Chapter 4a: Reducing emissions – opportunities and challenges across sectors

Heat, industry and power

Energy is a necessity in the modern world as a critical input into every good and service in our economy. Energy used in Aotearoa comes from a range of sources including bioenergy, petroleum, coal, natural gas, wind, solar, hydro and geothermal energy. Some of these energy sources can in turn be used to produce other forms of energy like hydrogen or electricity. Different forms of energy production and use have different emissions associated with them. Different forms of energy, such as heat and electricity, enable industries to produce goods and materials. Industrial activities are many and varied, industries all use energy, and some have process emissions as well.

This section outlines the opportunities and some of the key challenges for reducing emissions in heat, industry and power.

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4a.1 Introduction

Viable opportunities to reduce energy emissions (carbon dioxide (CO_2)) and adopt low emissions energy sources and technologies in Aotearoa exist now. However, businesses, households and communities face a number of challenges that hinder the uptake of these and other viable emission reduction opportunities.

This section outlines opportunities and challenges for reducing emissions for:

- Process heat
- Industrial processing and production
- Electricity system
- Fossil fuel production.

Transport emissions contribute the largest portion of emissions from energy use in Aotearoa. Opportunities and challenges for changing energy use are outlined in the following sections and reducing emissions from transport, as well as those from buildings are outlined in *Chapter 4b: Reducing emissions – opportunities and challenges across sectors: Transport, Buildings and Urban Form*.

4a.2 Process heat

Process heat refers to the thermal energy (heat) used to manufacture products in industry. Manufacturing has an important role in our economy. It creates and supports employment[1], is a significant regional employer, adds value to our primary industries, earns export revenue and increases our resilience to international supply chain shocks while reducing the emissions associated with the transport of goods from overseas.

It represents roughly 6 Mt CO_2 or nearly 8% of gross emissions in Aotearoa. Applications range from heating hot houses to grow capsicums, to milk pasteurisation and drying, to making steel. The largest users of process heat in Aotearoa are the food manufacturing and wood, pulp and paper manufacturing sectors.

Process heat emissions have steadily increased since 1990, predominantly due to an expansion in food processing. In recent years however, emissions from process heat have remained relatively steady due to a slowdown, and in some cases a decline, in production from industrial sectors.

[1] Manufacturing employs around 11% of the labour force

Process heat is supplied from a diverse range of fuel sources including, coal, gas, biomass, direct geothermal heat and electricity. Often a combination of fuels, for example electricity, gas and biomass, are used at a single industrial site.

4a.2.1 Options for reducing emissions

This section outlines the opportunities and challenges related to options for decarbonising process heat. Most potential emission reduction opportunities come from low and medium temperature applications which accounted for 4 Mt CO_2 in 2018. High-temperature process heat applications such as making steel, cement and methanol account for about 2 Mt CO_2 of process heat emissions but have limited direct measures to reduce emissions (discussed below in Industrial processing and production).

Overall, the evidence summarised below shows continued efforts to improve energy efficiency are important to reduce emissions in the short-term. Biomass and electricity can be used to decarbonise our low and medium temperature process heat manufacturing equipment (plant), over the next 20 years. However, barriers to this include the cost difference between fossil fuels and low emission alternatives, long-term fuel availability and the cost of plant conversion.

Opportunities to increase the use of low emissions fuels exist. At current carbon prices, the operating costs of low emissions fuels are generally considered more expensive than fossil fuels. The associated costs can vary widely from site to site, even within a single sector, but for some sites low emissions options are cost-competitive with fossil fuels. The key factors which affect the choice of fuel and the delivered cost of energy (heat) are the specific process and temperature requirements, site location and availability of fuel (including transport costs and access to and capacity of distribution and transmission lines) and the relative fuel costs.

The upfront capital cost of low emissions process heat equipment, while substantial, is often competitive with or cheaper than fossil fuel fired assets. However, the cost of refurbishing and extending the life of an existing fossil fuel asset is often cheaper and easier than replacing it with a low emission alternative. Additionally, under current business models, there may be limited opportunities during a given period for a company to undertake conversions outside regular maintenance and refurbishment cycles.

Retrofitting an existing plant can increase the cost of emissions reductions due to constraints on space, plant shut down times, process redesign and other factors. However, there are significant viable emissions reduction opportunities for existing plants. Generally, a new build plant offers the most cost-effective opportunities for optimising energy efficiency and utilising low emission fuels and production processes. It also ensures that full cycle emissions reduction opportunities can be assessed and implemented.

Globally, the decarbonisation of process heat is supported by natural gas as an option to displace coal. However, uncertainty regarding medium to long-term gas supply has largely resulted in process heat decarbonisation options centring around fuel switching to biomass and electrification. Additionally, there is no reticulated gas network in the South Island where much of the industrial coal use occurs. As the lowest emission intensity fossil fuel, the extent to which Aotearoa moves away from or towards gas depends on the availability of gas, stringency of climate change policies and carbon pricing.

Table 4a.1: Opportunities and challenges to reducing process heat emissions

Option	Opportunities and challenges
Energy efficiency	Energy efficiency improvements are often considered as the lowest cost, first step in reducing process heat emissions. These measures collectively reduce the amount of heat required, and emissions for, the same output from a coal or natural gas fuelled boiler, oven, burner or kiln. Efficiency can be improved through plant maintenance, optimising operations, heat recovery and high efficiency electric heating technologies. Reducing energy demand in industrial processes via energy efficiency measures can also enable future fuel switching opportunities (for example, coal to biomass, or coal to electricity) by lowering the operating cost of low emission fuels. Opportunities to improve energy efficiency in industrial process heat have been broadly assessed and quantified.[2] The Process Heat in New Zealand study[3] suggests an annual emissions reduction potential of 0.8 Mt CO_2 or a cumulative reduction potential of 30% in the food manufacturing sector, and 0.05 Mt CO_2 or 10% in the wood, pulp and paper manufacturing sector. Much of this opportunity is at low or negative emissions reduction cost but can range up to $300 per tCO_2 depending on the sector and application. For applications where a boiler is used to produce hot water (low temperature requirements), industrial heat pumps can offer a more efficient alternative. The coefficient of performance, which is the ratio of output energy (heat) to input energy, can be as high as 3-5 for electric applications[4], in comparison to 0.5 for a coal or gas boiler.[5] For modern mechanical vapour recompression (MVR) technologies, the coefficient of performance can be as high as 50.[6] This means certain electric technologies are far more efficient at producing heat than the combustion of fossil fuels. To date practical applications[7] are limited to temperatures of less than 100°C. The cost of these heat pumps are falling as units are produced at scale, as new technologies are commercialised and as installation practices become standardised. As many energy efficiency technologies increase the use of electricity and reduce the use of fossil fuels, some of the barriers applicable to electrification (discussed below) can also apply to some energy efficiency technologies. While many energy efficiency measures are commercially ready, cost-effective and widely applicable across sectors, opportunities have largely not been enacted due to practical constraints, competing investment priorities and a multitude of other barriers. These barriers have been explored in more detail, including consultation,

[2] (Atkins, 2019)
[3] (Ministry of Business, Innovation and Employment, 2019b)
[4] (Energy Efficiency and Conservation Authority, 2019b)
[5] (Transpower, 2019)
[6] (Energy Efficiency and Conservation Authority, 2019a)
[7] Only a handful of high temperature industrial heat pumps (90 - 180°C) have been deployed globally as pilot projects. The technology is at the research and development stage.

Option	Opportunities and challenges
	by the Ministry of Business, Innovation and Employment and the Energy Efficiency and Conservation Authority.[8] A key barrier can be the requirement for rapid payback periods on capital investments within companies. This can limit the number of projects that receive Board approval to proceed. Additionally, energy efficiency projects may not be substantial enough for banks to lend to so financing and accessing capital may be difficult. There is also a limited pool of expertise in Aotearoa with the specific knowledge and skills to identify energy efficiency opportunities and undertake the appropriate analysis to support the business case for investments. This is particularly the case when considered alongside other emissions reduction opportunities such as fuel switching. The limited pool of expertise can act as a constraint on the rate of plant conversions. *See also section on the Electricity System*
Electrification	Fossil fuelled boiler systems contributed 3.5 Mt CO_2 in 2018. There is an opportunity to reduce fossil fuel use in boiler systems through increasing the use of electricity for heating and increasing the use of biomass (see below). Solutions for the electrification of some applications of high temperature process heat are emerging internationally. Electric boilers and other electric heating technologies are technologies currently used for process heat in the food manufacturing and wood, pulp and paper manufacturing sectors. Electrification is expected to be driven by falling costs and improved performance of technologies such as industrial heat pumps for lower temperature heat applications and electrode boilers for medium heat applications. Economic solutions for electrifying low and medium temperature process heat are available today, at costs ranging from \$100 to \$250 per tCO_2. The capital cost of electric heating systems, such as electrode boilers, is generally more affordable than fossil fuel or biomass systems. However, the cost per gigajoule (GJ) of delivered electricity can be about three to five times more expensive than coal and gas at current carbon prices. Therefore, electrification of process heat can be a relatively expensive emissions reduction option, particularly when the cost is compared to the continued operation of existing equipment. For some applications however, this increased operational cost can be negated by the improved efficiency of electrical conversions, meaning less energy (fuel) is required to produce the same heat output.[9] The rate of electrification in industry would be limited by the time required to convert plants, upgrade transmission and distribution infrastructure and potentially build new renewable generation.

[8] (Ministry of Business, Innovation and Employment, 2019b)

[9] The cost of converting to electric heating technologies will be influenced by whether the existing plant is configured around steam driven or hot water driven processing. Steam processes require higher temperatures than water heating, this is generally more expensive to meet with electric technologies.

Option	Opportunities and challenges
	One of the key barriers to electrifying process heat, where significant onsite electrical upgrades are required, is the cost and time associated with distribution and/or transmission grid connections. For large industrial users, connection costs can make up a larger proportion of a project's cost than the equipment itself. In addition, it can take significantly longer, from planning and consenting to construction, to complete a new transmission line or interconnection upgrade than it does to develop and build a new processing plant. *See also section on 4a.4 The electricity* system *in this chapter*
Biomass	Biomass[10] is already used extensively in the wood, pulp and paper manufacturing sector as on-site waste material and processing by-product is readily available. In these applications, woody biomass provides more energy for process heat than coal and natural gas combined.[11] Other industrial sectors, such as food, cement, lime and glass manufacturing use the fuel more opportunistically and generally at manufacturing sites near forestry or wood processing operations. Biomass can be expected to play a significant role in decarbonising process heat. Costs can be comparable to coal and natural gas where biomass is easily available, with emissions reduction costs ranging from \$0 to \$100 per tCO_2. While biomass could supply high temperature process heat (>300°C), the fuel is most suitable for applications which require medium temperature process heat (100 to 300°C) due to size of plants and fuel availability limitations. Biomass can be blended with, or substituted for, coal in some existing boilers, furnaces and kilns. Although this may require changes to fuel handling systems and particulate (air quality) management, this presents a lower cost route than complete replacement of combustion systems and allows industrial users to begin decarbonisation with existing assets.[12] Dedicated biomass boilers would achieve greater efficiency of combustion for a wide range of biomass fuel types. Transportation distance and effort of recovery determine the extent to which biomass can be economically used for process heat. Regional mismatches in supply and demand coupled with differences in cost to transport biomass between regions can result in areas with oversupply and areas of scarcity.[13] Wide regional variation means that not all the potential biomass supply can be used. In addition, while the supply of woody biomass residues may appear to be abundant in some regions, economic trade-offs would need to be made when deciding whether to utilise such residues for process heat. There are alternative uses of these residues, such as nutrient recycling for plantation forest (in lieu of the use of fertiliser) or as liquid biofuel for hard to abate transport emissions. Trade-offs would also need to be made around the economics of residue recovery and the potential benefits of using residues for process heat and other purposes.

[10] Woody biomass is considered carbon neutral as the carbon dioxide released during combustion is equivalent to the amount absorbed by the tree during growth. If the wood originates in sustainable forestry, then this is a renewable energy source.
[11] (Energy Efficiency and Conservation Authority & Ministry of Business, Innovation and Employment, 2018)
[12] Industry engagement
[13] (Hall & Alcaraz, 2017)

Option	Opportunities and challenges
	For example, there may be opportunities to recover forestry slash in regions like the East Coast where forestry waste from nearby operations is deposited on beaches[14] but it may not be economically feasible to do so. Uncertainty regarding long-term biomass supply is an acknowledged issue and can impede decision-making and investment in process heat conversions.[15] The lack of robust and recent long-term data coupled with changes in forestry and wood processing market conditions such as log and lumber prices, fumigation requirements, transport costs and exchange rates could hamper biomass cost and availability.[16] In addition, there may only be a small pool of consultants who have in-depth knowledge about wood fuel supply options in Aotearoa and their knowledge is not widely shared. A significant increase in the use of biomass would also be contingent on the development of robust supply chains and long-run supply certainty.
Biogas	Biogas in the form of methane currently represents a relatively small proportion (3.3 PJ) of our total energy use. It is primarily used for electricity generation and supplying heat. Potential for increased biogas production and use is constrained by national waste recovery and processing infrastructure, requirements to upgrade and purify the biogas to meet specifications for use and injection into the existing natural gas distribution infrastructure and the low population density in Aotearoa. *See also Chapter 4d – Reducing emissions: options and challenges across sectors, Waste*
Direct geothermal heat	Direct geothermal heat use is currently located near sources within the North Island's Taupo Volcanic Zone for use in wood, pulp and paper manufacturing and food manufacturing sectors. It can provide a low cost and low emissions heat source for low and medium temperature processes. Direct heat from geothermal sources is unlikely to play a significant role in displacing existing coal and gas use in industry; however, it does provide a low emissions option for new industrial sites in certain regions. The New Zealand Geothermal Association (NZGA) has developed the Geoheat Strategy[17] and a complementary action plan which seeks to increase the use of direct heat in industry. The strategy outlines the approach to diversify the direct use of geothermal heat to create new businesses, decrease the use of fossil fuels in industry, support regional economic and social development and carve out a role for Aotearoa to promote the use of direct heat and associated technologies internationally.

[14] Internal Climate Change Commission document (2020 interview with representative from Puketawai Marae, Tolaga Bay)
[15] (Ministry of Business, Innovation and Employment, 2020c)
[16] (Ministry for Primary Industries, 2016)
[17] (New Zealand Geothermal Association, 2017)

Option	Opportunities and challenges
	Key challenges include the ability to source a sufficient load to justify the economics of drilling and operating of a well[18] and limited locations with access to geothermal resources. Proximity to primary commodities, labour, transport and market are key considerations that often take precedence over the specific type or emissions intensity of an energy source. The costs of scoping, drilling and operating a geothermal well are significant. Because of this it is unlikely new direct geothermal heat opportunities would be developed in isolation. When considered alongside new geothermal electricity generation projects however the cost and risk of exploring and utilising the resource can be significantly reduced. Direct heat use is likely to use only a small proportion of the energy in a geothermal well in comparison to electricity generation. When it is used as part of an industry cluster such as the Kawerau Industrial Complex, it can be a cost-effective and low emission heat source. Industry clusters tend to develop organically, but once established may benefit from a more organised approach to their ongoing growth and development.[19] *See also section on 4a.4 The electricity* system *in this chapter*
Hydrogen as a fuel	Hydrogen gas could be combusted to produce heat for buildings and industrial applications in much the same way that natural gas is used. To be considered a low emission fuel, hydrogen needs to be produced from renewable electricity (green hydrogen) or produced from fossil fuels but with carbon emissions captured and stored (blue hydrogen). A blend of approximately 20% (by volume) of hydrogen with natural gas may be compatible with existing gas equipment and infrastructure. Because of the lower energy density of the blended fuel, this equates to a 7% reduction in emissions intensity.[20] This may provide an affordable option for hydrogen to enter the system by leveraging the existing gas network infrastructure and reducing production volumes. However, this could also prolong natural gas production and use. A complete fuel switch to hydrogen may require replacement of distribution and storage infrastructure and process heat equipment. In principle, hydrogen could displace all fossil fuels used for industrial and building heating. However, hydrogen heating is highly unlikely to be a lower cost decarbonisation choice than direct electrification due to inherent inefficiencies in its production from electricity and then combustion for heat. Conversion losses can be upwards of 70%. Hydrogen production costs and transport and infrastructure requirements are unlikely to fall to the level where it is an economical fuel for heating applications in the next 15 years.[21] Beyond this, hydrogen could potentially be used for displacing or supplementing natural gas in some hard to abate sectors with high temperature requirements such as cement, lime and glass manufacturing.[22] Hydrogen heating in

[18] (Lawless Geo-consulting, 2020)
[19] (Hall et al., 2015)
[20] (Committee on Climate Change, 2018); Industry engagement
[21] (Concept Consulting, 2019)
[22] (BloombergNEF, 2020)

Option	Opportunities and challenges
	these applications is still at the research stage but has the potential to be used towards 2050.[23] An important consideration for hydrogen production is water consumption. Producing hydrogen through water electrolysis or fossil fuel reformation requires large amounts of high purity water. For example, to produce 1kg of hydrogen, nine times the amount of fresh water is necessary (nine litres).[24] This echoes a key challenge raised by submitters to MBIE's Vision for Hydrogen Green Paper. It was recognised there may be concern regarding Crown-Māori relations and kaitiakitanga.[25] *See also section on 4a.3 Industrial processing and* production *in this chapter*

4a.3 Industrial processing and production

Our heavy industries produce iron and steel, aluminium, cement and lime, methanol and urea for use across the economy and for export. In these industries, fossil fuels are combusted to both generate process heat and to drive chemical reactions. Fossil fuels also act as reactants in these chemical reactions that are intrinsic in the conversion of raw materials into a product. As such, these tightly integrated emitting activities (process heat and chemical reactions[26]) and their potential emissions reduction opportunities need to be considered together.

Emissions from these activities accounted for roughly 3 Mt CO_2e in 2018. Figure 4a.1 below illustrates the direct emissions from fuel combustion for energy (process heat) and industrial processes (chemical reactions) and the indirect emissions based on the sectors' electricity demand and fossil fuel consumption. Indirect emissions from emitting activities associated with the production and supply of electricity, oil and gas are allocated based on the sectors' demand for these commodities.

[23] (Concept Consulting, 2019)
[24] (Pflugmann & De Blasio, 2020)
[25] (Ministry of Business, Innovation and Employment, 2019a)
[26] Referred to as Industrial Processes and Product Use (IPPU) emissions in the New Zealand Greenhouse Gas Inventory and the United Nations Framework Convention on Climate Change.

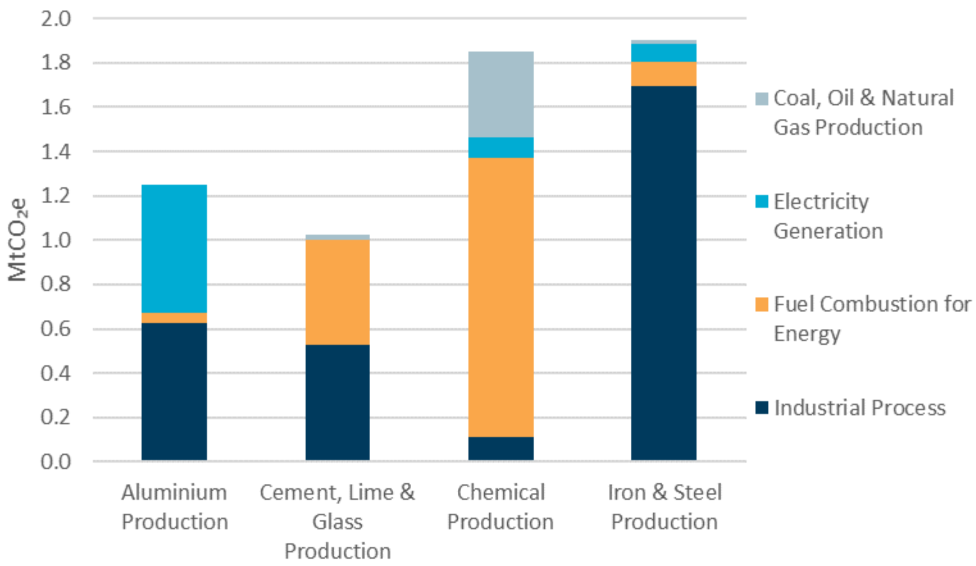

Figure 4a.1: Direct and indirect emissions from heavy industries in Aotearoa (2018)

Source: Commission analysis

The heavy industrial sector in Aotearoa is characterised by a small number of large manufacturing sites. For example, there is just one aluminium smelter and one integrated iron and steel mill in this country. This means that changes in production activity of a single firm can have a significant impact on overall emissions from the sector. It may also have significant impacts on adjacent sectors such as the electricity system and oil and gas sector.

Our heavy industries are producing at or near peak capacity, based on the size of the plant. As such, there is limited opportunity for production or emissions growth. Fuel resource availability and price, particularly natural gas, also directly impacts industrial production activity and emissions. Total emissions from heavy industry have remained largely unchanged since 1990 except for petrochemical production. Emissions from petrochemical production have increased 129% since 1990.[27] Notably, methanol production and resulting emissions fluctuate in line with natural gas production in the Taranaki region.

The sector is also characterised by their significant contribution to regional gross domestic product, employment and economic development. In certain areas, like the Bay of Plenty or Northland, industries were developed to take advantage of local natural resources and communities were formed around the industry.

Heavy industrial activity also supports activity in other sectors, for example, through the production and distribution of ammonia-urea based fertiliser for use in agriculture and cement and steel for the construction sector. Domestic production of these commodities provides security of supply and potentially greater control over product quality.

The current challenges faced by a number of our country's industrial firms can be partially attributed to the widespread economic impacts of COVID-19. Supply chain disruptions and changes in demand from lockdowns around the world has led to changes in production activity, global inventory oversupply and decreases in commodity prices. Over the course of a year, a number of industrial

[27] (Ministry for the Environment, 2020a)

firms across Aotearoa have undertaken or announced strategic reviews to restructure their operations and improve profitability in the face of changing market conditions. Changes in economic activity and employment from COVID-19 may be exacerbated by the uncertainty and potential employment and regional economic impacts of these strategic reviews.

Box 4a.1: Emissions leakage

Emissions leakage refers to the situation where there is an increase in emissions globally as a result of production moving from one country to another country with lower environmental standards. While closure of domestic industries would reduce domestic emissions, the global impact is less certain due to potential emissions leakage.

How likely emissions leakage is to occur depends on whether closure creates a global shortage in the commodity and if so, where production is likely to shift to. Another important consideration is how emissions-intensive domestic production in Aotearoa compares with international production.

Many of the emissions-intensive products manufactured in Aotearoa compete with internationally produced products. These products are classified as 'emissions intensive and trade exposed' for the purposes of the NZ ETS and receive a free allocation of units. This mitigates the cost the NZ ETS imposes on the production of these goods allowing them to compete on the international market.

4a.3.1 Options for reducing emissions

This section outlines the opportunities and challenges related to reducing emissions from our heavy industries. The most likely significant emissions reductions would result from the closure of industrial sites, such as the signalled exit of the Tiwai Point aluminium smelter. The loss of domestic production would result in an increase in imports and the associated embodied emissions. It would also impact the ability for Aotearoa to process recovered waste materials such as scrap steel and aluminium.

Evidence summarised below shows there is potential to reduce emissions through the increased use of alternative, low emissions construction materials to displace use of higher emissions materials. For example, where feasible and applicable, using structural engineered wood products in place of steel, or displacing Ordinary Portland Cement with low carbon concrete.

Reducing process heat emissions in heavy industry can be achieved by improving energy efficiency and greater use of low emissions fuels, including biomass, electricity and hydrogen-natural gas blends (see section on Process heat above). At present, there are technical constraints on the degree to which fuel switching in heavy industry can be adopted due to high-temperature requirements, the need for chemical reactants and the tightly integrated nature of these activities.

Longer term, there is potential to decarbonise a range of industrial processes through a range of emerging low emission technologies, particularly hydrogen. However, the economics of hydrogen production remain a barrier to more widespread use particularly when compared to costs of incumbent fossil fuels.

Additionally, our country's heavy industrial manufacturing plants are relatively old and built to certain specifications with integrated processes and equipment. As such, the capital investment required to fully transition an industrial process to a different feedstock can be prohibitive and on par with the establishment of a new plant. The small domestic market and high relative input costs may not support new at-scale industrial plant investment in Aotearoa.

Table 4a.2: Opportunities and challenges for reducing industrial processing and production emissions

Option	Opportunities and challenges
Waste Recovery	Aluminium and steel can be recycled indefinitely without product degradation. Aluminium is also the most cost-effective material to recycle and steel is the most recycled material in the world. Recycling avoids the direct greenhouse gas emissions associated with primary aluminium production and up to 95% of the energy-related emissions.[28] [29] Emissions reduction potential is influenced by the amount, quality, composition and type of scrap being recycled. Domestic steel and aluminium production are technically limited in how much of scrap metal can be incorporated into the production process and by the quality of available scrap metal. As such, the emissions reduction opportunity is limited, and benefit may be more weighted towards other environmental outcomes such as less waste going to landfills. Waste recovery is a critical component to reducing emissions from waste and increasing the circularity of our economy. In Aotearoa it is partially impeded by the limitations of domestic materials processing infrastructure and challenges around collection and transport of materials across a long country with a dispersed population. It may be difficult to reach the economies of scale required to make recycling of certain materials cost-effective. *See also Chapter 4b: Reducing emissions – opportunities and challenges across sectors, Transport, Buildings and Urban Form; and Chapter 4d: Reducing emissions – opportunities and challenges across sectors, Waste.*
Reducing demand for emissions intensive materials	Reducing demand for products made through an emissions intensive process may reduce overall emissions. Demand can be reduced through changes in construction practices and methods. However, reducing domestic demand for a product may not reduce the production activity levels of domestic plant, particularly for export-oriented industries. It may not be economically or technically feasible to decrease production. Additionally, reduced domestic demand may result in increased export of the material which would support continued economic activity and potentially help to reduce emissions in the importing country. *See also Chapter 4b: Reducing emissions – opportunities and challenges across sectors, Transport, Buildings and Urban Form; and Chapter 4d: Reducing emissions – opportunities and challenges across sectors, Waste.*
Use of supplementary materials	Cement is primarily composed of clinker which is produced by heating calcium carbonate and other minerals in a kiln to drive a calcination reaction. Clinker is a granular substance which acts as a binder in cement products. Concrete is made from cement.

[28] (The International Aluminium Institute, 2018)
[29] (Energy Transitions Commission, 2020)

Option	Opportunities and challenges
	Significant amounts of carbon dioxide are released from the fossil fuel combusted for heat (energy) to make the clinker and from the calcination reaction (chemical process). In 2018, process emissions from cement and lime manufacturing were 0.5 Mt CO_2. The emissions intensity of cement production can be improved by reducing the proportion of clinker in the product by blending it at higher fractions with supplementary cementitious materials (SCM). Ordinary Portland Cement is the industry preference in Aotearoa and has a SCM substitution of about 2%.[30] Shifting to use of blended cements with the global average substitution of 35%[31] would improve the emissions intensity of domestically manufactured cement. SCM includes blast furnace slag from steel mills, fly ash from coal power plants, or natural pozzolans from volcanic ash or pumicite from the North Island's Central Plateau. There may be natural variation in these materials, as such, its use may be constrained by the need to source SCM with consistent properties and the need to process the material from its raw state prior to use which would incur additional costs. Increased competition for these materials globally would also influence availability and cost, potentially constraining their use in Aotearoa. There are also challenges with the distribution and transport of natural pozzolans to our country's cement manufacturing facility. Given the different types of SCM which may be used, the emissions reduction cost ranges from \$0 to \$100 per tCO_2 depending on where the material is sourced from. Uptake of SCMs has been limited by perceptions of risk, preference towards familiar technologies and materials and limitations within the Building Code's product standards and specifications. Deeper exploration of mātauranga relating to the sustainability, ethics and applications of resource extraction can support regional development and community resilience if SCM is sourced from the North Island's Central Plateau. For example, the oyster reserves in the Kaipara harbour used to be a rich source of calcium carbonate for cement manufacture. In recent times, the oyster reserves are used more for customary management practices.[32] *See also Chapter 4b: Reducing emissions – opportunities and challenges across sectors, Transport, Buildings and Urban Form.*
Hydrogen as a feedstock or reductant	Petrochemical (methanol and urea) production and steelmaking are domestic industries which are technically compatible with hydrogen-based production.[33] [34] In 2018, petrochemical production and steelmaking accounted for 3.2 Mt CO_2[35] of our gross emissions. Hydrogen is an intermediate chemical in the standard production process for petrochemicals. Petrochemicals are currently produced in an emission intensive

[30] (thinkstep, 2019)
[31] (IEA, 2018)
[32] (Te Uri O Hau Settlement Trust, 2011)
[33] (BloombergNEF, 2019c)
[34] (BloombergNEF, 2019b)
[35] (Ministry for the Environment, 2020a)

Option	Opportunities and challenges
	process utilising natural gas as a fuel and feedstock. A green hydrogen supply would eliminate this stage of the process and decarbonise petrochemical production. For urea production, this change in feedstock cost is equivalent to an emission reduction cost of $250 per tCO_2. For methanol production, a change in feedstock is equivalent to an emissions reduction cost of approximately $500 per tCO_2. Additional costs are incurred compared to current urea production because a source of pure carbon dioxide is needed, the hydrogenation process requires more process heat than the current syngas (natural gas) route, so is less energy efficient, and three hydrogen molecules are required to make methanol via hydrogenation versus two via the syngas route. Co-location near the Kapuni Gas Treatment Plant could provide a source of pure carbon dioxide to be used in conjunction with green hydrogen. Hydrogen as a reductant in steelmaking is not yet commercially viable although it has been technically proven overseas in pilot and demonstration scale projects. Global outlooks suggest large scale zero carbon steel production could be economic and be deployed beyond 2030.[36] In Aotearoa however, domestic steelmaking utilises iron sand as the source of ore and operates a globally unique process using this available resource. Because of this, a transformation to hydrogen steelmaking might require a unique conversion to that being developed internationally and as such could incur significant additional costs. The cost of hydrogen is a key determinant in the economics of these emissions reduction opportunities. As hydrogen use in industry is still largely in the research and development stage, there are considerable uncertainties in the cost of future production. Large scale hydrogen production would be required to completely displace natural gas in heavy industries across Aotearoa and this would require significant new large scale, low cost renewable electricity generation, low cost transmission to production sites and declining costs in key technologies such as electrolysers. It would also require the development of a robust supply chain. *See also sections on 4a.2 Process* heat*– Hydrogen as a fuel and 4a.4 The electricity* system.

4a.4 The electricity system

In 2018, electricity generation in Aotearoa accounted for about 4.3 Mt CO_2e. Our country's electricity system has a high proportion of renewable electricity generation – 84% renewable in 2018. Historically, electricity generation emissions have come mainly from two fossil fuel resources; coal and natural gas.[37,38] This is shown in Figure 4a.2 below, which also illustrates the rising proportion of geothermal emissions since the late 2000s.

[36] (McKinsey & Company, 2020)
[37] (Interim Climate Change Committee, 2019)
[38] (Ministry of Business, Innovation and Employment, 2020a)

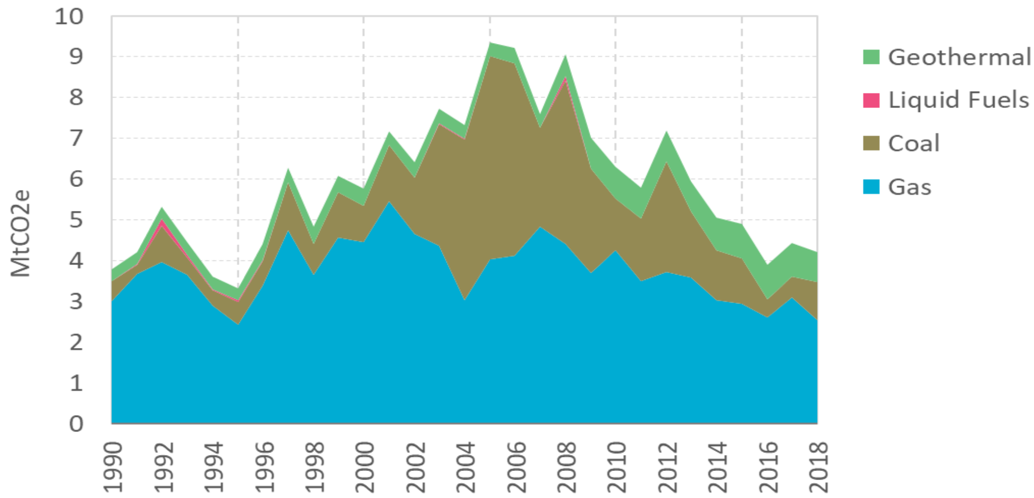

Figure 4a.2 Electricity emissions by fuel in Aotearoa, 1990 – 2018

Source: Commission analysis

Box 4a.2: Electricity in Aotearoa

The wholesale electricity market works as a 'spot' market, where power supply and demand are matched instantaneously. Matching supply and demand instantaneously has implications for the type of generation that can be used at any point and time.

Different electricity generation technologies have different capabilities. Fossil fuels, geothermal and hydro can all supply **baseload** generation, that is, they can produce electricity at a constant rate at any time, given the availability of resources (i.e. water and natural gas reserves). Wind and solar, on the other hand, are referred to as **intermittent** sources of generation. This means they can only generate at certain times, when the wind is blowing and the sun is shining. Fossil fuel and hydro generation can provide **flexibility** in the electricity system by being able to quickly ramp up or down generation to match demand. This is often referred to as **peaking** generation.

Electricity demand changes depending on the time of day, with daily demand peaks in the morning and evening. This means that electricity generation, distribution and transmission infrastructure must be built to meet peak capacity, otherwise there is a risk of brownouts or blackouts when demand peaks. Managing peak demand in Aotearoa is usually done with flexible fossil fuel generation or releasing more water from hydro dams (subject to hydro inflows).

Demand also varies with the season and is generally higher in winter than in summer.[39,40] Our country's hydro lakes contribute around 60% of our total electricity supply. However hydro lakes only hold enough generation (storage) for a few weeks of winter electricity demand if inflows (rain and snow melt) are very low. When inflows are low for long periods of time, hydro generation is reduced and the electricity system relies more heavily on fossil fuel generation to meet electricity demand. This issue is often referred to as '**dry year risk'**.

Managing daily peaks and seasonal variations in low hydro inflow years, are two of the key challenges in the electricity system as more renewable generation enters the electricity system to meet future demand and displace fossil fuel generation.

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[39] (Interim Climate Change Committee, 2019)
[40] (Stevenson et al., 2018)

Electricity emissions tend to be higher in years when hydro inflows are low (dry year) and more fossil fuels are used to meet the shortfall in generation. Geothermal energy also contributes to overall electricity emissions, but average emissions per kilowatt-hour are about a quarter that of natural gas, with substantial variation from field to field. Fossil fuel generation is also often used to meet daily demand peaks.

Total electricity emissions peaked in 2005 and have been mostly declining since due to increased geothermal and wind generation displacing fossil fuel generation. Electricity demand is expected to grow significantly as transport and industrial sectors electrify and as the population and the economy grow. In order to displace fossil fuels and achieve emission reductions, new renewable (or geothermal) generation will be required to meet this growing demand.

4a.4.1 Options for reducing emissions

This section outlines the opportunities and challenges related to options for decarbonising electricity generation. Overall, the evidence summarised below shows that large-scale wind and geothermal power projects become increasingly affordable to build and would comprise an increasing proportion of total generation towards 2035 and 2050. Utility scale solar photovoltaic (PV) is expected to become increasingly cost-competitive in Aotearoa beyond 2035.

New renewable (including geothermal) generation would be needed to meet the anticipated increase in demand from electrification of transport and process heat and to displace thermal power plants at their end of life. However, the signalled exit of the Tiwai Point aluminium smelter, which uses about 13% of our country's electricity,[41] has created a large degree of uncertainty in the generation market in the short-term. The impact of a Tiwai exit on the electricity system would likely depend on whether surplus power from Manapouri is distributed around the existing energy system (for example, displacing fossil fuels used in electricity generation or process heat) or is used by a single or multiple new entrants with a large demand for power.

The reduction of emissions from electricity generation would likely be achieved through a combination of the opportunities canvased below, which includes increasing the supply of low emissions electricity generation and improving energy efficiency and demand side management. Complete decarbonisation of the electricity sector would depend on the degree to which the electricity system can manage the issue of dry year risk and daily demand peaks, without using fossil fuel generation. Any dry year solution is likely to be a relatively high cost emissions reduction option that needs to balance cost, timing, emissions reduction potential and wider impacts across the economy over time.

Table 4a.3: Opportunities and challenges to reduce electricity generation emissions

Options	Opportunities and challenges
Wind and solar	Wind and solar supplied over 7.7 petajoules (PJ)[42] or 5% of electricity generation in 2018 across Aotearoa. Wind and solar are expected to comprise an increasingly greater proportion of our generation mix towards 2050 to meet increased electricity demand from the electrification of industry and transport and to gradually displace fossil fuel generation assets. Considerable and sustained improvements in the price-performance of wind and solar

[41] (Ministry of Business, Innovation and Employment, 2020a)
[42] To date, this is almost entirely wind.

Options	Opportunities and challenges
	technologies means they are increasingly cost-competitive against new fossil fuel generation. Wind generation is now cheaper than new baseload thermal generation. The annual rate of decline for the cost of utility scale solar PV has been on average 10% over the last five years and is expected continue to decline annually at about 3% out to 2030 as global demand increases and drives incremental technological improvements.[43] Wind turbine costs have declined on a continuous downward trend over the last ten years, falling between 44% and 64% since their peak between 2007-2010. Additionally, Aotearoa benefits from competition in the Australian and Chinese markets resulting in lower total project costs compared to the global average.[44] The considerable cost reductions projected for these technologies mean that solar and wind technologies are expected to play a significant role in displacing fossil fuel generation. As the proportion of intermittent generation from wind and solar in the electricity system increases managing the volatility of output and morning and evening peaks will become a more significant challenge. Dispersing wind farms around the country and taking into account potential changes in future prevailing wind patterns can manage some of this. There is a broad range of additional options to address this challenge including utilising demand response technologies, increasing short term storage or using existing hydro generation when possible. These options are discussed later in this table.
Geothermal	Geothermal power plants supplied 27PJ or 17% of electricity generation in 2018. Geothermal offers a cost-competitive investment option for large-scale development[45] of new baseload generation. Emissions from geothermal power generation grew from 0.3 Mt CO_2e in 1990 to 0.7 Mt CO_2e in 2018 due to the expansion of geothermal generation in Aotearoa. Fugitive emissions[46] (mostly carbon dioxide and methane) are associated with geothermal development. These emissions are relatively small in comparison to fossil fuel generation if they are effectively managed. The emission intensity of installed generation has been observed to decrease overtime which reflects the degassing of geothermal fields. The emissions intensity also varies by field location and operation of the generating station. As the electricity system becomes increasingly renewable, emissions from geothermal power generation are what remain. Improved generation technologies, higher efficiency plants, improved management of geothermal emissions through higher rates of reinjection or capture and storage can reduce the emissions intensity of new geothermal generation assets.[47] For example, an

[43] (BloombergNEF, 2019a; IRENA, 2018; Lazard, 2019)
[44] (Roaring40s Wind Power, 2020c)
[45] (Lawless Geo-consulting, 2020)
[46] Fugitive emissions are emissions of gases or vapours from pressurized equipment due to leaks and other unintended or irregular releases of gases, mostly from industrial activities.
[47] (Interim Climate Change Committee, 2019)

Options	Opportunities and challenges
	emissions price of $40/t CO2e could be sufficient for one geothermal operator to consider capturing their emissions.[48] When considering the potential development of geothermal, it is also important to consider iwi/Māori have long asserted tino rangatiratanga, or the unqualified exercise of chieftainship over lands and property, which includes the ability to control the use and management of resources. This has implications for geothermal generation as well as hydro, as geothermal fluids are treated in the same manner as freshwater from a legal perspective. Many of today's geothermal plants have been developed in partnership with iwi/Māori and there is opportunity for this to continue.[49]
Hydropower	In 2018, hydro generation supplied 94PJ of electricity generation in Aotearoa.[50] It supplies about 60% of the country's electricity generation on average annually. The majority of the hydro power stations are located in the South Island and a significant amount of electricity is sent north via the high-voltage transmission grid each year. Hydropower provides flexibility in our electricity system by being able to provide both baseload and peaking generation. However, hydro lakes in Aotearoa are low in water storage volume in comparison to international hydro-dams meaning careful management of water levels is necessary. The number of large-scale hydro plants has not changed for nearly 30 years. In that time, the technology associated with hydro generation has changed little. As such, there are limited opportunities to improve or enhance existing plants to increase output. For example, altering Resource Management Act consent conditions to reduce minimum flows downstream could increase power output of some of our country's hydro-generation assets. However, this could have additional ecological and environmental impacts. Iwi/Māori and others consider that existing consents and planning regimes give preference to hydro at the expense of ecological or cultural values.[51] There is also acknowledgement by the Government that some of the key freshwater bodies used for hydro generation are in poor and degraded states.[52] Consequently, pressure is mounting on hydro-generation to 'give back' some water by, for example, increasing minimum flows downstream of the dam. Iwi/Māori rights and interests in freshwater (including geothermal fluids) raise a distinctly different set of questions, with uncertain implications for existing hydro. Despite acknowledgement by the Crown that iwi/ Māori have legitimate rights and interests in water, the Crown asserts that no one (including iwi/Māori) owns or can own water. This remains a point of contention with many iwi/Māori and the Waitangi Tribunal.[53]

[48] Ibid
[49] Ibid
[50] (Roaring40s Wind Power, 2020b)
[51] (Interim Climate Change Committee, 2019; Whetu Consultancy Group, 2019)
[52] (Ministry for the Environment, 2020b)
[53] (Interim Climate Change Committee, 2019; Te Rūnanga o Ngāi Tahu, 2020)

Options	Opportunities and challenges
	It is unlikely new significant hydro plants are developed in the future in Aotearoa, apart from a potential pumped hydro scheme to expand storage volumes (discussed below). The low cost of developing new wind, geothermal and solar, the increased awareness of the impacts on biodiversity of hydro-schemes and the higher value and competition for freshwater than there was 30 years ago means that the number of potential opportunities for new large-scale hydro generation in Aotearoa are limited.[54] Small scale hydro generation schemes are still possible however these face regulatory uncertainty and often strong local opposition due to other environmental impacts.
Energy efficiency	Improving energy efficiency in buildings and industrial plants could reduce emissions from our electricity system by reducing peak demand and how frequently fossil fuel generation is needed. Reducing electricity demand via energy efficiency can be viewed as an alternative to building new generation to meet growing demand. For example, Transpower's analysis estimates a reduction in electrical intensity of our gross domestic product by 1.7% per year to balance the growth in energy demand as a result of a growing economy.[55] Typically, OECD[56] countries have seen population and economic growth increasingly decoupled from electricity consumption growth due to energy efficiency gains. Countries with large energy efficiency gains were often supported by regulatory and market interventions such as Energy Efficiency Obligations, Energy Efficiency Resource Standards, funding/financing programmes, or market mechanisms that compensate users for the full verified value of capacity savings. Emissions reductions could be achieved through the deployment of readily available energy efficient technologies; LED lighting, heat pumps for water and space heating, better insulation, energy saving fridges and other appliances and electric motors. Energy efficiency measures can be deployed quickly and often at a lower cost than building new generation to meet growing demand.[57] Energy efficiency is often a low or negative emissions reduction cost but can cost upwards of \$200 per tCO_2 depending on the application. One of the key barriers to energy efficiency investment at the scale needed to defer electricity generation is that many thousands of individual consumers or businesses need to make investment decisions. This may be difficult to achieve compared to a single company deciding to build a new generating station but presents a significant opportunity across Aotearoa. *See also section on 4a.2 Process* heat *and Chapter 4b: Reducing emissions – opportunities and challenges across sectors, Transport, Buildings and Urban Form.*
Demand response,	Better use of demand response, small-scale storage technologies and demand management practices have the potential to shift demand from morning and

[54] (Roaring40s Wind Power, 2020a)
[55] (Transpower, 2020)
[56] (IEA, 2020)
[57] (Energy Efficiency and Conservation Authority, 2019c)

Options	Opportunities and challenges
batteries and demand management	evening peaks to other times when demand is lower. This could reduce emissions from the electricity system and help to reduce the average cost of electricity. It may also defer costly upgrades to transmission and distribution lines, reducing upwards pressure on delivered electricity prices. Demand response enables or encourages electricity consumers to reduce their electricity demand for a period of time (often during peaks) in exchange for payment, or to avoid high electricity prices. A common example of a demand response enabled technology is hot water cylinders, though many more common technologies could also utilise demand response such as batteries, EVs, fridges, household appliances and a wide range of industrial technologies. Key enablers of demand response include, but are not limited to, smart metering and access to data, real-time pricing and smart devices. For example, if enabled by retailers, apps connected to smart meter data can allow consumers to monitor and manage their power use to show where energy savings can be made. This increased consumer engagement with the electricity system is a recognised future trend in the electricity system. Adding storage to the electricity system makes renewable generation more useful by providing a back-up for times when the renewable resource is insufficient (daily peaks). Transpower estimates that peak demand could increase from 7.3 GW in 2020 to 8.9 GW by 2035 and 10 GW by 2050.[58] Batteries can be large 'grid-scale' installations or distributed units in buildings and electric vehicles (EVs). Batteries can help to smooth peaks and troughs in demand. A battery charged over the course of the day using renewable generation can be rapidly discharged to meet a short period of peak demand which would otherwise be provided by a fossil fuelled power station. For example, Transpower estimates that by 2035, about 1.2GW of battery storage capacity could be deployed to support periods of peak demand. Using demand response and storage technologies together can play an important role in system security and reliability by potentially increasing system flexibility. It can also reduce emissions by reducing the need for fossil fuelled peaking generation. Emissions reduction cost of demand response technologies varies by technology, scale and application. Managing peak demand in a renewable electricity system may also require changes in electricity consumer behaviour (demand management). It is important that the electricity market can deliver clear and timely price signals to energy users to encourage changes to electricity demand. For example, as the uptake of electric vehicles increases it will be important that electric vehicle charging does not exacerbate daily morning and evening peaks. Electricity pricing incentives, such as low cost night rates (11pm to 5am), combined with smart charging technology may be an effective way to address this issue.

[58] (Transpower, 2020)

Options	Opportunities and challenges
	See also sections on 4a.2 Process heat *and Chapter 4b: Reducing emissions – opportunities and challenges across sectors, Transport, Buildings and Urban Form.*
Distributed generation	Distributed generation refers to a variety of technologies that generate electricity at or near where it will be used, such as solar panels. About 95% of distributed generation is from renewable sources such as wind, geothermal and hydro, and 'behind the meter' generation such as rooftop solar. These forms of decentralised generation play a role in reducing the amount of electricity that would otherwise have to be transmitted by the grid. This is particularly valuable when it can offset periods of peak demand, and potentially emissions and high electricity prices, and when the grid is limited in some way (for example if a line fails during a storm). The amount of distributed generation in the system is expected to increase as the cost of solar PV and wind generation decreases and more households and communities look for energy sovereignty. Community involvement in distributed generation may have social benefits, such as enhanced cohesion, acceptance of development (when there is control over where the generation is located) and self-sufficiency through self-supply. It can also adapt and affect consumer behaviour and energy use. For example, iwi/Māori through local marae schemes and rural communities may actively transition to distributed generation for a variety of reasons, including ownership, cost and resilience (particularly if they are in remote areas) and a desire to reduce their emissions. In Aotearoa, it can be challenging for owners or would-be investors in distributed generation to access the electricity market. Owners of distributed generation can either sell any generation not used on site to a retailer through a contract or sell it into the market and 'take' the wholesale price. It can be difficult to secure the long-term contracts. A liquid hedge market would be important in facilitating this.
Addressing dry year risk	Hydro lakes contribute around 60% of our total electricity supply. However hydro lakes only hold enough generation (storage) for a few weeks of peak winter electricity demand if inflows (rain and snow melt) are or have been very low. When inflows are low for long periods of time, hydro generation is reduced and the electricity system relies more heavily on fossil fuel generation to meet electricity demand to reduce the risk of an electricity shortage. As fossil fuels are retired from the system managing dry year risk would be more critical; without a dry year solution there may be a need to retain some gas generation and gas storage in the system. As hydro generation is sensitive to the hydrological effects of climate change, options to address the dry year risk must also consider future changes in hydro generation potential of different schemes across the national grid. For example, recent research by the National Institute for Water and Atmospheric Research (NIWA) projects that higher winter precipitation in major hydropower basins is

Options	Opportunities and challenges
	expected to boost national generation. Hydro generation dry season is also expected to shift from winter peaking to summer peaking.[59] There are multiple options that could be deployed to address the issue of dry year risk. This was examined alongside moving towards 100% renewable electricity in the Interim Climate Change Committee's (ICCC) *Accelerated Electrification* report. The results of the ICCC's modelling show that, instead of pursuing 100% renewable electricity by 2035, more emissions savings could be achieved through accelerated electrification of transport and process heat. However, while using natural gas in the electricity system may be an effective mechanism to minimise emissions and achieve security of supply until 2035, eventually all fossil fuel generation would need to be eliminated and the dry year issue addressed to contribute to efforts to limit the global average temperature increase to 1.5°C above pre-industrial levels. Options[60] to address dry year risk that the ICCC examined included, overbuilding renewables, using biomass or hydrogen for generation, long-term battery storage, indicative large-scale demand interruption and pumped hydro storage. The estimated marginal emission reduction costs of these options varied from \$250 to \$89,000 per tCO_2, with the most cost-effective option being a pumped hydro scheme. Further detailed analysis would be required to determine the actual cost and benefit of any dry year option. The Lake Onslow pumped hydro scheme is being investigated[61] along with alternative storage options that could provide a large amount of storage capacity to provide short-term peaking and management of dry year risk. Pumped hydro schemes are a way of storing and using water independent of inflows. This project could displace the requirement for thermal generation and achieve an abrupt decarbonisation of the electricity sector. The construction cost for the project has been estimated at \$4 billion.[62]
Transmission network	Electrification of transport and industrial energy use will see Aotearoa become increasingly dependent on electricity. This concentration of risk enhances the need for the electricity system to be reliable and resilient. Transmission infrastructure is critical in maintaining this. As we decarbonise the economy the national grid would need to rapidly expand its capacity. This expansion would be driven by the expected ramp up in the electrification of transport and process heat and the building of new renewable electricity generation. According to Transpower, by 2035, we may require 40 new grid connected generation projects, 30 connections to accommodate increased electricity demand, 10-15 new transmission interconnections and other network investments needed to enable energy to reach consumers.[63]

[59] (Collins et al., 2020)
[60] Options were assessed against the alternative of continuing to use natural gas to solve the dry year problem.
[61] (Ministry of Business, Innovation and Employment, 2020b)
[62] MBIE's early estimated capital costs of a project like Lake Onslow
[63] (Transpower, 2020)

Options	Opportunities and challenges
	Additionally, there are long lead times for major new and upgraded transmission assets relative to lead times for new generation or demand. Issues with cost allocation and risk associated with new transmission lines may slow or hold up the deployment and uptake of renewable electricity generation, risking delays in decarbonisation. There are also coordination challenges where investments involve multiple parties. The challenge is to deliver a timely, reliable and affordable build out of the national grid and to manage the opposing risks of under or over-investing in the national grid. Overinvestment in the national grid could increase the delivered cost of electricity disincentivising electrification, while underinvestment in the national grid could slow progress on decarbonisation efforts. To ensure security of supply transmission and distribution networks need to be built to meet peak demand. Moving forward, having materially lower peak demand growth than energy demand growth would help successfully deliver energy security and affordability alongside decarbonisation. Improving energy efficiency, demand response and management, and successfully integrating distributed energy resources into the electricity system will be important for achieving this. *See also section on 4a.2 Process* heat *in this chapter*
Distribution networks	Aotearoa has 29 different regional electricity distribution businesses that take electricity from the national grid to distribute to local communities, households and businesses. Like transmission, distribution networks need to be built to meet peak demand and need to manage a balance between over and underinvesting in their assets. Distributors face challenges to their capacity and capability to evolve networks to cope with the effects of emerging technologies, including electric vehicles and household solar and batteries. Technology changes will require distributors to be more proactive, better understand their networks and to adapt to meet the needs of existing and new customers. Changing technology provides new opportunities, such as demand response, but also creates increased risk if the wrong technology investment decisions are made or pricing incentives are put in place. Sufficient adaptability and flexibility in the regulatory environment are also necessary if networks are to respond to changing technologies and consumer patterns. For example, as the uptake of EVs increases in Aotearoa, it will be important that EV charging does not overload local network capacity or exacerbate daily morning and evening peaks. Investments in distribution assets are subject to regulation by the Commerce Commission that is designed to ensure that they have incentives to invest and meet customers' quality demands but are also limited in their ability to earn excessive profits. 17 distributors are under this price-quality regulation, the other 12 are consumer-owned and exempt from the regulation as the

Options	Opportunities and challenges
	Government considers that their consumers have enough input into how the business is run. All 29 are subject to its information disclosure rules.[64] Having materially lower peak demand growth than energy demand growth as we decarbonise our economy would help deliver energy security and affordability alongside decarbonisation. Much of the peak demand challenge could be managed at the distribution level. Innovation in the electricity sector, including greater demand response and smart charging, more transparent and stronger pricing signals and demand management practices may help in managing peak demand growth. *See also section on 4a.2 Process* heat *and Chapter 4b: Reducing emissions – opportunities and challenges across sectors: Transport, Buildings and Urban Form.*

4a.5 Fossil fuel production

Fossil fuel production emissions, as opposed to emissions from the use of the fuels itself, result from a diverse range of activities including oil refining, oil and natural gas production and the operation of coal mines. In 2018 gross emissions from these activities totalled 2.3 Mt CO_2e.

Aotearoa is a net oil importer; we predominantly import crude oil that is then processed at the Marsden Point refinery for use. The refinery produces petrol, diesel, jet fuel, marine fuel and bitumen from crude oil largely imported from the Middle East and South East Asia. At production capacity, the refinery supplies 70% of domestic demand for refined oil products.[65]

The refinery's owners have recently signalled a downscaling in production volumes and potential future operational changes.[66] Direct emissions from refining activities totalled 1 Mt CO_2 in 2018 and are largely from the combustion of crude oil sourced waste streams (refinery gas, fuel oil and asphalt) supplemented by natural gas for process heat and hydrogen manufacture to refine crude oil into finished transport fuels.

The remaining emissions are largely classified as fugitive and include:

- leaked methane from mines and oil production,
- leaked methane from natural gas production and reticulation network and
- vented and flared carbon dioxide during extraction and processing of natural gas and oil.

4a.5.1 Options for reducing emissions

The most significant changes in emissions would likely result from a decrease in fossil fuel production activity.

The refinery's decision to downscale production volumes will have an immediate impact on emissions from this sector, and the long-term viability of the refinery's remaining operations is still uncertain. Longer term, the refinery's operations and business models may change, but maintaining the refinery's infrastructure and skilled workforce could be critical to maintaining flexibility for our

[64] (Commerce Commission, 2018)
[65] (Refining New Zealand, 2020a)
[66] (Refining New Zealand, 2020b)

energy system in the future. For example, it could be used to produce different or complementary products like liquid biofuels and green hydrogen. Retaining the refinery's infrastructure could also provide long-term energy security by providing a means to diversify the energy supply mix.

Impacts on direct emissions from our country's coal and oil and gas extraction sector are more uncertain as this largely depends on international demand. However, there are emissions reduction opportunities that can be realised from current production activities. In 2018, Aotearoa exported 98PJ or 68% of domestically extracted coal and oil resources.[67] Additionally, iwi/Māori groups with large coal reserves[68] may be impacted by changes in domestic and international coal demand.

If a significant amount of process heat electrification or biomass conversion takes place, the emissions from natural gas production may decrease as a result of reduced production. There are options to directly reduce emissions from fossil fuel production which are outlined below, however investment in options may be limited by uncertainty in the oil and gas sector as a result of Government's 2018 decision to restrict new offshore oil and gas exploration.

Table 4a.4: Opportunities and challenges to reducing fossil fuel production emissions

Options	**Opportunities and challenges**
Prevention	Fugitive methane emissions in gas production can be reduced or eliminated through operational and engineering activities. Process engineering improvements can be made to the plant to reduce emissions during production. Flared emissions can be reduced with better operating practises, while leaks could be reduced in gas transmission and distribution pipelines through improved design, surveying and inspection.[69] An estimation of the total emissions reduction potential requires additional analysis.
Re-injection or capture and storage	In 2018, emissions from natural gas venting were approximately 0.3 Mt CO_2e. These are assumed to stem partly from the Kapuni gas field and Kapuni Gas Treatment Plant. The Kapuni gas field contains about 44% carbon dioxide which needs to be stripped out prior to use. While some of the carbon dioxide is used, the remainder is vented into the atmosphere. It may be possible to re-inject this carbon dioxide back into this reservoir or into a nearby reservoir. This source of pure carbon dioxide could also be used in petrochemical production in combination with green hydrogen to reduce emissions from the sector. Reinjection technologies and practices are mature and deployable emissions reduction opportunities in Aotearoa. *See also Chapter 5: Removing Carbon from our Atmosphere*
Efficiency	Efficiency in natural gas production can be achieved through monitoring energy consumption and the more efficient use of existing plant equipment, reducing the need for fuel gas. Other emissions reduction opportunities

[67] (Ministry of Business, Innovation and Employment, 2020d)
[68] (Begg et al., 2014)
[69] (Element Energy & Imperial College London, 2019)

Options	Opportunities and challenges
	include replacement of existing motors and heaters with more efficient equipment, pipe insulation and improved waste heat recovery.[70] Replacing compressor stations across natural gas distribution and transmission infrastructure with more efficient and/or electric equipment could achieve small reductions in emissions. Reducing or eliminating use of fuel gas for processing through electrification of equipment, such as diesel and gas compressors, fossil fuel boilers and drilling rigs.[71] An estimation of the total emissions reduction potential across the entire compressor fleet and oil and gas processing stations requires additional analysis. The refinery has previously invested $12 million in programmes and projects to improve the energy efficiency of processing units and utilities, optimising steam use, heat exchanger cleaning and maintenance, improving turbine efficiency, monitoring energy consumption and the phased introduction of LED lighting. An estimation of the total remaining emissions reduction potential requires additional analysis. *See also sections on 4a.4 The electricity* system *and 4a.3 Industrial processing and* production *in this chapter.*

[70] Industry engagement
[71] Industry engagement

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