Ministry for the Environment
Manatū Mō Te Taiao

# Identifying the social good co-benefits of electrifying process heat

New Zealand Government

This document may be cited as: Ministry for the Environment. 2019. *Identifying the social good co-benefits of electrifying process heat.* Wellington: Ministry for the Environment.

Published in May 2019 by the
Ministry for the Environment
Manatū Mō Te Taiao
PO Box 10362, Wellington 6143, New Zealand

ISBN: 978-1-98-857927-6
Publication number: ME 1422



This document is available on the Ministry for the Environment website: www.mfe.govt.nz.

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# Introduction

This report was produced by the Ministry for the Environment as an action under the *Roadmap to Transition to a Low Emission Future (the Roadmap)*. [1] The Ministry for the Environment and Fonterra partnered on the Roadmap in November 2017. The Roadmap outlines actions to work through barriers preventing large industrial users of fossil fuels for process heat, such as Fonterra, transitioning to a low emissions, renewable energy future in a cost effective manner.

Process heat is heat used mainly in the industrial sector for manufacturing products but also the commercial sectors, for example, in space heating. Process heat accounts for approximately nine per cent of New Zealand's gross greenhouse gas emissions – 60 per cent of process heat is supplied using fossil fuels, mainly coal and gas.

To transition to a low emissions economy, our energy use needs to be more efficient and to move away from relying on fossil fuels. To our advantage, New Zealand has a predominately renewables-based electricity system. While more can be done here, our biggest opportunities for further emissions reduction in energy lie in two areas – transport and process heat.

This report highlights the benefits from switching industrial heat plant and public sector space heating from coal to electricity that cannot be readily captured by the plant owner in New Zealand. Benefits that lie outside of market transactions, known as positive externalities are not currently adequately priced.

The report covers potential benefits in the following areas:

- benefits of improved air quality (reduced particulates)
- benefits to electricity consumers in terms of lower electricity costs (from the substantial change in seasonal electricity demand shape and better asset utilisation of generation and lower transmission)
- other benefits such as improved health and safety outcomes associated directly with heat plant, reduced waste, or transporting fuel to the plant.

These benefits are set out in the following sections of the report.

This report is exploratory, and does not seek to quantify the benefits in detail. The benefits are investigated on an 'order of magnitude' basis to determine if they are potentially substantial, and whether they warrant further investigation. The Ministry for the Environment does not intend to investigate further at this point. This fits best with relevant government agencies or private firms if they see fit, as actual benefits are likely to be site-specific.

[1] See https://www.fonterra.com/content/dam/fonterra-public-website/pdf/Roadmap-to-Transition-to-a-Low-Emission-Future.pdf.

# Air quality – particulates

Burning coal releases airborne particulate emissions into the atmosphere and deteriorates local air quality. These emissions have impacts on health. While these emissions are often monitored, and resource consents require plant owners to install infrastructure to minimise their effect (eg, baghouses), the economic costs of the impacts of the emitted particulates are not priced. Therefore, emitters don't see the full cost associated with their particulate emissions outside of meeting resource consents (eg, baghouses).

In 2016, 1.3 million tonnes of coal was consumed in New Zealand. Food processing was the biggest consumer of coal (not including co-generation and electricity generation).[2]

## Particulates

The term 'particulates' is used to describe very small air borne particles that can be either solid or liquid, and can arise from both human activities as well as natural processes.

Particulate matter is very small, typically less than 20 micrometres in diameter (equal in length to 0.001 millimetre). Particulates are specified by size (ie, particulate matter 10 micrometres or less in diameter is specified as '$PM_{10}$'; those less than 2.5 micrometres are denoted as '$PM_{2.5}$').

Particulates are of concern because they have been linked to health impacts ranging from respiratory and cardiac illnesses to cancer.[3]

Here, we focus on $PM_{10}$ emitted in New Zealand when burning coal in heat plant in urban areas only. The focus on heat plant in urban areas such as schools, hospitals and light industrial manufacturing is because they are often located in residential areas. People are more likely to be exposed to particulates from heat plants and have subsequent health implications in urban areas than in rural areas where heat plants are often located in more remote locations. Data from the Energy Efficiency and Conservation Authority (EECA) and Ministry of Business, Innovation and Employment (MBIE) indicates that between 5 and 10 per cent of the coal used for heat energy is used in (or near) the urban environment.[4]

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[2] Food processing is responsible for 65% of consumer coal consumed (not including co-generation and electricity generation). Gas responsible for another 15.46 PJs/approximately 18% of consumer gas consumed. Ministry for Business, Innovation and Employment 2017b.

[3] See http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/home/air/health-effects.aspx and http://www.hapinz.org.nz/.

[4] The EECA 'End Use Database' and MBIE coal sector data identify coal consumption by end use, allowing an indicative analysis of whether those uses are related to urban or rural environments.

**Table 1: Indicative examples of $PM_{10}$ emissions from coal combustion**

| | Indicative coal use (tonnes/year) | Indicative $PM_{10}$ emissions (kg/year) | Number of domestic wood burners to produce the same $PM_{10}$ |
|---|---|---|---|
| A medium-sized hospital | 1,500 | 2,000 | 2,000 |
| A large school | 100 | 200 | 200 |
| All NZ urban coal combustion | 100,000 | 200,000 | 200,000 |

Particulate emissions from urban coal use are likely to be substantial for two reasons.

- First, we can see from Table 1 (above) that particulate emissions are being released in substantial volumes. As a reference, an efficient domestic wood burner might produce about 1 kg $PM_{10}$/year. This data has been estimated using public sources including case study information on EECA's website, resource consent documentation, and reports in the public domain.
- Secondly, while regulations and resource consents set limits on $PM_{10}$ emissions (as measured at monitoring sites across New Zealand), there is no evidence of a safe level for particulates. Particulates could cause harm at any concentration.[5]

*Health and Air Pollution in New Zealand Study* (HAPINZ, 2012) noted the total social costs associated with anthropogenic air pollution in New Zealand are estimated to be $4.28 billion per year (particulates and $NO_x$).[6] The following overall contributions were attributed to each source, however, the impact of $NO_x$ may be underestimated in (HAPINZ, 2012)[7], which in turn would understate $NO_x$ emitted in the transport and industrial sectors:

- 56 per cent due to domestic fires
- 22 per cent due to motor vehicles
- 12 per cent due to open burning
- 10 per cent due to industry.

Given the electrification of urban coal plant would directly result in lower particulate emissions, we can expect to have corresponding positive health impacts. While it is not possible here to accurately quantify the air quality benefits of fuel, switching urban heat plant from coal to electricity; the HAPINZ study indicates that the 10 per cent of anthropogenic air pollution attributed to industry could be causing at the least tens of millions of dollars per year in health costs (and potentially up to a few hundred million dollars per year), assuming the health benefits accrue in proportion to particulate reductions.

[5] See the Environmental Health Indicators New Zealand (Massey University) website http://www.ehinz.ac.nz/indicators/air-quality/particulate-matter/.

[6] The oxides of nitrogen ($NO_x$) are pollutants, and are known to have adverse health impacts.

[7] See http://www.hapinz.org.nz/HAPINZ%20Update_Vol%201%20Summary%20Report.pdf.

# Potential benefits from the electrification of process heat

This section of the report explores the electricity system benefits that could arise from large-scale electrification of process heat requirements in the dairy and meat processing industries. Detailed modelling is required to determine if these potential benefits are real and material, but this is beyond the scope of this initial exploratory report. This would need to be undertaken as a separate piece of work.

The conversion of coal-fired boilers to electricity could have benefits to the wider electricity system because:

- industrial coal boilers are located predominantly in the South Island. Electrifying the boilers affects the electricity supply and demand balance in each island and could affect long-run marginal transmission costs (cost of transporting electricity from generation source to end users)
- food processing sector energy demand (particularly meat and dairy sectors) is highest in the spring and summer months (between September and March). At this time, national electricity demand reaches an annual low. Fuel-switching from coal to electricity flattens the seasonal electricity demand shape (such that it better matches the seasonality of water inflows into hydroelectric power stations).

The benefits that could arise from these changes are explored below, but first it is important to provide some background information on New Zealand's electricity system.

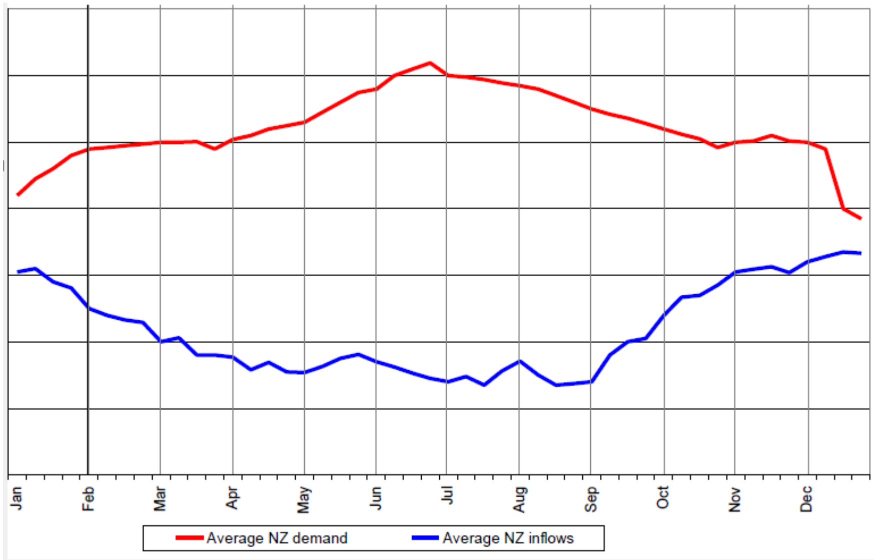
## Electricity system background

New Zealand's electricity system is characterised by having a high proportion of renewable generation (predominantly hydro), and is therefore subject to variations in weather and climate patterns (rain and snow variability).

The electricity system is particularly sensitive to extended dry periods (eg, about a month or more) due to the limited storage in our hydro lakes.

An important factor affecting the cost of electricity generation is average hydro inflows are negatively correlated to electricity demand over the year; ie, the period of low water inflows coincides with peak electricity and water (for electricity generation) demand and vice versa (see Figure 1). New Zealand's current electricity demand is correlated (negatively) with temperature. Electricity demand currently peaks in the winter months (May to August) as space heating and lighting requirements for households and businesses increase (see Figure 1). As average temperatures (and daylight hours) increase from winter to summer, national electricity demand declines.

**Figure 1: Comparison of weekly electricity demand and hydro inflow seasonal patterns**




Source: Meridian Energy investor presentation 2017

The counter-seasonality of electricity demand and hydro inflows means more expensive fossil fuel generation is required to help balance the seasonal demand and supply disparity.[8]

The cost of fossil fuel generation is related to both the megawatt capacity required (this is a function of the 'height' of the demand peak) and the capacity factor at which the plant operates (a function of shape of the peak, whether narrow or broad). The greater the capacity and the lower the capacity factor at which it operates, the higher the electricity generation cost on a $/MWh basis.

In general, the 'flatter' the winter demand peak, the less fossil fuel plant capacity is required, and thus generation cost to supply is low. This is because mid-merit and peaking generation is more expensive than generation that operates all year round.

# Food processing sector background

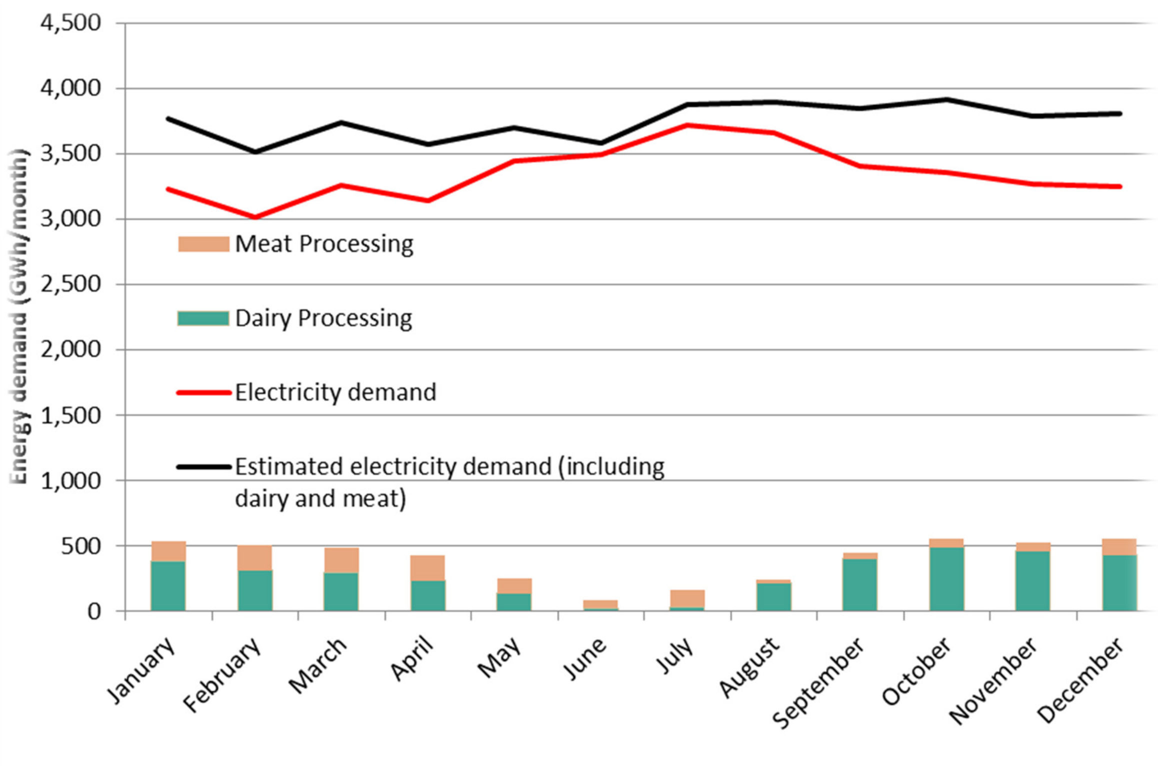
The dairy and meat processing sectors require a large amount of energy. Energy use depends on location and time and varies in terms of fuel used. Monthly energy demand fluctuates between about 100 gigawatt-hours (June) and 500 gigawatt-hours (December). Coal use is predominant in the South Island and natural gas in the North Island. Further, energy use is believed to be strongly biased towards spring and summer (ie, the growing season), with slight variations by island.[9]

[8] The fossil fuel generation is also currently the least-cost way to manage dry-periods caused by inter-year hydro inflow variability.

[9] Note that the annual energy use is relatively well known (via the EECA energy end-use database which is calibrated to MBIE's annual energy data. However, the monthly data is assumed to be in proportion to milk production (and animal processing volumes). The actual energy use may be slightly less seasonal in reality due to the way production processes are operated.

The seasonal pattern of food processing energy demand[10] is counter-cyclical to electricity demand (ie, negatively correlated). The variation in seasonal electricity demand (size of winter demand lull) is similar to the magnitude of energy demand for meat and dairy processing as demonstrated in figure 2. This means that fuel switching from coal to electricity in South Island food-processing plant will result in a much flatter seasonal electricity demand.

**Figure 2: New Zealand's current monthly electricity demand, compared to the indicative demand for electrification of dairy and meat processing (note the counter-seasonality)**




## Breakdown of potential benefits

As discussed above, flattening the seasonal variation in electricity demand could have electricity market and national grid benefits. These potential benefits include:

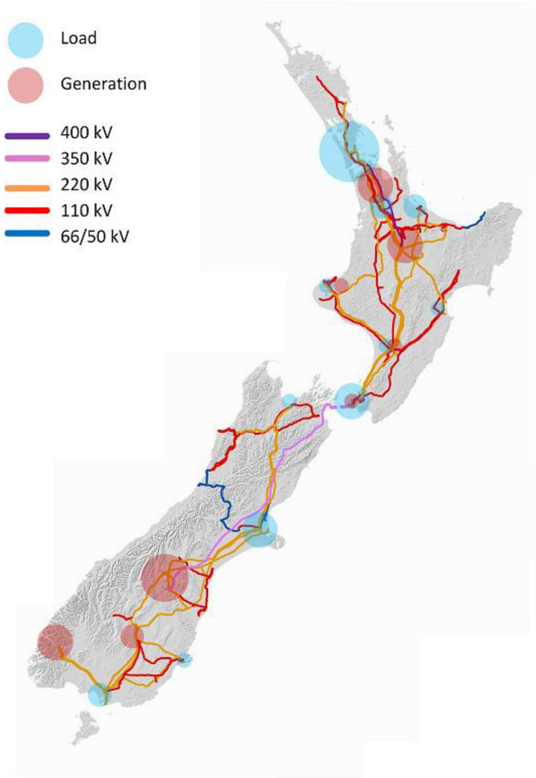
- decreased transmission costs (on a $/MWh basis)
- decrease in wholesale electricity costs (less or lower cost fossil fuel plant required to be operated to meet winter demand)
- reducing the cost of mitigating electricity sector greenhouse gas emissions
- deferring transmission investment on the core grid (eg, HVDC and core North Island HVAC transmission assets).

[10] The food processing demand assumes that energy demand is directly proportional to production (eg, milk volumes processed). In reality, however, it is a suitable 'first-order' approximation. The meat processing energy demand estimate was calculated using 2017 livestock processing volumes (https://www.nzmeatboard.org/the-industry/production-data/period/13#Period).

## Deferred transmission benefit

In New Zealand, a significant volume of electricity generated in the lower South Island is required in the upper North Island (see figure 3). To transport this electricity, a significant capacity of transmission is required over a relatively long distance, resulting in substantial costs (ie, long, and high-capacity, transmission lines).

Figure 3: New Zealand load, generation and the grid backbone




Source: Transpower (2017) [11]

Replacing coal with electricity in dairy and meat processing heat plant, would increase electricity demand in the South Island compared to the North Island. It is important to note that the volume of electricity generation[12] proposed for the North Island is much greater than that proposed for the South Island.

All else being equal, switching from coal to electricity mainly increases South Island's electricity demand, and North Island's generation. All else being equal, this would reduce the northward transfer of electricity from southern generation sources to the upper North Island load centres resulting in reduced transmission costs. All else being equal, less transmission capacity may be required on the core grid (ie, on average, generation will be built closer to demand)[13]. At the very least, there would likely be reduced electrical losses from lower average power flows.

[11] Transmission Planning Report 2017, p. 17.

[12] See the Electricity Authority website https://www.emi.ea.govt.nz/Wholesale/Datasets/Generation/Generation_fleet/Proposed.

[13] To achieve a net benefit, any cost reduction on the core grid would need to be greater than the incremental cost of connecting the heat plant to the grid. This of course will be highly location specific, and requires considerable additional analysis to asses this potential benefit.

A key question is whether this is a real and a material benefit. For the benefit to be substantial, there would need to be deferral or down-sizing of future core grid upgrades[14]. This seems possible, but detailed generation and transmission analysis is required to assess whether the potential benefits are real. Therefore, we don't attempt to answer this in any detail here, but we do note there are many pending transmission investments that may be able to be deferred. Transpower's 'Transmission Planning Report' (2017) identifies baseline and major capital investments on the HVDC and North Island HVAC 'grid backbone'.

## Lower electricity cost (on a $/MWh basis) due to higher asset utilisation

It is expected heat plant (at least some) can switch from coal to electricity with minimal adverse impact on the electricity transmission system. This is because the grid capacity is sized to meet the winter peak demand, and typically has 'spare' capacity in summer.[15]

Therefore, the volume of electricity conveyed on the grid is likely to increase at a faster rate than the additional transmission costs, so that the variablilised transmission cost reduces (ie, the transmission costs expressed as a $/MWh rate is likely to reduce).

Transpower collects a fixed amount of income determined through the transmission pricing methodology (TPM) to recover for the infrastructure and services it provides. Therefore, increased asset utilisation of the transmission grid would spread transmission costs more extensively and lower transmission prices (on a $/MWh basis) on an average for all users. This is effectively an increase in the asset utilisation of the transmission grid.

## Lower cost to reduce electricity sector greenhouse gas emissions

New Zealand is in a rare situation of having abundant renewable energy resources that are typically lower cost than fossil-fuel base-load electricity. While geothermal generation can have sizable greenhouse gas emissions, renewable generation, on average, has lower emissions than fossil generation.

As noted above, the seasonal pattern of electricity demand does not currently match the seasonal pattern of renewable electricity generation. This means that we are more reliant on fossil-fuel based generation than we would be if we had a flatter seasonal electricity demand shape.

Therefore, by electrifying food processing sector's heat demand and reducing the seasonal electricity demand variation, we make renewable generation more economic (ie, it is lower cost to displace more fossil-fuel generation). This means lower emissions in the electricity sector, as well as the direct emission reductions from reducing coal use.

[14] There is incremental transmission capacity required to connect food processing plant to the grid. This economic cost is assumed to be allocated to the heat plant, and balanced off against the higher cost of using coal with a moderate carbon price. That is, the incremental connection cost is already accounted for.

[15] Transmission line capacity ratings are lower in summer (compared to winter) because they are typically thermally limited and the warmer air temperatures and insolation result in the conductors reaching their 'sag-limit' at lower current ratings. However, the transmission demand is typically designed for the winter peak demand, which is the more critical load (with the exception of some areas now driven by summer irrigation peaks).

# Other benefits from electrifying process heat energy demand

There are many benefits of reducing coal use in heat plant. These are harder to quantify, and likely smaller in an economic sense, but they can be extremely important to those people affected.

## Health and safety

There are small, but potentially very valuable safety benefits in moving away from coal-fired heat plants. Boilers are dangerous when operated by inexperienced employees, or with maintenance oversight from organisations (such as boards) that lack technical expertise. This may be less applicable for larger plants in the private sector which are well-resourced and held to high standards of health and safety.

However, issues can arise in relation to smaller plant. For example, there are the issues associated with regular de-ashing of small-scale boilers (eg, schools) which is done manually. This is a very messy job and often done with inadequate personal protective equipment (eg, cheap dust masks) that results in higher than necessary exposure to coal-ash dust.

Unfortunately there has also been at least one death (2009), and various injuries suffered by boiler plant operators in New Zealand.

The boiler plant also poses dangers to plant operators and others. School boilers are a potential risk to curious children, whether through the coal bunkers, the heat plant itself, or vehicle movements for fuel deliveries. These hazards could be avoided by switching to electric heating.

## Transport

Dairy and meat processors require large volumes of coal for their process heat requirements. Depending on the processing sites' locations, coal is predominantly delivered via road (trucks), and a small amount by rail.

It is expected the switch from coal to electricity (to power the heat plant) would deliver social good benefits through reduced truck movements. Reduced truck movements could potentially reduce road accidents and deaths.

The estimated total social cost of serious truck related injuries in 2017 was $659.6 million and the total cost of fatal truck accidents was $354.6 million.[16] [17] In 2017, coal transportation in the dairy sector as a share of heavy fleet vehicle kilometres travelled was 0.1%. This suggests the value of reduced truck movements (ie, due to fuel switching dairy and meat sector heat plant

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[16] Figures calculated by multiplying the social cost per serious crash and value of statistical life respectively, with the number of serious truck accidents and truck fatalities in 2017.

[17] Ministry of Transport (2017).

away from coal) would be of the order of $1m/year.[18] This is only indicative, as heavy vehicle movements on different roads will have different risks (eg, urban versus rural, low versus high speed etc). However, it provides an order of magnitude indication of the benefits.

Again, at a national economic level, these benefits will be very small. However, they may well be very material for local communities where the coal delivery trucks may make up an appreciable proportion of local traffic movements. Reduced truck movements would also reduce greenhouse gas and $PM_{10}$ particulate emissions, though these are minor in comparison to the emissions resulting from burning coal and don't warrant further investigation.

## Waste

Coal combustion produces ash (clinker and fly ash) that can contain low concentrations of heavy metals. Typically coal ash is equivalent to five to eight per cent of total coal weight consumed. In 2016, this roughly equated to 65,000 to 100,000 tonnes[19] of ash from the total volume of coal consumed in New Zealand; with the food processing sector (including dairy and meat processing) producing approximately 42,851 to 68,562 tonnes of coal ash.[20]

Coal ash can be reused in some instances; ie, power station fly ash is used as a material in cement production. However, reduced coal use would equate to less coal ash and heavy metals in landfills and the environment. Reduced truck movements disposing of coal ash could slightly reduce greenhouse gas emissions (but at a level an order of magnitude less than coal deliveries).

[18] Reduced social cost fatal dairy sector truck movements: $354,000; reduced social cost of serious injuries related to dairy sector truck movements: $659,600.

[19] 2016 coal consumed in New Zealand: 27 PJ (1.3 million tonnes) (1 petajoule = 48,148 kg coal).

[20] Figures obtained from Ministry of Business, Innovation and Employment (2017).

# Conclusion

Process heat is essential for many businesses to operate in New Zealand. Around 60 per cent of this heat is derived from fossil fuels especially coal – this comes at a cost.

The purpose of this report was to give a high-level overview of the ‘social good’ benefits associated with electrifying process heat and reducing coal use.

Indicative findings have shown that there could be benefits to the public through increased renewable electricity generation, reduced greenhouse gas emissions, and slightly lower delivered electricity costs. There are also some health benefits through reduced particulates (air pollution) in urban areas. These two areas may warrant further investigation to get a more detailed account of the respective benefits. Findings also showed minimal to moderate benefits in reduced waste and transport, and improved health and safety.

With international efforts to limit the increase in global average temperatures to safe levels and reach net-zero emissions in the second half of the century, making our industrial and public use of process heat renewable would help in New Zealand’s transition to a low-emissions and resilient economy.

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