greater role for biofuel blended with fossil fuels but this is not reflected in the BEC2060 scenarios.
- Bioenergy features in all scenarios. BEC2060 scenarios see it as a source of energy for industrial heating and for energy to be used on farm. WEO2019 predicts its use in all forms of energy generation with a dominance on industrial heat and liquid fuels.

The Risk of Popular Science

In comparing BEC2060 with its predecessor BEC2050 released in 2015, both reports derive outlooks heavily based on the technology of the day. For instance, BEC2050 only saw limited potential for battery electric vehicles and did not consider hydrogen vehicles at all. This created a dramatically different outlook on fuel use in 40 years' time. BEC2060 highlights this risk of 'betting the house' on certain technology and suggests given the rapid change in all forecasting factors that very regular updates are required of all forecasts and policy.

[27] International Energy Agency (2019) (p.38)

The Influence of Technology

Of all the factors considered in both domestic and international energy forecasts, technological innovation is seen as a defining factor in the scenario outcomes.

During my travels I came across three technologies that are in early stage development that could potentially and dramatically influence future forecast scenarios.

Carbon Capture and Storage (CCS)

Carbon capture and storage (CCS) is the process of removing carbon dioxide from waste gases and storing it underground. It would be most viable at large industrial sites such as refineries, fossil fuel power plants, cement and steel factories. It is envisaged that the carbon dioxide is converted into a stable compressed form and injected into depleted gas or oil fields or other geological formations.

Given the process is not generally productive, in that it does not produce an economic outcome, its use is reliant on international carbon prices and policy. CCS is however seen as vital to reach international climate change targets to offset the continued use of fossil fuels well into the later part of the century.

With the right technology, the IEA predicts it could have such impacts as:

- Turning coal and gas power plants into carbon neutral power sources;
- Turn biofuel into a carbon negative fuel (carbon biologically sequestered from the atmosphere is captured and permanently stored); and
- Dramatically reduce the carbon emissions from industrial production methods for products such as cement and steel that have few other current mitigations to reduce emissions.

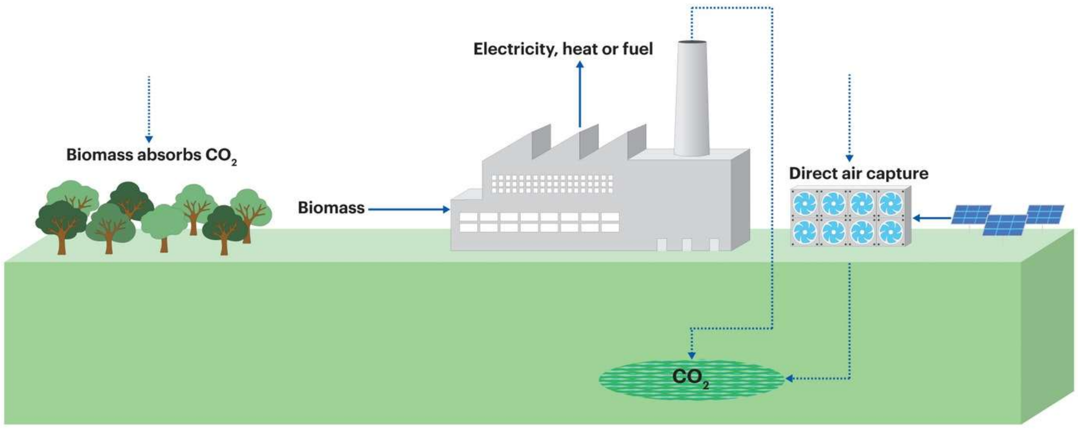

Fig 20. Bioenergy Carbon Capture and Storage.[28]

Bio Electric Vehicle

In 2016, Nissan built a trial vehicle that uses only ethanol to drive its electric motors. They call the technology e-Bio Fuel Cell. Hydrated ethanol enters a reformer that uses heat to split the ethanol into hydrogen and CO_2. The CO_2 is expelled and the hydrogen enters a solid oxide fuel cell where it reacts with oxygen to generate electricity. The electricity can either then be stored in batteries or drive the

[28] Budinis, S. (2020)

electric motors in the vehicle. The excess heat generated by the fuel cell is recycled into the reformer to generate more hydrogen.

Picture a vehicle with the convenience and range of a liquid fuel, with the environmental impact of a hydrogen vehicle and the fuel efficiency, power and running cost of a battery electric vehicle.

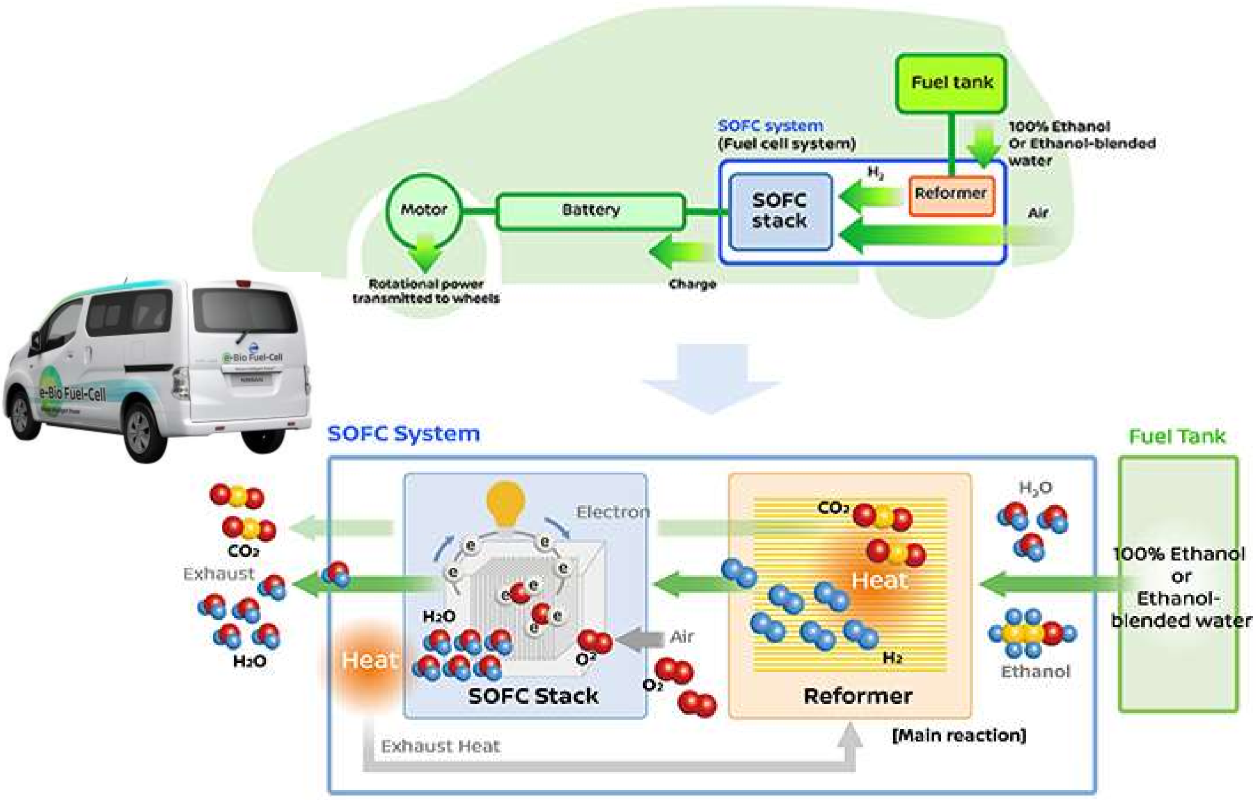

Fig 21. Design of the e-bio fuel cell engine[29]

The trial van is currently being tested in Brazil where 100% hydrated ethanol is readily available and is hoping to expand on the technology later this year.

The widespread commercialising of this technology could leapfrog the development of battery electric and hydrogen vehicles and provide a strong demand for biofuels.

Methane Tractor

In November 2019, New Holland released the world's first methane powered tractor. The tractor can run on 100% methane or biomethane with the same power performance as an equivalent diesel tractor. In Germany trials of the new tractor are showing 30% lower running costs. Given the regular use of biodigesters in Germany, the tractor could be powered from energy generated on farm[30].

[29] Nissan (2020)
[30] New Holland (2020)

Opportunities to Farm Energy

I have now detailed the current climate, the existing uncertainties and key predictions made on the national and global stage. It is evident there are opportunities for farming energy and with that opportunities for agriculture to contribute to the energy sector. I now turn the focus on how farmers have brought opportunities to life. This section details observations of international energy farming and the factors that have led to their success. The purpose is to inspire thought on what may be possible in New Zealand.

Observations on factors impacting energy farming internationally

Internationally I saw the type of energy generated often depended on a few key factors, economics, local energy demand and the natural farming environment:

- *Economics – Farms are economic businesses and every example of farming energy I saw did so because it was profitable. It may not have been the most profitable land use but could be used to compliment an existing use or to consume a waste product or simply as an economic diversification. The economic viability of the generating operation was always supported by a form of policy support backed by local or national regulatory bodies as part of a greater strategy to provide greater renewable energy supply.*
- *Local demand – Most examples of on farm energy generation I saw were built to supply energy to a local demand. This was due to the cost of transporting the energy to a non-local user. This was true for all forms of energy including liquids, heat and electricity. The result of this principle is farm scale generation built to supply either the farm demand or local industrial demand only.*
- *Natural resources and environmental conditions – Farmers have always built their agronomic systems to make the most of local environmental conditions. Weather, topography, soil types and access to water define a farms ability to produce traditional agricultural products. The same is true for energy generation. High sunshine hours support solar, consistent winds support wind turbines, tillable soils support energy crops.*

Solar Energy

Solar is by far the most common form of energy generation I saw on farm. Solar has a wide range of scale in installation size and requires little maintenance. This makes it easy to fit to nearly any farming operation. This provides two outcomes. The first, powering the farming operation itself. The second, providing energy into the local electricity network.

Lessons from California

In California, the Central Valley is famous for its sunshine hours, allowing it to feed over half of the US population. Central Valley food production has been heavily reliant on aquifer water supply for irrigation of crops however aquifer management has been poor and the aquifer is now in a depleted state. From January 2020, the California Sustainable Groundwater Management Act will gradually reduce the amount of water irrigators can draw on for crops. Irrigation has moved from flood irrigation to dripline, but many farmers are finding their soils turning saline as salt is drawn into once productive soils. Nature Conservancy, an environmental non-profit, predicts over 240,000 hectares will need to be retired from agriculture.[31] Alongside water supply restrictions, California State Government is aiming for 100% renewable electricity by 2045[32]. These challenges have led to the Nature Conservancy predicting 50,000 acres will end up in solar panels. Farmers are already well down this path with an estimated 13,000 acres of solar panels already installed in the valley.[33]

Stewart and Lynda Resnick, the largest farmers in the US, grow fruit and tree nuts in the central valley. They are investing in 157 acres of solar to make their California operation energy use 100% renewable by 2025. A spokesperson for their company, Wonderful, estimates they will make as much from solar power as from growing almonds and pistachios over the next 30 years.[34]

Wickstrom Farms, a 3,500 cow dairy farm located in Hilmar, has invested at a much smaller scale, but only smaller by American standards. They have a 1 MW solar utility installed on a corner of the farm. Enough to power approximately 500 homes[35].

Fig 23. Visiting Wickstrom Farms, Hilmar, California

Both operations are supported economically by the following local incentives and regulation.

In a policy called Net Energy Metering, over a twelve month period, an energy consumer only needs to pay for their net electricity usage, regardless of when the energy was consumed or generated throughout the year. As an example, Wickstrom Farms uses power throughout the day and night to run milk coolers, fans and lights with increased usage during the three daily milkings. Their solar panels only generate power during the day and more so in summer than winter. However, if the total annual energy usage for the farm matched the total energy generated by the panels then Wickstrom's power bill would be zero.

Uncoupling energy supply and demand supports the cyclical nature of solar power generation. If the panels generate more power than is consumed in a year, payments are available from local utility companies or in some cases be credited against another account.[36] The only limit is that of the solar installation. A minimum of 1kW and a maximum of 1MW. On a macro scale this can be difficult for the state network to manage. On occasion, excess solar power has been supplied free of charge to other states to help balance supply and demand[37].

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[31] Wu, G et al. (2019)
[32] California Energy Commission (2020)
[33] Wu, G et al. (2019)
[34] Roth, S. (2019)
[35] Wickstrom Farms, personal conversation, September 22 2019.
[36] Go Solar. (2020).
[37] Penn, I. (2017)

The California framework is different to New Zealand where net metering is available only on a live metering basis, whereby consumers are charged for their net power usage in real time. In the dairy farm example, any solar power generated that was not immediately consumed on farm would be sold into the grid at wholesale rates. As a result a greater proportion of the power generated by the panels in California earns retail energy rates than if those same panels were installed in New Zealand. With a difference in value of $0.07 per kWh wholesale versus $0.24 per kWh retail in New Zealand[38], the Net Energy Metering policy has a substantial impact of the value of solar electricity.

California Climate Investments (CCI) is the fund that collects payments from the state emissions cap and trade system (the Californian version an emissions trading scheme). The funds are reinvested in various programs to encourage reduced emissions. Projects include the Renewable Energy for Agriculture Programme (CaREAP) that offers grants to encourage investment in renewable energy technologies.[39]

The USA Federal Department of Agriculture's (USDA) Rural Energy for America Programme (REAP) offers funding assistance for investments in renewable energy development in two forms:

- Grants of up to $500,000 to cover 25% of the total investment; and
- Loan guarantees to cover 75% of total investment cost to help reduce lending rates.

This program is only available to businesses who receive greater than 50% of their gross income from agriculture.[40]

Solar panels may not necessarily replace crop growing either. Research from the University of Arizona is looking at growing crops under solar panels, a growing science known as Agrovoltaics.

Fig 24. Experiments in Agrovoltaics in the University of Arizona

The University measured growing conditions and tested the growth rates of jalapenos, peppers and tomatoes under solar installations. The shade from the panels resulted in lower daytime temperatures, higher night-time temperatures and more favourable humidity. As a result. tomato

[38] Electricity Authority New Zealand (2020)
[39] California Energy Commission (2019)
[40] United States Department of Agriculture (2020)

yield doubled compared to open air yields and pepper yields were three times higher. Jalapenos yields were the same but did so with 65% less irrigation. All crops tested used less water.

The research has shown benefits for the panels too. Solar panels are less efficient at higher temperatures. The cultivated growing environment under the panels cooled the panels as the plants transpired, acting like a natural cooling mister to the underside of the panels.[41]

Lessons from Ireland

During my week in Ireland I attended Rural Energy Now, a conference in Co. Kilkenny on energy generation on farm. The conference covered a range of energy generation opportunities alongside discussions on emissions targets for the country. Solar featured heavily in the conference, but unlike California, the environment to encourage investment in solar was not as favourable.

One Irish policy support programme is currently supportive for solar in Ireland. The Targeted Agricultural Modernisation Scheme (TAMS II) is designed to financially support farmers in targeted areas. €10 million is ringfenced annually for energy efficiency and renewable energy technologies. Farmers can apply for a grant to cover 40% (60% for young farmers) of the installation for installations of up to 6kw. The downsides are that all solar power must be consumed on the farming operation. No solar power can be used domestically or can be exported to the grid. Exporting power is of no value in Ireland as small scale installations receive no credit or payment for any power supplied to the grid. The economics of this situation limits the size of many installations to only a fraction of the power requirements the farm requires.

Despite this, there are businesses finding ways to create economic opportunities for farmers to install solar. One milk processor, Glanbia, is working with local solar company, SSE Airtricity, and Activ8 Solar Energies to deliver 6kW solar packages that comply with TAMS II grant conditions. These are backed by 100% financing. Under this scheme, farmers are encouraged to connect their panels to the grid, in the hope national policy will change in the future. Airtricity will even offer annual power export rebates to make the package more attractive.[42]

Fig 25. Visit with Kieran Dunfy, Co. Waterford, learning about TAMS II and Glanbia solar.

Large scale farm-based installations are not well supported in Ireland, with planning permission, grid connection and supply contracts difficult to come by, unless partnering with large scale energy generators[43]

[41] Piggott, S. (2019).
[42] Glanbia, personal conversation, Kilmacthomas, Ireland Oct 2019
[43] O'Sullivan, K. (2019)

The EU Common Agricultural Policy subsidy in Ireland, which plays a material part in farm economics, also disincentivises solar as any land covered in solar no longer receives a the subsidy[44].

At the Irish Energy Now conference, Tom Marren from CES Energy presented a possible solution to excess solar power. He talked of a farmers' "energy cooperative" whereby farmers pooled their excess energy (of any type) to form a single supplier that could primarily sell excess energy to other coop members then to market the energy to the wholesale and retail markets. He saw benefits similar to the current milk and meat cooperative where collection, processing, marketing and administration could be centralised for efficiency and profits passed back to the energy producing farmers.

Wind Energy

Wind turbines have the advantages of requiring little land for a large generation capacity. Technology has allowed turbines to grow in size, meaning fewer are required to generate the same amount of power. Land can be farmed beneath turbines and they are a common sight in many European countries, particularly The Netherlands.

Fig 26. Wind turbines over arable land in The Netherlands

Like solar power, wind turbines are heavily reliant on weather patterns. A strong consistent wind (9 to 55 mph) is more favourable to an irregular gale force wind. They generate no greenhouse gas emissions other than in their production, and require little maintenance. The turbines can stand over 150m tall and have a 25 year life span. Modern turbines in a good location generate electricity for over 90% of the time.

There are three main types of wind farms, all of which may have their place in New Zealand[45]:

[44] O'Donogue, M. (2019)
[45] American Wind Energy Association (2020)

- Utility-scale wind - Wind farms with turbines that range in size from 100 kilowatts to several megawatts, where the electricity is delivered to the power grid and distributed to the end user by electric utilities or power system operators.
- Distributed or "small" wind - Single small wind turbines below 100 kilowatts that are used to directly power a home, farm or small business and may or may not connected to the grid.
- Offshore wind: Wind turbines that are erected in large bodies of water, usually on the continental shelf. Offshore wind turbines are larger than land-based turbines and can generate more power.

Lessons from California

Wind is seen as a major contributor to future energy supply. It is already a material component of the Californian electricity supply, contributing 6000 MW of capacity. This is equal to two thirds of New Zealand's total generating capacity. Wind power in California contributes towards the state's Renewable Portfolio Standard legislation, which requires all utilities to procure 50% of retail sales from renewable sources by 2020[46].

Despite early growth in wind power generation, since 2013, the growth in wind power has all but stalled in California. There appears to be two reasons for this.

Fig 27. Wind turbines on the Altamont Pass windfarm, California

On a tour bus driving from San Francisco over the Altamont Pass to the Central Valley, wind turbines cover the ridgeline looking down on the golden grasses that give the state its nickname. The tour bus guide talks of the number of birds the turbines kill every year with particular emphasis on the native Golden Eagle[47]. The US Fish and Wildlife Service estimates between 140,000 and 540,000 birds are killed by wind turbines in the US each year. President Trump has commented on this statistic (with some embellishment). Environmental groups campaign on the deaths and the mud seems to have stuck, at least if tour bus guides are anything to go by. "*I never understood wind. You know, I know windmills very much. They're noisy. They kill the birds. You want to see a bird graveyard? Go under a windmill someday. You'll see more birds than you've ever seen in your life*." President Trump - Dec 2019

[46] California Energy Commission (2020)
[47] Kiger, P. (2013)

The environmental concerns have it harder to get consent for more hill top installations in recent years.

Going Offshore

Both California and Ireland are looking to offshore wind for growth. The wind resource offshore is often more consistent and turbines create less visual and audible pollution. California with its deep continental drop off and large naval military presence has yet to see much development. Ireland on the other hand is sees two thirds of wind power coming from fixed and floating offshore wind turbines by 2050.[48]

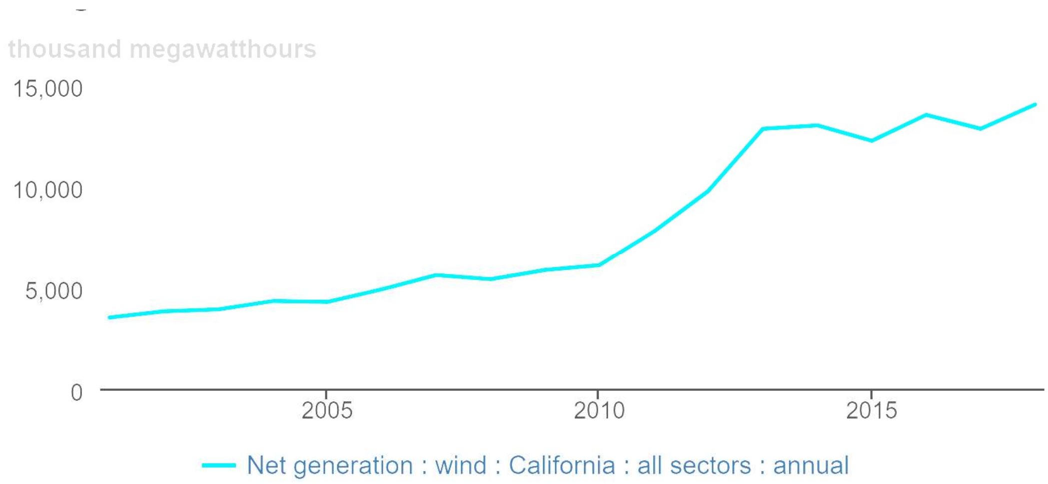

Fig 28. Electricity generated by California wind turbines.[49]

The other and far more common reason for a halt to more turbines is their appearance and noise. Placing wind turbines in the most efficient locations often places them in full view on ridge lines, making them visible from a long distance. Turbines placed near built up communities have received complaints about the rhythmic noise. President Trump even went so far as to say they cause cancer[50] although these comments have been discredited by the American Cancer Society. Overall it appears the public perception of turbines is positive so long so you can't hear them or see them. This is forcing new projects into smaller corners of the state.

Lessons from Ireland

Ireland has an abundance of wind generation capacity, but is facing similar challenges with poor public sentiment. Single and small multi-turbine installations are not uncommon, whereby private farm land is leased to large utility companies to place turbines in favourable locations. This is particularly popular with absentee owners of small blocks. But for the neighbours who get no financial benefit, but have to deal with the noise and visual pollution, the deal is not so favourable. The Keane family, dairy farmers in Co. Waterford talked of mounting a campaign against a local installation that was planned for opposite their farm and local school. The ensuing battle divided the community and ten years on, the scars have yet to fully heal.

[48] Sustainable Energy Authority Ireland (2019)
[49] US Energy Information Administration (2020)
[50] Bump, P. (2019)

Fig 29. Visiting the Keane family in Co. Waterford. The view from their house that would have been obstructed by a 150m wind turbine.

Despite growing social debate, Ireland generates 25% of its power from wind. Ireland has five times the wind power generation of New Zealand. Ireland's dependence on wind power has been aided by the country's Renewable Energy Feed Tariff (REFIT) programme which guarantees the price for wind energy for 15 years.[51]

[51] Sustainable Energy Authority Ireland. (2020)

New Zealand Example – Mt Cass

New Zealand has 690MW of installed wind capacity with 2500MW consented and waiting for economic conditions to improve before progressing[52].

One project under development is a 93MW installation at Mt Cass in the Hurunui District of the South Island. Once completed, the 22 turbine, $200 million dollar wind farm will be the largest in the South Island. The wind farm will be built on private farm land. While most New Zealand farmers may not have the capacity for such an installation, could smaller scale wind farms provide a financial opportunity for farmers in windy locations?

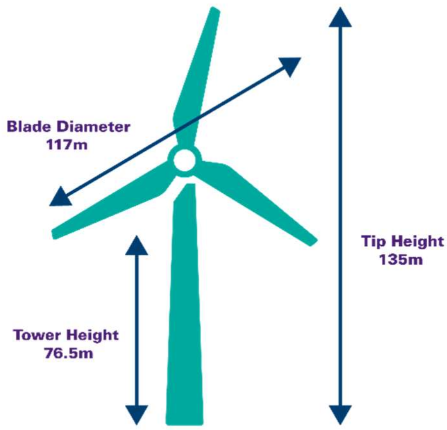

Fig 30. Mt Cass ridgeway, Hurunui.

[52] Wind Energy Association New Zealand. (2020)

BioEnergy

Bioenergy is any energy source derived from recently living organic material. Bioenergy covers a diverse range of energy forms that are generated as the biological energy stored in the plant is converted either chemically or through combustion to heat and/or electricity. The carbon dioxide emitted using bioenergy is generally equal to the carbon dioxide the plant used in photosynthesis to grow the plant therefore making bioenergy carbon neutral.

Biomass

Biomass is the burning of organic material to create heat and is humanity's oldest form of energy generation. For nearly 2 million years the ability to set fire to organic material to generate heat kept humans warm, allowed us to cook food and more recently, generate mechanical power and electricity.

Biomass is a common and relatively low-tech form of energy generation in New Zealand so I did not spend time investigating its use internationally. It does however provide some potential opportunities to New Zealand farmers.

In New Zealand, the main source of biomass is timber, which is burnt to create heat for industrial processes and in some homes for heating.

In 2018, the New Zealand Productivity Commission's report on the Low-Emissions Economy recommended biomass as a core substitute for industrial process heat. The report focused on the use of forestry and wood waste as the source of the biomass which could benefit farmland suitable for forestry.

Many different organic materials could be used as biomass. This could range from waste crop residues like straw, stover, waste food or vine trimmings to animal wastes such as dried effluent and used animal bedding.

In Ireland, I found some research on burning straw in a modern biomass burner for heat. It compared the heating value of straw to that of oil in industrial applications. The research shows, in certain circumstances, the heat value could well outstrip the feed value.

Bale Type	Bale Weight	Kilo watt hours (kWh) per bale	Oil equivalent (litres)	Oil Value equivalent (€0.60 c/L)
4 x 4 Round	150kg	690	66	€40
5 x 4 Round	250kg	1,150	110	€66
8 x 4 x 4 Square	500kg	2,300	220	€132

Fig 31. Energy value of straw bales.[53]

[53] Caslin, B. (2019)

Despite this work the vast majority of biomass research I saw focused on forestry being main economic crop to grow for biomass energy however as policy evolves this could change. High yield, low input crops like miscanthus, which can yield up to 40t/ha could be an option in some regions.

Going Carbon Negative with Biochar

Carbon negative technologies like, CCS and biochar, sequester more carbon than they emit. The International Energy Agency sees carbon negative technology as critical to achieving climate change targets. Biomass with biochar is one of the key current technologies capable of negative emissions[54].

Biochar is a form of charcoal formed when biomass is burned at a low heat in a low oxygen environment in a process called Pyrolysis. The biochar is a very stable form of carbon that can store carbon for hundreds or thousands of years. The biochar can be ground into a powder and spread on farmland to provide growing benefits:

- *Increased water storage capacity*
- *Increased nutrient holding capacity*
- *Habitat for soil microbes*

Massey University has a biochar research unit investigating potential uses for this technology in New Zealand.

[54] Budinis, S. (2020)

Biogas

Biogas is generated as organic materials decompose. In commercial biogas production, organic material is placed in an anaerobic digestor (also referred to as a biodigester), which is any sealed chamber that does not let air enter. Methanogenic bacteria are introduced to the digestor and under the right environmental conditions, the bacteria rapidly decompose the organic matter into biogas and digestate. The biogas components depend on the organic matter used. Biogas generally consists of methane (60%+) carbon dioxide, oxygen, carbon monoxide and a range of other gases in small quantities.

Biogas can be burnt to reduce its global warming potential. Burning the methane component in biogas converts it into carbon dioxide and water which both have lower global warming potential than methane. At larger scale, biogas can be further processed to create usable energy.

Biogas can be combusted in a combined heat and power (CHP) unit which generates electricity using a generator, while collecting the heat emitted during the combustion to be used commercially. Biogas can also be upgraded which strips the methane component from the gas to create near 100% pure methane called biomethane. This biomethane can be used as a direct substitute for natural gas, such as LPG for vehicles and gas heating and cooking in homes. It can also be pumped directly into natural gas pipe networks providing a carbon neutral substitute for natural gas.

The carbon dioxide can be captured separately and sold to industrial processes like carbonisation of drinks or in packaging.

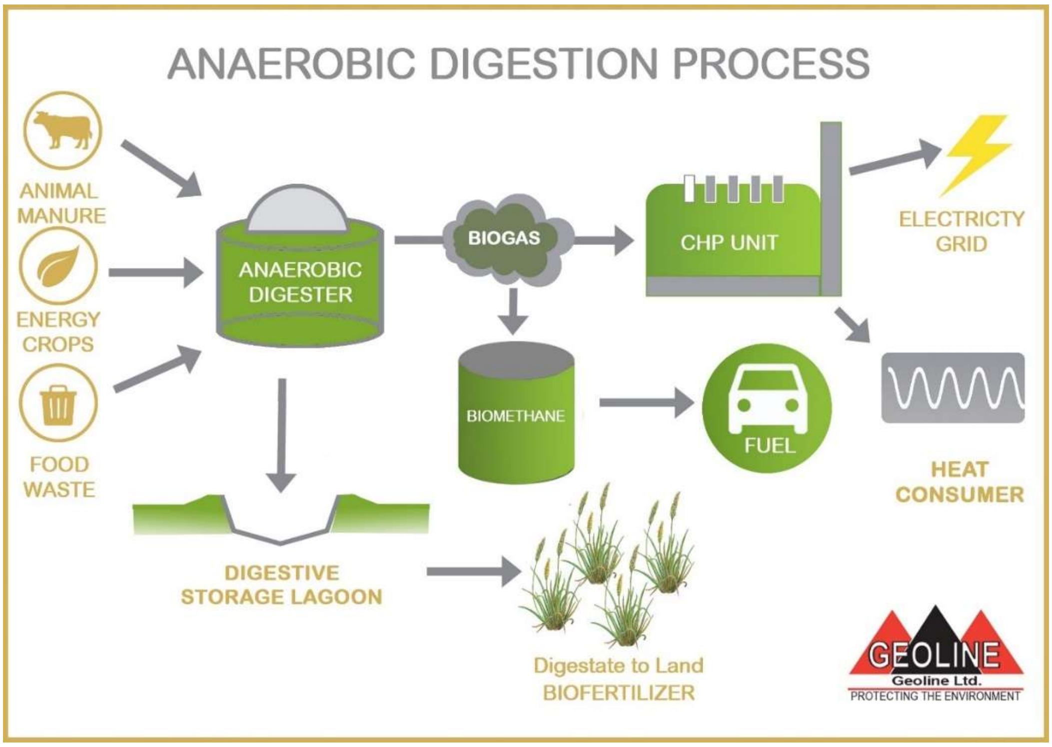

Figure 32. The anaerobic digestion process[55]

The digestate is the solid waste from the digestion process. It is high in organic nutrients and is often dried before being reapplied to farm land as organic fertiliser.

[55] Geoline Ltd (2020)

Lessons from California

Biogas and anaerobic digestors feature heavily in California's climate change plan for agriculture. The animal agricultural industry in California predominantly uses confinement systems, feeding crops grown out of state to animals living in barns and feedlots where all the effluent is collected. The collected effluent is stored in open air structures before being spread back on surrounding land.

Agriculture contributes 50% of all methane emissions in California. Of this, half is emitted from effluent storage[56].

Fig 33. Anaerobic digestor on a dairy farm in California

As part of the California's emissions reduction plan, farmers are being encouraged with research and development and grants to install biodigesters to convert their effluent emissions into usable forms of energy. The scale of many confinements and feedlots, and their close proximity allows larger installations to be positioned close to many cows. The confinements are often covered, meaning effluent is not diluted by rainfall and is very consistent composition. This makes it easier for commercial digestors according to John Campbell, an expat kiwi and environmental biotechnologist. John has helped build a state of the art biodigester for wastewater processing at Hilmar Cheese, the largest cheese factory in the world. The technology has developed whereby wastewater and effluent can be converted into drinkable water, energy and spreadable solid nutrients.

[56] California Air Resources Board (2020)

Fig 34. Tour of Hilmar Cheese, California with kiwi expat John Campbell

California's state government are investing US$500million into incentivising the construction of biodigesters on farms and fostering an economic market for their products, as fossil fuel equivalents remain more cost effective.

One incentive that will encourage the development in the biomethane market is California's Low Carbon Fuel Standard which incentivises the use of vehicle fuels with low life cycle carbon emission which they refer to as "carbon intensity" (CI). Over time, California requires the average CI of fuel sold by every provider to decline. One way to achieve this is through blending fossil fuels with biofuel (see next chapter). Another alternative is to replace the fuel altogether. As a comparison, gasoline and diesel have a CI of approx. 100 gmCO2e/MJ. Hydrogen for vehicles is an average of 40 gmCO2e/MJ. Biomethane for LPG vehicles is -272 gmCO2e/MJ, because it captures methane that would otherwise be released into the atmosphere[57].

As a result of these policies the California has reduced agricultural methane emissions by 25% and is well on its way to achieving its target of 40% by 2030.

Lessons from Ireland

In November 2019, the Irish government published '*Ag-Climatise – A Draft National Climate & Air Roadmap for the Agriculture Sector to 2030 and Beyond*'. Section three of the document focuses on agriculture's role in helping the country achieve its renewable energy targets. It reads:

Section 3 - Contribute to sustainable energy and decarbonisation of energy system

- ***Action 7:*** *Explore options for supporting sustainable energy ensuring a fair share for community engagement on the supply side.*
- ***Action 8:*** *Collaborate with DCCAE to ensure the enabling framework for microgeneration facilitates opportunities for the agri sector and rural communities to contribute to electricity decarbonisation.*
- ***Action 9:*** *Actively participate in the development of a National Anaerobic Digestor strategy including the consideration of appropriate sustainability criteria for biomass materials.*

[57] Male, J. (2019)

- ***Action 10:*** *Collaborate with DCCAE and other key stakeholders to set a target for the level of energy to be supplied by indigenous biomethane injection and consider the necessary supports including funding mechanisms.*
- ***Action 11:*** *We will double biomass production from forestry by 2030 and ensuring mobilisation for heat production –*
    - *Enable increased access into forests to allow for efficient and timely harvest of timber for delivery to the market*
    - *Displacing approx. 2 Mt CO2eq in the energy sector.*
- ***Action 12****: Continue to support actions such as photo-voltaic (PV) panels and energy efficiency measures to generate at least a 20% reduction in energy use in the agriculture sector by 2030.*
- ***Action 13****: Realise carbon savings from Anaerobic Digestion of up to 0.7Mt CO2 eq per year by 2030 and 2 Mt CO2eq per year by 2050*

Actions 9 and 13 speak directly to the benefits of biodigesters and biomethane and the role they can play in decarbonising Irish energy and agriculture.

The dairy farming systems in Ireland lend themselves to biodigesters as they house their animals for the winter. All effluent is collected and is now becoming a costly problem as storage is expensive and slurry spreading is prohibited for three months during winter. Biodigesters are seen as a possible solution on farm however at present there are just three on farm biodigesters in Ireland. This is in contrast to Northern Ireland where at least thirty are in operation even through the dairy systems are identical. The difference is in policy and support. In Northern Ireland, famers are paid for the power generated from the digestor that is supplied back into the grid. There is also a "Renewable Obligation Programme" which incentives the national energy supply to favour renewable energy sources. Small scale biodigesters are well rewarded under this scheme.

The support available in Ireland for biodigesters is focused around its heating ability. The Support Scheme for Renewable Heat (SSRT) offers installation grants and ongoing support for projects that provide renewable heat to communities. At the Energy Now conference, this was seen as a great fit with biodigesters using slurry and waste biomass and burning the biogas without any further processing to provide heat for farms and domestic community heating schemes. 40% of all energy in Ireland is used for heating. Ray Langton from Sustainable Energy Ireland predicted 10% of this heat could come from community biodigester schemes[58].

The challenges outlined are mostly practical, in that the dairy industry is made up of many small dairy units, making collection of large volumes of slurry difficult. This is made more difficult as slurry production is very seasonal. Biodigesters benefit from cost efficiency of scale, therefore many small digestors may be uneconomic even with supporting policy.

Farmed biomass could be another feedstock for the digestors, although the EU frowns on food crops being used for energy generation as it could jeopardise food security. One estimate I heard at the Energy Now conference for pasture as a feedstock was:

1 tonne dm grass = 140m3 biogas = 840 kwH x 0.22c* = $185 of power[59]

*approx. retail price/kwH of electricity in NZ

[58] Langton, R. (2019)
[59] Personal communication at Energy Now Expo, 23 October 2019, Kilkenny, Ireland

Jason Hannon, of Gas Networks Ireland, presented a vision of a carbon neutral gas network by 2050 that employed biomethane from digestors alongside natural gas with CCS. By 2030, he projected 20% of gas being renewable with 1.8m tonne of food waste, 11.1m tonne of grass (20% of national annual grass production) and 9.9m tonne of slurry (20% of national annual slurry production)[60]. His view was that digestors could be built closest to feed stocks and gas feeder lines connect the digestor to the national gas grid.

60 Hannon, J. (2019)

Biofuel

Biofuels are generally liquid fuels derived from plants that can be used to power vehicles. The two most common forms of biofuels are ethanol and biodiesel.

The Basics of Ethanol

Ethanol is a form of alcohol (C_2H_5O) made from the fermentation of organic sugars in crops. Crop commonly used crops for ethanol production include sugarcane in Brazil, corn in the USA and sugar beet in Europe. The crop is harvested, processed to create a sugary concentrate, fermented using specially breed yeast, then purified. Pure ethanol (E100) can be used in some internal combustion engines but is more often blended with gasoline to form a blend. Most vehicles on the road today can handle an ethanol blend of E15 (15% ethanol, 85% gasoline). FlexFuel vehicles can take E85. These vehicles are common in Brazil and increasingly common in the USA. It is possible to convert nearly any car to FlexFuel but it may void the warranty. The 15% of gasoline in E85 is needed to help the engine start in cooler temperatures.

Fig 35. Visiting sugar cane crops for ethanol, Brasilia, Brazil

There are a number of advantages that come from blending ethanol with gasoline:

- The carbon dioxide emitted when ethanol is burnt is offset by the carbon dioxide sequestered by the plant during photosynthesis, making it carbon neutral. When considering the life cycle carbon emissions for ethanol, the emissions from processing a crop into ethanol (electricity, transport, heating) generally means ethanol does have net positive emissions however, the more renewable energy sources used in its processing, the lower the footprint.
- Ethanol is a high octane fuel. The higher the octane rating (the number on the gasoline pump e.g. 91 gasoline, 95 gasoline), the less engine knocking and the better the engine will run. Therefore, adding ethanol to gasoline increases the performance of the engine compared to gasoline alone.
- Ethanol blended with gasoline reduces the particulate matter emitted from the tail pipe of a vehicle. E10, for example, has only one third the particulate matter emissions of straight gasoline. Particulate matter is important to cardiovascular and lung health of humans and is a major contributor to city smog.

- The by-product of the fermentation process often makes a valuable animal feed (corn ethanol produces dried distiller grain) .

While the positive outcomes of utilising biofuel are compelling, there are some negative considerations that come with using ethanol blends:

- Ethanol contains about 30% less energy per litre than gasoline, therefore the fuel efficiency of ethanol blends is lower than that of gasoline alone.
- Most current crops used for ethanol are grown in place of human food crops. This has created tension between sustainable food and sustainable fuel.

First generation ethanol is created from crops specifically grown for biofuels e.g. corn, beet, sugar cane. These feedstocks are uniform and high in sugar, making them the most economic to process into biofuel. However, the crop must provide an economic return to farmers, therefore processors must buy the crop at economic rates for the farmer to grow. The cost of the crop to the biofuel refinery often makes the biofuel uncompetitive with fossil fuel. There is also concern about the competition for biofuel crop land with food producing land and the possibility it will drive food prices up.

Second-generation ethanol aims to address the issues with first generation feedstocks by utilising waste streams to create biofuels. Second generation feedstocks might include waste food, waste timber, tree prunings or crop residues. Few commercial second generation biofuel processing plants exist as they have yet to overcome the technological challenges of converting cellulosic plants material into biofuel. There is also concern that waste streams may have value attached to them if this technology is readily available, increasing processing cost. The carbon emissions for second generation biofuels are better than first generation due to the use of waste products as a feedstock.

The Basics of Biodiesel

Biodiesel (chemically, a mix of methyl esters) is the result of refining (transesterification) of vegetable oils, animal fats, or recycled restaurant grease into complex esters. Common commercial feedstocks include waste fat from restaurants, tallow from meat processors and oilseed crops. Like ethanol, biodiesel is considered a renewable fuel, but the lifecycle emissions depend on the feedstock and refining process.

Biodiesel can be used in place of diesel in most diesel engines, but is more often blended with diesel to provide better low temperature performance and to make it usable in a wider range of vehicles.

There are a number of advantages of blending biodiesel with regular diesel[61]:

- In a 20% blend (B20), biodiesel can be used in any diesel engine.
- Biodiesel reduces particulate emissions and reduces toxic diesel emissions.
- Biodiesel lubricates engines and has a cleaning effect flushing out unwanted deposits from the engine.
- Biodiesel has a similar energy density to regular diesel, so retains fuel efficiency and engine power.

There are a few challenges with blending biodiesel with regular diesel:

- At higher blend levels, the biodiesel can gel in colder temperatures causing flow issues.

[61] US Department of Energy (2020)

Biofuel Blending Standards

Biofuel industries are established internationally. To date, 66 countries have mandated or targeted biofuel to be mixed with their fossil fuels[62]. Every country I visited during my Nuffield travels had a mandatory biofuel component in their fuel.

Country	Gasoline/Ethanol (%)	Diesel/Biodiesel (%)
Brazil	27	10
USA	10 (target 15)	5
Mexico	5.8 (target 10)	0
Netherlands	10	10
Ireland	10	10
Italy	9	9

Fig 35. Minimum national biofuel blends[63]

Lessons from California

California has a federally mandated minimum bioethanol standard of 10% and biodiesel standard of 5%. This is set by the US Federal Environmental Protection Agency (USEPA) as a climate change action and to reduce the reliance on imported oil[64].

In addition to biofuel blend standards, California also has Low Carbon Fuel Standard (LCFS) legislation. These laws aim to decrease the carbon intensity of California's transportation fuel and provide an increasing range of low-carbon and renewable alternatives, which reduce petroleum dependency and achieve air quality benefits.

Both programs have driven development of bioethanol markets with over 1.5 billion gallons of bioethanol used in California in 2015 mostly as E10[65]. There are 96 gas stations that stock E85 for a growing FlexFuel fleet in the state. A small amount of bioethanol is blended with diesel as a more sustainable jet fuel called e-diesel[66].

Most of the bioethanol in the USA is derived from corn and is processed in the mid-west close to the crop source. The emissions footprint of corn ethanol is approximately 43% of gasoline with many of the emissions coming from the fossil fuel electricity used in processing the corn to ethanol and in the transport of the fuel around the country.[67]

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62 US Department of Agriculture (2017)
63 ibid
64 US Environment Protection Agency (2020)
65 California Energy Commission (2020)

66 ibid

67 US Department of Agriculture (2017)

Fig 36. Bioethanol plant near Des Moines, Iowa

While attending the Advanced Bioeconomy Leadership Conference (ABLC Next) in San Francisco, I heard from companies rapidly commercialising second generation biofuel technology. The driver for the increased interest can be attributed to second generation biofuels commanding up to $3 per gallon premium over conventional fuels due to their lower carbon intensity. Some examples of project are:

- Aemetis Inc. has purchased a first generation corn ethanol plant in Keyes, California and is in the process of converting it to process cellulosic ethanol (ethanol made from the cellulose in plant cells) using the trimmings from California's almond trees.
- Covercress are developing a cress species that produces oil and can be grown in the grain belt in the USA over the winter when fields are generally fallowed. The oil can be processed into biodiesel.
- Arpa-E are looking at how to farm seaweed and algae on the coast as a source of biomass and oil.

All the companies above spoke of how important supporting legislation was in their investments. The hope is that one day policy and incentives are not required to make their products economically competitive, but it was definitely needed for the development phase.

Lessons from Ireland

Ireland follows the EU Renewable Energy Directive, where all Member States are obliged to achieve a minimum target of 10% renewable energy in the transport sector by 2020. The directive also set a limit on the amount for renewable energy from food based crops.

The Irish response is the Biofuel Obligation Scheme, which is the primary policy measure used to increase the share of renewable energy in the transport sector. In 2017, 225million litres of biofuel was sold in Ireland. In 2019, the scheme lifted the overall biofuel usage to 10% of all fuel sold by volume. This will increase to 11% for 2020.[68]

Ireland produces only a portion of its biofuel feedstock. Sugar beet, canola and corn are all grown for biofuel, but the majority of feedstock is either imported, or grown and processed elsewhere and the ethanol imported. Domestically produced ethanol is difficult to compete with internationally available biofuel under the Irish production system with the current price of carbon. Teagasc, the Irish

[68] Government of Ireland (2018)

agricultural and food development authority, compared bioenergy options in Ireland in 2019 and created a Marginal Abatement Cost Curve (MACC) for agriculture for 2021-2030.

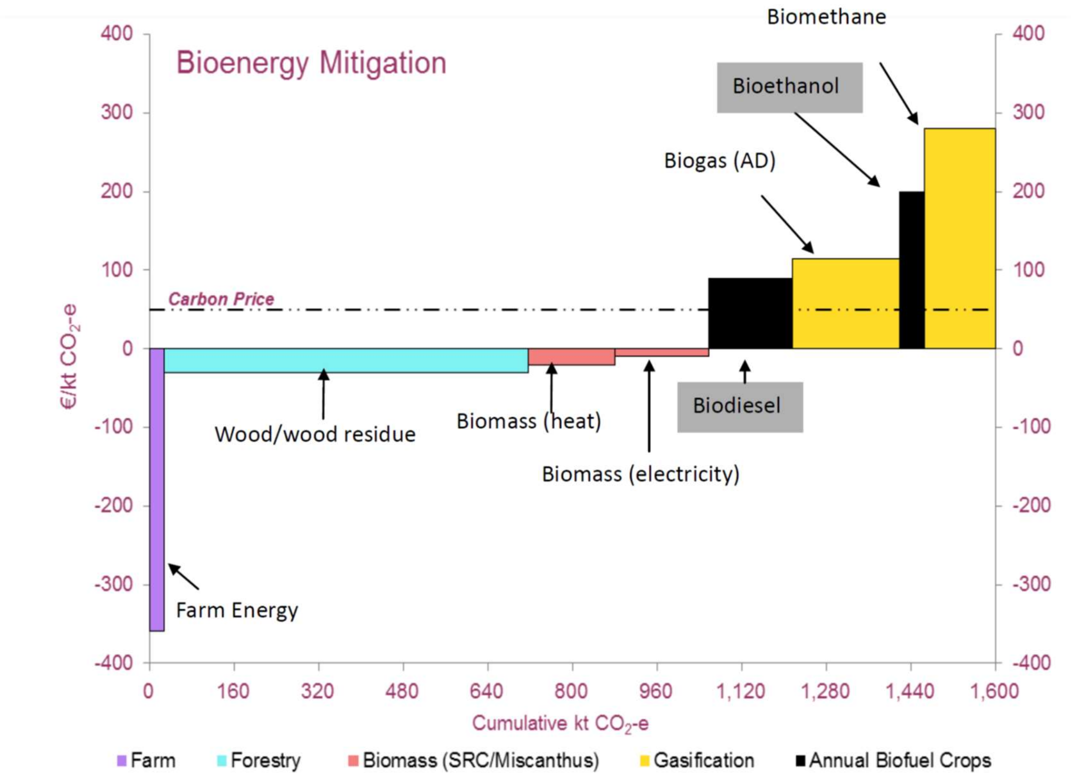

Fig 37. MACC of bioenergy options for Irish farmers[69]

The graph indicates the cost of abatement on the vertical axis versus the volume of emissions that could be mitigated on the horizontal axis. Any option below zero cost is profitable, any option below the carbon price is economic based on carbon credits and any option above the cost of carbon is uneconomic under current carbon pricing and policy. Both biodiesel and bioethanol sit above cost of production, making it unprofitable for most farmers. On the very left of the graph, the most profitable option is to reduce energy demand on farm, therefore negating the need to generaate energy supply.

Various agencies in Ireland are working to improve the economics of biofuel.

- Teagasc has a specialist division at their Oak Park crop research unit that looks at energy crops and ways of integrating them into crop rotations.
- Sustainable Energy Authority Ireland (SEAI) is looking at market adjustments and incentives for more domestically produced biofuel
- The Irish Bioenergy Association advocates and promotes biofuel and bioenergy to farmers, politicians and the public.

Most industry participants I talked to during my travels mention the price of carbon as the main driver for further biofuel (and bioenergy) development.

[69] Caslin, B. (2019)

What Will Work in New Zealand?

The examples of international energy farming provide inspiration for what may be possible in New Zealand. Technologically, it would be possible to replicate all of these energy farming options in New Zealand. The critical success factor in each international case study was supporting policy to drive profitability. It is impossible to assess the feasibility of individual energy farming options in New Zealand without understanding what supporting policy exists here in New Zealand.

In New Zealand, energy policy sits within the Ministry of Business, Innovation and Employment (MBIE). Currently, Hon. Megan Woods is Minister of Energy and Resources. MBIE is supported by the Energy Efficiency and Conservation Authority (EECA), the Ministry for the Environment (MfE) for environmental regulation and the Ministry of Transport for transport energy.

Developing Our Energy Strategy

New Zealand's current energy strategy was written in 2011 and is currently being reviewed in response to the Zero Carbon Act. In July 2019, Minister Woods presented a new vision for a 'Renewable Energy Strategy' and work programme.

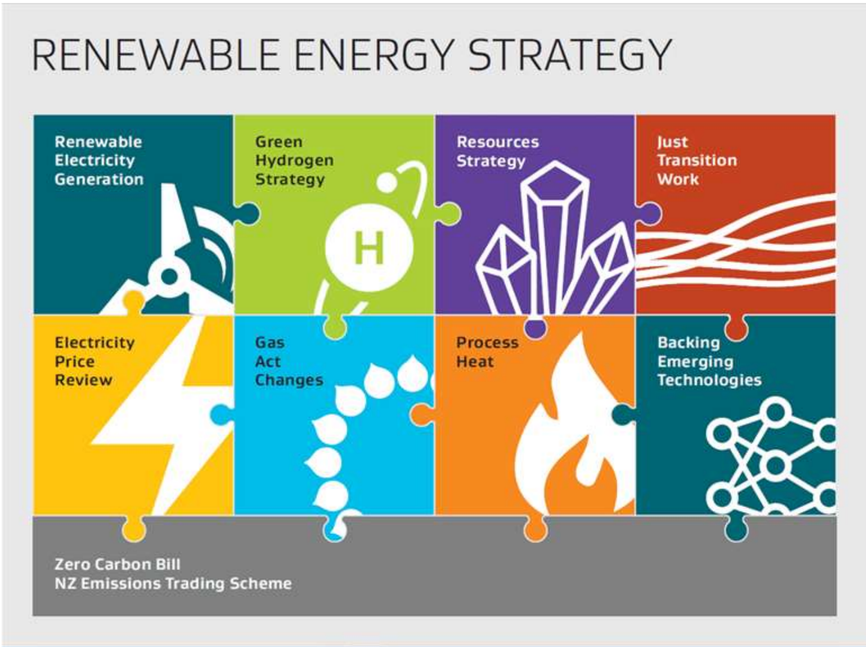

Fig 38. New Zealand Renewable Energy Strategy graphic[70]

The renewable energy strategy work programme focusses on three main outcomes[71]:

- *An inclusive and consumer focused energy system;*
- *A system that encourages increased investment in low emissions technologies; and*
- *An innovative and modern energy system that creates new opportunities for business and consumers*.

The most recent step in the work programme is the release of a discussion paper 'Accelerating Renewable Energy and Energy Efficiency'[72]. It is an excellent resource that discusses many of the

[70] NZ Ministry of Business, Innovation and Employment (2020)
[71] ibid
[72] NZ Ministry of Business, Innovation and Employment (2019)

issues, opportunities and challenges that relate to energy farming in New Zealand. It will be from these discussions that the next phase of legislation supporting future energy supply will arise. The strategy's vision talks of 'new opportunities for business'. These discussion papers are the opportunity for agriculture to present options and ideas that may benefit energy and agriculture.

'Hope is not a plan'

Michael Berube, Deputy Assistant Secretary for Transportation, US Department of Energy presented at the ABLC Next conference on the importance of a transition plan. His view was that setting a target was the easy step. To achieve these challenging targets a comprehensive plan is needed. 'Without a plan there is no hope and hope is not a plan'.

There was clear evidence of this in Ireland where emissions targets were clear but without a plan for agricultural emissions, Ireland has regularly missed their targets. This indicates the importance a strong plan for energy and agricultural transition in New Zealand.

Advocating for Farming Energy

Internationally, agricultural research, development and advocacy organisations have energy specialists researching and advocating for energy farming opportunities. This is in contrast to New Zealand where agriculture appears to be absent from the energy transition discussion.

In my view, this is a consequence of levy bodies, Crown Research Institutes and commercial entities focusing firmly on their own sector, as opposed to having a pan sector levy group such as Teagasc in Ireland, which looks at all agricultural opportunities. Farmers are unlikely to get involved directly in the national energy policy and incentives, therefore we need agricultural levy and advocacy groups to work together to build the capability to do it on our behalf.

Beyond the examples of policy support in this report, I came across a few other policy ideas that could prove useful to energy farming in New Zealand:

- A dedicated government entity managing policy and engagement in renewable energy, such as Sustainable Energy Authority Ireland or the California Energy Commission;
- Collaboration between Ministry for Primary Industries (MPI) and MBIE to investigate energy opportunities on agriculture, similar to the memorandum of understanding between the Department of Energy and the Department of Agriculture in the USA.;
- Protection from cheap imported renewable fuels that have high lifecycle carbon footprint like the EU;
- Carbon tax fund to support initial capital investments similar to California;
- Export opportunities to support smaller countries like the Pacific Islands towards renewable energy as happens within the EU; and
- No GST and 100% write down on renewable energy investments, similar to that being sought in Ireland.

Advocating for opportunities to farm energy will rely on sound case studies of it being feasible and profitable in New Zealand. Many of the examples of farming energy I came across are well suited to the environment in which they exist and may not be directly translatable to New Zealand. All of the science and technology I came across is being researched concurrently in some form in New Zealand. The University of Auckland and University of Canterbury have energy departments investigating biofuels and biogas. Scion, New Zealand's forestry research institute, is a world leader on cellulosic ethanol. Lincoln University even converted a Massey tractor to run on biogas in the 1970's[73].

The next step is the development of energy generation systems, suitable to New Zealand conditions. Each system needs to pull together technology, policy and economics to build a business case to promote opportunities to farm energy to decision makers and farmers.

[73] Campbell, J. Personal communication, Sept 2019

Conclusions

This study sought to answer the question:

What energy farming opportunities could New Zealand farmers pursue to help our country reach net zero carbon?

From a technological perspective, New Zealand farmers could pursue any of the examples of energy farming that I found internationally. Solar and wind power generation is already utilised in New Zealand and has potential for growth. Our high production of agricultural products and agricultural wastes (e.g. animal effluent, crop residue), would make excellent feedstock for biodigesters, and our productive soils could grow energy crops for biofuels. All the technology to process these feedstocks into energy exists both here and around the world. So technologically, all energy farming opportunities internationally should be pursued in New Zealand.

From an environmental perspective, each international energy farming option I visited had a lower GHG emissions footprint than the fossil fuel alternative. Using our highly renewable electricity supply in New Zealand to run bioenergy processing plants could further lower emissions compared to Ireland and California. Some options could even be carbon negative, sequestering more carbon than it released. So environmentally, all energy farming opportunities internationally should be pursued in New Zealand to help reach net zero carbon.

However, from an economic perspective, most energy farming opportunities are uneconomic internationally without government support. They rely heavily on policy and incentives to boost the value of farmed energy and make it competitive with fossil fuel alternatives. I believe the same is true here.

So how do we fix the economic roadblock to our energy farming future?

New Zealand is in the early stages of developing an energy strategy to help it achieve Net Zero Carbon 2050 targets. Such a strategy provides the best opportunity for New Zealand's agriculture sector to join the conversation on the future of energy in New Zealand. Using examples from international policies and adapting them to New Zealand could create break down economic barriers to invest in farming energy. New Zealand agriculture needs to divert its focus on purely sector-related policy (usually environmental) and participate in energy policy that could provide their farmers new opportunities.

Farmers will also need support to take up energy farming opportunities. Like any farming system, farmers will need to see what the opportunities look like before making any decisions. They need to know the benefits to their farm, any associated risks, and ultimately the economic case for investment. New Zealand agriculture will need to broaden its skill base to develop case studies that farmers could emulate. Energy farming demonstrations would also encourage farmer confidence in this new sector.

Who exactly do I mean by 'New Zealand agriculture'? New Zealand agriculture is currently a fragmented group of levy bodies, Crown Research Institutes, advocacy groups and commercial operators, who are each focused on a narrow band of the agricultural sector. As a result, opportunities such as energy farming slip between the cracks as they do not fall inside the mandate of any one group. Knowledge and input would be required from each of these groups to successfully create energy farming opportunities in New Zealand. Therefore, a pan-sector group made up of experts from across the sector would work alongside external energy experts to act as 'New Zealand agriculture' in this scenario.

Recommendations

Farming Energy Working Group

A Farming Energy Working Group (FEWG) needs to be created, pulling in technological, scientific, economic and policy knowledge from across the agricultural sector. This may include experts from levy bodies, Crown Research Institutes, advocacy groups and commercial operators, alongside energy sector experts. This working group would act as the champion on energy farming and actively pursue related policy, research and development.

Policy

The FWEG needs to participate in the formation of New Zealand's next 'Renewable Energy Strategy'. The discussion document 'Accelerating Renewable Energy and Energy Efficiency' from MBIE is an excellent place to start. Advocating for policy that will support farmers investments might include:

- A dedicated government entity managing strategy, policy and engagement in renewable energy such as Sustainable Energy Authority Ireland or the California Energy Commission.
- Formal collaboration between the FEWG, the Ministry for Primary Industries and MBIE to investigate energy opportunities on agriculture similar to the memorandum of understanding between the Department of Energy and the Department of Agriculture in the US.
- A carbon tax fund to support initial capital investments similar to California.
- Export opportunities to support the Pacific Islands towards renewable energy.
- No GST and 100% write down on renewable energy investments similar to that being sought in Ireland.
- A net metering policy on renewable energy generation similar to California.
- Long term pricing contracts similar to those in Northern Ireland.
- 'Renewable fuel standards' that specify biofuel content in petrol and diesel that will ensure a demand for biofuels.
- Options for financial incentives, installation grants, low interest loans (green loans), co-ownership or leasing.

Research and Development

To support the input into the strategy and to help farmers understand the energy farming opportunities available, the FEWG needs to pull together all the knowledge on energy farming options to create energy farming system options. Each option requires:

- A technical feasibility study outlining how the investment would fit into the operation of the farm and ongoing resource requirements;
- A business case which outlines what policy support and incentives may be required to make it profitable and the financial risk if policy was to change;
- An emissions profile to ensure the investment will achieve emission reductions and how those reductions will help the energy sector and the individual business meet its goals; and
- The MACC work by SEAI and Teagasc in Ireland investigating bioenergy options would provide a good blueprint.

Energy farming demonstrations would also provide policy makes and farmers with confidence in the success of each energy farming option.

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