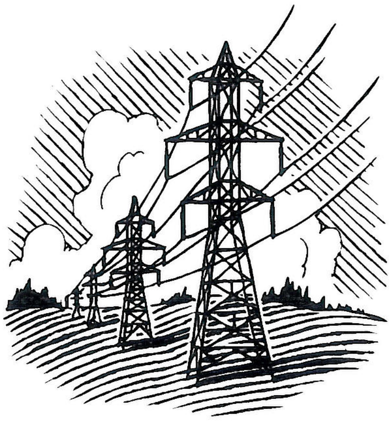
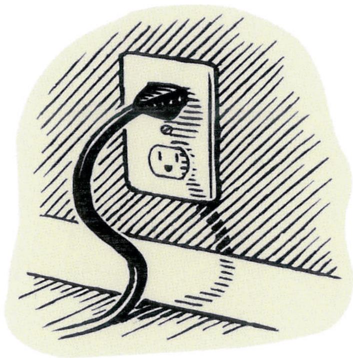
Optimisation Model to Estimate Potential Energy Savings in the New Zealand Economy





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Acknowledgments and Assistance
Some of the data for the OPENZ model and as presented in this report were provided by the Energy Efficiency and Conservation Authority staff. These data included energy savings data, technology-specific energy end-use data and costings. Dr Garry McDonald provided technical assistance in programming and operationalising the initial runs of OPENZ. Dr Anita King constructed the supply curves presented in this report, by manipulating the data provided by the OPENZ optimisations.

Data Accuracy/Precision
It should be noted that the data has generally been reported to two decimal places (and sometimes up to four decimal points) in this report and in the formulation of the associated model. This is undertaken to: (i) differentiate between the values of various options evaluated by the optimisation model; (ii) avoid rounding errors which in this analysis could compound due to the large number of calculations undertaken.

Executive Summary

Scope of the Report

This report outlines the nature of the OPENZ (Optimisation Energy End Use Model of New Zealand). It is the first version of its type in New Zealand, although previous modellers have constructed optimisation models of the New Zealand Energy System but from a supply-side perspective. This OPENZ model differs from previous optimisation models because of its focus on the *end-use of energy* in the economy, and it does this by drawing much of its data from the EECA End-Use Database.

The initial application of the OPENZ model is to quantify the *energy savings potential* for New Zealand at yearly intervals over the time period 2007 to 2026[1]. Specifically, three energy savings potentials are quantified: *technical* energy savings potential, *economic* savings potential and *realisable* savings potential. In addition, a realisable greenhouse gas reductions potential is also included.

Main Features of OPENZ

OPENZ differs from previous economy-wide energy models in New Zealand in two important respects. Firstly, OPENZ focuses on meeting the demand for *end-use services* such as for example: space heating, water heating, industrial heating, lighting, motive power, refrigeration, space cooling and so forth. In contrast, other previous models have characterised demand in terms of delivered energy quantities (electricity, coal, natural gas). Secondly, unlike most previous economy-wide energy models in New Zealand, OPENZ is fully technology explicit for both energy supply and demand options. This is important as OPENZ can only determine future energy policy options for New Zealand that are *technological feasible,* which is a major advantage over existing macro-economic models that lack technological specifics and/or make assumptions about general levels of technical improvements. Another critical feature of OPENZ is that it is a *dynamic model* which provides the user with important insights into the phasing in of new energy supply and demand technologies.

For every year, OPENZ consists of 584 technologies available for either converting energy from one form to another or for saving energy. For each year, OPENZ will satisfy the supply of energy end-uses, in terms of a specified *objective function* which reflects various energy policy goals:

- minimisation of primary energy inputs[2]
- minimisation of economic cost
- minimisation of economic cost (including carbon price)

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[1] These refer to years ending 31 March. For example, "2007" refers to the year ending 31 March 2007.

[2] These can be measured either in terms of 'heat units' (which is the measurement unit commonly use by statistical agencies) or 'heat units' that have been adjusted for energy quality.

[3] The 'energy potentials' and 'energy consumption' data in the *Executive Summary* are enumerated in terms of primary energy inputs, measured according to their 'heat contents'. Measurement of energy input in terms of their 'heat content' is common practice particularly by statistical agencies. However, exergy and emergy (quality equivalent) units are often used to take account of energy quality. It should be noted that in the minimisation of 'primary energy inputs' for the determination of the 'technical energy savings potential', we used data adjusted for energy quality by using quality equivalent (emergy) units. Refer to Appendix A for further discussion of the energy quality issue.

[2] These can be measured either in terms of 'heat units' (which is the measurement unit commonly use by statistical agencies) or 'heat units' that have been adjusted for energy quality.

[4] The primary energy consumption for the 'technical potential' only decreases by 55% (not 61%) if measured in quality-adjusted

- minimisation of greenhouse gas emissions

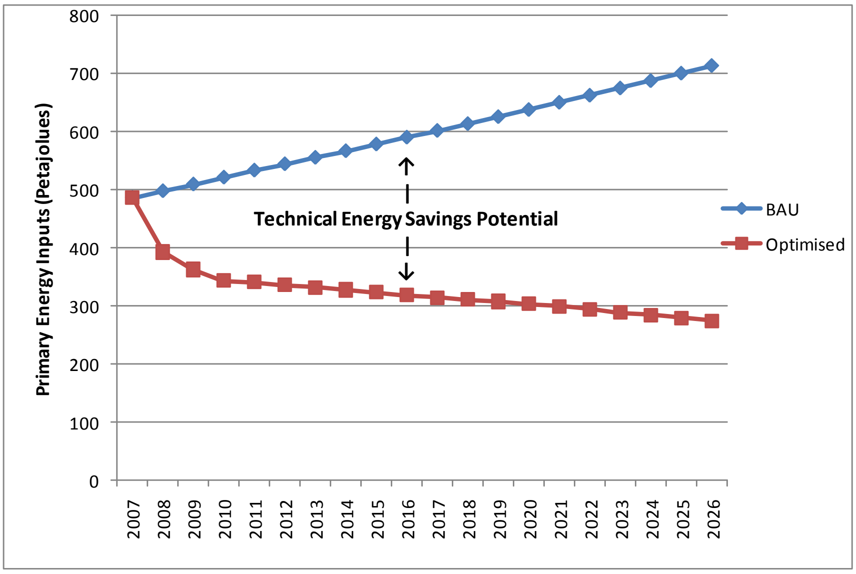
Besides the objective function, OPENZ users can *either control a number of variables, or just accept the default settings* – these include: (1) GDP levels of 37 Sectors. Overall, the default setting has the economy increasing by 48% from 2007 to 2026; (2) Amount of Natural Gas used for Petrochemicals; (3) Size of Remaining Natural Gas fields; (3) Rebound Effects for space heating interventions; (4) Future Carbon Prices; (5) Future Energy Prices for 11 delivered energy types, with the remaining 8 delivered energy types bind endogenously determined by OPENZ; (6) land available for energy biomass production; (7) Discount Rates used for the discounted cash flows; (8) Penetration Rates for adoption of new end-use technologies; (9) the maximum percentage of electricity that can be generated from wind – the default value is 20%. Although all of these variables have 'default values' that reflect the 'Business-As-Usual' (BAU) situation, it is often instructive to explore the impact of departures from the BAU default settings such as for example increasing the price of carbon. In addition, OPENZ users can also specify a number of *policy constraints:*

- Percentage of electricity being generated from renewable sources.
- Percentage of primary energy from renewable sources
- Maximum amount of CO_2 emissions (kilotonnes/yr) that is permitted to be produced by the economy. This amount could be reflective of Kyoto Protocol imposed targets.

Technical Energy Savings Potential[3]

The 'technical energy savings' potential is the maximum energy that can be saved, by employing the best available technology and energy savings measures. These 'technologies' and 'energy savings' measures may not necessarily be the most economic or commercially viable. OPENZ determined the 'Technical Energy Savings Potential' by *minimising the amount of primary energy input* required to produce projected levels of energy end-use services. Once the primary energy inputs have been adjusted by energy quality factors, the optimisation (minimisation) was undertaken. The technical energy savings potential allows for a relatively high rate of technology uptake. The following graph quantifies the result of the optimisation – the gap between the 'Business-As-Usual' (BAU) and 'Optimised' (minimised) energy inputs, is the 'technical energy savings potential':

[3] The 'energy potentials' and 'energy consumption' data in the *Executive Summary* are enumerated in terms of primary energy inputs, measured according to their 'heat contents'. Measurement of energy input in terms of their 'heat content' is common practice particularly by statistical agencies. However, exergy and emergy (quality equivalent) units are often used to take account of energy quality. It should be noted that in the minimisation of 'primary energy inputs' for the determination of the 'technical energy savings potential', we used data adjusted for energy quality by using quality equivalent (emergy) units. Refer to Appendix A for further discussion of the energy quality issue.

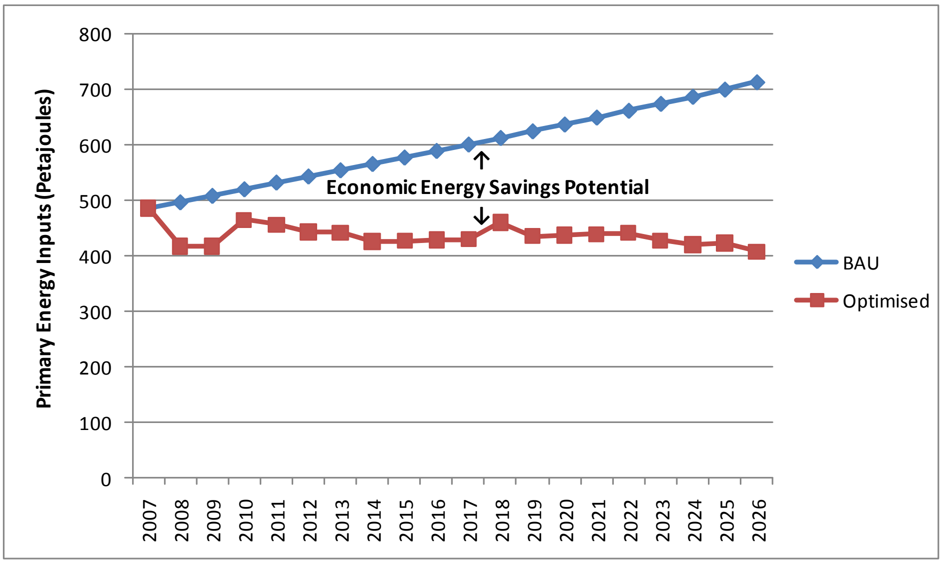


This graph shows that by 2026 it is technically possible to reduce New Zealand's primary energy consumption by 61%[4] of the projected BAU situation. The cost of doing this is estimated to be $$_{2006/07}$ 6.55 billion/yr, which is equivalent to 2.95% of the projected GDP. Accompanying this energy savings would also be a 15.1% reduction in energy-related greenhouse gases from 2007 to 2026. A wide range of energy savings measures were adopted as is outlined in the report in detail. From an end-use perspective the biggest energy savings were in the transport sector, with an important feature of the results also being the decrease use of electricity and the switching to the direct use of fuels (particularly natural gas) for heating applications. In the demand sectors, OPENZ estimated 166 PJ/yr savings, in 2026 from adopting various energy savings measures.

Economic Energy Savings Potential

The 'economic energy savings' potential, is the maximum energy that can be saved, by employing the most economic means of energy supply and energy savings measures. In OPENZ, this was determined by minimising the 'total economic cost' ($) which included a modest carbon cost, and uses a discount rate of 10%. The economic energy savings potential also allows for a relatively high rate of technology uptake. The following graph quantifies the result of the optimisation – the gap between the BAU and optimised energy inputs, is the 'economic energy savings potential':

[4] The primary energy consumption for the 'technical potential' only decreases by 55% (not 61%) if measured in quality-adjusted terms (quality equivalents/emergy units).



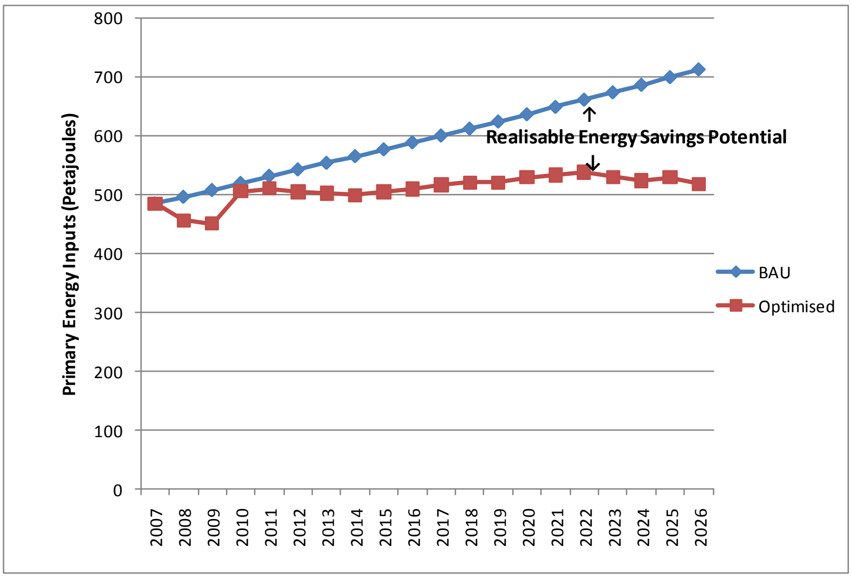
This graph shows that by 2026 Zealand's primary energy consumption reduced by 43%[5] of the projected BAU situation. This can be achieved with a very significant cost savings of an estimated $\$_{2006/07}$ 13.58 billion/yr in 2026 – reducing the cost of energy supply in New Zealand by 19%, achieved because OPENZ selects only the economically most efficient (least discounted cost) means of energy supply[6]. However, this means a slightly increased level of greenhouse gas emissions, as OPENZ selects the least cost means of energy supply which doesn't necessarily always have low greenhouse gas emissions. A wide range of energy savings measures were adopted as is outlined in the report in detail. From an end-use perspective the biggest energy savings were in the transport sector, with an important feature of the results also being the increased use of coal and natural gas. Coal usage particularly increased in the industrial sector for heating end-uses, but also recorded some increased use in the commercial sector. The main increases in Natural Gas use were increased hot water provision and some industrial heat applications. In the demand sectors, OPENZ estimated 124.80 PJ/yr savings, in 2026 from adopting energy savings measures.

Realisable Energy Savings Potential

The 'realisable energy savings' potential is the maximum energy saving that can be saved given more 'realistic' assumptions about technology uptake rates than assumed in the 'economic energy savings potential'. Therefore, in OPENZ, the 'realisable energy savings potential' is achieved by minimising 'total economic cost', and by assuming slower rates of end-use technology uptake. The following graph quantifies the result of the optimisation – the gap between the BAU and optimised energy inputs, is the 'realisable energy savings potential':

[5] The primary energy consumption for the 'economic potential' only decreases by 30% (not 43%) if measured in quality-adjusted terms (quality equivalents/emergy units).

[6] Energy supply in this context refers to *supply of end-uses of energy*. It does not refer to supply of delivered energy which is often the intended meaning.

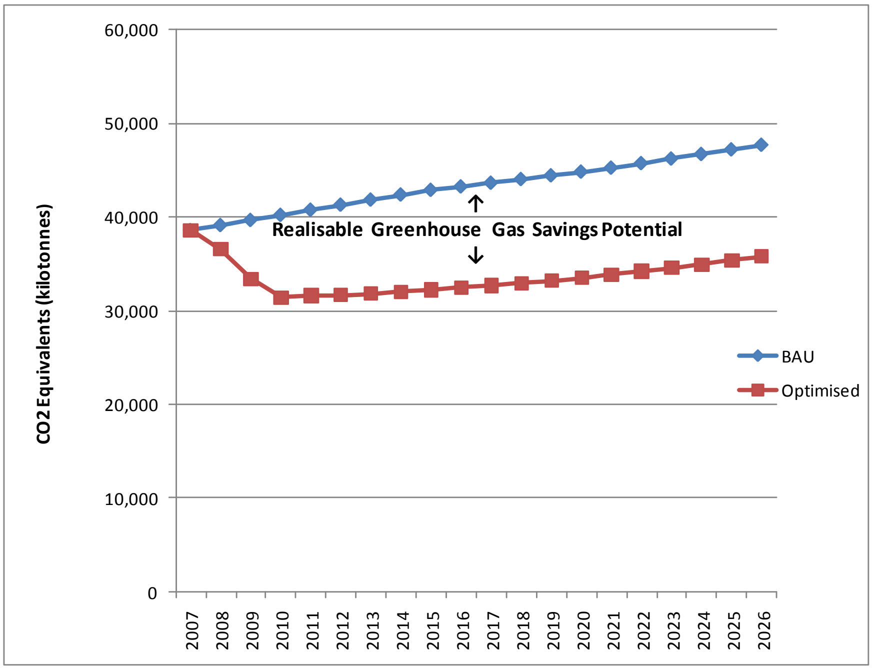


This graph shows that by 2026 Zealand's primary energy consumption reduced by27%[7] of the projected BAU situation. This can be achieved with a very significant cost savings of an estimated $\$_{2006/07}$ 10.25 billion/yr in 2026, compared with BAU cost projection. Nevertheless in spite of these energy savings compared with BAU projection, the optimised primary energy still increases by 6.8% over the 2007-2026 period. Natural Gas use increased primarily due to more industrial gas use and to a lesser extent increased use of Natural Gas for cooking and water heating in the household sector. Coal consumption increased significantly over this period, mainly through greater use in the industrial sector. Electricity use lagged below the rate of GDP growth. A wide range of energy savings measures were adopted as is outlined in the report in detail, the most significant again being in the transport area. In the demand sectors, OPENZ estimated 63.53PJ/yr savings, in 2026 from adopting various energy savings measures.

Greenhouse Gas Reductions Potential

The 'realisable greenhouse gas reductions' potential is the maximum greenhouse reductions that can be achieved by making 'realistic' assumptions about technology uptake rates. Therefore, in OPENZ, the 'realisable greenhouse gas reductions potential' is estimated by minimising 'greenhouse gas emissions[8]', and by assuming 'slow' rates of end-use technology uptake. The following graph quantifies the result of the optimisation:
to

[7] The primary energy consumption for the 'realisable potential' only decreases by 11% (not 27%) if measured in quality-adjusted terms (quality equivalents/emergy) units.
[8] Greenhouse gases are measured in terms of carbon dioxide equivalents, as 'adding-up' kilotonnes of carbon dioxide, methane and nitrous oxide would be invalid as they have different global warming potentials. Analogously the same type of issue arises when 'adding up' petajoules of different types of energy, as they have different *energy qualities* which invalidates their simple addition without first of all adjusting for energy quality. Hence, in this report primary energy inputs are converted to *crude oil equivalents.*



This graph shows that a considerable reduction in greenhouse gases can be achieved compared with the BAU situation. In fact, greenhouse gas emssions actually decrease from 38,584 kilotonnes CO_2e in 2007 to 35,790 kilotonnes CO_2e in 2026 in spite of GDP increasing by a projected 48% over this period. Primary energy consumption also decreases by 4.9% over this period. However, the cost of energy supply for this optimisation increases in 2026 to $\$_{2006/07}$ 3.88 billion above the BAU. In other words, 1.75% of projected GDP is required to achieve this reduction in greenhouse gases – this is broadly consistent with estimates for overseas economies made by Nordhaus (1993a, b) and Stern (2007, 2008). One of the main features of this optimisation is on the supply-side with increased electricity usage (in contrast to the other optimisations reported here), with electricity only being generated from sources with *no* (hydro, wind) or *very low levels* (geothermal) of *greenhouse gas emissions*. On the demand side, energy savings measures saved 84.66 PJ/yr in 2026, remembering that some of these measures were not necessarily 'economic' because of the choice of minimisation of greenhouse gases as the objective function in this optimisation.

Detailed Database Underpins Each of the 'Headline' Potentials

In a sense OPENZ is not just a model, but also a database. That is, a detailed database of technologies, energy conversion processeses and energy savings methods that can be employed to achieve the technical, economic and realisable energy saving potentials. Care therefore needs to taken in interpreting the 'headline' energy savings potential results reported in this Executive Summary. These 'headline' Potentials are not just broad unsubstantiated numbers, but numbers that are derived from a very detailed quantitative analysis of the technologies, energy conversion processes and energy savings methods actually required for each 'Potential'. Readers are therefore strongly encouraged to refer to Sections 5, 6, 7 and 8 of this publication (as well as Appendices E, F and G) to see, from a detailed engineering perspective, how each of the energy saving potentials are designed and constructed.

Overall Energy Savings Potentials

By drawing on data from the body of the report, the overall energy savings potentials for the entire economy (and each sector within it) can be assessed**.** One way of assessing energy savings is to measure it relative to a 'Business-as-Usual' forecast or baseline. Another way, is to measure energy savings relative to a 'Frozen Efficiency' forecast or baseline, where it is assumed that there are no energy efficiency improvements in the economy – using this criterion the 'energy savings' can be assessed for the 'technical', 'economic' and 'realisable' potentials for 2025/26:

Sector	**Technical** (PJ/yr) [4]			**Economic** (PJ/yr)			**Realisable** (PJ/yr)		
	'Frozen Efficiency' Energy Use	Optimised Energy Use	Energy Savings	'Frozen Efficiency' Energy Use	Optimised Energy Use	Energy Savings	'Frozen Efficiency' Energy Use	Optimised Energy Use	Energy Savings
Household	237	121	116	237	171	66	237	196	40
Industrial	286	205	81	286	220	67	286	233	54
Commercial	73	38	35	73	62	11	73	68	5
Primary	60	53	7	60	53	6	60	55	4
Transport	131	103	29	131	106	25	131	116	16
Total	787	519	267	787	612	175	787	667	119

Notes:
1. Measured in terms of 'Delivered Energy', not 'Primary Energy'
2. Measured in conventional heat content units for the sake of comparison with other statistics and forecasts
3. 'Energy Savings' = 'Frozen Efficiency Energy Use' *minus* 'Optimised Energy Use'
4. 'Technical Potential' results obtained by optimising using 'heat content units'. Not adjusted for energy quality.

As can be ascertained from this table of data, across the entire economy, by definition the Technical Potential optimisation recorded the highest level of 'energy savings', reducing the 'frozen efficiency' energy use by 33%. OPENZ assesses lower levels of 'energy savings' for the 'economic potential' (22%) and for the 'realisable potential' (15%).

Consistently, no matter which potential is considered ('technical', 'economic' or' realisable'), the household and industrial sectors show the largest potential 'energy savings' opportunities. For example, for the technical potential, the industrial sector records 38% of all the potential 'energy savings', closely followed by the household sector at 37%, with the other sectors significantly behind. It needs, however, to be noted that the household sector, and to a lesser extent the industrial sector, under the ANZSIC statistical categories includes significant transport activities.

Conclusions and Future Research

The development of OPENZ as a practical tool for energy policy analysis was successful. It differs from other models economy-wide energy models in New Zealand, in that it has a focus on energy *end-use services*, and it is *technology explicit*. It is hoped that these features of OPENZ will impose a 'realism' which is sometimes missing in other economy-wide energy models. Initial applications reported upon in this report focused on quantifying energy savings potentials (Technical, Economic, Realisable). It was found that by 2026 that it is technically possible to make energy savings of 55% given known technologies, which reduces to 30% when just considering 'economic' measures. It reduces even further to 11% energy savings when further allowances are made for realistic rates of technology uptake. Future applications of OPENZ should focus on considering a broader array of energy policy objectives than just energy efficiency and energy savings, as the concentration on just one policy objective runs the risk of producing results that are unacceptable from the viewpoint of another policy objective or set of stakeholders. The future development of OPENZ could benefit from a fuller integration with economic models (such as CGE models) to better portray linkages and flow-on effects in the macro-economy.

The Big Picture – Energy Savings Supply Curves

Dr Anita King and Dr Murray Patterson [9]

The data presented in this section summarises the very detailed data presented in the main body of the report. It provides an overview of how much energy can be saved, and at what financial cost (and in some cases with financial benefits). Readers are urged to refer to the body of the report to gain a deeper and more detailed appreciation of how these energy savings can be achieved, and on what basis OPENZ calculated these energy savings[10] [11].

Supply curves are a basic tool of economic analysis and communication. In general, a supply curve provides a *ranked list of possible options/technologies for producing a commodity* – starting with those technologies with the smallest 'marginal cost' first and thereafter those technologies with increasing 'marginal costs'. Because from each step on the supply curve gets progressively bigger (ie, the marginal cost increases), the *supply curve is always upwards sloping*[12].

Supply curves have a number of practical implications for guiding economic behaviour and policy analysis: (1) The simplest and most straightforward implication, is that it is economically rational to use those technologies with the lowest marginal costs first; (2) However, at some point, as you move up the supply curve the 'marginal cost' will equal the 'marginal benefit'. This is called the equilibrium point, and it is very important is economic analysis as it is the point where economic welfare is maximised – all the possible net benefits have been extracted and there is nothing more to be achieved by 'moving further up the supply curve'; (3) That is, beyond the equilibrium point, it is no longer economically rational to use the technologies described by the supply curve, because the 'marginal costs outweigh the 'marginal benefits'.

Two important assumptions underpin our analysis: (1) the 'energy savings' measured by OPENZ are those *additional* to those that would be achieved by a 'Frozen Efficiency' 'forecast. That is we are implicitly measuring accelerated levels of uptake of energy savings and energy efficient technologies; (2) It needs to be noted that our supply curve analysis, does not take account of externalities (unpriced benefits and costs) such as the health benefits of clean air resulting from using less coal for example in open fires. Many economists would argue that these externalities need to be taken into account, before we can make any valid conclusions about the welfare effects of the various energy savings options.

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9 These supply curves were produced by Dr Anita King (EECA) from OPENZ data and interpreted by Dr Murray Patterson in this overview commentary.

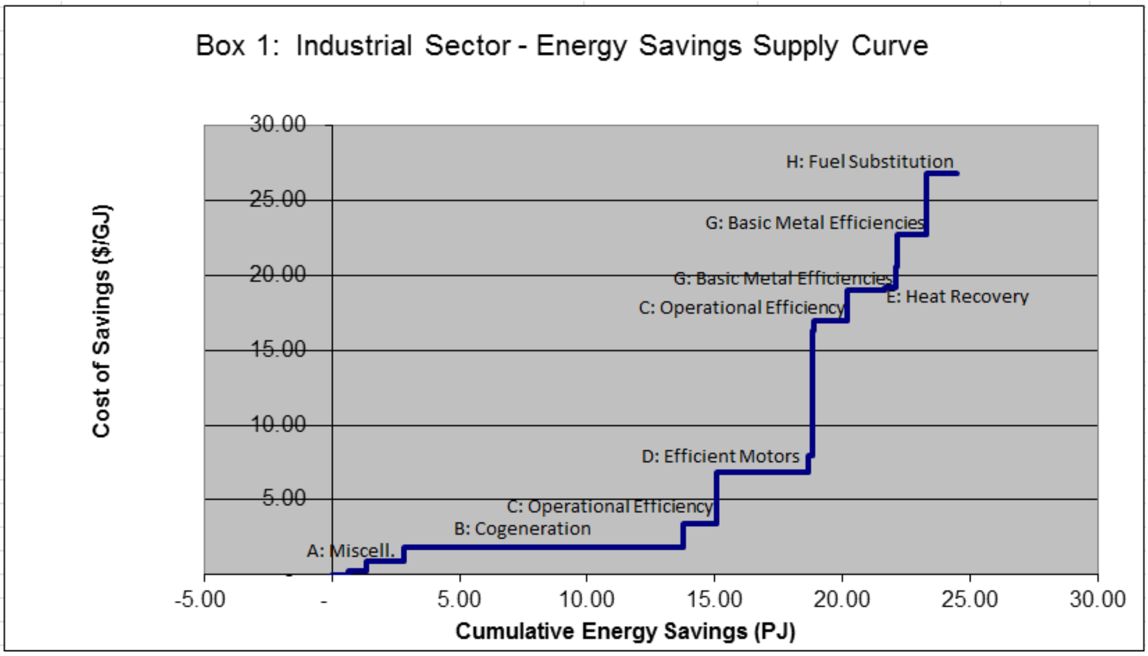
10 The results presented in this overview are, unless otherwise stated, based on the supply curves produced by OPENZ for the 'Economic Potential'. Readers should therefore refer to Chapter 5 'Economic Potential' for the detailed results, and Appendices F.1 and G.1. The 'Technical Potential' results are used for the 'Transport and Storage Sector' as it provides a wider range of energy savings options.

11 Data in this overview is presented in a more streamlined fashion than would normally be the case. Costs are always expressed in $\$_{2006/07}$, but this is not repeatedly specified in the text. Energy inputs are expressed in 'Delivered Energy Inputs' measured in 'heat content' units. This measurement on energy in terms of it 'heat content' is the conventional approach in energy statistics and accounting – however if should be noted that this author questions this approach to energy accounting, as it takes no account on *energy quality* – refer to Appendix A for further discussion of this issue.

12 The supply curves reported in Appendix H are however not always upwards sloping because from the point of view of the global optimum, it sometimes makes sense to use more energy input for some particular end-use (ie, to have negative entries for PJ saved) and save more energy elsewhere. For ease of communication these 'blocks' have been removed from the results reported in this overview section, but are available in Appendix H.

Industrial Sector: Aggregative Energy Savings Supply Curve

The energy savings supply curve for the industrial sector is presented below (refer to Box 1)[13] [14], with detailed quantitative results being presented in Appendix H:



- *Miscellaneous (A):* These include a small number of energy saving options that deliver significant energy saving at a very low or no cost: Refining and Rejects Handling in Forest Products (0.63 PJ/yr); cool and cold store improvements in the food industry (0.71 PJ/yr); and improving boiler efficiency (1.47 PJ/yr). The total cost of achieving these savings of 1.81 PJ/yr is estimated to be only $1.5 million/yr. OPENZ assesses the average cost of these options is 0.54 $/GJ of savings.
- *Cogeneration (B):* Additional cogeneration (of heat and electricity) was assessed by OPENZ to save 10.97 PJ/yr of energy by 2025/26, as a more efficient option to generating process heat and electricity by other means. More specifically 4.3PJ of process heat would be produced by cogeneration and 4.4PJ of electricity. These energy savings of 10.97 PJ/yr were estimated to be achieved with a net cost of $20million/yr for 2025/26. OPENZ assesses an average net cost of 1.80 $/GJ of savings.
- *Improved Operations and Maintenance (C):* This includes better day-to-day attention to energy efficiency ('housekeeping'), better process control and management. This is expected to, by 2025/26, lead to an energy saving of 1.32 PJ/yr of electricity (Ind. 91) and 1.30 PJ/yr of natural gas (Ind. 137). Some of the energy savings measures identified in the

[13] For ease of interpretation the first 5 segments have been deleted – these include fuel/technology switching for various end-use categories. For fuller details refer to Section 6.3.2, in the report. Some of these so-called 'energy savings' recorded in Appendix H are arguably just a function of the conventional way energy data in measured in terms 'heat content' units – when the data is adjusted for energy quality, the results energy savings are not as great as they first appear. Nevertheless, in particular, the 'economic potential' optimisation does demonstrate that significant financial saving can be achieved switching to less expensive forms of energy (black liquor, geothermal heat and coal) for providing *Intermediate Process Heat (100-300 C*), even though the energy savings are small. These financial savings by changing these cheaper fuels to supply *Intermediate Process Heat (100-300 C*) are estimated to be $757million/year.

[14] Due to its small size the category "Improved Operation of Electronic Equipment" is not included in the main overview. This was assessed by OPENZ to save 0.02 PJ/yr at an assessed cost of 20.55 $/GJ.

'technical energy savings' optimisation were assessed to be uneconomic: Ind. 113, Ind. 133 and Ind. 106. OPENZ assesses the average cost of these energy savings to be 10.26 $/GJ.

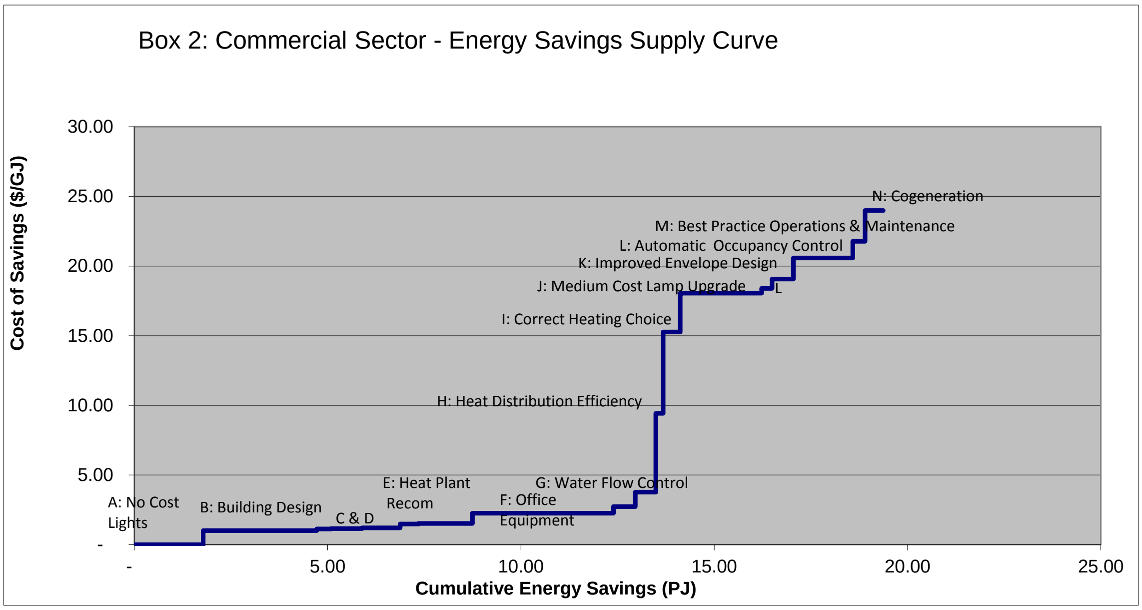
- *Motor Efficiency and Sizing Improvements (D):* Over the 20 year period, this energy saving amounts to 1.18 PJ/yr of electricity by 2015 and increasing to a saving of 3.58 PJ/yr by 2025/26. These Motor Efficiency and Sizing Improvements are additional to significant improvements that have been made in this area and are additional to the BAU trend from 2006/07to 2025/26. OPENZ assesses the average cost of these energy savings to be 6.89 $/GJ.
- *Heat Recovery (E):* OPENZ identified many practical mechanisms of heat recovery (Ind. 127, Ind. 116, Ind. 128, Ind. 105, Ind. 110, Ind. 115, Ind. 195, Ind. 121, Ind. 125, Ind. 101) that were technically feasible which lead to 0.96 PJ/yr potential savings by 2025/26. Only 0.16 PJ/yr of this 0.96 PJ/yr was however found to be economically viable. OPENZ assesses the average cost of these energy savings to be 7.96 $/GJ.
- *Improved Lighting (F):* Some relatively small economically viable energy savings from improving lighting efficiency were identified including upgrading existing fluorescents and upgrading gas discharge lamps. By 2025/26, this was estimated to achieve 0.07 PJ/yr savings. OPENZ assesses the average cost of these energy savings to be 16.29 $/GJ.
- *Efficiency improvements in the Basic Metals Sub-Sector (G):* NZ Aluminium Smelters have made consistent improvements in their efficiency (in terms of TJ/tonne product). It is however more difficult to obtain efficiency data for NZ Steel which is the other large industrial site in this sub-sector. Nevertheless, OPENZ assessed further economically viable savings to be 3.05 PJ/yr in 2025/26. OPENZ assesses the average cost of these energy savings as being close to 20 $/GJ.
- *Fuel Substitution in the Provision of Kiln/Furnace Heat, 100-300C (H):* This fuel mix used for this end-use category changed away from the use of (less energy efficient) wood more towards to the use of (more energy efficient) natural gas. This resulted in 1.19 PJ/yr of saved energy in 2025/26 relative to the BAU trend. OPENZ assesses the average cost of this fuel substitution to be 26.78 $/GJ of savings

Commercial Sector: Aggregative Energy Savings Supply Curve

The energy savings supply curve for the commercial sector is presented below (refer to Box 1)[15], with detailed quantitative results being presented in Appendix H:

- *No Cost Lighting Options (A):* Lighting is a major end-use of electricity in the commercial sector. A number of no cost options were identified such de-lamping of interior spaces and improved lighting purchasing decisions. OPENZ assessed these measures to save 0.74 PJ/yr in 2025/26.
- *Building Design (B):* Although often requiring long lead times, as old building stock is replaced by new building stock, there is significant potential for energy savings in this category, in addition to on-going retrofitting options. Com 51 andCom53 were estimated by OPENZ to save 1.96 PJ/yr in 2025/2026. OPENZ assesses the average cost of these energy savings at 0.77 $/GJ.
- *Motor Sizing (C):* Motors are used for a variety of purposes in the Commercial Sector and it was estimated by more appropriate motor sizing that 0.38 PY/yr of energy could be saved in 2025/26. OPENZ assesses the average cost of these energy savings at 1.12 $/GJ.

[15] Only the largest blocks of energy saving are described here, as the Supply Curve generated by OPENZ for the commercial sector is more detailed than for other sectors – for a full list refer to Appendix H.



- *Task Lighting and other Design Changes (D):* Task lighting, uplighting, daylighting, as well as other design changes to improve the efficiency of indoor lighting were estimated to save 0.80 PY/yr in 2025/26. OPENZ assesses the average cost of these energy savings at 1.15 $/GJ.
- *Heat Plant Recommissioning (E):* OPENZ identifies a number of energy savings measures that are economically viable including: Com. 56, Com. 57, Com. 61, Com. 120, Com. 64, Com. 135 and Com. 136. Of these recommissioning old plant was estimated to save 1.87PJ/yr in 2025/26. OPENZ assesses the average cost of these energy savings at 1.51 $/GJ.
- *More Efficient Use of Office Equipment (F):* This includes better office equipment management, switching equipment on/off and the optimum location of office equipment. In spite of all of the recent research and awareness of the increasing heavy load of office equipment, this still remains the largest potential area for energy savings in the Commercial Sector (IEA, 2009a,b). The IEA (2009b) estimates across its member countries that energy consumed by IT and consumer electronics will double by 2020 and triple by 2030. It is therefore not surprising that OPENZ assesses the very significant 'energy savings' to be from better operational use of office equipment (measure Com. 57) – OPENZ estimates that it is economically viable that by 2025/26 3.65 PJ/yr could be saved by this measure. OPENZ assesses the average cost of these energy savings at 2.26 $/GJ.
- *Water Flow Control (G):* Optimised Flow Controls (Spray Nozzles, Shower Heads etc.) were estimated to save 0.46 PJ/yr in 2025/26. OPENZ assesses the average cost of these energy savings at 3.37 $/GJ.
- *Heat Distribution Efficiency (H):* More efficient heat distribution through local heaters, better pipe and cylinder insulation, etc) was estimated to save 0.46 PJ/yr in 2025/26. OPENZ assesses the average cost of these energy savings at 9.43 $/GJ.
- *Correct Heating Choice (I):* The 'correct' heating choice (radiant/convector/air) was estimated to save 0.45 PJ/yr in 2025/26. OPENZ assesses the average cost of these energy savings at 15.26 $/GJ.
- *Medium Cost Lamp Upgrade (J):* Medium cost lamp upgrade (reflectors, triphosphor tubes, CFL's) was estimated to save a very significant 2.11 PJ/yr of electricity, in 2025/26. OPENZ assesses the average cost of these energy savings at 18.06 $/GJ.

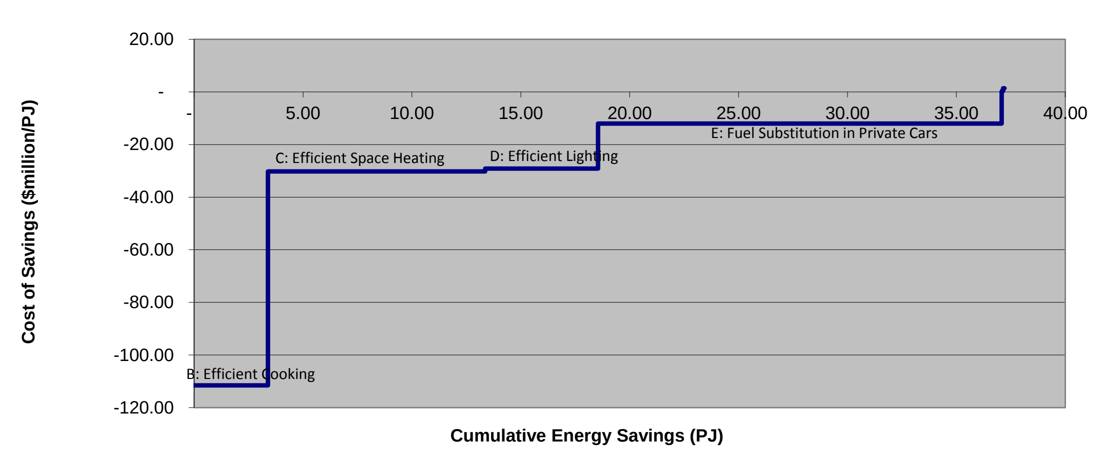
- *Improved Envelope Design (K):* These refer to more expensive envelope design options that occur in addition to those considered above. They were estimated to save 1.54 PJ/yr in 2025/26, in addition to those that would be saved in the BAU case. OPENZ assesses the average cost of these energy savings at 20.58 $/GJ.
- *Automatic Occupancy Control (L):* Automatic Controls (occupancy, time-switching, daylight linked) although more frequently used over the last decade still offer an opportunity to save further energy. It is estimated that 0.55 PJ/yr of energy could be saved by such controls in 2025/26. OPENZ assesses the average cost of these energy savings at 19.07 $/GJ.
- *Best Practice Operations and Maintenance (M):* This includes optimising after hours use of office space, cleaning staff scheduling, occupant switching, re-commissioning, luminaire cleaning, lamp replacement scheduling and so forth. It estimated that this category could save 0.32 PJ/yr in 2025/26. OPENZ assesses the average cost of these energy savings at 21.77 $/GJ.
- *Cogeneration (N):* There is a relatively small amount of energy that can be saved by co-generation of electricity and heat. This mainly applies to hospitals and swimming pools. It is estimated by OPENZ that by 2025/26 that it is economically viable to save about 0.47 PJ/yr from using co-generation in the commercial sector. OPENZ assesses the average cost of these energy savings at 23.99 $/GJ.

Household Sector: Aggregative Energy Savings Supply Curve

The energy savings supply curve for the industrial sector is presented below (refer to Box 3), with detailed quantitative results being presented in Appendix H:

- *More Efficient Water Heating (A):*[16] Electric hot water cylinders which supplied 82.1% of the hot water in 2006/07, declined to only 14.5% of hot water provision in 2025/26. By 2025/26, this was replaced by almost all of hot water being provided by natural gas and solar technologies including instantaneous gas water heaters and heating systems with improved insulation. In total, by 2025/26, 0.48 PJ/year of energy is saved, with a financial savings of $204 million/year in 2025/26.
- *More Efficient Cooking (B):* This consists of energy saved by more energy efficient cooking in homes. In total, by 2026/26 3.39 PJ/year of energy is saved, with a financial savings of $378million/year in 2025/26. From 2006/07 to 2025/26 there was a gradual decrease in traditional electric and gas powered cooking equipment, with an increased use of more energy efficient microwave ovens.

[16] It was not possible to easily depict this block of water heating energy saving on the supply curve (Box 3).

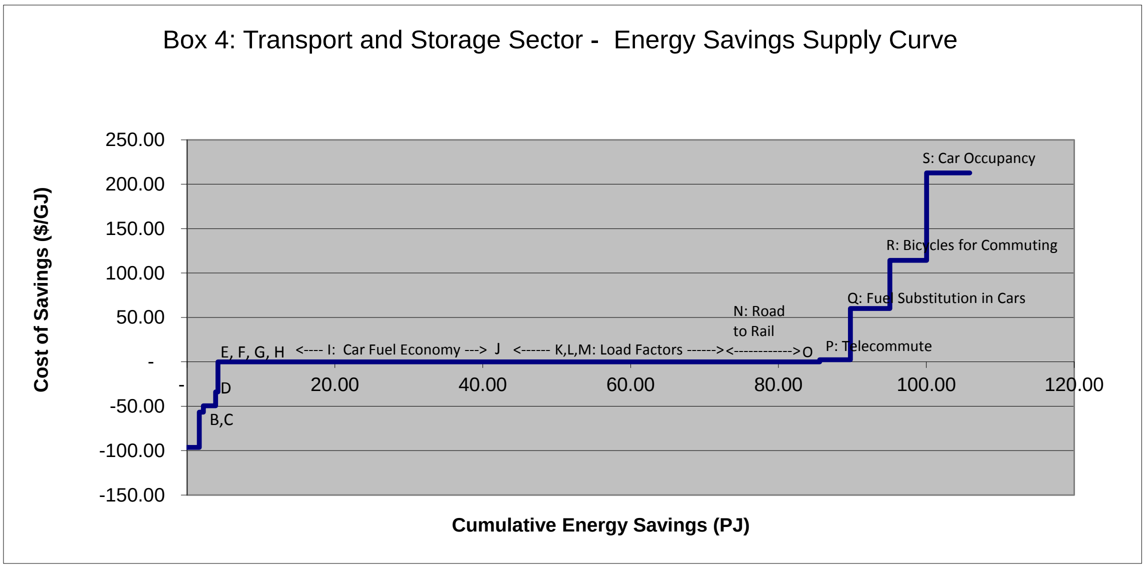


Box 3: Household Sector - Energy Savings Supply Curve

- *More Efficient Space Heating (C):* This consists of energy saved by more energy efficient space heating in homes. In total, by 2026/26 9.97 PJ/year of energy is saved, with a financial savings of $301 million/year in 2025/26. By 2025/26 there was a complete elimination of open fires, except for open fires with wet backs. Notably, however unlike the 'technical potential' optimisation resistance heaters and nightstores (which were eliminated) still provided 30.3% of the space heating. The remainder of the space heating by 2025/26 was provided by natural gas heaters (44.0%) and heat pumps (19.3%).
- *More Efficient Lighting (D):* The change of mix of lighting technologies is exactly the same as for the 'technical potential' optimisation. That is, by 2019 there was the complete elimination of tungsten incandescent lights and the replacement by more energy efficient (and cost effective) forms of lighting. By 2025/26, 53% of lighting is from compact fluorescent lights, 27.0% from LED lights and 19.9% from long tube fluorescent lights. In total, by 2025/26 5.18 PJ/year of electricity is saved, with a financial savings of $150 million/year in 2025/26.
- *Fuel Substitution in Private Cars (E):* Unlike the 'technical potential' optimisation there was no uptake of alcohol fuels (ethanol, methanol), although there was a significant uptake of electricity-petrol hybrid cars by 2025/26 to 16.2% of market share. There was also some uptake of diesel powered vehicles, increasing from 12.8% in 2006/07 to 23.4% in 2025/26, as well as a very small uptake of natural gas vehicles. This led to a significant decline in petrol fuelled private vehicles from 85.4% of market share in 2006/07 to 60.2% in 2025/26. In total, by 2025/26 18.53 PJ/year of fuel is saved, with a financial savings of $222 million/year in 2025/26.

Transport and Storage Sector: Aggregative Energy Savings Supply Curve

The energy savings supply curve for the transport and storage sector is presented below (refer to Box 4), with detailed quantitative results being presented in Appendix H. Some of the costings in this assume there is zero financial cost of adopting the energy saving options, based on using data from Henderson (1994). Although this may be the case in a narrow financial sense, it is doubtful if this is the case in terms of broader calculations of welfare effects and therein probably lies the reason why many of these options have not been adopted in spite of their zero financial cost.



- *Fuel Substitution in Land Freight (A)*: OPENZ assesses a slight shift towards diesel powered vehicles. That is, diesel increases from 93.4% of the market share in 2006/07 to 98.0% in 2025/26. Petrol is phased out. By 2025/26 besides diesel, 1.53% of freight vehicles are using LPG and 0.45% natural gas. OPENZ assesses that these energy savings of 1.65PJ/yr also result in financial savings of $159 million/yr in 2025/26.
- *Fuel Substitution in Buses (B):* OPENZ assesses steady increase in both electric and natural gas powered buses, based on their superior energy efficiencies. From 2006/07 electric buses increase from 6.6% to 14.1% by 2025/26. Similarly natural gas powered buses increase from 1.12% in 2006/07 to 2.2% in 2025/26. Diesel powered buses decrease, but still dominate, at 83.3% in 2025/26, whilst petrol powered buses are phased out. OPENZ assesses that these energy savings of 0.56 PJ/yr also result in financial savings of $32 million/yr in 2025/26.
- *Fuel Substitution in Rail Freight (C) and Passenger Rail (D):* In 2006/07 88.9% of this category of end-use energy was supplied by electricity. By 2025/26 all rail freight locomotives used electricity. The same pattern occurred for rail passenger services. OPENZ assesses that these energy saving of 1.96 PJ/yr also result in financial savings of $82 million/yr in 2025/26.
- *Increased the Load Factor in Passenger Air Services by 10% (E):* It is assessed based on updating of data previously compiled by Henderson (1994) that increasing the load factor in passenger air travel by 10% would save 4.08 PJ/yr by 2025/26.
- *Shift Air Travel Passenger to Rail and Ship (F):* This only includes domestic travel, as international air travel is not included in the model. It is assessed again from updated data from Henderson (1994) that this could save 6.39 PJ/yr by 2025/26. This would require a major upgrading of the New Zealand rail system to achieve this target, and probably a significant change in price relativities between the competing services. New Zealanders' travel by rail is small between the major centres compared with other developed countries particularly those in Europe as well as in Asian countries.
- *Increased the Load Factor of Coastal Freight Services by 10% (G):* This is assessed by OPENZ to be 1.08 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adjusted by applying growth rates to OPENZ processes-sectors combinants.

- *Increase Load Factor of Passenger Rail Services by 10% (H):* This is assessed by OPENZ to be 0.11 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adjusted by applying growth rates to OPENZ processes-sectors combinants.
- *Improved Car Engine Efficiency (I):* This is achieved by reducing the fuel consumption in cars used commercially and privately. Strictly speaking most of these efficiency gains should be recorded in the Household Sector of OPENZ, but is recorded here for convenience. There has over the last couple decades been a significant improvement in the rated fuel economy (litres/100km) of vehicles in New Zealand's passenger fleet due to design and technological improvements. Nevertheless it is projected by OPENZ that there will be further energy savings of 23.50 PJ/yr, by 2025/26, achieved by improved engine efficiency and vehicle design
- *Driver Education Programmes and Improved Car Maintenance (J):* This is assessed by OPENZ to be 0.11 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adjusted by applying growth rates to OPENZ processes-sectors combinants
- *Increase the Load Factor on Passenger Buses by 10%. (K):* Load factors on New Zealand buses are low (average of about 30%). OPENZ calculates that by increasing this load factor by 10% by 2025/26, then 2.17 PJ/yr energy could be saved.
- *Increased the Load Factor of Light Goods Vehicles by 10% (L):* Improved logistics, planning and organisation, could save a very significant amount of energy, due to the large amount of end-use energy used for light goods freight. It is estimated by OPENZ, using updated data provided by Henderson (1994), that by 2025/26 16.86 PJ/yr could be saved which is due in part to the strong relative growth of this sector.
- *Increased the Load Factor of Heavy Goods Vehicles by 10%. (M):* Although the load factor of heavy goods vehicles (about 50%) is better than light goods vehicles (about 30%), there is still considerable potential for improvement. OPENZ assesses that by 2025/26 10.6 PJ/yr could be saved by improving the load factor of heavy freight vehicles by another 10%.
- *Shift Road Freight to Rail Freight (N):* This is assessed to be 9.84 PJ/yr energy saving by 2025/26. Again this would require a significant upgrading of the New Zealand freight rail system, and the appropriate financial incentives put in place.
- *Improved Road Surfaces and Alignment (O):* This is assessed by OPENZ to be 1.71 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adapted in growth rates applied to OPENZ. No reliable costing of these improvements could be obtained.
- *Telecommute 4 out of 5 days per week (P):* This is assessed by OPENZ to be 4.15 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adjusted by applying growth rates to OPENZ processes-sectors combinants. OPENZ assessed the cost of 'telecommuting' to be $9 million/yr based on updated data from Henderson (1994).
- *Fuel Substitution in Passenger Cars (Q):* By 2025/26 all these vehicles are converted to electric, hybrid electric or natural gas. OPENZ assesses energy savings of 5.34 PJ/yr costing $320 million/yr. The average cost of these energy savings is calculated to be 5.34 $/GJ.
- *Use Bicycles More for Commuting (R):* This is assessed by OPENZ to be 4.99 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adapted in growth rates applied to OPENZ. OPENZ assessed the cost to be $569 million/yr based on updated data from Henderson (1994).
- *Car Pooling to Increase Occupancy from 1.25 to 2 per vehicle in Commuting (S):* This is assessed by OPENZ to be 5.83 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adapted in growth rates applied to OPENZ. OPENZ assessed the cost to be $1,241 million/yr based on updated data from Henderson (1994).

Primary Sector: Aggregative Energy Savings Supply Curve

The energy savings supply curve for the primary production sector is presented below with detailed quantitative results being presented in Appendix H:

- *Fuel Substitution in Freight Transport (A):* Petrol was phased out, with all freight vehicles converted to diesel. In total, by 2025/26 0.28 PJ/year of fuel is saved, with a financial savings of $26 million/year in 2025/26.
- *Improved Building Insulation (B):* This mainly applied to greenhouses but also pig and poultry farms. In total, by 2025/26 0.25 PJ/yr energy savings by improved insulation, with a net cost close of 1 $/GJ which is very low.
- *Improved Efficiency in Kiln Drying (C):* In total, by 2025/26 0.13 PJ/yr energy savings by improving the efficiency in kiln drying with a net cost of only 0.32 $/GJ.

As noted in the report there are other 'energy savings' mechanisms that could be implemented in the Primary Sector. However, there is a lack of reliable costings and energy savings data particularly on alternative fuels (for tractors), improving efficiency of tractor operation and on improving the operation of dairy sheds. For example, it should be possible in future versions of OPENZ, to evaluate options for water heating and milk chilling in dairy sheds. There were insufficient data on the primary sector to construct a meaningful energy savings supply curve.

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1. Introduction

1.1 Project's Scope

The aim of this report is to provide detailed documentation of OPENZ (Optimisation energy End-Use Model of New Zealand). OPENZ has been designed to define energy savings that can be achieved in New Zealand over the 2006/07 to 2025/26 period. It is in a sense an extension of the EECA End-Use Database (Patterson and McDonald, 2009), as OPENZ draws much of its data directly from the EECA End-Use Database and the data is often structured in the same way.

The overall aim of the project is to build a model which will be used to define the:
- Technical Energy Savings Potential (2006/07 - 2025/26)
- Economic Energy Savings Potential (2006/07 - 2025/26)
- Realisable Energy Savings Potential (2006/07 - 2025/26)

The approach in this project will be to construct a hybrid 'bottom-up' and 'top down' model of possible energy use and supply options in New Zealand. Most previous attempts to model energy supply and demand in New Zealand are based on 'top down models' which assume that their energy projections are technologically feasible which unfortunately may not be the case.

1.2 Strategic Context for the Modelling

The Energy Efficiency and Conservation Authority (EECA) is responsible for promoting economy-wide and sector level energy efficiency, renewable energy and energy conservation measures. The *Energy Efficiency and Conservation Act 2000* assigns EECA a key role in assisting the Government in designing and implementing the New Zealand Energy Efficiency and Conservation Strategy (NZEECS). An essential part of this role is to develop advice on the status and opportunities for sustainable energy. In October 2007, New Zealand released its new energy efficiency and conservation strategy. The updated NZEECS provides an action plan aimed at maximising energy efficiency and renewable energy use in New Zealand.

New Zealand's energy demand is growing. From 2001 to 2006, national energy use increased by 53 PJ or 12%, from 439 PJ to 492 PJ, giving an average increase of 2.3% p.a. A significant energy efficiency 'saving' of 19.7 PJ was achieved due to decreased energy demand growth. However, further decreases are required to meet New Zealand's targets. In order to devise a strategic response to this challenge, it is important to know where and how energy is used; how energy use is changing; how much energy can be saved; and where that energy can be saved.

Reducing energy use or realising energy saving opportunities is one of the best and most effective ways of improving energy sustainability. Reduced energy use has many positive effects as it improves energy services, reduces pollution, cost and it can offer social benefits in the form of increased energy security (through the reduced reliance on imported fossil fuels).

It is believed that New Zealand's current energy use profile offers significant potential for large-scale reduction efforts. Technological breakthroughs and government-sponsored programmes (e.g. energy audits for the industrial sector) are imperative to achieving our energy savings potential. Information programmes, which seek to increase productivity, encourage energy efficiency and conservation and offer technical assistance, are also important elements to reduce energy use. To best achieve that potential, it is necessary to identify and strategically select the most effective opportunities and measures from the range of potential options that exist today.

A realistic estimation of New Zealand's energy savings potential - and particularly identification of those potentials across sub-sector levels, fuel type and regional end-use - is problematic. Differences in the nature of sectors and the nature of potentials within those sectors are the principal cause of difficulties. For example, the industrial sector is more concentrated than the residential sector and efficiency gains in the industrial sector are mainly measured as energy and cost savings, whereas in the residential sector, service improvements are paramount. Despite the sectoral difference, a common thread remains, namely that we cannot plan for what we have not identified and can not manage what we do not measure. Closing these gaps is where an energy potentials analysis comes in.

1.3 Synopsis of the Modelling Approach

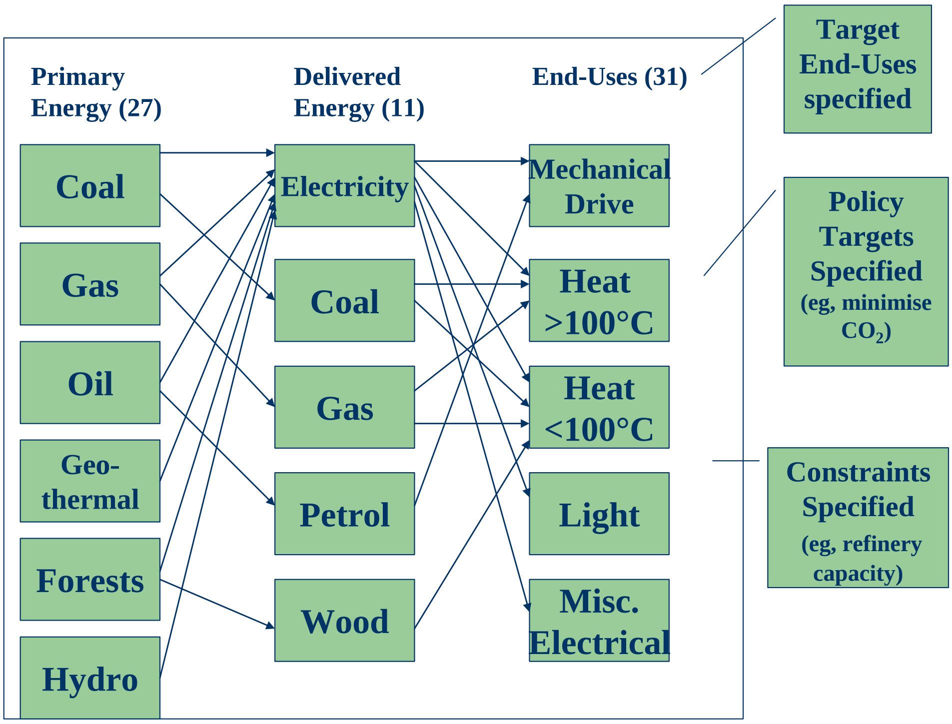
An optimisation model will be used to define *'the technical', 'economic' and 'realisable' energy savings potential in New Zealand, over the next 20 years*. As previously pointed out, the optimisation model differs from previous modelling attempts in New Zealand in that is based on specifying energy demand in terms of *'demand for the end-uses of energy'*. This is in contrast to previous attempts that use the 'demand for delivered energy'. It is argued that the end-use approach provides a better basis for evaluating 'energy savings potential', as it illustrates how different technologies can be used to achieve savings while still supplying consumers with the services that they require.[17]

This model is constructed by using the EECA End-Use Database 2006/07 and updated data from Henderson (1994) as the primary sources of data, as well as some data mainly for the Household sector provided by EECA staff. The model itself is based on a 'mini' model developed at Massey University and has been used as a basis for student projects and teaching for many years.

For the estimation of the '*technical energy savings potential'*, the optimisation model will determine the minimum energy input (quality-adjusted PJ) to supply given amounts of end-use energy in the New Zealand economy. For the estimation of the '*economic energy savings potential'*, the optimisation model will determine the least cost ($) way to supply given amounts of end-use energy in the New Zealand economy. For the estimation of the '*realisable energy savings potential'*, the optimisation model will determine the least cost ($) way to supply specified amounts of end-use energy in the New Zealand economy, given an additional set of technology uptake constraints.

The model itself will consist of *a network of possible energy supply-use options*, starting with energy end-uses (of which there are 31), and working back through the supply network to delivered energy forms (11) and eventually back to primary energy forms (27). This network is schematically portrayed by Figure 1.1

[17] Consumers require heating, lighting and other end-use services (fundamental demand). They don't necessarily require any specific delivered energy (derived demand) such as coal or electricity. Instead they require the end-use services from that which can be derived from delivered energy sources.



NB: Actual numbers of energy quantities are in brackets.

Figure 1.1 Schematic Representation of the New Zealand Energy End-Use Optimisation Model

Like any optimisation model the model contains a number of *constraints* that are critical in defining the optimal solution[18]:

- *Policy Constraints.* For example, the user may wish to constrain the level of allowable CO_2 emissions in line with Kyoto Protocol targets. Or the user may wish to set specific minimum energy efficiency savings targets as outlined in the National Energy Efficiency Conservation Strategy.
- *Technology Uptake Constraints.* There are limits to how quickly a new technology can replace an existing technology – eg, the maximum uptake rate for heat pumps for space heating in the domestic sector may be 10% per year. These technology uptake constraints are important as they have a direct role in defining each of the 'energy savings potentials'; increasingly the case as we move from the 'technical' to the 'economic' and finally to the realisable energy savings potential.
- *Supply Constraints.* There are critical constraints on the supply of primary energy sources. For example, the supply of natural gas is 'so many' petajoules per year and the Maui gas field has 'so many' petajoules of energy remaining. The hydroelectricity supply in New Zealand is also 'so many' petajoules per year.

[18] In the initial development of OPENZ, no locational constraints have been entered into the model. However, the EECA End-Use database contains specific data on the locational demand for energy. The model can therefore in the future be formulated to incorporate these data as constraints. Also, probably more importantly the supply of energy is often constrained by locational constraints e.g., natural gas is only available in certain areas of the North Island. In the initial model some very occasional ad hoc adjustments were required to allow for the areas that don't have natural gas supply.

The model is a *dynamic (multi-stage) optimisation model*, tracing energy savings potential from 2006/07 to 2025/2026. The model needs to be dynamic in order to effectively track the impact of technology uptake rates over time, and the change of energy supply options (eg, the impacts of the depletion of a gas field). This dynamic optimisation model will be used to evaluate the implications of various population, GDP, energy price and other scenario assumptions that are spelt out in Section 2.

Table 1.1 Supply Processes, End Use Processes and Energy Savings Measures

Sector	New/Existing	Number of Supply and End-Use Processes	Number of Energy Savings Measures	Data Source
Energy Supply	Existing	26		Various, Including MED Database
Energy Supply	New	40		Various, mainly MED commissioned reports
Household	Existing	77		EECA Database 2006/07
Household	New	31		EECA Experts
Household	Existing and New		7	Updated Henderson (1994)
Primary	Existing	27		EECA Database 2006/07
Primary	New	6		EECA Experts
Primary	Existing and New		9	Updated Henderson (1994)
Commercial	Existing	40		EECA Database 2006/07
Commercial	New	6		EECA Experts
Commercial	Existing and New		109	Updated Henderson (1994)
Industry	Existing	75		EECA Database 2006/07
Industry	New	4		EECA Experts
Industry	Existing and New		61	Updated Henderson (1994)
Transport	Existing	42		EECA Database 2006/07
Transport	New	6		EECA Experts
Transport	Existing and New		18	Updated Henderson (1994)
Total		**380**	**204**	

End-Use Processes and Energy Savings Measures

Another distinguishing feature of OPENZ is the very detailed coverage of end-use ‘technologies’ and end-use ‘energy savings measures’. Past energy supply and demand models constructed in New Zealand did however contain some specification of end-use ‘technologies’. Most notably the optimisation model constructed by Smith (1978) did contain some technological specificity in the supply sectors, but notably very little in the energy demand sectors. Previous econometric modelling approaches in New Zealand (e.g. Dokter, 1985), certainly contained no technology based details. In more recent years, as pointed out by Denne *et al.* (2005a), SADEM (the main model used by MED), contains very little technology-explicit data as it is essentially a 'top-down' model on the demand side containing no end-use data or characterisation[19].

The following definitions are important in understanding how 'technologies' and 'energy savings measures' are dealt with in OPENZ:

- *Technology Explicit End-Use Process.* This is an OPENZ end-use process, which is *explicit* concerning the technology used. An example of a technology explicit end-use process is: the conversion of electricity (1PJ) to space heat (3PJ) using heat pumps. In OPENZ, data describing these processes are mainly drawn from the 2006/2007 EECA Energy End Use Database.
- *Energy Savings Measures*. This is an OPENZ process that quantitatively describes the amount of 'delivered energy' that can be 'saved' by a particular energy saving measure. The 'energy savings' measures are rarely specific to one end-use conversion technology, often applying to a number of technologies in rather general/non-attributable fashion. An example of an 'energy savings measure' is 'zone control in commercial buildings.' In OPENZ, data describing these 'energy savings measures' are drawn from (updated) data from Henderson (1994).

1.4 Previous and Related Studies in New Zealand

The current project's aim is to build an operational model to estimate and evaluate the technical, economic and realisable 'energy savings' potentials that New Zealand can capture. In doing so, the current project builds on and has a context in terms of both previous studies on 'energy savings potential' and on 'economy-wide energy modelling'.

1.4.1 Energy Savings Potential Studies

Wright and Baines (1986) estimated the energy conservation potential for the household sector in New Zealand, using a supply curve methodology. It was the first significant study of this type in New Zealand. The supply curve analysis highlighted the energy savings potential for a number of measures – eg, for hot water provision, the energy savings from thermostat set back, increased thermal insulation, solar water heaters and heat pumps were quantified. The supply curve methodology introduced by Wright and Baines (1986) was based on the idea of 'supply curves of conserved energy' an idea that was being promoted by Lovins (1985) and others at that time.

Henderson (1994) took the 'supply curve' methodology to another level, providing the first comprehensive analysis of energy savings potential in New Zealand, across all the main sectors (residential, commercial, industrial and transport). Supply curves were accordingly developed for the 'economic potentials' of each of the energy sectors for six fuel types (electricity, gas, oil, coal, wood and geothermal heat). The data used for this detailed analysis was drawn from: (1) the 'Energy End Use Database of the New Zealand Economy' (Patterson, 1993a); (2) expert interviews (Lumsden *et al.*, 1994; Brander, 1994); (3) existing research (Collins, 1993; Wright and Baines, 1986).

[19] The electricity supply component of SADEM does contain some technology-explicit data, but this is not the case on the demand side.

Table 1.2 Evaluation of Previous Studies 'Energy Savings Potentials' in New Zealand

Characteristic	Wright and Baines (1986)	Henderson (1994)	Denne (2006a,b)	KEMA (2007a,b)
Coverage	Household Sector All Energy Types	Residential, Commercial, Industrial and Transport Sectors All Energy Types	Residential, Commercial and Industrial Sectors All Energy Types	Residential, Commercial, Industrial Sectors Electricity Only
Strengths	Established the Supply Curve Analysis in NZ Good coverage of the full range of technologies and energy end-uses	Very comprehensive (All Sectors, All Energy Types) Many 'energy savings measures' evaluated (about 150)	Links energy demand to macro-economic variables and trends (GDP, Prices)	Sets the benchmark for level of detail in the analysis (detailed engineering, financial analysis) Clear and transparent presentation of results Top level results justified by detailed bottom up analysis
Weaknesses	Restricted by lack of data available in 1986	The accuracy of the data is hard to gauge.	The top-down (econometric) approach had a poor ability to analyse energy efficiency potentials Only a few energy efficient interventions were evaluated	Based mainly on USA data of questionable applicability to NZ. Ignores 'fuel switching' (eg. electricity to natural gas) which may lead to savings in primary energy

Spreadsheet analysis processed this data in a 'bottom up' fashion to estimate 'supply curves' for energy savings for New Zealand. Henderson (1994) acknowledged the limitations of the approach:

- it depended on the accuracy of the Patterson (1993) database,
- not all options for improving energy efficiency were considered,
- it treats all 'options' as being independent from each other,
- it assumed a fixed ratio between a quantity of consumer energy and the primary energy[20] required to produce it. Whereas, these ratios are constantly changing, as the quantitative mix of fuels producing primary energy inputs change on a yearly basis – for example, the ratio for electricity differs from year to year, and could change quite significantly if new energy sources such as wind are considered in the future.

[20] Henderson (1994) measure the energy savings potential in terms of quantities of primary energy. No rationale is given for this course of action, or indeed the problem of aggregating different forms of primary energy (refer to Patterson, 1993b).

There was an apparent hiatus in 'energy savings potential' studies in New Zealand until COVEC[21] produced a series of analysis of energy efficiency potentials across three sectors (residential, commercial, heavy industry) in the economy. This analysis was carried out as part of the *Project Tui* – a whole-of-government project led by EECA to replace the National Energy Efficiency and Conservation Strategy (Denne, 2006a). The analysis undertaken by COVEC, used a combination of 'top down' and 'bottom up' modelling tools. The 'top down' analysis provided estimates of 'aggregative energy demand' based (apparently) econometric approach that used GDP, population and energy prices as the explanatory variables. This 'aggregative energy demand' was then 'allocated to individual energy uses within sectors', using a 'bottom up model'.

Using this approach COVEC assessed a number of interventions (e.g. insulation retrofits, Energy Star, Building Energy Rating Schemes), across the three sectors in terms of their potential energy savings using a cost-effectiveness criterion. By 2030, using a 10% discount rate, it was found that these interventions could lead to 2.684 PJ/yr savings in the residential sector, 1.270 PJ/yr savings in the commercial sector, and 3.264 PJ/yr in the industrial sector. A number of supply curves of 'energy savings' and 'CO_2 emission reductions' were produced to substantiate these aggregative level results.

KEMA (2007 a, b) undertook a very detailed technology-specific and end-use specific study of electricity 'energy efficiency potentials' for the Electricity Commission. The level of specificity (technology, end-use) overcomes one of the weaknesses of the COVEC studies, although it needs to be remembered that KEMA (2007a,b) only focussed on the 'electricity' potentials ignoring other fuel types. KEMA quantified three electricity savings potentials: (1) technical (complete penetration of technical feasible options); (2) economic potential (technical potential options that are 'economically' feasible); (3) achievable programme potential (savings that would occur in response to a specific programme). KEMA (2007a) found that by 2016 for the entire economy that 112 PJ/yr of electricity could be saved according to the 'technical potential' and 64 PJ/yr according to the economic potential.

Although the KEMA (2007a) study provides an impressive benchmark for the level of 'bottom up' data, its very significant weakness was that it was based primarily on USA data rather than NZ data. For example, for the industrial sector, it used data from US Department of Energy's '1998 Manufacturing Energy Consumption Survey' and the USDOE's 'Motor Assessment Study'; and it very heavily relied on data provided by the Laurence Berkeley National Laboratory. To what extent this liberal use of USA data for a NZ study is valid and leads to results that are applicable to New Zealand is unknown and very questionable.

Table 1.2 summarises the strengths and weaknesses of all of the previous studies of 'energy savings potentials' in New Zealand. One limitation of all of these approaches, which we have attempted to overcome in our current study, is the lack of an integrative modelling framework. Henderson (1994) and KEMA (2007a,b.) appears to have relied on spreadsheet analysis (models) and Denne (2006a,b.) on a system of moving data (manually) between 'top down' and 'bottom up' models/databases. None of these previous studies have undertaken their analysis, within one integrative modelling framework that enables 'energy potentials' to be evaluated in terms of their impact across the entire energy supply and demand system. Such an analysis is important as, for example energy savings in a particular sector can have serious consequences in terms of how we optimally configure electricity generation and supply, and the tradeoffs that might ensue with the supply of energy to other demand sectors.

21 Refer to reports by Denne (2006a,b) and Denne *et al*. (2006).

Modelling also provides the opportunity to simulate energy savings potentials across time – perhaps the next 20 years. Earlier attempts (Wright and Baines, 1986; Henderson, 1994) in particular ignored this dynamic/temporal dimension to the problem.

1.4.2 Economy-Wide Energy Models

OPENZ is a dynamic optimisation model of the New Zealand energy system that particularly focuses on *energy end-use processes* in a *technology-explicit* fashion. OPENZ's initial development has been driven by the need to quantify energy savings potentials that could result from various technological and policy options. OPENZ can be contrasted and compared with other current and past economy-wide energy models[22]:

SADEM

SADEM is the only significant, currently used, economy-wide energy model in New Zealand. It was first been developed in 1991 by the Ministry of Commerce and is now maintained by the Ministry of Economic Development. SADEM was reviewed by Denne *et al.* (2005), in the context of a broader review of 'MED's Energy Modelling Capability.' SADEM is characterised by Denne *et al*. (2005) as having the following main features:

- SADEM is a partial equilibrium model. In other words, it projects movements in supply, consumption and price for a limited number of factors, while factors not in the model are assumed to be unaffected. It contrasts with general equilibrium (GE) models which equilibrates supply and demand across all sectors in the economy.
- The demand side of SADEM is largely econometric – it uses regression analysis with historical data to define relationships between energy demand, energy prices and movements in factors such as GDP, population and temperature variables. The key electricity supply component of the model is a simulation model. It includes costs and performance specification of plant technologies (geothermal, cogeneration, gas combined cycle, etc) and some individual plants. On the basis of demand, determined econometrically, it simulates plant behaviour to predict the cost of supply.
- Apart from the electricity supply component, it can be described as a top-down model. It has very little detail about behaviour within a sector or specification of performance and cost characteristics. In contrast bottom-up models have detailed specification of technologies.

One of the limitations of SADEM in terms of our study of 'energy savings' potential is its lack of technological specificity, although as pointed out by Denne *et al.* (2005) it is, at least in principle, possible for econometric models (like the demand side of SADEM) to take account of technological improvements in an aggregative sense using measurements such as the Autominous Energy Efficiency Improvement (AEEI) factor. Nevertheless, it is impossible in 'top-down' models like SADEM to exactly know what technologies can be used to bring about energy efficiency improvements in the economy; or indeed if the demand projections being made by econometric models are even technologically feasible given known technologies.

[22] This brief review only covers *economy-wide* energy models in New Zealand *that are publicly available*. It therefore excludes: (1) models of specific energy production/generation plants or networks. For example, these exclusions include hydro-scheduling optimisation models such as those by Kerr and Read (1997), George et al. (1995) and Read (1979), or of the oil refinery such as the model by Earl *et al*. (1979); (2) not published economy-wide models constructed by private sector interests. With the government's withdrawal from the energy sector in the mid-late 1980's, some energy models that were previously publicly available are no longer; (3) some in-house models constructed by the Ministry of Energy prior to its disestablishment in 1989, which were never published.

Econometric Regression Models of Energy Demand

Unlike SADEM which is more correctly a ‘hybrid model’, there has been a number of models developed in New Zealand that are purely econometric, dating back to the early work of Hughson (1968), followed by others such as Lermit (1979), Dockter (1985), Hughes, Baas and Trealor (1979), Mohamed and Bodger (2005), McDermott Associates (1987), New Zealand Business Council for Sustainable Development (2005); as well as a number of unpublished econometric forecasts produced by the Ministry of Energy in the late 1970’s to early 1980’s which were used to support its energy planning functions. Such models attempt to ‘predict’ or ‘forecast’ energy demand at a very aggregative level (usually 1-4 sectors), using variables such as GDP, population, energy prices and temperature. In spite of the statistical robustness of this regression/econometric approach, caution needs to be displayed in applying these methods, in the context of medium-long term problems, because it is unlikely that the structural relationship quantified by these regression equations will persist over medium-long term time periods. One further limitation of these econometric/regression based methods, which is often cited, is the lack of detail about specific technologies, which is a particular difficulty when assessing ‘energy efficiency interventions’.

Computable General Equilibrium and Input-Output Models

One of the difficulties with many energy system models, is that they fail to take account of ‘flow-on’ effects in the rest of the economy, which can be an ‘achilles heel’ when undertaking policy analysis. Input-output models initially addressed this issue (of ‘flow-on’ effects in the economy) by modelling the interactions between sectors in the economy, either through (static) multiplier analysis or by (dynamic) input-output modelling. Computable General Equilibrium Models (CGE) however now go one step further (than Input-Output models) in allowing for *price adjustments*[23], so that there is an equilibration between supply and demand simultaneously across all sectors (markets) in the economy. Perhaps the earliest attempt to do this genre of modelling in New Zealand was the development of a ‘linear programming inter-sector model’ by Philpott and Stroombergen (1979) based on an input-output matrix (with explicit energy sectors). With the development of Computable General Equilibrium (CGE) models in the 1980’s, Boshier *et al*., (1984, 1986) went one step further to develop a simple (14 sector) computable general equilibrium model connected to a more detailed (23 sector) input-output model with energy end-use services. In more recent years with the advancement and mainstreaming of CGE models, Stroombergen (2007) has developed a CGE model of aggregative energy use as it relates to CO_2 emissions. To date, however, as is the case internationally, the full potential of CGE energy modelling to analyse energy and climate change policy options for New Zealand has yet to be achieved.

Optimisation Models

Strictly speaking CGE models are optimisation models, as they optimise (maximise) utility and profits across the economy. Notwithstanding that comment, there has been a history of constructing ‘engineering-based’/bottom up’ optimisation models in New Zealand. Smith (1978) constructed an optimisation model of energy supply and demand in New Zealand with 3 discrete models (1985, 1990, 2000). It is probably best described as being a ‘bottom-up’ model for supply and ‘top down’ for demand. Certainly compared with OPENZ, it lacks details on energy end-use services and technologies. The objective function of this model was to

[23] Input-Output models can only adjust for *quantities* not prices, although prices are embedded within the input-output matrix (model) structure.

minimise cost ($) of energy supply. Moy (1979) developed the first MARKAL model (the most widely used energy optimisation model worldwide) for New Zealand. This was part of early efforts by the International Energy Agency (IEA) to develop MARKAL as the ‘gold plate’ method of energy modelling. This early MARKAL model covered a range of technologies with energy demand being treated as an exogenous variable. It remains however unclear as to what extent this MARKAL model was ever fully operationalised and utilised in policy analysis and energy planning in New Zealand.

In recent years, there have been further attempts to design an operational 'bottom-up' optimisation model in New Zealand. Bruckner *et al.* (2003) developed a modelling framework for optimising energy services supply, either from the point of view of minimising exergy loss or minimising cost ($). This framework was however never operationalised due to the lack of data. An initial version of MARKAL was also developed in 2003 by Read, Lermit and Rossouw (2003) but also did not progress any further due to lack of funding.

Van Beek's (1999) review of national energy models shows that optimisation models are the most widely used (perhaps with econometric models) worldwide. MARKAL is the 'standard' method, promoted by the International Energy Agency (Zonooz et al, 2009). It is therefore surprising that optimisation modelling (particularly MARKAL) has not gained a stronger foothold in New Zealand. Most attempts to construct energy policy optimisation models in New Zealand have not succeeded, primarily due to lack of funding which can be a considerable requirement with the suggestion that it can take according to one authoritative source[24] 'about 1 man year of modelling but 10 years of data collection.'

Simulation Modelling

There have been very few attempts to construct simulation models of energy supply and demand in New Zealand. One documented case is that of Bodger and May (1992) who constructed a simple 6 supply sector model for New Zealand, based on Odum's (1983) modelling framework, which incidentally was earlier applied to evaluating New Zealand's trade (Odum, 1979).

In sum, OPENZ has specifically been developed to be a model that focuses on end-uses of energy and explicit about the technologies required to provide these end-uses. It covers 31 end-uses, 20 end-use technologies and 584 end-use processes/energy savings measures. OPENZ also has a reasonable degree of technological specificity for the energy supply processes. Furthermore, OPENZ captures the major influences on the energy system in New Zealand, including prices, GDP, a number of possible policy interventions and rates of technological uptake. OPENZ is essentially a 'bottom-up' model, whereas SADEM which is New Zealand's official energy model is essentially 'top-down.' In that sense, both models are very much complementary to each other, as well as they serve different purposes as outlined by van Beek (1999) and Table 1.3.

[24] International Energy Agency/ OECD: *http://www.etsap.org/MARKAL/faq.htm//how*

Table 1.3 Classification of Selected National Energy Models in Terms of Distinguishing Features

Characteristic	SADEM	OPENZ	MARKAL (USA)	Mohamed (2005)
Purpose	Project Future Supply and Demand	Detailed Technology-Based Appraisal of Future Energy Options[1]	Defining Least Cost($) Supply	Demand Forecasting
Top Down vs. Bottom Up	Top Down	Bottom Up	Bottom Up	Top Down
Country	New Zealand	New Zealand	United States	New Zealand
Coverage	Supply Processes focused on electricity, 4 Demand Sectors, No End-Uses, No Technologies	66 Supply Processes, 5 Demand Sectors, 31 End-Uses, 20 Technologies, 380 End-Use Processes, 204 End-Use Energy Savings Measures[2]	> 600 supply and demand processes, 150 materials, 10 sectors, 30 end-use services	5 sectors, 6 delivered energy
Time Horizon	30 Years	20 Years	30 Years	Realistically 5 Years
Mathematics	Mixed methods including regression/econometrics for demand sectors	Dynamic Optimisation	Dynamic Optimisation, Some Non-Linear and Integer	Multiple Regression
Technological Specificity	Some for electricity sector. None elsewhere.	Broad technologies for energy supply. Very detailed technologies for Energy End-Use processes.	Detailed technologies for Energy Supply, Demand and End-Use Services processes	None
Data Requirements	Manageable: readily available from public sources	Demanding: detailed cost, emissions, end-use data required.	Very Demanding: detailed cost, engineering, energy and emissions data. Extensive database built up since 1970s.	Straight Forward

Notes:
1. Initial application outlined in this report was to define 'energy savings potentials' and 'greenhouse gas reductions'.
2. 37 demand sectors are used to calculate the 'demand for the energy end-uses'. For 'computational ease', these are aggregated to 5 demand sectors for the optimisations.

1.5 Definition of Terms

Business As-Usual
"Business-As-Usual" is a forecast of future energy supply and demand based on a continuation of past and current trends. The "Business-As-Usual" forecast is used throughout this report – with the one exception that it is replaced by the "Frozen Efficiency" forecast which is used in the "*Overall Energy Savings Potentials"* section of the Executive Summary.

Carbon Dioxide
Carbon dioxide, or CO_2, is a naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as of land-use changes and other industrial processes. It is the most important man-made greenhouse gas.

CO_2e or CO_2 equivalent
Measures the combined climate changing potential of emissions of multiple greenhouse gases. Emissions of each gas are converted to an amount of CO_2 that would cause the same climate change impact.

Delivered Energy
Being produced from the primary energy sources, delivered energy is specifically the energy measured at its point of delivery to the location of its end-use. "Delivered Energy" is synonymous with the term "Consumer Energy".

Energy Quality
Not all energy is created equal. Some forms of energy are more useful than others and therefore are considered to be of higher quality. Energy is usually measured in terms of its 'heat content' particularly by statistical agencies – such measurements do not take account of the energy quality of energy sources. Exergy and Emergy measures are used to adjust energy data to take account of its energy quality. Somewhat analogously it can be said that not all currencies are equal –a New Zealand dollar does not have the same purchasing power as the American dollar – it would be incorrect to add a New Zealand dollar to an American dollar, without an exchange rate conversion. The same is the case with energy.

End Use Energy
These are useful energy outputs which result from end-use processes in a given economy. They include those proportions of energy actually useful to consumers. For example in cooking it includes the energy absorbed into the cooking load, but not the waste heat lost to the surrounding environment. The terms "effective", "useful" and "final" energy are synonymous and as such are used interchangeably in the literature (World Energy Conference, 1987; D'Ermo, 1988).

Energy Efficiency
Any measure of the ratio of useful energy services to energy input. For the purposes of the NZEECS, energy efficiency is defined by the Energy Efficiency and Conservation Act 2000 as "a change to energy use that results in an increase in net benefits per unit of energy used". Patterson (1996) provides a critical review of the various definitions of the term 'energy efficiency'.

Frozen Efficiency Forecast
This is a forecast of future energy use based on no change (improvement) in the efficiency of conversion of delivered energy to end-use energy. Assuming that there will always be some improvement in energy end-use efficiency in the future, the energy use for the *Frozen Efficiency Forecast* will always be greater than the energy use for the *Business-As-Usual Forecast.*

Objective Function
An objective function is simply any variable in the model that the user of the model wishes to minimise and maximise. Constraints (and bounds) place a limit on the value of any variable of model, and this limit can't be violated in the solution of the model. Objective functions are indeed the most 'powerful' driver of optimisation models like OPENZ, in the sense the selection of different objective functions will usually lead to very different results. For example, in OPENZ, the selection of 'minimising energy inputs', as opposed to 'minimising economic cost' will lead to very different patterns of energy supply and demand as well as different technology mixes.

Primary Energy Inputs
Primary energy inputs refer to the inputs of energy obtained from sources *external* to the economy. That is, these energy inputs are *either* obtained from natural sources (e.g. falling water, fossil fuel in the ground, wood, geothermal steam from the wellsite), *or* from other countries (e.g. crude oil or electricity flows across national borders). By definition these represent inward flows of energy across the system's boundaries

1.6 Ambiguity of the Terms 'Energy Savings' and 'Energy Efficiency'

Central to this project is the definition of terms 'energy savings' and 'energy efficiency'. These are however general concepts that don't have one unequivocal agreed upon definition (Jollands, 2006; Patterson, 1996). Unfortunately, the definition of 'energy efficiency' used in the Energy Efficiency and Conservation Act 2000, does not help much in terms of operational specificity, as it is still very general: "a change to energy use that results in an increase in net benefits per unit of energy used".

There are a number of problems with this definition, in terms of usefulness in guiding the operational definition of the concept of energy efficiency:

- the term 'net benefits' is very open to interpretation, although one assumes it means 'net benefit' in the way that it is used in cost:benefit analysis and is therefore measured in monetary units.
- the term 'per unit of energy used', is problematic as there are many different ways of measuring 'energy'.

This last point is most pertinent, in relation to the current optimisation modelling project. That is, defining the energy savings potential in a valid way, also requires 'energy' to be measured in a 'valid' way. The main issue here is that it is not valid to add-up 'energy types' of different quality, when they are measured in terms of their 'heat content'. In energy analysis, this issue is called the 'energy quality problem' (Patterson, 1993).

There are a number of different ways that have been proposed to deal with the 'energy quality' problem, all of which require the measurement of energy in units that attempt to commensurate their energy quality: Gibbs Free Energy, Exergy, Available Work, OECD Thermal Equivalents, Fossil Fuel Equivalent, Transformity and Quality Equivalents. It is widely accepted the conventional measurement of energy inputs in terms of their ‘Heat Content’, although often used for energy accounting purposes, is not appropriate for ‘adding up’ energy inputs of quality, in evaluation exercises such as in this energy savings potential modelling exercise (Edwards, 1976; Webb and Ricketts, 1980; Roberts, 1979; Cleveland et al,. 2000). Appendix A critically reviews the various different ways of measuring and adjusting for energy quality. In the development and application of OPENZ, energy quantities were adjusted for energy quality by using the ‘Quality Equivalent Methodology’ developed by Patterson (1993, 1996b). As pointed out by Li *et al.* (2010): (1) the ‘Quality Equivalent Methodology’ is conceptually equivalent to the Emergy method developed by Odum (1983, 1996); (2) the ‘Quality Equivalent Methodology’ situates the Emergy method in a more rigorous and internally consistent mathematical framework, whereas earlier versions of the Emergy Method were based on cumbersome algorithmic routines such as the ‘track summing procedure’.

2. Key Assumptions and How to Drive the Model

OPENZ has a number of *key assumptions* which the user of the model can control, or leave at the 'default settings'. The default settings reflect a 'Business-As- Usual' (BAU) Situation. These 'Key Assumptions' don't include the 'Mathematical Assumptions of Linear Optimisation' that are outlined in Appendix B.2 – these mathematical assumptions are more difficult to change, as they require a re-formulation of the model equations and variables which most users will be unable to do.

These key assumptions can be considered to be exogenous inputs[25] into the model. It needs to be noted however many macro-economic modellers often show contempt for models that have a significant number of exogenous inputs (assumptions), as these models are considered to lack in mathematical and theoretical elegance. We don't subscribe to that view.

Another way of viewing many of these key assumptions is that they are 'control levers' for the model. That is, these assumptions are 'levers' by which the user can 'control' the model to explore the implications of different assumptions. For example, there is a 'default setting' on the size of 'remaining natural gas reserves' in New Zealand, but a particular user may wish to understand the implications of there being a new discovery of natural gas. Similarly, a user may wish to understand the implications of different 'technology penetration' rates and the impacts of a government investing in an 'accelerated retro-fit programme' for commercial buildings. By assuming that these 'control levers' only remain at the BAU default setting, precludes the opportunity of exploring future energy policy and energy efficiency possibilities. This is important as there are few commentators that would subscribe to the view, that the 'Business-As-Usual' pathway is the preferred option for New Zealand, as it won't and hasn't dealt with new imperatives such as climate change.

An optimisation model, like OPENZ, is also driven by the specification of *objective functions and constraints.* Objective functions are simply any variable in the model that the user of the model wishes to minimise and maximise. Constraints (and bounds) place a limit on the value of any variable in the model, and this limit can't be violated in the solution of the model. Objective functions are indeed the most 'powerful' driver of optimisation models like OPENZ, in the sense that the selection of different objective functions will usually lead to very different results. For example, in OPENZ, the selection of 'minimising energy inputs', as opposed to 'minimising economic cost' will lead to very different patterns of energy supply and demand as well as different technology mixes.

2.1 Future GDP Contribution of Economic Sectors

The level of activity in the New Zealand economy is the key determinant of the quantitative demand for end-use energy services (31 categories) in OPENZ. The greater the level of production in the economy (of goods and services), the higher the demand of energy end-use

[25] It is technically possible to endogenise many of the *exogenous inputs* into an optimisation model. For example, the GDP projections of sectors could be endogenised if OPENZ is fully integrated with the EFM (Economic Futures Model). It is part of the 'art of model building' to decide to what extent to endogenise variables. There is then a trade-off between model transparency (more exogenous variables) versus model comprehensiveness (more endogenous variables). In OPENZ, we have erred on the side of 'transparency' (more exogenous variables) as it was considered important that Users of the model can understand and control the assumptions driving the model. That is, we wanted to avoid creating a 'black box' model.

inputs to produce these goods and services. It is argued in Appendix B (section B.5.3) that there is a very strong correlation between GDP production and the demand for energy end-use inputs – furthermore, there is good empirical evidence from a number of sources (e.g. Cleveland *et al.*, 1984; Hall *et al.*, 1986) that on a macro-level there is a strong correlation between economic production and energy inputs.

Table 2.1 Business-As-Usual Growth Rates for the NZ Economy

Year	Primary Sector Real GDP	Commercial Sector Real GDP	Industrial Sector Real GDP	Transport and Storage Sector Real GDP	Household Sector Household Consumption
2007	1.0000	1.0000	1.0000	1.0000	1.0000
2008	1.0300	1.0227	1.0276	1.0198	1.0195
2009	1.0690	1.0460	1.0560	1.0400	1.0394
2010	1.0927	1.0697	1.0852	1.0606	1.0596
2011	1.1254	1.0940	1.1152	1.0816	1.0803
2012	1.1514	1.1166	1.1417	1.1018	1.0991
2013	1.1780	1.1396	1.1687	1.1223	1.1183
2014	1.2053	1.1631	1.1964	1.1432	1.1378
2015	1.2331	1.1871	1.2248	1.1645	1.1576
2016	1.2616	1.2116	1.2538	1.1862	1.1778
2017	1.2914	1.2354	1.2826	1.2076	1.1963
2018	1.3219	1.2596	1.3122	1.2294	1.2152
2019	1.3531	1.2844	1.3424	1.2515	1.2343
2020	1.3851	1.3096	1.3733	1.2741	1.2537
2021	1.4178	1.3353	1.4049	1.2970	1.2735
2022	1.4511	1.3606	1.4364	1.3198	1.2917
2023	1.4851	1.3863	1.4686	1.3429	1.3101
2024	1.5199	1.4125	1.5014	1.3665	1.3289
2025	1.5556	1.4391	1.5351	1.3905	1.3479
2026	1.5921	1.4663	1.5695	1.4149	1.3671

Notes:
1. Index Base = 1.0000 for Year Ending March 2007.
2. From 'Business-As-Usual Projection from the Economics Future Model, Market Economics Ltd.

GDP projections (as a predictor of sectoral energy end-use demand), were obtained from the Economic Futures Model (EFM) developed by McDonald and Patterson (2008) – refer to Appendix B (Section B.5.2 and B.5.3) for further details. The GDP projections for a 'Business-As-Usual' NZ Economy, at the 4 sector level, as produced by the EFM model, outlined by Table 4.1. These EFM 'Business-As-Usual' projections indicate large increases in the GDP output of sectors, and hence in aggregated end-use demand: Primary Sector (59.2%), Commercial Sector (46.7%), Industrial Sector (56.9%) and Transport and Storage Sector (41.5%).

The reasons for using the Economic Futures Model (EFM) for projecting the 'Business-As-Usual' GDP output, rather than other sources is that it offers two advantages: (1) the EFM is available at the 48 sector level, which can be readily aggregated to the 37 EECA database model sector categories. The author is not aware of other models that project GDP to 2025/26 at such a fine level of sectoral disaggregation and certainly does not have access to them; (2) The author of this report has ready access to the EFM, as he was a PhD supervisor overseeing the development of this model which gives him some propriety rights to use it. This could prove to be very useful if the decision is made to fully integrate the EFM and OPENZ at some future stage, as is argued in Section 10.

In addition it should be noted that the BAU GDP projection for the *entire NZ economy* produced by the EFM for 2006/07 to 2025/26 are very similar to those produced by the Treasury's 2005 Budget Forecast. This Treasury 2005 Budget Forecast was used in the Ministry of Economic Development's (2006) *New Zealand's Energy Outlook to 2030.* Overall the Economic Futures Models BAU saw the NZ economy increasing its GDP by 47.66% over the 2006/07 to 2025/26, whereas the Treasury forecasted a GDP increase of 52.95% (refer to Table 4.2). This is a quite similar forecast projection, bearing in mind the inherent difficulties of economic forecasting over a 20 year period and the different methodology used to produce these forecasts/projections.

For projecting household sector end-use demand (across 22 end-use categories) 'household consumption' ($) is used instead of the sometimes used proxy 'household population'. The reason for using 'household consumption' is that population will probably under-estimate the increase in end-use demand. This is due to the end-use demand per capita probably increasing due to more disposable income ($) being spent on energy consuming capital goods. There is anecdotal evidence, partially substantiated by the HEEP studies (Isaacs, *et al.*, 2006), that there has been an energy intensification in the household sector over the last decade with the proliferation of entertainment based electronic equipment and the rapid increase in the use of heat pumps. Such trends in energy intensification would more adequately be predicted by the use of a 'household consumption ($)' scalar rather than a population scalar. Over the 2006/07 – 2025/26 period population is only projected to increase by 16.83% (Statistics New Zealand, 2009), whereas according to the EFM BAU projection household consumption ($) is calculated to increase by 36.71%.

2.2 Natural Gas Use for Methanol and Urea Production

In 2007 the petrochemicals sector accounted for 14.6% of New Zealand natural gas use during that year, of which 10.5% was for methanol production and 4.1% for ammonia/urea production.

The 'default setting' in OPENZ for methanol and urea production is 23.7 PJ/yr which is the 2007 level of production reported by the MED's (2008b) *Energy Data File*. This assumption about the level of petrochemical (methanol, ammonia, and urea) production has to be made in OPENZ, because petrochemicals are still a significant use of New Zealand's very limited known natural gas reserves. That is, at the 'default setting' of 23.7 PJ/yr, this amounts to 470 PJ over the 2006/07 – 2025/26 period, which compares to 2,428 PJ of known natural gas reserves considered to be available by the Ministry of Economic Development (2008b).

Table 2.2 Comparison of Business-As-Usual GDP Projection

Year End March	Economic Futures Model	Treasury and 'Energy Outlook'	Difference (%)
2007	1.0000	1.0000	0.00
2008	1.0233	1.0325	0.90
2009	1.0471	1.0637	1.58
2010	1.0715	1.0929	2.00
2011	1.0965	1.1212	2.25
2012	1.1194	1.1495	2.69
2013	1.1427	1.1778	3.07
2014	1.1666	1.2062	3.39
2015	1.1909	1.2344	3.65
2016	1.2158	1.2626	3.85
2017	1.2401	1.2907	4.08
2018	1.2649	1.3187	4.25
2019	1.2901	1.3464	4.36
2020	1.3159	1.3740	4.41
2021	1.3422	1.4012	4.39
2022	1.3681	1.4280	4.38
2023	1.3944	1.4542	4.29
2024	1.4213	1.4799	4.13
2025	1.4487	1.5050	3.89
2026	1.4766	1.5295	3.58

Notes:
1. Index Base = 1.0000 for Year Ending March 2007.
2. From 'Business-As-Usual Projection from the Economics Future Model, Market Economics Ltd.
3. Treasury 2005 Budget Forecast and ales used as the 'Base Case' NZ Energy Outlook to 2030 (MED, 2006).

The 23.7 PJ/yr 'default setting' for petrochemical use could be considered to be too high, in view of the increasingly more difficult commercial viability of petrochemical production from natural gas. In this regard Statistics New Zealand (2008) report the Motunui Methanol Plant was closed in November 2004 as a consequence of natural gas restraints, and the Waitara Methanol plant operates when economically priced gas is available.

2.3 Size of Remaining Natural Gas Use Reserves

New Zealand over the last three decades has heavily relied upon the Maui Gas field for its natural gas supply, not only for electricity production, direct use by industry, commerce and households and petrochemical production, but also in the not too distant past for synthetic petrol production. Those days are all but ended, with the MED (2008) reporting 489.6 PJ of 'remaining' Maui Gas reserves at 1 January 2008.

In spite of considerable known remaining natural gas reserves (1,705 PJ) available from other fields, particularly Pohakura (1,064 PJ), the size of remaining natural gas reserves could be critical in determining the optimal pattern of energy use in New Zealand, in the OPENZ model.

The 'default setting' for known remaining gas reserves in OPENZ, at March 2006 has been set at 2,427.6 PJ, based on data of known 'remaining' gas reserves reported by the Ministry of Economic Development (2008). There is however considerable uncertainty about this figure, over the 2006/07 – 2025/26 time horizon of the OPENZ model, as new discoveries will probably be made over this period. For this reason, the User of the OPENZ model needs to estimate the level of new natural gas discoveries as a percentage increase of known reserves at March 2006. The default setting is 20%, which increases the remaining reserves at March 2006 from 2,427.6PJ to 2,913.1PJ. It should be noted that this default setting at 20% may be considered to be too pessimistic by some experts[26]. For example, the Crown Minerals website states:

> *"All of New Zealand's production so far has been from the Taranaki Basin, the country's most explored and commercially successful hydrocarbon province. However, the basin is only moderately explored compared with basins world-wide, and there is considerable scope for further commercial discoveries as demonstrated by recent exploration successes.*
>
> *The rest of New Zealand is severely under-explored, and most sedimentary basins have the potential for commercial hydrocarbon discoveries. Many untested structural closures are potentially larger than the giant Maui field in the Taranaki Basin ... Ongoing exploration can be expected to lead to further finds here and in other basins."*

The 'backstop position' if New Zealand's natural gas reserves are depleted to economically unviable levels, is to import natural gas either as liquefied natural gas or compressed natural gas. Indeed, the economics of natural gas supply may mean that imported natural gas is a preferred option some time before the actual projected depletion of remaining natural gas reserves in NZ (Centre for Advanced Engineering, 2005). Details of how OPENZ quantifies these dynamics are contained in the description of the 'Energy Supply Module' (Section 3).

2.4 Rebound Effects

The rebound (or 'take back') effect is when an increase in 'energy efficiency' actually leads to some increase in energy use. For example, a householder who installs a heat pump, theoretically should decrease their electricity use. This would be the case if the householder, heated his/her home to exactly the same level. However, what actually happens in many cases is that with the improved technology, the householder increases his/her electricity use proportionately.

OPENZ only quantifies and evaluates the 'Rebound Effect' in the Household Sector, with respect to home insulation modalities (ceiling, wall, floor, double glazing) and heat pump installations. There are also possible 'rebound effects' from the installation of energy efficient lighting, other space heating improvements in addition to heat pumps, and perhaps energy efficient transport based on overseas evidence. These 'rebound effects', and those from non-household sectors, could be included could be quantified in the future development of OPENZ – although the numerical magnitude of these rebound are expected to be generally much smaller.

The 'default setting' for the 'rebound effect' for all home insulation modalities (ceiling, wall, floor, double glazing) is assumed to be 44%. That is, 44% of the 'energy savings' obtained

[26] Notwithstanding the optimism about new discoveries by Crown Minerals (and others) even if there are new discoveries, as is pointed out by the Ministry of Economic Development (2006), there is a considerable lead time required to put in place the infrastructure to utilise newly discovered gas reserves. For example, it took 10 years from the discovery of the Maui Gas Field in 1969, to when the first gas was used in 1979.

from improved insulation, is actually used to heat homes to a higher level of comfort. The OPENZ model equations therefore for the 'default setting': (a) calculates the net energy savings (56% of the theoretical) of delivered energy inputs; (b) calculates the increase in space heating levels from the rebound effect. The 'default setting' in OPENZ at 44% for home insulation rebound effect was derived from Howden-Chapman *et al.* (2005, 2009) survey of 1,100 households in New Zealand. It needs to be noted that: (a) this 44% rebound effect for home insulation is significantly higher than that obtained for studies in other countries, which generally show a rebound effect for insulation in the range of 10-35% (Greening, et al, 2000; Haas and Biermayer, 2000; Schipper and Grubb, 2000). This higher than average rebound effect for New Zealand however is probably not unexpected due to the relatively poor level of insulation in New Zealand housing stock, which means that the motivation for improving insulation is not only to 'save energy' but almost equally important is to 'improve comfort levels', (b) there is no distinction, due to lack of data, in the rebound effect for the different types of insulation (ceiling, wall, floor, double glazing). That is, OPENZ applies the same percentage effect to all types of insulation. Future developments at OPENZ could easily apply different 'rebound effects' to different insulation types if the requisite empirical evidence becomes available.

The 'default setting' for the 'rebound effect' from newly installed heat pumps in OPENZ is 20%. This figure of 20% could be considered to be too low in view of the figure of 44% for insulations. However, it is selected as it is broadly consistent with the overseas empirical evidence (Greening, *et al.*, 2000). No known reliable New Zealand data is available for the 'rebound effect' of heat pumps, which is a concern given the rapid increase in Heat Pump use by householders in the last 5-10 years (French, *et al*., 2007). As with home insulation, the OPENZ equations calculate: (a) the net energy savings (80% of the theoretical savings for the default settings); (b) increase in space heating levels (Terajoules of end-use) from the rebound effect.

2.5 Carbon Prices

The proper evaluation of the economic potential for energy savings should include benefit externalities (e.g. improved health) and cost externalities (e.g. environmental impacts caused by emissions). Although it is largely beyond the scope of this optimisation modelling exercise to measure these externalities, the cost externality of energy related greenhouse gas emissions can be taken account of. In this respect, the cost ($) per tonne of CO_2 equivalents are used (for each process) to calculate the carbon credits, which would need to be purchased to 'offset' greenhouse gas emitted by each process – this resultant cost ($) can then be added to the other (market-based) costs of running that process.

It is important to include these carbon costs ($) into the calculations as they are not only probably in an overall sense the largest externality related to energy use, but there is a strong likelihood that in the foreseeable future such carbon prices will be 'internalised' into market prices, whether that be direct through a carbon tax or indirectly through an emissions trading scheme.

There is a large uncertainty about the future price of carbon, as these markets are only in their very infancy and more critically it is uncertain to what extent governments worldwide will act to establish these markets. Until specifics, such as quantity caps are agreed upon in an enduring way, it is very difficult to forecast future market prices of carbon, certainly not up to 2025/26 as needed in this modelling exercise. Unfortunately reports such as the 'State and Trends of

Carbon Markets 2008' by the World Bank (2008) although comprehensive provides little reliable data on future carbon prices.

The 'default setting' in OPENZ for carbon price is $17.61 for 2006/07. This is based on an inflation adjusted figure of $$_{2003}$15/tonne CO_2 equivalents, used by East Harbour Management Services (2004, 2005) in various reports for the Ministry of Economic Development. This base year figure in OPENZ of $17.61/$CO_2$ equivalent tonnes[27] is progressively increased to $27.0/$CO_2$ equivalent tonnes by the end of the 20 year period, with increases of $0.50/$CO_2$ equivalent tonnes for each year. This annual increase in the price of carbon is based on the assumption that the price of carbon will inevitably increase due to: (1) *increased demand* for carbon credits as economies expand (due to strong forecasted global GDP growth); (2) a tight market of *close-to-fixed supply* quantity (or even reduced quantity) of carbon credits as government progressively set quantitative targets for greenhouse gas emissions.

2.6 Imported Versus Indigenous Supply of Fuels

Energy self sufficiency for New Zealand has been under previous governments an important energy policy goal (Patterson, 1995). This was particularly the case in the 1970's and early 1980's, during the so-called 'energy crisis' years where lack of oil supply (high prices of oil) was considered to be a significant external threat to New Zealand's well-being and security. Nowadays 'energy self sufficiency' is less important and often not considered at all, in government energy policy documents such as the *New Zealand Energy Strategy to 2050* (Ministry of Economic Development, 2007). The reasons for this shift of policy emphasis away from energy 'self sufficiency' lies in a number of factors but perhaps most importantly the increased globalisation and interdependencies of markets and economies worldwide. In this context the dominant policy paradigm assumes that any deficiency in energy supply (e.g. depletion of our natural gas fields) will be overcome by importing energy products. This argument seems to hold weight in spite of the relative isolation of New Zealand from potential energy suppliers.

Nevertheless, OPENZ does require the user to specify permissible levels of imported supply for crude oil and coal. It should be noted that perhaps OPENZ could endogenously determine whether to import these primary fuels, based on cost ($) or other criteria specified in the objective function. Unfortunately this is not possible due to the lack of reliable cost ($) data for importing fuels and model degeneracy (due to equally favourable options) that arise between selecting 'indigenous' verses 'imported' fuels, if criteria like GHG emissions are used in the objective function.

The 'default setting' in OPENZ for the maximum allowable level of imported Crude Oil is 84.97% based on the actual 2006/07 level; with 15.49% being the maximum allowable level of imported Coal also based on the actual 2006/07 level.

2.7 Land Available for Biomass Energy Farming

A wide range of technologies exist for converting biomass into liquid fuels, and good data is available on the costs of these conversion processes. Perhaps the most comprehensive review is

[27] This is lower than the price of 10 Euros/tonne CO_2 equivalent ($NZ 23.95/tonne CO_2 equivalent) for 31 December 2008, by the New Zealand Treasury. Refer to the Treasury's information release "Carbon Price Information Releases: New Zealand's Position under the Kyoto Protocol: http/www.treasury.govt.nz/government/kyotoposition/carbon price

the International Energy Agency's (2004) 'Biofuels for Transport' publication, which nicely complements a New Zealand orientated review by EME Consulting (2007). There is also very valuable data available from previous studies carried out in New Zealand in the 1970's and 1980's dating back to original work by the DSIR (1975). Perhaps the most exhaustive study was that undertaken by Harris *et al.* (1979) which contains detailed feasibility studies of a number of options for producing transport fuels ranging from the project economics, net energy analysis, regional development, environmental and social impacts. A recently completed study by Hall *et al.* (2009) similarly reviewed 'bio-energy options from forestry', albeit at a somewhat broader and less-technology specific level.

Although New Zealand seemingly has abundant land for biomass energy farming, there are constraints on how much land can be set aside for this purpose particularly when competing land uses are considered. In this respect the most pressing constraint is 'using land for biomass farming' versus 'using land for export orientated food production'. This is particularly the case when it comes to producing agricultural crops like lucerne, fodder beet, sugar beet, maize (and so forth) for conversion to transport fuels. The opportunity cost of using agricultural high quality land for biomass energy farms, is significant whether viewed from a business perspective or a national economic perspective.

Harris *et al.* (1979) estimated the land available in New Zealand for various agricultural crops: Maize (2,447,000 ha), Beet (3,087,000 ha) and Lucerne (4,373,000 ha). We selected the land area for Beet as being the 'proxy' for the amount of land available for all agricultural crops in the OPENZ model. This proxy value of 3,087,000ha is the maximum area of the appropriate land use classification category, which is available to grow agricultural crops. This is considered to be a 'theoretical upper limit', on the land available rather than a 'realistic upper limit' of land available to grow agricultural crops to produce liquid transport fuels. The reason being is that much of this high quality land is currently used for food production primarily for export and it would be 'unrealistic' to convert it for use for biomass energy farming given the importance of export food (and fibre) production to the New Zealand economy. Therefore, the 'default setting' is that 20% of this agricultural land, is made available for biomass energy farming in order to minimise the impact on food (and to some extent fibre) production.

Harris *et al.* (1979) also estimated that 7,068,600 ha are available for Radiata Pine plantations. Following a similar argument for the 'default setting', as for agricultural crops, it is assumed that realistically only 20% of this would be available for growing trees for liquid fuel production.

In sum, the 'default settings' for biomass farms for liquid fuels production is:

- 617,940 hectares for agricultural crops
- 1,411,500 hectares for silviculture (forestry)

This figure for silviculture compares with the various 'bio-energy from forestry scenarios' determined by Hall *et al.* (2009) of: 800,000 ha; 1,800,000ha; 3,300,000ha; and 4,900,00ha. The OPENZ user is of course free to use any of these land areas from Hall *et al.* (2009), instead of the OPENZ default setting.

Ideally, of course, the economics of biomass energy (farming versus food/fibre production), should determine the exact division of land between the two competitive land uses, rather than selecting a particular 'default setting.'

2.8 Technology Penetration Rates

A critical factor in determining 'energy savings potential' is the rate of penetration of new technologies. One of the key limitations of macro-economic models (e.g. Computable General Equilibrium models) is that they often assume instantaneous uptake of new technologies – though it needs to be acknowledged that macro-economic modellers are very aware of this problem, and have developed various methods to address this issue (McFarland, Reilly and Herzog, 2004).

In some circumstances the adaptation of new technology can be very rapid (e.g. adoption of LCD televisions, or DVD players), in the household sector. In other cases, the adoption of new technologies, although *ipso facto* appearing to be optimal, often is notoriously slow. This particularly applies to the Industrial sector, when new plant and equipment is not instantaneously adopted even though it is better and more efficient, until the old plant and equipment has reached the end of its lifetime. The large investment required to put in place new more efficient technology is often a disincentive, as well as sometimes there are technical/engineering barriers that prevent the immediate adoption of a new technology (Brown, 2001).

Economists such as Ruth and Amato (2002) have developed operational 'Vintage Capital Models' to constrain the rate of adoption of new technologies. These models give some attention to the 'long lead times needed' in adopting new technologies, 'slow turnover rates' for capital items (energy plant and equipment), the 'long-lived nature' of capital stock and the extent to which capital is 'malleable'. To operationalise, these 'Vintage Capital Models', requires a detailed knowledge and quantification of energy capital stock, which would be difficult in the New Zealand context due to the lack of data. Another approach is to mathematically specify market penetration functions, typically sigmoid to specify the rate of new technology uptake (e.g. McFarland, Reilly and Herzog, 2004). Again the base data required to specify these mathematical functions is not readily available in New Zealand, although for some technologies 'historical' rates of update of similar technologies in New Zealand could provide some basis for their specification.

In OPENZ 'upper bounds' applied to the activity levels of all of the processes (518) in the five energy demand sectors. These 'upper bounds' reflect the maximum possible *market penetration* of a new technology.

For the five[28] *energy demand sectors*, the market penetration rates are controlled differently by the OPENZ user, depending on whether it is an 'energy savings measure' or a 'technology-explicit end-use process'. To be specific:

- *Energy Savings Measures*: For each of the 204 'energy savings measures' drawn from updated Henderson (1994) data, the OPENZ user needs to specify: (i) the maximum level of permissible uptake by 2026/27: (ii) the estimated uptake of the technology that has already been achieved from 1991/92 to 2006/07. Based on this data, OPENZ then calculates the annual maximum uptake rates permissible based on a linear interpolation of the 2006/07 and 2026/27 values. The OPENZ algorithm allows the user to specify these values generically across all sectors of the economy or specifically for each individual energy savings measure.

[28] The model reports and computes the optimum energy supply and demand patterns, at the 5 sector level. However, the end-use energy demand projections are calculated at the 37 sector level using projections of future sector activity from the 'Economic Futures Model'.

- *Technology-Explicit End-Use Processes.* For each of the 380 'technology-explicit end-use processes' the OPENZ User needs to specify: (i) for *existing technologies*, the maximum growth of these processes from the base year (2006/07) to the terminal year (2026/27). For each sector, some generic maximum growth rates are provided in terms of the descriptions 'maximum penetration', 'medium penetration' and 'low penetration' [29,30]; (ii) for *new technologies*, the proportion of each end-use energy that can be supplied by new technologies by 2026/27 needs to be specified by the OPENZ User. For example, if the OPENZ User considers that all lighting in the Householder sector can be supplied by 'new' technologies, then s/he would enter 100%. The OPENZ algorithm allows the OPENZ User to specify values generically across all new technology processes for a particular end-use, or alternatively individually for each process if that degree of specificity is required.

For the *energy supply sectors*, it is possible for further, quicker adaptation of new technologies (albeit that there are often considerable lead-up times required) – e.g. a new hydro-electric dam may be capable of generating 5PJ electricity/year which translates in going from zero activity for that process to 5PJ within a year, which is a far greater 'switch' than is the case with end-use demand processes that change more incrementally. Furthermore, in most of our initial runs at OPENZ, the energy supply processes, in the absence of penetration constraints, generally exhibit plausible penetration rates. For example, in the case of OPENZ runs that minimise economic cost ($), the new electricity processes gradually come on stream according to a very well defined merit order. Therefore, at the current stage of OPENZ development we have put little effort into 'constraining' the uptake of new energy supply technologies simply because it was not deemed necessary.
We have only found it necessary to 'constrain' the uptake in the case of using 'minimised primary energy inputs' as the objective function, as the 'merit order' for 'energy inputs' does not necessarily favour existing plant – in this case, simply imposing a constraint to ensure that existing hydro-electricity, geothermal and wind plant were used first, sufficed.

For most, technologies (as depicted by a process), these maximum penetration rates, are considerably higher than historical rates of change in the household, but nevertheless are considered 'realistic' if there was a concerted effort by government and private sector interests to adopt energy efficient technologies. Indeed, in some areas, for example like heat pumps over recent years, the rate of adoption has been close to the aforementioned maximum penetration rates (French *et al.*, 2007). Furthermore, in some instances the rate of market penetration could be even higher than these 'default settings' – for example, regulation to prohibit the use of incandescent light could mean that the realistic maximum rate for new forms of lighting technology could be as high as 90%.

2.9 Discount Rates

Discount rates in a public sector cost:benefit analysis remain a controversial area. This particularly applies to investment options that have long term environmental impacts, because the procedure of discounting inherently places less importance on benefits and costs that occur further into the future. Although the application of relatively high discount rates as applied to

[29] For example, for the Household Sector there are: high (220%), medium (135%) and low (50%) penetration bounds. This means, by point of illustration, that for the 'low' penetration bounds (50%), the activity level of each *existing* 'technology-explicit end-use process', in the household can only increase by 50% of the 2006/07 base-year value – e.g., lighting supplied by incandescent lights in 2025/26 can only increase by 50% of the 2006/07 level.

[30] In general terms, if the OPENZ User specified a 'penetration bounds' less than 'low', then this would lead to an 'infeasible' solution to the optimisation problem. That is, in general terms, 'low' represents the lowest possible penetration rate. Whereas, 'high' represents the maximum penetration rate that could be optimistically expected.

environmental management problems has been widely questioned for some time (Wright, 1988; Howarth and Norgaard, 1993) only recently have mainstream economists begun to accept this criticism. Most notably has been the use of a 1.4% discount rate used in the Stern Review (Stern, 2007) which argued that for analysing climate change policy this lower than normal rate was a more appropriate rate. In spite of this position by Stern (2007), a number of economists, most notably Nordhaus (2007), disagree with the use of such a low discount rate for evaluating climate change policy options.

The position of the New Zealand Treasury for many years has been to use a 10% real discount rate for public sector cost:benefit analysis. Many of the costings and feasibility studies undertaken by East Harbour Management Services (2004, 2005) and other analysts, that have been used in OPENZ, have used a discount rate of 10% although frequently the results are also presented in terms of other discount rates.

The ‘default setting’ for the real discount rate in OPENZ, is set at 10% to be consistent with the New Zealand Treasury official rate. However, it could be legitimately argued, because OPENZ is implicitly evaluating energy policy options that have long term consequences (climate change, resource depletion), then much lower discount rates are applicable. If on the other hand, OPENZ Users are evaluating the options in terms of commercial decision rules (as appropriate to businesses), then higher discount rates as recommended by the Treasury are more appropriate.

2.10 Energy Prices

The prices and costs in ‘OPENZ’ model are measured in $2006/07 including GST payments where appropriate. For example, GST is included in Household Sector prices as GST is generally not refundable to most householders. Road-user charges are also included, where they are applicable.
In the OPENZ, some prices are *endogenously determined* by the model itself, and some are *exogenously* imported into the model.

2.10.1 Exogenously Determined Prices

Exogenously prices generally (but not always)[31] occur in OPENZ, when energy prices are primarily determined by international market prices. That is, when New Zealand is a ‘price-taker’, and hence it is not appropriate to endogenously determine the energy prices within the OPENZ model.

Where possible the base year delivered energy prices for all sectors were obtained from data in the *Energy Data File* published by the Ministry of Economic Development (2008). Unfortunately there were a number of significant omissions in the price data in the *Energy Data File* (e.g. coal prices), that required these prices to be obtained from other sources including other published reports or internet sources. The most valuable alternative source of price data were the various reports by East Harbour Services Management (2004, 2005) and Donovan *et al.* (2009).

[31] The notable exceptions are ‘wood’, ‘black liquor’ and ‘geothermal heat’ with are minor fuels where there simply is not enough data to endogenise their price determination within OPENZ

The future delivered energy costs were almost entirely drawn from Donovan *et al.'s* (2009) report to the Auckland Regional Council that provides a very thorough analysis of future energy prices from 2008 to 2060. This analysis by Donovan *et al.* (2009) utilizes various pricing models, in conjunction with sophisticated statistical analyses as well as judgemental inputs from industry experts. Donovan *et al.'s* (2009) price forecast, were normalised, so that they corresponded with actual delivered energy inputs for the base year.

Specifically the following 'delivered energy prices' were imported into the OPENZ model, as exogenous variables:

- Aviation Fuel
- Black Liquor
- Coal
- Diesel
- Fuel Oil
- Geothermal
- LPG
- Petrol
- Wood
- Liquefied Natural Gas (Imported)[32]

The 'default settings' for these 'delivered energy' types across the four main sectors in the Economy are outlined by Tables C1 – C9 in Appendix C.

In reality all of these delivered energy prices are subject to uncertainties, which are difficult to reliably estimate. Forecasting energy prices is a notoriously difficult task even over short time horizons, not to mention over a 20 year time horizon. Many of these prices are linked to international crude oil prices which are very difficult and unpredictable where invariably even expert/consensus forecasts being proven to be inaccurate.
The 'default settings' for the delivered energy inputs are therefore considered to be 'best available estimates' in an uncertain world. Users of OPENZ can accordingly adjust these default settings for the prices, according to new information that comes to hand, and as part of a sensitivity analysis that can test out the implications of changing prices across a plausible range.

2.10.2 Endogenously Determined Prices

For some delivered energy inputs that are, or can be, produced within New Zealand, the delivered energy prices are determined endogenously by the OPENZ model. These include:

- Electricity
- Ethanol
- Methanol
- Biogas
- Synthetic Petrol
- Synthetic Diesel
- Natural Gas

The delivered energy price for Natural Gas (from indigenous fields) is determined by a block-wise supply curve, based on data from the Centre for Advanced Engineering (2005), Ministry of

[32] No reliable data could be found for Primary Sector delivered energy prices. However, generally speaking primary sector delivered energy prices, are similar to Commercial Sector delivered energy prices.

Economic Development (2006), Wilkinson (2005) and Donovan *et al.* (2009). The delivered energy price for all the other indigenously produced delivered energy types listed above is calculated endogenously in the Energy Supply Module at OPENZ – refer to Section 5 for further details. The *modus operandus* for these endogenous price determination calculations by OPENZ, is to calculate the energy production costs, and then add a wholesale and retail margin equal to the 2006/07 base year level for that particular energy type.

2.11 Policy Goals and the Objective Functions

OPENZ is an optimisation model and as such the most powerful 'driver' of the model is the choice of objective function. As argued elsewhere in the report, there is actually considerable flexibility within OPENZ to select a range of objective functions that are reflective of actual or potential government energy policy goals:

- Minimisation of energy inputs
- Minimisation of CO2 emissions
- Minimisation of the economic cost of energy supply (of end-use services)

In the initial operationalisation of OPENZ in this report to EECA, however, the emphasis has been defining 'energy savings potential'. This means that we have used *minimisation of energy inputs* and *minimisation of the economic costs* as the objective functions. Specifically, the following 'energy savings' potentials have been defined by using these objective functions:

- *Technical Energy Savings Potential* (minimisation of energy inputs, with 'high' technology penetration constraints.)
- *Economic Energy Savings Potential* (minimisation of economic costs, with 'high' technology penetration constraints.)
- *Realisable Energy Savings Potential* (minimisation of economic costs, with 'low' technology penetration constraints.)

The 'energy savings' to be achieved would be *a priori* expected to be: Technical Energy Savings > Economic Energy Savings > Realisable Energy Savings.

2.12 Policy Constraints

Another way of reflecting government policy goals in OPENZ, is by way of specifying 'constraints'. For example, the user of OPENZ may wish to make sure that the CO_2 emissions don't exceed, say, 1990 levels of CO_2 emissions.

At this stage in the development of OPENZ the following policy goals can be imposed (by way of 'constraints') on the model solutions:

- Percentage of electricity being generated from renewable sources. The New Zealand Government's current target is 90%.
- Percentage of primary energy sources that are from 'renewable sources'.
- Percentage of electricity from wind. It has been suggested by PA Consultants (2009) and the Electricity Commission (2007) that the upper limit is about 20%, due to technical operational reasons.
- Maximum amount of CO_2 emissions (kilotonnes/yr) that is permitted to be produced by the economy. This amount could be reflective of Kyoto Protocol imposed targets.

3. Energy Supply Module

3.1 Rationale for Including an Energy Supply Module

Some may question why an 'energy savings potential model' should have an 'energy supply module'. The reasons for including an 'Energy Supply Module' in OPENZ are essentially twofold. *Firstly*, and most, importantly, you cannot validly assess 'energy savings' or CO_2 emissions' effects by just in isolation considering end-use processes – although that is often the way analysts approach the problem with a sole focus on end-use processes – e.g. Henderson (1994). The case of an electric car provides a good example of this. The 'potential savings of energy and/or reduction of 'CO_2 emissions', that an electric car can achieve, depends on how the electricity is supplied – there will be very different answers to the questions of 'energy savings' or 'CO_2 reductions' achieved, if for example the electricity is supplied by a coal-fired thermal power station or from wind generation. *Secondly*, and related to the first point, an assessment of the 'Economic Potential for Energy Savings' also depends on the cost of energy supply. Taking the electric car example again, the cost ($) of electricity is not fixed, but depends on how the electricity is generated – e.g., extra electricity generation caused by widespread adoption of electric cars, may push upwards the cost ($) of electricity as existing electricity capacity is not sufficient. The trade-off between costs incurred on the supply side versus cost savings (and other benefits) on the demand side needs to be assessed in an interactive way, if a realistic assessment of the 'Economic Potential for Energy Savings' is to be achieved. Demand-side 'supply curves' exercises such as those carried out by Henderson (1994) and Wright and Baines (1986), although helpful, do ignore these trade-offs/interactions.

The intention of including an Energy Supply Module in OPENZ, does not duplicate or replace other models that have a supply-side focus (e.g. Ministry of Economic Development's SADEM Model). Rather, the intention is to include an Energy Supply Module that has sufficient detail to capture the main linkages between demand-side energy efficiency options, and supply-side dynamics. In particular, with respect to the supply-side, OPENZ will focus in a technology-specific way on the *new options (processes)* for extra energy supply capacity in the future, drawing on the now very good data on the economics of new energy supply options for New Zealand that is currently available. The treatment of *existing capacity* in OPENZ is more aggregative, as it is assumed that this capacity is a given 'starting point' and it is unlikely for example that New Zealand's existing hydro electricity supply capacity will not be used in the foreseeable future. In this way existing capacity in OPENZ is characterised by 66 aggregative equations that quantify the main energy supply options: 42 for electricity supply, 20 for transport fuels supply and 4 for heating fuels supply. Other models, such as SADEM, will contain more detailed data on supply-side options that utilise existing capacity.

3.2 Electricity Supply Processes

New Zealand's electricity supply system is complex and much modelling effort could be put into capturing this complexity. SADEM and other models have a focus on capturing this complexity and there are many possibilities to include pricing and generating options in the electricity sector (Denne *et al*., 2005a). As previously stated, it is not our goal to even attempt to encapsulate the complexity (including pricing, temporal, spatial aspects) in OPENZ, rather to provide a sufficient characterisation of electricity supply to answer our primary research questions ('energy savings potentials', 'CO_2 emissions reductions'). Needless to say, in the future, there may be an opportunity to provide a more detailed electricity supply module in OPENZ, or to interface OPENZ with other models that have such a focus.

3.2.1 Existing Electricity Supply Processes

OPENZ characterises New Zealand's existing electricity supply system in terms of 13 existing processes (E1 to E13). The term 'processes' here is used in a general sense as each of the 'processes' (E1 to E13) is more precisely an aggregation of processes. For example, process (E1) summarises the activity of all New Zealand's hydro-electricity generation dams into one aggregate process ranging from the largest dams like Benmore and Clyde to relatively small dams like Mangahao.

Table 3.1 provides a summary of the data for those 13 existing electricity generation processes (E1 to E13) that form part of the Energy Supply Module of OPENZ. It is possible to construct a 10 block supply curve of these processes, arranged in terms of merit order:

Hydro → Electricity	1.02 $/GJ	79.25PJ
Geothermal → Electricity	1.04 $/GJ	11.08 PJ
Wind → Electricity	1.37 $/GJ	2.22 PJ
Biogas → Electricity	1.69 $/GJ	0.70PJ
Waste Heat → Electricity	1.69 $/GJ	0.20PJ
Wood → Electricity	1.69 $/GJ	1.03PJ
Natural Gas (Co-gen) → Electricity	5.26 $/GJ	27.70PJ
Coal (Co-gen) → Electricity	13.90 $/GJ	2.10PJ
Coal & Gas (Huntly) → Electricity	17.47 $/GJ[33]	25.25PJ
Fuel Oil → Electricity	28.03 $/GJ	0.20PJ

The supply curve data for electricity generation was primarily derived from data contained in various reports by East Harbour Management Services (2003, 2004, 2005) supplemented and cross-checked with data from Ministry of Economic Development reports (2000, 2006), which were of a more general nature.

[33] The exact cost depends on the proportion of coal and gas inputs. The cost 17.47$/GJ takes the weighted mean of the estimated coal cost and the estimated gas cost.

Table 3.1 Existing Electricity Generation Supply Processes (E1…E13) in the OPENZ Model

Process Characteristics	Units	Electricity Supply Processes										
Process Codes		E1	E2	E3	E4	E5	E6	E7	E8	E11	E12	E13
Existing/ New		Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Energy Input		Hydro[1]	Wellhead Geothermal	Biogas	Wood	Wind	Fuel Oil	Natural Gas	Coal	Coal	Natural Gas	Waste Heat
Energy Output		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Technology		Dam, Hydro Turbine	Steam Turbine	Various	Various	Wind Turbine	Steam Turbine	Steam & Gas Turbine	Steam Turbine	Other & Cogeneration	CCGT & Cogeneration	Cogeneration
Thermal Efficiency[2]	$\Delta H_{out}/\Delta H_{in}$	0.90	0.15	0.29	0.13	0.90	0.40	0.36	0.35	0.41	0.42	0.15
Marginal Cost[3]	$\$10^6_{2006/07}$ / PJ output	1.02	1.04	1.69	3.75	1.37	28.03	18.66	16.28	13.90	5.26	1.69
CO_2 Emissions	kt CO_2 equivalents / PJ output	0.00	0.00	223.54	784.03	0.00	181.25	181.11	252.65	215.68	155.24	0.00
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	0.00	0.00	223.54	784.03	0.00	181.25	181.11	252.65	215.68	155.24	0.00
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	0.97	0.70	2.06	0.71	1.00	1.28	1.75	0.74	0.63	1.50	0.67
Energy Input per Unit of Output	PJ input / PJ output	1.11	6.70	3.43	7.52	1.11	2.50	2.78	2.86	2.44	2.38	6.67
Carbon Charge	$\$10^6_{2006/07}$ / PJ output	0.00	0.00	6.04	21.17	0.00	4.89	4.89	6.82	5.82	4.19	0.00
Renewable/Non-Renewable/ Recycled		Renewable	Renewable	Renewable	Renewable	Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Recycled Wastes
Upper Bound of Process	PJ output /Year	79.25	11.08	0.70	1.03	2.22	0.08	free[4]	free[4]	2.10	27.70	0.20

Notes:

1. "Hydro" refer to falling water, as per definitions in the text
2. Data obtained primarily from MED's (2008) Energy DataFile
3. Sunk costs are ignored because they are:
(a) not relevant to future commercial decisions as they cannot be recovered
(b) often very difficult to estimate accurately due to their historic nature
4. There is an 'indirect' bound on these Huntly Power Station Processes,
due a to constraint that limits the total electricity output of Huntly to 25.25 PJ/yr

In deriving these cost estimates we did not consider ‘sunk costs’. This is on the basis that: (a) it is not relevant to decisions about future investments in electricity generation to consider sunk (past) costs. This is the standard procedure from a micro-economic analysis perspective where the ‘economic actor’ should not let sunk costs influence his/her decision. This point however is debatable and experimental (behavioural) economics shows the sunk costs do (even if they shouldn’t from a ‘rational’ point of view) influence human behaviour; (b) sunk costs for many of New Zealand’s electricity supply systems and infrastructures are very difficult to estimate, particularly in the hydro-electricity sector when many dams were built 3-5 decades ago; (c) by not considering sunk costs, the OPENZ optimisation procedure will nearly always select the existing electricity generating processes first, which makes good ‘intuitive sense’ as it seems implausible that existing capacity would not be used first.

This electricity supply cost curve is perhaps best seen as a ‘stylistic’ representation of the costs. In this regard there are a few pertinent assumptions: (1) that there is a smooth divisibility in each block of electricity supply. That is for example, any percentage of the first block (hydro → electricity) of 79.25PJ is physically plausible. Given our knowledge of electricity power stations in New Zealand, this seems a reasonable assumption; (2) when a block is divisible, then the mean cost ($/GJ) for that block applies. Power station economics are complex, and therefore it seems unlikely that this assumption will always hold firm but on the other hand it seems that it is a reasonable approximating assumption.

Setting the ‘Upper Bound’ (last row Table 3.1) is quite difficult for some processes, as it varies considerably from year to year. For example, the ‘realistic upper-bound’ for process E1 (Hydro → Electricity) depends on weather conditions in a particular year. The general approach was to set the base-year activity (PJ/yr) as the upper bound. Further refinement of OPENZ, may require a more sophisticated approach, perhaps developing different ‘upper bound’ limits depending on how risk-adverse the User wishes to be – a risk adverse (conservative) approach would set the bound quite low which would ‘force’ OPENZ to develop new capacity by invoking new processes whereas a risk taking approach would do the opposite. All of this is pertinent to the policy issue of ‘security of electricity supply’ which has been a matter of public concern in recent years and hence is reflected as a policy objective in the *New Zealand Energy Strategy to 2050.*

Table 3.1 describes other data (apart from cost) to characterise each electricity supply process: technology type, thermal efficiency, CO_2 emissions, GHG emissions, carbon charge, renewable/non-renewable/recycled wastes, energy input, energy output and process codes. These data are considered to be reasonably accurate having been mainly drawn from data in the MED’s (2008) *Energy Data File*.

3.2.2 New Electricity Supply Processes

Along with the replacement of Maui Gas and other natural gas reserves, future electricity supply is probably New Zealand’s biggest challenge for future energy supply.

Data on the future electricity supply options were primarily obtained from the reports: (1) *Fossil Fuel Electricity Generating Costs* by East Harbour Management Services (2004); (2) *Availabilities and Costs of Renewable Sources of Energy for Generating Electricity and Heat* by East Harbour Management Services (2005). To a much lesser extent data was also obtained from the report *Emerging Supply-Side Energy Technologies* by PB Power (2006). Data from all of these sources, needed to be adjusted so it fitted the required format for OPENZ, for example, including conversion to $2006/2007. The approach was to estimate the cost of each electricity supply option according to the following cost categories: ‘total cost’, ‘variable costs’ ‘(fuel, operations and maintenance, tax)’. Unlike ‘existing’ electricity costs in OPENZ, *all* costs (including sunk costs) were entered into the objective function as this was seen as the appropriate cause of action in considering new supply options.

These data on new electricity supply options are summarised in the following tables: Table 3.2 (E15-E25), Table 3.3 (E26-E35), Table 3.4 (E36 – E42) and are directly incorporated into OPENZ as ‘new’ electricity supply options. It is possible to construct a 29 block supply curve of these processes, arranged in terms of ‘merit order’:

		$/GJ	**PJ**
Natural Gas	Open Cycle Gas Turbine	6.66	4.54
Natural Gas	Combined Cycle Advanced Gas Turbine	7.04	11.36
Natural Gas	Combined Gas Turbine	7.34	7.10
Purpose Grown Wood	Various	8.59	0.36
Wellhead Geothermal	Steam Turbine	9.47	0.72
Wellhead Geothermal	Steam Turbine	15.78	5.96
Wind	Wind Turbine	15.78	14.80
Mine Coal (Southland Lignite)	Supercritical Pulverised Boiler, Flue Gas Desulphurisation	18.38	14.20
Natural Gas	Open Cycle Advanced Gas Turbine	20.64	6.53
Purpose Grown Wood	Various	21.22	1.02
Hydro	Dam, Hydro Turbine	22.09	0.94
Wellhead Geothermal	Steam Turbine	22.09	7.66
Wind	Wind Turbine	22.09	13.97
Mine Coal (Lignite Southland)	Supercritical Pulverised Boiler, No Flue Gas Desulphurisation	22.57	4.26
Mine Coal (Sub-Bituminous: North Island)	Supercritical Pulverised Boiler, Flue Gas Desulphurisation	23.54	14.20
Coal (Bituminous)	Supercritical Pulverised Boiler, Flue Gas Desulphurisation	23.54	14.20
Mine Coal (Bituminous)	Supercritical Pulverised Boiler, Flue Gas Desulphurisation	24.18	4.26
Mine Coal Bituminous Mine Coal	Supercritical Pulverised Boiler, Flue Gas Desulphurisation	24.83	4.26
Purpose Grown Wood	Various Technologies	27.53	1.02
Hydro	Dam, Hydro Turbine	28.41	14.38
Wellhead Geothermal	Steam Turbine	28.41	0.82
Wind	Wind Turbine	28.41	8.33
Hydro	Dam/Hydro Turbine	34.72	2.21
Wind	Wind Turbine	34.72	5.36
Purpose Grown Wood	Various	35.79	3.82
Hydro	Dam, Hydro Turbine	41.03	8.19
Wind	Wind Turbine	41.03	3.40
Hydro	Dam, Hydro Turbine	47.34	8.19
Wind	Wind Turbine	47.34	2.52

These costs only include the ‘generation cost’/’ex-power plant generation’ and don’t include distribution, wholesale and retail costs, that are included in the other modules of OPENZ.

It can be observed from this ‘block supply curve’ that there are a number of electricity supply options, (E26, E18, E19, E15, E14, E16, E17), that have better or at least similar costs ($) to existing supply options, although OPENZ will tend to first of all select ‘existing’ options because for these options the ‘sunk costs’ are not included. However, beyond these ‘competitive’ relatively ‘low cost’ options that are capable of supplying an extra 44.8PJ of electricity, the next 20 new electricity supply processes show steeply rising electricity costs ($/GJ) which has significant implications in the later years of OPENZ scenarios that minimise the cost ($) of electricity supply.

Finally it should be noted in defining the ‘Upper Bounds’ (PJ/Yr) of the electricity supply processes in OPENZ, we have set these bounds at 90% of the levels specified in the East Harbour Management Services (2003, 2004, 2005) reports. This is on the basis that it is unlikely under realistic circumstances that the ‘full capacity’ of these energy supply options will actually materialise.

Table 3.2 New Electricity Generation Supply Processes (E15…E25) in the OPENZ Model

Process Characteristics	Units	Electricity Supply Processes										
Process Code		E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25
Existing/ New		New	New	New	New	New	New	New	New	New	New	New
Energy Input		Purpose Grown Wood	Wellhead Geothermal	Wind	Natural Gas	Natural Gas	Mine Coal (Southland Lignite)	Natural Gas	Hydro	Wellhead Geothermal	Wind	Mine Coal (Lignite: Southland)
Energy Output		Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]	Electricity[1]
Technology		Various	Steam Turbine	Wind Turbine	Combined Cycle Advanced Gas Turbine	Combined Cycle Gas Turbine	Supercritical Pulverised Boiler, including Flue Gas Desulpurisation	Open Cycle advanced Gas Turbine	Dam, Hydro Turbine	Steam Turbine	Wind Turbine	Supercritical Pulverised Boiler, with no Flue Gas Desulpurisation
Thermal Efficiency	$\Delta H_{out}/\Delta H_{in}$	0.35	0.15	0.90	0.54	0.49	0.40	0.40	0.90	0.15	0.90	0.40
Marginal Cost	$\$10^{6}_{2006/07}$ / PJ output	8.59	15.78	15.78	7.04	7.34	18.38	20.64	22.09	22.09	22.09	22.57
CO_2 Emissions	kt CO_2 equivalents / PJ output	297.71	0.00	0.00	121.76	134.16	221.07	163.41	0.00	0.00	0.00	221.07
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	297.71	0.00	0.00	121.76	134.16	221.07	163.41	0.00	0.00	0.00	221.07
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	0.27	0.70	1.00	1.18	1.30	0.65	1.58	0.97	0.70	1.00	0.65
Energy Input per Unit of Output	PJ input / PJ output	2.86	6.70	1.11	1.87	2.06	2.50	2.51	1.11	6.70	1.11	2.50
Carbon Charge	$\$10^{6}_{2006/07}$ / PJ output	8.04	0.00	0.00	3.29	3.62	5.97	4.41	0.00	0.00	0.00	5.97
Renewable/Non-Renewable/		Renewable	Renewable	Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Renewable	Renewable	Renewable	Non-Renewable
Upper Bound of	PJ output /Year	0.36	5.96	14.80	11.36	7.10	14.20	6.53	0.94	7.66	13.97	4.26

Note:

1. 'Electricity' refer to Electricity at the 'Point of Generation'. Losses are incurred before it is delivered to the point of end-use.

Table 3.3 New Electricity Generation Supply Processes (E26…E35) in the OPENZ Model

Process Characteristics	Units	Electricity Supply Processes									
Process Code		E26	E27	E28	E29	E30	E31	E32	E33	E34	E35
Existing/ New		New	New	New	New	New	New	New	New	New	New
Energy Input		Natural Gas	Mine Coal (Sub-Bituminous: North Island)	Coal (Bituminous)	Mine Coal (Bituminous Mine Coal: West Coast South Island)	Mine Coal (Bituminous Mine Coal: West Coast South Island)	Purpose Grown Wood	Hydro[1]	Wellhead Geothermal	Wind	Purpose Grown Wood
Energy Output		Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]
Technology		Open Cycle Gas Turbine	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	Various	Dam, Hydro Turbine	Steam Turbine	Wind Turbine	Various
Thermal Efficiency	$\Delta H_{out}/\Delta H_{in}$	0.33	0.40	0.40	0.40	0.40	0.35	0.90	0.15	0.90	0.35
Marginal Cost	$\$10^6{}_{2006/07}$ / PJ output	6.66	23.54	23.54	24.18	24.83	21.22	28.41	28.41	28.41	27.53
CO_2 Emissions	kt CO_2 equivalents / PJ output	199.39	221.07	221.07	221.07	221.07	297.71	0.00	0.00	0.00	297.71
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	199.39	221.07	221.07	221.07	221.07	297.71	0.00	0.00	0.00	297.71
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	1.93	0.65	0.65	0.65	0.65	0.27	0.97	0.70	1.00	0.27
Energy Input per Unit of Output	PJ input / PJ output	3.06	2.50	2.50	2.50	2.50	2.86	1.11	6.70	1.11	2.86
Carbon Charge	$\$10^6{}_{2006/07}$ / PJ output	5.38	5.97	5.97	5.97	5.97	8.04	0.00	0.00	0.00	8.04
Renewable/Non-Renewable/ Recycled Wastes		Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Renewable	Renewable	Renewable	Renewable	Renewable
Upper Bound of Process	PJ output /Year	4.54	14.20	14.20	4.26	4.26	1.02	14.38	0.82	8.33	1.02

Table 3.4 New Electricity Generation Supply Processes (E36…E42) in the OPENZ Model

Process Characteristics	Units	Electricity Supply Processes						
Process Code		E36	E37	E38	E39	E40	E41	E42
Existing/ New		New	New	New	New	New	New	New
Energy Input		Hydro[1]	Wind	Hydro	Wind	Purpose Grown Wood	Hydro[1]	Wind
Energy Output		Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]	Electricity[2]
Technology		Dam, Hydro Turbine	Wind Turbine	Dam, Hydro Turbine	Wind Turbine	Various	Dam, Hydro Turbine	Wind Turbine
Thermal Efficiency	$\Delta H_{out}/\Delta H_{in}$	0.90	0.90	0.90	0.90	0.35	0.90	0.90
Marginal Cost	$\$10^6_{2006/07}$ / PJ output	34.72	34.72	41.03	41.03	35.79	47.34	47.34
CO_2 Emissions	kt CO_2 equivalents / PJ output	0.00	0.00	0.00	0.00	297.71	0.00	0.00
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	0.00	0.00	0.00	0.00	297.71	0.00	0.00
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	0.97	1.00	0.97	1.00	0.27	0.97	1.00
Energy Input per Unit of Output	PJ input / PJ output	1.11	1.11	1.11	1.11	2.86	1.11	1.11
Carbon Charge	$\$10^6_{2006/07}$ / PJ output	0.00	0.00	0.00	0.00	8.04	0.00	0.00
Renewable/Non-Renewable/		Renewable	Renewable	Renewable	Renewable	Renewable	Renewable	Renewable
Upper Bound of Process	PJ output /Year	2.21	5.36	8.19	3.40	3.82	8.19	2.52

Notes:
1. "Hydro" refer to falling water, as per definitions in the text
2. 'Electricity' refer to Electricity at the 'Point of Generation'. Losses are incurred before it is delivered to the point of end-use.

Table 3.5 Existing Transport Fuel Supply Processes (T1 - T8) in the OPENZ Model

Process Characteristics	Units	Transport Supply Processes							
Process Code		T1	T2	T3	T4	T5	T6	T7	T8
Existing/ New		Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Energy Input		Crude Oil	Imported Petrol	Crude Oil	Imported Diesel	Crude Oil	Imported Aviation Fuel	Wellhead LPG	Imported LPG
Energy Output		Petrol	Petrol	Diesel	Diesel	Aviation Fuel	Aviation Fuel	LPG	LPG
Technology		Oil Refinery	Tanker Delivery	Oil Refinery	Tanker Delivery	Oil Refinery	Tanker Delivery	Tanker Delivery	Tanker Delivery
Thermal Efficiency	$\Delta H_{out}/\Delta H_{in}$	0.94	1.00	0.94	1.00	0.94	1.00	0.89	1.00
Marginal Cost[1]	$\$10^6_{2006/07}$ / PJ output	0.00	0.50[2]	0.00	0.50[2]	0.00	0.50[2]	0.00	0.50[2]
CO_2 Emissions	kt CO_2 equivalents / PJ output	10.62	10.62	10.62	10.62	10.62	10.62	7.00	7.00
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	10.62	10.62	10.62	10.62	10.62	10.62	7.00	7.00
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	0.51	0.59	0.51	0.59	0.51	0.59	0.37	0.34
Energy Input per Unit of Output	PJ input / PJ output	1.06	1.00	1.06	1.00	1.06	1.00	1.13	1.00
Carbon Charge	$\$10^6_{2006/07}$ / PJ output	0.29	0.29	0.29	0.29	0.29	0.29	0.19	0.19
Renewable/Non-Renewable/ Recycled Wastes		Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable
Upper Bound of Process	PJ output /Year	76.47	free	86.75	free	42.23	free	10.80	free

Notes

1. In OPENZ, due to lack of data all costs for 'existing transport fuels' are included in the final retail price, for end-uses processes that use these fuels - ie, processes (H317a - H408; P1-P20; C1-c220; Ind1-Ind230; T1-T30) In other words, there was insufficient available data to separate out 'production' costs from other costs.
2. In OPENZ, a margin of 0.50 $mil/PJ was added the cost of imported fuels, to avoid model degeneracy when minimising costs. This had the effect of OPENZ selecting first of all indigenous sources of fuels up to the bound limit, and then after that limit switching to imported fuels. It is possible to change this 'default setting'.

3.3 Transport Fuel Supply Options[34]

As with the 'electricity supply options', for the 'transport fuel options' it is not our intent to provide detailed coverage of these options. For example, it is possible to model 'oil refinery' operations as has been carried out in the past in New Zealand dating back to the work of Earl, Garner and Boshier (1979) and others. Rather our goal is to provide sufficient characteristics of the 'transport fuel options' in OPENZ to answer our primary research questions ('energy savings potentials', 'CO_2 emissions reductions').

3.3.1 Existing Transport Fuel Processes

'Existing Transport Fuel Supply Processes' (T1-T8) cover all of the 'conventional fossil fuels that totally dominate New Zealand's transport fuel mix: Petrol, Diesel, Aviation Fuel and LPG. In 2006/07 New Zealand consumed 108.54PJ of Diesel, 112.18 PJ of Petrol, 17.33PJ of Aviation Fuel and 7.94PJ of Liquified Petroleum Gas, with very small amounts of CNG (0.37PJ) and Electricity (0.08PJ) being used for transport purposes.

Table 3.5 outlines the data used to describe these 'existing transport fuel supply processes' in OPENZ. Most of the base data required to generate this table was drawn from the Ministry of Economic Development's (2008) *Energy Data File.*

It needs to be noted: (1) that due to the lack of data on the cost of producing transport fuels (primarily at the Marsden Point Refinery), all production costs are subsumed in the final retail cost. This 'tactic' is needed because there is insufficient publicly available data to separate the 'production cost' (of transport fuels) from the other costs at the distribution and retail levels; (2) In OPENZ, a margin of $0.5mil/PJ was added to the cost of importing fuels, to avoid degeneracy when minimising costs ($). This had the effect of OPENZ selecting first of all indigenous sources of the transport fuels up to the upper bound limit, and after that limit switching to imported fuels. It is of course possible to change this 'default setting'.

As for existing electricity generation the 'sunk costs' of transport are ignored in the OPENZ optimisation because (a) they are difficult to robustly estimate, (b) more importantly they are considered to have no effect on current-day decision-making as these sunk (past) costs cannot be recovered. It should however be noted that these costs are considerable, with for example the Marsden Point Oil Refinery expansion costing about $1.8billion.

For transport fuel produced in New Zealand, it is difficult to set upper bounds based on production capacities (primarily those at the Marsden Point refinery). The approach however was to set the upper bound by selecting from the *Energy Data File*, the highest annual level of production in the 'post-syn fuel' era (1997-2009). This is seen as a reasonable proxy for the upper bound for the domestic production of transport fuels. There is no limit set on the importation of transport fuels, and it is assumed the question whether to import these fuels or to produce them within New Zealand is purely cost/price driven.

[34] It needs to be noted that several of these so called 'transport fuels' are used for non-transport purposes – e.g. petrol for lawn-mowers. This non-transport use is relatively minor.

3.3.2 New Transport Fuel Supply Processes

There is relatively abundant information available on the technological and economic feasibility of alternative transport fuels in New Zealand, dating back to the 1970's when alternative sources of transport fuels were being investigated during the 'oil crises' years. Accordingly, the main New Zealand sources of data for OPENZ for transport fuels were: Garrod and Clemens (2007), Taylor (2007) and Harris *et al.* (1979). Data for processes that are applicable to New Zealand were also obtained from the publication *Biofuels for Transportation* produced by the International Energy Agency (2006).

Other than processes (T19 and T20) all of the other processes are based on biomass production and therefore ultimately constrained by land available rather than the arbitrary 30PJ output limit placed on each process. Some effort therefore went into calculating the land use requirements of each of the production of these biomass sources of transport fuels[35]:

T9: Fodder Beet →Ethanol: 5,060ha crop land/PJ output
T10: Radiata Pine → Methanol: 9,659ha forest land/PJ output
T11: Radiata Pine → Methanol: 9,659ha forest land/PJ output
T12: Radiata Pine → Ethanol: 16,151ha forest land/PJ output
T13: Forage → Methane: 10,526ha crop land/PJ output
T14: Maize → Ethanol: 6,702 ha crop land/PJ output
T15: Eucalyptus → Diesel: 13,889ha forest land/PJ output
T16: Eucalyptus → Diesel: 13,889ha forest land/PJ output
T17: Eucalyptus → Diesel: 13,889ha forest land/PJ output
T18: Eucalyptus → Diesel: 13,889ha forest land/PJ output

The costing of these options required detailed calculations and requires careful interpretation of the 'marginal cost' data outlined in Table 3.6. The overall approach was to calculate the following cost categories for each process: 'capital costs', 'fuel costs' (as all of these processes required fuel and sometimes significant amounts), 'operations and maintenance costs', 'taxes' and 'other variable costs'. For processes T9 – T14, the 'production costs plus all other costs of delivering the transport fuel to the point of end-use' was calculated. Due to data constraints for the processed T15-T20, the costs were calculated relative to 'existing retail costs' of the fuel (diesel and petrol) – hence a negative cost ($/GJ) for processes T16, T19 and T20 meant fuel was produced at lower cost than 'existing retail cost', whereas a positive cost ($/GJ) for processes T15, T17 and T18 meant fuel was produced at a higher cost than 'existing retail cost'.

[35] Technologies for each process are: T9 (Fermentation), T10 (Gasification), T11 (Gasification), T12 (Acid Hydrolysis, followed by Fermentation), T13 (Fermentation), T14 (Enzyme Hydroloysis, followed by Fermentation), T15 (FAME: Transesterification), T16 (HTU), T17 (Gasification), T18 (Pyrolysis).

Table 3.6 New Transport Fuel Supply Processes (T9 - T20) in the OPENZ Model

Process Characteristics	Units	Transport Supply Processes											
Process Code		T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20
Existing/ New		New	New	New	New	New	New	New	New	New	New	New	New
Energy Input		Fodder Beat	Radiata Pine	Radiata Pine	Radiata Pine	Forage	Maize	Eucalyptus	Eucalyptus	Eucalyptus	Eucalyptus	Mine Coal (Lignite: Southland)	Mine Coal (Lignite: Southland)
Energy Output		Ethanol	Methanol	Methanol	Ethanol	Methane	Ethanol	Diesel	Diesel	Diesel	Diesel	Diesel	Petrol
Technology		Fermentation	Gasification	Gasification	Acid Hydrolysis followed by Fermentation	Methane Ferment-ation	Enzyme Hydrolysis followed by Ferment-ation	FAME (trans-esterification)	HTU	Gastification	Pyrolysis	Fischer-Tropsch	Fischer-Tropsch
Thermal Efficiency	$\Delta H_{out}/\Delta H_{in}$	0.54	0.51	0.51	0.31	0.38	0.40	0.40	0.40	0.40	0.40	0.44	0.44
Marginal Cost	$\$10^{6}_{2006/07}$ / PJ output	70.03[1]	79.47[1]	108.16[1]	103.91[1]	127.11[1]	219.73[1]	8.96[2]	-0.64[2]	4.16[2]	31.35[2]	-5.83[2]	-11.21[2]
CO_2 Emissions	kt CO_2 equivalents / PJ output	3.30	2.99	2.99	2.99	3.49	4.83	2.99	2.99	2.99	2.99	132.06	132.06
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	3.30	2.99	2.99	2.99	3.49	4.83	2.99	2.99	2.99	2.99	132.06	132.06
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	0.15	0.19	0.19	0.31	0.21	0.24	0.24	0.24	0.24	0.24	0.59	0.59
Energy Input per Unit of Output	PJ input / PJ output	1.85	1.96	1.96	3.28	2.63	2.50	2.50	2.50	2.50	2.50	2.28	2.28
Carbon Charge	$\$10^{6}_{2006/07}$ / PJ output	0.09	0.08	0.08	0.08	0.09	0.13	0.08	0.08	0.08	0.08	3.57	3.57
Renewable/Non-Renewable/ Recycled Wastes		Renewable	Renewable	Renewable	Renewable	Renewable	Renewable	Renewable	Renewable	Renewable	Renewable	Non-Renewable	Non-Renewable
Upper Bound of Process	PJ output /Year	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	44.69	44.69

Notes
1. Production Costs plus all costs in delivering the Fuel to the Point of End-Use.
2. Additional Costs to the Existing Retail Costs of these Fuels.

3.4 Heating Fuel Supply Processes

To some extent this is a 'miscellaneous' category as the supply of heating fuels are covered elsewhere in OPENZ (in the transport supply fuel section), or because the heating fuel requires no production from primary sources[36]. There are four processes for 'heat fuel supply' (processes HF2, HF3, HF5, HF6) that are summarised by Table 3.7.

It should be noted that in OPENZ: (1) the cost of importing Liquid Natural Gas, as a backstop technology to using existing indigenous natural gas, is \$10.00/GJ in 2006/07 increasing to \$14.40 GJ in 2025/26. This is based on data obtained from Wilkinson (2005) and the Centre for Advanced Engineering (2005); (2) in OPENZ, a margin of \$0.5/GJ was added to the cost of importing fuel oil (HF6) to avoid degeneracy when minimising costs. This had the effect of OPENZ selecting first of all indigenous sources of transport fuels up to the limit, and after that switching to imported fuel oil. It is, of course, possible to change this 'default setting'.

Table 3.7 Existing Heating Fuel Supply Processes (HF2 - HF6) in the OPENZ Model

Process Characteristics	Units	Transport Supply Processes			
Process Code		HF2	HF3	HF5	HF6
Existing/ New		New	Existing	Existing	Existing
Energy Input		Imported Gas	Imported & Mine Coal	Crude Oil	Imported Fuel Oil
Energy Output		Natural Gas	Coal	Fuel Oil	Fuel Oil
Technology		Liquefied via Tanker Delivery	Various	Oil Refinery	Oil Refinery
Thermal Efficiency	$\Delta H_{out}/\Delta H_{in}$	0.98	1.00	0.93	0.93
Marginal Cost	$\$10^6_{2006/07}$ / PJ output	10.00[1]	0.00[2]	0.00[2]	0.50[3]
CO_2 Emissions	kt CO_2 equivalents / PJ output	7.00	0.00	10.62	10.62
Greenhouse Gas Emissions	kt CO2 equivalents / PJ output	7.00	0.00	10.62	10.62
Energy Input per Unit of Output	PJ elect equivalents in / PJ output	0.64	0.26	0.52	0.52
Energy Input per Unit of Output	PJ input / PJ output	1.02	1.00	1.08	1.08
Carbon Charge	$\$10^6_{2006/07}$ / PJ output	0.19	0.00	0.29	0.29
Renewable/Non-Renewable/ Recycled Wastes		Non-Renewable	Non-Renewable	Non-Renewable	Non-Renewable
Upper Bound of Process	PJ output /Year	free	free	25.93	free

Notes
1. Cost of importing Liqufied Natual Gas. Under 'default settings' this cost gradually increases each year.
2. In OPENZ, due to lack of data all costs for 'existing heating fuels' are included in the final retail price, for end-uses processes that use these fuels - ie, processes (H317a - H408; P1-P20; C1-c220; Ind1-Ind230; T1-T30) In other words, there was insufficient available data to separate out 'production' costs from other costs.
3. In OPENZ, a margin of 0.50 \$mil/PJ was added to the cost of Imported Fuel Oil, to avoid model degeneracy when minimising costs. This had the effect of OPENZ selecting first of all indigenous Fuel Oil up to the bound limit, and then after that limit switching to imported Fuel. It is possible to change this 'default setting'.

36 For example, wood and black liquor just appear as exogeneous inputs into OPENZ, and go directly from delivered energy → end use – viz, there is no primary energy → delivered energy process for these 'delivered energy inputs'.

4. Energy Demand Modules

4.1 Modules and Sectors Covered

OPENZ contains five energy demand modules: (1) Household Sector; (2) Primary Sector; (3) Commercial Sector; (4) Industrial Sector; (5) Transport and Storage Sector. These are based on the definitions in the EECA 2006/07 End Use Database. The full definition of these modules in terms of ANZSIC classifications can be found in Appendix B.5.2.

Briefly however the modules cover the following economic activities:

- *Primary Sector:* This includes agricultural production; fishing and hunting; forestry and logging; and mining and quarrying.
- *Industrial Sector:* This includes manufacturing and processing of primary products whether they be domestically or internationally sourced. As such the industrial sector covers: meat processing; dairy products; other food processing; textile, apparel and leather-goods; wood processing; paper and paper products; chemicals manufacturing; concrete, clay, glass and related minerals manufacture; basic metal industries including steel production and aluminium smelting; fabricated metal products; machinery manufacturing; construction activities and other manufacturing industries.
- *Commercial Sector:* This mainly includes services, wholesaling and retailing activities in the New Zealand economy. As such it covers: retail trade; wholesale trade; education; health and welfare services; finance, insurance, real estate and business services; central and local government; motel, hotel and accommodation services; sanitary and cleaning services; communication; and water supply.
- *Transport and Storage Sector*: This includes all transport and storage activities in the New Zealand economy, except (i) private transport undertaken by householders; (ii) transport fleets or vehicles directly operated by businesses in the 'industrial', 'primary sector' or 'commercial sector'. For example, milk tankers operated by Fonterra are included in the Industrial sector. As such the transport and storage sector includes: rail transport; scheduled road passenger transport; taxis; freight transport; car rentals; water transport; air transport; storage and warehousing and services supporting these transport activities.
- *Household Sector:* This includes all residences in New Zealand, but not institutional places of residence such as hospitals, rest homes or university halls of residence. It is sometimes referred to as the 'residential sector'. There were 1,624,500 households in New Zealand at 31 December 2009 (Statistics NZ, 2009).

4.2 End-Uses of Energy Covered

A distinguishing feature of OPENZ is that it characterises and measures energy end use demand in terms of energy end-uses. This contrasts other energy models in New Zealand that have measured energy demand in terms of the 'delivered energy' required by various sectors in the economy.

The argument put forward in this report, and the philosophical foundation of OPENZ, is that it is inadequate to measure energy demand in terms of 'delivered energy' which is the conventional case. This is because fundamentally consumers require 'energy end-use' services (e.g. heating, lighting, transport); and they don't necessarily require coal, natural gas or any other particular delivered energy that can provide these 'services'. Internationally, one of the reasons that many analysts persist with this conventional approach of using 'delivered energy' as a proxy for energy demand, is because of the lack of energy end-use data available. However, in New Zealand this lack of end-use data, is not so much of a problem due to the existence of the EECA End-Use Database.

The specific energy end-uses covered by OPENZ include:

- *High Temperature Process Heat (≥ 300ºC):* This refers to those end-uses of heat in industrial processes where heat is required at temperatures of greater than or equal to 300ºC. This includes the heat requirements of processes in the iron and steel, cement, engineering and kilning industries, where heat temperatures exceeding 1000ºC are often required.
- *Intermediate Temperature Process Heat (100º-300ºC):* This refers to those end-uses of heat in industrial processes where heat is required at temperatures between 100-300ºC. This includes most of the heat used in the chemical, paper, food and textile industries. This is split into 3 sub-categories: 'kiln and furnace', 'industrial ovens' and 'general' (which mainly includes boiler applications).
- *Cooking (100º-300ºC):* This refers to the heating of cooking loads in households, restaurants, cafes and other similar situations. It only includes heat actually entering the cooking load.
- *Water Heating (50º-70ºC):* This refers to the heating of water in the household and commercial sectors to relatively low temperatures.
- *Space Heating (20º-25ºC):* This refers to the heating of rooms primarily in the household and commercial sectors to an acceptable environmental temperature of about 20º-25ºC.
- *Space Cooling (20º-25ºC):* This refers to the cooling of rooms primarily in the household and commercial sectors to an acceptable environmental temperature of about 20º-25ºC.
- *Refrigeration (<3ºC):* This refers to the removal of heat from refrigeration spaces (cabinets, rooms, stores) so as to attain a temperature below 3ºC.
- *Lighting:* This refers to the generation of electromagnetic radiation (0.4µm- 0.7µm) that can be perceived by the human eye. This end-use occurs mainly in buildings – *Street Lighting* is a separate category.
- *Electronics and Other Electrical Uses*: This refers to electrical energy used by electronic equipment such as televisions, radios and computers. The systems boundary is drawn at the end-use efficiency of such equipment.
- *Pumping:* This refers to energy being applied to move a fluid along a system of pipes and valves. The systems boundary is drawn at the point of the fluid entering the pumping system under pressure, and where losses due to the electric motors operating the system are taken into account. This does not include losses in the pumping system itself; such as head losses, friction losses, and losses due to value and joint enlargement which are all extremely difficult to quantify.
- *Stationary Motive Power:* This is mechanical energy generated mainly in industrial situations from stationary engines and motors.
- *Land Transport:* This refers to that mechanical energy required to power road and land vehicles taking full account of friction and other losses. These vehicles include automobiles, trucks, buses, motor cycles, tractors and other related vehicle types which operate on roads and/or land surfaces. Land transport is split into *3 sub-categories* in the OPENZ optimisation matrix: Freight, Passenger Cars, Passenger Buses.
- *Rail Transport*: This refers to that mechanical energy required to power railroad stock, taking full account of friction and other losses.

- *Sea Transport:* This refers to that mechanical energy required to power vessels that are designed to move across the surface of water bodies, taking full account of friction and other losses.
- *Air Transport:* This refers to that mechanical energy required to power aircraft, taking full account of friction and other losses. This includes both domestic aircraft, as well as aircraft travelling overseas but receiving fuel in New Zealand.
- *Reduction of Aluminium Oxides:* This refers to the electro-chemical reduction of aluminium oxides (primarily $A1_2O_3$) to elemental aluminium.
- Reduction of Iron Oxides: This refers to the chemical reduction of Fe_3O_4 to elemental iron.
- *Low Temperature Process Heat (<100ºC):* This refers to end-uses of where heat is required at temperatures below 100ºC. This occurs mainly in the wood and food processing industries. This is split into 2 subcategories: 'kiln/furnace' and 'general' (which mainly includes boiler applications).
- *Street Lighting:* This refers to lighting of streets, road and other vehicular routes for safety and security reasons. This mainly includes fluorescent, high intensity discharge and high pressure sodium lights.
- *Clothes Drying (<100ºC):* This refers to the removal of water from clothes that have been washed.
- *Motive Power, Mobile:* This is mechanical power generated by a mobile machine (forklift, tractor, grader) in an off-road situation. It does not include the use of cars, trucks, vans or other vehicles that are primarily used on road, even if they are being used in an 'off-road' situation.
- *Spa Pools Low Temperature Heat (<40ºC):* This is heating of water in spa pools or hot tubs up to 40ºC, mainly in the household and accommodation sectors of the economy.

4.3 Two Key Definitions

Another distinguishing feature of OPENZ is the very detailed coverage of end-use 'technologies' and end-use 'energy savings measures'. Past energy supply and demand models constructed in New Zealand did contain some specification of 'technologies'. Most notably the optimisation model constructed by Smith (1978) did contain some technological specificity in the supply sectors, but notably very little in the energy demand sectors. Previous economic modelling approaches in New Zealand (e.g. Dokter, 1985), certainly contained no technology based details. In more recent years as pointed out by Denne *et al.* (2005a), SADEM (the main model used by MED), contains very little technology data as it is essentially a 'top-down' model with only some technology specificity in the electricity supply component of the model.

Table 4.1 Characterisation Energy Efficiency Options OPENZ's 'Demand Modules'

Characteristics	Technology-Explicit Process	Energy Savings Measures
Data source	*ECCA End-Use Database 2006/7* for existing processes. EECA staff for new processes.	*Henderson (1994)*
OPENZ Energy Data	End-Use Output (PJ/yr)	No data for 'End-Use Output (PJ/yr)'
	Delivered Energy Input (PJ/yr)	Delivered Energy Savings (PJ/yr)
Example	Space Heat (3 PJ/yr) from Electricity (1 PJ/yr), using Heat Pumps	0.5 PJ/yr of Delivered Energy saved by Zone Control in Commercial Buildings
Technological Specificity	Specific categories from the EECA End-Use Database 2006/07.	Rarely specific to one end-use technology. Often applies to a number of technologies, in a rather general/non-attributable fashion.
Row Data in the OPENZ Optimisation Matrix [1]	Negative Entry for Delivered Energy (input) Positive Entry for End-Energy (output)	Positive Entry for Delivered Energy (to indicate amount of savings)
Necessity to be in the 'feasible' solution	Necessary. Sufficient technology processes to supply the required amounts of end-use energy (31 categories). That is, ≥1 technology processes for each end-use energy category	Not Necessary
Delivered Energy is saved by	By *switching* to a more efficient 'technology-explicit process'	By *adopting* the 'energy savings measure'

Note:
1. Each 'energy efficiency option' is entered as a row in the OPENZ optimisation matrix. OPENZ determines the optimal activity of each row (energy efficiency option).

The following key definitions are important in understanding how 'technologies' and 'energy savings measures' are dealt with in OPENZ:

- *Technology Explicit End-Use Process.* This is an OPENZ end-use process, which is *explicit* concerning the technology used. For end-use processes[37], data is entered into an OPENZ row, which enumerates the amount of 'delivered energy input' (negative number) and the amount of 'energy end-use output; (positive number), as well as explicitly describing the technology. An example of a technology explicit end-use process is: the conversion of electricity (1PJ) to space heat (3PJ) using heat pumps. In OPENZ, data describing these processes are mainly drawn from the 2006/2007 Energy End Use Database.
- *Energy Savings Measures*. This is an OPENZ row that quantitatively describes the amount of 'delivered energy' that can be 'saved' by a particular energy saving measure. The 'energy savings' measures are rarely specific to one end-use conversion technology, often applying to a number of technologies in a rather general/non-attributable fashion. An example of an 'energy savings measure' is 'zone control in commercial buildings.' In

[37] There are other 'processes' (conversion of an energy input to an energy output) in OPENZ, but they aren't end-use processes – e.g. the conversion of 'coal' to 'electricity'

OPENZ, data describing these ‘energy savings measures’ are drawn from (updated) data from Henderson (1994).

In the OPENZ model, each ‘technology-explicit end-use process’ and each ‘energy savings’ measure are entered as a row into OPENZ. The main blocks of rows in OPENZ are according:

- Household: Technology-Explicit End Use Processes (n=73)
- Primary Sector: Technology-Explicit End Use Processes (n=33)
- Commercial Sector: Technology-Explicit End Use Processes (n=46)
- Industrial Sector: Technology-Explicit End Use Processes (n=79)
- Transport and Storage Sector: Technology Explicit Processes (n=28)
- Household Sector: Energy Savings Measures (n=4)
- Primary Sector: Energy Savings Measures (n=9)
- Commercial Sector: Energy Savings Measures (n=109)
- Industrial Sector: Energy Savings Measures (n=61)
- Transport and Storage Sector: Energy Savings Measures (n=18)

In OPENZ, there is a potentiality for ‘double counting’ between the ‘technology explicit end-use processes’ and the ‘energy savings measures’, which was dealt with by eliminating the ‘energy savings measures’ if it was already taken account of in a ‘technology explicit end-use process’.

Table 6.1 summarises the distinctions between ‘technology explicit processes’ and ‘energy savings measures’ in OPENZ. Of most note, in the actual operationalisation of OPENZ, are the following distinctions:

- a certain minimum number of ‘technology explicit end-use processes’ must be contained in feasible solutions in OPENZ. At the very least, there must be at least one process in supplying each of 31 end-use categories, for a feasible solution. In an optimal solution, it is likely that there will be more than one ‘technology specific end-use process’, per end-use category.
- ‘energy savings’ of delivered energy are achieved: (i) in the technology explicit end-use processes, by ‘switching’ to a more efficient technology explicit process; (ii) by adopting an ‘energy savings measure’. In ‘adopting’ an ‘energy savings measure’, OPENZ immediately records an ‘energy savings’ by way of saving ‘delivered energy’ (positive entry). There is no need to calculate the *difference* in ‘delivered energy use’ which is the case between two alternative ‘technology explicit end-use processes’.

4.4 Technology-Explicit End-Use Processes Covered

4.4.1 Existing Technology-Explicit End-Use Processes Covered

A rich source of data on ‘existing’ processes, described in a ‘technology explicit’ format is the EECA End-Use database 2006/07[38]. The core database quantifies the conversion of ‘delivered energy’ via a ‘technology’ to an ‘energy end-use’ across 34 sectors. Extra data is also provided on the greenhouse gas emissions, thermal efficiency and spatial location of the energy use across 74 Territorial Local Authorities.

[38] EECA End-Use databases (1991/92, 1995/96, 2001/02, 2006/07) also provide some historical coverage of energy end-use in a ‘technologically explicit’ format.

Although it is possible to use this data across the 37 sectors, in OPENZ, it was decided to only use the 5 sector aggregation. (Household, Primary, Commercial, Industry, Transport and Storage) end data because: (1) it simplified the solution of the OPENZ equations as there were fewer with the 5 sector aggregation; (2) it maintained compatibility with the 'energy savings data' – refer to section 4.5.

In OPENZ, 'technology-explicit end-use processes' for existing processes are summarised in a series of tables for each aggregated sector (module):

- Household Sector (refer to Table 4.2)
- Primary Sector (refer to Table) 4.3
- Commercial Sector (refer to Table 4.4)
- Industrial Sector (refer to Table 4.5)
- Transport and Storage Sector(refer to Table 4.6)

Table 4.2 Household Sector: Existing Technology Explicit End-Use Processes

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajoules)	Thermal Efficiency
H347	Existing	Electricity	Dishwasher: Low Temperature Heat (<100 C), Water Heating	Dish Washer	2.50	1.00	0.40
H322	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	1.12	1.00	0.90
H317 A	Existing	Coal	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	6.64	1.00	0.15
H323 A	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	6.36	1.00	0.16
H323 B	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Electric Stovetop	1.25	1.00	0.80
H323 D	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Microwave	1.00	1.00	1.00
H334_B	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Oven & Cooktops	4.35	1.00	0.23
H337	Existing	Wood	Intermediate Heat (100-300 C), Cooking	Wood Cooking Oven	6.67	1.00	0.15
H324_A	Existing	Electricity	Lighting	Tungsten Incandescent Lights	16.08	1.00	0.06
H324_B	Existing	Electricity	Lighting	Compact Fluorescent Light	4.02	1.00	0.25
H324_C	Existing	Electricity	Lighting	Halogen Lightis	12.06	1.00	0.08
H324_E	Existing	Electricity	Lighting	'Non-Compact' Fluorescent Light	9.65	1.00	0.10
H325	Existing	Electricity	Low Temperature Heat (<100 C), Clothes Drying	Clothes Dryer	4.00	1.00	0.25
H318	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.82	1.00	0.55
H319	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire	10.00	1.00	0.10
H320	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	2.50	1.00	0.40
H326	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Existing Heat Pumps	0.50	1.00	2.00
H327	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater & Nightstore	1.00	1.00	1.00
H333	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.33	1.00	0.75
H355	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.25	1.00	0.80
H331	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	1.00	1.00	1.00
H338_A	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	3.33	1.00	0.30
H339	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire	10.00	1.00	0.10
H340	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	2.50	1.00	0.40
H328_C	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.25	1.00	0.80
H380	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Existing Technology Mix	1.33	1.00	0.75
H342	Existing	Solar (Elect +Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas/elec boosted& elect pu	1.07	1.00	0.94
H332	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Water Heating	Direct Heat	1.00	1.00	1.00
H338	Existing	Petrol	Motive Power, Mobile	Internal Combustion (Lawnmower)	3.34	1.00	0.30
H329	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.33	1.00	0.75
H330	Existing	Electricity	Refrigeration	Refrigeration Systems	1.18	1.00	0.85
H343	Existing	Electricity	Spa Pools: Low Temperature Heat (<100 C), Water Heating	Water Heater	2.50	1.00	0.40
H346	Existing	Electricity	Space Cooling	Heat Pumps	0.50	1.00	2.00
H400	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
H404	Existing	Electricity	Transport, Land (Cars)	Electric Motor (Land Transport)	1.05	1.00	0.95
H401	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
H402	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	7.69	1.00	0.13
H403	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12

Table 4.3 Primary Sector: Existing Technology Explicit End-Use Processes

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajolues)	Thermal Efficiency
P9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	1.00	1.00	1.00
P10	Existing	Electricity	Intermediate Heat (100-300 C), Process Requirements	Resistance Heater	1.00	1.00	1.00
P17	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process Requirements	Boiler Systems	1.47	1.00	0.68
P21	Existing	Natural Gas	Intermediate Heat (100-300 C), Process Requirements	Boiler Systems	1.43	1.00	0.70
P1	Existing	Diesel	Kiln/Furnace_ High Temperature Heat (>300 C), Process Requirements	Furnace/Kiln	1.47	1.00	0.68
P18	Existing	Fuel Oil	Kiln/Furnance_Intermediate Heat (100-300 C), Process Requirements	Furnace/Kiln	1.47	1.00	0.68
P2	Existing	Diesel	Kiln/Furnance_Low Temperature Heat (<100 C), Process Requirements	Furnace/Kiln	1.47	1.00	0.68
P11	Existing	Electricity	Lighting	Lights	11.99	1.00	0.08
P12	Existing	Electricity	Low Temperature Heat (<100 C), Process Requirements	Resistance Heater	1.00	1.00	1.00
P1	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.33	1.00	0.75
P3	Existing	Diesel	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.30	1.00	0.77
P22	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.33	1.00	0.75
P13	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.14	1.00	0.88
P4	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
P23	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	8.32	1.00	0.12
P5	Existing	Diesel	Motive Power, Stationary	Stationary Engine	3.33	1.00	0.30
P14	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.33	1.00	0.75
P24	Existing	Petrol	Motive Power, Stationary	Stationary Engine	3.34	1.00	0.30
P15	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.33	1.00	0.75
P16	Existing	Electricity	Refrigeration	Refrigeration Systems	0.87	1.00	1.15
P1	Existing	Aviation Fuel	Transport, Air	Aircraft	3.98	1.00	0.25
P6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
P25	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	6.27	1.00	0.16
P7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	6.25	1.00	0.16
P26	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.32	1.00	0.12
P8	Existing	Diesel	Transport, Sea	Internal Combustion Engine (Sea Transport)	6.66	1.00	0.15
P19	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	6.66	1.00	0.15

Table 4.4 Commercial Sector: Existing Technology Explicit End-Use Processes

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajoules)	Thermal Efficiency
Com9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	1.00	1.00	1.00
Com10	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Elements	2.27	1.00	0.44
Com11	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	2.46	1.00	0.41
Com27	Existing	LPG	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	4.60	1.00	0.22
Com33	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	4.61	1.00	0.22
Com2	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	1.86	1.00	0.54
Com12	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	1.00	1.00	1.00
Com34	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	1.33	1.00	0.75
Com13	Existing	Electricity	Lighting	Lights	8.27	1.00	0.12
Com3	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.88	1.00	0.53
Com4	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	2.09	1.00	0.48
Com15	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump (for Heating)	0.50	1.00	2.00
Com16	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	1.00	1.00	1.00
Com23	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.43	1.00	0.70
Com24	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.48	1.00	0.68
Com26	Existing	Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	2.50	1.00	0.40
Com28	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.11	1.00	0.90
Com35	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.11	1.00	0.90
Com5	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.86	1.00	0.54
Com17	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Heat Pump (for Heating)	0.50	1.00	2.00
Com18	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.17	1.00	0.86
Com25	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	6.66	1.00	0.15
Com29	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	2.04	1.00	0.49
Com36	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.35	1.00	0.74
Com37	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.50	1.00	0.67
Com30	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	8.68	1.00	0.12
Com38	Existing	Natural Gas	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	7.64	1.00	0.13
Com19	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.33	1.00	0.75
Com21	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.33	1.00	0.75
Com22	Existing	Electricity	Refrigeration	Refrigeration Systems	1.27	1.00	0.79
Com8	Existing	Electricity	Space Cooling	Heat Pump (for Cooling)	0.55	1.00	1.80
Com14	Existing	Electricity	Street Lighting	Street Lights	8.25	1.00	0.12
Com1	Existing	Aviation Fuel	Transport, Air	Aircraft	4.00	1.00	0.25
Com6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	6.85	1.00	0.15
Com31	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.36	1.00	0.12
Com41	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	7.15	1.00	0.14
Com7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	6.28	1.00	0.16
Com32	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.34	1.00	0.12
Com39	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	7.77	1.00	0.13
Com48	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	6.66	1.00	0.15

Table 4.5 Industrial Sector: Existing Technology Explicit End-Use Processes

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajoules)	Thermal Efficiency
Ind19	Existing	Electricity	Al2O3 Reduction	Electric Furnace	2.27	1.00	0.44
Ind20	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	1.00	1.00	1.00
Ind3	Existing	Coal	Fe3O4 Reduction	Furnace/Kiln	9.09	1.00	0.11
Ind50	Existing	Natural Gas	Fe3O4 Reduction	Furnace/Kiln	9.09	1.00	0.11
Ind4	Existing	Coal	High Temperature Heat (>300 C), Process	Boiler Systems	1.85	1.00	0.54
Ind21	Existing	Electricity	High Temperature Heat (>300 C), Process	Electric Furnace	1.72	1.00	0.58
Ind23	Existing	Electricity	High Temperature Heat (>300 C), Process	Resistance Heater	1.00	1.00	1.00
Ind32	Existing	Fuel Oil	High Temperature Heat (>300 C), Process	Boiler Systems	1.47	1.00	0.68
Ind41	Existing	LPG	High Temperature Heat (>300 C), Process	Boiler Systems	2.12	1.00	0.47
Ind51	Existing	Natural Gas	High Temperature Heat (>300 C), Process	Boiler Systems	1.33	1.00	0.75
Ind13	Existing	Diesel	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	2.94	1.00	0.34
Ind24	Existing	Electricity	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	1.00	1.00	1.00
Ind35	Existing	Fuel Oil	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	2.93	1.00	0.34
Ind56	Existing	Natural Gas	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	1.89	1.00	0.53
Ind2	Existing	Black Liquor	Intermediate Heat (100-300 C), Process	Boiler Systems	1.67	1.00	0.60
Ind6	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	1.86	1.00	0.54
Ind12	Existing	Diesel	Intermediate Heat (100-300 C), Process	Boiler Systems	1.47	1.00	0.68
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	1.52	1.00	0.66
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	1.41	1.00	0.71
Ind40	Existing	Geothermal	Intermediate Heat (100-300 C), Process	Direct Heat	1.03	1.00	0.97
Ind43	Existing	LPG	Intermediate Heat (100-300 C), Process	Boiler Systems	1.36	1.00	0.74
Ind44	Existing	LPG	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	1.33	1.00	0.75
Ind53	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	1.44	1.00	0.70
Ind54	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	1.25	1.00	0.80
Ind69	Existing	Wood	Intermediate Heat (100-300 C), Process	Boiler Systems	3.12	1.00	0.32
Ind5	Existing	Coal	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	3.12	1.00	0.32
Ind11	Existing	Diesel	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	2.27	1.00	0.44
Ind22	Existing	Electricity	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	1.72	1.00	0.58
Ind33	Existing	Fuel Oil	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	6.41	1.00	0.16
Ind42	Existing	LPG	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	2.27	1.00	0.44
Ind52	Existing	Natural Gas	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	2.23	1.00	0.45
Ind68	Existing	Wood	Kiln/Furnace_ High Temperature Heat (>300 C), Process	Furnace/Kiln	3.33	1.00	0.30
Ind7	Existing	Coal	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	2.94	1.00	0.34
Ind55	Existing	Natural Gas	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	1.34	1.00	0.74
Ind71	Existing	Wood	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	3.12	1.00	0.32

Table 4.5 Industrial Sector: Existing Technology Explicit End-Use Processes (continued)

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajoules)	Thermal Efficiency
Ind9	Existing	Coal	Kiln/Furnace_Low Temperature Heat (<100 C), Process	Furnace/Kiln	1.85	1.00	0.54
Ind37	Existing	Fuel Oil	Kiln/Furnace_Low Temperature Heat (<100 C), Process	Furnace/Kiln	1.47	1.00	0.68
Ind59	Existing	Natural Gas	Kiln/Furnace_Low Temperature Heat (<100 C), Process	Furnace/Kiln	1.33	1.00	0.75
Ind73	Existing	Wood	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	3.13	1.00	0.32
Ind25	Existing	Electricity	Lighting	Lights	8.48	1.00	0.12
Ind8	Existing	Coal	Low Temperature Heat (<100 C), Process	Boiler Systems	1.85	1.00	0.54
Ind14	Existing	Diesel	Low Temperature Heat (<100 C), Process	Boiler Systems	1.44	1.00	0.70
Ind26	Existing	Electricity	Low Temperature Heat (<100 C), Process	Heat Pump (for Heating)	0.50	1.00	2.00
Ind27	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	1.00	1.00	1.00
Ind28	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	1.00	1.00	1.00
Ind36	Existing	Fuel Oil	Low Temperature Heat (<100 C), Process	Boiler Systems	1.94	1.00	0.52
Ind45	Existing	LPG	Low Temperature Heat (<100 C), Process	Boiler Systems	1.33	1.00	0.75
Ind57	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Boiler Systems	2.11	1.00	0.47
Ind58	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Burner (Direct Heat)	1.11	1.00	0.90
Ind72	Existing	Wood	Low Temperature Heat (<100 C), Process	Boiler Systems	3.12	1.00	0.32
Ind60	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.11	1.00	0.90
Ind10	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.85	1.00	0.54
Ind38	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.48	1.00	0.68
Ind46	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.33	1.00	0.75
Ind61	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.33	1.00	0.75
Ind15	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	7.77	1.00	0.13
Ind47	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	8.34	1.00	0.12
Ind64	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	8.37	1.00	0.12
Ind16	Existing	Diesel	Motive Power, Stationary	Stationary Engine	3.94	1.00	0.25
Ind29	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.33	1.00	0.75
Ind39	Existing	Fuel Oil	Motive Power, Stationary	Stationary Engine	3.33	1.00	0.30
Ind65	Existing	Petrol	Motive Power, Stationary	Stationary Engine	3.33	1.00	0.30
Ind30	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.33	1.00	0.75
Ind31	Existing	Electricity	Refrigeration	Refrigeration Systems	0.56	1.00	1.80
Ind1	Existing	Aviation Fuel	Transport, Air	Aircraft	3.72	1.00	0.27
Ind17	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Ind75	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	1.05	1.00	0.95
Ind48	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.34	1.00	0.12
Ind74	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	7.69	1.00	0.13
Ind66	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Ind18	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	6.26	1.00	0.16
Ind49	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Ind62	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	7.98	1.00	0.13
Ind63	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	7.72	1.00	0.13
Ind67	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	7.15	1.00	0.14

Table 4.6 Transport and Storage Sector: Existing Technology Explicit End-Use Processes

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajoules)	Thermal Efficiency
Trans8	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	1.00	1.00	1.00
Trans9	Existing	Electricity	Lighting	Lights	9.09	1.00	0.11
Trans10	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.33	1.00	0.75
Trans1	Existing	Aviation Fuel	Transport, Air	Aircraft	3.45	1.00	0.29
Trans3	Existing	Diesel	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	6.25	1.00	0.16
Trans11	Existing	Electricity	Transport, Land (Buses)	Electric Motor	1.43	1.00	0.70
Trans15	Existing	LPG	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Trans18	Existing	Natural Gas	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	7.16	1.00	0.14
Trans20	Existing	Petrol	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Trans4	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Trans24	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	1.05	1.00	0.95
Trans16	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Trans23	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	7.69	1.00	0.13
Trans21	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Trans5	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	6.25	1.00	0.16
Trans17	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.34	1.00	0.12
Trans19	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	7.75	1.00	0.13
Trans22	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
Trans7	Existing	Diesel	Transport, Rail (Freight)	Locomotive (Rail)	11.11	1.00	0.09
Trans13	Existing	Electricity	Transport, Rail (Freight)	Electric Motor	1.43	1.00	0.70
Trans2	Existing	Coal	Transport, Rail (Passenger)	Locomotive (Rail)	11.11	1.00	0.09
Trans6	Existing	Diesel	Transport, Rail (Passenger)	Locomotive (Rail)	11.11	1.00	0.09
Trans12	Existing	Electricity	Transport, Rail (Passenger)	Electric Motor	1.43	1.00	0.70
Trans14	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	6.67	1.00	0.15

4.4.2 New Technology-Explicit End-Use Processes Covered

Primarily for the Household Sector, EECA staff provided useful data that enabled us to quantitatively characterise a number of 'new' technology-explicit processes, not currently included in the EECA End-Use database. These so-called new processes are not in the EECA End-Use database because: (1) they currently used only very small amounts of energy; or (2) they are 'new and emerging' technologies. EECA staff for each of these 'new processes' provided data on: first-law (enthalpic) efficiencies, power ratings, capital cost, lifetimes and projected levels of maximum uptake (refer to Table D.1 in Appendix D).

The 'new technology-explicit processes' are summarised for;

- Household Sector (by Table 4.8)
- All Other Sectors (by Table 4.7)[39]

Table 4.7 All Non- Household Sectors : New Technology Explicit End-Use Processes

Process Codes	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajolues)	Thermal Efficiency
P27	LPG	Transport, Land (Cars)	Internal Combustion Engine	8.33	1.00	0.12
Com44, P29, Ind76, Trans25	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine	1.62	1.00	0.62
Com43	Electricity	Transport, Land (Cars)	Internal Combustion Engine	1.05	1.00	0.95
Com45, P30, Ind77, Trans26	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine	8.33	1.00	0.12
Com47, P32, Ind79, Trans28	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine	8.33	1.00	0.12
Com42, P28	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine	7.69	1.00	0.13
Com46, P31, Ind78, Trans27	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine	11.11	1.00	0.09

[39] There is an obvious lack of new technology data for the other sectors. These new technologies are, however, essentially captured by the data outlined in the 'energy savings measures' (Section 4.5).

Table 4.8 Household Sector: New Technology Explicit End-Use Processes

Process Code #	Existing/ New	Delivered Energy	End-Use Energy	Technology	Delivered Energy (Terajoules)	End-Use Energy (Terajoules)	Thermal Efficiency
H334	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Ovens	15.87	1.00	0.06
H334_A	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Cooktops	2.50	1.00	0.40
H324_D	New	Electricity	Lighting	LED Lights	2.50	1.00	0.40
H326_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.03 kW reverse cycle	0.33	1.00	3.03
H326_B	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.88 kW reverse cycle	0.38	1.00	2.62
H326_C	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 3.94 kW reverse cycle	0.42	1.00	2.38
H327_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	1.00	1.00	1.00
H363	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Night Store	1.00	1.00	1.00
H333_A	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (unflued)	1.25	1.00	0.80
H333_B	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (flued)	1.43	1.00	0.70
H335_A	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, unflued, bayonet fitting c	1.05	1.00	0.95
H335_B	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, flued	1.25	1.00	0.80
H360	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Central Heating	1.11	1.00	0.90
H345	New	Wood	Low Temperature Heat (<100 C), Space Heating	Wood pellet stoves	1.33	1.00	0.75
H338_B	New	Wood	Low Temperature Heat (<100 C), Space Heating + Low Temperature Heat (<100 C), Water Heating	Enclosed wood burner with wet back, space h	1.43	1.00	0.70
H328	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	1.43	1.00	0.70
H328_A	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	1.11	1.00	0.90
H344_B	New	LPG	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	1.20	1.00	0.84
H344_A	new	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	1.20	1.00	0.84
H380_A	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	1.54	1.00	0.65
H380_B	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	1.18	1.00	0.85
H342_A	New	Solar (+Elect)	Low Temperature Heat (<100 C), Water Heating	Solar water heater, electricity boosted & elect	1.05	1.00	0.95
H342_B	New	Solar (+Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas boosted& elect pump	1.13	1.00	0.89
H346_A	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.35	1.00	2.87
H346_B	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.38	1.00	2.62
H346_C	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.42	1.00	2.38
H408	New	Methanol 15% with Petr	Transport, Land	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
H405	New	Electicity & Petrol	Transport, Land (Cars)	Hybrid Electric Motor & Internal Combustion E	1.62	1.00	0.62
H406	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	8.33	1.00	0.12
H407	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	11.11	1.00	0.09

4.5 Energy Savings Measures Covered

The data for ‘energy savings measures’ based on updated data from Henderson (1994). Henderson (1994) developed a number of ‘supply curves’ for improving the efficiency of end-use of energy in New Zealand. It does this covering four demand sectors: residential, commercial, industrial (including agricultural) and transport; across six delivered energy types: electricity, gas, oil, coal, wood and geothermal heat. Implicitly there is also some recognition and characterisation of end-uses of energy as the analysis also draws upon the 1991/92 EECA End-Use Database.

The data from Henderson (1994), although it implicitly made references to energy end-uses (e.g. lighting, refrigeration), it only measured ‘energy savings’ in terms of delivered energy units (GWh). For example, Henderson (1994) quantifies the ‘energy savings’ in the Commercial Sector from a ‘low cost lamp upgrade’ to be 56 GWh/year (202 TJ/yr). This meant that in OPENZ the ‘logic’ of these so-called ‘energy savings measures’ was different to the ‘logic’ ‘Technology Explicit End-Uses Processes’.

- ‘Technology Explicit End-Use Processes’: OPENZ selects the most energy efficient (if that is the objective function) mix of processes for satisfying an end-use demand. In selecting, the most energy efficient processes (say for lighting), there is a measurable decrease in delivered energy use (say electricity).
- ‘Energy Savings Measures’: OPENZ will only select an ‘Energy Savings Measure’ (if minimising cost is the objective function) if the cost ($) of saving a unit of electricity is less than the cost ($) of generating another unit of electricity.[40]

The data from Henderson (1994) had to be updated before it could be entered into OPENZ. This involved a number of steps:

- *Step One:* Elimination of any processes that were already accounted for in the EECA Database processes or the ‘new’ processes in that format;
- *Step Two:* Adjustment for inflation of the ‘cost data’, using where appropriate the CPI and PPI;
- *Step Three:* Change the magnitude of the energy savings (GWh, TJ) according to the change in the ‘delivered energy→ energy end-use’ magnitude over the 1991/92 to 2006/07 period. For example, according to the EECA Energy Use Databases, the amount of electricity used in the Commercial Sector for space heating increased 2.77 times (3,188 TJ/ 1,152TJ) – so therefore all energy efficiency measures relating to electricity usage for space heating in the commercial sector, were multiplied by a factor of 2.77;
- *Step Four:* Estimation of the amount of ‘savings’ already actioned by this measure between 1991/92 and 2006/07.

The updated Henderson’s (1994) data of ‘energy savings’ measures, included in OPENZ are summarised by Tables 4.9 to 4.13.

[40] This is the logic of the ‘Supply Curve of Energy Efficiency Conservation’ measures advocated by Henderson (1994) following the lead of Lovins (1985). That is, by adopting ‘energy efficiency / conservation measures, there is an ‘energy savings.’ These ‘energy savings’ can be aggregated to form a ‘supply curve’ of energy saved and therefore saved ‘energy’ not needed to be produced in the first place.

Table 4.9 Industrial Sector: Energy Savings Measures

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Ind90	Better Insulation of Cold and Cool stores (floor, wall and ceiling)	Electricity	Refrigeration	0.51
Ind102	Cogeneration	Natural Gas & LPG	Elect & Process Heat	11.89
Ind81	Controlled Door Opening in Cold and Cool Stores	Electricity	Refrigeration	0.76
Ind81	Cool Chain Concept in Food Industry	Electricity	Refrigeration	0.21
Ind132	Distributional Efficiency (local heaters, pipe and cylinder insulation)	Coal	Water Heating	0.06
Ind114	Distributional Efficiency (local heaters, pipe and cylinder insulation)	Natural Gas & LPG	Water Heating	0.02
Ind133	Generally Improved O&M (housekeeping, process control and management)	Coal	General Industrial	0.85
Ind138	Generally Improved O&M (housekeeping, process control and management)	Geothermal	General Industrial	0.16
Ind113	Generally Improved O&M (housekeeping, process control and management)	Natural Gas & LPG	General Industrial	0.93
Ind117	Generally Improved O&M (housekeeping, process control and management)	Oil Products	General Industrial	0.60
Ind137	Generally Improved O&M (housekeeping, process control and management)	Wood	General Industrial	1.41
Ind91	Generally Improved Operations and Maintenance (housekeeping, process controls and management)	Electricity	General Industrial	1.43
Ind128	Grey Water Heat Recovery	Coal	Water Heating	0.19
Ind95	Grey Water Heat Recovery	Electricity	Water Heating	0.03
Ind110	Grey Water Heat Recovery	Natural Gas & LPG	Water Heating	0.08
Ind121	Grey Water Heat Recovery	Oil Products	Water Heating	0.01
Ind89	Higher Efficiency Electronic Equipment	Electricity	Electronics & Electrical End-Uses	0.01
Ind131	Improved Boiler Efficiency	Coal	Med Temp Process Heat	0.21
Ind106	Improved Boiler Efficiency	Natural Gas & LPG	Med Temp Process Heat	0.55
Ind120	Improved Boiler Efficiency	Oil Products	Med Temp Process Heat	0.21
Ind136	Improved Boiler Efficiency	Wood	Med Temp Process Heat	1.59
Ind87	Improved Efficiency from Existing Cells at NZ Aluminium Smelters (better material and design)	Electricity	General_Basic Metals	1.28
Ind103	Improved O&M steel	Natural Gas & LPG	Fe2O3 Reduction	0.02
Ind86	Improved Operation of Electronic Equipment	Electricity	Electronics & Electrical End-Uses	0.02
Ind88	Improved Transmissions (cogged V-belts etc.)	Electricity	Motive Power_Stat	1.19

Table 4.9 Industrial Sector: Energy Savings Measures (continued)

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Ind85	Improvements incl. Cogeneration from Waste Heat at NZ Steel	Electricity	General_Basic Metals	1.55
Ind99	Induction Heating in Metal Fabrication Industries (electricity substitution)	Electricity	High Temp Process Heat	0.06
Ind93	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	Electricity	High Temp Process Heat	0.08
Ind107	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	Natural Gas & LPG	High Temp Process Heat	0.22
Ind124	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	Oil Products	High Temp Process Heat	0.03
Ind84	Install New Cells (larger, magnetically compresses at NZ Aluminium Smelters	Electricity	General_Basic Metals	0.50
Ind112	Instantaneous Water Heating	Natural Gas & LPG	Water Heating	0.04
Ind130	Insulation of Hot Water Tanks and Pipes	Coal	Water Heating	0.14
Ind96	Insulation of Hot Water Tanks and Pipes	Electricity	Water Heating	0.03
Ind111	Insulation of Hot Water Tanks and Pipes	Natural Gas & LPG	Water Heating	0.05
Ind122	Insulation of Hot Water Tanks and Pipes	Oil Products	Water Heating	0.01
Ind82	Motor Efficiency/ sizing improvements	Electricity	Motive Power_Stat	3.88
Ind129	MVR Evaporators in Food Processing	Coal	Med Temp Process Heat	0.13
Ind109	MVR Evaporators in Food Processing	Natural Gas & LPG	Med Temp Process Heat	0.21
Ind119	MVR Evaporators in Food Processing	Oil Products	Med Temp Process Heat	0.13
Ind97	Plate Freezing in the Meat Industry	Electricity	Refrigeration	0.87
Ind80	Refining and Rejects Handling in Forest Products	Electricity	General Wood Processing & Wood Prc	0.68
Ind83	Upgrade Fluorescents (reflectors-triphoshors,CFLs)	Electricity	Lighting	0.08
Ind80	Upgrade Gas Discharge lamps (replace HG with High press Na.)	Electricity	Lighting	0.02
Ind94	Variable Speed Pumps /fans (eg, freezers and chillers)	Electricity	Motors_Various	1.84
Ind127	WH Recovery	Coal	Water Heating	0.20
Ind105	WH Recovery	Natural Gas & LPG	Water Heating	0.17
Ind116	WH Recovery	Oil Products	Water Heating	0.19
Ind134	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	Coal	Water Heating	0.11
Ind115	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	Natural Gas & LPG	Water Heating	0.04
Ind125	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	Oil Products	Water Heating	0.01

Table 4.10 Commercial Sector: Energy Savings Measures

Process (	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Com50	Appropriate Chiller Size and Technology	Electricity	Space Cooling	0.12
Com65	Automatic Controls (occupancy, time-switching, daylight linked)	Electricity	Lighting	0.60
Com97	Cogeneration, especially in hospitals and pools	Natural Gas & LP	General Commercial	0.51
Com92	Conndensing Boilers/European Design Practices	Natural Gas & LP	Water Heating	1.02
Com77	Cooling Efficiencies	Electricity	Space Cooling	0.12
Com123	Correct Heating Choice (radiant/convector/air)	Coal	Space Heating	0.13
Com61	Correct Heating Choice (radiant/convector/air)	Electricity	Space Heating	0.45
Com93	Correct Heating Choice (radiant/convector/air)	Natural Gas & LP	Space Heating	0.19
Com136	Correct Heating Choice (radiant/convector/air)	Wood	Space Heating	0.03
Com48	Delamping /Fine- tuning	Electricity	Lighting	0.37
Com55	Design Changes (Task lighting, Uplighting,daylighting)	Electricity	Lighting	0.86
Com122	Distribution Efficiency (local heaters, pipes and cylinder insulation)	Coal	Water Heating	0.01
Com60	Distribution Efficiency (local heaters, pipes and cylinder insulation)	Electricity	Water Heating	0.20
Com147	Distribution Efficiency (local heaters, pipes and cylinder insulation)	Geothermal	Water Heating	0.01
Com90	Distribution Efficiency (local heaters, pipes and cylinder insulation)	Natural Gas & LP	Water Heating	0.03
Com130	Economisers	Coal	General Commercial	0.17
Com129	Exhaust Air Recovery	Coal	Space Heating	0.08
Com100	Exhaust Air Recovery	Natural Gas & LP	Space Heating	0.12
Com140	Exhaust Air Recovery	Wood	Space Heating	0.03
Com76	Exhaust Heat Recovery	Electricity	Space Heating	0.27
Com121	Flow Controls (Spray Nozzles, Shower Heads etc.)	Coal	Water Heating	0.03
Com59	Flow Controls (Spray Nozzles, Shower Heads etc.)	Electricity	Water Heating	0.50
Com146	Flow Controls (Spray Nozzles, Shower Heads etc.)	Geothermal	Water Heating	0.01
Com88	Flow Controls (Spray Nozzles, Shower Heads etc.)	Natural Gas & LP	Water Heating	0.08
Com94	Generally Improved O&M (housekeeping, process control and management)	Natural Gas & LP	Water Heating	0.08
Com83	Grey Water Heat Exchanges in Commercial Kitchens and Laundries	Electricity	Water Heating	0.03
Com128	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absor	Coal	Water Heating	0.04
Com71	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absor	Electricity	Water Heating	0.55
Com154	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absor	Geothermal	Water Heating	0.01
Com99	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absor	Natural Gas & LP	Water Heating	0.10
Com84	High Cost Lamp Upgrade (low loss ballasts, diffusers, high pressure sodium lamps)	Electricity	Lighting	0.80
Com126	Improved envelope design (insulation, glazing, shading, window size, thermal mass, pa	Coal	Space Heating	0.87
Com66	Improved envelope design (insulation, glazing, shading, window size, thermal mass, pa	Electricity	Space Heating	1.67
Com111	Improved envelope design (insulation, glazing, shading, window size, thermal mass, pa	Fuel Oil	Space Heating	0.01
Com152	Improved envelope design (insulation, glazing, shading, window size, thermal mass, pa	Geothermal	Space Heating	0.03
Com96	Improved envelope design (insulation, glazing, shading, window size, thermal mass, pa	Natural Gas & LP	Space Heating	1.30
Com138	Improved envelope design (insulation, glazing, shading, window size, thermal mass, pa	Wood	Space Heating	0.24

Table 4.10 Commercial Sector: Energy Savings Measures (continued)

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Com73	Improved Controls	Electricity	Space Cooling	0.07
Com75	Improved Envelope Design	Electricity	Space Cooling	0.23
Com79	Improved Operations and Maintenance	Electricity	Space Cooling	0.08
Com67	Improved Operations and Maintenance (after hours use, cleaning staff scheduling, occupant switching,	Electricity	Lighting	0.34
Com124	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching,	Coal	Space Heating	0.07
Com132	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching,	Coal	Space Heating	0.03
Com82	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching,	Electricity	Space Heating	0.09
Com149	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching,	Geothermal	Space Heating	0.01
Com102	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching,	Natural Gas & LPG	Space Heating	0.04
Com143	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching,	Wood	Space Heating	0.01
Com62	Improved Operations and Maintenance (eg, Temperature Settings, Distribution Controls, Drips, Leaks)	Electricity	Water Heating	0.50
Com74	Induction Cooking in Commercial Kitchens	Electricity	Cooking	0.32
Com72	Instantaneous Water Heaters	Electricity	Water Heating	1.57
Com91	Instantaneous Water Heaters	Natural Gas & LPG	Water Heating	0.16
Com119	Integrated Design	Coal	Space Heating	0.58
Com144	Integrated Design	Geothermal	Space Heating	0.04
Com86	Integrated Design	Natural Gas & LPG	Space Heating	0.87
Com134	Integrated Design	Wood	Space Heating	0.12
Com52	Internal Heat Gain Reduction	Electricity	Space Cooling	0.49
Com49	Low Cost Lamp Upgrade: 38mm to 26mm)	Electricity	Lighting	0.43
Com63	Medium Cost Lamp Upgrade (Reflectors-triphoshor tubes,CFLs)	Electricity	Lighting	2.28
Com54	Motor Sizing	Electricity	Motive Power_Stationar	0.41
Com51	New Buildings/ Integrated Design	Electricity	Space Cooling	0.51
Com53	New Buildings/ Integrated Design	Electricity	General Commercial	1.61
Com57	Operational (office equipment management, switch off, optimum location)	Electricity	Electronics & Electrical E	3.96
Com125	Plant Control (eg, compensator control with reset)	Coal	Space Heating	0.09
Com64	Plant Control (eg, compensator control with reset)	Electricity	Space Heating	0.29
Com95	Plant Control (eg, compensator control with reset)	Natural Gas & LPG	Space Heating	0.13
Com137	Plant Control (eg, compensator control with reset)	Wood	Space Heating	0.03
Com69	Purchase (selection of efficient equipment)	Electricity	Electronics & Electrical E	1.17
Com120	Recommissioning	Coal	Space Heating	0.35
Com56	Recommissioning	Electricity	Space Heating	1.08
Com58	Recommissioning	Electricity	Space Cooling	0.61
Com105	Recommissioning	Fuel Oil	Space Heating	0.00
Com145	Recommissioning	Geothermal	Space Heating	0.03
Com87	Recommissioning	Natural Gas & LPG	Space Heating	0.52
Com135	Recommissioning	Wood	Space Heating	0.07

Table 4.10 Commercial Sector: Energy Savings Measures (continued)

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Com127	Re-engineering	Coal	Space Heating	0.27
Com68	Re-engineering	Electricity	Space Heating	0.93
Com112	Re-engineering	Fuel Oil	Space Heating	0.00
Com153	Re-engineering	Geothermal	Space Heating	0.01
Com98	Re-engineering	Natural Gas & LPG	Space Heating	0.41
Com139	Re-engineering	Wood	Space Heating	0.07
Com81	Variable Speed Drives on Pumps in Hospitals and Polls	Electricity	Pumping	0.13
Com70	Ventilation Efficiency	Electricity	Space Cooling	0.12
Com131	Zone Control (eg, thermostatic radiator valves)	Coal	Space Heating	0.08
Com78	Zone Control (eg, thermostatic radiator valves)	Electricity	Space Heating	0.28
Com101	Zone Control (eg, thermostatic radiator valves)	Natural Gas & LPG	Space Heating	0.12
Com142	Zone Control (eg, thermostatic radiator valves)	Wood	Space Heating	0.03

Table 4.11 Primary Sector: Energy Savings Measures

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
P38	"Tractor facts"programe(operator education)	Oil Products	Motive Power_Mobile	1.00
P39	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	Coal	Low Temp Process He	0.22
P35	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	Natural Gas & LPG	Low Temp Process He	0.07
P36	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	Oil Products	Low Temp Process He	0.06
P37	Efficiency Improvement for Kiln Drying of Forest/Agricultural products	Oil Products	Med Temp Process H	0.27

Table 4.12 Transport and Storage Sector: Energy Savings Measures

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Tran33	Increase load factor of **passenger air** services from 60% to 70%	Diesel & Petrol	Transport, Land (Cars)	4.43
Tran34	Shift passenger transport from air to rail-ship	Avaition & Diesel & Petrol	Air Transport	6.93
Tran35	Increase load factor of **coastal freight** services from 50% to 60%	Diesel & Fuel Oil	Sea Transport	1.17
Tran36	Increase load factor of **passenger rail** services from 30% to 40%	Diesel & Elect	Transport, Rail (Passenger)	0.12
Tran41	Increase load factor of **passengers bus** services from 30% to 40%	Diesel & Petrol	Transport, Land (Buses)	2.35
Tran42	Increase load factor of **light goods** vehicles from 20% to 30%	Diesel & Petrol	Transport, Land (Freight)	18.28
Tran43	Increase load factor of **heavy goods** vehicles from 50% to 60%	Diesel & Petrol	Transport, Land (Freight)	11.49
Tran44	Shift road freight to rail	Diesel & Petrol	Transport, Land (Freight)	10.67
Tran45	Improve road surfaces and alignment	Diesel & Petrol	Transport, Land (Cars & Freight)	1.85

Table 4.13 Household Sector: Energy Savings Measures

Process Code	Energy Savings Measure	Delivered Energy	End-Use	Estimated Saved Delivered Energy By 2026/27 (PJ), Techincal Potential
Tran30	Car Pool to Increase Occupancy from 1.25 to 2 per vehicle in Commuting	Diesel & Petrol	Transport, Land (Cars)	6.32
Tran40	Driver Education Programmes, tune-up, tyres, exhaust testing (assume = "O&M")	Diesel & Petrol	Transport, Land (Cars)	5.50
Tran39	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km a US projection)	Diesel & Petrol	Transport, Land (Cars)	15.26
Tran38	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	Diesel & Petrol	Transport, Land (Cars)	10.22
H410	Infiltration Reduction	Electricity	Space Heating	0.51
H411	New House Market	Electricity	Space Heating	0.69
H412	Passive Solar Refits	Electricity	Space Heating	0.13
Tran29	Reduce Average Car Engine Size from 2000 to 1700cc (fuel consumption from 9.2 to8.7 1/100 km	Diesel & Petrol	Transport, Land (Cars)	7.30
Tran32	Telecommute 4 out of 5 days per week	Diesel & Petrol	Transport, Land (Cars)	4.50
Tran31	Use bicycles more for Commuting	Diesel & Petrol	Transport, Land (Cars)	5.41

4.6 Economic Cost

The total economic cost of each 'technology-explicit end-use process' and 'Energy Savings Measure' included the *direct energy cost, any other operating cost and the capital cost.* The default discount rate of 10% was used for annualising capital costs.

4.6.1 Energy Cost

Care needs to be taken not to double-count energy costs. For example, the cost of generating electricity has already been accounted for in the energy supply module processes, and therefore this cost should not be taken into account by the end-use processes that use inputs of electricity. Instead, those end-use processes that use electricity should only account for the ex-generation costs of electricity –viz, distribution, wholesale and retail costs.

Essentially in OPENZ, energy costs ($) of 'technology explicit end-use processes' are taken account of in three different ways:

- *Electricity, Natural Gas and Biogas*: Since the production (generation) cost of these delivered energy forms are already endogenously determined within OPENZ, only the ex-production/ex-generation energy costs are entered into OPENZ energy demand module processes.
- *Coal, Geothermal, LPG, Wood, Diesel and Petrol*[41]: The total retail costs ($) are entered into OPENZ in the energy demand module processes – viz, the energy costs/prices for these delivered energy types are entered into OPENZ as exogenous data.
- *Ethanol and Methanol*: For ethanol and methanol it proved difficult to separate a 'retail and wholesale' margin, so therefore in OPENZ all energy costs ($) were entered in the energy supply module processes that produced methanol and ethanol.

4.6.2 Capital Costs

Capital cost ($) for energy end-use processes are often of a similar magnitude to energy costs ($) and sometimes there is a 'trade-off' between 'energy savings' that can be achieved versus 'capital plant' investment – 'energy savings' from 'heat pumps' in the household sector is a good example of this.

Capital costs ($) that were entered into OPENZ were calculated using a variety of methods and data sources:

(1) Boiler Plant Analysis, using data from a Heat Plant database, combined with data from the SCENZ Capital Cost Estimator.
(2) Non-Boiler Plant Capital for Non-Household Sector, using data supplied by EECA, combined with data from SCENZ Capital Cost Estimator.
(3) Household Sector Data, using data supplied by EECA.

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[41] Due to data constraints, the cost of synthetic diesel and petrol, was entered into the appropriate processes in the Energy Supply Module as a '*relativity' to non-synthetic diesel and petrol*. That is
(i) *if* synthetic diesel/petrol was the same cost as non-synthetic diesel/petrol to produce, *then* zero is entered in the energy supply module process;
(ii) *if* synthetic diesel and petrol is more expensive to produce, *then* a negative number is entered (into the energy supply module process) to indicate how much more expensive it was;
(iii) *if* synthetic diesel and petrol is less expensive to produce, *then* a positive number is entered (into the energy supply module process) to indicate how much less expensive it was.

The above capital costs [(1), (2), (3)] relate to the ‘technology explicit end-use processes’. The capital costs for the ‘energy savings measure’ options are encapsulated in the costs provided by Henderson (1994) which were updated before being entered into OPENZ. From the data provided by Henderson (1994) it is not possible to separate out the ‘capital costs’ from other costs.

Boiler Plant Analysis: Boilers account for most of energy use in the industrial sector, and a significant amount of the energy use in the commercial sector, as well as being also used to some extent in the agricultural sector.

East Harbour Management Services (2008) maintain a database of all boilers used in New Zealand, of >100kW, or in sites where the combined capacity is >100kW. As such, there is a very detailed coverage of boiler plants in New Zealand, including the following data fields: company, plant name, boiler make, boiler type, year installed, capacity (MW), output type (hot water, steam, saturated steam, superheated steam and so forth), output (t/h), pressure (bars), boiler and heat output (GWh), annual process heat (GWh), co-generated electricity output (kWh) temperature of heat (ºC), boiler efficiency, fuel use, load factor, annual energy use (TJ) and annual CO_2e emissions (tonnes).

This data from East Harbour Management Services (2009) database for the year ending 31 December 2006, was combined with data from the SCENZ Capital Cost Estimator (Jesen and Earl, 2006) and EECA Energy Use Database 2006/07, to estimate the capital cost of each ‘boiler-based end-use process’ in OPENZ. The *first step* involved estimating the very few missing data points in the East Harbour database (mainly efficiencies). For example, in the case of missing boiler efficiencies, this was achieved by extrapolating data from known boiler efficiencies – taking account of the type and rating of the boiler. The *second step* was to calculate the capital cost of each boiler in the East Harbour Database, based on using the SCENZ Capital Cost Estimator of Process Plants in New Zealand (Jesen and Earl, 2006 – this required specifying as an input into the calculator the ‘type’ of boiler, its ‘fuel type’ (delivered energy type) and its rated capacity. The *third step* involved calculating the annualised capital cost of each boiler using the capital cost from the previous step and lifetime data from the East Harbour database:

$$A = K/AF \qquad (4.1)$$

Where:

A = Annualised Capital Cost of Item ($)

K = Capital Cost of an Item ($, current)
AF = Annuity Factor

The annuity factor (AF) is:

$$(1-(1/(1 - i)^n))/i$$

Where:

i = Interest Rate (as a proportion)
n = Lifetime of the capital item

The *fourth step*, involved reconciling data from the 'EECA Energy Database' and the 'East Harbour Heat Plant Database' so as to obtain consistent data of boiler process outputs (TJ) and inputs (TJ) – refer to Table 4.14. The data from the 'East Harbour Heat Plant Database' was scaled at the record-by-record level, so that at the aggregative level the two datasets reconciled. The *fifth step* involved dividing the annualised capital cost of each boiler ($) from step three, by the output (TJ) from step four, to obtain the annualised capital cost ($) per output (TJ). Step five involved adjusting the step four data for a 'Lang Factor'. The Lang Factor is a multiplier that enables the total capital cost to be estimated from the equipment cost. For example, in an oil refinery the cost of the process equipment is relatively low, with significant costs involved in the installation of piping, insulation and expensive instruments. The appropriate Lang Factors were obtained from Earl, Boumon, Jesen and Wake (2005).

Non-Boiler Plant Equipment: Although 'Boiler Plant' accounts for most of the energy use in the industrial sector, as well as some energy use in other non-household sectors, there is also significant energy use by other equipment covered by the SCENZ Capital Cost Estimator – e.g. conveyers (auger and apron, belt and bucket, pneumatic), dryers (freeze, spray), electric motors, evaporators, fans, heat exchangers, industrial ovens, mixers, pumps, refrigeration units, separators, size reduction equipment, filtration plant and variable speed drives. Unfortunately, no inventory of this other equipment is available in New Zealand, which is analogous to the 'Boiler Plant' database maintained by East Harbour Management Services (2008). However, we were able to obtain capital cost estimates ($) of such equipment types that are covered by the EECA End Use Database, based on data supplied by EECA and literature searching. The annualised capital cost ($) were then calculated on a unit basis, and then scaled up by a multiplier so that the energy use data matched the data in the EECA database.

For *non-household sectors*, for some technologies covered by the SCENZ Capital Cost Estimator, data is available from the household costings (refer to the next section). This includes data, for example, for the following technologies: lights, car transport, cooking equipment, electronics, domestic-scale refrigerators/freezers, and domestic scale water-heaters.

Household Capital Costs: The *first step* in the cost estimation ($) process was to collect data for every process, covering: Unit Power Rating; Unit Thermal Efficiency; Unit Capital Cost; Units Required per Household; Total Cost of Capital per Household and Unit Lifetime The majority of this data were collected and verified by staff at the Energy Efficiency and Conservation Authority. This 'base data' required for the cost estimation process is summarised by Table D.1 (Appendix D). The *second step* in the cost estimation ($) process, was to calculate the annualised capital cost per unit of end-use energy (refer to equation 4.1). The estimates of the end use energy amounts were drawn from the EECA/database, combined with data on the 'saturation rates' of households requiring various end-uses. (Refer to Table 6.2a). Implicit in these energy costings is a 'loading divisibility/assumption', about the use of technologies – e.g. if 40% of household lighting is from incandescent lights and 60% from compact fluorescent lights, then it is assumed that the 'loading' is also split according to these percentages – this may not be the case, as there is some anecdotal evidence that households may for example use compact fluorescent lights more frequently at a higher loading.

Table 4.14 Comparison of Boiler Energy Use Data from the "EECA End Use' and 'East Harbour' Databases

		EECA End Use Database[1]			East Harbour Database[2,3]		
Delivered Energy Type	End Use Type	Delivered Energy (TJ)	End-Use Energy (TJ)	Efficiency	Delivered Energy (TJ)	End-Use Energy (TJ)	Efficiency
Black Liquor	Intermediate Heat (100-300 C), Process Requirements	21,700	13,020	0.60	17,419	10,282	0.59
Coal	High & Inter. Temperature Heat, Process Requirements	9,055	4,873	0.54	12,532	9,777	0.78
Coal	Low Temperature Heat + Water Heat Process Requirements	2,544	1,373	0.54	971	745	0.77
Diesel	Intermediate Heat (100-300 C), Process Requirements	943	640	0.68	146	119	0.81
Diesel	Low Temperature Heat (<100 C), Process Requirements	178	124	0.69	280	227	0.81
Electricity	Low Temperature Heat (<100 C), Process Requirements	59	59	1.00	0	0	1.00
Fuel Oil	High & Inter. Temperature Heat, Process Requirements	421	278	0.66	964	783	0.81
Fuel Oil	Low Temperature Heat + Water Heat Process Requirements	52	30	0.58	31	22	0.70
LPG	High & Inter.Temperature Heat, Process Requirements	856	572	0.67	37	32	0.86
LPG	Low Temperature Heat (<100 C), Process Requirements	49	36	0.75	110	94	0.86
Natural Gas	High & Inter. Temperature Heat, Process Requirements	19,778	13,963	0.71	12,647	10,028	0.79
Natural Gas	Low Temperature Heat (<100 C), Water Heating	1,902	1,274	0.67	2,422	1,879	0.78
Wood	Intermediate Heat (100-300 C), Process Requirements	27,099	8,672	0.32	31,145	21,254	0.68
Wood	Low Temperature Heat (<100 C), Process Requirements	117	38	0.32	8,608	5,445	0.63
Total		84,752	44,951	0.53	87,313	60,686	0.70

Notes:
1. EECA End Use Database for the March year 2006/07
2. East Harbour Database is for the calendar year end 31 December 2006
3. East Harbour Database covers 'Heat Plant' >100 MW on one site

4.7 Energy Data for End-Use Processes and Energy Savings Measures

This involved two steps:

Step One: Entry of Input and Output Data: For the 'end-use processes', data were entered into OPENZ, in the same format as the EECA End Use Database 2006/07.That is all 'end-use processes' had two entries: *Input* (TJ, Heat Content), *Output* (TJ, Heat Content)[42]. Implicitly, the first law efficiency (enthalpy efficiency) is *output* divided by *input*. Analogous data was also derived for the 'new' technology explicit end-processes, using data collected and verified by EECA staff. For 'energy savings' measures, there was only one entry, which was the amount *of Delivered Energy Saved* (TJ, Heat Content)[43].

Step Two: Adjustment for Energy Quality. As argued in Appendix A, as elsewhere by Patterson (1993, 1996), for energy inputs to be aggregated they must be first of all adjusted for energy quality Appendix A outlines a number of possible ways of adjusting for energy quality: Gibbs Free Energy, Exergy, Emergy/Transformity, Available Work, OECD Thermal Equivalents, Fossil Fuel Equivalents and Quality Equivalents. For reasons explained in Appendix A and by Patterson (1993), the quality coefficients (derived from the quality equivalent methodology) are the preferred way of adjusting for energy quality in OPENZ. The delivered energy inputs, in the energy demand modules are therefore converted to quality equivalent terms by using the following quality coefficients:

1.2298 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Aviation Fuel
0.5418 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Coal
1.2298 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Diesel
2.0816 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Electricity
1.0633 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Fuel Oil
0.4457 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Geothermal
1.2298 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for LPG
1.3114 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Natural Gas & Methane
1.2298 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Petrol
1.1465 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Ethanol
1.1465 PJ Crude Oil Equivalents	*per*	1 PJ (ΔH)	for Methanol

4.8 Greenhouse Gas Emissions

As with economic cost ($) data, it is important that 'double counting' between 'primary energy → delivered energy' and 'delivered energy→end-uses of energy' be avoided. For example, for diesel GHG emissions for the process of crude oil → diesel and (say) diesel → transport (land) have to be separated into two components and not double counted. In this respect, end-use processes that involve the use of electricity are most critical. In this case the end use process of electricity → end-use has zero GHG emissions, with all of the GHG being 'indirect' and accounted for in the supply processes (coal, gas, hydro) that generate electricity.

[42] In OPENZ, the 'end-use processes' data were *normalised* in terms of one terajoule of end-use output, so that the solution vector was then expressed in terms of terajoule units of end-use output.

[43] In OPENZ, the 'energy savings measures' were *normalised* in terms of one terajoule of delivered energy, so that the solution vector was then expressed in terms of terajoule units of delivered energy saved.

The first step in calculating the greenhouse gas emissions (kilotonnes) for the 'technology-explicit end-use processes' and 'energy savings measures' row in OPENZ was to multiply the delivered energy input (PJ) by an emissions factor (kilotonnes/PJ). The emission factors were obtained from the MED (2008) publication 'New Zealand Greenhouse Gas Emissions 1990-2007.' This MED publication shows that N_2O and CH_4 emissions, depends to some extent, on the end-use technology (e.g. stationary vs. mobile engines) and the sector where it was used – these data fields are routinely available in OPENZ.

Not all of the end-use processes could easily be enumerated in this way using emission factors from the MED (2008) publication. In these cases emission factors were drawn from the Intergovernmental Panel on Climate Change (2006) publication. Of most note was the fact that the MED (2008) publication did not contain an emission factor for 'Black Liquor' which is a significant delivered energy source in the New Zealand Forest Processing industry. The emission factor for 'Black Liquor' was accordingly abstracted from the Intergovernmental Panel on Climate Change (2006) data.

The second step was to convert the kilotonnes of CO_2, CH_4 and N_2O to CO_2 equivalents, by using the standard conversion factors outlined by MED: That is, the data was equivalenced in terms of Global Warming Potential (GWP) using CO_2 kilotonnes as the numeraire[44]:

CO_2 = 1 (by definition)
CH_4 = 21
N_2O = 310

These GWPs are calculated for a specific time period, and therefore these 'equivalents' vary according to the time horizon. For example, CH_4 has a GWP of 25 (relative to CO_2 over 25 years), compared to 72 over 20 years. It is unclear what 'time horizon' was used by the MED (2008) for the above cited GWPs used in our calculations in OPENZ.

4.9 Household Sector Measures

In OPENZ, there were extra rows of data included in the household sector module to account for: (1) insulation options; (2) rebound effects from installing insulation and heat pumps.

4.9.1 Insulation Options

OPENZ considered 4 types of insulation options for the Household Sector:

H355 Ceiling Insulation
H356 Wall Insulation
H357 Floor Insulation
H358 Double Glazing

Upper bound limits are placed on the activities of these processes ($0.36 \leq$ H355; $0.55 \leq$ H356; $0.82 \leq$ H357; $0.91 \leq$ H358). The numeric values here are the proportion of households, not

[44] Incidentally, the same type of issue arises in 'adding up' delivered energy types of differing qualities. It is methodologically incorrect to add-up energy, measured in terms of 'heat content', when the energy types have differing abilities to be converted to useful energy (Patterson, 1983). Patterson (1983, 1996) has developed a mathematical method for measuring energy in terms of quality 'equivalents'. This method measures the relative ability of delivered energy types to be converted to useful outputs. This method is somewhat analogous to the method used to 'add up' (equivalence) greenhouse gases.

having this form of insulation – e.g., '0.36 ≤ H355' means that 36% of houses have no ceiling insulation which represents the percentage of homes that could adopt this type of technology.

The approach in OPENZ is to calculate the 'energy saved' by improved insulation, initially by assuming that there is no rebound effect. This 'saved energy' is then entered into the appropriate cells of OPENZ as 'positive values' as it represents energy that no longer needs to be used up. Hence, for example, if there was maximum uptake (as specified by the above ≤ constraints) and no rebound use of the 'saved energy' for ceiling insulation, then the 'saved energy' would be:

Geothermal	0.01 PJ
Wood	0.88 PJ
Coal	0.07 PJ
Electricity	0.67 PJ
LPG	0.24 PJ
Natural Gas	0.29 PJ

Details of the calculation[45] of these data are contained in the OPENZ spreadsheet interface (Opt Set Up/ B572:J625). These 'delivered energy' data will reduce to zero 'saved energy' if there is a 100% rebound effect, and instead the level of end-use delivery of space heat will increase, as recorded in appropriate cells of OPENZ (Opt Set Up Sheet/ BQ1351:BQ1354).

4.9.2 Rebound Effects

The 'default setting' for the 'rebound effect' for all home insulation modalities (ceiling, wall, floor, double glazing) is assumed to be 44%. That is, 44% of the 'energy savings' obtained from improved insulation, is actually used to heat homes to a higher level of comfort. The OPENZ model equations therefore for the 'default setting': (a) calculates the net energy savings (56% of the theoretical) of delivered energy inputs; (b) calculates the increase in space heating levels from the rebound effect. The 'default setting' in OPENZ at 44% for home insulation rebound effect was derived from Howden-Chapman *et al.* (2005, 2009) survey of 1,100 households in New Zealand. It needs to be noted that: (a) this 44% rebound effect for home insulation is significantly higher than that obtained for studies in other countries, which generally show a rebound effect for insulation in the range of 10-35% (Greening, et al, 2000; Haas and Biermayer, 2000; Schipper and Gribb, 2000). This higher than average rebound effect for New Zealand however is probably not unexpected due to the relatively poor level of insulation in New Zealand housing stock, which means that the motivation for improving insulation is not only to 'save energy' but almost equally important is to 'improve comfort levels', (b) there is no distinction, due to lack of data, in the rebound effect for the different types of insulation (ceiling, wall, floor, double glazing). That is, OPENZ applies the same percentage effect to all types of insulation. Future developments at OPENZ could easily apply different 'rebound effects' to different insulation types if the requisite empirical evidence becomes available.

The 'default setting' for the 'rebound effect' from newly installed heat pumps in OPENZ is 20%. This figure of 20% could be considered to be too low in view of the figure of 44% for insulations. However, it is selected as it is broadly consistent with the overseas empirical evidence (Greening, *et al.*, 2000). No known reliable New Zealand data is available for the

[45] These calculations were made drawing on data from Wright and Baines (1986), Isaacs *et al.*, (2006) and Patterson and McDonald (2009).

‘rebound effect’ of heat pumps, which is a concern given the rapid increase in Heat Pump use by householders in the last 5-10 years (French, et al, 2007). As with home insulation, the OPENZ equations calculate: (a) the net energy savings (80% of the theoretical savings for the default settings); (b) increase in space heating levels (Terajoules of end-use) from the rebound effect.

5. Technical Energy Savings Potential

The 'technical energy savings' potential is the maximum energy that can be saved, by employing the best available technology and energy savings measures. These 'technologies' and 'energy savings' measures may not necessarily be the most economic or commercially viable.

For the estimation of the 'technical energy savings potential' OPENZ will determine the minimum energy input (quality adjusted PJ) to supply the required amount of end-use energies[46] each year from 2006/07 to 2025/26. The *difference* between the 'Minimum' and the 'Business-As-Usual' primary energy input, is the 'technical energy savings' potential.

5.1 Assumptions

The key assumptions in quantifying the 'Technical Energy Savings Potential' were:[47]

- The size of natural gas reserves in 2,427.6PJ (allowing 20% for new discoveries).
- Rebound effect from new Household Insulation is 44%.
- Rebound effect from new Heat Pumps is 10%.
- Energy Prices are at the 'default' levels as outlines in Appendix C. These default prices only apply to the exogenously determined prices (refer to section 2.10.1), not the prices for endogenously determined prices (electricity, ethanol, methanol, biogas, synthetic petrol, synthetic diesel and natural gas). These default energy prices were almost entirely drawn from Donovan *et. al's* (2009) report that provides a very thorough analysis of future energy prices from 2008 to 2060.
- 617,940 ha are available for agricultural bio-energy crops and 1,411,500 ha are available for silviculture energy crops. In actuality neither of these constraints (availabilities) become binding.
- The activity levels of the 37 sectors of the economy from 2006/07 to 2025/26 are the 'default values' as estimated by the Economic Futures Model. These 'activity levels' are directly based on the projected contributions to GDP (value added) of each sector in the economy. For the household sector, the projected activity is based on 'household consumption ($)', which is forecasted to increase by 37% over this period. These GDP (and household consumption) based activity levels were used to estimate the projected amounts of energy end-uses for each sector.
- Carbon Prices are at the 'default' levels outlined in OPENZ and discussed in Section 2.5. These 'carbon prices' are arguably quite conservative (low), but broadly consistent with those used by East Harbour Management Services (2004, 2005) and The Treasury (2005).
- A 'default' setting of 23.7 PJ/yr for methanol and urea production is assumed for each year.
- Penetration rates for both new and existing energy end-uses processes are set at 'high' levels. This reflects an underlying assumption for the 'technical energy savings' optimisation, that OPENZ can relatively quickly switch to new optimal mixes of

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[46] The energy end-uses required (37 categories) are projected for each year from 2006/07 to 2026/27 using the Economic Futures Model – see Appendix B.4.1. In brief, these projections are calculated at the 37 sector level, by multiplying the growth/decline in each sector by the base year energy end-uses (PJ). For example, if the demand for water heating in the dairy farming sector is 1,010TJ in 2006/07 base year and the growth in the dairy farmer sector is projected to be 30% by 2020; then the projected amount of water heating energy required by the dairy farming sector is: 1,010TJ x 1.30 = 1,313TJ. There are a number of assumptions implicit in this calculation that are outlined and critically reviewed in Appendix B.4.2.

[47] The rationale and calculation underpinning these key assumptions is provided in the appropriate sections of Section 2 of this report.

technologies. These penetration rates therefore can be seen as 'optimistic' compared with those specified for the realisable energy savings' optimisation. The specific penetration rates for new and existing energy end-use processes, for the 'technical energy savings' optimisation are detailed in one of the worksheets of the OPENZ model.

- Penetration rates for 'energy savings measures' are all set at 100%. This means that by 2025/26 all of these energy savings measure could be fully adopted. Again, as with the energy end-use processes, that can be seen to be a relatively 'optimistic' set of assumptions.
- Penetration rate between 1991/92 and 2006/07 of Henderson's (1994) energy savings measure were all set at 30%.
- For a small number of energy supply processes, a constraint was placed on the process activity, to ensure that it would not be adopted for a minimum of 10 years. This avoided the situation of a supply process like enzyme hydrolysis of maize to ethanol' only being adopted for 3 years before it was discarded, which is obviously unrealistic.
- Percentage of electricity that could be generated from wind was set at an upper limit of 20%, due to this being considered the upper technical level possible in New Zealand electricity supply system.
- It was assumed that by 2026/27 that 95% of New Zealand households could have ceiling insulation, wall insulation, floor insulation and double glazing. This was from a base of 2006/07 where 64% of households had ceiling insulation, 45% had wall insulation, 18% had floor insulation and 9% had double glazing. There was a linear interpolation between the 2006/07 and 2025/26 levels of insulation, to allow for a technically feasible level of uptake.

5.2 Headline Results

5.2.1 Primary Energy Savings

The BAU projection shows primary energy consumption to be 714PJ [48] in 2025/26. This is a 43.5 % increase in primary energy consumption from 2006/07 to 2025/26, with the economy as a whole expanding by nearly 48%.

OPENZ however shows that all of the energy end-uses (37) in the economy can be supplied at a much lower level of primary energy inputs. That is, by minimising primary energy inputs (adjusted for energy quality) according to the assumptions spelt out in Section 5.1, it is technically possible to reduce primary energy consumption to only 374PJ (crude oil equivalents), and still meet the required level of energy end-uses. This minimised level of quality-adjusted primary energy inputs equals 275 PJ in heat content units.

The difference between the 'BAU' and 'optimised' primary energy consumption is the 'technical energy savings.' In this case, the 'technical energy savings' is 439PJ [49] in 2025/26. Fig 5.1 shows the savings for all of the years from 2006/07 to 2025/26, which indicates an average rate of primary energy reduction of 2.3% per annum (in heat content terms).

[48] This is 714PJ (heat content) which in this case equals 844PJ (crude oil equivalents)
[49] This is 439PJ (heat content) which in this case equals 470PJ (crude oil equivalents)

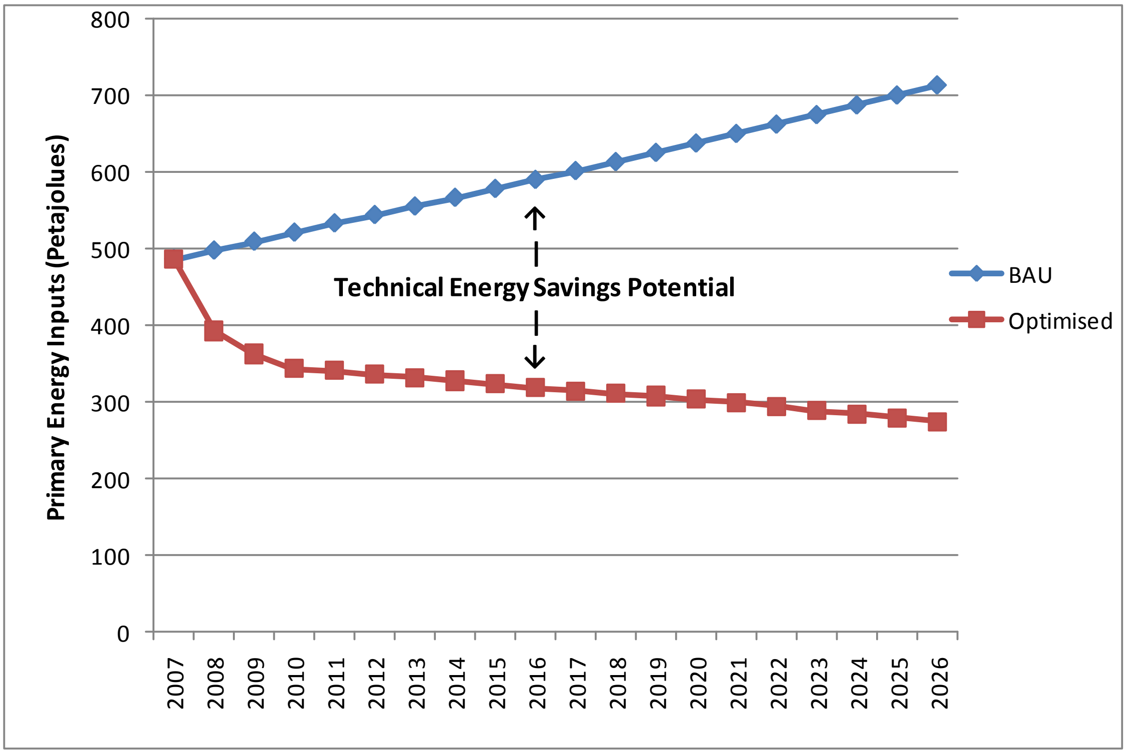


Figure 5.1 Primary Energy Inputs for the Technical Energy Savings Optimisation
(Measured in terms of 'Heat Content')

5.2.2 Energy Intensity

Energy Intensity is a measure of 'gross energy efficiency' of a nation (Patterson, 1996). That is, the lower energy intensity (J/\$), the higher the energy efficiency of the nation.

Because of structural shifts in the New Zealand economy, even with 'BAU' projections the energy intensity of the economy is projected to decrease from 4.55PJ (Crude Oil Equivalents)/$\$_{2006\text{-}07}$ billion in 2006-07 to 3.80 in 2025/26. This decrease in energy intensity is accelerated even further in the 'technical energy savings' optimisation – that is, it decreases to 1.69 PJ(Crude Oil Equivalents)/$\$_{2006\text{-}07}$ billion in 2025/26 – refer to Fig. 5.2.

This decrease in the energy intensity of 63.0% according to the 'technical savings' optimisation indicates a dramatic improvement in New Zealand's economy-wide energy efficiency. By direct implication, 16.4% is due to structural shifts in the economy from 2006/07 to 2025/26, with the remainder of 46.5% due to 'technical' improvements. This represents an annual rate of close to 2.3% for technical energy efficiency improvements, which is significantly better than technical improvements in the order of 1% historically recorded by using the divisia decomposition method. (Lermit and Jollands, 2001; Jollands, Lermit and Patterson, 2004; Patterson, 1993).

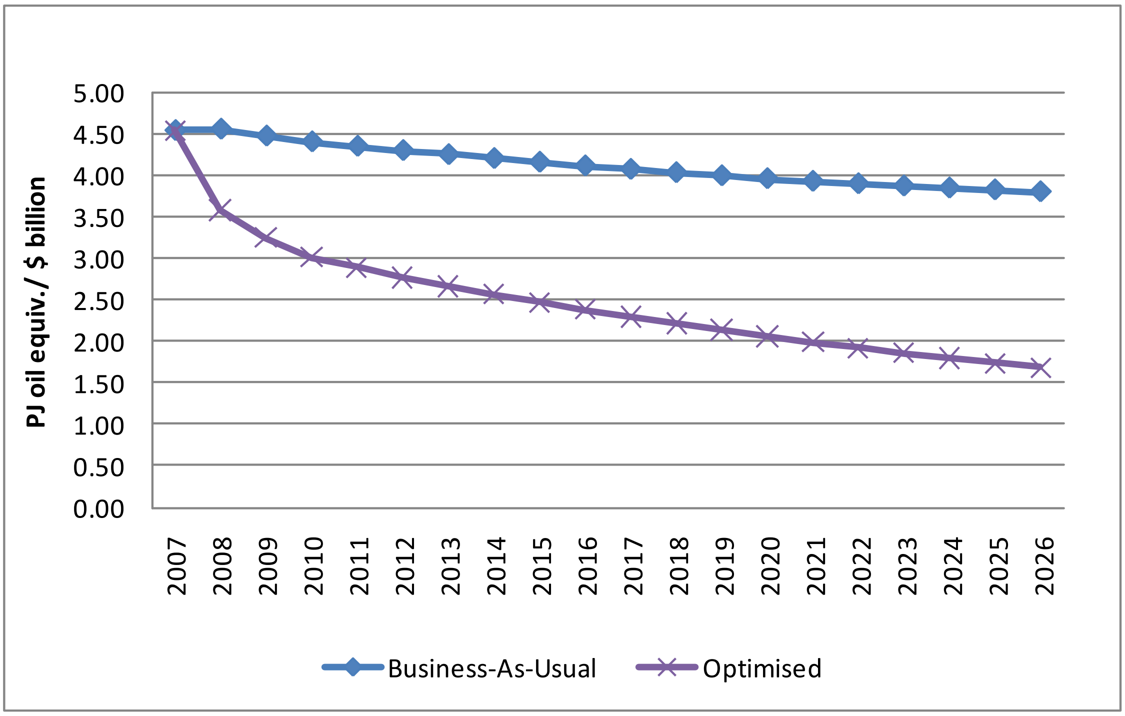


Figure 5.2 NZ Energy Intensity for Technical Energy Savings Optimisation

5.2.3 Greenhouse Gas Emissions

As would be expected, there is also a significant decrease in greenhouse gas emissions that parallels the decrease in primary energy consumption. For the 'technical energy savings' optimisation, greenhouse gas emissions decrease from 38,584 CO_2e kilotonnes in 2006/07 to 32,760 in 2025/26 (refer to Fig 5.3). This represents a 15.1% decrease. It should be noted that even though there has been a dramatic decrease in primary energy inputs (many would argue unrealistically so), this still only translates to a 15.1% reduction in greenhouse gases over the 20 year period. Furthermore, this 15.1% reduction to 31,007 CO_2e kt in 2025/26 it is still above the often referred to baseline 1990 target – according to the Ministry of Economic Development, New Zealand's energy system emitted 21,360 CO_2e kt in 1990.

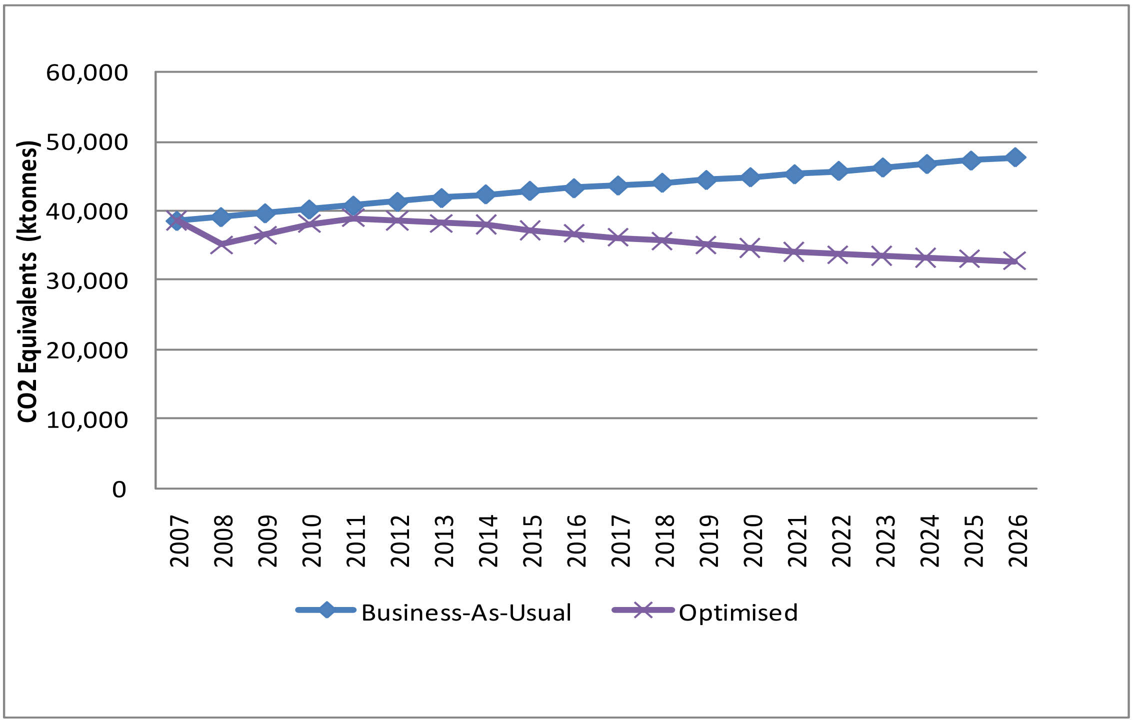


Figure 5.3 Greenhouse Gas Emissions for the Technical Energy Savings Optimisation

All of this underlines the technical difficulty of reaching this 1990 baseline target, even given the most optimistic assumptions about reducing New Zealand's primary energy consumption (as per the 'technical energy savings' optimisation.)

5.2.4 Economic Cost

The cost of energy supply for the 'Technical Energy Savings' optimisation is $\$_{2006\text{-}07}$ 76.66 billion for 2025/26. This compares with the cost of energy supply for the 'Business As Usual' projection of $\$_{2006\text{-}07}$ 70.11 billion for 2025/26. That is, the 'Technical Energy Savings' optimisation had an extra cost of $\$_{2006\text{-}07}$ 6.55 billion – essentially this is the cost of achieving an energy saving of 470 PJ(crude oil equivalents)/yr and reducing greenhouse gas by 14,929 CO_2e kilotonnes/yr . This cost of $\$_{2006\text{-}07}$ 6.55 billion equals 2.95% of projected GDP for 2025/26.

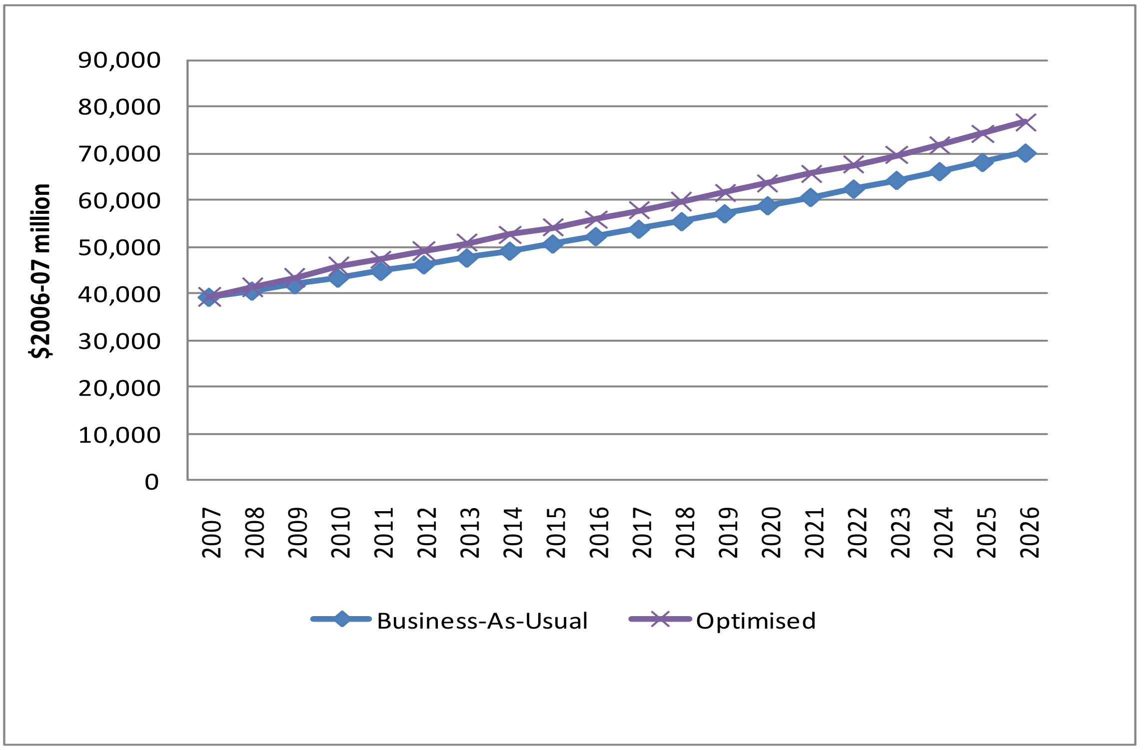


Figure 5.4 Economic Cost for the Technical Energy Savings Optimisation

This figure of 2.95% of GDP is seemingly higher to compared with similar studies overseas – although it is difficult to directly compare our study with those elsewhere, because of their different foci, study boundaries and greenhouse gas emission targets. Furthermore none of these studies specifically focus on 'energy savings potential. Nevertheless, Nordhaus (1993a,b) in his landmark study found that "1% of the world's output" would be required to reduce greenhouse gases to 50% of current levels. In more recent times Stern (2007) calculated that 1% of global GDP would be required to stabilise the atmosphere between 500-550ppm CO_2e, although Stern (2008) has since revised this upwards to 2% of global GDP. Again, although not directly comparable, Lennox and van Nieuwkoop (2010) evaluated emission trading schemes for New Zealand, using a Computable General Equilibrium modelling approach. Their modelling results showed decreases in GDP from about 0.7% to 2%, depending on various permit allocation, taxation recycling, and carbon price assumptions. Lennox and van Nieuwkoop's (2010) scenarios involve decreases in the 2006 GHG emissions between 10 to 20% depending on the various assumptions that they employed[50].

5.2.5 Primary and Delivered Energy

For this optimisation of the 'Technical Energy Savings', this translates into the pattern of delivered energy consumption as outlined by Table 5.1. The data in this table, is presented in the more familiar 'Heat Unit's rather than quality-adjusted 'crude oil equivalents.' Overall, as can be ascertained from Table 5.1, the total delivered energy consumption decreased very slightly from 575.65 PJ/yr in 2006/07 to 572.89 PJ/yr in 2025/26.

[50] The Lennox and van Nieuwkoop (2010) model includes *all* greenhouse gas emissions produced by the New Zealand economy, not just energy-related greenhouse gas emissions as is the case in OPENZ. Caution therefore needs to be exercised in directly comparing Lennox and van Nieuwkoop (2010) results with the OPENZ results.

Due to ‘fuel switching’ and more efficient use of electricity, there is a significant decrease in electricity consumption from 147.80PJ in 2006/07 to 105.01PJ in 2025/26. Petrol use also dramatically decreased from 115.96PJ in 2006/07 to only 39.21PJ in 2025/26, due largely to increased usage of diesel and methanol and more particularly ethanol fuels for transport, but also due to some efficiency improvements in the use of petrol.

Coal decreased (-45.5%) as a source of mainly industrial heat, often being replaced by Natural Gas. On the other hand Natural Gas use lifted very significantly (225.5%) being the most important source of industrial heat and also water heating, space heating and cooking in other sectors. Wood (-56.3%) like Coal consumption also decreased across these end-uses, often being replaced by more energy efficient ‘Natural Gas’.

Table 5.1 Delivered Energy Consumption (PJ, Heat Units) for the *Technical Energy Savings Potential*

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	530.48	130.29	97.04	113.35	17.46	38.20	7.29	9.18	52.43	38.84	24.09	2.10	0.21
2009	533.86	127.98	89.28	118.13	17.58	35.36	6.67	10.28	59.10	39.86	25.00	4.21	0.42
2010	537.79	126.48	83.21	121.70	17.69	33.40	6.50	11.12	65.69	40.07	25.00	6.31	0.63
2011	541.64	124.96	83.28	119.15	17.81	31.89	5.75	12.19	72.25	40.09	25.00	8.42	0.84
2012	543.84	122.67	85.07	114.31	17.89	31.18	5.45	11.78	78.81	40.12	25.00	10.52	1.05
2013	545.66	121.16	86.89	109.45	17.98	30.26	5.16	11.86	83.94	40.14	25.00	12.62	1.18
2014	551.36	119.80	86.86	108.66	18.05	29.67	5.10	11.56	90.69	40.00	25.00	14.70	1.27
2015	550.88	118.42	83.33	110.17	18.13	29.47	5.15	10.99	97.51	34.55	25.00	16.72	1.45
2016	552.43	117.23	79.77	111.53	18.20	29.46	5.15	9.99	104.05	31.66	25.00	18.77	1.63
2017	553.40	115.94	75.96	112.84	18.26	29.57	5.20	8.60	110.54	28.81	25.00	20.85	1.81
2018	554.74	114.38	72.11	114.15	18.32	29.68	5.25	8.18	116.70	26.02	25.00	22.94	2.00
2019	556.33	112.73	68.22	115.45	18.38	29.71	5.30	8.16	122.88	23.29	25.00	25.02	2.18
2020	557.90	111.54	64.32	116.73	18.44	28.87	5.35	8.51	129.05	20.62	25.00	27.11	2.36
2021	559.45	110.33	60.40	118.00	18.49	28.04	5.40	8.80	135.25	18.01	25.00	29.20	2.54
2022	560.62	109.30	56.24	119.20	18.53	27.32	5.45	8.67	141.44	16.75	25.00	30.00	2.72
2023	562.67	108.28	52.02	120.39	18.57	26.50	5.50	8.96	147.56	17.00	25.00	30.00	2.90
2024	565.73	107.16	47.75	121.54	18.60	25.92	5.55	9.67	153.39	17.24	25.00	30.81	3.09
2025	569.13	106.05	43.42	122.66	18.63	25.36	5.60	9.83	159.26	17.49	25.00	32.56	3.27
2026	572.89	105.01	39.21	123.75	18.65	24.80	5.65	10.18	165.15	17.73	25.00	34.30	3.45
Growth Rate	-0.48%	-28.95%	-66.19%	5.17%	3.95%	-45.54%	-31.72%	18.18%	225.49%	-56.26%	10.78%	n.a.	n.a.
Average Growth Rate	-0.03%	-1.78%	-5.55%	0.27%	0.20%	-3.15%	-1.99%	0.88%	6.41%	-4.26%	0.54%	n.a.	n.a.

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even though this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

Full details of the patterns of primary energy supply for the ‘technical energy savings’ potential are contained in Appendix E. For the ‘Technical Energy Savings’ potential, by 2025/26 most electricity is supplied by Hydro-electricity (80.89%) followed by Geothermal (10.71%), Wood (5.45%), Wind (2.01%) and Coal (0.94%). The most significant change in electricity generation since 2006/7 is the complete elimination of Natural Gas as an energy source. This is because OPENZ determines it is more (energy) efficient to use Natural Gas to directly use to produce heat, rather than first convert natural gas to electricity and then subsequently to heat. The use of Coal for generating electricity also declined dramatically from 18.0 PJ/yr in 2006/07 to 1.1 PJ/yr in 2025/26. For the transport fuels, there was some substitution of the crude-oil based fuels (petrol, diesel) by fuels produced from biomass feedstocks. By 2025/26, 68.2 PJ/yr diesel were produced from woody biomass feedstocks, 34.3 PJ/yr ethanol from agricultural crops, and 3.5 PJ/yr methanol from radiata pine. Consequently, Petrol and Diesel derived from crude oil decreased to 62.4.2 PJ/yr, by 2025/26.

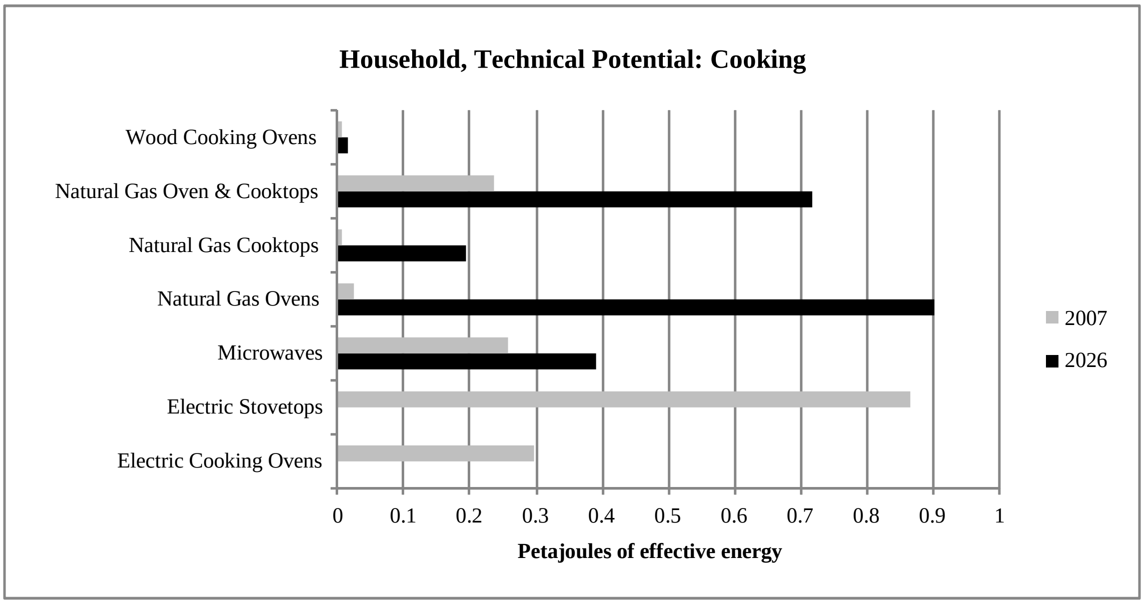
5.3 Detailed Sector-by-Sector Results

5.3.1 Household Sector

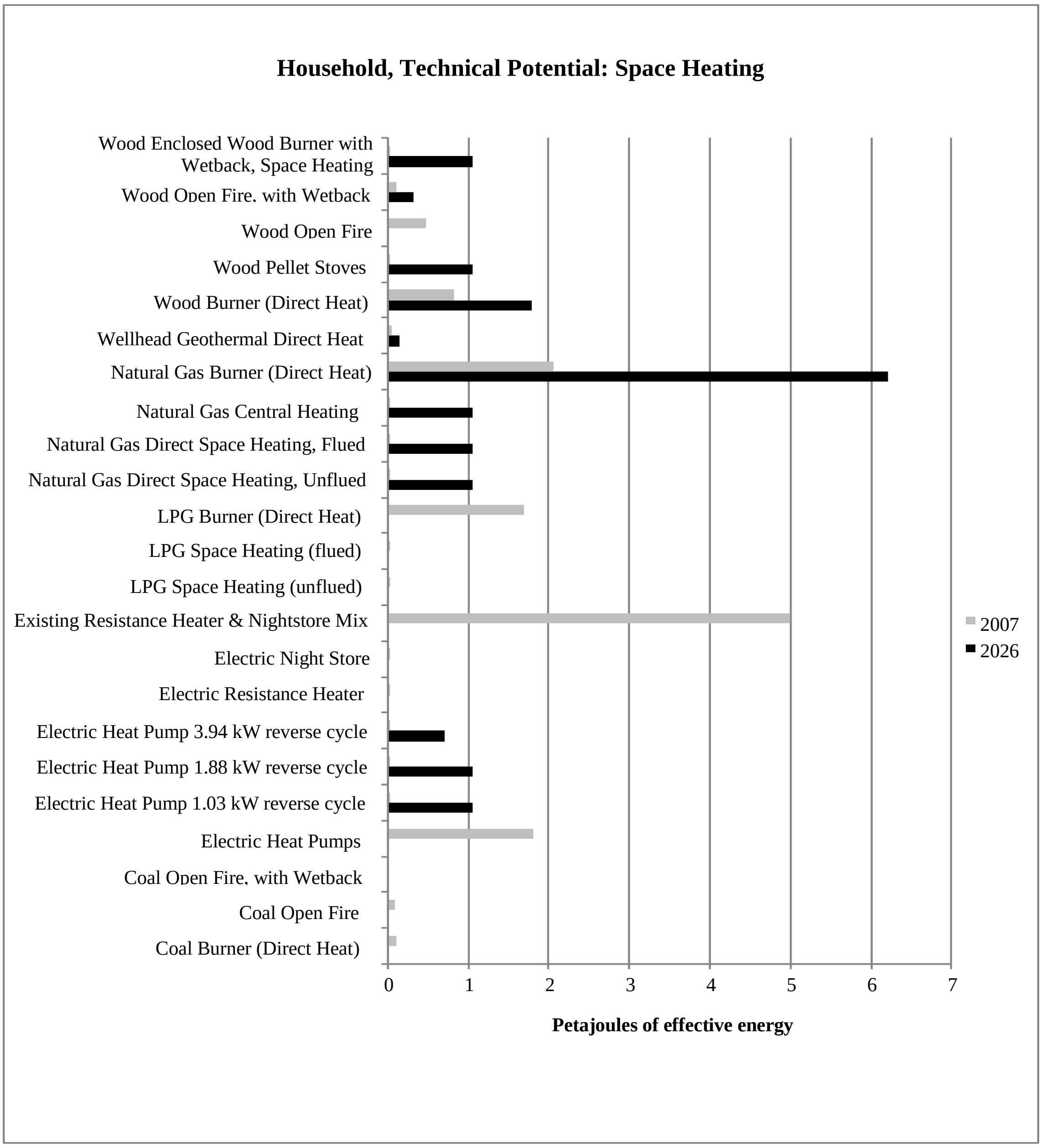
Full details of the supply of energy end-uses, for each year of 'technical energy savings' optimisation are contained in Appendix F.1. Similarly, full details of the 'energy savings measure' for 'technical energy savings' optimisation are contained in Appendix F.1.

The main shifts in the 'energy end-use' supply processes for the household sector were:

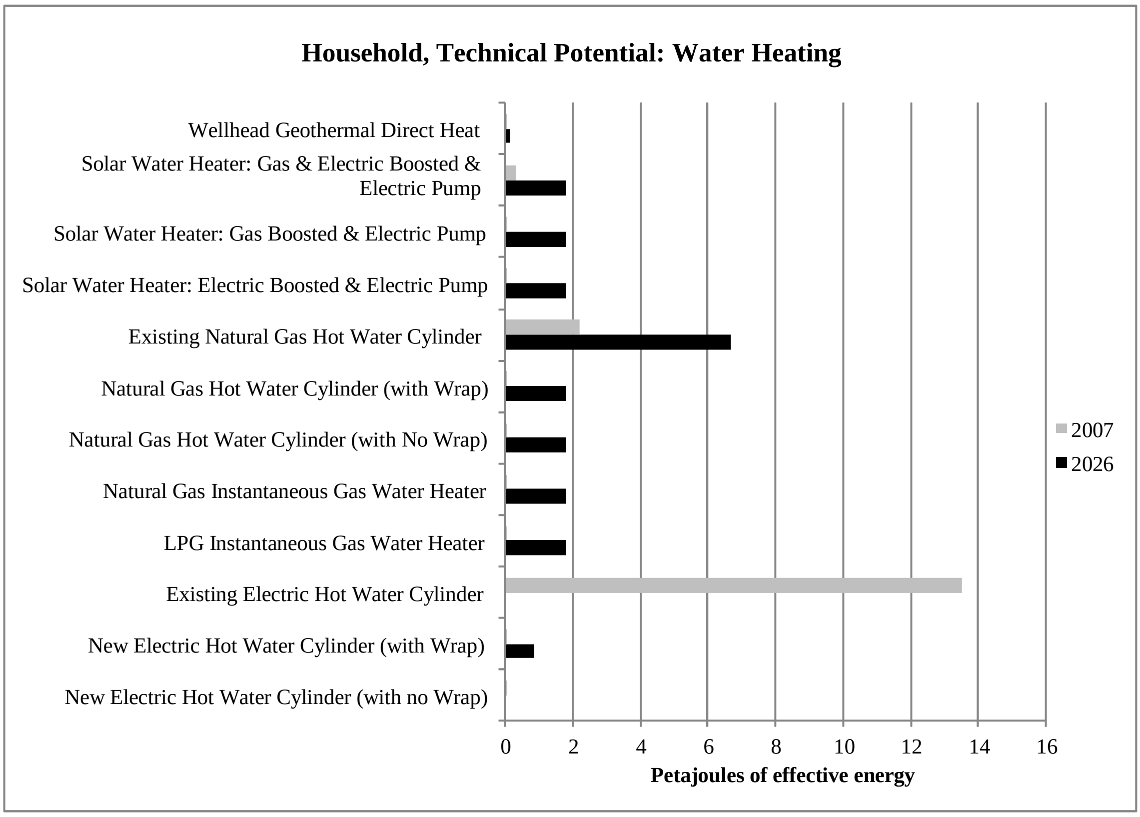
- *Cooking*. Gradual decrease in traditional electric powered cooking equipment (ovens and cooktops), as well as an increased use of more energy efficient microwave ovens. By 2025/26, Natural Gas supplied 82.3% of the cooking end-use energy with 17.60% from microwave ovens.



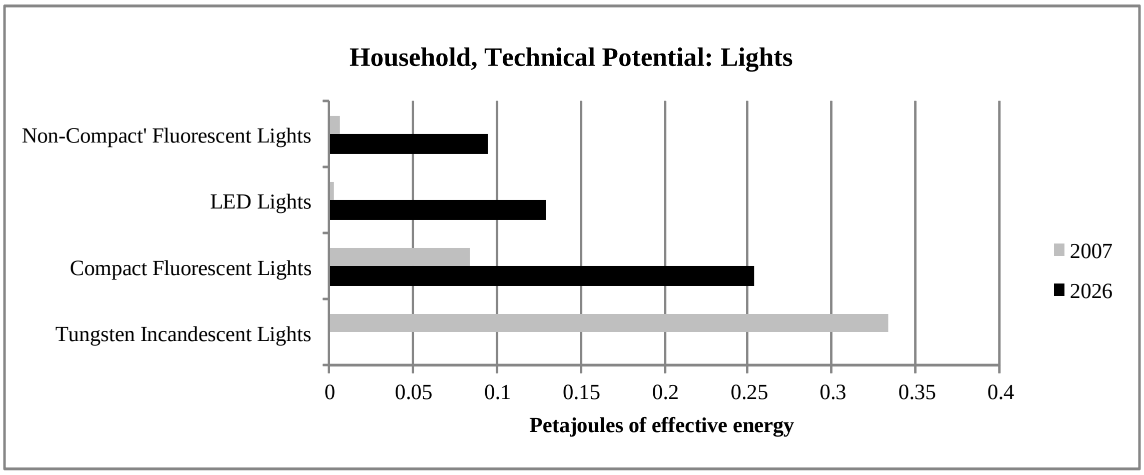
- *Space Heating*. By 2025/26 there was a complete elimination of open fires, except for the small use of wood open fires with wetbacks. Also eliminated by 2025/26, was the use of resistance heaters and night-store heaters, as well as the use of LPG for space heating. By 2025/26 space heating was predominantly supplied by natural gas heaters (56.6%), wood enclosed burners (23.6%) and heat pumps (17.0%).



- *Water Heating.* Electric hot water cylinders which were the main source of hot water in 2006/07 were almost completely eliminated supplying only 4.3% of water heating in 2025/26. Instantaneous gas water heaters (both LPG and Natural Gas) supplied 17.7% of domestic hot water, solar-based water heaters supplied 26.6%, and conventional natural gas hot water cylinders 50.6%.

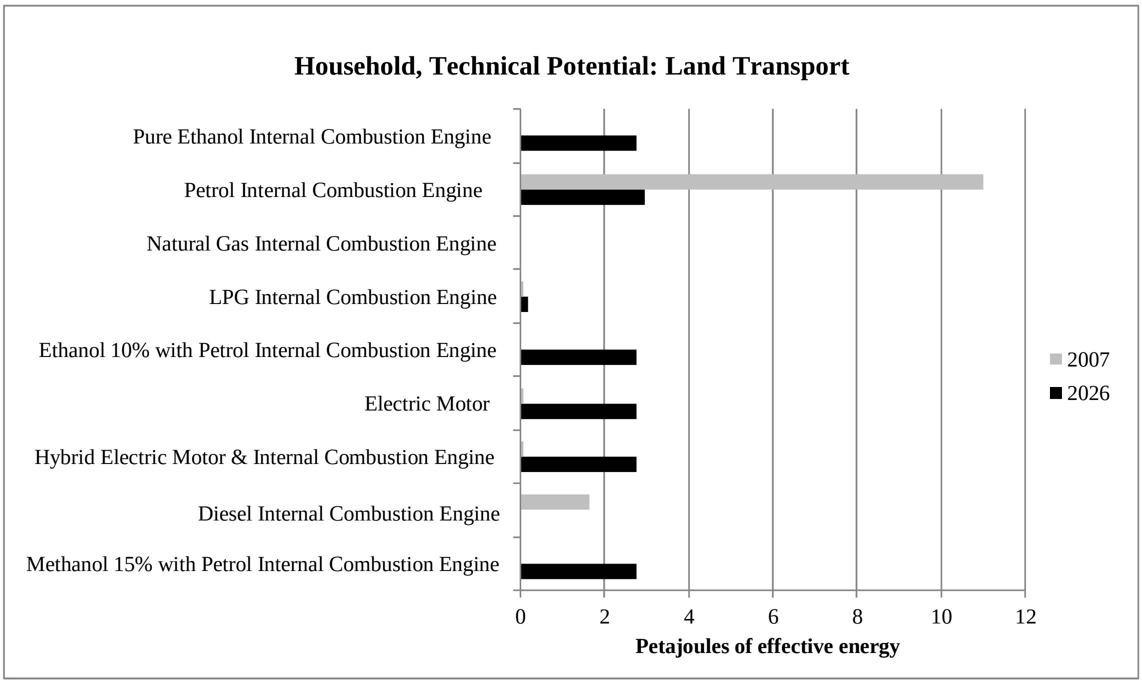


- *Lighting*. By 2019 elimination of tungsten incandescent lights, and replacement by more energy efficient forms of lighting. By 2025/26, 53.0% of lighting from compact fluorescent lights, 27.0% from LED lights and 19.9% from long tube fluorescent lights.



- *Electric End-Uses.* Obligatory electrical end-uses (electronics, refrigeration, etc) make up a considerable portion of household electrical end-uses. These increased by 33.3% over the 2006/07 to 2025/26 period.

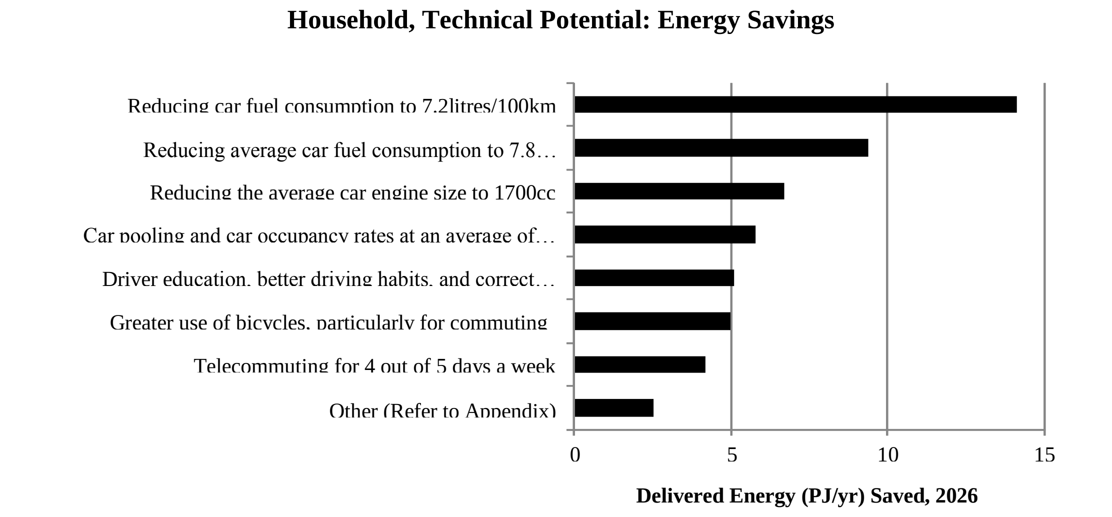
- *Land Transport*. There was a dramatic decrease in the use of petrol by private vehicles from 85.4% of the market share in 2006/07, down to 17.5% in 2025/26. The use of diesel in domestic vehicles was completely eliminated from 12.96% of market share to 0% in 2025/26. This drop in the use of 'traditional' fuels of petrol and diesel was replaced by pure and hybrid electric cars having 32.5% of market share, petrol/alcohol blended fuels also at 32.5%, then ethanol fuelled cars at 16.2% and a smaller market share of 1.1% for LPG vehicles.



The main uptake in 'energy savings measures' in the household sector by 2025/26 were those related to land transport:

- 9.4PJ/yr in reducing average car fuel consumption to 7.8 litres/100km.
- 14.1PJ/yr in reducing car fuel consumption to 7.2litres/100km
- 6.7PJ/yr in reducing the average car engine size to 1700cc.
- 5.8PJ/yr from car pooling and car occupancy rates at an average of 2 people per car.
- 5.0PJ/yr from the greater use of bicycles, particularly for commuting.
- 4.2PJ/yr from telecommuting for 4 out of 5 days a week.
- 5.1PJ/yr from driver education, better driving habits, and correct maintenance of cars (tyres, exhaust checks, tune-ups, etc.)

If all of these technically feasible transport sector 'energy savings' are implemented, then by 2025/26 52.84PJ/yr of savings will be achieved. This is significantly more than the other sectors.



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Energy savings and an improved level of comfort were also brought about by better insulation. By 2025/26:

- 95% of houses had ceiling insulation
- 95% of houses had wall insulation
- 95% of houses had floor insulation or a concrete floor
- 95% of houses had double glazing.

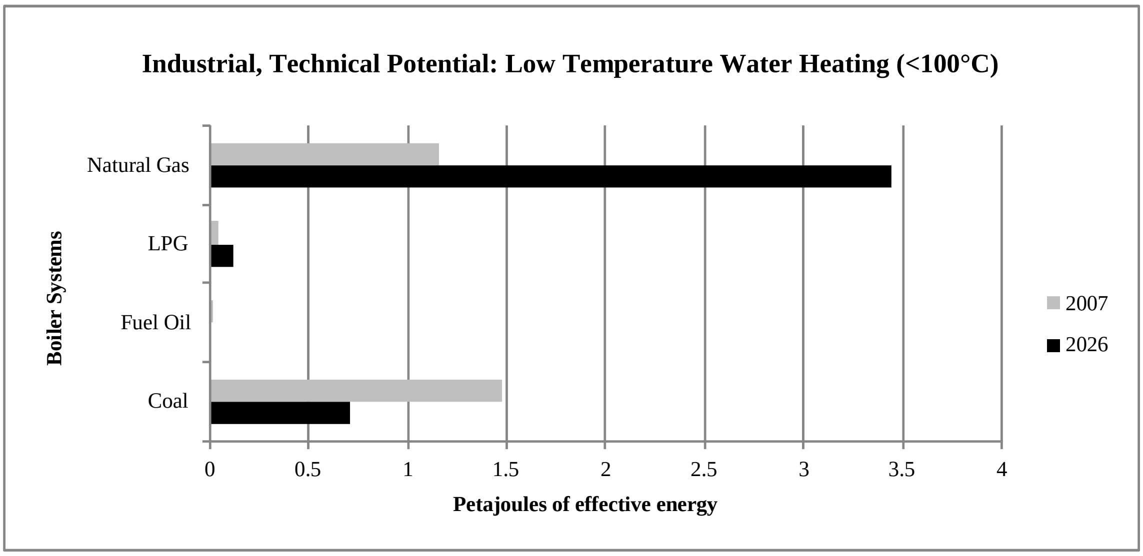
There was an assumed rebound effect based on data from Howden, Chapman *et.al* (2010) of 2,527PJ of 'effective' space heat being provided by this improved insulation. That is, 44% of the nominal 'energy savings' was used to heat houses to a higher temperature.

5.3.2 Industrial Sector

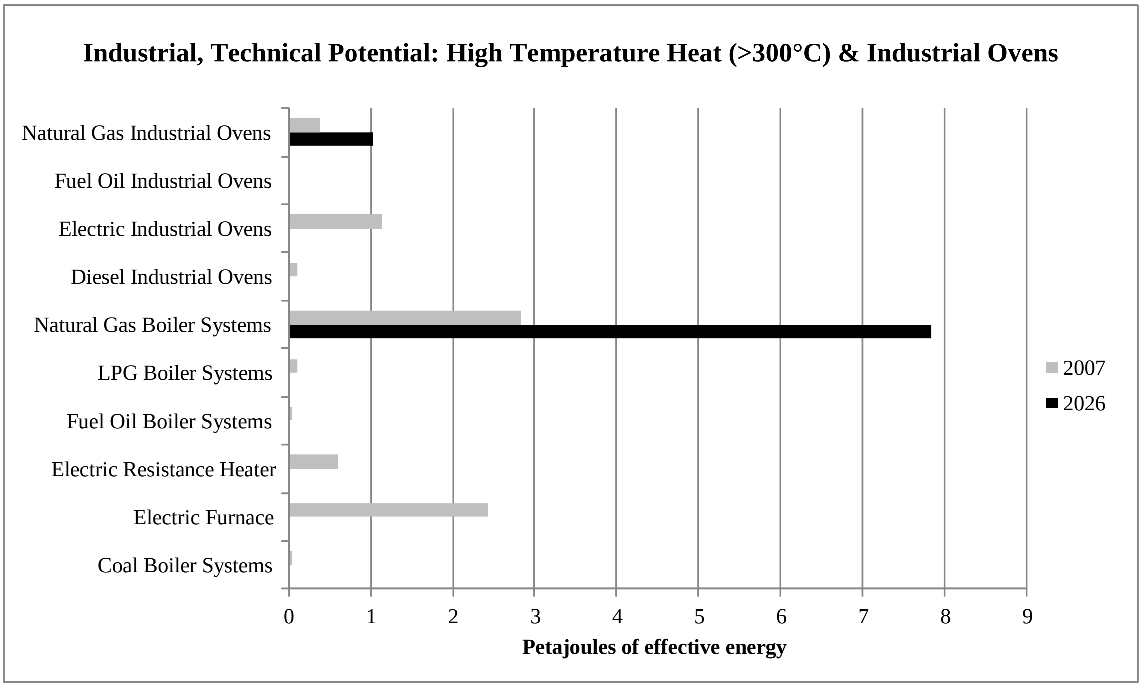
Full details of the supply of energy end-uses, for each year of the technical energy savings optimisation are contained in Appendix F.1. Similarly, full details of the 'energy savings measures' for the 'technical energy savings optimisation' are contained in Appendix G.1.

The main shifts in the 'energy end-use' supply processes for the industrial sector were:

- *Low Temperature Water Heating (<100˚C).* Over the 20 year period there was some decline in the use of coal replaced by more natural gas. By 2025/26 natural gas (80.6%) supplied most heat in this category, followed by coal (16.6%) and then LPG (2.8%).

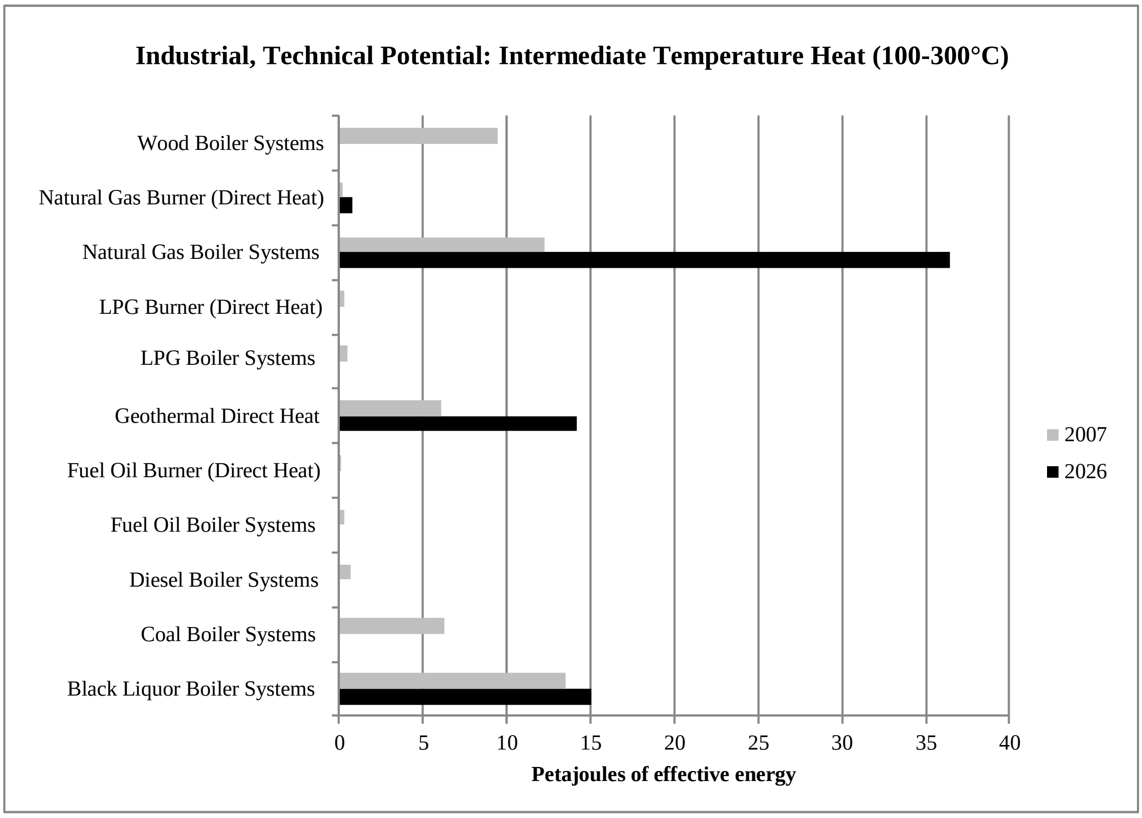


- *High Temperature Process Heat (>300˚C) and Industrial Ovens: (100- 300˚C).* There is consolidation of already heavy use of natural gas for these end-uses, with the phasing out of use of coal, electricity and fuel oil. By 2025/26, Natural Gas is the only source, except in those areas where is cannot be accessed.



Note: As with other end-uses, under the technical potential optimisation, naively selects the most 'energy efficient' means of supplying heat irrespective of cost. In this particular case 'natural gas' is selected because of its energy efficiency, which implies that natural gas would need to be exported (by tankers) to currently non-reticulated areas, particularly the South Island. This obviously would not be economically viable. This naivety does not occur in the other optimisations report upon this publication.

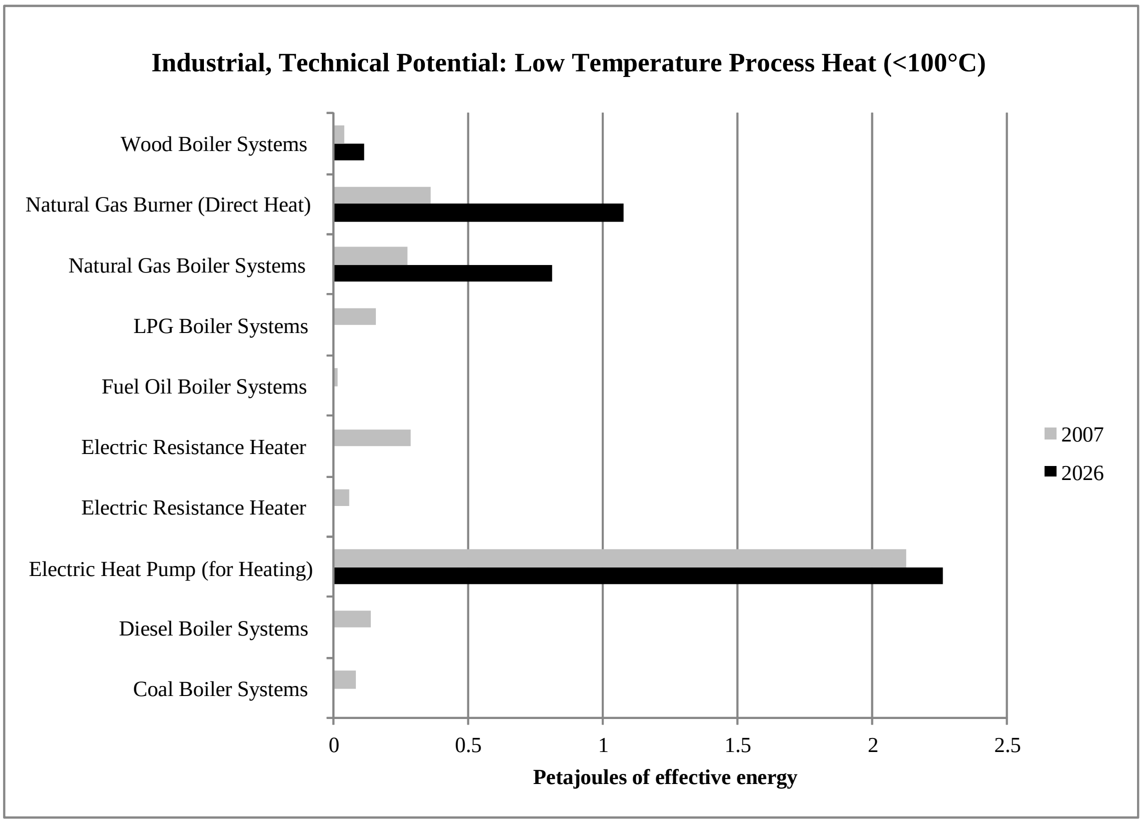
- *Intermediate Temperature Process Heat (100-300˚C).* Again natural gas was found to be the most energy efficient means, and therefore there was an increase in this form of heating. By 2025/26, natural gas (56.0%) supplied most 100-300˚C heat, followed by black liquor (22.0%) and then geothermal (21.4%).



- *Kiln/Furnace (100-300˚C).* Over the 20 year period there was a gradual substitution of wood for natural gas. By 2025/26, most (87.7%) was supplied by natural gas and the remainder (12.3%) by wood.

- *Kiln/Furnace (<100˚C).* There was a phasing out of coal and fuel oil. By 2025/26 wood (52.3%) and natural gas (47.7%) supplied all the heat in this category.

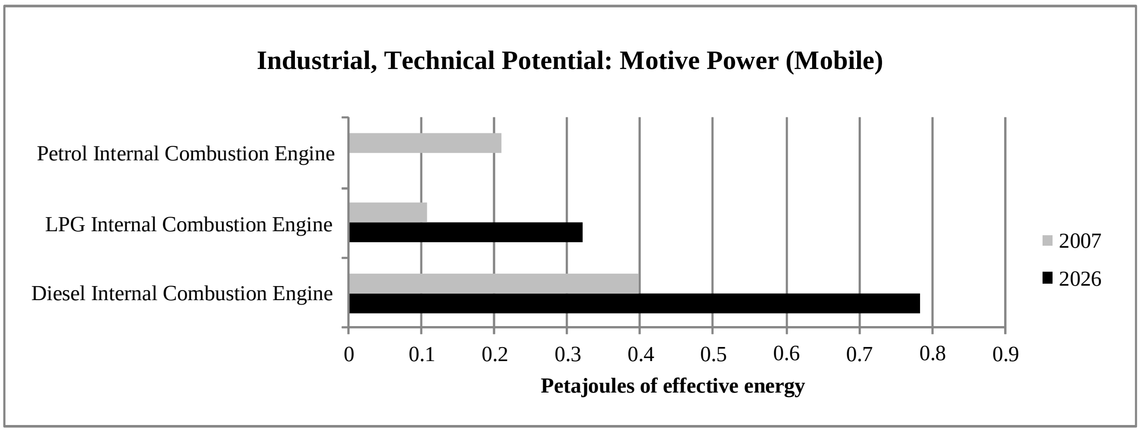
- *Low Temperature Process Heat (<100˚C).* By 2025/26 there was a more diverse range of supply sources for this end-use, reflecting the many uses low temperature heat is needed for. By 2025/26, heat pumps (53.0%) provided most heat in this category followed by natural gas by direct heat (23.2%), then natural gas via boiler systems (19.0%) and wood (2.7%) via boiler systems.



- *Obligatory Electricity*. Most (31.4%) of the energy consumed in this category is required for so called 'obligatory electricity'. This is electricity required for refrigeration, pumping, electrical and electric control equipment and lighting. Electricity use decreased slightly over the 20 year study period, due to substitution of use of electricity for heating by other sources, and due to the application of some of the energy savings measure outlined below. Consequently by 2025/26 electricity usage in the industrial sector had decreased from 53.7PJ in 2006/07 to 47.8PJ in 2025/26.

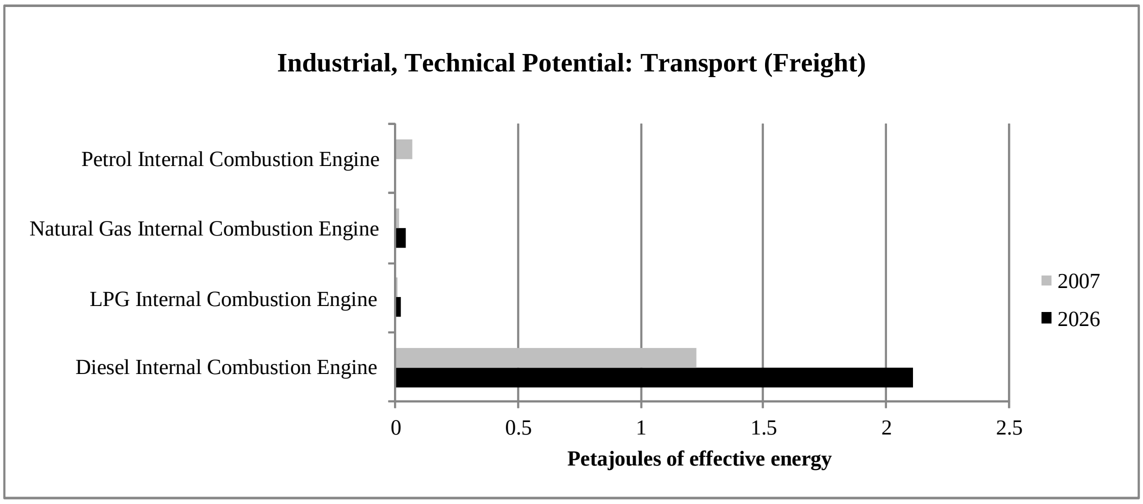
- *Motive Power (Mobile).* This category included the use of non-road vehicles (eg. forklifts) in industrial situations. By 2015, there was a phasing out of petrol, with the gradual replacement by LPG and Diesel vehicles. By 2025/26, diesel supplied most (70.1%) of the motive mobile power and LPG (29.2%).

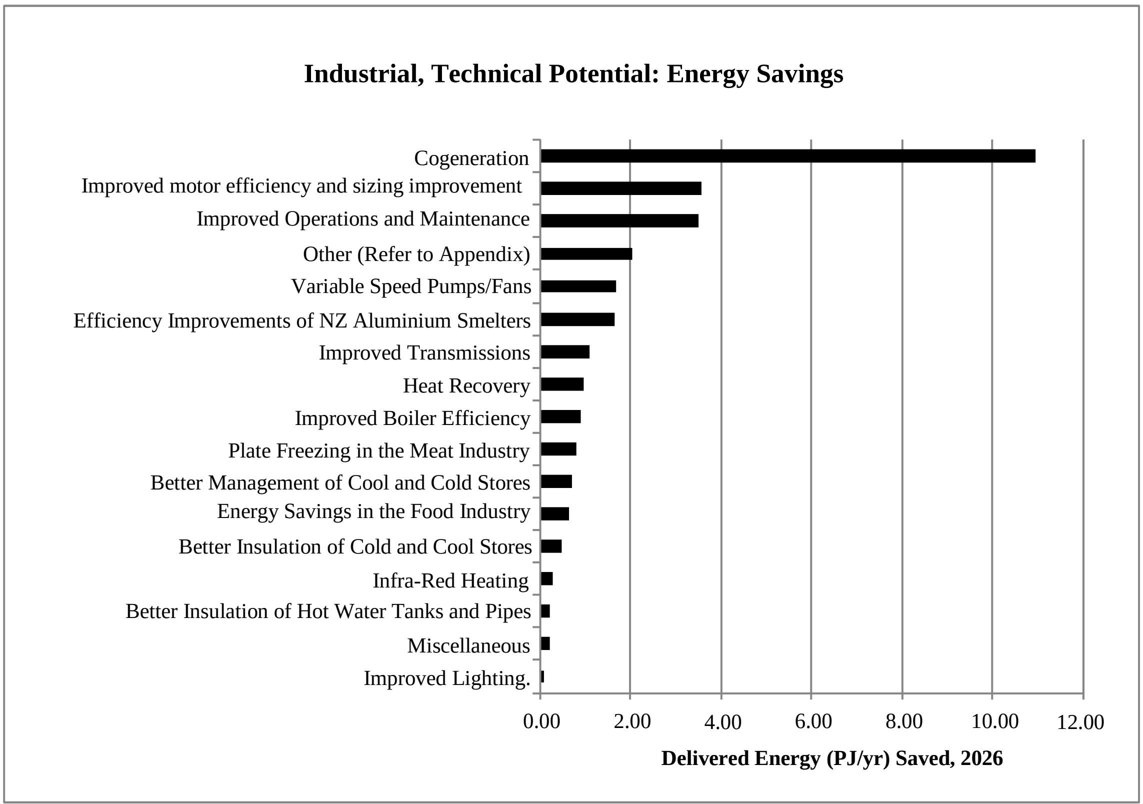
- *Motive Power (Stationary).* By 2025/26 electric motors were the only source of motive (stationary) power, many of which were variable speed – see below for the energy savings measures.



- *Transport (Cars).* This is a minor category of end-use for the industrial sector. As for the household sector, OPENZ for the 'technical potential optimisation' had traditional fuels replaced by hybrid cars (petrol, electricity), electric cars and greater use of natural gas.

- *Transport (Freight).* This category relates to freight vehicles, run by industrial companies, rather than sub-contracted to commercial freight operators. There was little change in the fuels used in this sector over the 20 year period, with by 2025/26 almost all (96.9%) still using diesel.





The implementation of 'energy savings' measures in the industrial sector were:

- *Cogeneration*. Additional cogeneration (of heat and electricity) was assessed by OPENZ to save 10.97 PJ/yr of energy by 2025/26, as a more efficient option to generating process heat and electricity by other means. More specifically 4.3PJ of process heat would be produced by cogeneration and 4.4PJ of electricity.
- *Improved motor efficiency and sizing improvement* would gradually increase over the 20 year period, saving 1.18 PJ/yr of electricity by 2015 and increasing to a saving of 3.58 PJ/yr by 2025/26.
- *Variable Speed Pumps/Fans* (e.g. freezers and chillers) would also achieve significant savings, estimated to be 1.70 PJ/yr by 2025/26.
- *Efficiency Improvements of NZ Aluminium Smelters*. NZ Aluminium Smelters have made consistent improvements in their energy efficiency (in terms of TJ/tonne of product). This is expected to increase, leading to further savings of 1.64 PJ/yr in 2025/26.
- *Improved Operations and Maintenance.* This includes better day-to-day attention to energy efficiency ('housekeeping'), better process control and management. This is expected to lead to energy savings of 3.5 PJ/yr by 2025/26. Specifically this includes: 1.32PJ of electricity (Ind 91), 0.85PJ of natural gas (Ind 133) and 0.55PJ of oil products (Ind 106).
- *Improved Transmissions* (e.g. cogged V-belts). The greater application of improved means of mechanical transmissions in factories, were assessed to save 1.10 PJ/yr of electricity by 2025/26.
- *Plate Freezing in the Meat Industry*. This was assessed to provide a savings of 0.80 PJ/yr by 2025/26, by the use of this more energy efficient means of freezing meat.
- *Better Management of Cool and Cold Stores,* including for example 'controlled door opening'. This was assessed to provide a saving of 0.70 PJ/yr by 2025/26.

- *Better Insulation of Cold and Cool Stores,* including wall, floor and ceiling. This was assessed to save 0.47 PJ/yr by 2025/26, if implemented.
- *Improved Boiler Efficiency.* Boiler systems are the main consumer of energy in the industrial sector. It is assessed with improved operation of boilers could save 0.90 PJ/yr by 2025/26. Specifically this includes 0.51 PJ/yr of natural gas, 0.20 PJ/r of coal and 0.19 PJ/yr of oil products.
- *Infra-Red Heating.* There is seen to be a small but significant potential in the metal fabrication, printing and apparel industries, for natural gas powered infra-red heaters. It is estimated by OPENZ this would lead to overall energy savings of 0.28 PJ/yr by 2025/26.
- *Energy Savings in the Food Industry.* Based on estimates from Henderson (1994), it is assessed that by 2025/26 use of the 'Cool Chain Concept in the Food Industry' (Ind. 81) and Mechanical Vapour Recompression in Food Processing (Ind. 109) could lead to 0.20PJ/yr and 0.44 PJ/yr of energy savings respectively.
- *Heat Recovery.* OPENZ identifies many practical mechanisms of heat recovery (Ind. 127, Ind. 116, Ind, 128, Ind. 105, Ind. 110, Ind. 115, Ind. 95, Ind, 121, Ind. 1525, Ind. 101). This includes heat recovery from process activities, refrigeration systems and grey water. Recovered heat for hot gases generally cannot be transmitted over distances of 50 metres, but can be effectively done with hot liquids up to 500 metres assuming good insulation. A wide range of heat exchanger and heat recovery options are available (refer to CAE, 1996). By 2025/26, OPENZ estimates that 0.96 PJ/yr of energy savings could be achieved, due to the implementation of these heat recovery mechanisms.
- *Better Insulation of Hot Water Tanks and Pipes.* These interventions (Ind. 130, Ind. 111, Ind. 96) are estimated to achieve energy savings of 0.22 PJ/yr.
- *Improved Lighting.* Some relatively small savings were achievable from upgrading existing fluorescents and upgrading gas discharge lamps. By 2025/26, this was estimated to achieve 0.09 PJ/yr savings.
- *Miscellaneous.* Other 'energy savings measures' were collectively estimated to save 0.21 PJ/yr by 2025/26. These included: distribution efficiency (local heaters, pipe and cylinder insulation), instantaneous water heating, improved operation of electronic equipment and higher efficiency electronic equipment (Ind. 132, Ind. 112, Ind. 86, Ind. 89, Ind. 123).

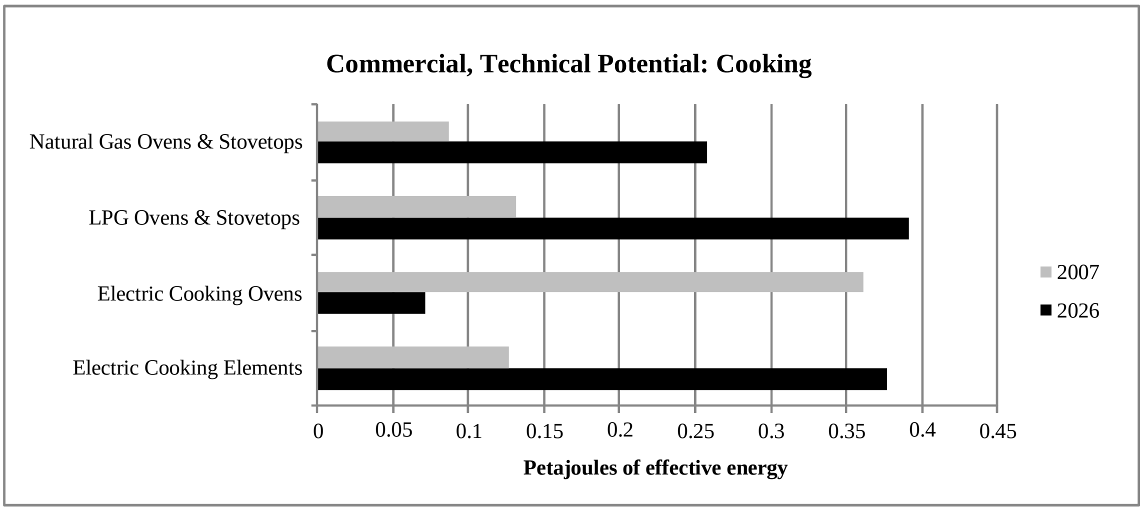
In total these 'energy savings' measures by 2025/26 for the industrial sector, were estimated to save 29.8 PJ/yr. Without these 'energy savings' the total energy use by the industrial sector in 2025/26 is estimated to be 246.3PJ. Therefore, these 'energy savings measures' reduce the industrial energy demand by 12.1%.

5.3.3 Commercial Sector

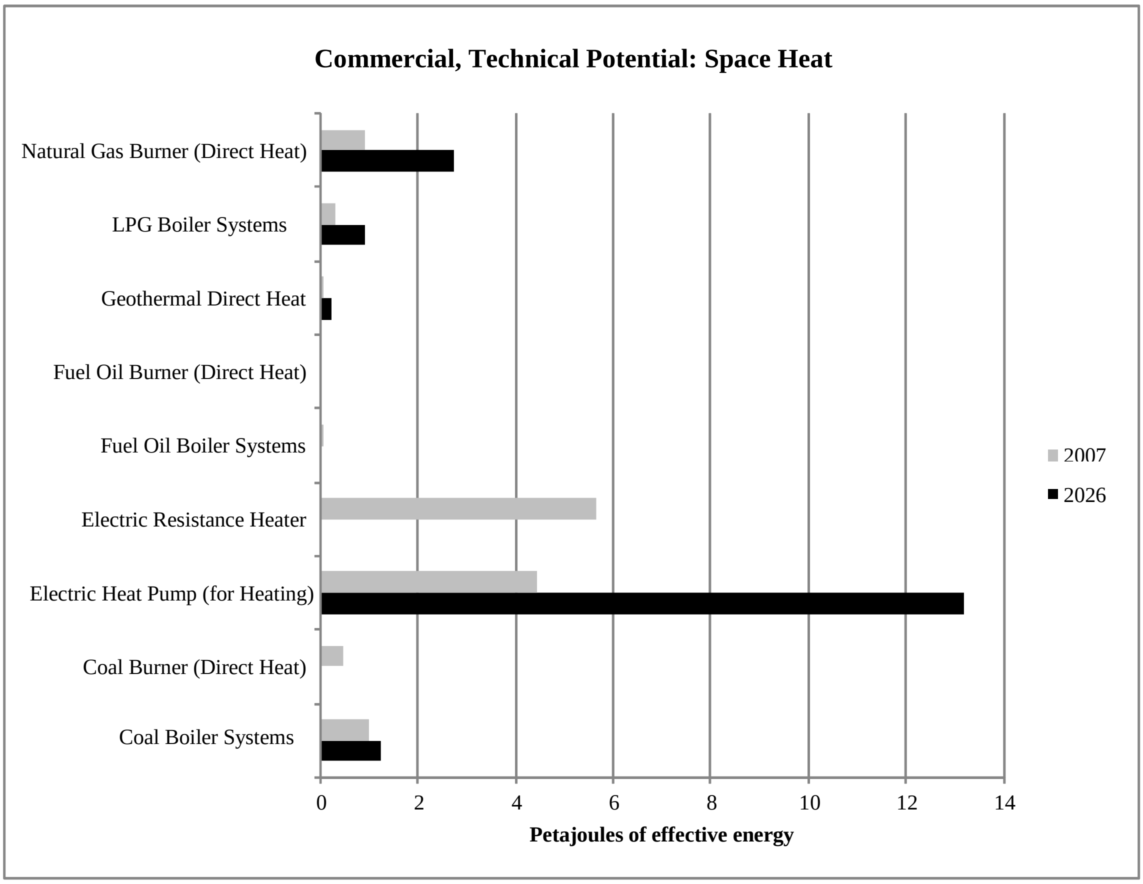
Full details of the supply of energy end-uses, for each year of the technical energy savings optimisation are contained in Appendix F.1. Similarly, full details of the 'energy savings measures' for the 'technical energy savings optimisation' are contained in Appendix G.1.

The main shifts in the 'energy end-use supply process 'for the commercial sector were:

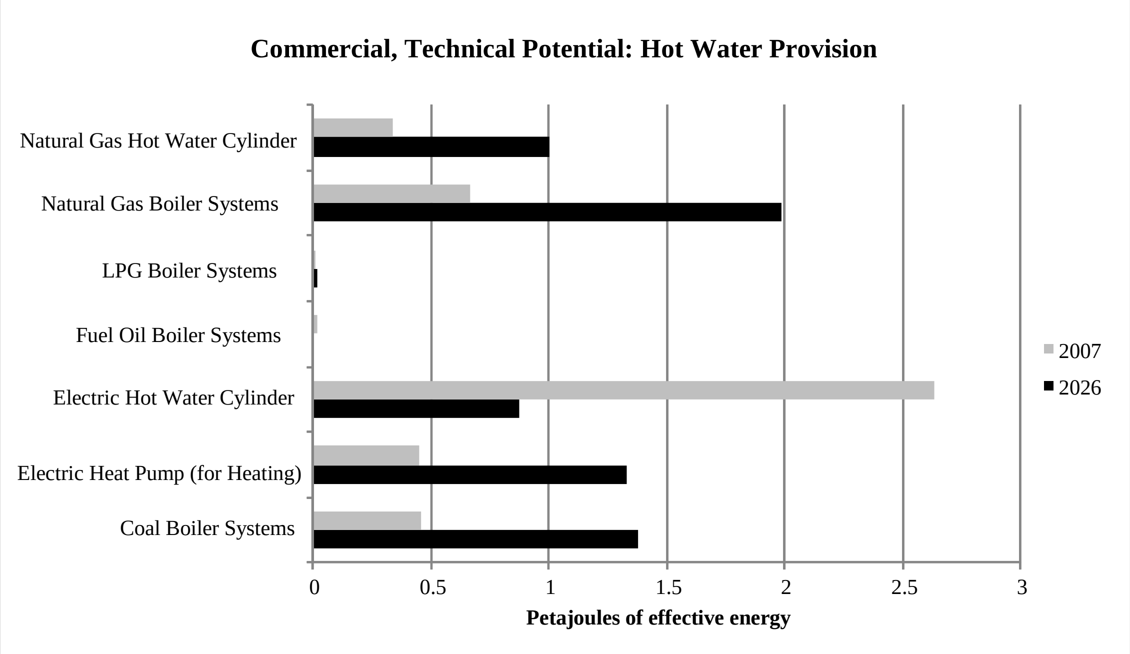
- *Cooking.* The main shift in cooking is the movement away from the use of electric ovens, to using gas ovens. Thermodynamically electric ovens are very energy inefficient. By 2025/26, electric ovens were down to 6.5% of the cooking energy supplied.



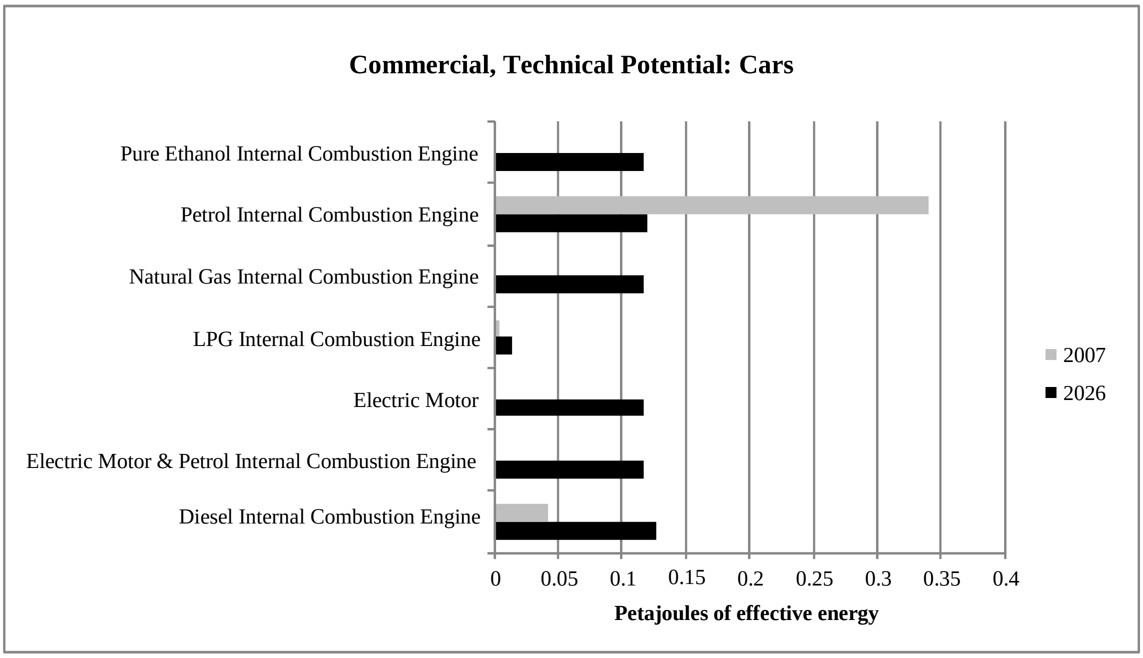
- *Space Heat.* The most significant change was the complete phasing out of resistance heaters as a means of space heating from a situation where it supplied 43.7% of the space heat in 2006/07. This replacement of resistance heaters was primarily by greater heat pump use, whereby by 2025/26 71.9% of the space heat in commercial buildings was supplied by heat pumps. Of the remainder of the space heat, natural gas supplied 15%, coal 6.8% (mainly in hospitals), LPG 5.1% and geothermal 1.3%.



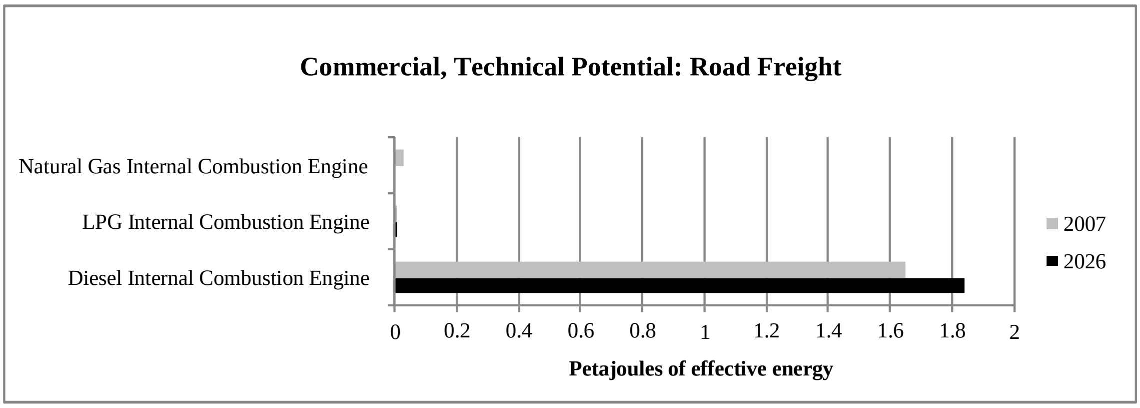
- *Hot Water Provision.* There was a dramatic decrease in the use of hot water cylinders for providing hot water in commercial buildings, dropping from 57.6% in 2006/07 to 13.3% in 2025/26. This was made up for by increases in the use of heat pumps (20.2% of hot water in 2025/26), coal-fired boilers (20.9% of hot water in 2025/26), natural gas fired boilers (30.1% of hot water in 2025/26) and natural gas fired hot water cylinders (15.2% of hot water in 2025/26).



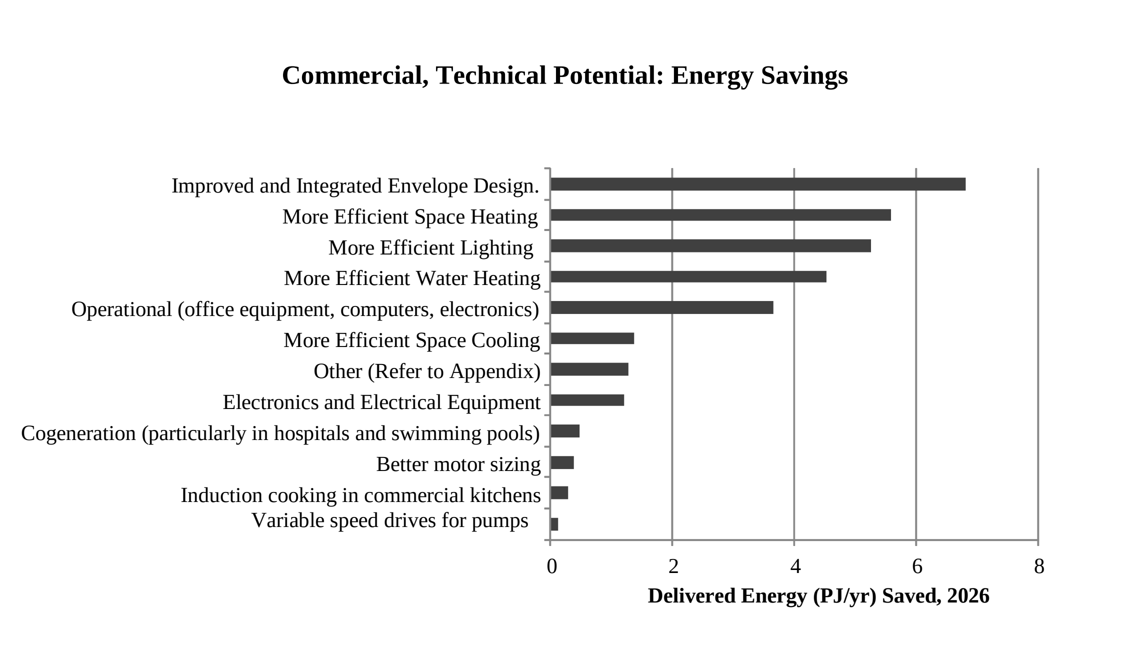
- *Transport (Cars).* This is a minor category of end-use in the commercial sector. As for the household sector, OPENZ for the 'technical potential' run had 'traditional' fuels gradually replaced by 'non-traditional fuels'. In this way, electric and alcohol-fuelled cars (Com. 44, Com. 43, Com, 46) made up 48.1% of the car usage by 2025/26.



- *Transport (Freight).* This category refers to freight vehicles, run by commercial sector businesses rather than contracted out to freight companies (in the transport and storage sector). There was little change in the fuels used in this sector over the 20 year period, with by 2025/26 diesel almost completely dominating with 99.5% of the market-share.



- *Obligatory Electricity.* Much of the commercial sector's energy use and electricity load falls in this category, which includes electronic equipment, computers, as well as a significant amount of refrigeration energy which is needed in retailing (restaurant, shops, supermarkets and wholesaling activities including in this sector). Although this obligatory electricity consumption nominally increased by 38% over this period, there were a number of 'energy savings measures' (e.g. improved purchasing of equipment) considered below that effectively reduced this nominal obligatory electricity demand.



The main implementation of 'energy savings' measures were:

- *Operational.* This includes better office equipment management, switching equipment on/off and optimum location of equipment. In spite of all of the recent research and awareness of the increasing heavy load of office equipment, this still remains the largest potential area for energy savings in the commercial sector (IEA, 2009; b). The IEA (2009b) estimates across its member countries that energy consumed by IT and consumer electronics will double by 2020 and triple by 2030. It is therefore not surprising that OPENZ assesses the very significant 'energy savings' will result from better operational use of office equipment (measure Com. 57) – OPENZ estimates that by 2025/26 3.65 PJ/yr could be saved by this measure.
- *Lighting.* Lighting is a major end-use of electricity in the commercial sector. OPENZ identified a number of 'energy savings measures' in the 'technical potential optimisation' for reducing that load – that is, by 2025/26 the following savings were achieved: 2.11 PJ/yr by medium cost lamp upgrade (reflectors, triphosphor tubes, CFL's, etc); 0.80 PJ/yr high cost lamp upgrades (low loss ballasts, diffusers, high pressure sodium lamps); 0.55 PJ/yr by automatic controls (occupancy, time and daylight linked); 0.39 PJ/yr by low cost lamp upgrade (38mm to 26mm); 0.35 PJ/yr by delamping/fine tuning and 0.32 PJ/yr by improved operations and maintenance (optimising after hours use, cleaning, staff scheduling, luminaire cleaning, etc). In total, if all of these measures were adopted, 5.25 PJ/yr of electricity would be saved by 2025/26, compared with the BAU situation.
- *Improved and Integrated Envelope Design.* Although often requiring long lead-in times, as old building stock is replaced by new building stock, as well as retrofitting options; these options (Com. 66, Com. 96, Com. 126, Com. 75, Com. 138, Com. 152, Com. 53, Com. 86, Com. 119, Com. 57, Com. 104, Com. 134, Com. 144) do provide for significant energy savings over the medium-long run. The type of design options considered under this category include improved insulation (wall, ceilings, floor, double glazing); optimising design for shading/heating effects; optimising window sizes, maximising thermal mass in the building; and designs that allow for passive solar heating. In total, if all of these measures were gradually adopted over the next 20 years, OPENZ predicts that 6.82 PJ/yr of energy would be saved for the year 2025/26.

- *Water Heating.* Water heating is a somewhat surprisingly significant use of energy in the commercial sector, particularly in institutional settings like hospital, schools but also in food-related retail outlets. OPENZ identifies a number of energy saving measures including: Com. 72, Com. 92, Com, 71, Com. 59, Com. 62, Com. 60, Com. 91, Com. 99, Com. 88, Com. 94, Com. 128, Com. 121. Com. 90, Com. 83, Com. 122, Com. 103, Com. 133, Com. 89, Com. 106, Com. 107. Com. 113, Com. 118, Com. 146, Com. 147, Com. 154, Com. 158. More specifically this includes: use of instantaneous water heaters, condensing boilers/European Design practices; use of alternative means of hot water provision (e.g. from solar or cogeneration sources), flow controls on showers, optimised temperature settings, distribution efficiencies, lagging and insulation of pipes and cylinders, use of grey water heat in commercial kitchens and laundries. In total, by 2025/26, energy savings achieved by introducing this measure would save 4.53 PJ/yr.
- *Space Heating.* Space Heating is another significant end-use of energy in commercial buildings. OPENZ identifies a number of energy saving measures which include: Com. 56, Com, 68, Com. 87, Com. 61, Com. 98, Com. 04, Com. 78, Com. 76, Com. 27, Com. 93, Com. 123, Com. 95, Com. 100, Com. 101, Com. 82, Com. 125, Com. 131, Com. 129, Com. 124, Com. 102, Com. 132, Com. 104, Com. 112, Com. 105, Com. 108, Com. 110, Com. 115, Com. 116, Com. 117, Com. 110, Com. 115, Com. 116, Com.117, Com. 85, Com, 109, Com. 135-137, Com. 139, Com. 140, Com. 142, Com. 143, Com. 148-150, Com. 153, Com. 155-157. More specifically these include: Correct heating choice (radiant/convector/air), re-engineering existing heating plant, plant control (e.g. compensator control with reset), zone control (e.g. thermostatic radiator values), exhaust heat recovery, improved operations and maintenance (e.g. after hours cleaning schedules). In total, by 2025/26, energy savings achieved by introducing these measures saves 5.59 PJ/yr.
- *Electronics and Electrical Equipment.* There are significant potential energy savings to be achieved by purchasing electronic and computing equipment that have lower per unit energy use. It was estimated that 1.20 PJ/yr could be saved in 2025/26 if commercial uses purchased the most energy efficient office equipment.
- *More Efficient Space Cooling.* Space cooling is a significant and increasing end-use of energy in commercial buildings. In total, OPENZ assesses the ‘energy savings’ that could be achieved by more efficient provision of space cooling to be 1.38 PJ/yr by 2025/26.
- *Other Savings.* Other significant savings assessed by OPENZ included: 0.47 PJ/yr savings in 2025/26 by the use of cogeneration (particularly in hospitals and swimming pools); 0.38 PJ/yr savings in 2025/26 by better motor sizing; 0.29 PJ/yr savings in 2025/26 by the use of induction cooking in commercial kitchens; and 0.12 PJ/yr savings in 2025/26 by the use of variable speed drives for pumps.

In total, 30.95 PJ/yr in 2025/26 could be saved if all of these energy savings measures were adopted. This, along with the efficiencies gained from switching fuels, means that the total energy consumption of the commercial sector could reduce 37.4% over the study period from 63.41 PJ (crude oil equivalents)/yr in 2005/06 to 39.58 PJ (crude oil equivalents)/yr in 2025/26.

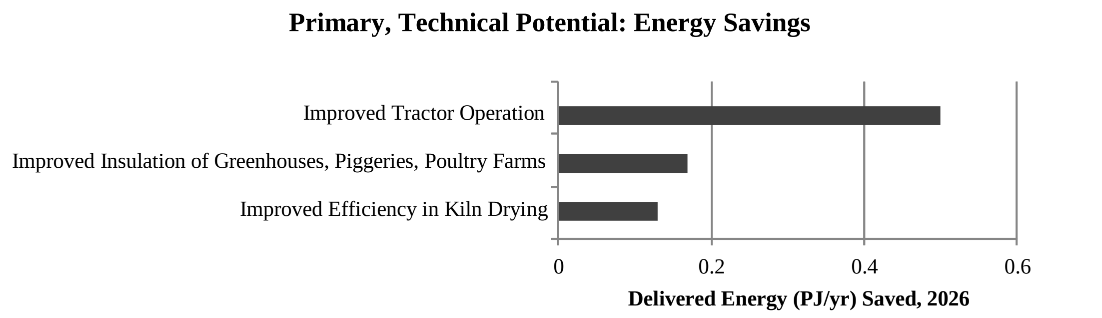
5.3.4 Primary Sector

Full details of the supply of energy end-uses for each year of the ‘technical energy savings’ optimisation is contained in Appendix F.1. Similarly full details of the ‘energy savings measure’ for the ‘technical energy savings’ optimisation are contained in Appendix G.1.

In general, compared with the other sectors, OPENZ identified significantly less opportunities for reducing energy inputs into the primary production sector. This is for two reasons: (1) the primary sector is far smaller, accounting for only 7.36% of delivered energy use in the New Zealand economy; (2) there is fewer energy savings mechanisms identified by Henderson (1994) for the primary sector – which OPENZ relies upon.[51]

The main changes in the supply energy end-uses by OPENZ were:

- *Intermediate Temperature Heat (100-300˚C).* There was a decline in the use of electricity from 26.9% in 2006/07 to only 11.00% in 2025/26. Fuel oil was completely phased out by 2013. As a consequence by 2025/26 Natural Gas provided 89.0% of the heat in this category.
- *Low Temperature Heat (<100˚C).* This heat is mainly required in the Protected Crop sector. For this end-use there was a phasing out of coal and diesel and where practical replacement by natural gas.
- *Motive Power (Mobile).* This includes farm vehicles, such as tractors and other off-road vehicles. There was a decrease in diesel use from 85.5% in 2006/07 to 70.1% in 2025/26, made up by a concomitant increase in petrol use.
- *Freight Transport.* At the base year a small percentage (7.9%) of the freight transport was petrol powered. This was phased out by 2009, from which point all freight transport was by diesel powered vehicles because of their superior energy efficiency.



The main 'energy saving measures' identified for the primary sector by OPENZ were:

- *Improved Insulation*. The mainly applied to greenhouses, but also pig and poultry farms. OPENZ assessed 0.17 PJ/yr energy savings by improved insulation by 2025/26.
- *Improved Efficiency in Kiln Drying*. OPENZ assessed 0.13 PJ/yr energy savings by improved efficiencies in this area by 2025/26.
- *Improved Tractor Operation.* This involves implementing the 'Tractor Facts' driver education programme 0.50 which encompasses: optimisation traction by more appropriate tyre selection, ballasting and loading; matching tractor and implement; appropriate engine speed and gear selection and efficient use of hydraulics (Barber, 2004). OPENZ indicates that PJ/yr could be saved by implanting this 'Tractor Facts' programme.

[51] There are a number of publications on energy conservation measures for the Primary Sector in New Zealand: Barber and Pellow (2005), Centre for Energy Research (2004), Ministry for the Environment (2007 a,b,c,d) and Morrison (2007). None of these publications however provide sufficient quantitative and economic data to adequately model the energy conservation options in OPENZ.

As noted above there are other ‘energy savings’ means that could be implemented in the Primary Sector. However, there is a lack of data particularly on alternative fuels (for tractors) and on improving the operation of dairy shed operations. For example, it should be possible in future versions of OPENZ, to re-evaluate options for water heating and milk chilling in dairy sheds.

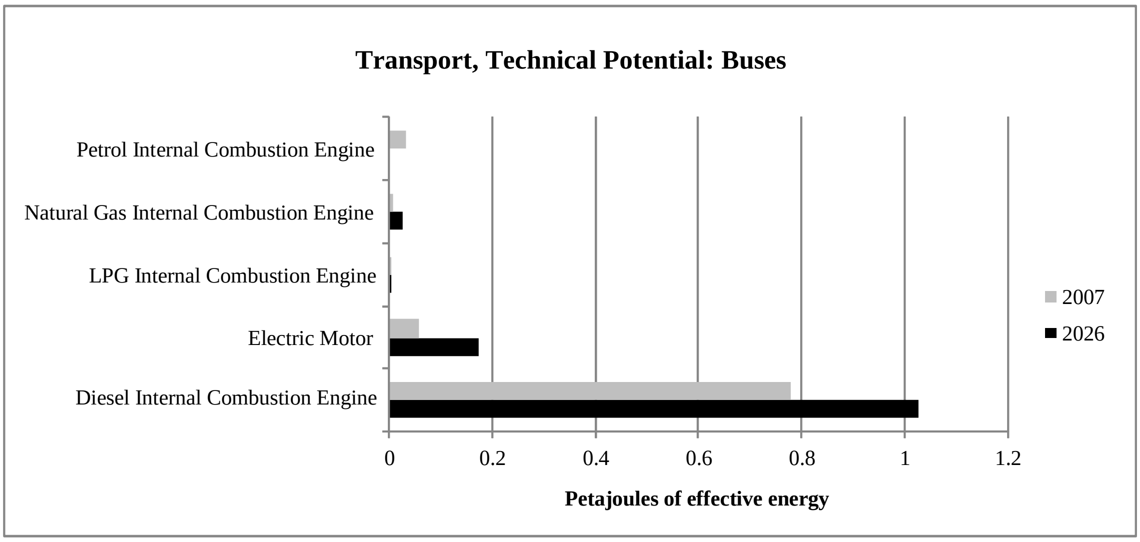
5.3.5 Transport and Storage Sector

Full details of the supply of energy end-uses for each year of the ‘technical energy savings’ optimisation is contained in Appendix F.1. Similarly full details for the ‘energy savings measures’ for the ‘technical energy savings’ optimisation are contained in Appendix G.1.

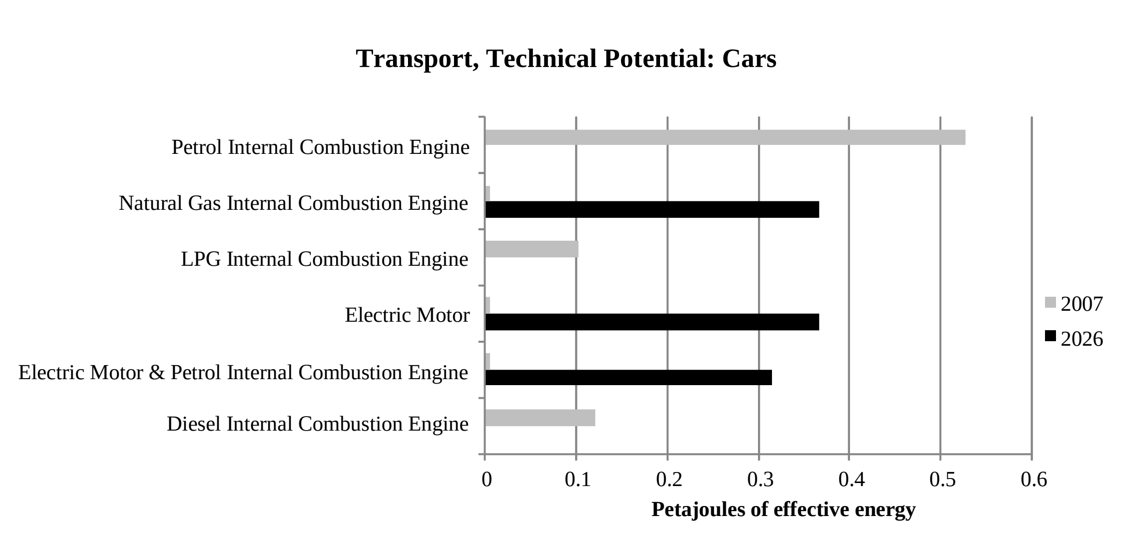
It should be noted that transport activities are also included in all other sectors (Household, Commercial, Primary, Industry). In compliance with ANZSIC, the transport and storage sector *only* includes transport and storage activities sub-contracted by clients from the other sectors.

The main shifts in ‘energy end-use’ supply processes for the transport and storage sector were:

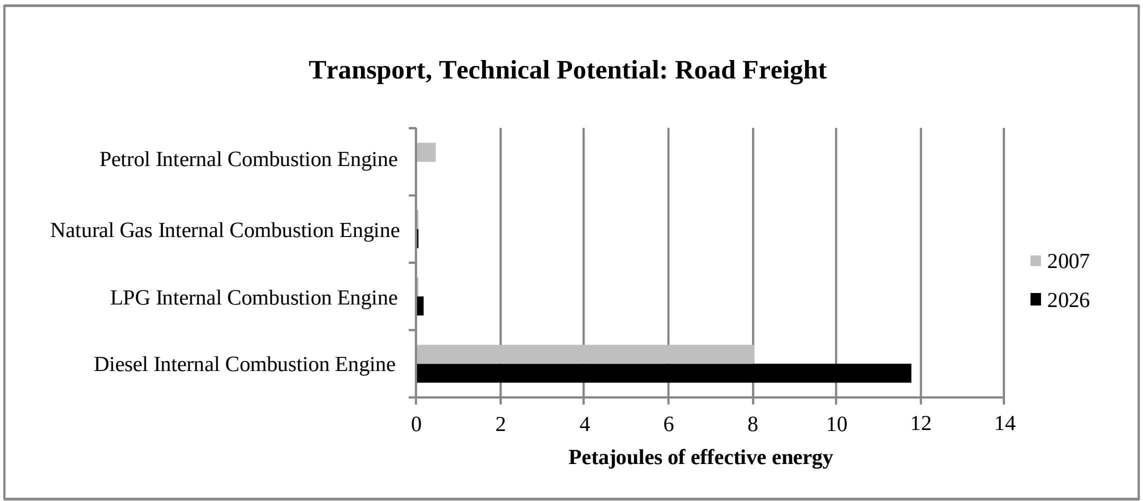
- *Buses for Land Transport.* OPENZ assesses steady increase in both electric and natural gas powered buses, based on their superior energy efficiencies. From 2006/07 electric buses increase from 6.6% to 14.1% by 2025/26. Similarly natural gas powered buses increase from 1.12% in 2006/07 to 2.2% in 2025/26. Diesel powered buses decrease, but still dominate, at 83.3% in 2025/26, whilst petrol powered buses are phased out by 2009.



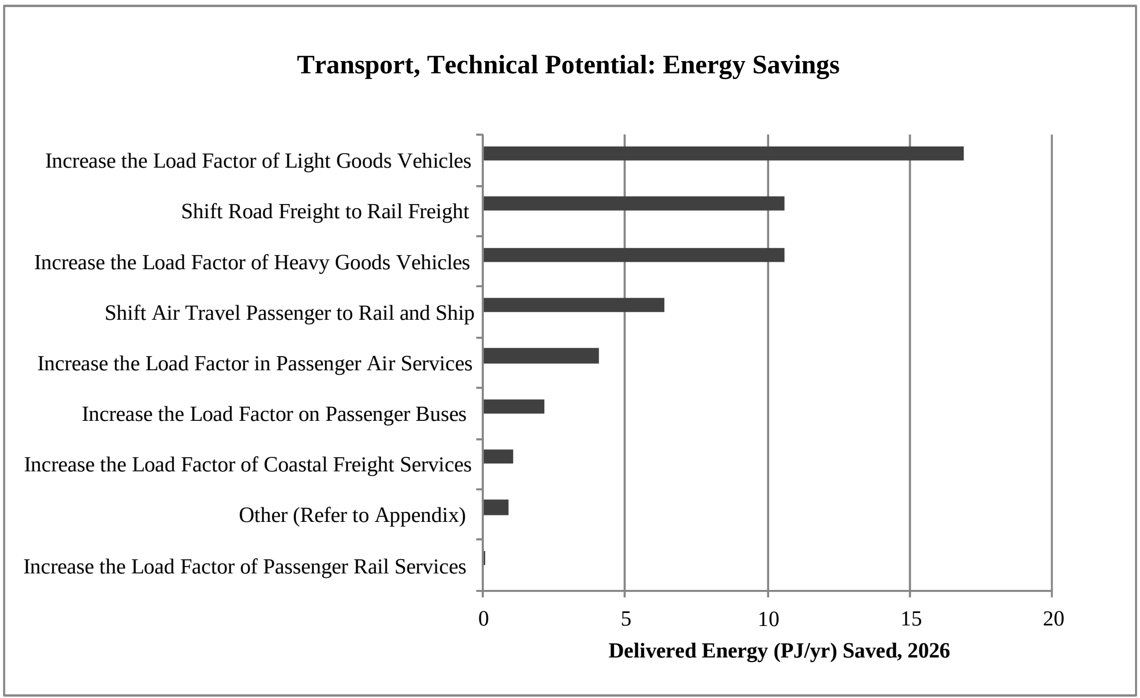
- *Cars for Land Transport.* This is a very small sub-sector, mainly consisting of taxis. By 2025/26 all these vehicles are converted to electric, hybrid electric or natural gas.



- *Freight Transport (Land).* OPENZ assesses a slight shift towards diesel powered vehicles. That is, diesel increases from 93.4% of the market share in 2006/07 to 98.0% in 2025/26. By 2009 petrol is phased out. By 2025/26 besides diesel, 1.53% of freight vehicles are using LPG and 0.45% natural gas.



- *Rail Freight.* In 2006/07 88.94% of this category of end-use energy was supplied by electricity. By 2025/26 all rail freight locomotives used electricity. The same pattern occurred for rail passengers services.



The main 'energy savings measures' implemented were:

- *Increase the Load Factor in Passenger Air Services by 10%.*[52] It is assessed based on updating on data previously compiled by Henderson (1994) that increasing the load factor in passenger air travel by 10% would save 4.08 PJ/yr by 2025/26.
- *Shift Air Travel Passenger to Rail and Ship*. This only includes domestic travel, as international air travel is not included in the model. It is assessed again from updated data from Henderson (1994) that this could save 6.39 PJ/yr by 2025/26. This would require a major upgrading of the New Zealand rail system to achieve this target, and probably a significant change in price relativities between the competing services. New Zealanders' travel by rail is small between the major centres compared with other developed countries particularly those in Europe.
- *Increase the Load Factor of Passenger Rail Services by 10%* [53] This was assessed by OPENZ to be 0.11 PJ/yr by 2025/26.
- *Increase the Load Factor of Coastal Freight Services* by *10%.*[54] This is assessed by OPENZ to be 1.08 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adapted in growth rates applied to OPENZ.
- *Increase the Load Factor on Passenger Buses by 10%.*[55] Load factors on New Zealand buses are low (average of about 30%). OPENZ calculates that by increasing this load factor by 10% by 2025/26, then 2.17 PJ/yr energy could be saved.

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52 It is not known for certain what the load factor for Passenger Air Services is. It is therefore assumed that there is a 10% increase, from 60% to 70% loading.

53 It is not known for certain what the load factor for Passenger Rail Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.

54 It is not known for certain what the load factor for Coastal Freight Services is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

55 It is not known for certain what the load factor for Passenger Bus Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.

- *Increase the Load Factor of Light Goods Vehicles by 10%.*[56] Improved logistics, planning and organisation, could save a very significant amount of energy, due to the large amount of end-use energy used for light goods freight. It is estimated by OPENZ, using updated data provided by Henderson (1994), that by 2025/26 16.9 PJ/yr could be saved which is due in part to the strong relative growth of this sector.
- *Increase the Load Factor of Heavy Goods Vehicles by 10%.*[57] Although the load factor of heavy goods vehicles (about 50%) is better than light goods vehicles (about 30%), there is still considerable potential for improvement. OPENZ assess that by 2025/26 10.6 PJ/yr could be saved by improving the load factor of heavy freight vehicles by another 10%.
- *Shift Road Freight to Rail Freight.* This is assessed to be 10.60 PJ/yr energy saving by 2025/26. Again this would require a significant upgrading of the New Zealand freight rail system, and the appropriate financial incentives put in place.

If all of these technically viable transport sector 'energy savings measures' are implemented, then by 2025/26 52.84 PJ/yr of savings will be achieved. This is significantly more than the other sectors.

[56] It is not known for certain what the load factor for Light Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 20% to 30% loading.

[57] It is not known for certain what the load factor for Heavy Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

6. Economic Energy Savings Potential

The 'economic energy savings' potential, is the amount of energy that can be saved, by employing the most economic means of energy supply and energy savings measures. In OPENZ, this was determined by minimising the 'total economic cost' ($). In this context, 'total economic cost' ($) was defined as the sum total of the energy cost ($) annualised capital cost at a 10% discount rate ($), any other cost ($) including operating costs, plus a cost ($) for Greenhouse Gas Emissions.

6.1 Assumptions

In essence all of the assumptions that apply to the 'Technical Energy Savings Potential' also apply here:

The key assumptions in quantifying the 'Economic Energy Savings Potential' were: [58]

- The size of natural gas reserves in 2,427.6PJ (allowing 20% for new discoveries).
- Rebound effect from new Household Insulation is 44%.
- Rebound effect from new Heat Pumps is 10%.
- Energy Prices are at the 'default' levels as outlines in Appendix C. These default prices only apply to the exogenously determined prices (refer to section 2.10.1), not the prices for endogenously determined prices (electricity, ethanol, methanol, biogas, synthetic petrol, synthetic diesel and natural gas). These default energy prices were almost entirely drawn from Donovan *et. al's* (2009) report that provides a very thorough analysis of future energy prices from 2008 to 2060.
- 617,940 ha are available for agricultural bio-energy crops and 1,411,500 ha are available for silviculture energy crops. In actuality neither of these constraints (availabilities) become binding.
- The activity levels of the 37 sectors of the economy from 2006/07 to 2025/26 are the 'default values' as estimated by the Economic Futures Model. These 'activity levels' are directly based on the projected contributions to GDP (value added) of each sector in the economy. For the household sector, the projected activity is based on 'household consumption ($)', which is forecasted to increase by 37% over this period. These GDP (and household consumption) based activity levels were used to estimate the projected amounts of energy end-uses for each sector.
- Carbon Prices are at the 'default' levels outlined in OPENZ and discussed in Section 2.5. These 'carbon prices' are arguably quite conservative (low), but broadly consistent with those used by East Harbour Management Services (2004, 2005) and The Treasury (2005).
- A 'default' setting of 23.7 PJ/yr for methanol and urea production is assumed for each year.
- Penetration rates for both new and existing energy end-uses processes are set at 'high' levels. This reflects an underlying assumption for the 'technical energy savings' optimisation, that OPENZ can relatively quickly switch to new optimal mixes of technologies. These penetration rates therefore can be seen as 'optimistic' compared with those specified for the realisable energy savings' optimisation. The specific penetration rates for new and existing energy end-use processes, for the 'economic energy savings' optimisation are detailed in one of the worksheets of the OPENZ model.

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[58] The rationale and calculation underpinning these key assumptions is provided in the appropriate sections of Section 2 of this report.

- Penetration rates for ‘energy savings measures’ are all set at 100%. This means that by 2025/26 all of these energy savings measure could be fully adopted. Again, as with the energy end-use processes, that can be seen to be a relatively ‘optimistic’ set of assumptions.
- Penetration rate between 1991/92 and 2006/07 of Henderson’s (1994) energy savings measure were all set at 30%.
- For a small number of energy supply processes, a constraint was placed on the process activity, to ensure that it would not be adopted for a minimum of 10 years. This avoided the situation of a supply process like enzyme hydrolysis of maize to ethanol’ only being adopted for 3 years before it was discarded, which is obviously unrealistic.
- Percentage of electricity that could be generated from wind was set at an upper limit of 20%, due to this being considered the upper technical level possible in New Zealand electricity supply system.
- It was assumed that by 2026/27 that 95% of New Zealand households could have ceiling insulation, wall insulation, floor insulation and double glazing. This was from a base of 2006/07 where 64% of households had ceiling insulation, 45% had wall insulation, 18% had floor insulation and 9% had double glazing. There was a linear interpolation between the 2006/07 and 2025/26 levels of insulation, to allow for a technically feasible level of uptake.

6.2 Headline Results

6.2.1 Primary Energy Savings

The *difference* between the ‘BAU’ and ‘Optimised’ primary energy inputs is the energy savings. For the ‘technical energy savings’ potential the primary energy savings was 439PJ/year[59] by 2025/26, compared with the ‘economic energy savings potentials’ for 2025/26 of 305 PJ/year[60]. In other words, by selecting the most economic means of energy supply and demand, the ‘energy savings’ decreased by 30.5% compared with the technical energy savings potential.

As can be ascertained from Fig 6.1 primary energy consumption remains quite constant from 2007/08 to 2025/26 in the range of 418 to 461 PJ, in spite of a growing economy and a concomitant increase in the requirements for energy end-uses. Overall, in fact over the entire 20 year period (2006/07 – 2025/26) primary energy consumption for ‘economic energy savings potentials’ optimisation, actually drops by 15.9%.

[59] This is 439PJ (heat content) which in this case equals 470PJ (crude oil equivalents).

[60] This is 305PJ (heat content) which in this case equals 251PJ (crude oil equivalents).

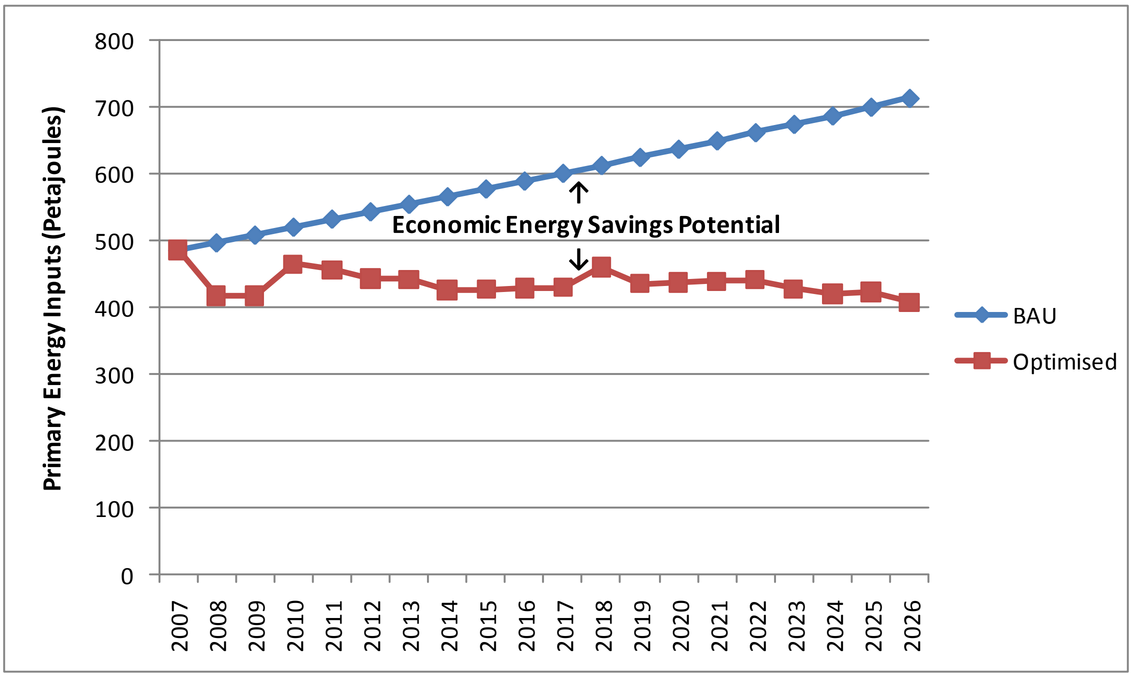


Figure 6.1 Primary Energy Inputs for the Economic Energy Savings Optimisation ***(Measured in terms of 'Heat Content')***

6.2.2 Energy Intensity

Energy intensity is a measure of gross energy efficiency (Patterson, 1996). That is, the lower the energy intensity (J/$), the higher the energy efficiency of the nation or sector.

Because of structural shifts in the New Zealand economy, even with 'BAU' projections, the energy intensity of the economy is projected to decrease from 4.55 PJ (Crude Oil Equivalents/$$_{2006/07}$billion) in 2006/07 to 3.80 in 2025/26. As has been seen in Section 5.2.2, this decrease in energy intensity is accelerated even further with the 'technical energy savings' potential to 1.69 PJCrude Oil Equivalents/$$_{2006/07}$ billion in 2025/26. The same trend occurs for the energy intensity with the 'economic savings potentials', although not quite so fast a rate of decline. That is, by 2025/26 under the 'economic savings potential', the national energy intensity drops to 2.67 PJ (crude oil equivalents)/$$_{2006\text{-}2007}$ billion.

This decrease in the energy intensity of 41.2% according to the 'economic savings potential' optimisation represents a very significant improvement in New Zealand's economy-wide energy efficiency. By direct implication, 16.4% is due to structural shifts in the sectoral make up of the economy from 2006/07 to 2025/26, with the remainder of 24.8% due to 'technical improvements'. This represents an annual rate of close to 1.9% for technical energy efficiency improvements which compares with technical improvements of about 1% historically recorded by using the divisia decomposition method (Lermit and Jollands, 2001; Jolland, Lermit and Patterson, 2004; Patterson, 1993).

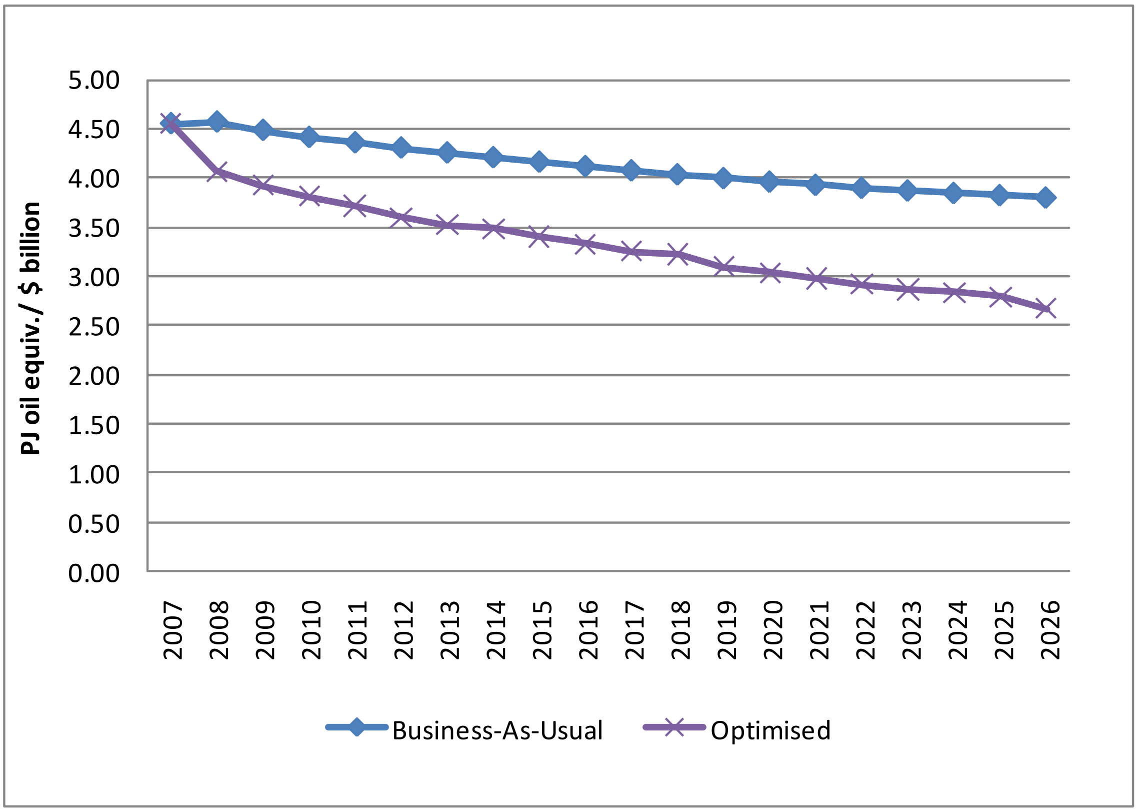


Figure 6.2 NZ Energy Intensity for the Economic Energy Savings Optimisation

6.2.3 Greenhouse Gas Emissions

Unlike the 'technical energy savings' optimisation there was not a decrease in greenhouse gas emissions. In fact under the 'economic energy savings' optimisation, the greenhouse gas emissions increased from 38,584 kilotonnes (CO_2 equivalents) in 2006/07 to 49,958 kilotonnes (CO_2 equivalents) in 2025/26. This represents a 29.5% increase over a 20 year period, compared with the Business-As-Usual projection of 23.6% in greenhouse gas emissions over the same period. The main reason for the increase in greenhouse gas emissions is the significant increase in the use of both coal and natural gas as they are often less expensive options albeit options that produce higher GHG emissions.

6.2.4 Economic Cost

The advantage of the 'economic energy savings' optimisation, is that (by definition) it is economically the least costly ($) option. That is, by 2025/26 it supplies New Zealander's energy needs (end-use services) at a cost of $ 2006/07 56,524 billion – this compares with:

- $\$_{2006\text{-}07}$ 70,106 million for the 'Business-As-Usual' case.
- $\$_{2006\text{-}07}$ 76,661 million for the 'Technical Energy savings Potential'.

The other advantage of the 'economic savings optimisation' is that it reduces primary energy consumption by 251 PJ (crude oil equivalents)/yr in 2025/26 compared with the Business-As-Usual projection. The 'trade-off' is that, it does this at the expense of the relatively high greenhouse gas emissions, and in fact an increase in greenhouse gas emissions compared with the 'Business-As-Usual' projection.

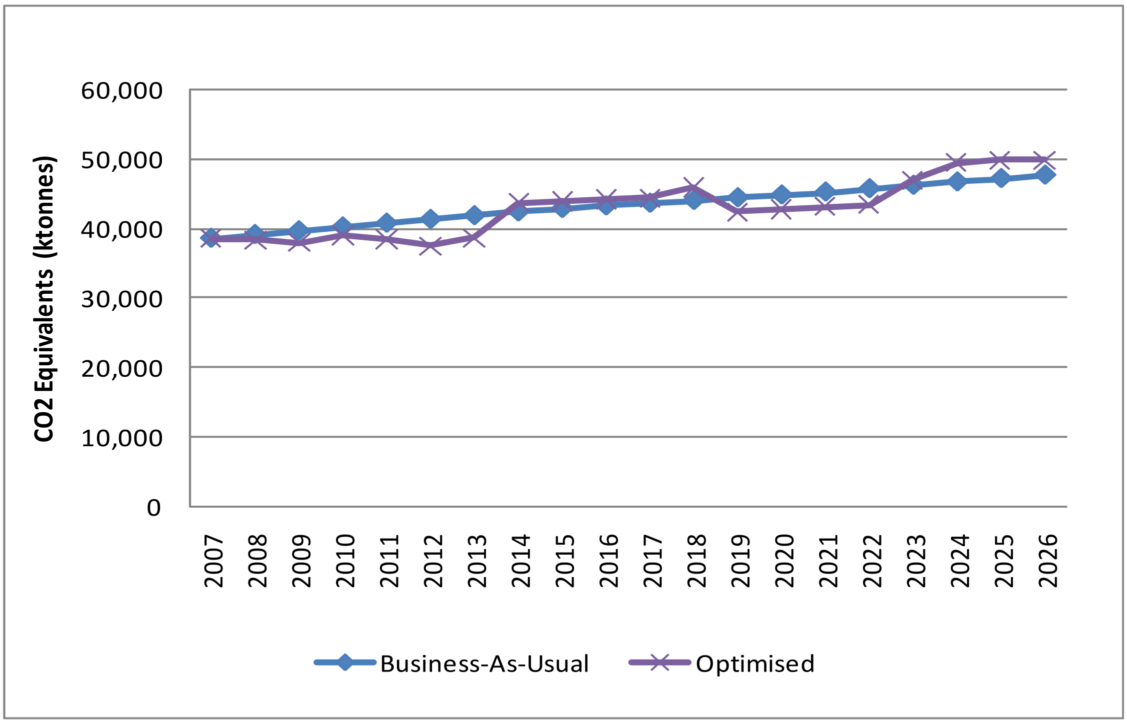


Figure 6.3 Greenhouse Gas Emissions for the Economic Energy Savings Optimisation

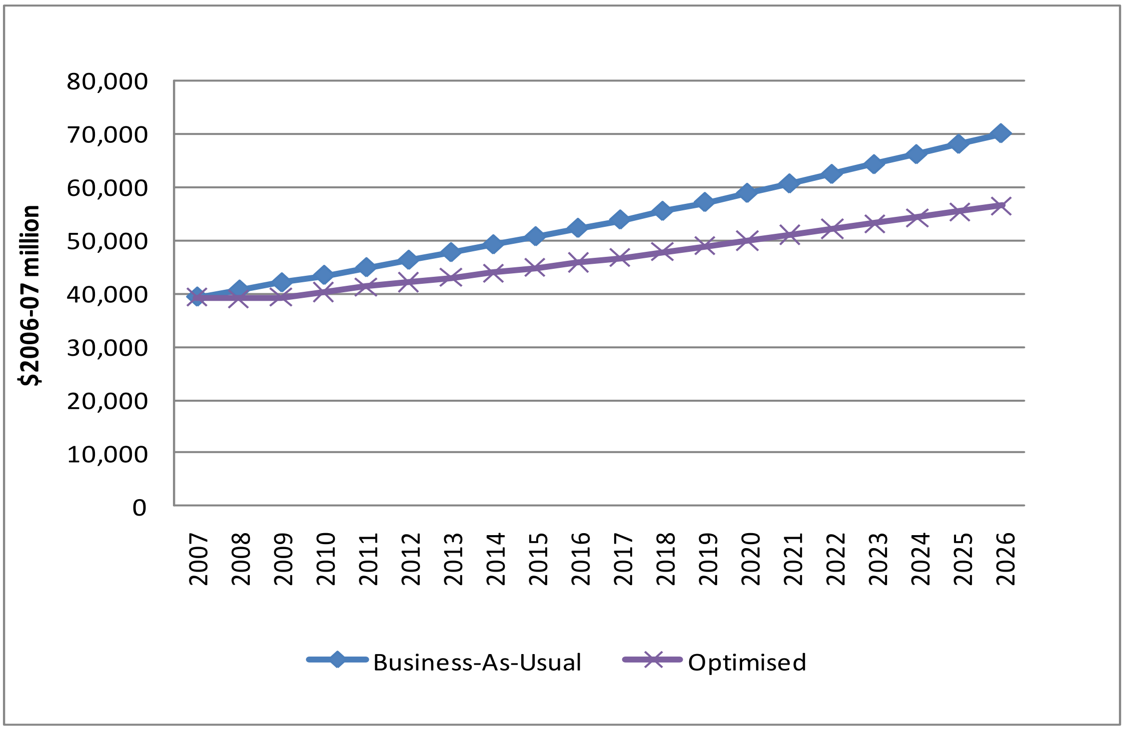


Figure 6.4 Economic Cost for the Economic Energy Savings Optimisation

6.2.5 Primary and Delivered Energy

Under the 'Economic Energy Savings' optimisation, the total delivered energy consumption increased 10.5% over the 20 year period, up to 636.3 PJ/yr in 2025/26. This contrasts with the 'Technical Energy Savings' optimisation where the delivered energy consumption remained close to unchanged over this period. Overall, there was a decline in electricity of 11.89%, down to 130.2 PJ/yr in 2026/27. This decline was mainly due to more efficient use of electricity but also some fuel switching away from electricity. Natural Gas (57.5%) and Coal (114.9%) recorded significant increases in their levels of consumption. Coal usage particularly increased in the industrial sector for heating end-uses, but also recorded some increase use in the commercial sector. The main increases in Natural Gas use were increased hot water provision and some industrial heat applications. In transport, there was some switching from petrol to diesel, which mainly explains the decline in Petrol (-34.34%) use and the increase in Diesel (36.3%) use over the study period.

Full details of the patterns of primary energy supply for the 'Economic Energy Savings' optimisation are contained in Appendix E.2. For the 'Economic Energy Savings' optimisation, by 2025/26, most electricity continues to be supplied by Hydroelectricity (65.22%), followed by Wind (18.98%), Geothermal (18.91%), Coal (2.10%) and Others (0.95%). Notably, Natural Gas as a source of electricity is phased out by 2018. Based on the economic criteria of the 'Economic Energy Savings' optimisation, by 2025/26, significant amounts of Petrol (44.7 PJ/yr) and Diesel (44.7 PJ/yr) are produced from Southland Lignite, replacing crude-oil sources of these transport fuels which have come more expensive according to the price projections used in OPENZ.

Table 6.1 Delivered Energy Consumption (PJ, Heat Units) for the Economic Energy Savings Potential

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	530.63	133.22	102.10	116.13	17.46	47.15	8.22	3.44	45.54	33.27	24.09	0.03	0.01
2009	536.30	133.92	100.00	118.89	17.58	50.42	8.21	1.66	47.26	33.32	25.00	0.04	0.00
2010	541.41	134.89	98.49	122.30	17.69	53.71	8.57	1.48	48.61	30.61	25.00	0.06	0.00
2011	549.07	136.18	96.84	125.76	17.81	56.73	8.92	0.93	50.17	30.66	25.00	0.07	0.00
2012	554.68	136.06	94.89	128.94	17.89	59.60	9.27	0.84	51.28	30.82	25.00	0.09	0.00
2013	560.65	136.05	93.20	131.66	17.98	62.47	9.62	0.74	52.83	30.99	25.00	0.11	0.00
2014	566.62	135.88	91.25	134.80	18.05	65.34	9.96	0.56	54.49	31.15	25.00	0.13	0.00
2015	572.40	135.27	89.30	137.93	18.13	68.21	10.31	0.59	56.21	31.32	25.00	0.15	0.00
2016	578.10	134.89	87.33	141.05	18.20	71.08	10.66	0.27	57.98	31.48	25.00	0.17	0.00
2017	583.64	134.21	85.13	144.13	18.26	73.80	11.00	0.31	59.96	31.65	25.00	0.18	0.00
2018	589.26	133.61	82.90	147.20	18.32	76.49	11.35	0.34	62.03	31.82	25.00	0.20	0.00
2019	594.97	133.03	80.66	150.05	18.38	79.18	11.69	0.38	64.38	31.99	25.00	0.22	0.00
2020	601.05	132.54	78.66	152.80	18.44	81.88	12.04	0.42	66.88	32.15	25.00	0.24	0.00
2021	607.32	132.06	76.87	155.76	18.49	84.57	12.38	0.46	69.16	32.32	25.00	0.26	0.00
2022	612.77	131.64	74.95	158.17	18.53	87.28	12.72	0.50	71.21	32.49	25.00	0.28	0.00
2023	618.59	131.21	73.16	160.89	18.57	89.99	13.01	0.55	73.26	32.66	25.00	0.30	0.00
2024	624.41	130.80	71.34	163.57	18.60	92.63	13.33	0.59	75.40	32.83	25.00	0.31	0.00
2025	630.36	130.52	69.51	166.21	18.63	95.26	13.67	0.64	77.61	33.00	25.00	0.31	0.00
2026	636.30	130.23	76.14	160.33	18.65	97.89	14.00	0.69	79.89	33.17	25.00	0.30	0.00
Growth Rate	**10.54%**	**-11.89%**	**-34.34%**	**36.26%**	**3.95%**	**114.93%**	**69.23%**	**-92.04%**	**57.45%**	**-18.19%**	**10.78%**	**n.a**	**n.a**
Average Growth Rate	**0.53%**	**-0.66%**	**-2.19%**	**1.64%**	**0.20%**	**4.11%**	**2.81%**	**-12.47%**	**2.42%**	**-1.05%**	**0.54%**	**n.a**	**n.a**

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even though this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

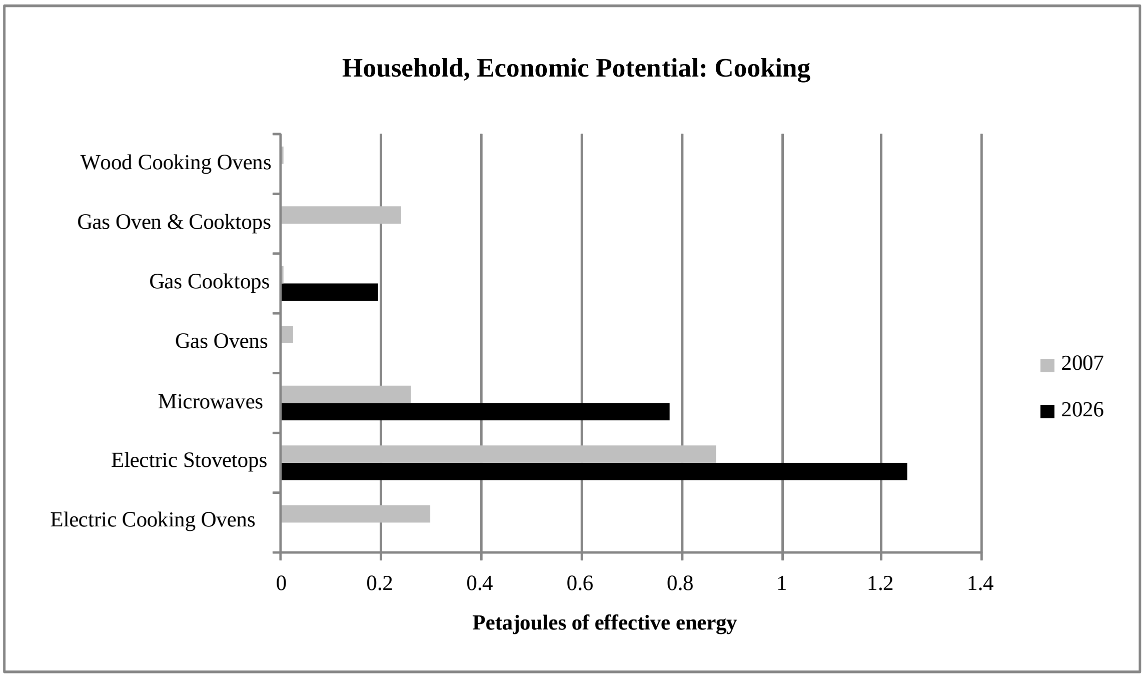
6.3 Detailed Sector-by-Sector Results

6.3.1 Household Sector

Full details of the supply of energy end-use, for each year of the 'Economic Energy saving' optimisation are contained in Appendix F.2. Similarly, full details of the 'energy savings measures' for the 'economic energy savings' optimisation are contained in Appendix G.2.

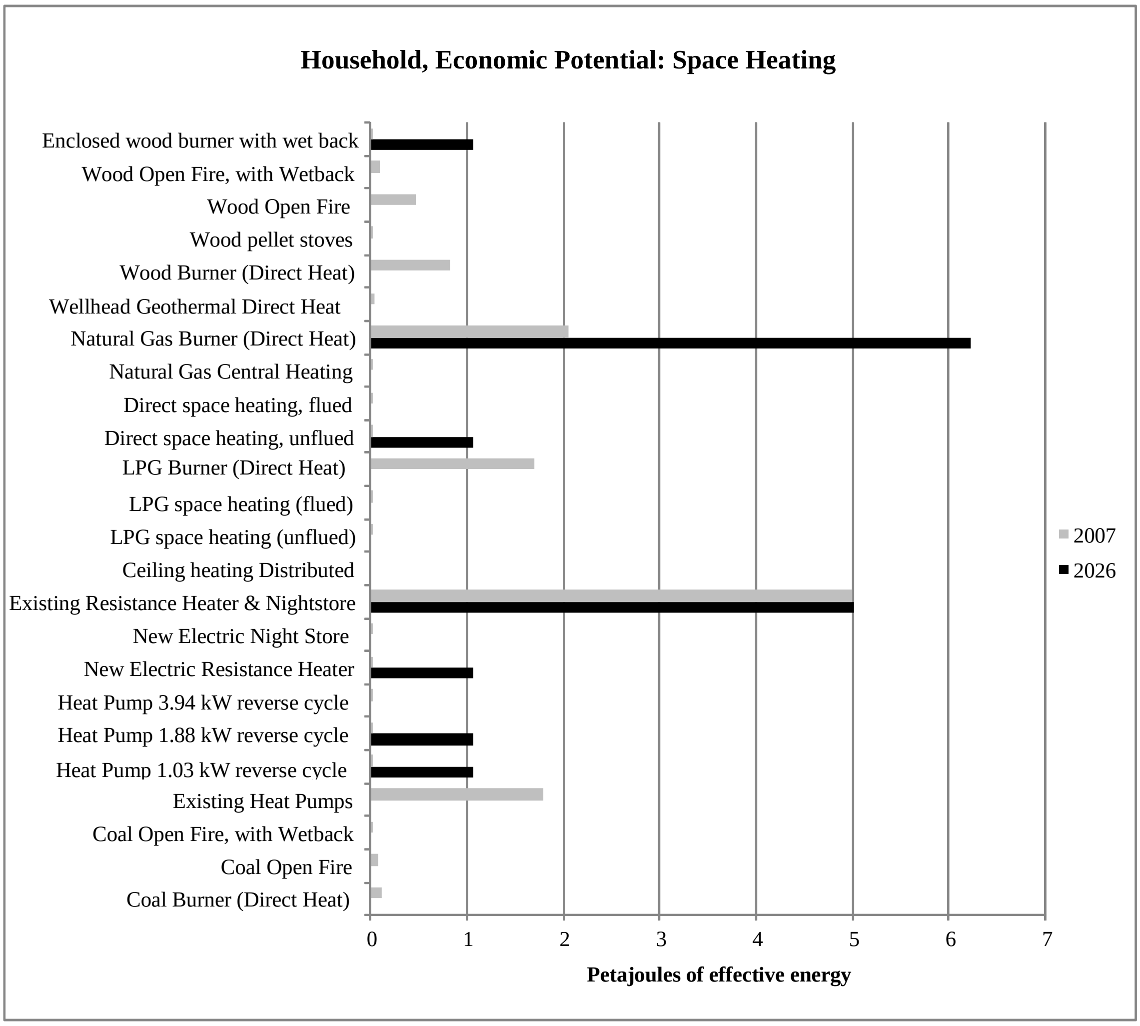
The main shifts in the 'energy end-use' supply processes for the household sector were:

- *Cooking.* The electric stovetop increased slightly from 51.2% to 56.4% of this end-use category, over the 2006/07 to 2025/26 period. There were also increases in the use of microwave ovens over the same period from 15.2% to 34.9%. Overall this was counterbalanced by a decrease in gas cooking from 15.75% in 2006/07 to 8.74% in 2025/26. By point of contrast with the 'technical energy savings' optimisation, electricity dominated rather than natural gas. This is because of the relative low cost of using electricity, even though it is 'energetically' inefficient to do so.[61]

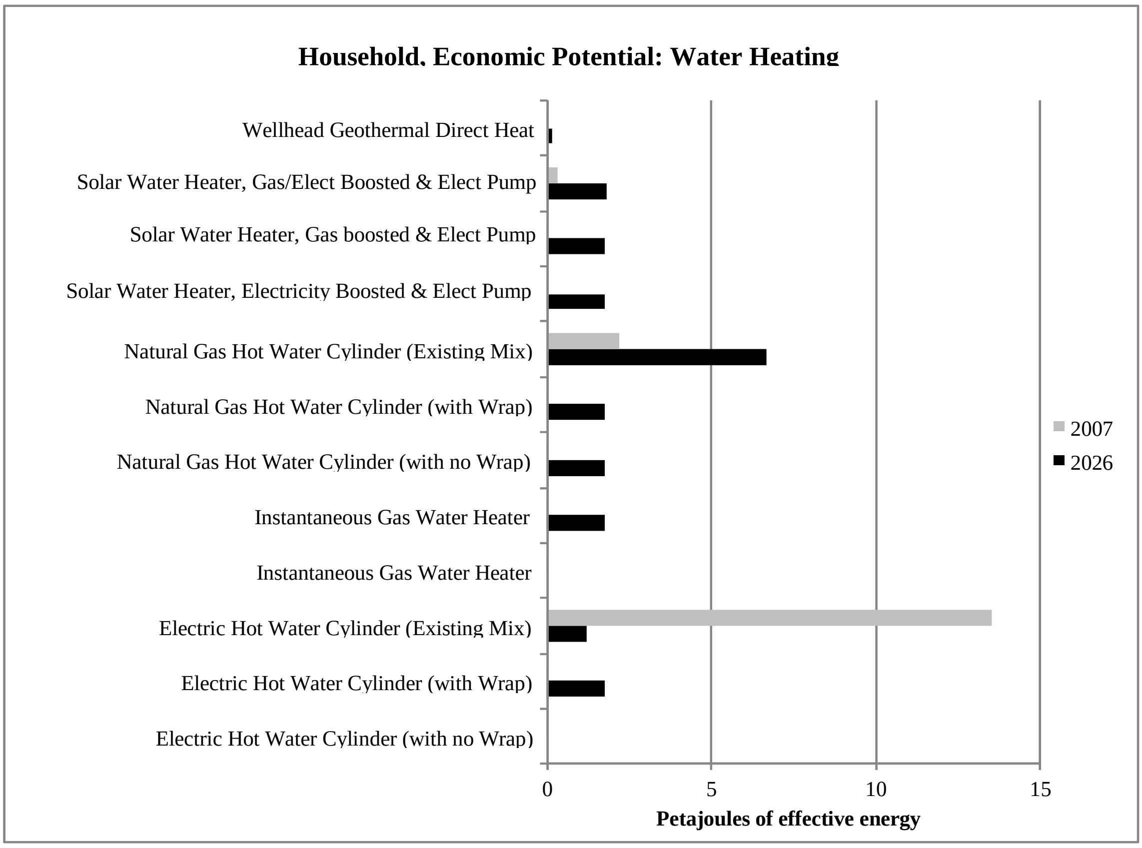


- *Space Heating.* By 2025/26 there was a complete elimination of open fires, except for open fires with wet backs – this is the same situation as for the 'technical energy savings' optimisation. Notably, however unlike the 'technical energy savings' optimisation resistance heaters and nightstores (where they were eliminated) still provided 30.3% of the space heating. The remainder of the space heating by 2025/26 was provided by natural gas heaters (44.0% and heat pumps (19.3%).

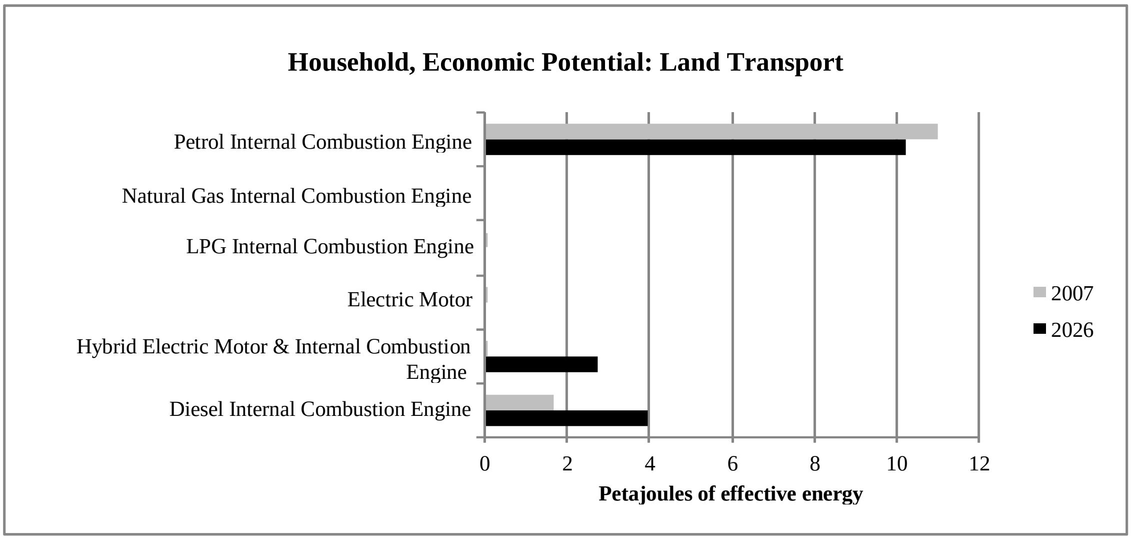
61 Even though, there is some debate concerning the legitimacy of different definitions of energy efficiency – (refer to section 1.6 and Patterson 1996), almost all definitions of energy efficiency consider the direct use of electricity for heating purposes to be energetically inefficient



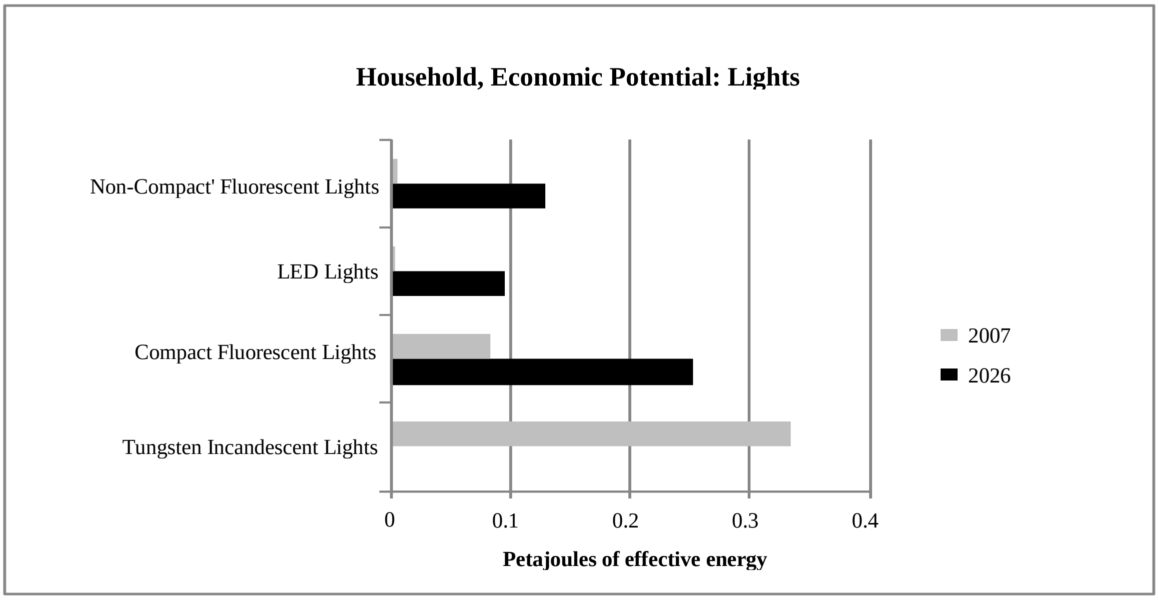
- *Water Heating.* Electric hot water cylinders which supplied 82.1% of the hot water in 2006/07, declined to only 14.5% of hot water provision in 2025/26. By 2025/26, this was replaced by 58.5% of hot water being provided by natural gas technologies. This was a similar pattern to the 'technical energy saving optimisation', although in that case the decline in electric hot water provision was even more marked.



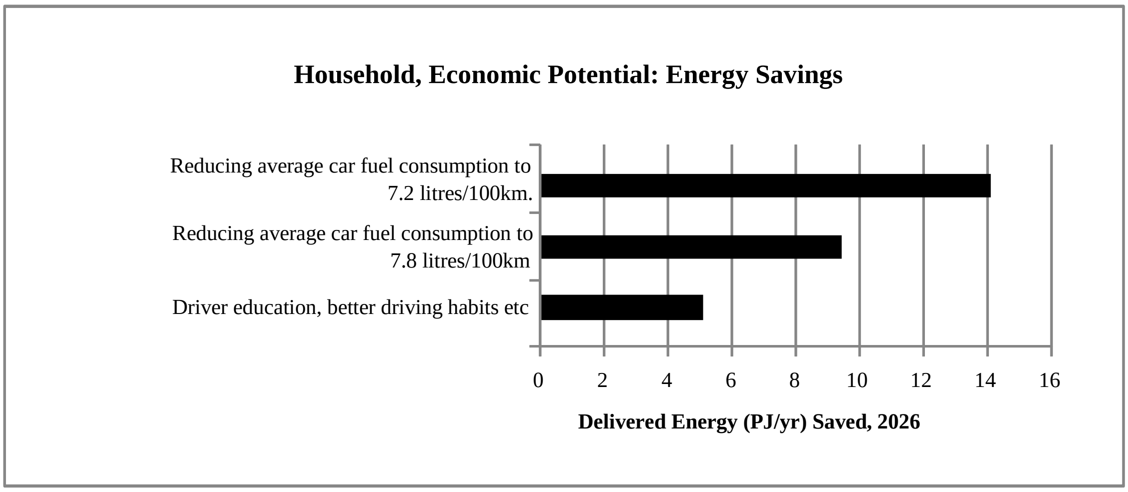
- *Land Transport.* Unlike the 'technical energy savings' optimisation there was no uptake of alcohol fuels (ethanol, methanol), although there was a significant uptake of electricity-petrol hybrid cars by 2025/26 to 16.2% of market share. There was also some uptake of diesel powered vehicles, increasing from 12.8% in 2006/07 to 23.4% in 2025/26, as well as a very small uptake of natural gas vehicles. This lead to a significant decline in petrol fuelled private vehicles from 85.4% of market share in 2006/07 to 60.2% in 2025/26.



- *Lighting.* The change of mix of lighting technologies, is exactly the same as for the 'technical energy savings' optimisation. That is, by 2019 there was the complete elimination of tungsten incandescent lights and the replacement by more energy efficient (and cost effective) forms of lighting. By 2025/26, 53% of lighting is from compact fluorescent lights, 27.0% from LED lights and 19.9% from long tube fluorescent lights.



- *Obligatory Electrical End-Uses.* Obligatory electrical end-uses (electronic, refrigeration, etc.) make up a considerable portion of household electric uses. These increased by 33.3% over the 2006/07 to 2025/26 period.



The main implementation of 'energy savings' measures in the household sector achieved by 2025/26 were those related to land transport:

- The 'technical energy savings' optimisation identified a number of 'behavioural' mechanisms for saving energy – car pooling (2 people per vehicle), use of bicycles for commuting and telecommuting (4 days out of 5 days). The economic cost of these options ($211 million /PJ saved car pooling and $112 million / PJ saved for bicycle commuting) was simply too high compared, with the energy savings they achieved, so they were eliminated in the 'economic energy savings' optimisation.

- 9.47 PJ/yr in reducing average car fuel consumption to 7.8 litres/100km. This is exactly the same amount as for the 'technical energy savings' optimisation.
- 14.1 PJ/yr in reducing average car fuel consumption to 7.2 litres/100km. This is exactly the same amount as for the 'technical energy savings' optimisation.
- 5.1 PJ/yr from driver education, better driving habits and correct maintenance of cars (tyres, exhaust checks, tune-ups, etc.).

Notably, under the 'economic energy savings' potential there was no further insulation of homes from the 2006/07 base year. That is, the level of insulation in New Zealand households remained at:

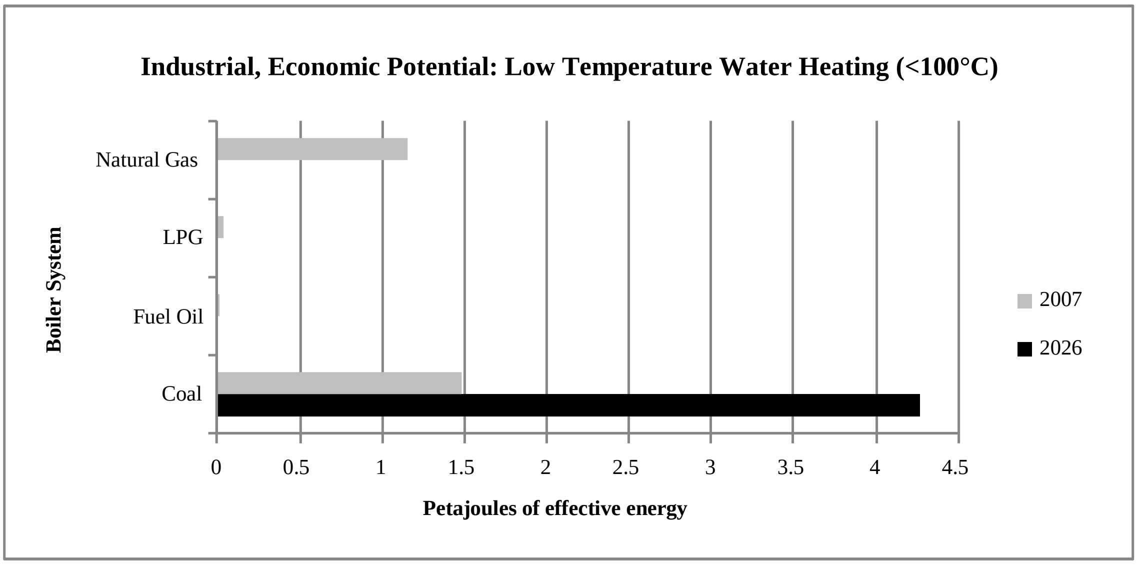
- 64% for ceiling insulation
- 45% for wall insulation
- 18% for floor insulation
- 9% for double glazing.

6.3.2 Industrial Sector

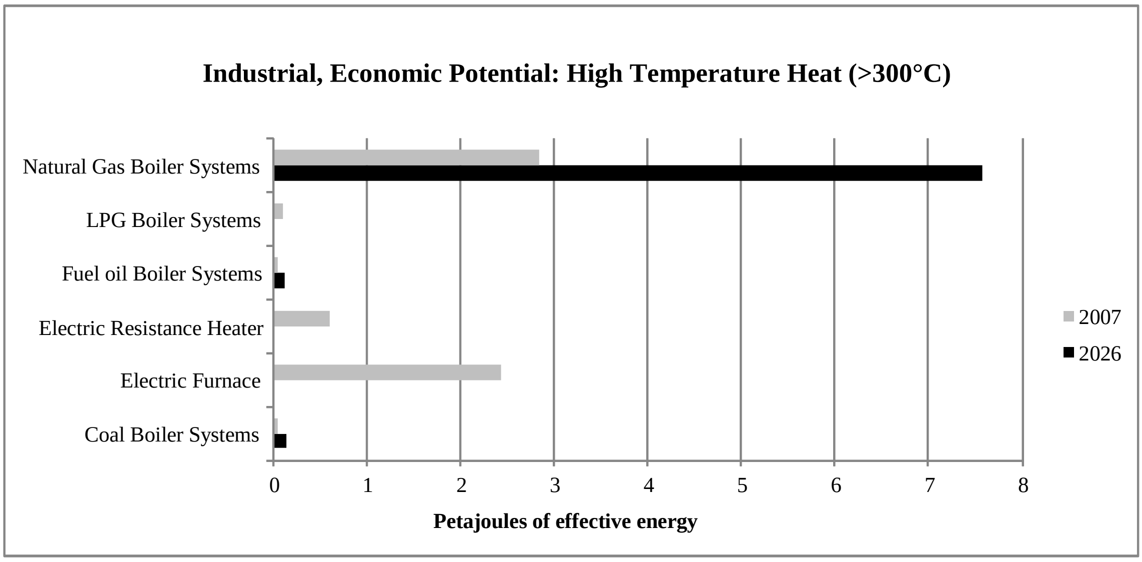
Full details of the supply of energy end-uses, for each year of the 'economic energy savings optimisation' are contained in Appendix F.2. Similarly, full details of the 'energy savings measures' for the 'economic energy savings optimisation' are contained in Appendix G.2.

The main shifts in the 'energy end-use supply' processes for the industrial sector were:

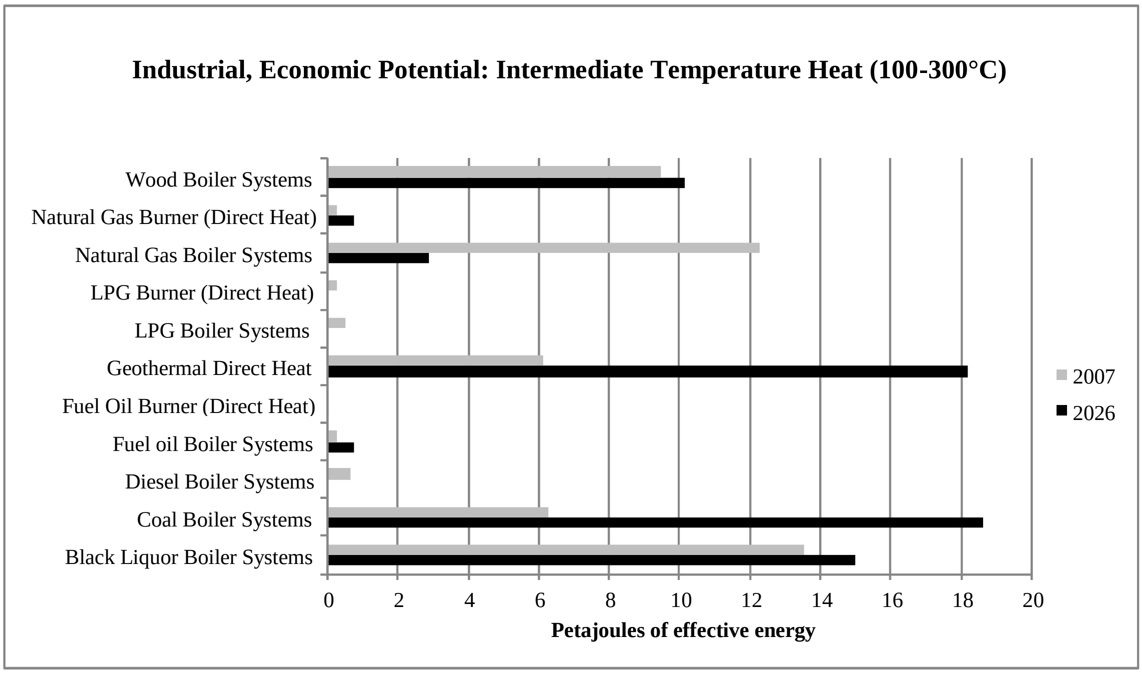
- *Low Temperature Water Heating (<100˚C).* By 2025/26 coal replaced all other sources of fuel, with fuel oil being phased out by 2024, natural gas being phased out by 2022, and LPG being phased out much earlier, by 2008.



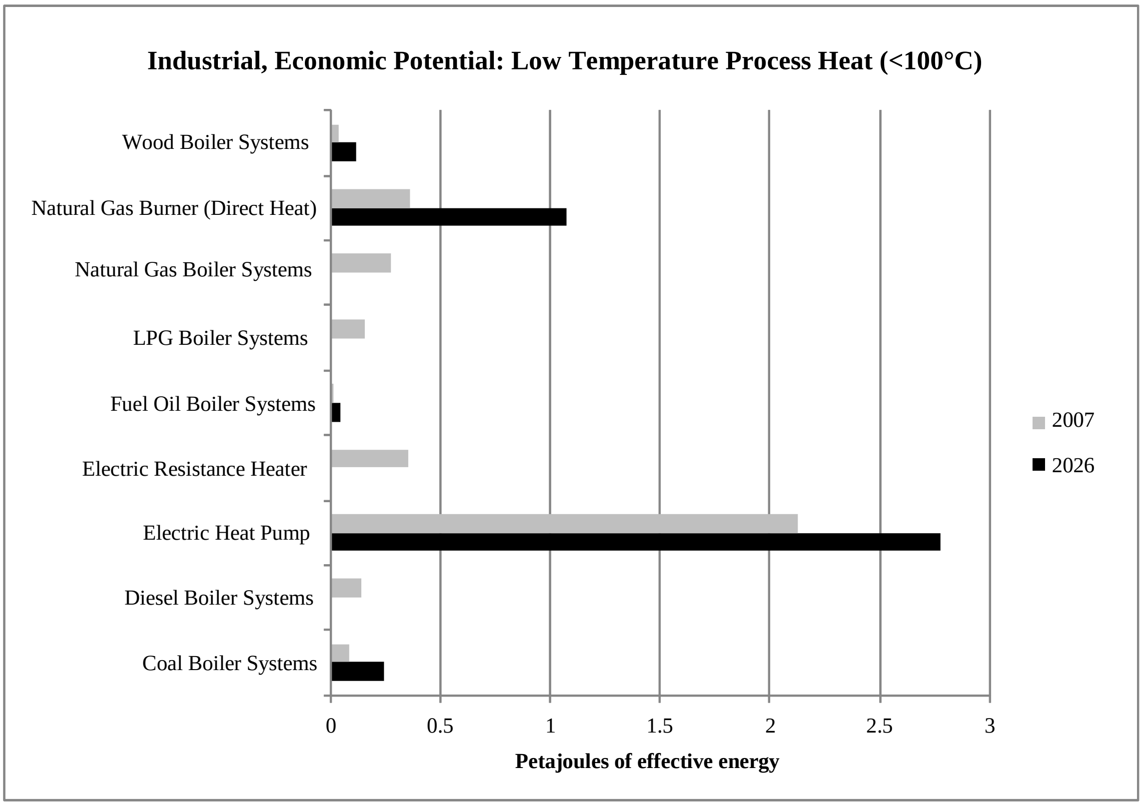
- *High Temperature Process Heat (>300˚C).* There is a consolidation of already heavy use of natural gas. By 2025/26 natural gas provided 96.7% of this end-use category, with small amounts of coal (1.9%) and fuel oil (1.5%) mainly in areas where natural gas isn't feasibly available. This fuel mix is very similar as for the 'technical energy savings' optimisation.



- *Intermediate Temperature Process Heat (100-300˚C).* By 2025/26, the main sources of this category of heat were coal (28.1%), geothermal (27.4%), and black liquor (22.6%). Unlike the 'technical savings optimisation' (where there was an increase), there was a decrease in the use of natural gas from 25.2% in 2006/07 to 5.5% in 2025/26.



- *Low Temperature Process Heat (<100˚C)*. By 2025/26, heat pumps provided 65.1% of the heat, following by natural gas at 25.2%, coal at 5.8%, wood at 2.7% and fuel oil at 1.1%.

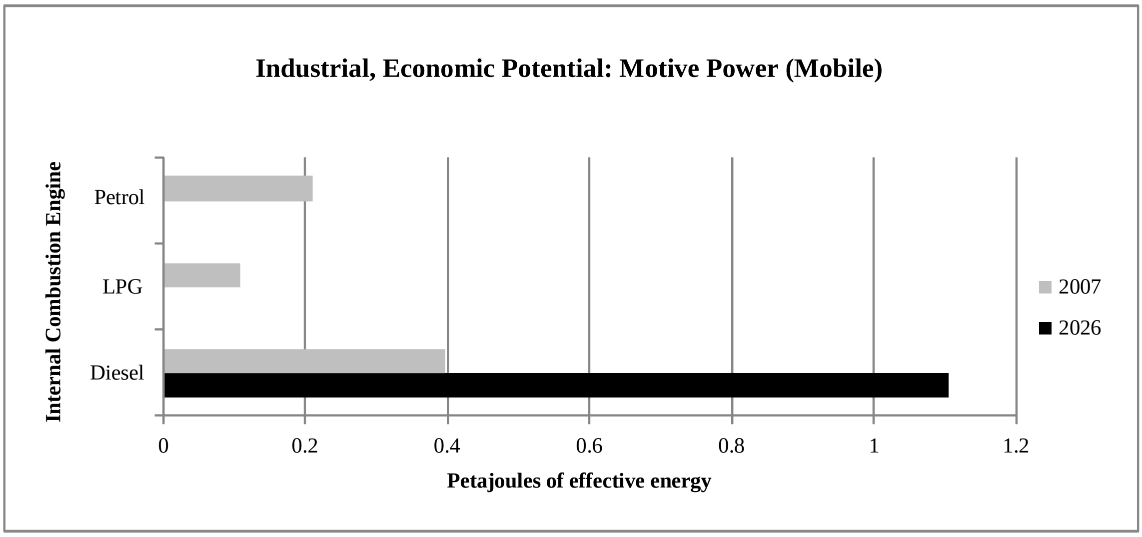


- *Kiln/Furnace (100-300˚C).* Over the 20 year period there was an increase in coal usage from 25.3% to 50.0%. This was almost matched by the use of natural gas (46.7%) at the end of the period. There was also a small amount (3.31%) of wood use.

- *Kiln/Furnace (<100˚C).* In this category coal usage increased from 22.3% in 2006/07 to 73.8% in 2025/25. Fuel oil usage at 2025/26 was 21.4% and wood 1.83%. There was no use of natural gas, as per the 'technical energy savings optimisation'.

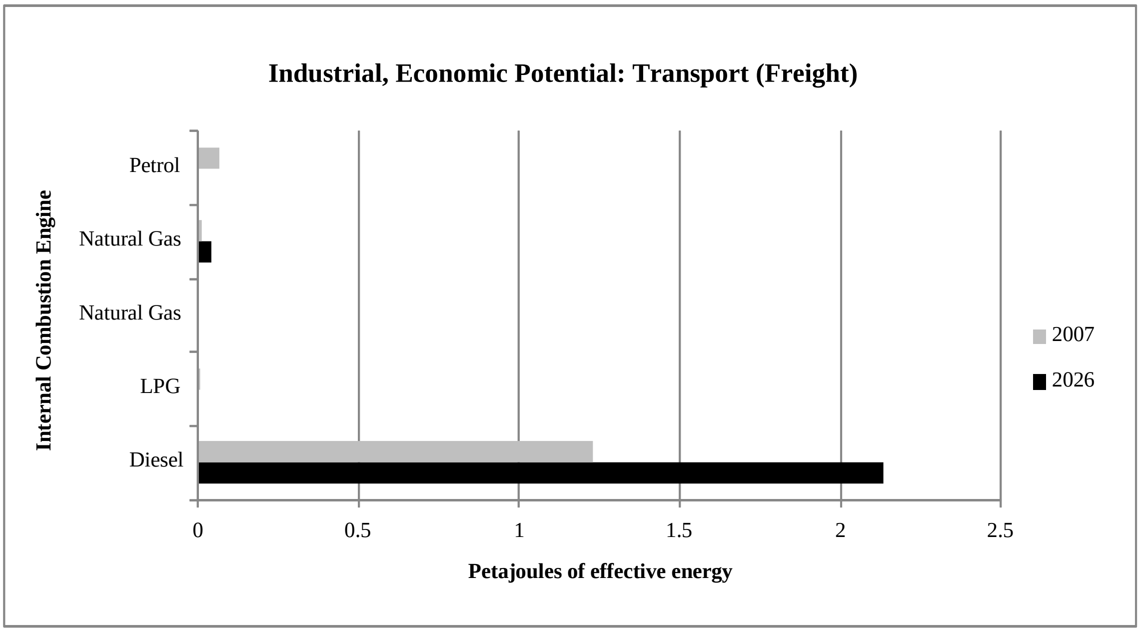
- *Obligatory Electricity.* Much (31.4%) of the energy consumed in this category is required for so called 'obligatory electricity'. This is electricity required for refrigeration, pumping, electrical and electronic control equipment and lighting. Electricity use decreased slightly over the 20 year study period, due to substitution of use of electricity for heating by other sources and due to the application of some of the energy savings measures outlined below. Consequently by 2025/26 electricity usage in the industrial sector had decreased from 53.7 PJ in 2006/07 to 47.8 PJ in 2025/26.

- *Motive Power (Mobile).* This category includes the use of non-road vehicles (e.g. forklifts). By 2022 petrol was phased out, and LPG was eliminated by 2010. At the end of the 20 year period only diesel was used for motive power (mobile).

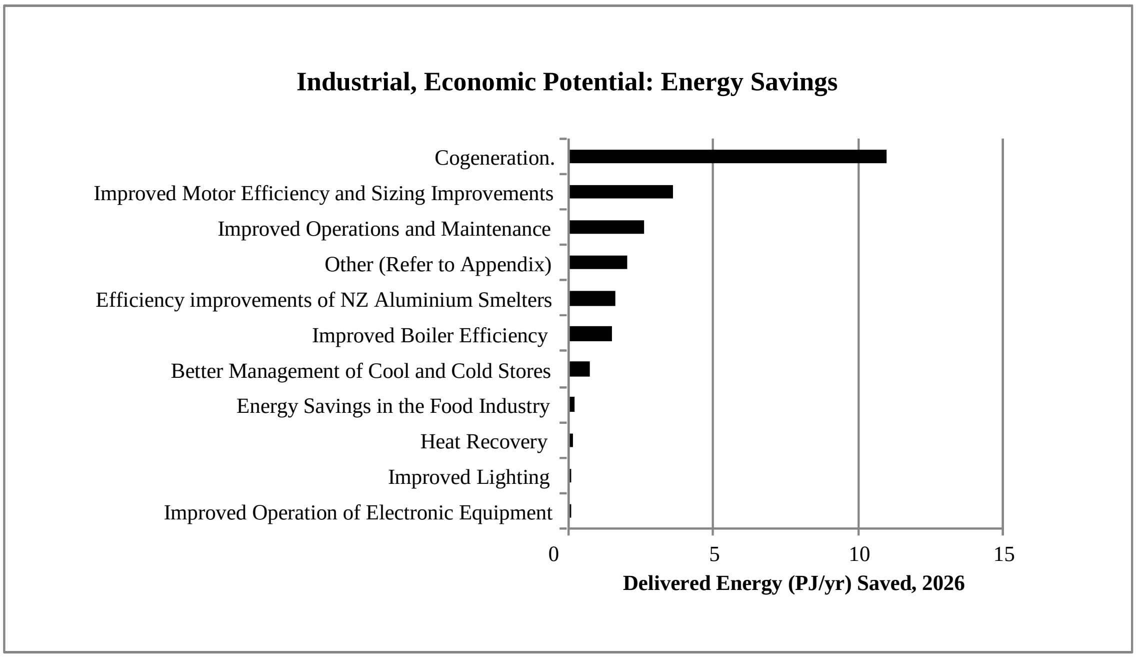


- *Transport (Cars).* This is a minor category of end-use for the industrial sector. By the end of the 20 year period the fleet was fuelled in broadly equal proportions by petrol (10% ethanol), diesel and natural gas.

- *Transport (Freight).* This category refers to freight vehicles, run by industrial companies rather than sub-contracted to commercial freight operators. There was little change to the fuels used in the industrial sector over the 20 year period, with by 2025/26 diesel still dominating with 97.9%.



The implementation of ‘energy savings measures’ in the industrial sector were also evaluated by OPENZ. In general, far fewer of these ‘energy savings’ measure were selected than in the ‘technical energy savings’ optimisation. This is because many of these measures proved to be ‘uneconomic’ in the sense, that economic cost of implementing these measures outweighed their economic benefits.



The ‘energy savings measures’ for the industrial sector, for the ‘economic energy savings’ optimisation were:

- *Cogeneration.* Additional cogeneration (of heat and electricity) was assessed by OPENZ to save 10.97 PJ/yr of energy, as a more economic option that processing extra process heat and electricity by other means. More specifically 4.3 PJ of process heat would be produced by co-generation and 4.4 PJ of electricity.
- *Improved Motor Efficiency and Sizing Improvements* over the 20 year period, saving 1.18 PJ/yr of electricity by 2015 and increasing to a saving of 3.58 PJ/yr by 2025/26.
- *Improved Boiler Efficiency.* Specifically by 2025/26 1.47 PJ of wood was assessed to be saved. Unlike the ‘technical energy savings’ optimisation energy savings from improved efficiency of natural gas, oil and coal fired boilers were not selected as they were uneconomic.
- *Improved Operations and Maintenance.* This includes better day-to-day attention to energy efficiency (‘housekeeping’), better process control and management. This is expected to, by 2025/26, lead to an energy saving of 1.32 PJ/yr of electricity (Ind. 91) and 1.30 PJ/yr of natural gas (Ind. 137). Some of the energy savings measures identified in the ‘technical energy savings’ optimisation were assessed to be uneconomic: Ind. 113, Ind. 133 and Ind. 106.
- *Better Management of Cool and Cold Stores* including for example ‘controlled door opening’. This was assessed to provide a saving of 0.71 PJ/yr by 2025/26.

- *Efficiency improvements of NZ Aluminium Smelters*. NZ Aluminium Smelters have made consistent improvements in their efficiency (in terms of TJ/tonne product). This is expected to lead to further economically viable savings of 1.64 PJ/yr in 2025/26.
- *Energy Savings in the Food Industry.* Based on estimates from Henderson (1994) it is assessed that by 2025/26 that the use of the cool chain concept in the food industry (Ind. 81) would lead to 0.20 PJ/yr of economically viable energy savings.
- *Heat Recovery*. OPENZ identified many practical mechanisms of heat recovery (Ind. 127, Ind. 116, Ind. 128, Ind. 105, Ind. 110, Ind. 115, Ind. 195, Ind. 121, Ind. 125, Ind. 101) that were technically feasible which lead to 0.96 PJ/yr potential savings by 2025/26. Only 0.16 PJ/yr of this 0.96 PJ/yr was however found to be economically viable.
- *Improved Lighting.* Some relatively small economically viable energy savings from improving lighting efficiency were identified including upgrading existing fluorescents and upgrading gas discharge lamps. By 2025/26, this was estimated to achieve 0.09 PJ/yr savings.
- *Improved operation of Electronic Equipment.* This was assessed by OPENZ to save 0.02 PJ/yr by 2025/26 under the ‘economic energy savings’ optimisation.

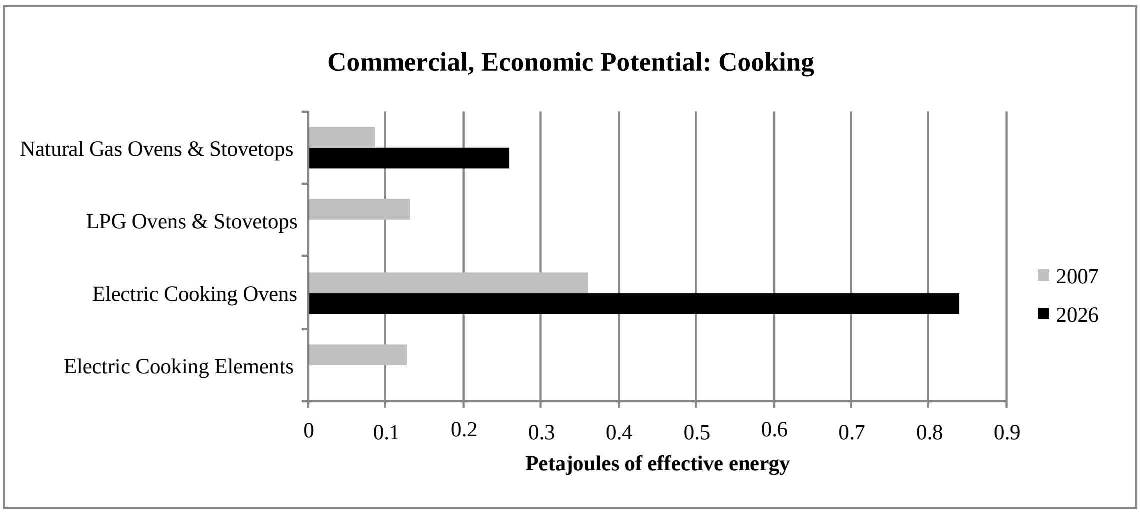
In total, these economically viable energy savings were estimated to save 23.5 PJ/yr for 2025/26 for the industrial sector. This compares with the technically viable energy savings of 30.05 PJ/yr for 2025/26. In other words, 78.2% of the technical possible energy savings measures in the industrial sector, are economically viable for the year 2025/26.

6.3.3 Commercial Sector

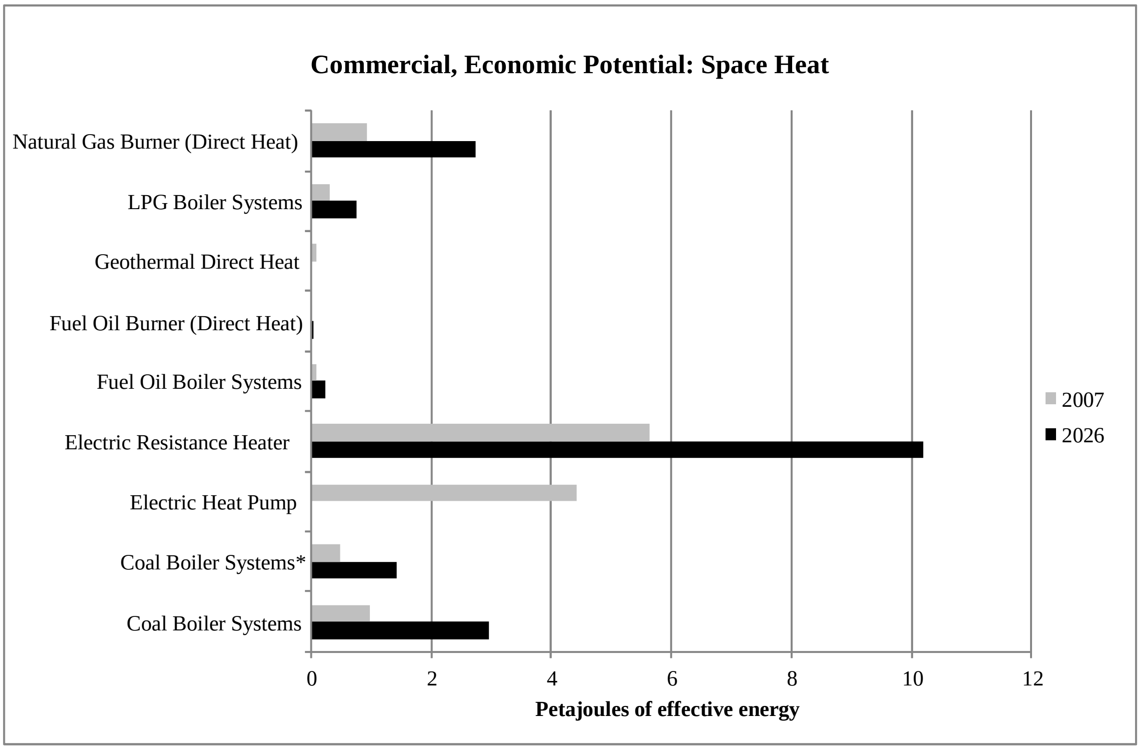
Full details of the supply of energy end-uses, for each year of the economic energy savings optimisation are contained in Appendix F.2. Similarly full details of the energy savings measures for the ‘economic energy savings optimisation are contained in Appendix G.2.

The main shifts in the energy end-use supply processes (fuel switching) for the commercial sector were:

- *Cooking.* There is a slight increase in electricity for cooking from 69.1% in 2006/07 to 76.5% in 2025/26. The remaining amount is gas based cooking, with, where possible natural gas replacing LPG. This shift towards electricity for cooking, is the opposite in the ‘technical energy savings’ optimisation. This is because, put simply, electricity is more economically efficient whereas natural gas is thermodynamically (energetically) more efficient.

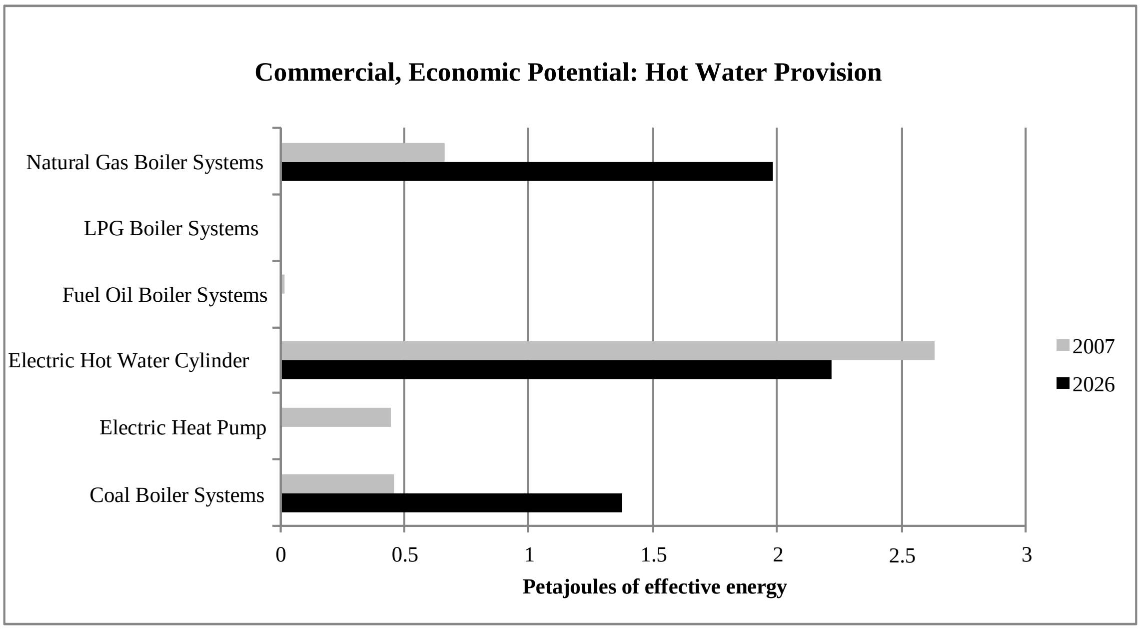


- *Space Heat.* In the 'technical energy savings' optimisation, there was a complete phasing out of resistance heaters and the significant increase in heat pumps. The opposite is the case here, with resistance heater use increasing to 55.6% of space heat provision by 2025/26. The high capital cost of heat pumps make them less economically viable than resistance heaters. Based on these economic criteria there was also a significant increase in the use of coal for space heating from 11.4% in 2006/07 to 23.9% in 2025/26 and smaller increases in the use of LPG and natural gas.

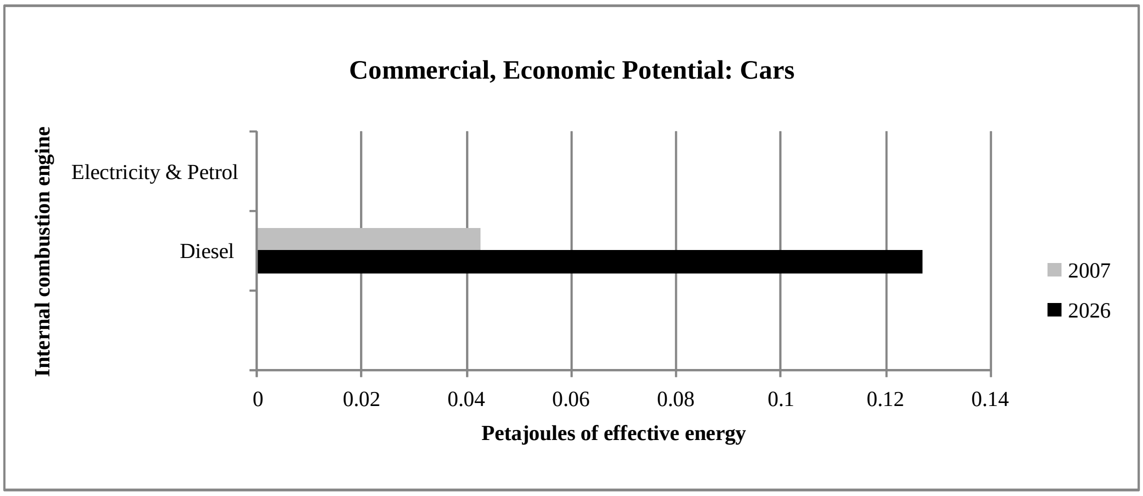


- *Hot Water.* In this category of end-use there were increases in both coal and natural gas hot water provisions. Hot water supplied by coal-fired boilers increased from 10.1% to 20.9% over the 20 year period. Hot water supplied by natural gas fired boilers increased form

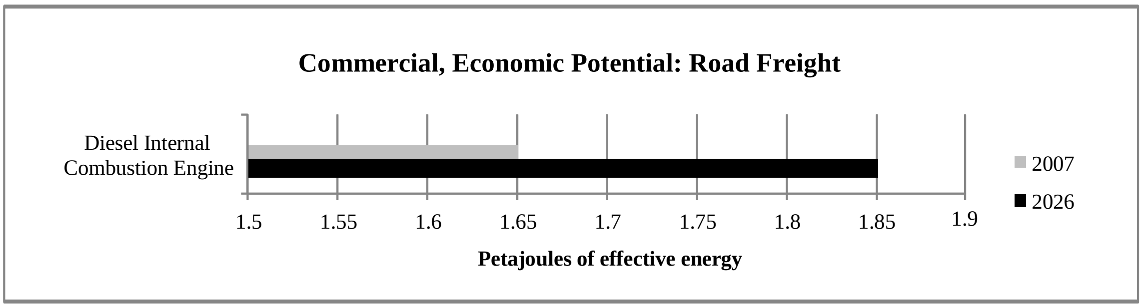
14.57% to 30.15% over the study period. Electric hot water cylinders decreased from 57.7% in 2006/07 to 33.7% in 2025/26, which was partially compensated for by the increase in natural gas hot water cylinders.

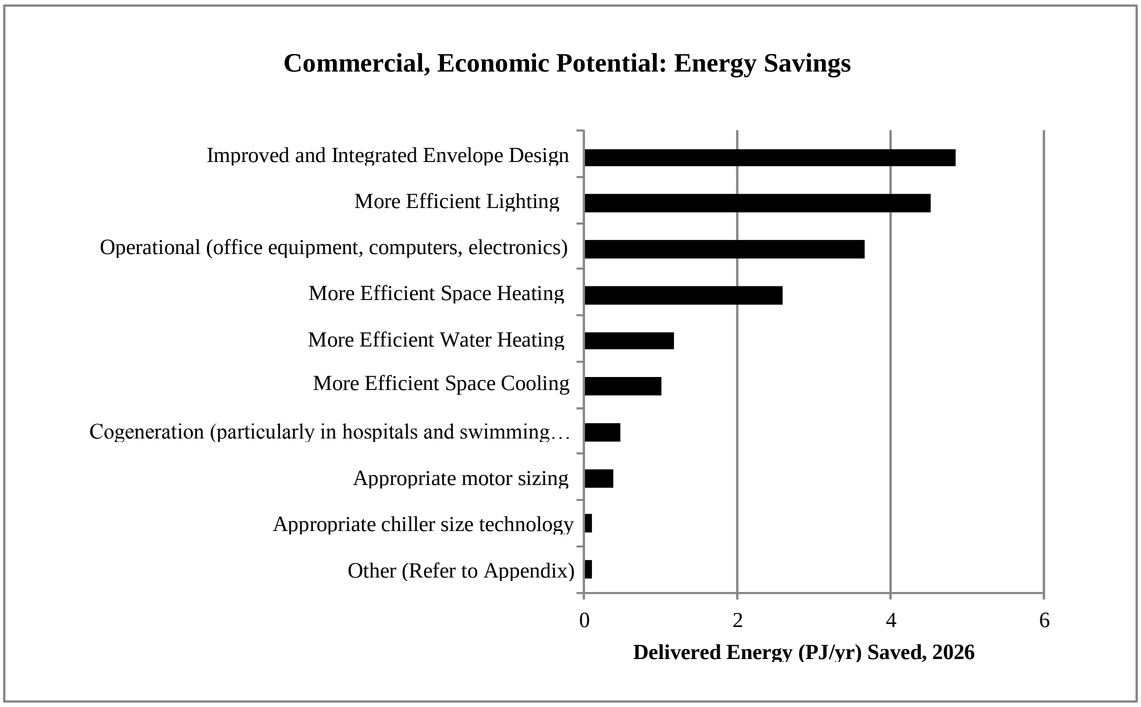


- *Transport (Cars).* This is a minor category of end-use in the commercial sector. There were significant increases in diesel (to 17.5%) and natural gas (to 16.0%) by 2025/26. This lead to a decline in petrol's market share although it was still 66.5% of the market share by 2025/26.



- *Transport (Freight).* This category refers to freight vehicles, run by Commercial Sector businesses, rather than contracted out to freight companies (in the transport and storage sector). There was virtually no change in this end-use with diesel fuelled vehicles accounting for nearly 100% of fuel use. *Obligatory Electricity.* Much of the commercial sector's energy use and electricity load falls in this category which includes electronic equipment, computers, as well as a significant amount of refrigeration energy which is needed in retailing (restaurant, shops, supermarkets and wholesaling activities included in this sector). This 'obligatory electricity' consumption nominally increased by 38% over this period. There were a number of 'energy savings measures' (e.g. improved purchasing of equipment) considered below that effectively reduced this nominal obligatory electricity demand.





The main implementation of 'energy savings' measures were:

- *Operational*. This includes better office equipment management, switching equipment on/off and the optimum location of office equipment. In spite of all of the recent research and awareness of the increasing heavy load of office equipment this still remains the largest potential areas for energy savings in the commercial sector (IEA, 2009a,b). The IEA (2009b) estimates across its member countries that energy consumed by IT and consumer electronics will double by 2020 and triple by 2030. It is therefore not surprising that OPENZ assesses the very significant 'energy savings' to be from better operational use of office equipment (measure Com. 57) – OPENZ estimates that it is economically viable that by 2025/26 3.65 PJ/yr could be saved by this measure.

- *Lighting.* Lighting is a major energy end-use in the commercial sector. OPENZ identified a number of economically viable 'energy savings measures' for reducing that load – that is by 2025/26 the following could be achieved: 2.11 PJ/yr by medium cost lamp upgrade (reflectors, triphosphor tubes, CFL's); 0.80 PJ/yr by design changes (task lighting, uplighting, day lighting); 0.55 PJ/yr by low cost lamp upgrade; 0.35 PJ/yr by delamping/fine tuning and 0.32 PJ/yr by improved operations and maintenance (optimising after hours use, cleaning, staff scheduling, luminaire cleaning, etc.). In total, these economically viable options could save 4.51 PJ/yr by 2025/26, compared with the BAU situation. The only technically viable option that was not economically viable was Com. 84 (High Cost Lamp Upgrade).
- *Improved and Integrated Design.* Although often requiring load lead times, as old building stock is replaced by new building stock, as well as retrofitting options these options (Com. 53, Com. 86, Com. 119, Com. 51, Com. 66) do provide economically viable ways of saving energy. In total, 4.84 PJ/yr by 2025/26 can be saved using these economically viable options. These economically viable options can account for about 71% of the energy that could be saved by technically viable options.
- *Water Heating.* OPENZ identifies the following economically viable means of saving energy in this energy end-use category by 2025/26: 0.52 PJ/yr from flow controls (spray nozzles, shower heads, etc.), 0.46 PJ/yr from improved operations and maintenance (e.g. temperature settings, distribution controls, controlling drips and leaks); and 0.19 PJ/yr from improved distributional efficiency (local heaters, pipes and cylinder insulation). In total, the economically viable energy savings from the application of these methods adds up to 1.18 PJ/yr by 2025/26. This is only about 26% of the savings that are technically viable in this end-use category.
- *Space Heating.* OPENZ identifies a number of energy savings measures that are economically viable including: Com. 56, Com. 57, Com. 61, Com. 120, Com. 64, Com. 135 and Com. 136. These include: recommissioning old plant, correct heating choice (radiant, convector, air) and plant control (e.g. compensator control with reset). In total, the economically viable energy savings from the application of these methods adds up to 2.58 PJ/yr by 2025/26. This is only about 46% of the savings that are technically viable in this energy end-use category.
- *Space Cooling.* Space Cooling is a significant and increasing end-use of energy in Commercial buildings. In total, OPENZ assess the economically viable energy savings in this category, by 2025/26, to be 1.02 PJ/yr.
- *Cogeneration*. There is a relatively small amount of energy that can be saved by co-generation of electricity and heat. This mainly applied to hospitals and swimming pools. It is estimated by OPENZ that by 2025/26 that it is economically viable to save about 0.47 PJ/yr from using co-generation in the commercial sector.
- *Other Savings*. Other significant economically viable savings identified by OPENZ include the appropriate chiller size technology (0.11 PJ/yr in 2025/26) and appropriate motor sizing (0.38 PJ/yr in 2025/26).

In total by 2025/26, OPENZ assesses that 18.83PJ/yr of energy could be saved in an economically viable manner. This compares with 30.05 PJ/yr which is technically viable. In other words 62.7% of the technically possible energy savings measures in the commercial sector are economically viable.

6.3.4 Primary Sector

Full details of the supply of energy end-uses for each year of the ‘economic energy savings’ optimisation are contained in Appendix F.2. Similarly full details of the ‘energy savings measures’ for the economic energy savings’ optimisation are contained in Appendix G.2.

In general, compared with the other sectors, OPENZ identified significantly less opportunities for reducing energy inputs into the primary production sector. This is for two reasons: (1) the primary sector is far smaller, accounting for only 7.36% of delivered energy use in the New Zealand economy; (2) there is fewer energy savings mechanisms identified by Henderson (1994) for the primary sector – which OPENZ relies upon.[62]

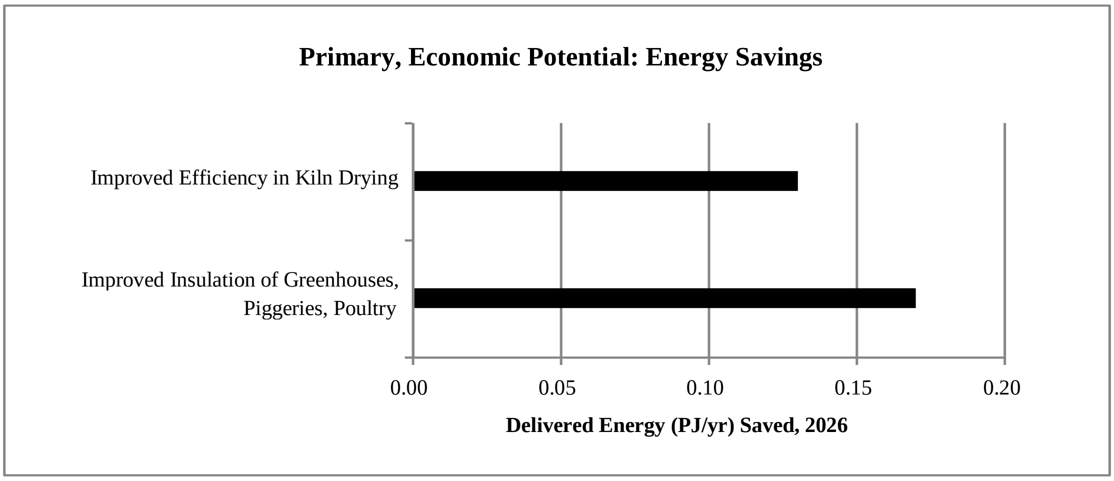
The main changes in the supply of energy end-uses by OPENZ were:

- *Intermediate Temperature Heat (100-300˚*C). Resistance Heaters were eliminated and replaced by the use of fuel oil as a source of intermediate temperature heat. By 2025/26 fuel oil supplied 84.4% of the heat in this end-use category and natural gas 15.5%.

- *Low Temperature Heat (<100˚*C). This heat is mainly required in the Protected Crop sector. Diesel was immediately eliminated as a source of this end-use heat category, and natural gas was phased out by 2016. From this point all low temperature heat (<100˚C) was supplied by coal.

- *Motive Power (Mobile).* This includes farm vehicles, such as tractors and other off-road vehicles. There was a replacement (where possible) for diesel instead of petrol.

- *Freight Transport.* Petrol was phased out by 2009, with all freight vehicles converted to diesel. This was based on the least cost ($) criteria, which in this case gave very similar results for the energy efficiency criteria previously used in the ‘technical energy savings optimisation’.



62 There are a number of publications on energy conservation measures for the primary sector in New Zealand: Barber and Pellow (2005), Centre for Energy Research (2004), Ministry for the Environment (2007a,b,c,d.) and Morrison (2007). None of these publications however provide sufficient quantitative and economic data to adequately model the energy conservation options in OPENZ.

The main 'energy savings' measures for the primary sector, by OPENZ were:

- *Improved Insulation*. This mainly applied to greenhouses but also pig and poultry farms. OPENZ assessed 0.17 PJ/yr energy savings by improved insulation by 2025/26.
- *Improved Efficiency in Kiln Drying*. OPENZ assessed 0.13 PJ/yr energy savings by improved efficiencies in this area by 2025/26.

As noted above there are other 'energy savings' means that could be implemented in the Primary Sector. However, there is a lack of data particularly on alternative fuels (for tractors) and on improving the operation of dairy shed operations. For example, it should be possible in future versions of OPENZ, to evaluate options for water heating and milk chilling in dairy sheds.

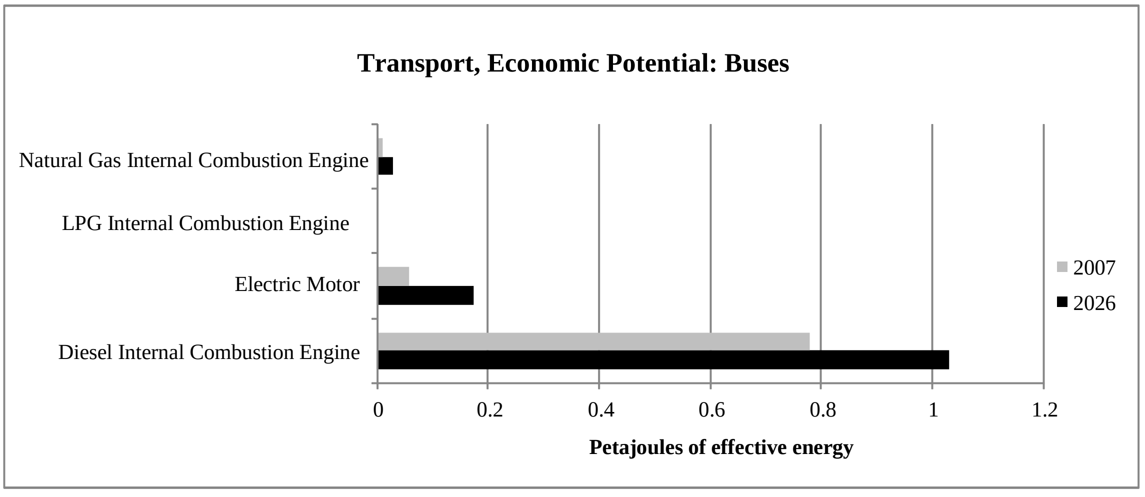
6.3.5 Transport and Storage Sector

Full details of the supply of energy end-uses for each year at the 'economic energy savings' optimisation are contained in Appendix F.2. Similarly full details for the 'energy savings measures' for the 'economic energy savings' optimisation are contained in Appendix G.2.

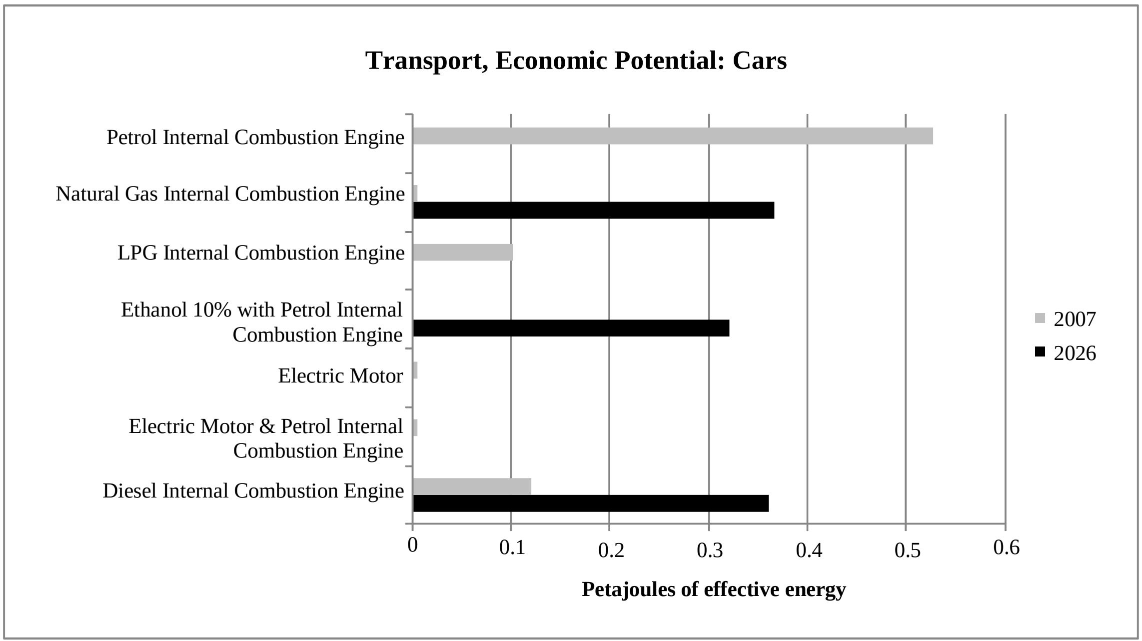
It should be noted that transport activities are also included in all other sectors (Household, Commercial, Primary, Industry). In compliance with ANZSIC, the transport and storage sector *only* includes transport and storage activities sub-contracted by clients from these other sectors.

The main shifts in 'energy end-use' supply processes (fuel substitution) for the transport and storage sector were:

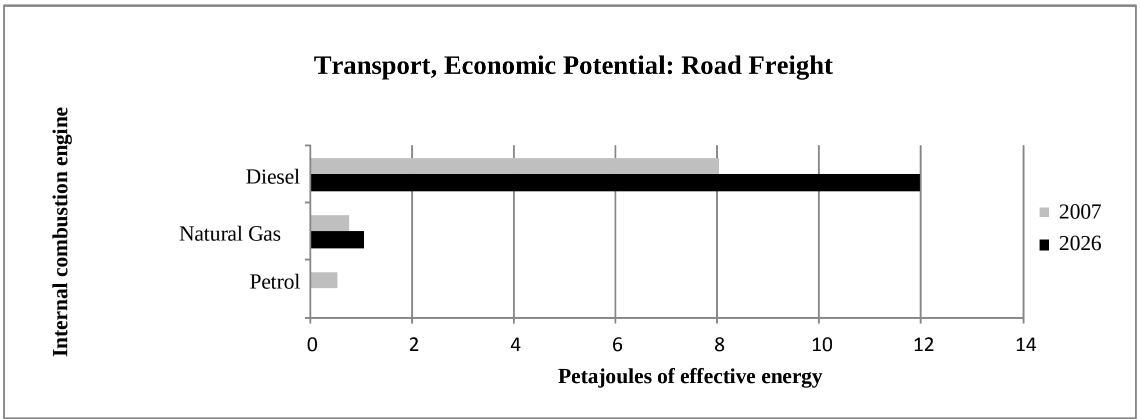
- *Buses for Land Transport.* OPENZ assesses a steady increase in both electric and natural gas powered buses. From 2006/07 electric buses increase from 6.6% to 14.1% by 2025/26. Similarly natural gas powered buses increase from 1.1% in 2006/07 to 2.2% in 2025/26. Diesel powered buses (83.7%) still however heavily dominate the bus sector, even though it recorded some decline in its share of this end-use category. Both petrol and LPG buses are completely phased out.



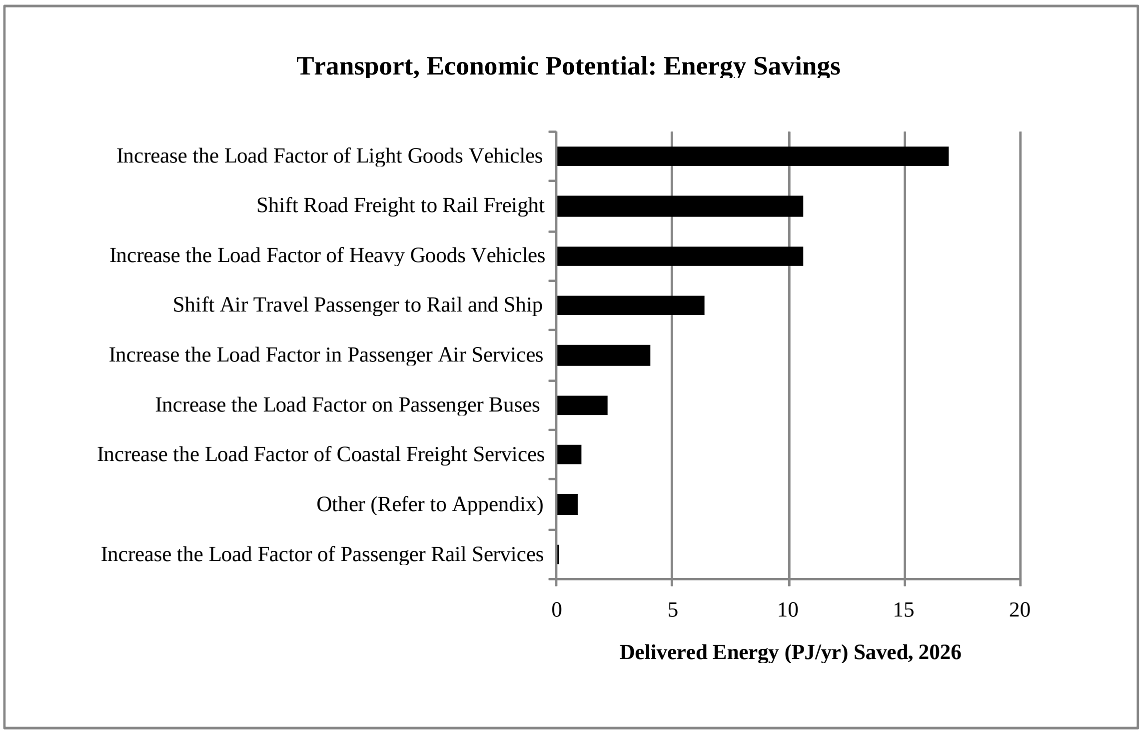
- *Cars for Land Transport.* This is a very small sub-sector, mainly consisting of taxis. By 2025/26 all these vehicles in this subsector are using diesel, petrol/ethanol blended fuel and natural gas almost in equal shares.



- *Freight Transport (Land).* OPENZ assesses a slight shift towards diesel powered vehicles. That is, diesel increases its market share from 93.4% in 2006/07 to 99.5.0%. By the end of the 20 year period, natural gas accounts for the remaining 0.4%, whilst LPG and petrol are completely phased out.



- *Rail Freight.* In 2006/07 88.94% of this category of end-use energy was supplied by electricity. By 2025/26 all rail freight locomotives used electricity. The same pattern occurred for rail passengers services.



The main 'energy savings measures' implemented were:

- *Increase the Load Factor in Passenger Air Services by 10%.*[63] It is assessed based on updated Henderson (1994) data, that increasing the load factor in passenger air travel by 10% would save 4.08 PJ/yr by 2025/26.
- *Shift Air Travel Passenger to Rail and Ship.* This only includes domestic travel, as international air travel is not included in the model. It is assessed again on updated Henderson (1994) data that this could save 6.39 PJ/yr by 2025/26. This would require a major upgrading of the New Zealand rail system to achieve this target, and probably a significant change in price relativities between the competing services. New Zealanders travel by rail is small between the major centres compared with other developed countries particularly those in Europe.
- *Increase the Load Factor of Passenger Rail Services by 10%.*[64] This is assessed by OPENZ to be 0.11 PJ/yr by 2025/26.
- *Increase the Load Factor of Coastal Freight Services by 10%.*[65] This is assessed by OPENZ to be 1.08 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adjusted for growth rates by OPENZ.
- *Increase the Load Factor on Passenger Buses by 10%.*[66] Load factor in New Zealand buses are low (average of about 30%). OPENZ calculates that by increasing this load factor by 10% by 2025/26, then 2.17 PJ/yr energy could be saved.

[63] It is not known for certain what the load factor for Passenger Air Services is. It is therefore assumed that there is a 10% increase, from 60% to 70% loading.

[64] It is not known for certain what the load factor for Passenger Rail Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.

[65] It is not known for certain what the load factor for Coastal Freight Services is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

[66] It is not known for certain what the load factor for Passenger Bus Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.

- *Increase the Load Factor of Light Goods Vehicles by 10%.*[67] Improved logistics, planning and organisation, could save a very significant amount of energy, due to the large amount of end-use energy used for light goods freight. It is estimated by OPENZ, using updated Henderson (1994) data, that by 2025/26 16.9 PJ/yr could be saved which is due in part to the strong relative growth of this sector.
- *Increase the Load Factor of Heavy Goods Vehicles by 10%.*[68] Although the load factor of heavy goods vehicles (about 50%) is better than light goods vehicles (about 30%), there is still considerable potential for improvement. OPENZ assess that by 2025/26 10.6 PJ/yr could be saved by improving the load factor of heavy freight vehicles by another 10%.
- *Shift Road Freight to Rail Freight.* This is assessed to be a 10.60 PJ/yr energy saving by 2025/26, based on using updated data from Henderson (1994) that applied growth factors for this sector. Again this would require a significant upgrading of the New Zealand freight rail system, and the appropriate financial incentives put in place.

If all of these economically viable transport sector 'energy savings' are implemented, then by 2025/26 52.84 PJ/yr of savings will be achieved. This is significantly more than the other sectors.

[67] It is not known for certain what the load factor for Light Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 20% to 30% loading.

[68] It is not known for certain what the load factor for Heavy Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

7. Realisable Energy Savings Potential

The 'realisable energy savings' potential is the maximum energy saving that can be saved given more 'realistic' assumptions about technology uptake rates than are assumed in the 'economic energy savings potential'. In OPENZ, the 'realisable energy savings potential' is therefore achieved by minimising 'total economic cost', by assuming slower rates of end-use technology uptake.

7.1 Assumptions

In essence all of the assumptions that apply to the 'economic energy savings potential' also apply here; except those that apply to the penetration rates:

- The size of natural gas reserves in 2,427.6PJ (allowing 20% for new discoveries).
- Rebound effect from new Household Insulation is 44%.
- Rebound effect from new Heat Pumps is 10%.
- Energy Prices are at the 'default' levels as outlines in Appendix C. These default prices only apply to the exogenously determined prices (refer to section 2.10.1), not the prices for endogenously determined prices (electricity, ethanol, methanol, biogas, synthetic petrol, synthetic diesel and natural gas). These default energy prices were almost entirely drawn from Donovan *et. al's* (2009) report that provides a very thorough analysis of future energy prices from 2008 to 2060.
- 617,940 ha are available for agricultural bio-energy crops and 1,411,500 ha are available for silviculture energy crops. In actuality neither of these constraints (availabilities) become binding.
- The activity levels of the 37 sectors of the economy from 2006/07 to 2025/26 are the 'default values' as estimated by the Economic Futures Model. These 'activity levels' are directly based on the projected contributions to GDP (value added) of each sector in the economy. For the household sector, the projected activity is based on 'household consumption ($)', which is forecasted to increase by 37% over this period. These GDP (and household consumption) based activity levels were used to estimate the projected amounts of energy end-uses for each sector.
- Carbon Prices are at the 'default' levels outlined in OPENZ and discussed in Section 2.5. These 'carbon prices' are arguably quite conservative (low), but broadly consistent with those used by East Harbour Management Services (2004, 2005) and The Treasury (2005).
- A 'default' setting of 23.7 PJ/yr for methanol and urea production is assumed for each year.
- Penetration rate between 1991/92 and 2006/07 of Henderson's (1994) energy savings measure were all set at 30%.
- For a small number of energy supply processes, a constraint was placed on the process activity, to ensure that it would not be adopted for a minimum of 10 years. This avoided the situation of a supply process like enzyme hydrolysis of maize to ethanol' only being adopted for 3 years before it was discarded, which is obviously unrealistic.
- Percentage of electricity that could be generated from wind was set at an upper limit of 20%, due to this being considered the upper technical level possible in New Zealand electricity supply system.
- It was assumed that by 2026/27 that 95% of New Zealand households could have ceiling insulation, wall insulation, floor insulation and double glazing. This was from a base of 2006/07 where 64% of households had ceiling insulation, 45% had wall insulation, 18% had

floor insulation and 9% had double glazing. There was a linear interpolation between the 2006/07 and 2025/26 levels of insulation, to allow for a technically feasible level of uptake.

Specifically the end-use technology penetration rate assumptions were:

- Penetration rates for both new and existing energy end-use processes, are set at 'low levels'. These penetration rates are assessed to be 'realistic' given what is known about past uptake rates of new technologies.
- Penetration rates for the energy savings measures are all set at 50%. This means that by 2025/26 that only 50% of the full potential for each 'energy savings measure' can be realised. This may be considered to be too pessimistic, but evidence shows (even from the existing pattern of technology deployment) consumers may not use what appears to be the least cost ($) means of energy end-use supply, in part because there are other motivational factors beside from cost ($) and energy savings, and in part due to lack of information, finance and other well known factors that underlie 'market failure.'

7.2 Headline Results

7.2.1 Primary Energy Savings

The difference between the 'BAU' and the 'Optimised' primary energy inputs, is the energy savings. From the 'technical energy savings' potential the primary energy savings was 439PJ/yr[69] by 2025/26. Whereas, for the 'realisable energy savings' potential the primary energy savings was 195PJ/yr[70] by 2025/26. That is, of the energy savings that are technically viable, only 44% is assessed to be *economically viable* and can be achieved according to the *realistic technology penetration rates* applied to this optimisation.

As can be seen by Fig 7.1, the primary energy consumption is assessed to still increase over the 2006/07 to 2025/26 period, even though these realisable energy savings have been implemented. OPENZ assesses primary energy consumption to increase 6.8% over this period, from 485PJ in 2006/07 to 518PJ in 2025/26.[71] This however is significantly better than the 'Business-As-Usual' case where over this period primary energy consumption increases by 47%.[72]

[69] This is 439 PJ (heat content) which in this case equals 374 PJ (crude oil equivalents).

[70] This is 195 PJ (heat content) which in this case equals 110 PJ (crude oil equivalents).

[71] Measured in terms of 'heat content'.

[72] Measured in terms of 'heat content'. However, the 'Business-As-Usual' primary energy consumption only increased by 24.8% when measured in terms of energy quality-adjusted crude oil equivalents

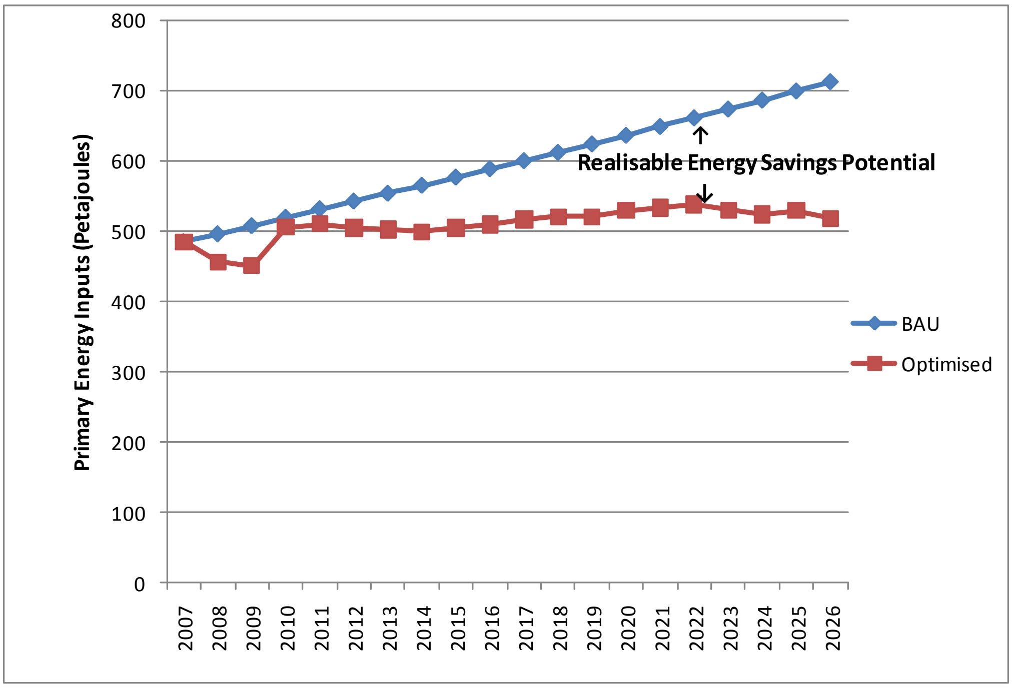


Figure 7.1 Primary Energy Inputs for the Realisable Energy Savings Optimisation
(Measured in terms of 'Heat Content')

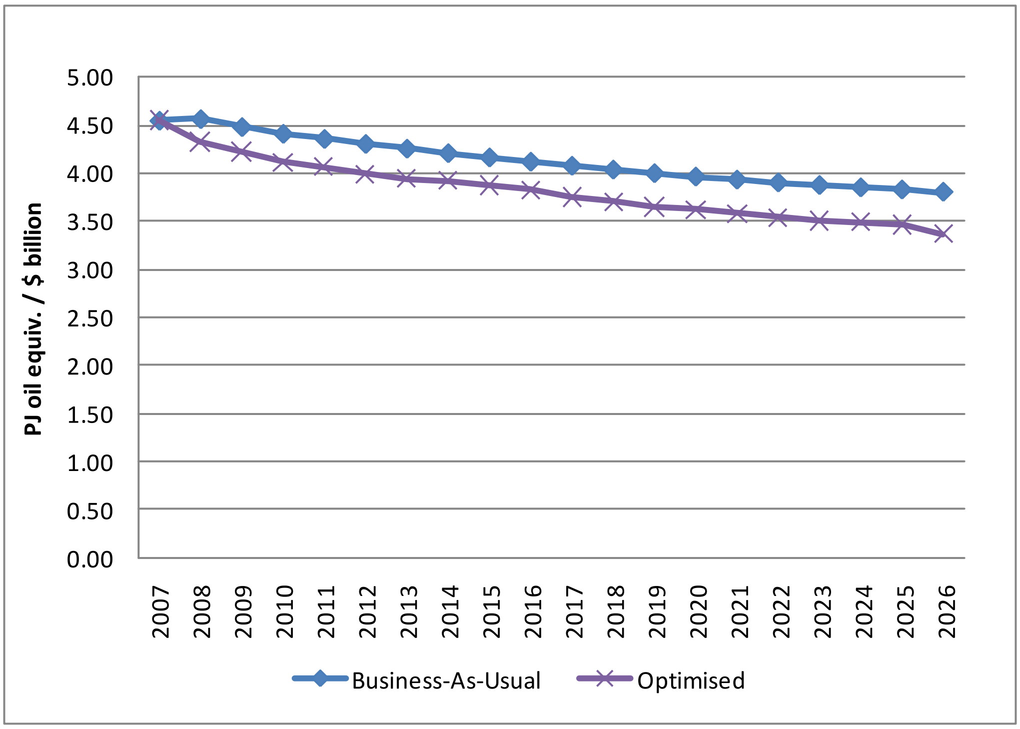


Figure 7.2 NZ Energy Intensity for the Realisable Energy Savings Optimisation

7.2.2 Energy Intensity

Energy intensity is a measure of the gross energy efficiency, usually applied at the national and sometimes sectoral level. That is, the lower the energy intensity (J/$), the higher the energy efficiency of a nation or sector.

Because of structured shifts in the New Zealand economy, even at the 'BAU projections' the energy intensity of the economy is projected to decrease from 4.55 PJ (crude oil equivalents)/$\$_{2006/07}$ billion in 2006/07 to 3.80 in 2025/26. As has been seen in the previous sections (5.2.2 and 6.2.2), the energy intensity of the economy is projected to decrease even further than the 'realisable energy savings potential':

- For the 'technical energy savings potential' to 1.69 PJ (crude oil equivalents)/$\$_{2006/07}$ billion.
- For the 'economic energy savings potential' to 2.67 PJ (crude oil equivalents)/$\$_{2006/07}$ billion.

In sum, the decrease in the national energy intensity is 26.0% over the 20 year period according to the 'realisable' energy savings potential optimisation. This represents a significant improvement in New Zealand economy-wide energy efficiency. By direct implication, 16.4% is due to structural shifts in the sectoral make up of the economy, from 2006/07, with the remainder of 9.56% being due to technical improvements.

7.2.3 Greenhouse Gas Emissions

The greenhouse gas emissions for the 'realisable energy savings' optimisation increased to 70,106 kilotonnes (CO_2 equivalents) in 2025/26, from a base of 38,584 kilotonnes (CO_2 equivalents) in 2006/07. This represents a 78.4% increase over the 20 year period, compared with the Business-As-Usual projection of 23.6% in greenhouse gas emissions in the same period.

The main reason for this increasing greenhouse gas emissions are first of all the increasing amounts of coal consumption. In 2006/07 the amount of coal consumption was 91.0 PJ (heat units)/year, which is projected to increase to 380.9 PJ (heat content)/year in 2025/26. Most of this coal use is for energy production (transport fuels and electricity) although there are is a significant amount of coal use in the demand sectors of the economy. It is possible in future development of OPENZ to restrict the model from using these fuels.

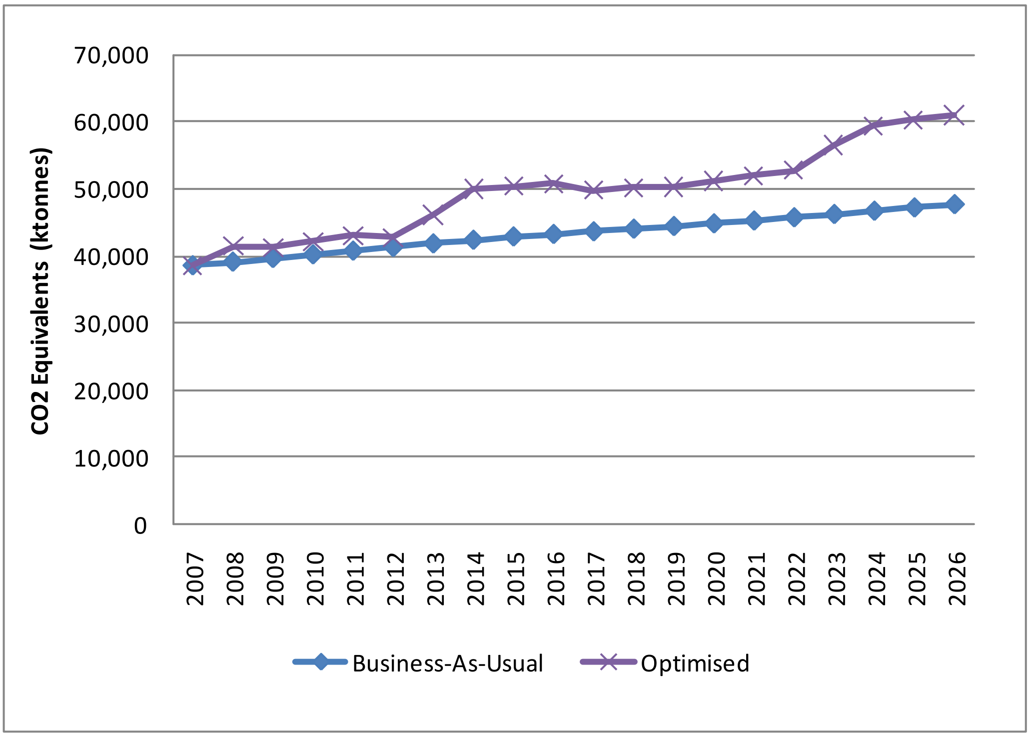


Figure 7.3 Greenhouse Gas Emissions for the Realisable Energy Savings Optimisation

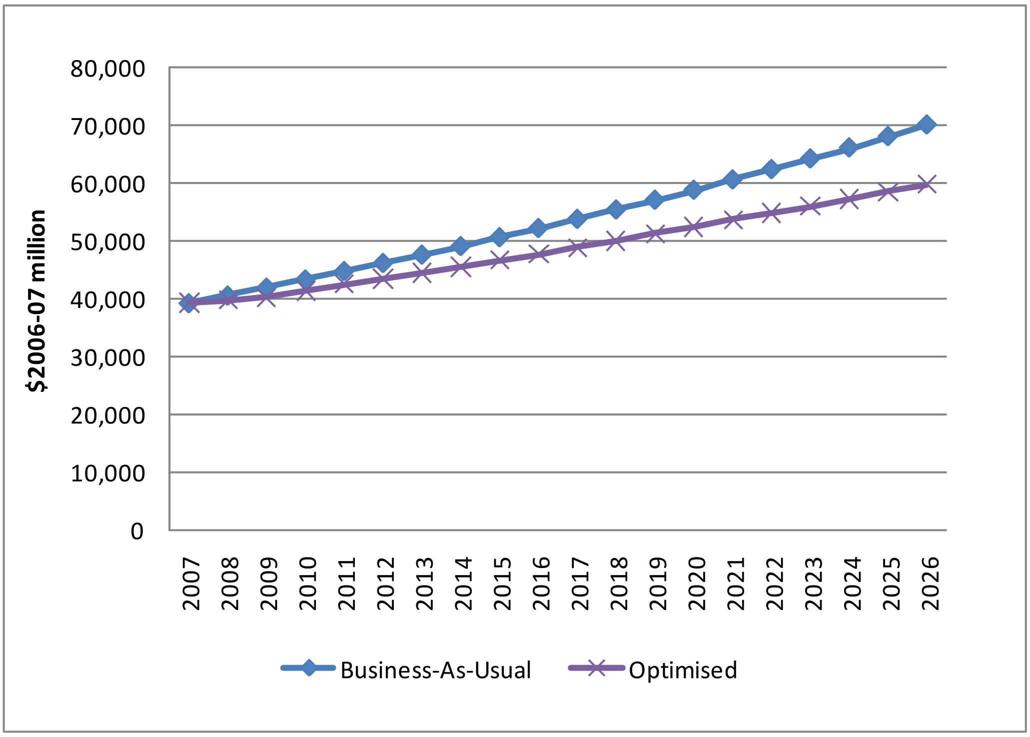


Figure 7.4 Economic Cost for the Realisable Energy Savings Optimisation

7.2.4 Economic Cost

Like the ‘economic energy savings’ optimisation, the ‘realisable energy savings’ optimisation reduces the economic cost ($) of energy supply and demand in New Zealand. That is, by 2025/26 New Zealand’s energy needs (end-use services) cost $\$_{2006/07}$ 59,853 million. This compares with the Business-As-Usual cost of $\$_{2006/07}$ 70,106 million.

The other advantage of the ‘realisable energy savings’ optimisation, is that it reduces primary energy consumption by 97 PJ (crude oil equivalents)/year. The ‘trade-off’ is that it does this at the expense of relatively high greenhouse gas emissions, and in fact leaders to significant higher greenhouse gas emissions.

To take these high greenhouse gas emissions into account, in Section 7, the results for an optimisation that reduces greenhouse gas emissions (as the objective function) is presented for consideration by EECA.

7.2.5 Primary and Delivered Energy

For this optimisation, the ‘realisable energy savings’ translates into the pattern of delivered energy consumption as is outlined in Table 7.1. The data in this table is presented in the more familiar ‘heat units’ rather than quality adjusted ‘crude oil equivalents’.

Overall, the delivered energy consumption increases by 21.5%, which compares with 10.5% for the ‘economic savings potential’. This is primarily due to the slower uptake rate of energy efficient technology in the ‘realisable energy savings’ case, leading to a significantly lower level of energy savings. Natural gas use lifted from 50.74 PJ/yr in 2006/07 to 86.31 PJ/yr, primarily due to an increase in industrial gas use and to a lesser extent increased use of Natural gas for cooking and water hearting in the household sector. Coal consumption (50.09%) also lifted significantly over this period, mainly through greater use in the industrial sector. Electricity use (19.68%) lagged below the rate of GDP growth, which in that sense is a ‘relative’ decline. Some of this ‘relative' reduction is due to more efficient electricity use and some is due to minor switches away from electricity to other fuel types. Petrol use declined (-3.00%) mainly due to replacement by diesel. Notably, for this optimisation, by 2025/26 there was still only a very small use of alternative transport fuels including 1.24 PJ/yr of ethanol and 1.72 PJ/yr of methanol.

Full details of the primary energy supply process for this optimisation are contained in Appendix E.3. By 2025/26, hydro-generated electricity is still the largest source of electricity, but there is a wider diversity of sources of electricity compared with the previous optimisation – viz, Hydro (48.51%), Coal (20.82%) from the Waikato and Southland, Wind (16.15%), Geothermal (13.82%) and Others (0.7%).

Based on the economic criteria which underpin this ‘realisable energy savings’ optimisation, by 2025/26, significant amounts of petrol and diesel are produced from indigenous feedstocks. Diesel (44.69PJ/yr) and Petrol (44.69 PJ/yr) are produced from Southland Lignite. Additional Diesel (30.00 PJ/yr) is also produced from Forest Biomass, as well as small amounts of Methanol (1.72 PJ/yr) from Forest Biomass and Ethanol (1.24 PJ/yr) from Fodder Beet.

Table 7.1 Delivered Energy Consumption (PJ, Heat Units) for the Realisable Energy Savings Potential

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	546.52	142.16	108.26	112.65	17.58	44.74	8.07	6.08	47.43	36.81	22.57	0.07	0.10
2009	553.03	144.83	108.02	114.95	17.82	46.43	8.25	5.94	49.37	33.64	23.44	0.13	0.20
2010	562.86	147.59	107.84	117.85	18.07	48.03	8.46	5.63	51.31	33.29	24.30	0.20	0.29
2011	573.28	150.23	107.75	120.90	18.32	49.71	8.67	5.09	53.47	33.48	25.00	0.26	0.39
2012	580.95	152.29	107.36	123.86	18.55	51.35	8.88	4.26	54.93	33.67	25.00	0.33	0.48
2013	589.00	153.93	107.29	126.45	18.78	52.53	9.08	3.87	57.27	33.85	25.00	0.39	0.55
2014	597.28	155.70	107.59	128.82	19.00	53.72	9.29	3.28	59.75	34.04	25.00	0.46	0.64
2015	605.88	157.34	107.88	131.32	19.23	54.90	9.50	2.96	62.27	34.23	25.00	0.52	0.73
2016	614.32	159.16	108.26	133.76	19.47	56.09	9.25	2.67	64.84	34.42	25.00	0.59	0.82
2017	622.87	160.86	108.65	136.17	19.70	57.30	9.44	2.34	67.23	34.61	25.00	0.65	0.91
2018	631.06	162.76	109.14	138.44	19.93	58.52	9.64	2.23	69.38	34.30	25.00	0.72	1.00
2019	639.17	164.71	109.61	140.74	20.17	59.74	9.83	2.25	71.59	33.66	25.00	0.79	1.09
2020	647.22	166.42	110.07	142.95	20.40	60.95	10.03	2.28	74.06	33.03	25.00	0.85	1.18
2021	655.22	168.07	110.51	145.53	20.64	62.17	10.22	2.31	76.08	32.50	25.00	0.92	1.27
2022	664.32	169.47	110.93	148.22	20.88	63.41	10.42	2.34	78.08	33.23	25.00	0.98	1.36
2023	672.42	171.41	111.34	150.66	21.12	64.64	10.62	2.37	80.10	32.67	25.00	1.05	1.45
2024	680.94	173.26	111.73	153.45	21.36	65.88	10.82	2.41	82.14	32.23	25.00	1.11	1.54
2025	690.08	175.05	112.11	156.33	21.60	67.12	11.02	2.46	84.22	32.37	25.00	1.18	1.63
2026	699.33	176.88	112.48	159.14	21.85	68.36	11.22	2.63	86.31	32.50	25.00	1.24	1.72
Growth Rate	**21.48%**	**19.68%**	**-3.00%**	**35.24%**	**21.76%**	**50.09%**	**35.60%**	**-69.51%**	**70.11%**	**-19.83%**	**10.78%**	**n.a.**	**n.a.**
Average Growth Rate	**1.03%**	**0.95%**	**-0.16%**	**1.60%**	**1.04%**	**2.16%**	**1.62%**	**-6.06%**	**2.84%**	**-1.16%**	**0.54%**	**n.a.**	**n.a.**

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even though this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

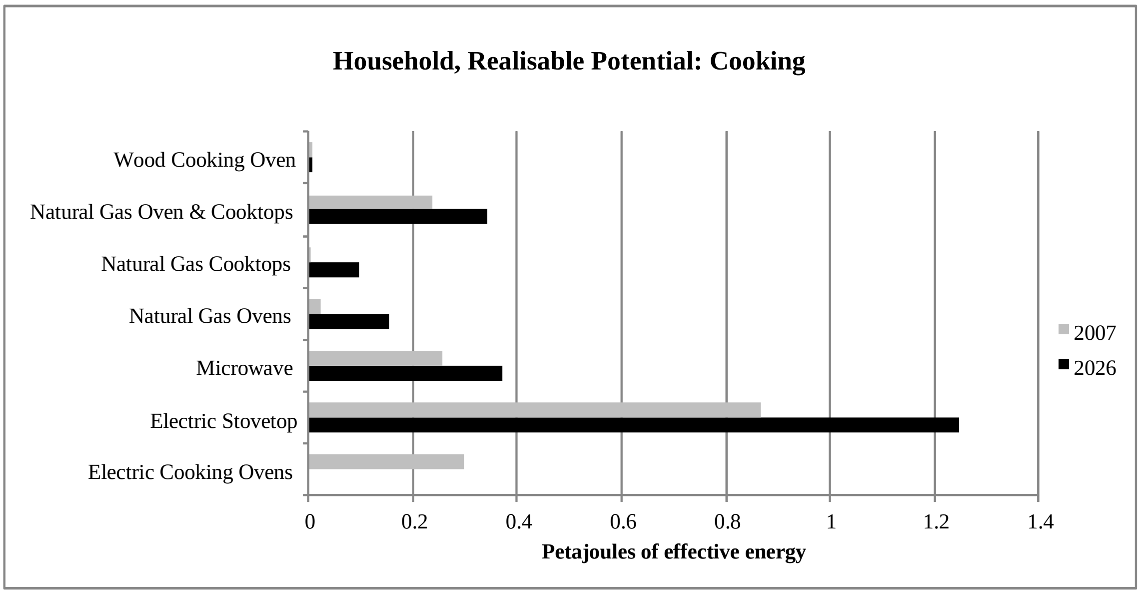
7.3 Detailed Sector-by-Sector Results

7.3.1 Household Sector

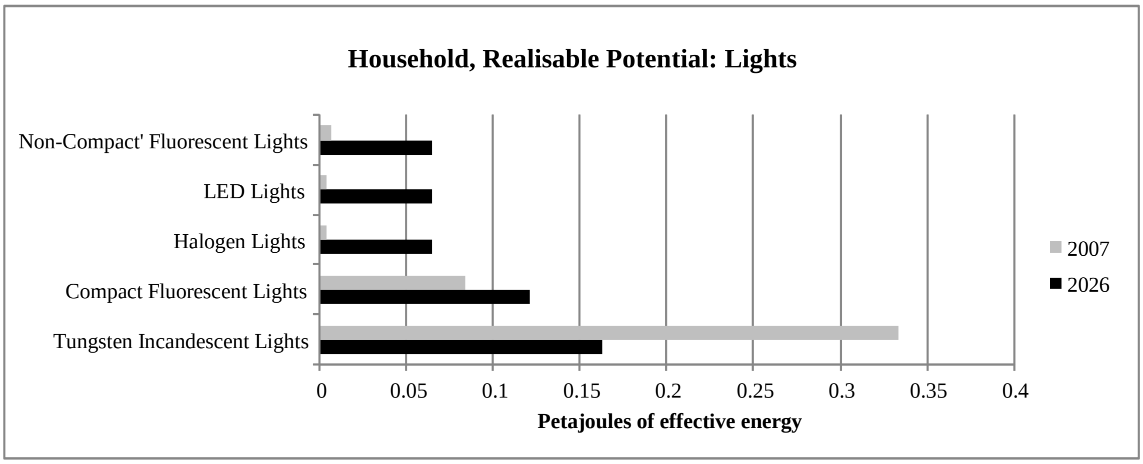
Full details of the supply of energy end-use services for each year of the 'realisable' energy savings optimisation are contained in Appendix F.3. Similarly full details of the 'energy savings measures' optimisation are contained in Appendix G.3.

The main shifts in the 'energy end-use' supply process for the household sector were:

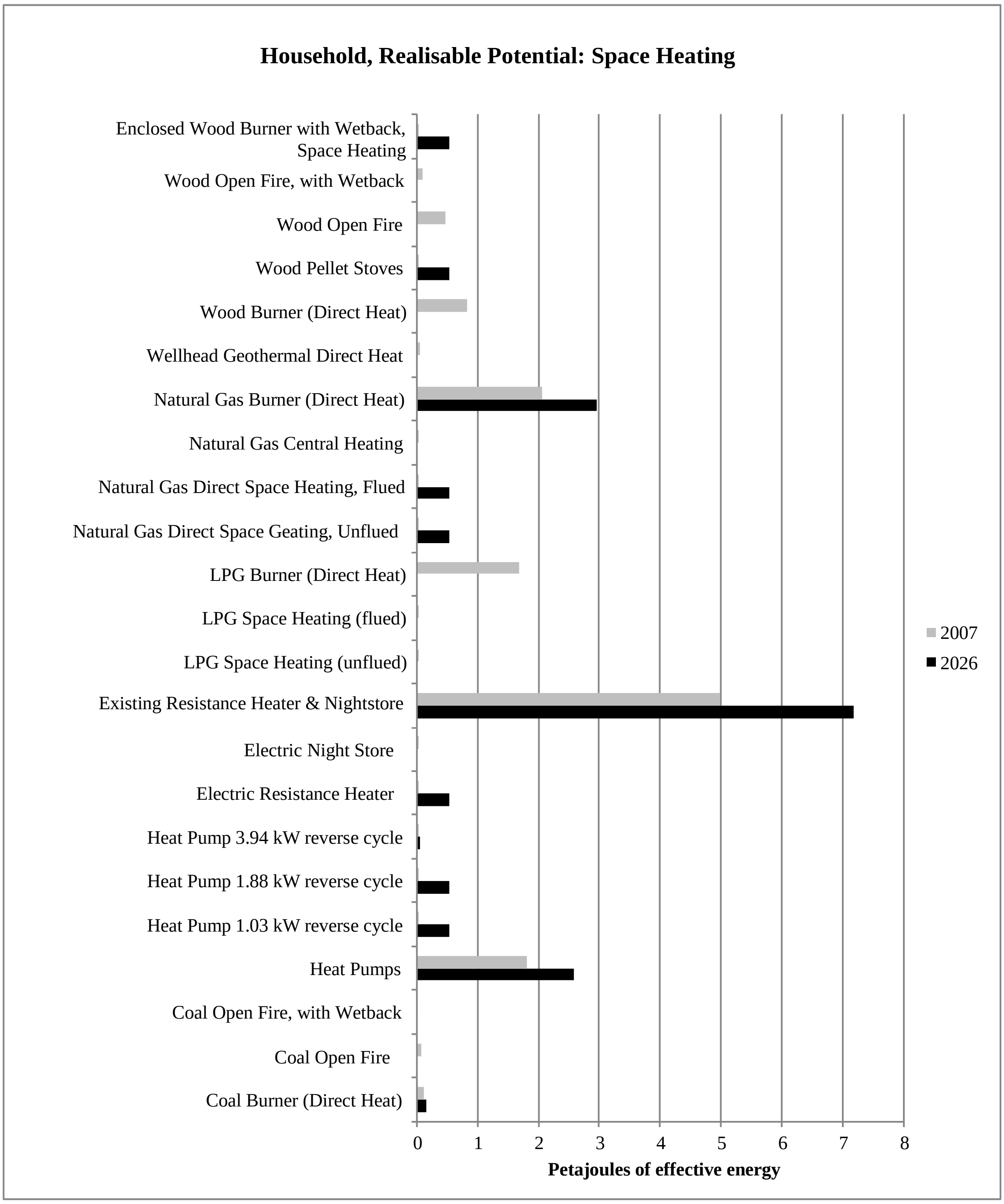
- *Cooking*. Electric ovens were phased out by 2017, and replaced by gas ovens. However by the end of the 20 year period electrical elements (rather than ovens) remained the main cooking energy end-use increasing to 56.1% in 2025/26 from 51.2% in 2006/07. Gas cooking (oven and cooktop) accounted for 26.7% of cooking end-use energy in 2025/26. Very small amounts of coal and wood made up the remainder of the cooking end-use energy in 2025/26.



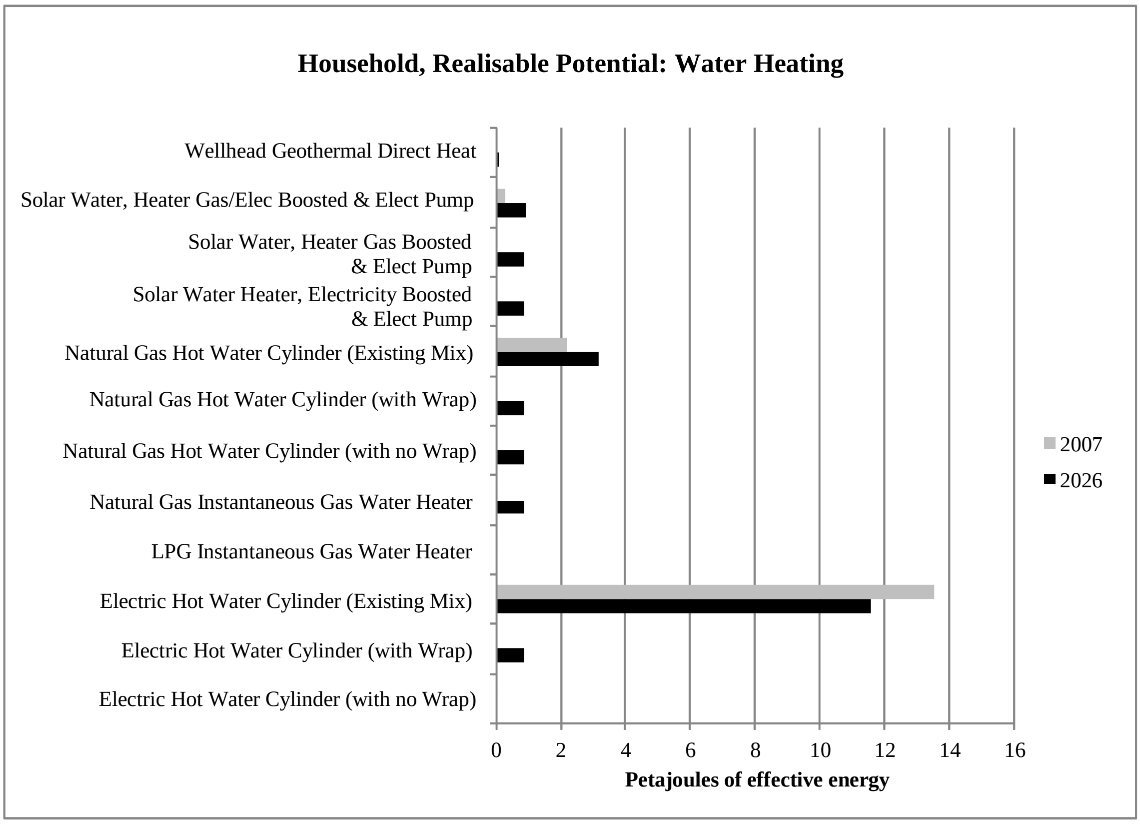
- *Lighting.* Incandescent lighting provided 34.1% of the lighting by 2025/26, down from 77.4% in 2006/07. Compact fluorescent lighting provided 25.3% of the lighting in 2025/26, increasing from 19.5% in 2006/07. The remainder of the lighting in 2025/26, was provided by long-tube fluorescent (13.6%), halogen lights (13.5%) and LED lights (13.5%).



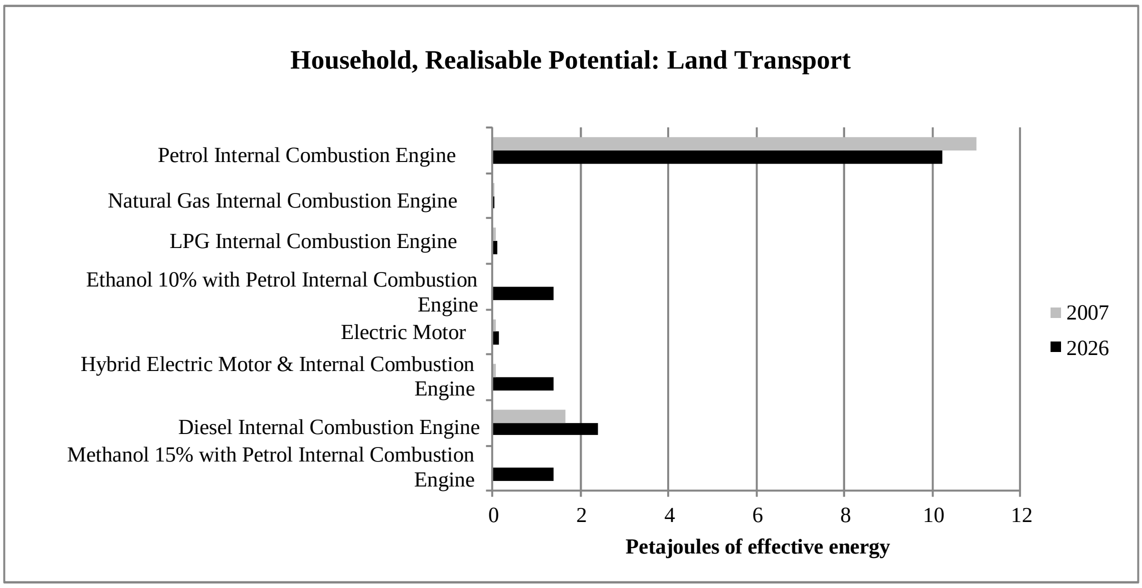
- *Space Heating.* Open fires which provided 5.4% of the space heat in 2006/07 were eliminated. Similarly LPG heating which provided 13.9% were also phased out. Electric heaters and nightstores increased from 40.2% in 2006/07 of the space heating to 46.2% in 2025/26. Heat pumps increased slightly to providing 22.2% of the space heat in 2025/2026. There was also a significant increase in natural gas heating from 17.1% in 2006/07 to 24.2% in 2025/26.



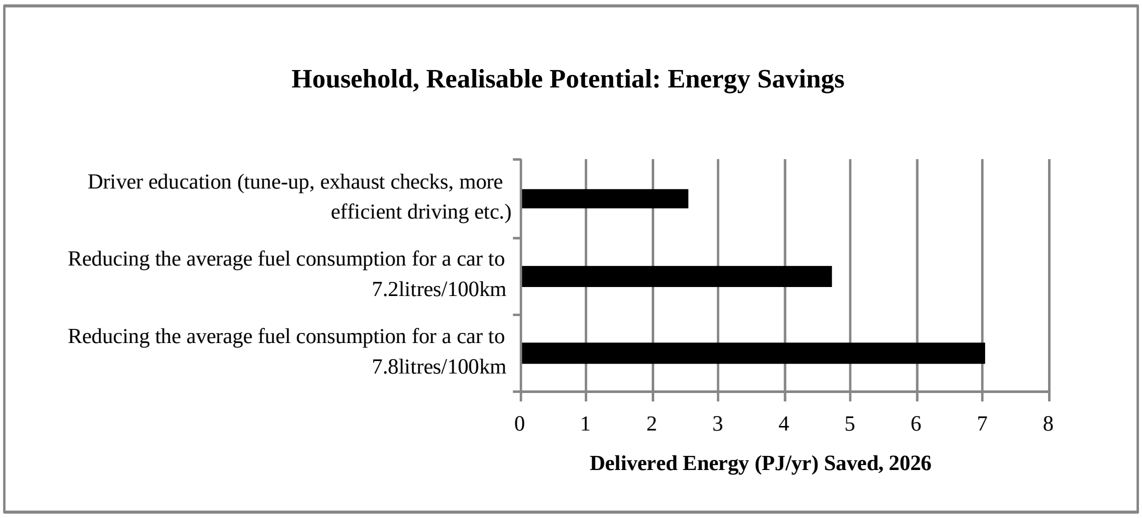
- *Water Heating.* There was a significant decline in electric hot water cylinders from 82.7% of hot water provision in 2006/07 to 59.0% in 2025/26. This decline was made up first of all by increased solar heating which by 2025/26 provided 12.8% of all household hot water provision. Secondly there was also a significant increase in natural gas hot water provision up to 27.8% by 2025/26 from a base of 14.3% in 2006/07.



- *Land Transport.* Petrol driven cars and vehicles made up 85.4% of the market share (in terms of end-use energy) in 2006/07. This declines to 60.2% in 2025/26. These petrol driven vehicles consist of increases in a number of fuel types – Hybrid (electric & petrol) and electric cars increased to 9.7% of market share; and cars fuelled by alcohol/petrol blends increased to 16.24% of market share by 2025/26. Diesel cars increase slightly from 12.9% in 2006/07 to 14.0% in 2025/26. There are also small increases in LPG and Natural Gas fuelled cars.



- *Obligatory Electrical End-uses.* Obligatory electrical end-uses (electronics and refrigeration) make up a considerable portion of household electricity use. These increased by 33.3% over the 2006/07 to 2025/26 period.



The main implementation of 'energy savings' measures in the household sector were those related to land transport:

- The 'technical energy savings' optimisation identified a number of 'behavioural' mechanisms for saving energy – car pooling (2 people per vehicle); use of bicycles for commuting and telecommuting (4 days out of 5 days). The economic cost of these options ($211 million/PJ saved for car pooling, and $112 million/PJ for bicycle commuting) was simply not high enough compared with the energy savings benefits they achieved, so they were eliminated from the 'realisable energy savings optimisation'.
- Reducing the average fuel consumption for a car to 7.8litres/100km, was assessed to save 7.04 PJ/yr energy for 2025/26.
- Reducing the average fuel consumption of a car for a further increment to 7.2litres/100km, was assessed to save a further 4.71 PJ/yr by 2025/26.
- Driver education (tune-up, exhaust checks, more efficient driving patterns etc.) was estimated to save 2.54 PJ/yr for 2025/26.

Notably, for the 'realisable energy savings' potential no further insulation of households was assessed to be economic in terms of the least cost ($) criteria. That is the level of insulation in New Zealand households remained at: 64% for ceiling insulation, 45% for wall insulation, 18% for floor insulation and 9% for double glazing.

7.3.2 Industrial Sector

Full details of the supply of energy end-uses for the industrial sector for the 'realisable energy savings' optimisation are contained in Appendix F.3. Similarly, full details of the 'energy savings' measures for the 'realisable energy savings' optimisation are contained in Appendix G.3.

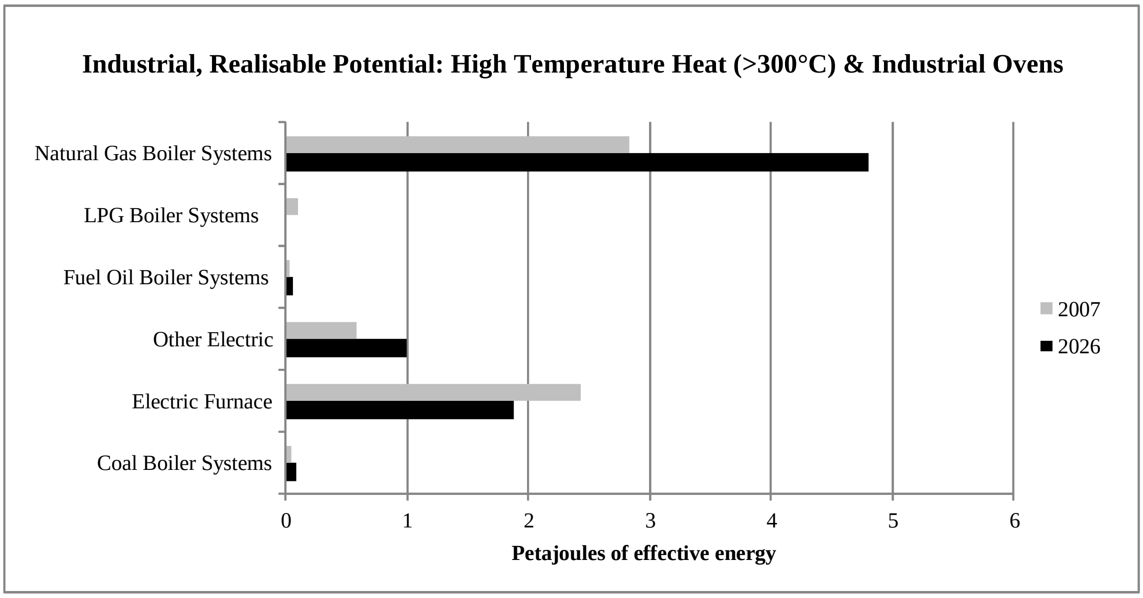
The main shifts in the 'energy end-use supply' processes for the industrial sector are:

- *Kiln/Furnace (>300˚C).* Over the 20 year period there was an increase in both coal and natural gas, replacing electricity, fuel oil and LPG that were phased out. By 2025/26 natural gas (67.1%) provided most of the heat in this category, followed by coal (28.5%) and a small percentage (1.9%) of wood.

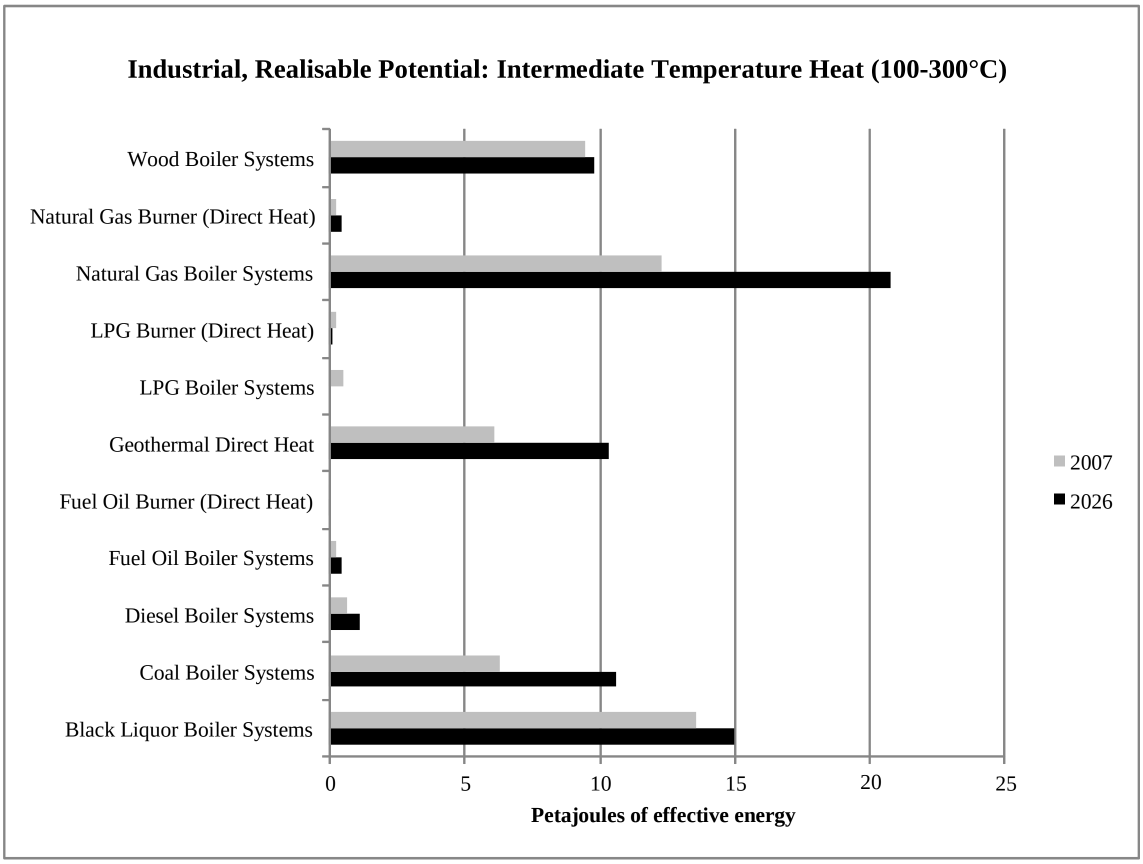
- *Kiln/Furnace (100-300˚C).* Natural gas consolidated as the main source for this category of heat, increasing from 66.0% in 2006/07 to 95.7% in 2025/26. By 2025/26, coal provided the remainder of the heat (100-300˚C) for kilns/furnaces.

- *Kiln/Furnace (<100˚C).* By 2025/26 most of the heat in this category was provided by coal and wood, with natural gas being phased out. By 2025/26, coal usage was at 42.0%, wood at 45.8% and fuel oil at 12.2%.

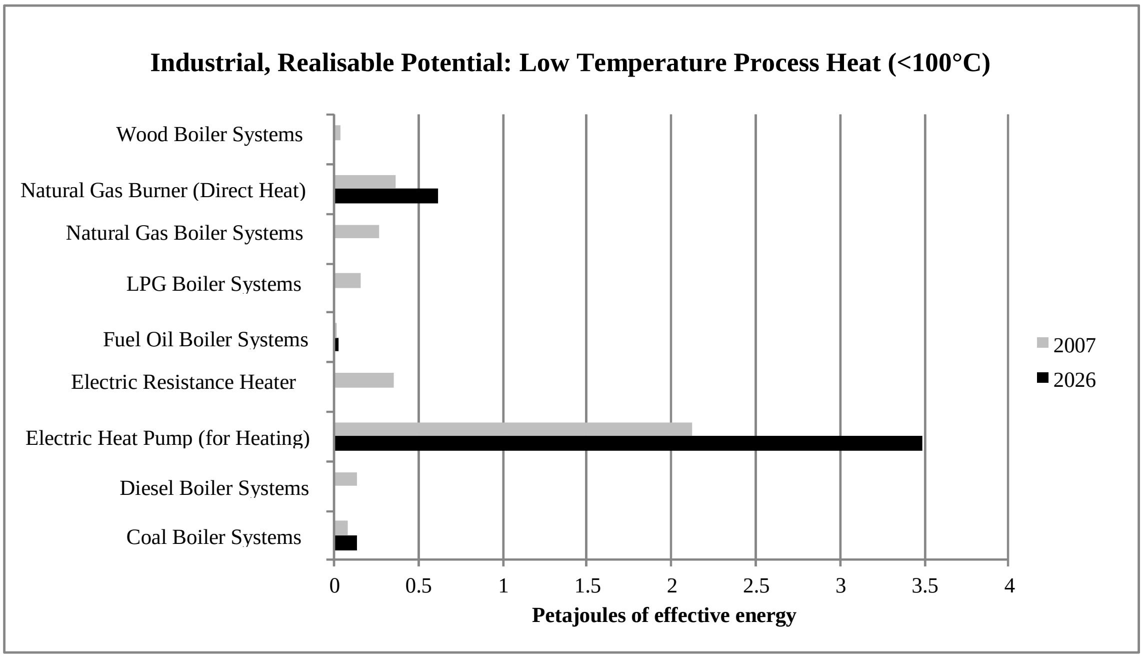
- *High Temperature (>300˚C) Process Heat.* Natural gas becomes the largest provider of high temperature heat, increasing from 46.8% in 2006/07 to 61.2% in 2025/26. Electric furnace at the end of the 20 year period provided 24.0% of the heat in this category, with other electrical sources providing 12.8%. Relatively small amounts of coal (1.07%) and LPG (0.83%) boiler systems provided the remainder of the high temperature heat by 2025/26.



- *Intermediate Temperature Heat (100-300˚C).* The mix of fuels and technologies providing intermediate temperature heat, both remained relatively unchanged. The use of natural gas primarily provided by boiler systems increased from 25.2% in 2006/07 to 30.9% in 2025/26. Over the same period coal fired boiler systems also increased from 12.7% in 2006/07 to 21.9% in 2025/26. These increases were counterbalanced by a decrease in black liquor from 27.3% to 21.9%, and wood from 19.1% to 14.3%. By 2025/26 there were small amounts of diesel (1.6%), fuel oil (0.63%) and LPG (0.1%) used to supply intermediate temperature heat.

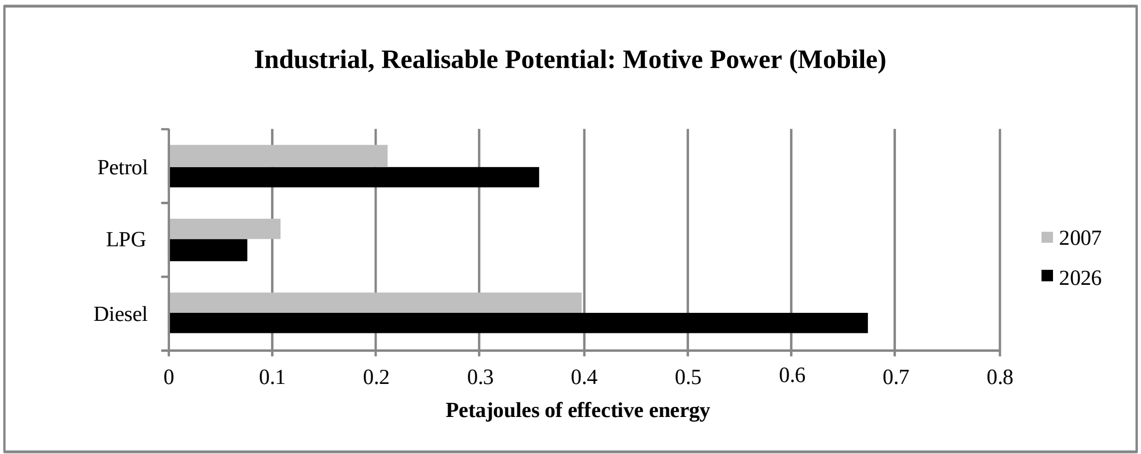


- *Low Temperature (<100˚C).* The use of heat pumps dominated this category by 2025/26. By then 82.7% of low temperature heat (<100˚C) was provided by heat pumps. The remainder by 2025/26 was provided by natural gas (14.4%) and coal (3.3%).

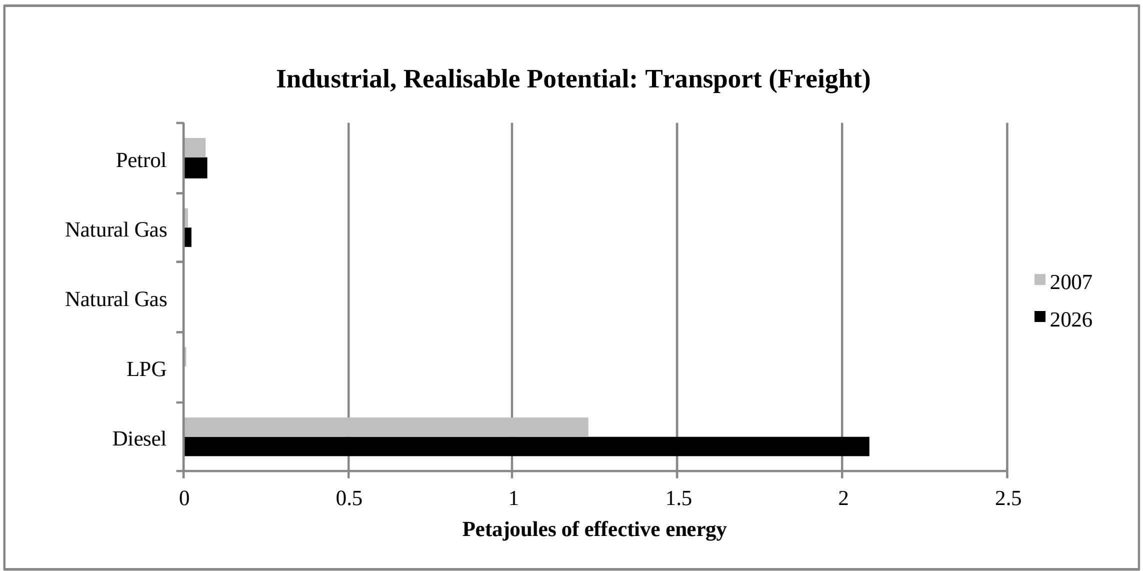


- *Obligatory Electricity.* Much (31.4% at the base year) of the energy consumed in this category is required for so called 'obligatory electricity'. This is electricity required for refrigeration, pumping, electrical and electronic control equipment and lighting. Electricity use decreased slightly over the 20 year study period, due to substitution of use of electricity for heating by other sources, and due to the application of some of the energy savings measure outlined below. Consequently by 2025/26 electricity usage in the industrial sector had decreased from 53.7 PJ in 2006/07 to 47.8 PJ in 2025/26.

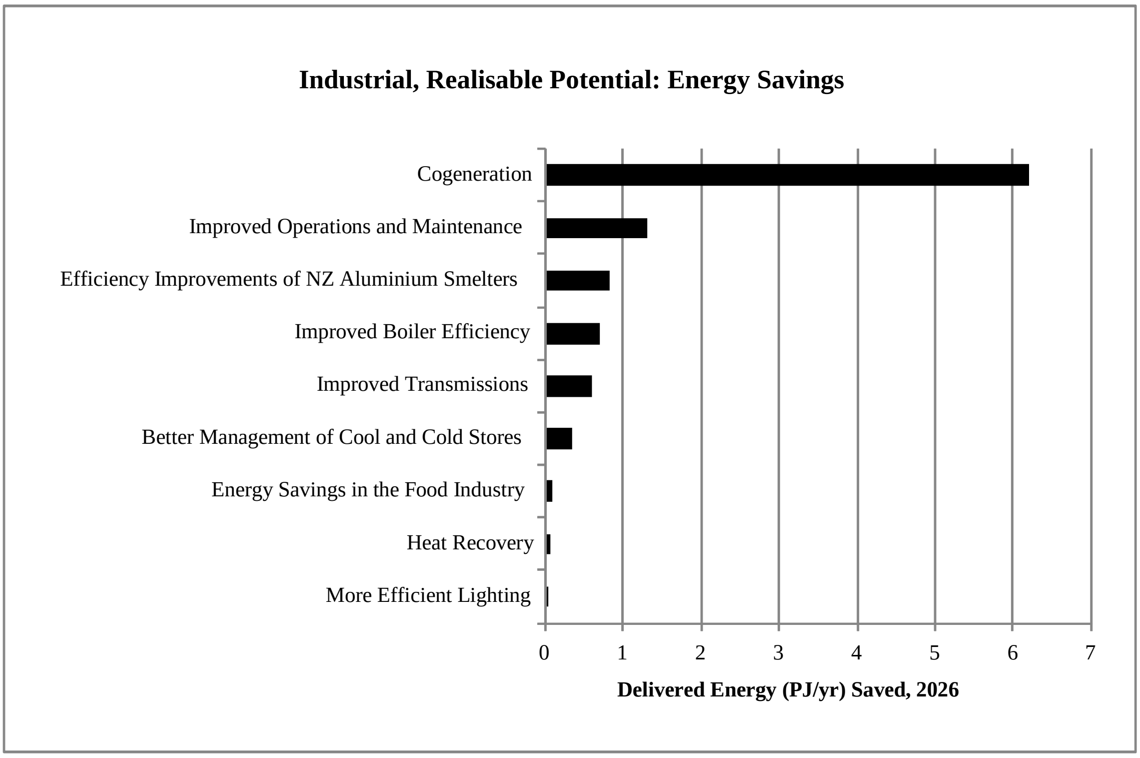
- *Motive Power (Mobile).* This category includes non-road vehicles (e.g. forklifts) by industry. By 2025/26 diesel provided 60.9% of the motive power in this category, followed by petrol (32.3%) and LPG (6.90%).



- *Transport (Freight).* This category refers to freight vehicles run by industrial companies rather than sub-contracted to commercial freight operators. There was little change in the fuels used in the industrial sector with diesel still dominating at 95.6%. There were smaller amounts of petrol (3.3%) and natural gas (0.1%).



- *Transport (Cars).* This is a minor category of end-use for the industrial sector. By the end of the 20 year period most cars were powered by petrol (59.2%), followed by diesel (20.5%), ethanol-petrol blend (10.1%) and natural gas (10.1%).



The 'energy savings measures' for the industrial sector, for the 'realisable energy savings' optimisation were:

- *Cogeneration.* Additional co-generation of heat and electricity was assessed by OPENZ to save 6.20 PJ/yr by 2025/26, being gradually phased in over the 20 year period. More specifically 2.4 PJ/yr of process heat and 2.5 PJ/yr of on-site electricity would be generated from this measure.
- *Improved Boiler Efficiency.* Boiler systems are the main consumer of energy in the industrial sector. It is assessed that by 2025/26 0.71 PJ/yr could be saved according to the 'realisable energy savings' optimisation.
- *Improved Operations and Maintenance.* This includes better day-to-day attention (housekeeping), better process control and management. Under the 'realisable energy savings' optimisation this is expected to lead to 1.32 PJ/yr of savings by 2025/26. This compares with 3.51 PJ/yr that is technically viable under the 'technical energy savings' optimisation.
- *Efficiency Improvements of NZ Aluminium Smelters.* NZ Aluminium Smelters have made consistent improvements in their efficiency (in terms of TJ/tonne of product). This is expected to increase to further savings in the 'realisable energy savings' of 0.82 PJ/yr by 2025/26.
- *Improved Transmissions (e.g. cogged V belts).* The greater application of improved means of mechanical transmission in factories, were assessed to save 0.59 PJ/yr by 2025/26.

- *Better Management of Cool and Cold Stores* including, for example, 'controlled door opening'. This was assessed to realisable energy savings of 0.35 PJ/yr by 2025/26.
- *Energy Savings in the Food Industry.* Based on adjustment estimates from Henderson (1994), it was assessed that by 2025/26 that the use of the 'cool chain concept in the food industry' (Ind. 81) could produce 0.10 PJ/yr of realisable savings.
- *Heat Recovery*. OPENZ identifies many energy savings options, from recovering and then using 'waste' heat from process operation. Of the estimated 0.96 PJ/yr of technical viable savings, by 2025/26 OPENZ identifies only 0.08 PJ/yr of realisable savings, due to the practical difficulties and economic barriers involved in reaching this potential.
- *Lighting.* A small amount of realisable savings by 2025/26 were identified. This included 0.04 PJ/yr from the upgrade of fluorescents and upgrade of gas discharge lamps to more energy efficient technologies.

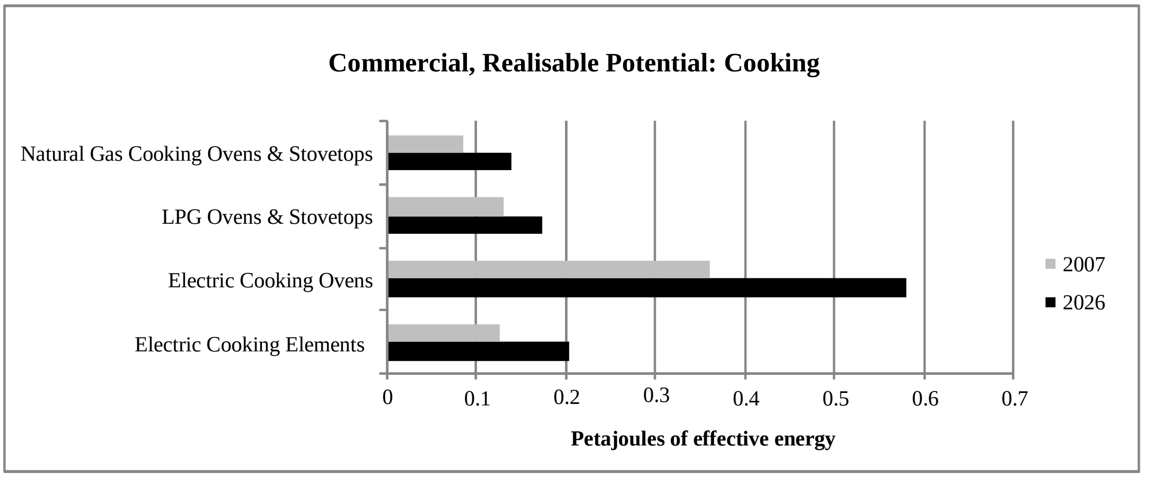
In total, these realisable 'energy savings measures' by 2025/26 were estimated to save 12.3 PJ/year. This compares with technically viable energy savings in the industrial sector for the same year of 20.8 PJ/yr.

7.3.3 Commercial Sector

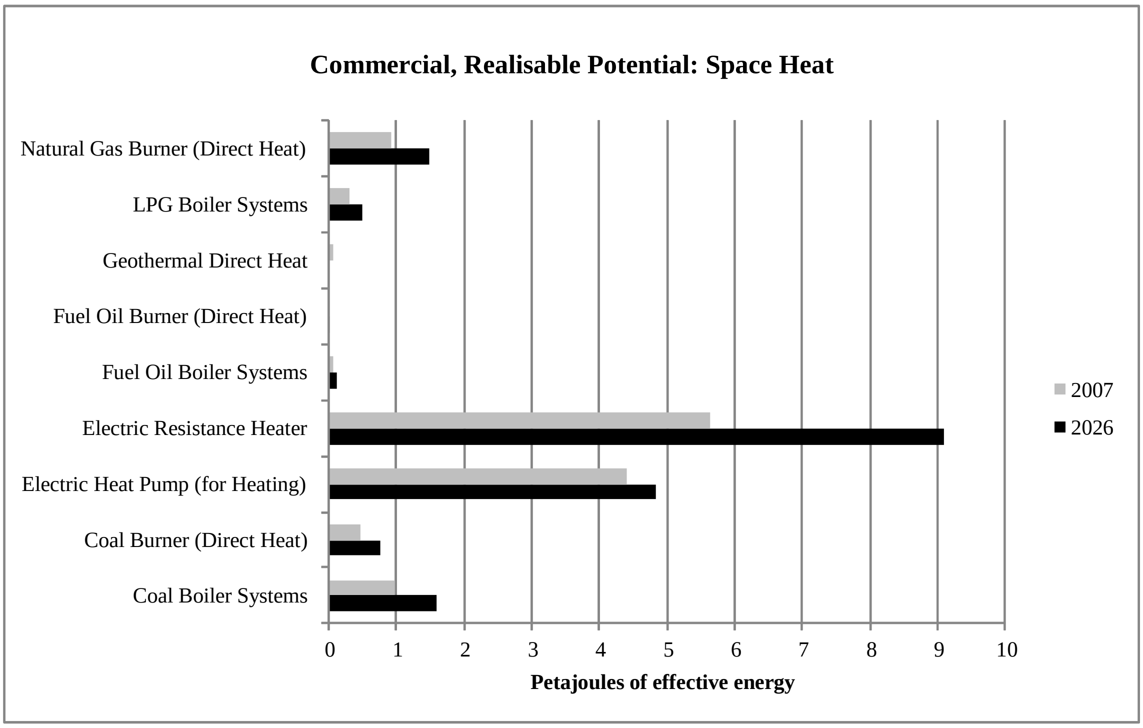
Full details of the supply of energy end-uses, for each year of the realisable energy savings optimisation are contained in Appendix F.3. Similarly, full details of the 'energy savings' measures for the 'realisable savings optimisation' are contained in Appendix G.3.

The main shift in 'energy end-use supply processes' (fuel substitutions) for the commercial sector were:

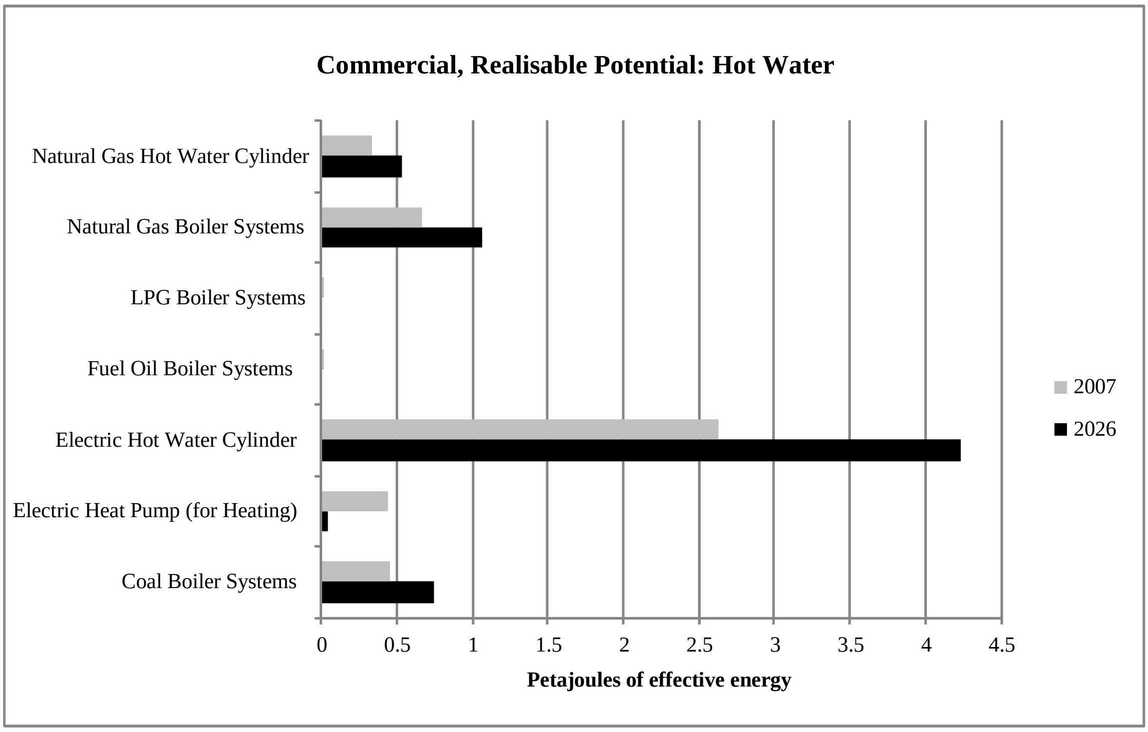
- *Cooking.* There is very little significant change in the energy sources used in the commercial sector. By 2025/26 electricity (conventional ovens, microwaves, cooktops) provided 71.4% of the cooking end-use energy. LPG (15.9%) and natural gas (12.7%) provided the remainder of the cooking end-use energy by 2025/26.



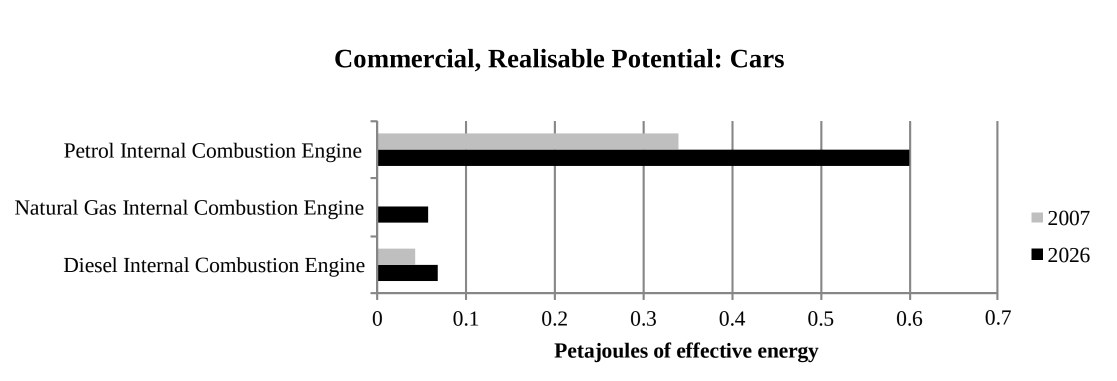
- *Space Heat.* In the 'technical energy savings' optimisation, there was a complete phasing out of resistance heaters and a significant increase in heat pumps. This did not occur in the 'realisable energy savings' optimisation due to the high capital cost of heat pumps. By 2025/26 resistance heaters provided 49.4% of the space heat, followed by heat pumps (25.3%), coal (12.8%), natural gas (8.1%), LPG (2.7%) and fuel oil (0.8%).



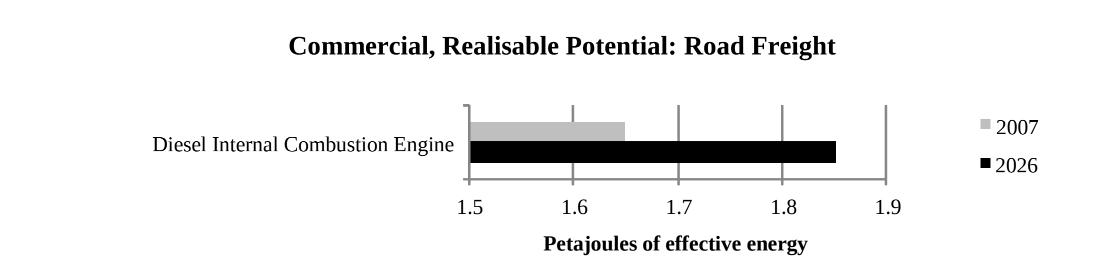
- *Hot Water*. There were very few changes in the fuel and technologies required to provide hot water in the commercial sector. Heat pumps again although 'technically viable' and energy efficient, were not widely used due to the high capital costs. By 2025/26, electric hot water cylinders (63.8%) provided most of the hot water, followed by coal boiler systems (11.2%), natural gas boiler systems (16.1%) and gas hot water cylinders (8.1%).



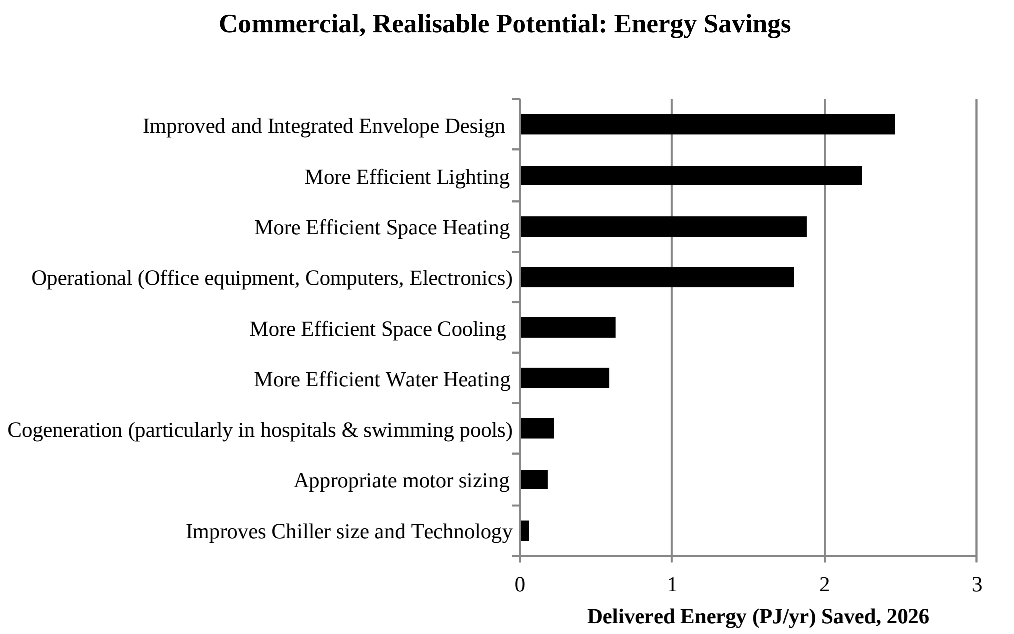
- *Transport (Cars).* This is a minor category of end-use in the commercial sector. Unlike the 'technical energy savings' optimisation, where non-traditional fuels were used to achieve energy savings, there was very little change in the fuel mix over the 20 year period. The only significant change was the uptake of natural gas to 8.0% of market share, replacing some petrol use that still dominated with 82.5% of the market share.



- *Transport (Freight).* This category refers to freight vehicles, run by Commercial sector businesses rather than contracted out to freight companies (in the transport and storage sector). There was very little change in the fuels used in this sector over the 20 year period, with by 2025/26 diesel almost completely dominating.



- *Obligatory Electricity.* Much of the commercial sector's energy use and electricity load falls in this category which includes electronic equipment, computers, as well as a significant amount of refrigeration energy, which is needed in retailing, restaurant, shops, supermarkets and wholesaling activities included in this sector. This obligatory electricity consumption nominally increased by 38% over the period. However, there was a number of 'energy savings measures' (e.g. improved purchasing of equipment) considered below that effectively reduced this nominal obligatory electricity demand.



The main 'energy savings' measures identified in the 'realisable energy savings optimisation' were:

- *Operational*. This includes better management of office equipment, switching equipment on/off and optimum location of office equipment. As previously noted computers and electronic equipment are growing end-use category (IEA, 2009 a,b.) world-wide. It is therefore perhaps not surprising that this end-use category provides one of the most important areas for realistic energy savings. OPENZ estimates that by 2025/26 1.8 PJ/yr of realisable energy savings can be achieved by the more efficient operations of computers, electronics and other electrical equipment.
- *Lighting*. Lighting is a major end-use of electricity in the commercial sector. OPENZ identified a number of 'realisable energy savings'. These included by 2025/26: 1.05PJ/yr by medium cost lamp upgrade (reflectors, triphosphor tubes, CFLs etc.); 0.40PJ/yr by design changes (task lighting, uplighting, daylighting); 0.28 PJ/yr by automatic controls (occupancy, time and daylight linked); 0.20 PJ/yr by low cost lamp upgrade (38mm to 26mm); 0.17 PJ/yr by delamping/fine tuning; and 0.16 PJ/yr by improved operations and maintenance (optimising after hours use, cleaning staff scheduling, luminaire cleaning, etc.). In total, if all of these realisable energy savings measures were adopted 2.25 PJ/yr of electricity would be saved compared with the BAU situation. This is just less than half of the 'amount of savings' compared with the 'technical energy savings' potential.
- *Improved and Integrated Envelope Design*. Although often requiring long lead-in times as old building stock is replaced by new buildings, as well as retrofitting options, these options do provide significant realisable energy savings potentials over the medium-long term. A number of options (Com. 53, Com. 56, Com. 119, Com. 5, Com. 06) do provide economically viable and realistic means of capturing those energy savings over the 20 year time horizon of this study. In total 2.47 PJ/yr by 2025/26 are assessed to be saved, under the 'realisable energy savings optimisation'. These realisable energy savings account for 36% of the savings that are technically feasible.

- *Water Heating*. OPENZ identifies the following amounts of realisable energy savings in this end-use category by 2025/26: 0.27 PJ/yr from flow controls (spray nozzles, shower heads, etc.); 0.23 PJ/yr from improved operations and maintenance (e.g. temperature settings, distributions controls, controlling leaks/drips); and 0.66 PJ/yr from improved distributional efficiency (local heaters, pipes and cylinder insulation). In total, the realisable energy savings from the application of these methods adds up to 0.59 PJ/yr by 2025/26. This is only about 9% of that which are technically viable from this end-use category.
- *Space Heating*. OPENZ identifies a number of energy savings measures including recommissioning old plant, correct heating choice (radiant, convector, air) and plant control (e.g. compensator control with reset). In total, the realisable energy savings from the application of these methods adds up to 1.88 PJ/yr by 2025/26. This is only about 26% of the savings that are technically viable in this end-use category.
- *Space Cooling*. Space Cooling is a significant and increasing end-use of energy consumed in Commercial buildings. In total, OPENZ assesses the realisable energy savings in this category, by 2025/26 to be 0.63 PJ/yr.
- *Cogeneration*. This is a relatively small amount of energy that can be saved by cogeneration of electricity and heat. This mainly applies to hospitals and swimming pools. It is estimated by OPENZ that by 2025/26 it is realistic to save about 0.23 PJ/yr from using cogeneration in the commercial sector.
- *Other Savings*. Other significant realisable savings identified by OPENZ include the appropriate chiller size and technology (0.06 PJ/yr in 2025/26) and appropriate motor sizing (0.19 PJ.yr in 2025/26).

In total by 2025/26, OPENZ assesses that 10.00 PJ/yr of realisable energy could be saved in commercial sector. This compares with 30.05 PJ/yr which is technically viable. In other words, only 29.9% of the technically possible energy savings measures in the commercial sector are considered to be realisable.

7.3.4 Primary Sector

Full details of the supply of energy end-uses for each year of the ‘economic energy savings’ optimisation are contained in Appendix F.3. Similarly full details of the ‘energy savings measures’ for the ‘economic energy savings’ optimisation are contained in Appendix G.3.

In general, compared with the other sectors, OPENZ identified significantly less opportunities for reducing energy inputs into the primary production sector. This is for two reasons: (1) the primary sector is far smaller than other sectors, accounting for only 7.36% of delivered energy use in the New Zealand economy; (2) there is fewer energy savings mechanisms identified by Henderson (1994) for the primary sector – which OPENZ relies upon[73].

The main changes in the supply of energy end-uses by OPENZ were:

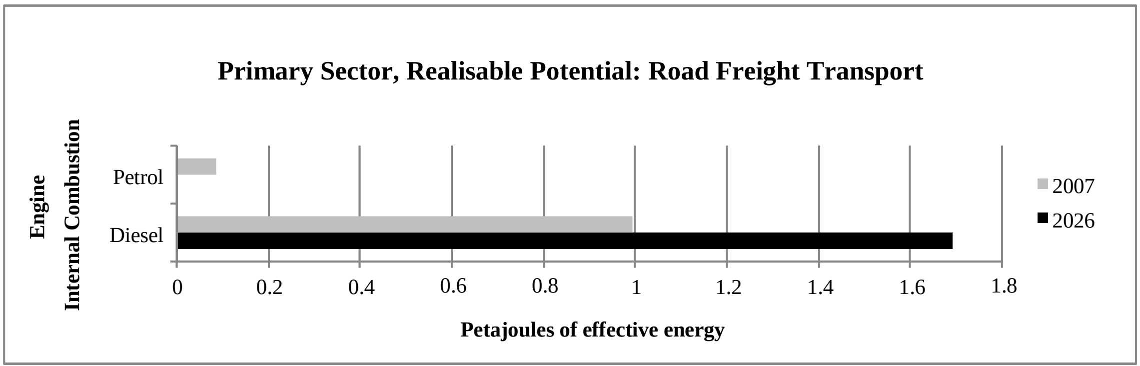
- *Intermediate Temperature Heat (100-300˚C).* Resistance heaters were eliminated and replaced by the use of fuel oil and natural gas as sources of intermediate heat. By 2025/26 fuel oil supplied 50.7% of the intermediate heat in this end-use category, with natural gas at 49.3% supplying a similar amount.

[73] There are a number of publications on energy conservation measures for primary sectors in New Zealand: Barber and Pellow (2005), Centre for Energy Research (2004), Ministry for the Environment (2007 a,b,c,d) and Morrison (2007). None of these publications however provide sufficient quantitative and economic data to adequately model the energy conservation options in OPENZ

- *Low Temperature Heat (<100˚C).* This heat is mainly required by the Protected Crop Sector. Coal increased as a source of low temperature heat lifting from 53.7% in 2006/07 to 82.7% by 2025/26. Natural gas declined as it was replaced by coal. By 2025/26 Natural gas only provided 17.3% of heat in this end-use category.

- *Motive Power (Mobile).* This includes farm vehicles, such as tractors and other off-road vehicles. For Motive Power (Mobile), where possible, there was a replacement of diesel instead of petrol.

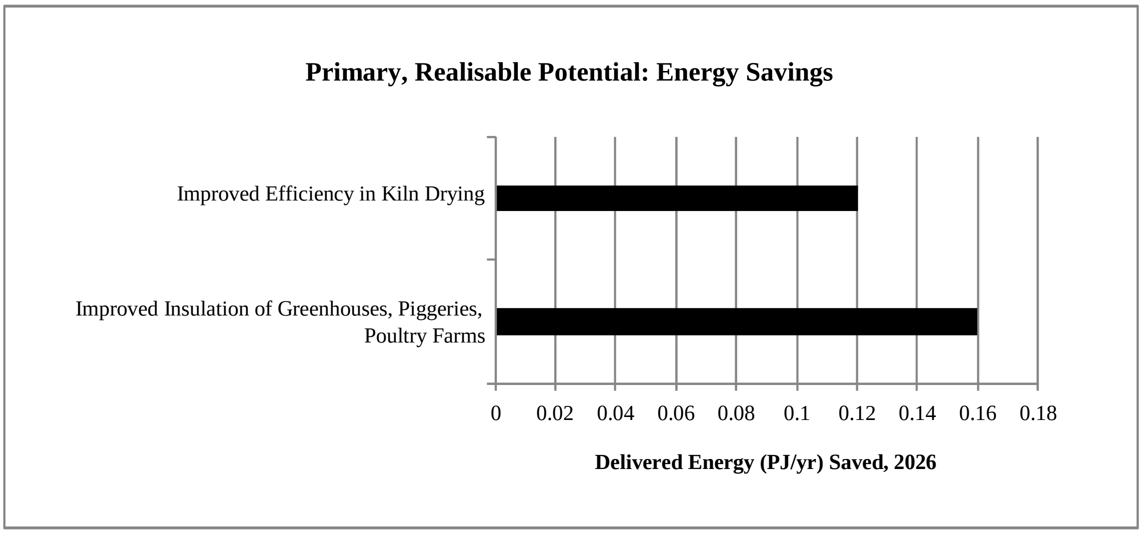
- *Freight Transport.* Petrol was phased out by 2009, with all freight vehicles converted to diesel. This was based on the least cost ($) criteria, which, in this case, gave very similar results for the energy efficiency criteria previously used in the 'technical energy savings' optimisation.



The main 'energy savings' measure for the primary sector, by OPENZ were:

- *Improved Insulation*. This mainly applied to greenhouses but also to pig and poultry farms. OPENZ assessed 0.16 PJ/yr realisable energy savings by improved insulation by 2025/26.
- *Improved Efficiency in Kiln Drying*. OPENZ assessed 0.12 PJ/yr energy savings by improved efficiencies in this area, by 2025/26.

As noted above there are other 'energy savings' measures that could be implemented in the Primary Sector. However, there is a lack of data particularly on alternative fuels (for tractors) and on improving the operation of dairy shed operations. For example, it should be possible in future versions of OPENZ, to evaluate options for water heating and milk chilling in dairy sheds.



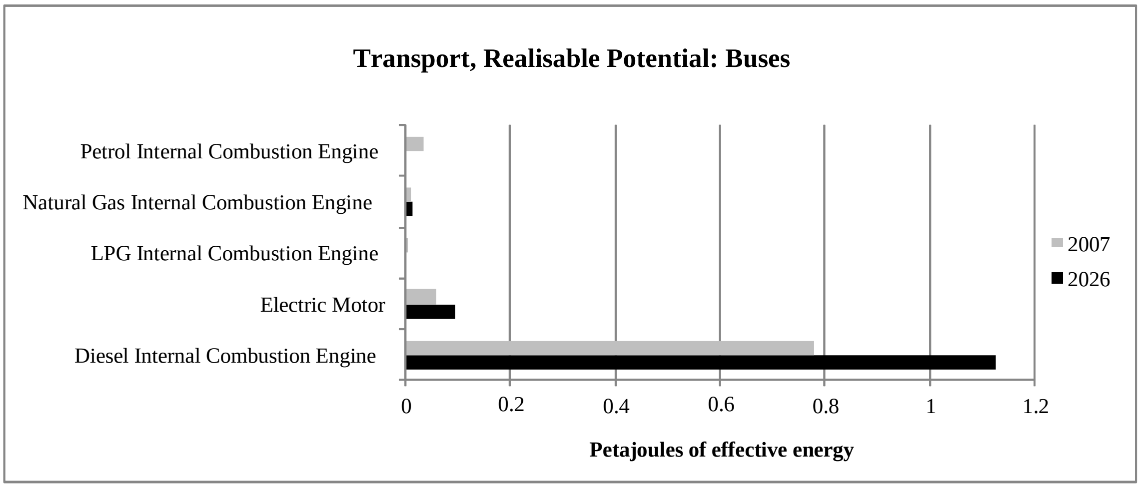
7.3.5 Transport and Storage Sector

Full details of the supply of energy end-uses for each year of the 'realisable energy savings' optimisation are contained in Appendix F.3. Similarly full details for the 'energy savings measures' for the 'realisable energy savings' optimisation are contained in Appendix G.3.

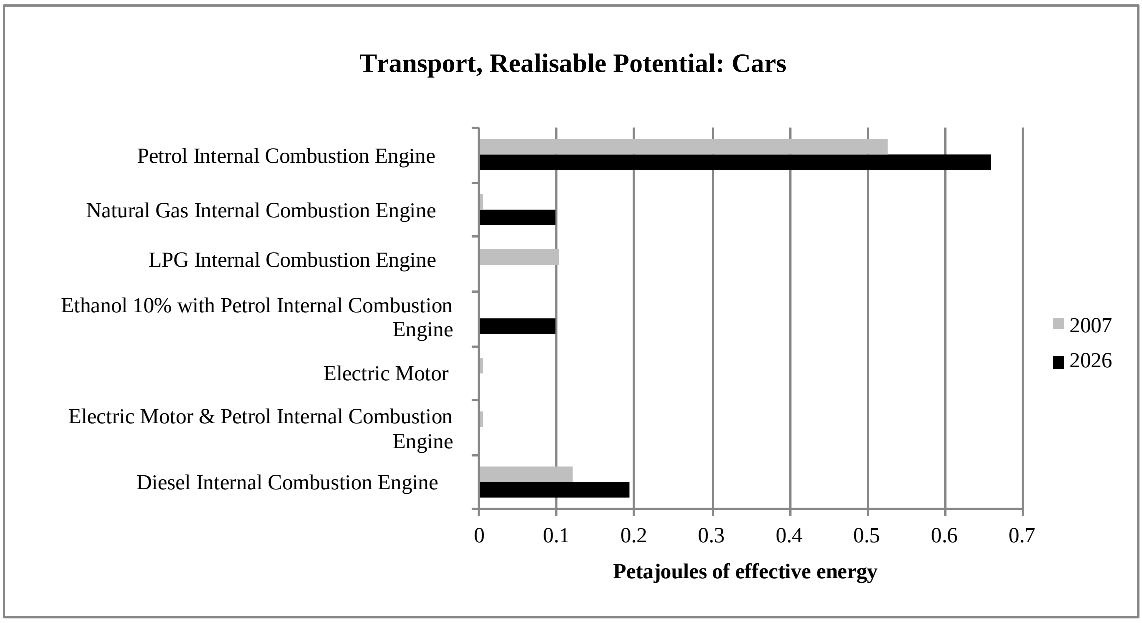
It should be noted that transport activities are also included in all other sectors (Household, Commercial, Primary, Industrial). In compliance with ANZSIC, the transport and storage sector *only* includes transport and storage activities sub-contracted by clients from these other sectors.

The main shifts in 'energy end-use' supply processes for the transport and storage sector were:

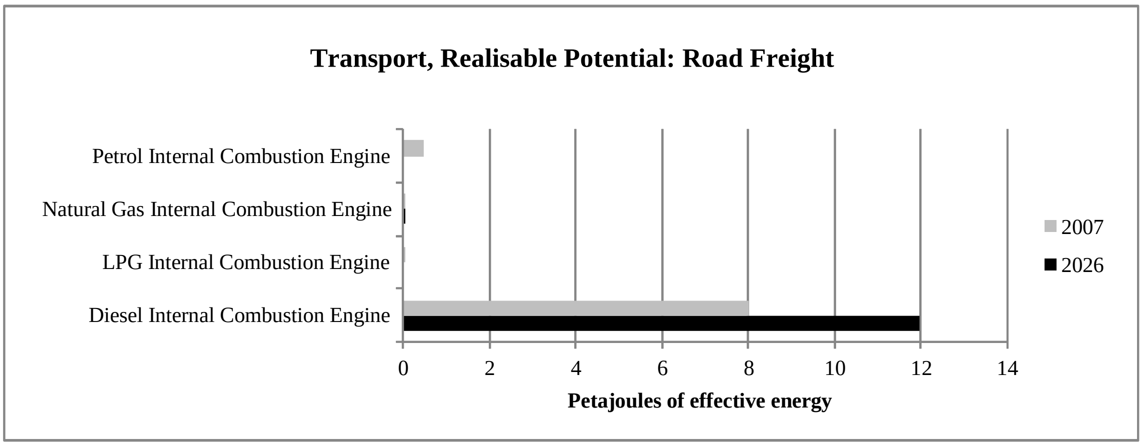
- *Buses for Land Transport.* Diesel increased from 88.2% in 2006/07 to 91.2% in 2025/26. There were also small increases in electric and natural gas powered buses. By 2025/26 electricity provided 7.6% of the end-use energy and natural gas 1.2%. LPG and petrol powered buses were completely phased out.



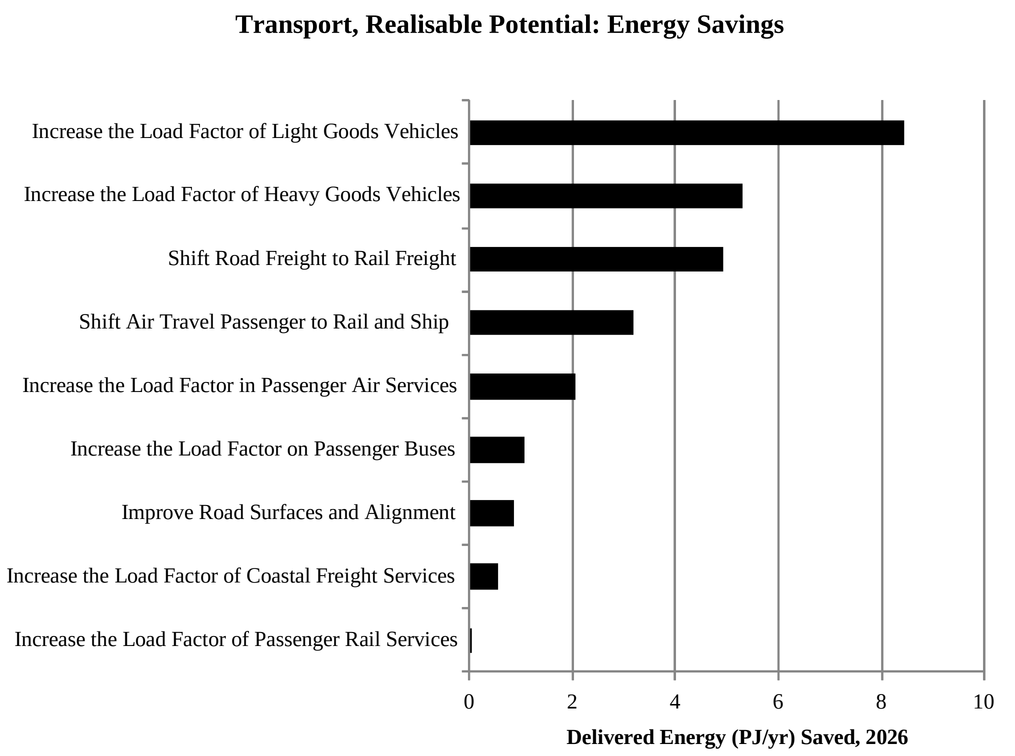
- *Cars for Land Transport.* This is only a very small sub-sector mainly consisting of taxis. By 2025/26 petrol (62.8%) remained the main source of end-use energy, although there was a small decline since 2006/07. By 2025/26 diesel provided for 18.5% of the end-use energy, with petrol-ethanol blends the remaining 9.3%.



- *Freight Transport (Land).* OPENZ assesses a slight shift towards diesel powered vehicles. That is, diesel increases its dominant market share from 93.4% to 99.8%. The remaining 0.2% is provided by natural gas, and petrol use is completely phased out.



- *Rail Freight.* In 2006/07 88.9% of this category of end-use was supplied by electricity. By 2025/26 all rail freight locomotives used electricity. Similar patterns occurred in passenger rail services.



The main 'energy savings measures' implemented were:

- *Increase the Load Factor in Passenger Air Services by 10%.*[74] It is assessed on data updated from Henderson (1994) that increasing the load factor in passenger air travel by 10% would save 2.04 PJ/yr by 2025/26.
- *Shift Air Travel Passenger to Rail and Ship*. This only includes domestic travel, as international air travel is not included in the model. It is assessed again on data updated from Henderson (1994) that this could save 3.20 PJ/yr by 2025/26. This would require a major upgrading of the New Zealand rail system to achieve this target, and probably a significant change in price relativities between the competing services. New Zealanders travel by rail is small between the major centres compared with other developed countries particularly those in Europe.
- *Increase the Load Factor of Passenger Rail Services by 10%.* [75] This is assessed by OPENZ to be 0.06 PJ/yr by 2025/26.
- *Increase the Load Factor of Coastal Freight Services by 10%.*[76] This is assessed by OPENZ to be 0.54 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) with growth rates applied in the OPENZ calculations.

[74] It is not known for certain what the load factor for Passenger Air Services is. It is therefore assumed that there is a 10% increase, from 60% to 70% loading.

[75] It is not known for certain what the load factor for Passenger Rail Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.

[76] It is not known for certain what the load factor for Coastal Freight Services is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

- *Increase the Load Factor on Passenger Buses by 10%.*[77] Load factors in New Zealand buses are low (average of about 30%). OPENZ calculates that by increasing this load factor by 10% by 2025/26, then 1.08 PJ/yr energy could be saved.
- *Increase the Load Factor of Light Goods Vehicles by 10%.*[78] Improved logistics, planning and organisation, could save a very significant amount of energy, due to the large amount of end-use energy used for light goods freight. It is estimated by OPENZ, using data updated from Henderson (1994), that by 2025/26 8.43 PJ/yr could be saved which is due in part to the strong relative growth of this sector.
- *Increase the Load Factor of Heavy Goods Vehicles by 10%.*[79] Although the load factor of heavy goods vehicles (about 50%) is better than light goods vehicles (about 30%), there is still considerable potential for improvement. OPENZ assess that by 2025/26 5.30 PJ/yr could be saved by improving the load factor of heavy freight vehicles by another 10%.
- *Shift Road Freight to Rail Freight.* This is assessed to be 4.92 PJ/yr energy saving by 2025/26, based on updated data from Henderson (1994) that had growth and other factors for this sector applied to it. Again this would require a significant upgrading of the New Zealand freight rail system, and the appropriate financial incentives put in place.

If all of these transport sector 'realisable able energy savings' measures were implemented, then by 2025/26 26.42 PJ/yr of savings will be achieved. This is significantly more than the other sectors.

[77] It is not known for certain what the load factor for Passenger Bus Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.

[78] It is not known for certain what the load factor for Light Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 20% to 30% loading.

[79] It is not known for certain what the load factor for Heavy Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

8. Realisable Greenhouse Gas Reductions Potential

Due to the potential ambiguity of the terms 'energy savings' and some lack of consensus of how to deal 'energy quality', we suggest that are certain advantages to running OPENZ in order to define 'Greenhouse Gas Reductions' Potential.

It is recommended at the conclusion of Appendix A that EECA considers using the 'minimisation of GHG emissions' as the objective function in OPENZ, in order to define the 'Greenhouse Gas Reductions Potential'. The advantages of using minimisation of GHG emissions' are: (a) it is more easily defined than minimising 'primary energy inputs' because the commensuration problem is more easily resolved by the use of CO_2 equivalents to take account of 'global warming potential'; (b) it avoids the ambiguity and methodological problems associated with using 'energy savings potential' and 'energy efficiency measures'[80]; (c) it could be argued that minimising 'greenhouse gas emissions' is now a far more pressing and important policy goal than the 'minimisation of energy inputs'.

Apart from 'Energy Efficiency' and 'Reducing Greenhouse Gas Emissions' there are many other energy policy goals that should be reflected in government policy and indeed in many cases specifically covered in the *New Zealand Energy Strategy*. These for example could include: energy security, fair pricing, resilience of the supply system, reducing the cost of supply, industrial competitiveness, self-sufficiency and so forth. Although the implicit focus of this potential modelling exercise is energy efficiency, it would be unwise not to consider these other energy policy goals. It is therefore recommended in the further development and application of OPENZ that EECA at least pay some attention to these other policy goals. For example, it is argued that it would be helpful to 'minimise energy inputs', subject to the constraint that CO_2 emissions not exceed the 2006/07 base year level or some other government target. This is for the obvious reason, that government policy makers are unlikely to take seriously any theoretical 'energy savings potential' that involves CO_2 emissions that exceeds a Government target or expectations.

8.1 Assumptions

All of the assumptions apply as for the 'realisable energy savings' potential optimisation – viz, the intention is to identify the optimal way of reducing greenhouse gas emissions, given a scenario of realistic technology penetration rates of end-use technologies. The only analytical differences between the two optimisation is the specification of the objective function – in the case of the 'realisable energy savings', the objective function is minimisation of total economic cost ($) of supply; whereas, in the case of the 'greenhouse gas reductions potential' the objective function is the minimisation of greenhouse gas emissions. In a sense the optimisation being reported here could consequently be termed 'realisable greenhouse gas reductions'.

The key assumptions for this optimisation are therefore as follows:

- The size of natural gas reserves in 2,427.6PJ (allowing 20% for new discoveries).
- Rebound effect from new Household Insulation is 44%.

[80] For example, quite different results can ensue depending on which energy numeraire is used in the objective function, and most numeraires will give a different 'energy efficiency' results depending on whether 'primary energy inputs' or 'delivered energy inputs' are using in the 'objective function'. For further discussion of this matter, refer to Appendix A.

- Rebound effect from new Heat Pumps is 10%.
- Energy Prices are at the 'default' levels as outlines in Appendix C. These default prices only apply to the exogenously determined prices (refer to section 2.10.1), not the prices for endogenously determined prices (electricity, ethanol, methanol, biogas, synthetic petrol, synthetic diesel and natural gas). These default energy prices were almost entirely drawn from Donovan *et. al's* (2009) report that provides a very thorough analysis of future energy prices from 2008 to 2060.
- 617,940 ha are available for agricultural bio-energy crops and 1,411,500 ha are available for silviculture energy crops. In actuality neither of these constraints (availabilities) become binding.
- The activity levels of the 37 sectors of the economy from 2006/07 to 2025/26 are the 'default values' as estimated by the Economic Futures Model. These 'activity levels' are directly based on the projected contributions to GDP (value added) of each sector in the economy. For the household sector, the projected activity is based on 'household consumption ($)', which is forecasted to increase by 37% over this period. These GDP (and household consumption) based activity levels were used to estimate the projected amounts of energy end-uses for each sector.
- Carbon Prices are at the 'default' levels outlined in OPENZ and discussed in Section 2.5. These 'carbon prices' are arguably quite conservative (low), but broadly consistent with those used by East Harbour Management Services (2004, 2005) and The Treasury (2005).
- A 'default' setting of 23.7 PJ/yr for methanol and urea production is assumed for each year.
- Penetration rate between 1991/92 and 2006/07 of Henderson's (1994) energy savings measure were all set at 30%.
- For a small number of energy supply processes, a constraint was placed on the process activity, to ensure that it would not be adopted for a minimum of 10 years. This avoided the situation of a supply process like enzyme hydrolysis of maize to ethanol only being adopted for 3 years before it was discarded, which is obviously unrealistic.
- Percentage of electricity that could be generated from wind was set at an upper limit of 20%, due to this being considered the upper technical level possible in New Zealand electricity supply system.
- It was assumed that by 2026/27 that 95% of New Zealand households could have ceiling insulation, wall insulation, floor insulation and double glazing. This was from a base of 2006/07 where 64% of households had ceiling insulation, 45% had wall insulation, 18% had floor insulation and 9% had double glazing. There was a linear interpolation between the 2006/07 and 2025/26 levels of insulation, to allow for a technically feasible level of uptake.

Specifically the end-use technology penetration rate assumptions were:

- Penetration rates for both new and existing energy end-use processes, are set at 'low levels'. These penetration rates are assessed to be 'realistic' given what is known about past uptake rates of new technologies.
- Penetration rates for the energy savings measures are all set at 50%. This means that by 2025/26 that only 50% of the full potential for each 'energy savings measure' can be realised. This may be considered to be too pessimistic, but evidence shows (even from the existing pattern of technology deployment) consumers may not use what appears to be the least cost ($) means of energy end-use supply, in part because there are other motivational factors beside from cost ($) and energy savings, and in part due to lack of information, finance and other well known factors that underlie 'market failure.'

8.2 Headline Results

8.2.1 Primary Energy Savings

The difference between the ‘BAU’ and the ‘Optimised’ primary energy inputs is the energy savings. The energy savings for this optimisation increases over the 20 year period to 252 PJ/year[81] in 2025/26. This is actually better than the energy savings for the realisable energy savings optimisation (195 PJ/year[82]). However, the energy savings were not as much as for the ‘economic energy savings’ optimisation (305 PJ/year[83]), or the ‘technical energy savings’ optimisation (439 PJ/year[84]).

These ‘energy savings’ for the ‘realisable greenhouse gas reductions’ potential were primarily achieved by switching to agricultural crops, wood, wind, geothermal primary energy sources, and decreasing the reliance on imported oil products and coal.

8.2.2 Energy Intensity

Energy intensity is a measure of the gross energy efficiency, usually applied at the national and sometimes sectoral level. That is, the lower the energy intensity (J/$), the higher the energy efficiency of a nation or a sector.

Because of structural shifts in the New Zealand economy, even with the ‘BAU projections’ the energy intensity of the economy is projected to decrease from 4.55 PJ (crude oil equivalents)/$\$_{2006/07}$ billion in 2006/07 to 3.80 in 2025/26. With the ‘GHG reductions optimisation’, this rate of decline is even greater, with the energy intensity declining to 3.37 PJ (crude oil equivalents)/ $\$_{2006/07}$ billion in 2025/26.

This decrease in the energy intensity of 33.7% according to the ‘GHG reductions’ optimisation, indicates a significant improvement in New Zealand’s economy-wide energy efficiency. By direct implication, 16.4% of this is due to structural shifts in the economy from 2006/07 to 2025/26, with the remainder of 17.3% being due to ‘technical improvements’. This represents an annual rate of close to 1.2% of technical energy efficiency improvements, which is a little more than technical improvements in the order of 1% that has been historically recorded by using the divisia decomposition method (Lermit and Jollands, 2001; Jollands, Lermit and Patterson, 2004; Patterson, 1993).

[81] This is 252 PJ (heat content) for the ‘Realisable GHG Potential’, which in this case equals 175 PJ (crude oil equivalents).
[82] This is 195 PJ (heat content) for the ‘Realisable Energy Potential’ which in this case equals 110 PJ (crude oil equivalents).
[83] This is 305 PJ (heat content) for the ‘Economic Energy Potential’ which in this case equals 251 PJ (crude oil equivalents).
[84] This is 439 PJ (heat content) for the ‘Technical Energy Potential’ which in this case equals 470 PJ (crude oil equivalents).

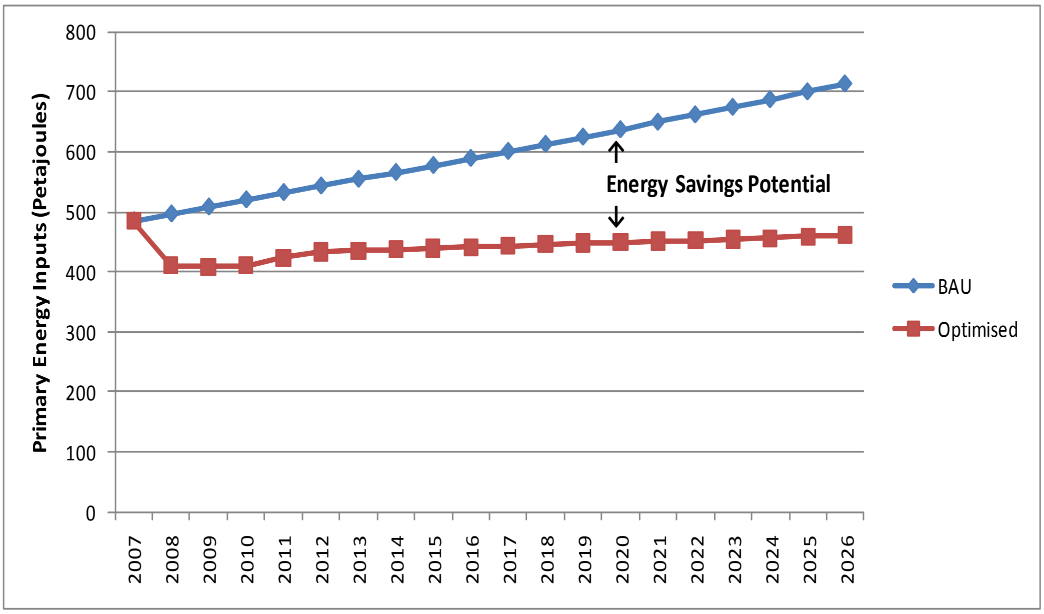


Figure 8.1 Primary Energy Inputs for the Greenhouse Reductions Optimisation
(Measured in terms of 'Heat Content')

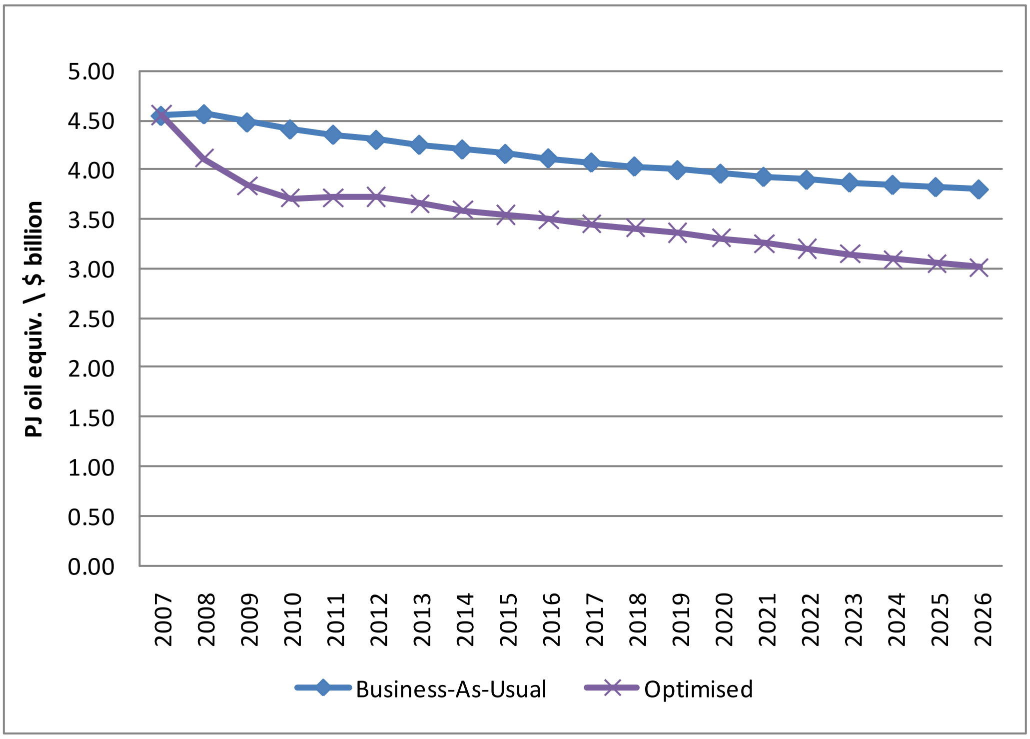


Figure 8.2 NZ Energy Intensity for the Greenhouse Reductions Optimisation

8.2.3 Greenhouse Gas Emissions

The GHG optimisation reveals a significant potential for reducing greenhouse gases compared with the BAU projection. That is, the BAU projection has greenhouse gases increasing from 38,584 kilotonnes (CO_2 equivalents) in 2006/07, to 47,689 kilotonnes (CO_2 equivalents) in 2025/26. This is a 23.6% increase. Oppositely, the GHG optimisation projects greenhouse gases to decrease by 7.2% to only 37,790 kilotonnes (CO_2 equivalents) by 2025/26.

It should, however, be noted that although this 7.2% reduction is significant, it is still above the much referred to baseline 1990 target – according to the Ministry of Economic Development (2008) New Zealand's energy system emitted 23,600 kilotonnes (CO_2 equivalents) in 1990. All of this underlines the very significant challenge of reaching 1990 baseline targets. Indeed OPENZ clearly demonstrates that this is technically infeasible, given current known technologies that make up the OPENZ database. The only way the 1990 emissions target can be achieved, is to use new technologies which is unlikely given the slow lead in time and uptake rates of new and emerging technologies such as those covered in studies like those by the Global Environmental Research Fund (2008) study of Japan and by the IEA (2008).[85]

8.2.4 Economic Cost

The optimised cost of energy supply was $\$_{2006\text{-}07}$ 73,982 million/year in 2025/26, which is above the BAU cost of $\$_{2006\text{-}07}$ 70,106 million/year. The most important policy implications that can be drawn from this cost data, is that it will cost an extra $\$_{2006\text{-}07}$ 3.876 billion/year to reduce GHG emissions to 35,790 kilotonnes CO_2e in 2025/26. In other words it would cost about 1.75% of the projected GDP to achieve this reduction to 35,790[86] kilotonnes CO_2e/year

This figure of 1.75% of GDP is seemingly higher than results for comparable studies overseas – although it is difficult to directly compare our study with those elsewhere, because of their different foci, study boundaries and greenhouse gas emission targets. Nordhaus (1993a,b) in his landmark study found that "1% of the world's output" would be required to reduce greenhouse gases to 50% of current levels. In more recent times Stern (2007) calculated that 1% of global GDP would be required to stabilise the atmosphere between 500-550ppm CO_2e, although Stern (2008) has since revised this upwards to 2% of global GDP. Again, although not directly comparable, Lennox and van Nieuwkoop (2010) evaluated emission trading schemes for New Zealand, using a Computable General Equilibrium modelling approach. Lennox and van Nieuwkoop (2010) modelling results showed decreases in GDP from about 0.7% to 2%, depending on various permit allocation, taxation recycling, and carbon price assumptions. Their scenarios led to decreases in the 2006 GHG emissions[87] of between 10 to 20% depending on which assumptions they employed.

85 It is beyond the scope of this initial operationalisation of OPENZ, to study technologies expected to come on stream up to the year 2050 – as in the IEA (2008) and Global Environmental Research Fund (2008) studies. However, future development could extend OPENZ's coverage to new technologies used in these two international studies.

86 This figure only includes energy-based greenhouse gases reduction to 35,790 kt CO_2e by 2025/26. It does not include greenhouse gases from non-energy sources, which are considerable in New Zealand.

87 Lennox and van Nieuwkoop's (2010) model includes all greenhouse gas emissions produced by the New Zealand economy, not just energy-related greenhouse gas emissions as in OPENZ. Caution therefore needs to be exercised in directly comparing Lennox and van Nieuwkoop's (2010) and the OPENZ results

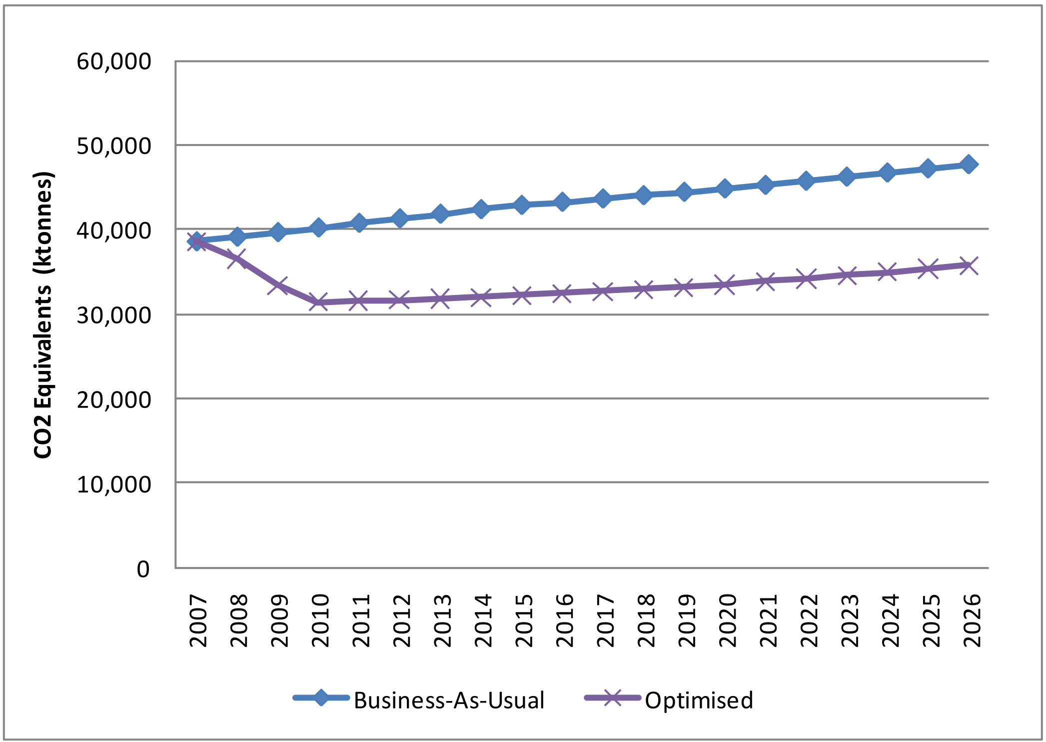


Figure 8.3 Greenhouse Gas Emissions for the Greenhouse Reductions Optimisation

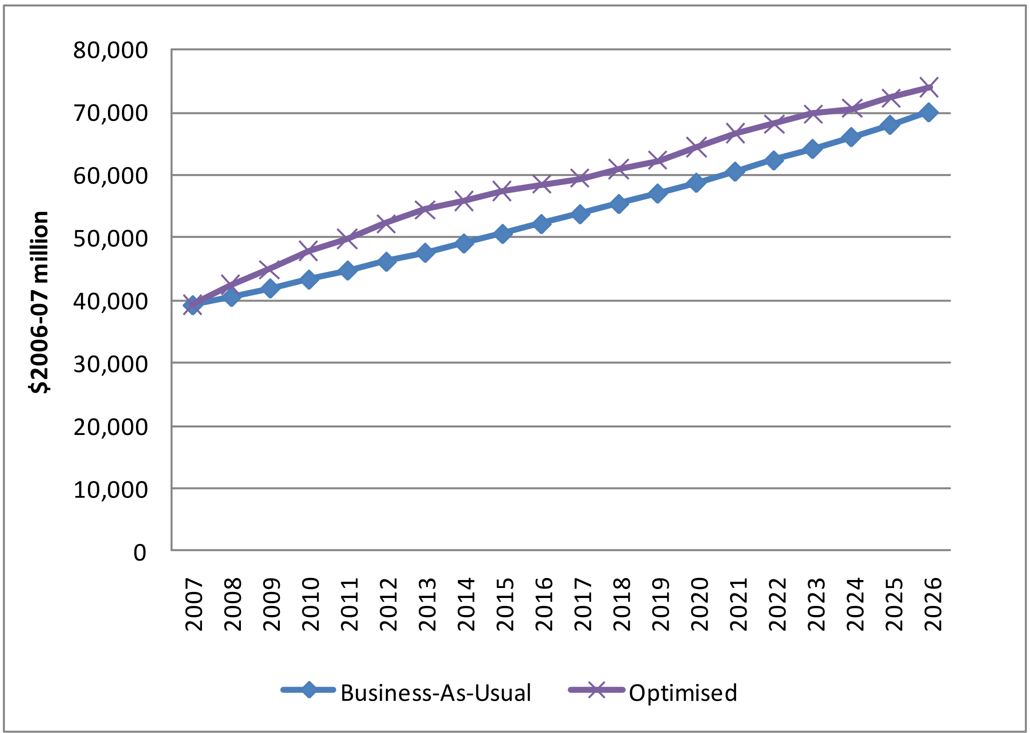


Figure 8.4 Economic Cost for the Greenhouse Reductions Optimisation

8.2.5 Primary and Delivered Energy

The Realisable Greenhouse Gas reductions' optimisation translates into the pattern of delivered energy consumption as outlined by Table 8.1. The data in this table is presented in the more familiar heat content units, rather than the quality adjusted 'crude oil equivalents'.

Overall, as can be ascertained from Table 8.2, the delivered energy consumption increases by 14.78% over the 20 year period. Natural Gas consumption (56.62%) increased most significantly, although electricity consumption (22.05%) also increased and indeed more so than any of the other optimisations. This is because electricity in the 'Realisable Greenhouse Gases Reductions' case only generated from sources with *no* (hydro, wind) or *very low levels* (geothermal) *of greenhouse gas emissions* – which is only logical given that minimising the aggregate level greenhouse gases was the objective function for the 'Realisable Greenhouse Gas Reductions' optimisation. Over the 20 year period, petrol (-13.98%) was the only delivered energy type to decline due, primarily to the switching to ethanol and methanol for transport fuels.

Table 8.1 Delivered Energy Consumption (PJ, Heat Units) for the Greenhouse Gas Reductions Potential

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	541.70	141.77	107.79	111.73	17.58	44.39	7.74	8.35	48.29	30.43	22.57	0.97	0.10
2009	545.91	144.34	107.32	112.37	17.82	44.36	7.82	8.70	50.76	26.83	23.44	1.94	0.20
2010	551.36	151.27	106.84	113.49	18.07	45.00	7.73	8.40	48.16	24.88	24.30	2.92	0.29
2011	559.01	154.79	106.25	115.21	18.32	45.78	7.85	8.60	49.39	23.53	25.00	3.89	0.39
2012	567.55	161.03	105.31	116.74	18.55	45.83	7.93	8.78	50.68	22.34	25.00	4.86	0.49
2013	570.96	161.39	105.16	118.25	18.78	46.06	8.02	8.16	51.72	21.99	25.00	5.83	0.59
2014	576.04	163.01	104.91	119.34	19.00	46.40	8.12	7.96	52.94	21.87	25.00	6.80	0.69
2015	582.50	165.72	104.73	120.50	19.23	46.76	8.22	7.78	54.14	21.85	25.00	7.78	0.79
2016	590.03	168.73	104.62	121.64	19.47	47.14	8.32	7.89	55.66	21.92	25.00	8.75	0.88
2017	597.41	171.70	104.46	122.61	19.70	47.48	8.42	7.98	57.27	22.08	25.00	9.72	0.98
2018	604.34	174.43	104.28	123.64	19.93	47.84	8.53	7.85	58.75	22.31	25.00	10.69	1.08
2019	611.35	177.05	104.07	124.71	20.17	48.23	8.65	7.73	60.29	22.61	25.00	11.66	1.18
2020	616.70	178.10	103.83	125.86	20.40	48.67	8.77	7.24	61.93	22.98	25.00	12.64	1.28
2021	622.32	178.46	103.57	127.11	20.64	49.31	8.89	6.70	64.22	23.43	25.00	13.61	1.37
2022	629.75	178.77	103.26	129.12	20.88	50.06	9.02	6.52	67.24	23.82	25.00	14.58	1.47
2023	637.74	179.19	102.93	131.33	21.12	50.82	9.16	6.61	70.18	24.28	25.00	15.55	1.57
2024	645.55	179.60	102.23	133.56	21.36	51.60	9.31	6.74	73.14	24.81	25.00	16.52	1.67
2025	653.10	180.00	100.99	135.80	21.60	52.40	9.46	6.88	76.29	25.43	25.00	17.50	1.77
2026	660.75	180.40	99.74	138.06	21.85	53.22	9.55	7.01	79.47	26.12	25.00	18.47	1.87
Growth Rate	**14.78%**	**22.05%**	**-13.98%**	**17.33%**	**21.76%**	**16.85%**	**15.47%**	**-18.57%**	**56.62%**	**-35.57%**	**10.78%**	**n.a.**	**n.a.**
Average Growth Rate	**0.73%**	**1.05%**	**-0.79%**	**0.84%**	**1.04%**	**0.82%**	**0.76%**	**-1.08%**	**2.39%**	**-2.29%**	**0.54%**	**n.a.**	**n.a.**

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even though this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

Full details of the primary energy supply processes are contained in Appendix E.4. By 2025/26, hydro (64.38%) continued to be the main source of electricity, supplemented by wind (21.57%) and geothermal (13.97%). For transport fuel, by 2025/26, there were very significant increases in the use of biomass feedstock to produce quite a wide variety of transport fuels. However, by 2025/26, 57.33% of the land transport was still powered by crude oil derived fuels, while the remainder (42.67%) from biomass fuels. That is, by 2025/26, 62.26PJ/yr of diesel was manufactured from forest biomass sources, 30.00 PJ/yr of ethanol from forage, 18.47 PJ/yr of ethanol from fodder beat and 1.87 PJ/yr of methanol from radiata pine. Incidentally, it should be noted in this optimisation, no CO_2e credit is given for actually growing these biomass feedstocks. If this 'credit' was given, as many do argue, then these biomass energy vectors would increase to even higher levels in the optimisation.

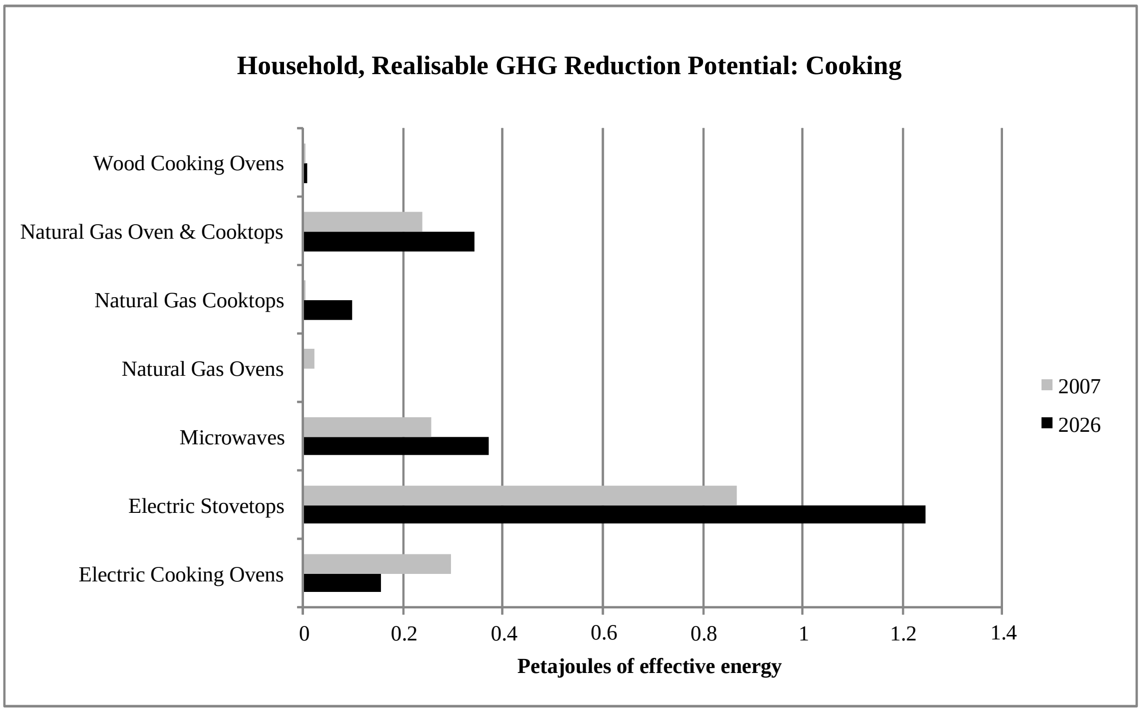
8.3 Detailed Sector-by-Sector Results

8.3.1 Household Sector

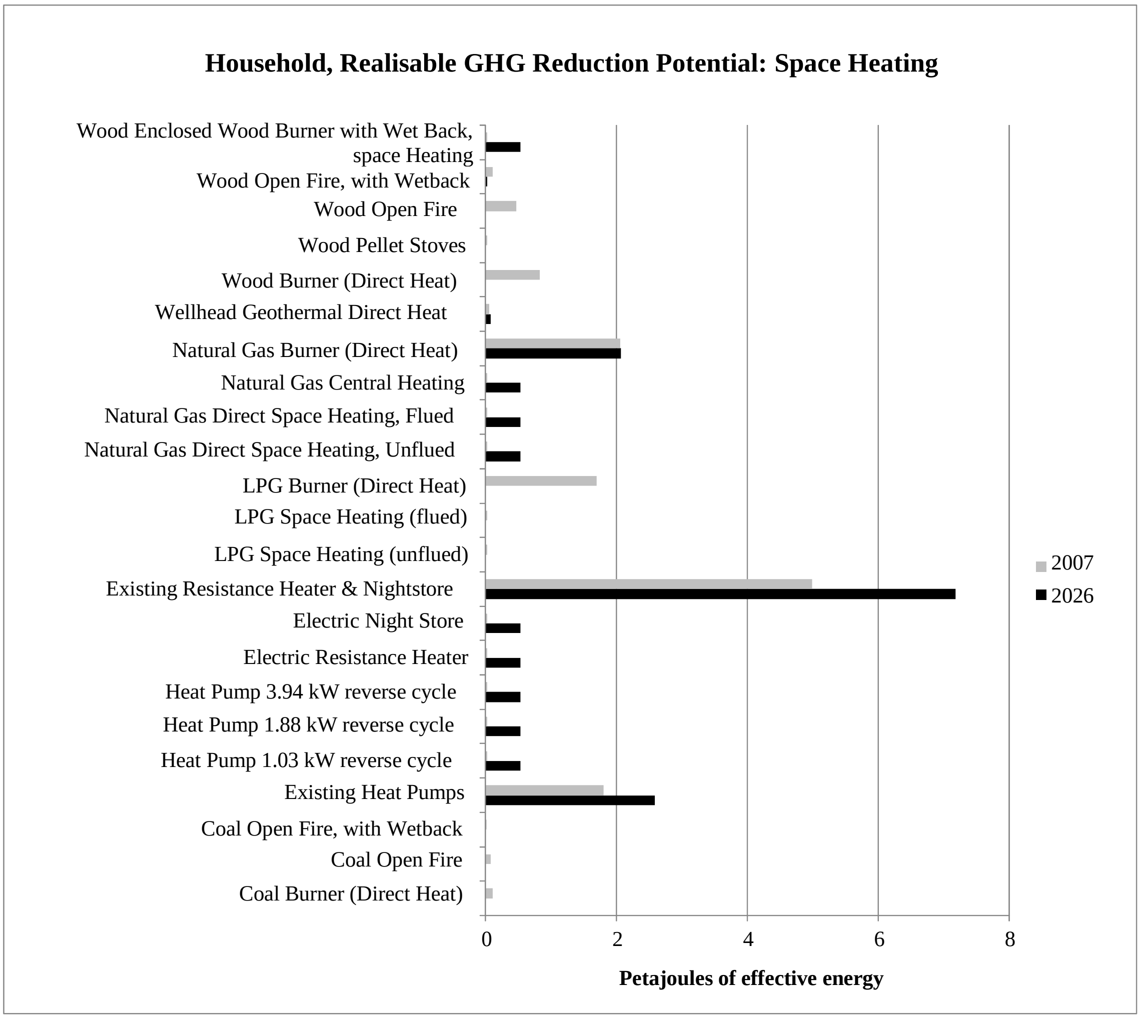
Full details of the supply of energy end-use services for each year of the 'GHG reductions optimisation' are contained in Appendix D.4. Similarly, full details of the 'energy savings measures' for this optimisation are contained in Appendix E.4.

The main shifts in the 'energy end-use supply processes' for the household sector were:

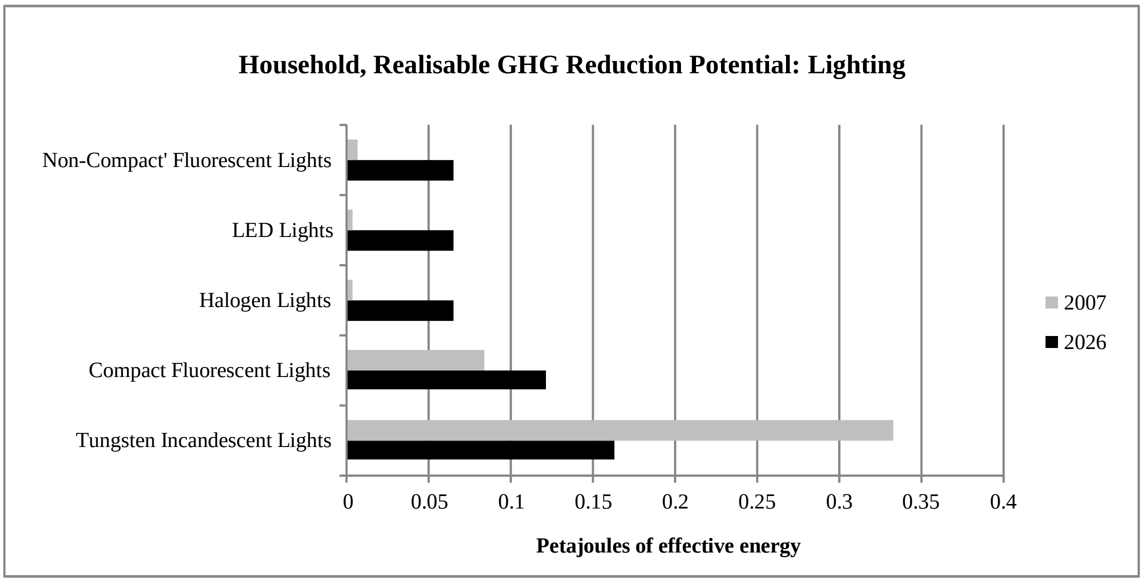
- *Cooking.* Compared with the other optimisations there were no significant shifts in the fuel mixes and technologies required to provide cooking end-use energy. The most significant shift was the decrease in the use of electric ovens 17.5% (of end-use energy) in 2006/07, to 7.0% in 2025/26. This was matched with a smaller shift to microwave ovens and electric stovetops. Overall, the use of gas ovens and cooktops increased slightly from 15.8% in 2006/07 to 19.8% in 2025/26.



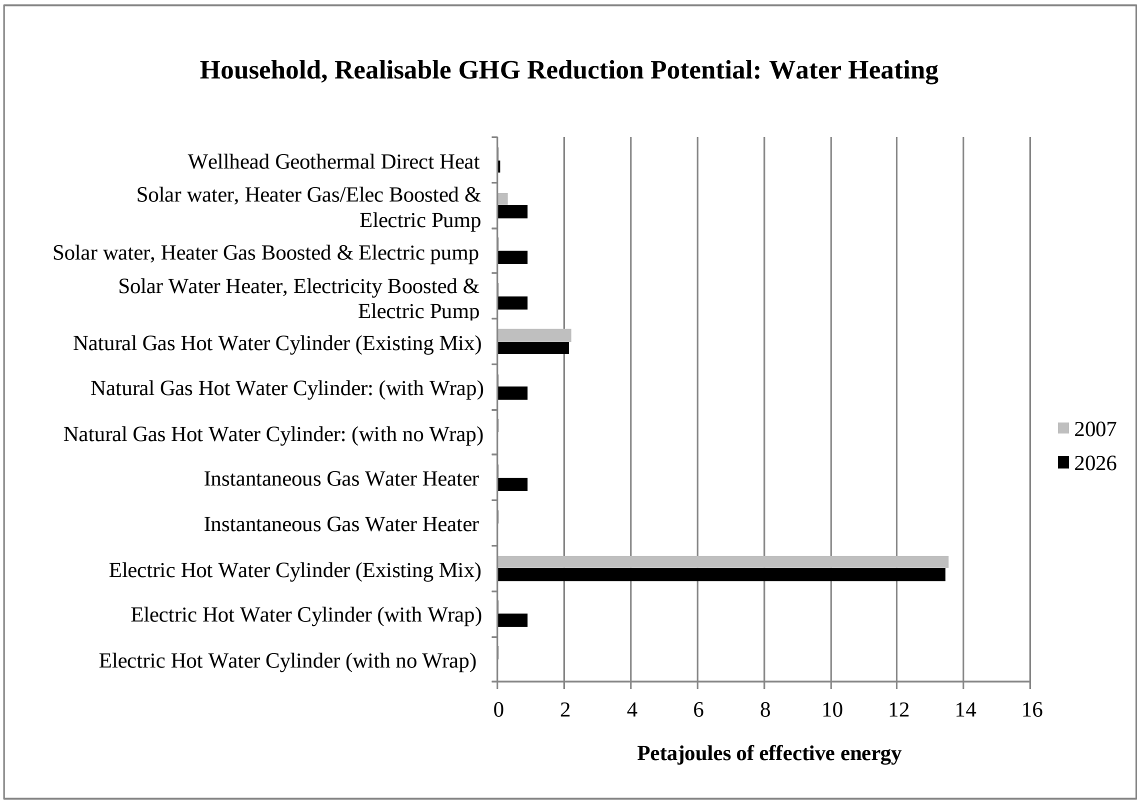
- *Space Heating.* Over the 2006/07 to 2025/26 there was a complete elimination of open fires, except for a very small amount of wood open fires with wetbacks (0.2%). LPG, coal and wood burners were also phased out over this period. Most of the space heat by 2025/26 was provided from electric sources. Heat pump space heat had increased from 14.95% in 2006/07 to 25.0% in 2025/26. Resistance heaters (including night stores) had increased from 40.2% in 2006/07 to 49.3% of the space heat provision in 2025/26. There was also a small increase in the use of space heating technologies up from 17.1% in 2006/07 to 21.9% in 2025/26.



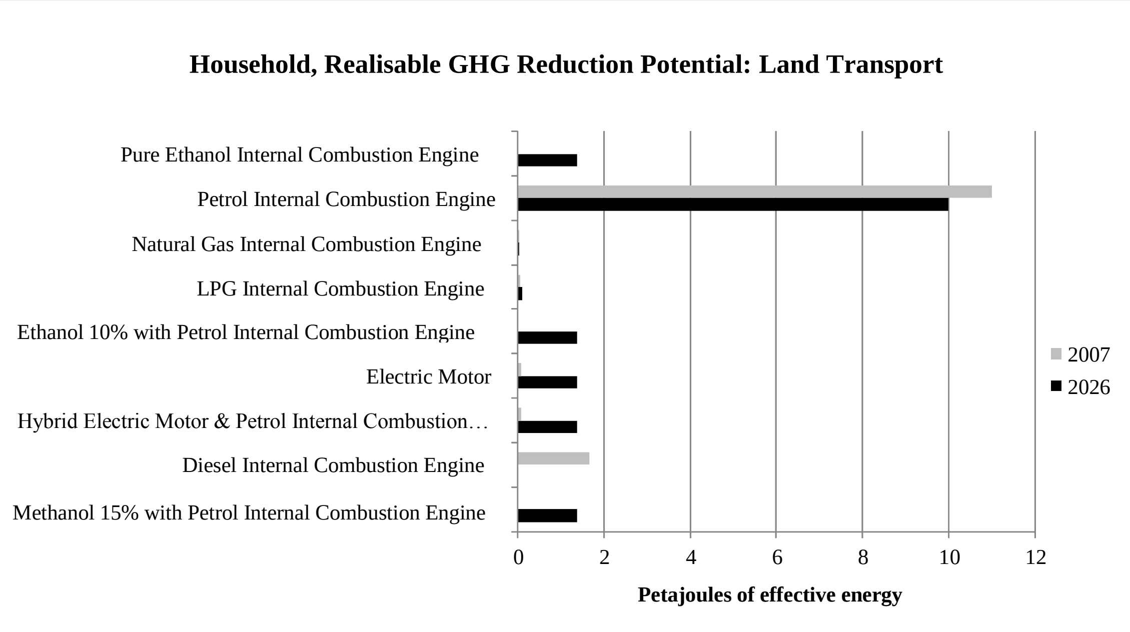
- *Lighting.* Exactly the same mix of lighting technologies applied as for the 'realisable energy savings' optimisation. Incandescent lighting provided 34.1% of the lighting by 2025/26, down from 77.4% in 2006/07. Compact fluorescent lighting provided 25.3% of lighting in 2025/26, increasing from 19.5% in 2006/07. The remainder of the lighting in 2025/26 was provided by long tube fluorescent (13.5%) and LED lights (13.5%).



- *Hot Water Provision.* Hot water cylinders still remained the main source of hot water, although this decreased from 82.1% in 2006/07 to 63.9% in 2025/26. This was made up for by increases in both natural gas to 18.6% and solar heaters to 12.8%.



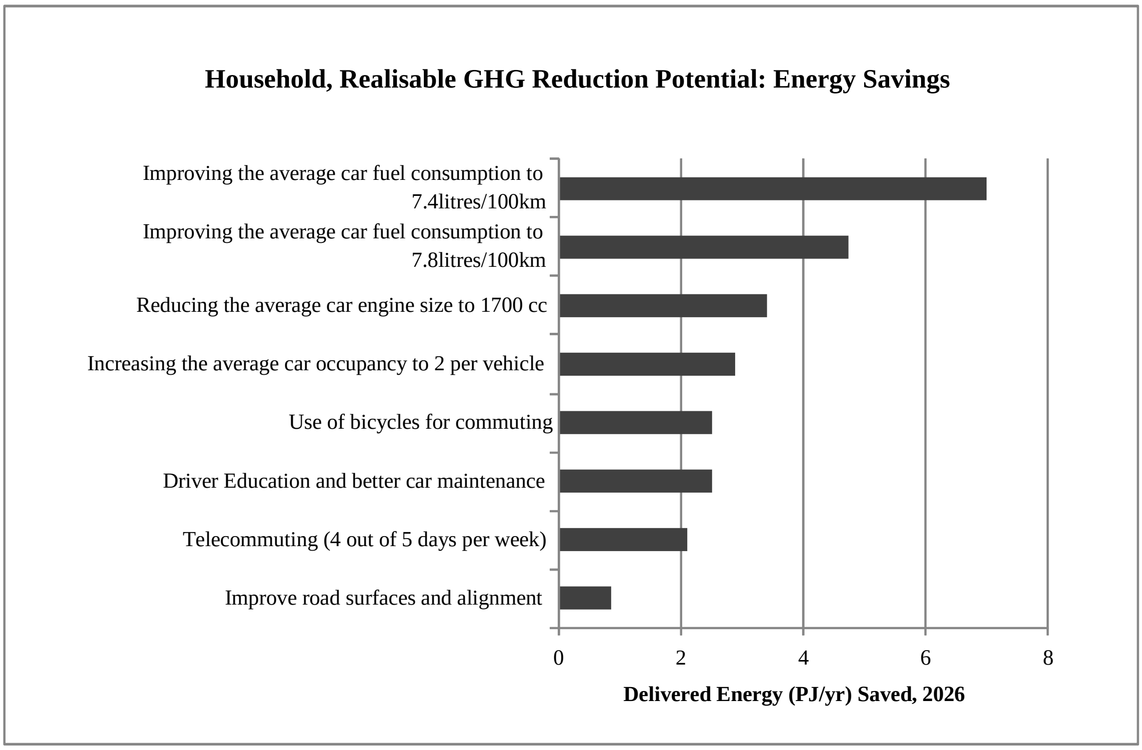
- *Car (transport).* Petrol fuelled cars decreased from 85.4% of the market share in 2006/07 to 58.8% in 2025/26. Diesel cars were phased out by 2024. To make up for these shortfalls there were increases in alcohol fuelled cars (ethanol, methanol, plus blends) to 24.4% of the market share in 2025/26, as well as electric and hybrid electric cars to 16.2% of the market share by 2025/26.



- *Obligatory Electrical End-Uses.* Obligatory electrical end-uses (electronics and refrigeration) make up a considerable portion of household electricity uses. These increased by 33.3% over the 2006/07 to 2025/26 period.

The main implementations of 'energy savings measures' in the household sector related to transport and improved insulation.

- *Household Insulation.* Ceiling insulation, by 2025/26, increased to 91% of all households, wall insulation to 86.3%, floor insulation (or concrete pads) to 79.5% and double glazing to 77.3%. There was also a considerable increase due to the 'rebound effect' of better insulation, which led to improved heating levels in homes.
- *Improving the average car fuel consumption to 7.8litres/100km*, was assessed to save 4.74 PJ/yr in 2025/26.
- *Improving the average car fuel consumption even further to 7.4litres/100km*, was assessed to save 7.0 PJ/yr in 2025/26.
- *Reducing the average car engine size to 1700 cc* was assessed to save 3.4 PJ/yr in 2025/26.
- *Increasing the average car occupancy to 2 per vehicle*, by car pooling and other action, was assessed to save 2.9 PJ/yr in 2025/26.
- *Driver Education practices to ensure more efficient driving practices and better car maintenance* was assessed to save 2.5 PJ/yr in 2025/26.
- *Use of bicycles for commuting* was assessed to save 2.5 PJ/yr in 2025/26.
- *Telecommuting (4 out of 5 days per week)* was assessed to save 2.1 PJ/yr in 2025/26.

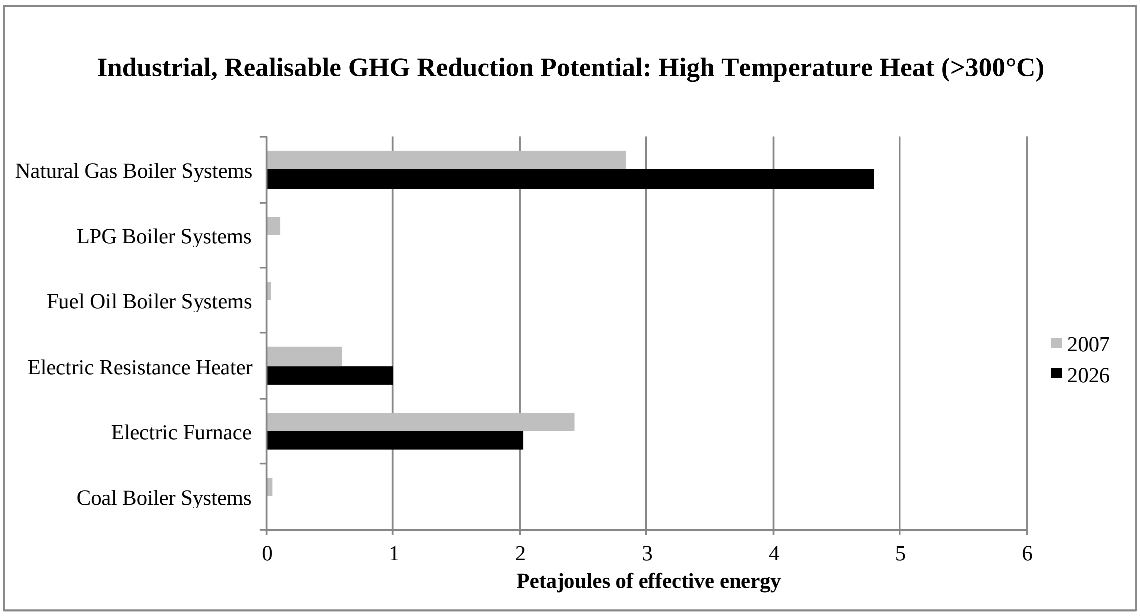


8.3.2 Industrial Sector

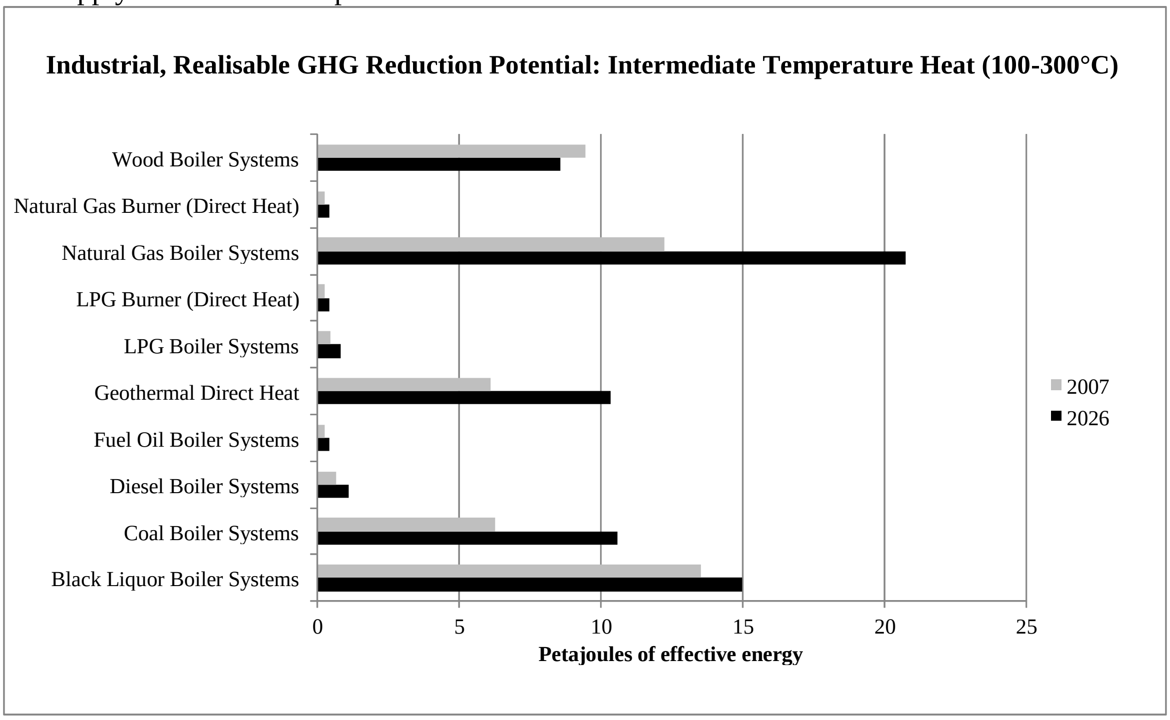
Full details of the supply of end-uses for the industrial sector for the 'greenhouse gas reductions' optimisation are contained in Appendix F.4. Similarly, full details of the 'energy savings measures' for the 'greenhouse gas reductions' optimisation are contained in Appendix G.4.

The main shifts in the 'energy end-use supply' processes for the industrial sector are:

- *High Temperature (>300˚C).* Natural gas became the largest provider of high temperature heat increasing from 46.8% in 2006/07 to 61.2% in 2025/26. Electric furnaces at the end of the 20 year period provided 25.9% of the heat in this category, with other electrical sources providing 12.8%.

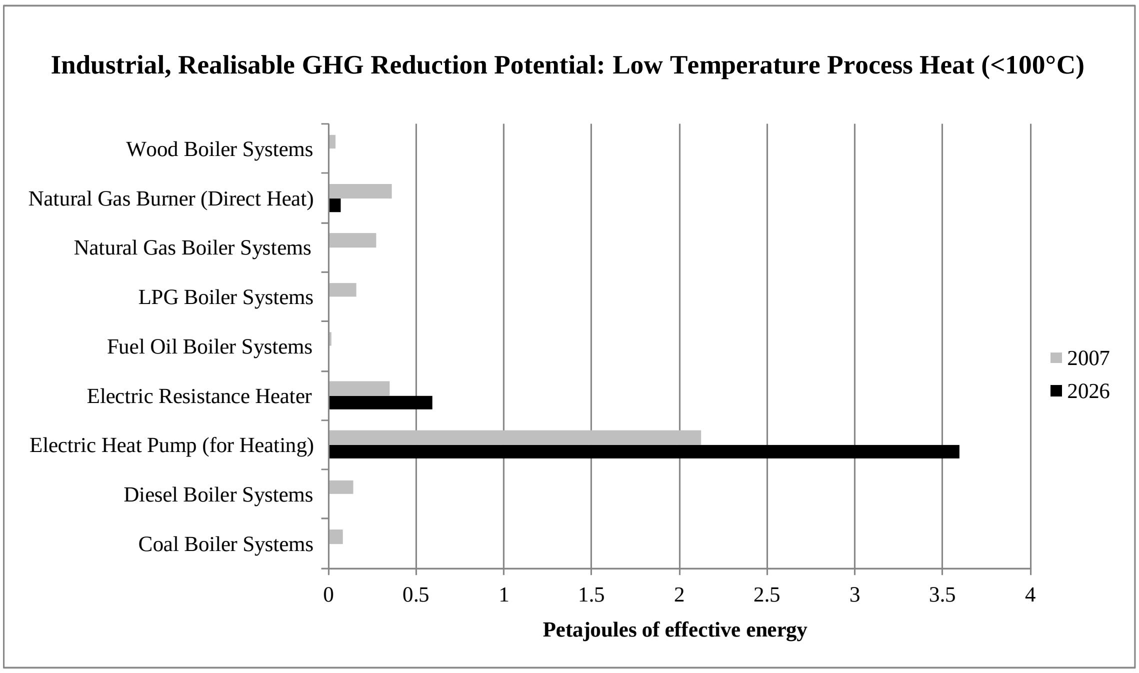


- *Intermediate Temperature Heat (100-300˚C).*The mix of fuels and technologies providing intermediate temperature heat remained relatively unchanged. The use of natural gas primarily provided by boiler systems increased from 25.2% in 2005/06 to 30.9% in 2025/26. Over the same period geothermal sources also increased from 12.4% to 15.1%, as did coal boiler systems from 12.7% to 15.5%. These increases were counterbalanced by a decrease in black liquor from 27.3% to 21.9% and wood from 19.1% to 12.5%. By 2025/26 there were also small amounts of diesel (1.6%), fuel oil (0.63%) and LPG (1.84%) used to supply intermediate temperature heat.



- *Kiln/Furnace (100-300˚C).* Natural gas consolidated as the main source of this category of heat, increasing from 66.0% in 2006/07 to 95.7% in 2025/26. By 2025/26, coal provided the remainder of the heat (100-300˚C) for kilns/furnace.

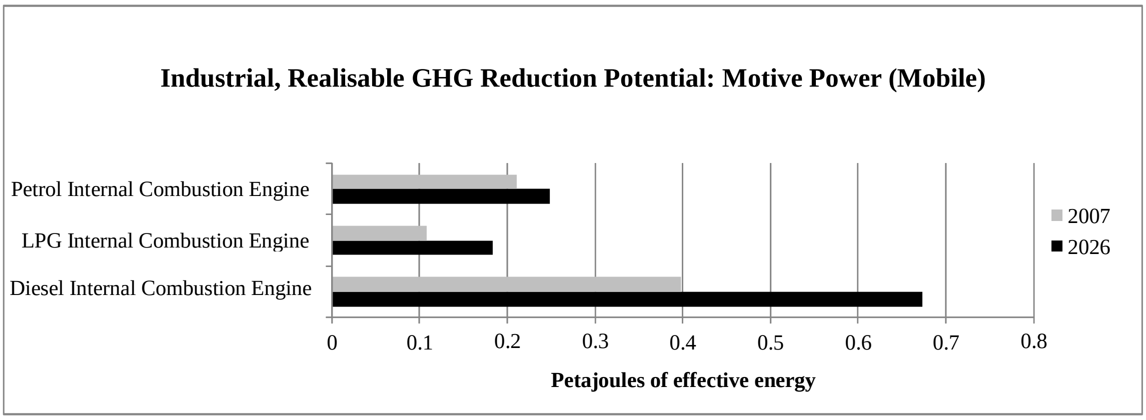
- *Low Process Temperature (<100˚C).* Due to their low GHG emissions, electric sources[88] completely dominated this end-use category, with only a small amount of natural gas. By 2025/26, heat pumps supplied 84.3% of the low temperature heat in the industrial sector.



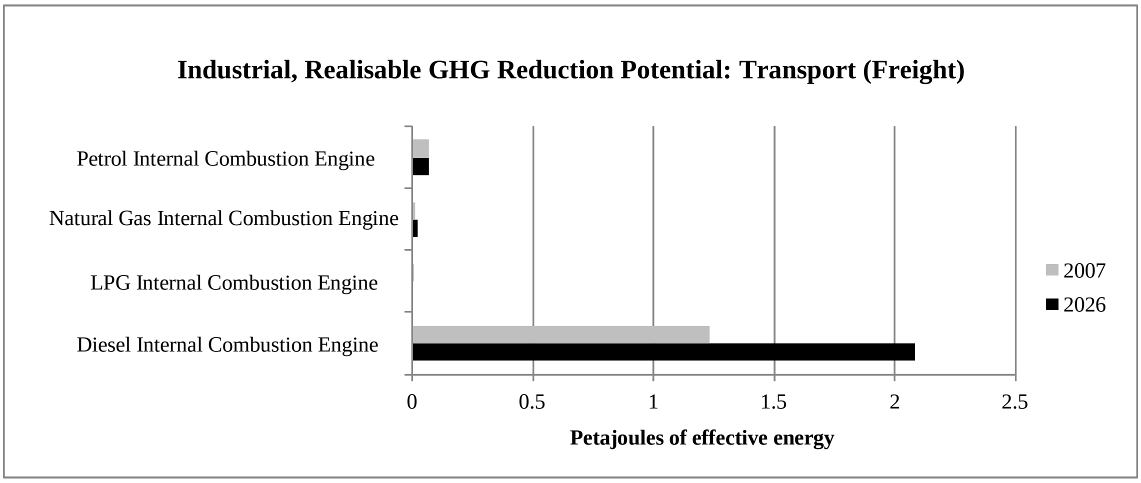
- *Obligatory Electricity.* Much (31.4% at the base year) of the energy consumed in this category is required for so called 'obligatory electricity.' This is electricity required for refrigeration, pumping, electrical and electronic control equipment and lighting. Electricity use decreased slightly over the 20 year study period, due to substitution of the use of electricity for heating by other sources, and due to the application of some of the energy savings measures outlined below. Consequently by 2025/26 electricity usage in the industrial sector had decreased from 53.7 PJ in 2006/07 to 47.8 PJ in 2025/26.

- *Motive Power (Mobile).* This category includes all non-road vehicles (eg forklifts) by industry. By 2025/26 diesel provided 60.9% of the motive power in this category, followed by petrol (22.5%) and LPG (16.6%).

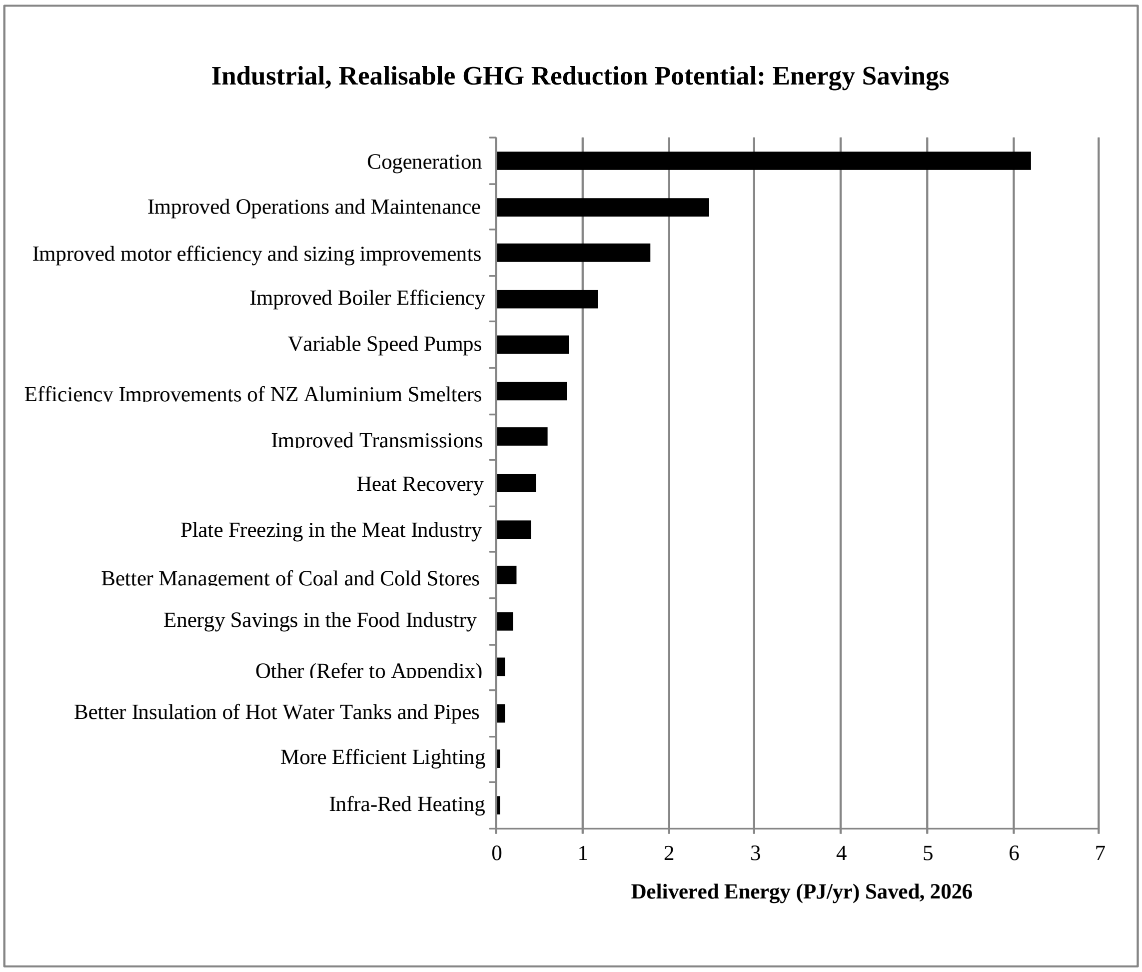
88 In this optimisation, by 2025/26 electricity was supplied by sources that had very low GHG emissions: hydro (126 PJ/yr), geothermal (27.4 PJ/yr) and wind (42.3 PJ/yr). In other optimisations electricity could be supplied from sources that have higher GHG emissions (e.g. coal and natural gas) which under-lines the importance of considering the entire production chain (from primary to end-use energy) in these optimisations.



- *Transport (Freight).* This category refers to freight vehicles run by industrial companies rather than sub-contracted to commercial freight operators. There was little change in the fuels used in the industrial sector with diesel still dominating at 95.6%. There were smaller amounts of petrol (3.3%) and natural gas (1.1%).



- *Transport (Cars).* This is a minor category of end-use in the industrial sector. Petrol use dropped very significantly over the 20 year period from 64.1% in 2006/07 to 25.1% in 2025/26. Diesel cars were completely phased out. These declines were made up by increases in the use of electric, hybrid-electric, alcohol fuels, LPG and natural gas fuelled cars.



The 'energy savings measures' for the industrial sector for the 'greenhouse gas emissions' optimisation were:

- *Cogeneration:* Additional co-generation (of heat and electricity) was assessed by OPENZ to save 6.2 PJ/yr of energy by 2025/26, as a more efficient option for generating process heat and electricity. More specifically, 2.4 PJ/yr of process heat would be produced by cogeneration and 2.5 PJ of electricity.
- *Improved motor efficiency and sizing improvements* would generally increase over the 20 year period, saving 0.59 PJ/yr of electricity by 2015 and increasing to a saving of 1.79 PJ/yr by 2025/26.
- *Variable Speed Pumps* (e.g. for freezers and chillers), would achieve significant savings, estimated to be 0.85 PJ/yr by 2025/26.
- *Improved Boiler Efficiency.* Boiler systems are the main consumer of energy in the industrial sector. It is assessed that improved operation of boilers saved 1.18 PJ/yr by 2025/26.
- *Improved Operations and Maintenance.* This includes better day-to-day attention to energy efficiency ('housekeeping'), better process control and management. This is assessed to lead to energy savings of 2.48 PJ/yr by 2025. Specifically this includes: 0.66 PJ/yr of electricity (Ind. 91), 0.65 PJ/yr of wood (Ind. 137), 0.43 PJ of natural gas (Ind. 113),

0.39 PJ/yr of coal (Ind. 133), 0.28 PJ/yr of oil products, and 0.07 PJ/yr of geothermal (Ind. 138).

- *Efficiency Improvements of NZ Aluminium Smelters.* NZ Aluminium Smelters have made consistent improvements in their energy efficiency (in terms of TJ/tonne of product). These efficiency improvements are assessed to lead to energy savings of 0.82 PJ/yr in 2025/26.
- *Improved Transmissions (*e.g. cogged V-belts). The greater application of improved means of mechanical transmissions in factories were assessed to save 0.59 PJ/yr of electricity by 2025/26.
- *Plate Freezing in the Meat Industry.* This was assessed to provide savings of 0.40 PJ/yr by a more energy efficient means of freezing meat (which in this optimisation lead to reduced GHG emissions).
- *Better Management of Coal and Cold Stores,* including better wall, floor and ceiling insulation. This was assessed to save 0.23 PJ/yr by 2025/26, under the GHG savings optimisation.
- *Infra-Red Heating.* There is seen to be a small yet significant potential in the metal fabrication, printing and apparel industries, for reducing energy use (and GHG emissions) by infra heating. This was assessed to save 0.05 PJ/yr by 2025/26.
- *Energy Savings in the Food Industry.* It is assessed under the GHG reductions optimisation, that by 2025/26 with the use of the 'Cool Chain Concept' in the Food Industry (Ind. 81) and Mechanical Vapour Recompression (Ind. 109), that energy savings of 0.20 PJ/yr would be achieved.
- *Heat Recovery.* Under the GHG reductions optimisation several opportunities for recovering heat in the industrial sector are realised (Ind. 127, 116, 128, 105, 134, 110. Ind. 115, 95.) In total by 2025/26, these heat recovery mechanisms add up to 0.47 PJ/yr.
- *Better Insulation of Hot Water Tanks and Pipes.* These interventions (Ind. 130, Ind. 111, Ind. 96.) were estimated to save by 2025/26 0.10 PJ/yr, under the GHG reductions optimisation.
- *Lighting.* Some relatively small savings were achievable from the upgrading of fluorescents and upgrading of gas discharge lamps. By 2025/26, this was estimated to save 0.05 PJ/yr.
- *Miscellaneous* energy savings measures were collectively estimated to save 0.10 PJ/yr by 2025/26. These included: distributional efficiency (local heaters, pipe and cylinder insulation); improvements in the metal fabrication industry; adoption of instantaneous water heating: and improved operation of electronic equipment.

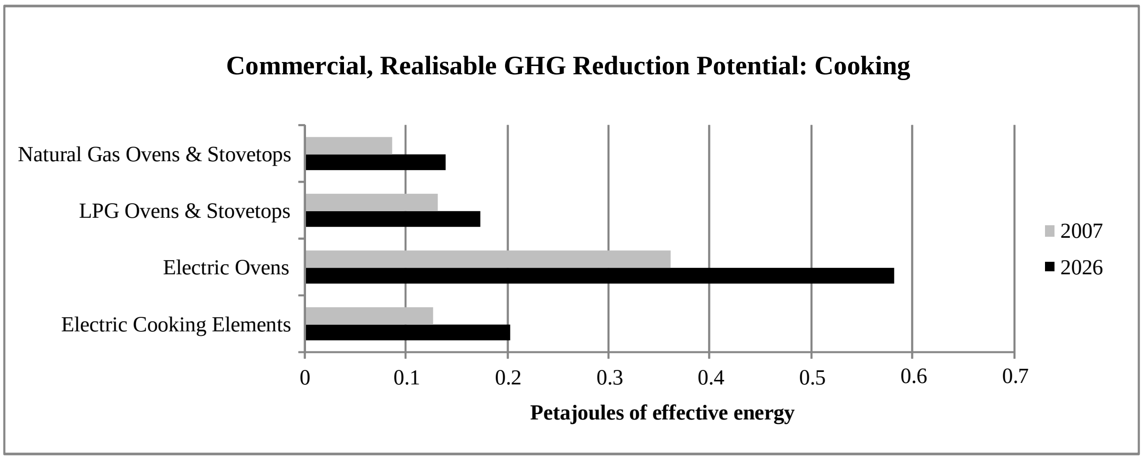
In total, under the GHG reductions optimisation by 2025/26 were estimated to be 16.4 PJ/yr in the industrial sector. This compares with 20.16 PJ/yr in the 'technical energy savings' optimisation.

8.3.3 Commercial Sector

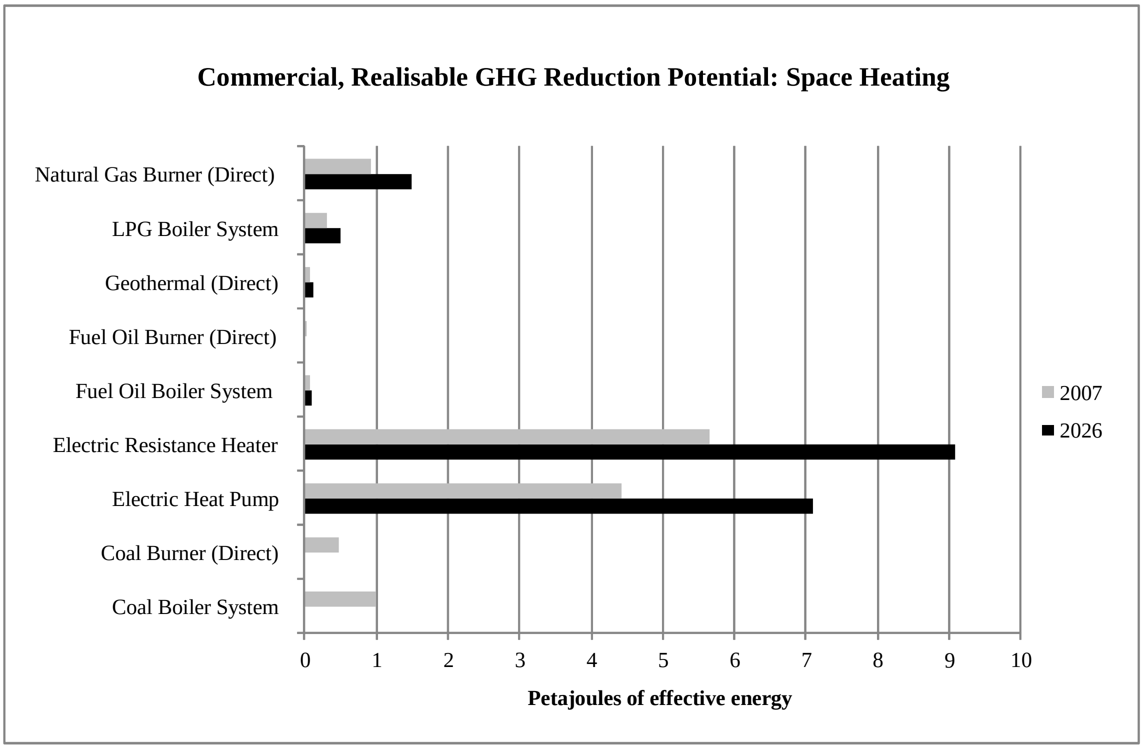
Full details of the supply of end-uses for the industrial sector for the 'greenhouse gas reductions' optimisation are contained in Appendix F.4. Similarly, full details of the 'energy savings measures' for the 'greenhouse gas reductions' optimisation are contained in Appendix G.4.

The main shifts for the commercial sector were:

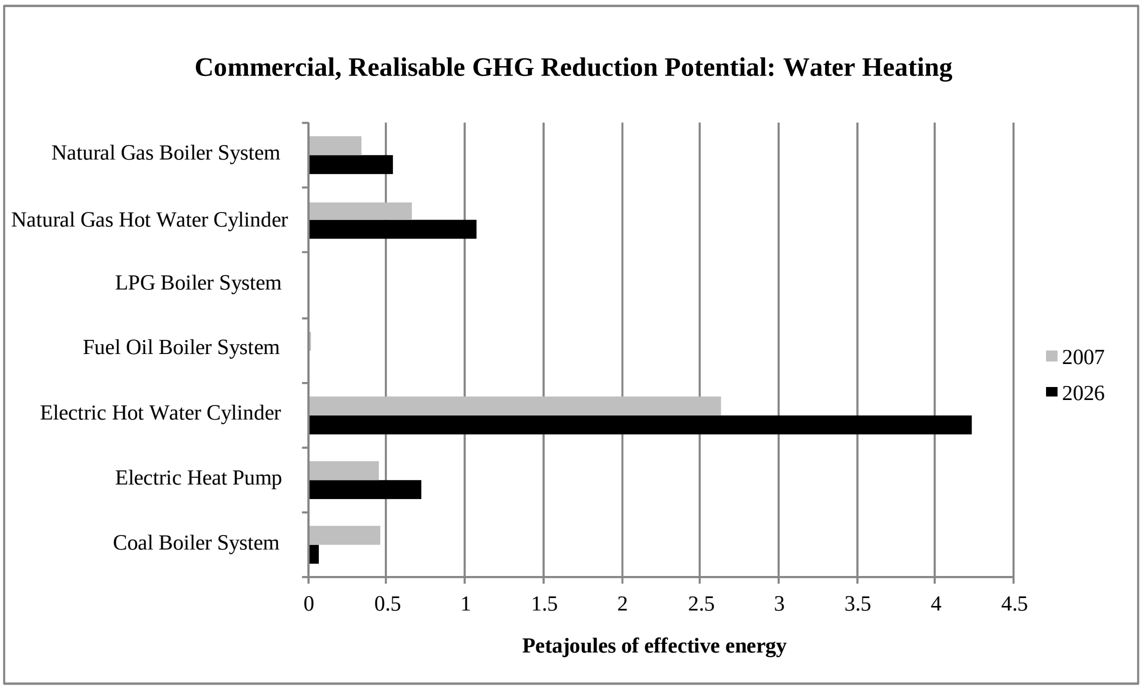
- *Cooking.* The mix of fuels used for cooking stayed relatively unchanged. At the end of the 20 year period, electric (oven and cook tops) provided 71.4% of the cooking end-use energy with the remainder being natural gas and LPG.



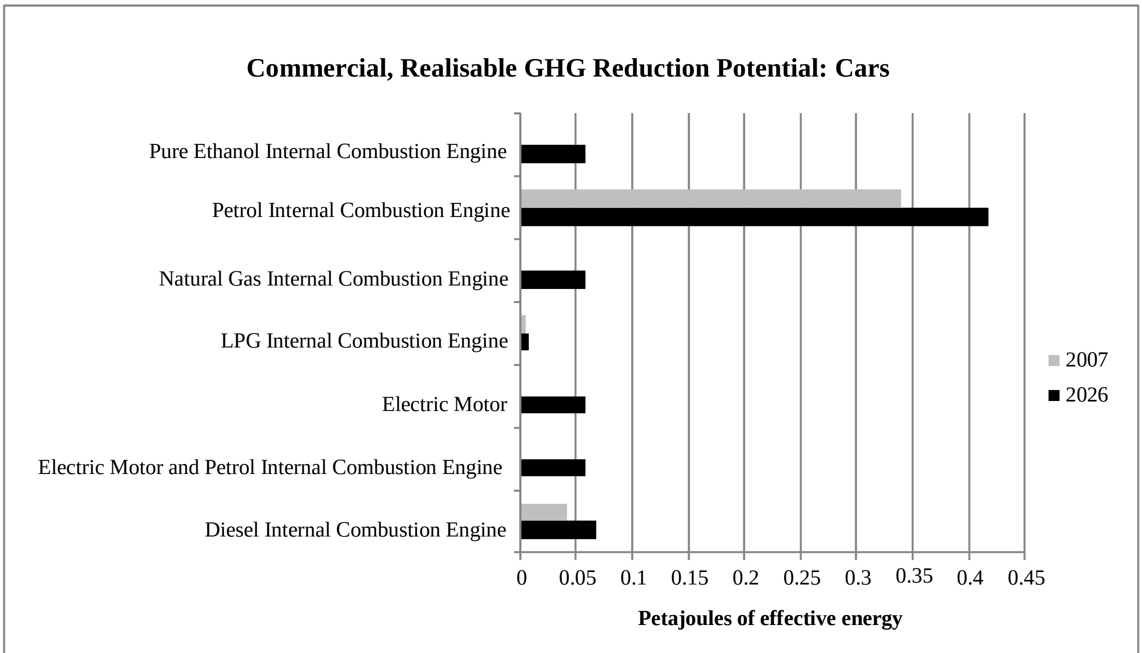
- *Space Heating.* Like cooking there was very little change in the mix of fuels used for space heat. Because electricity was supplied mainly from very low GHG emissions generated electricity, electricity continued to provide most of the space heat. By 2025/26, resistance heaters (49.3%) and heat pumps (38.6%) provided most of the space heat. Smaller amounts of space heat were provided by natural gas (8.1%), geothermal (8.1%), LPG (2.7%) and fuel oil (0.5%).



- *Water Heating.* Again, because electricity was supplied mainly from very low GHG emissions generated electricity, electricity continued to provide most of hot water in the commercial sector. By 2025/26 hot water cylinders provided 63.8% of hot water in the commercial sector and heat pumps (10.8%). Most of the remainder by 2025/26 was supplied by natural gas sources (24.2%), with also a significant amount of coal (11.1%).



- *Transport (Cars).* This is a minor category of end-use in the commercial sector. There was a significant decrease in petrol use from 87.8% in 2006/07 to 57.5% in 2025/26. The decline in petrol was mainly made up by increases in electric and hybrid electric (16.0%)

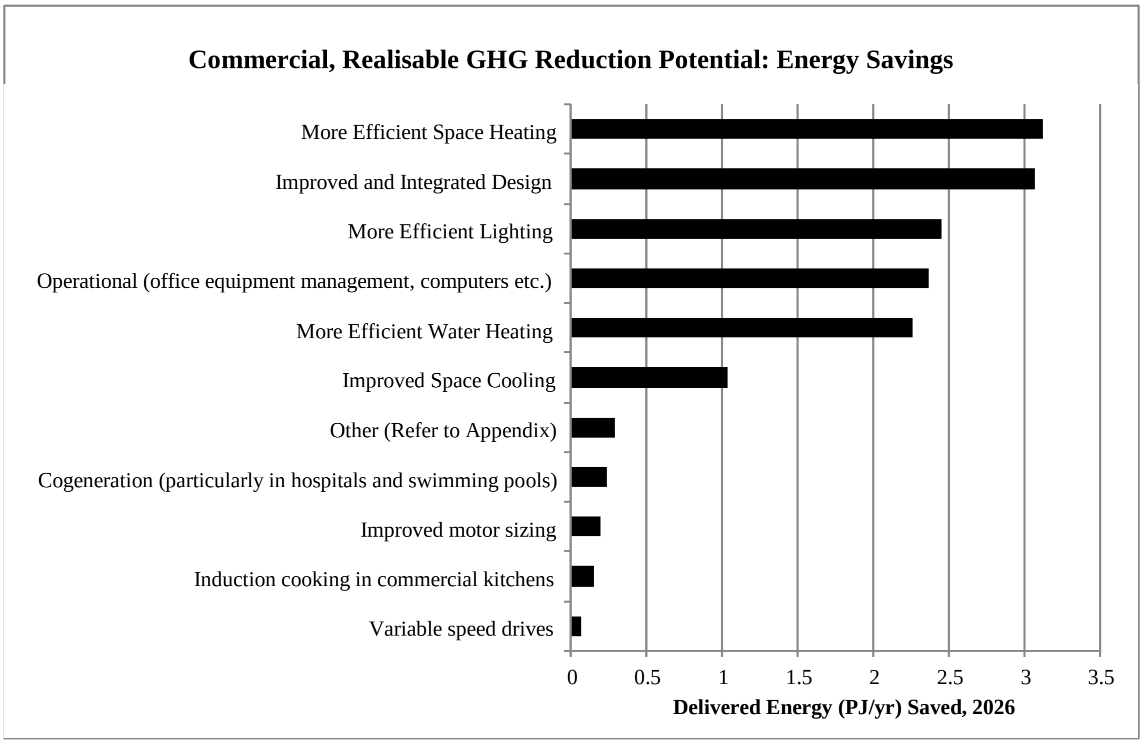


- *Transport (Freight).* This category refers to freight vehicles, run by commercial sector businesses (rather than contracted out to freight companies in the transport and storage sector). Diesel continued to completely dominate in this category with 100% of the market share.

- *Obligatory Electricity*. Much of the commercial sector's energy use and electricity load falls in this category, which includes electronic equipment, computers, as well as a significant amount of refrigeration energy which is needed in retailing (restaurant, shops, supermarkets) and wholesaling activities included in this sector. This obligatory electricity consumption nominally increased by 38% over this period. However, there was a number of 'energy savings measures' (e.g. improved purchasing of equipment) considered below that effectively reduced this nominal obligatory electricity demand.

The main 'energy savings' measures for the commercial sector for 'greenhouse gas' reduction optimisation were:

- *Operational* (office equipment management, switching equipment on/off, optimum location). As previously discussed energy use by office equipment, electronics and computers is one of the fastest growing end-use categories worldwide. The IEA (2009 b) estimates across its member countries that energy consumed by IT and consumer electronics will double by 2020 and triple by 2030. It is therefore not surprising that OPENZ identifies 1.82 PJ/yr from more efficient use of office equipment savings in GHG optimisation by 2025/26. There was also estimated to be an additional energy savings of 0.54 PJ/yr from purchasing more energy efficient office equipment.
- *Lighting*. Lighting is a major end-use in the commercial sector. OPENZ identified a number of energy savings in lighting end-use, under the GHG optimisation, by 2025/26, including: 1.05 PJ/yr by medium cost lamp upgrade (reflectors on triphosphor tubes, CFL's); 0.40 PJ/yr from design changes (task lighting, uplighting, daylighting); 0.37 PJ/yr high cost lamp upgrade (low loss ballasts, diffusers, high pressure sodium lamps); 0.27 PJ/yr from low cost lamp upgrade (38mm to 26mm); 0.16 PJ/yr from improved operations and maintenance (optimising after hours use, cleaning staff scheduling, luminaire cleaning etc.) In total under the GHG optimisation by 2025/26 2.45 PJ/yr could be saved by improving lighting practices, compared with the BAU situation.



- *Improved and Integrated Design.* Although often requiring long lead-in times, as old building stock is replaced by new building stock, as well as retrofitting options, there are significant energy savings in this category. In total under the GHG optimisation, by 2025/26 3.07 PJ/yr could be saved by improved and better integrated building design.
- *Water Heating.* OPENZ indicates that under the GHG optimisation, there are several ways of making energy savings in the improved provision of hot water. By 2025/26 it was assessed that the following savings could be made: 0.80 PJ/yr for instantaneous water heaters, 0.47 PJ/yr from condensing boilers / European design practice, 0.28 PJ/yr from better flow controls (spray nozzles, shower heads, etc), 0.23 PJ/yr from improved maintenance and operations, 0.32 PJ/yr from improved heat generation (solar, condensing boilers, cogeneration, heat recovery), 0.11 PJ/yr from improved distributional efficiency (local heaters, pipes and cylinder insulation) and 0.01 PJ/yr grey water heat exchange. In total these and other more minor savings, amounted to 2.26 PJ/yr, under the GHG optimisation.
- *Space Heating.* OPENZ under the GHG optimisation identifies a number of energy saving measures including: Com 56, Com68, Com 126, Com 87, Com 61, Com 98, Com 120, Com 64, Com 78, Com 76, Com 127, Com 138, Com 93, Com 123, Com 95, Com 100, Com 101, Com 82, Com 125, Com 131, Com 129, Com 124, Com 105, Com 139, Com 102, Com 144, Com 136, Com 137, Com 140, Com 102, Com 144, Com 136, Com 137, Com 140, Com 142, Com 132, Com 145, Com 152, Com 143. In total, the application of these energy savings methods adds up to 3.12 PJ/yr by 2025/26. This is about 56% of the energy savings that are technically viable from this end-use category.
- *Space Cooling.* Space Cooling is a significant and increasing end-use of energy consumed in commercial buildings. In total, OPENZ estimate for the GHG optimisation, that by 2025/26 the energy savings in this category will be 1.03 PJ/yr.
- *Cogeneration.* There is a relatively small amount of energy that can be saved by cogeneration of electricity and heat. This mainly applies to hospitals and swimming pools. It is estimated by 2025/26 that under the GHG optimisation of 0.23 PJ/yr of energy is saved from greater use of cogeneration in the commercial sector.
- *Other Savings.* Other significant savings by 2025/26 identified under the GHG optimisation include: 0.19 PJ/yr from improved motor sizing, 0.15 PJ/yr from induction cooking in commercial kitchens and 0.06 PJ/yr from variable speed drives.

In total, by 2025/26, OPENZ assesses that 15.21 PJ/yr of energy is saved in the commercial sector, under the GHG optimisation. This is close to 50% of the technical potential energy savings in the commercial sector.

8.3.4 Primary Sector

Full details of the supply of end-uses for the industrial sector for the ‘greenhouse gas reductions’ optimisation are contained in Appendix F.4. Similarly, full details of the ‘energy savings measures’ for the ‘greenhouse gas reductions’ optimisation are contained in Appendix G.4.

In general, compared with the other sectors, OPENZ identified significantly less opportunities for reducing energy inputs into the primary production sector. This is for two reasons: (1) the primary sector is far smaller than other sectors, accounting for only 7.36% of delivered energy use in the New Zealand economy; (2) there is fewer energy savings mechanisms identified by Henderson (1994) for the primary sector – which OPENZ relies upon[89].

The main changes in the supply of energy end-uses by OPENZ were:

- *Low Temperature Heat (<100˚C).* This is heat that is mainly required in the Protected Crop Sector. By 2025/26 coal usage had nearly halved down to 28.6% of effective heat provided. Coal replaced mainly by an increase in natural gas usage up from 42.8% in 2006/07 to 66.0% in 2025/26. The remainder of the heat in 2025/26 was provided by a small (5.4%) amount of diesel.

- *Motive Power (Mobile).* This includes farm vehicles, such as tractors and other off road vehicles. There was a slight decrease in diesel usage down to 82.1% by 2025/26. This was matched by a slight increase in petrol usage up to 17.9% by 2025/26.

- *Car Transport.* This is a minor end use category in this sector. By 2025/26 OPENZ, under the GHG optimisation, assessed petrol to provide 83.1% of this end-use category with the remainder being from electric-petrol hybrid cars.

- *Freight Transport.* Petrol was phased out by 2015, with all freight vehicles being diesel. At the beginning of the period in 2006/07 petrol had 7.9% of the market share, and diesel 92.1%. By 2025/26 only diesel vehicles were used.

The main ‘energy savings measures, from the primary sector as assessed by OPENZ were:

- *Improved Tractor Operation.* This involves implementing the ‘Tractor Facts’ driver education programme which encompasses: optimisation of traction by more appropriate tyre selection, ballasting and loading; matching tractor and implement; appropriate engine speed and gear selection and efficient use of hydraulics (Barber, 2004). OPENZ assesses that under the GHG optimisation 0.46 PJ/yr could be saved in 2025/26 by implementing this ‘Tractor Facts’ programme.
- *Improved Insulation.* This is mainly applied to greenhouses, but also to pig and poultry farms. OPENZ assessed 0.16 PJ/yr of savings by 2025/26.
- *Improved Efficiency in Kiln Drying.* OPENZ assessed 0.12 PJ/yr energy by improved efficiencies in this area by 2025/26.

As noted above there are other ‘energy savings measures’ that could be implemented in the Primary Sector. However, there is a lack of data particularly on alternative fuels (for tractors) and on improving the operation of dairy shed operations. For example, it should be possible in future versions of OPENZ, to evaluate options for water heating and milk chilling in dairy sheds.

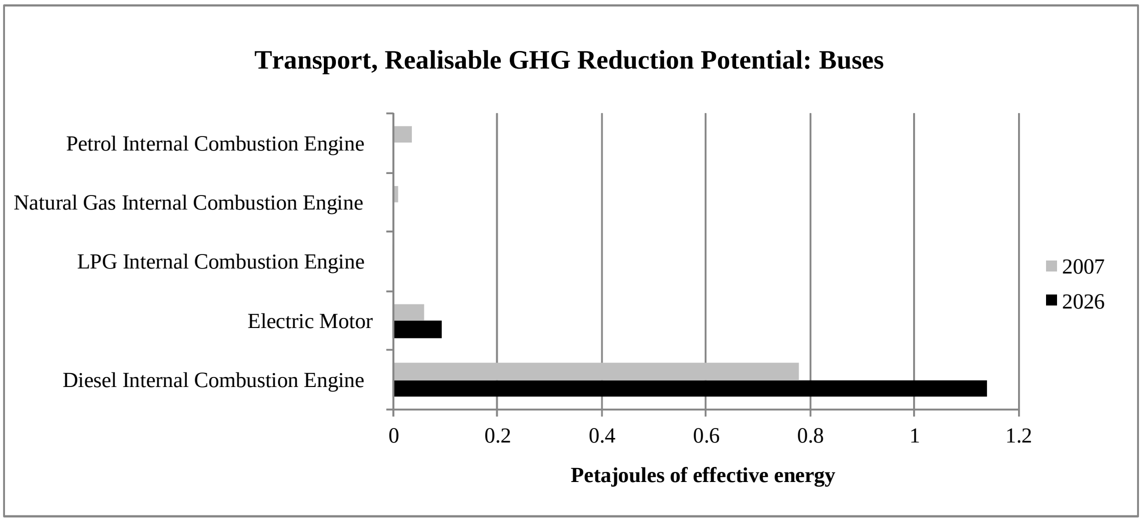
8.3.5 Transport and Storage Sector

It should be noted that transport activities are also included in all other sectors (Household, Commercial, Primary, Industry). In compliance with ANZSIC, the transport and storage sector, includes only transport (and storage) sub-contracted by these other sector businesses to transport operators.

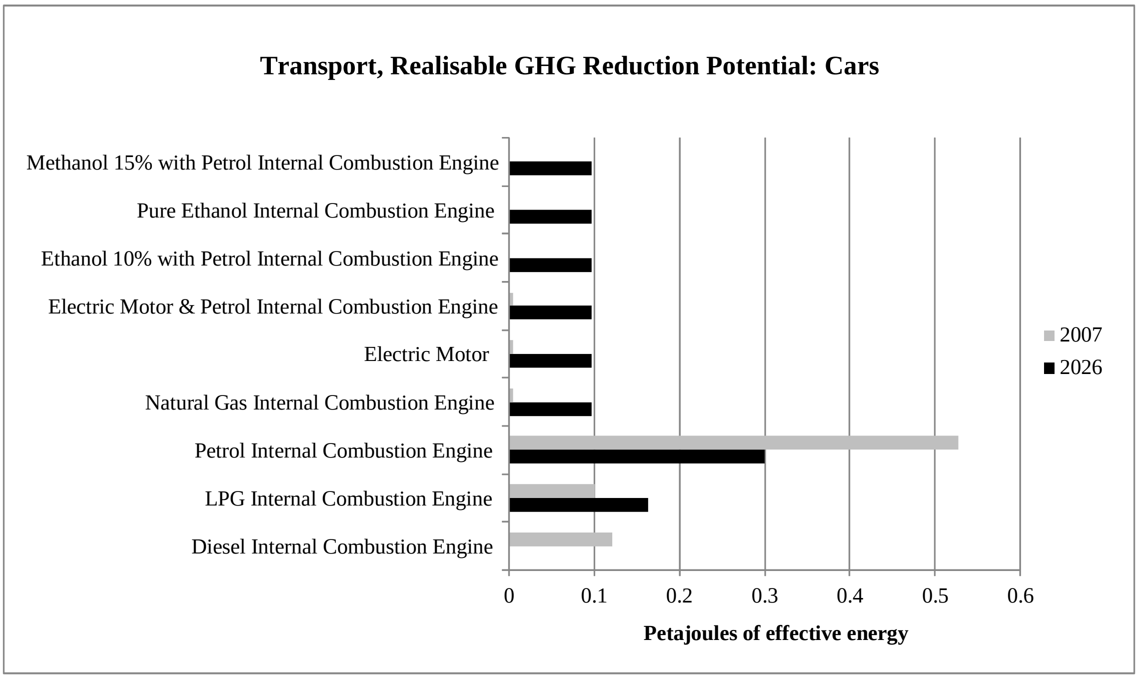
[89] There are a number of publications on energy conservation measures for the primary sector in New Zealand: Barber and Pellow (2005), Centre for Energy Research (2004), Ministry for the Environment (2007 a,b,c,d) and Morrison (2007). None of these publications however provide sufficient quantitative and economic data to adequately model the energy conservation options in OPENZ.

The main shifts in 'energy end-use' supply processes for the transport and storage sector were:

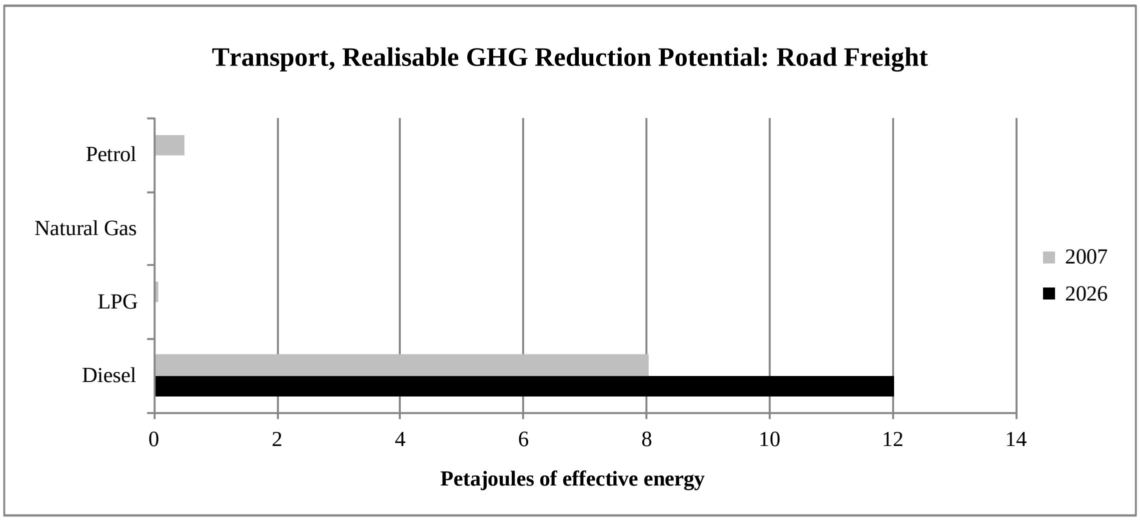
- *Buses for Land Transport, LPG, Natural Gas and Petrol powered buses* were phased out. Diesel increased its dominance from 88.3% of the market share in 2006/07 to 92.4% in 2025/26. Electricity-powered buses also slightly increased over this period from 6.6% in 2006/07 to 7.60% in 2025/26.



- *Cars for Land Transport*. This is a very small sub-section mainly consisting of taxis. Petrol and diesel usage declined over the 20 year period. By 2025/26 this end-use category consisted of petrol (28.6%), diesel (15.6%), electricity/hybrid (18.6%) and alcohol fuels (27.9%).

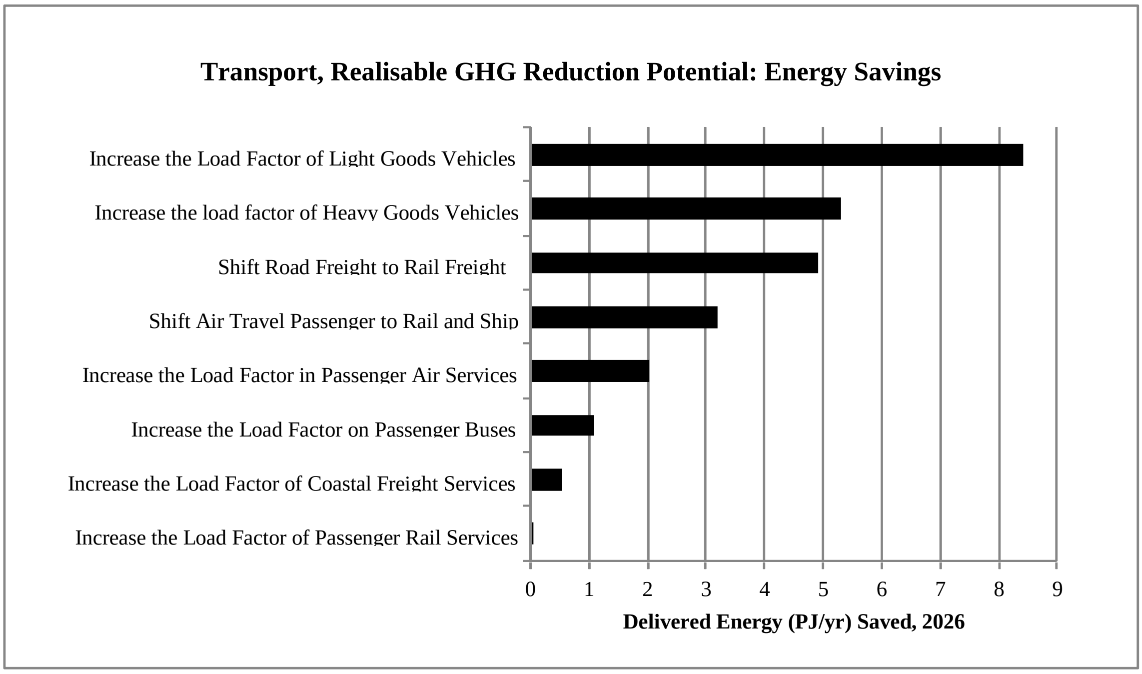


- *Freight Transport (Land).* At the beginning of the study period in 2006/07 diesel provided 93.4% of the freight transport (land), petrol (5.7%), natural gas (0.2%) and LPG (0.7%). By 2025/26, under the GHG optimisation, OPENZ determined 100% of the freight fleet to use diesel fuel.



- *Rail Freight.* In 2006/07 88.9% of this category of end-use was supplied by electricity almost entirely in the electrified portion of main trunk lines in the North Island. By 2025/26 all freight locomotives were powered by electricity.

- *Passenger Rail.* By 2025/26 most passenger rail was electric powered (97.3%), with a small amount of diesel (2.7%) in this end use category. Coal use was completely eliminated.



The main 'energy savings measures' implemented were:

- *Increase the Load Factor in Passenger Air Services by 10%.*[90] It is assessed on data updated from Henderson (1994) that increasing the load factor in passenger air travel by 10% would save 2.04 PJ/yr by 2025/26.
- *Shift Air Travel Passenger to Rail and Ship.* This only includes domestic travel, as international air travel is not included in the model. It is assessed again on data compiled by Henderson (1994) that this could save 3.20 PJ/yr by 2025/26. This would require a major upgrading of the New Zealand rail system to achieve this target, and probably a significant change in price relativities between the competing services. New Zealanders travel by rail is small between the major centres compared with other developed countries particularly those in Europe.
- *Increase the Load Factor of Passenger Rail Services by 10%.*[91] This assessed by OPENZ to be 0.06 PJ/yr by 2025/26.
- *Increase the Load Factor of Coastal Freight Services by 10%.*[92] This is assessed by OPENZ to be 0.54 PJ/yr for 2025/26 based on data originally obtained from Collins (1993) and adjusted for growth rates in OPENZ.
- *Increase the Load Factor on Passenger Buses by 10%.*[93] Load factors in New Zealand buses are low (average of about 30%). OPENZ calculates that by increasing this average load factor by 10% by 2025/26, then 1.08 PJ/yr could be saved.
- *Increase the Load Factor of Light Goods Vehicles by 10%.*[94] Improved logistics, planning and organisation, could save a very significant amount of energy, due to the large amount of end-use energy used for light goods freight. It is estimated by OPENZ, using updated Henderson (1994) data, that by 2025/26 8.43 PJ/yr could be saved which is due in part to the strong relative growth of this sector.
- *Increase the load factor of Heavy Goods Vehicles by 10%.*[95] Although the load factor of heavy goods vehicles (about 50%) is better than light goods vehicles (about 30%), there is still considerable potential for improvement. OPENZ assess that by 2025/26 5.30 PJ/yr could be saved by improving the load factor of heavy freight vehicles by another 10%.
- *Shift Road Freight to Rail Freight.* This is assessed to be 4.92 PJ/yr energy saving by 2025/26, based on data from Henderson *et al.* (1994) with growth factors for the sector applied. Again this would require a significant upgrading of the New Zealand freight rail system, and the appropriate financial incentives put in place.

If all 'energy savings' are implemented, then by 2025/26 under the GHG optimisation, 25.27 PJ/yr of energy savings in the transport and storage sector will be achieved. This is significantly more than the other sectors.

[90] It is not known for certain what the load factor for Passenger Air Services is. It is therefore assumed that there is a 10% increase, from 60% to 70% loading.
[91] It is not known for certain what the load factor for Passenger Rail Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.
[92] It is not known for certain what the load factor for Coastal Freight Services is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.
[93] It is not known for certain what the load factor for Passenger Bus Services is. It is therefore assumed that there is a 10% increase, from a 30% to 40% loading.
[94] It is not known for certain what the load factor for Light Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 20% to 30% loading.
[95] It is not known for certain what the load factor for Heavy Goods Vehicles is. It is therefore assumed that there is a 10% increase, from a 50% to 60% loading.

9. Assessment of the Data Priorities and Gaps for OPENZ

The reliability of OPENZ depends *inter alia* on the quality and availability of the data it uses. The aim of this section of the report is to assess the quality of the main sources of data used in constructing OPENZ, as well as pinpointing critical gaps in the data and priorities for updating future versions of OPENZ. The findings of this assessment are summarised by Table 9.1, with a detailed explanation provided by the text below.

9.1 Energy End-Use and Demand Data Processes

A unique feature of OPENZ is its assessment of energy demand, in terms of end-uses of energy rather than the more-often-used focus on 'delivered energy'. In adopting this approach OPENZ attempts to get closer to the 'energy end-use services' that consumers demand. The challenge, however, in this approach is the availability of data to operationalise such a model.

OPENZ classifies end-use demand in terms of 21 categories, which is a few more than the *EECA End-Use Database*. The actual specification of the end-use demand for the base year, is directly drawn from the EECA database (Patterson and McDonald, 2009) and this database is available on the internet: http://end-use.ecca.govt.nz The data for the EECA database has been compiled over the last 24 years by this author and has been regularly updated by this author, Massey University and EECA (Patterson, 1992; Soo, 1993; Toop, 2002; Patterson, McDonald and MacGregor, 2004). The original end-use data was drawn from NZERDC reports, Ministry of Energy reports (some unpublished) and over the last 18 years updated from end-use data primarily collected by EECA commissioned reports. The *EECA End-Use Database* characterises and quantifies energy conversion of delivered energy types (12) to end-use categories (18), by specified generic technologies (28).

Our assessment of the end-use energy and end-use technology data is that it is of good quality across most sectors, with perhaps the greatest uncertainty in the industrial sector. It draws on approximately over 1,000 reports (some unpublished from the former Ministry of Energy) and historical data series, which means even where there are gaps for particular sectors for particular years, there is sufficient historical data available to establish trends and make reasonable estimates of these data gaps.

In relation to the latest EECA Database update, we assess the quality of the data used in that update in Table I.1 (Appendix I). As can be ascertained from Table I.1, most data is deemed to be 'very good' or 'excellent'. Data considered to be either 'fair', 'good', or 'fair-good' included: Sectoral National Gas Data from the *Energy Datafile*, the EECA Audit Database and the Energy Use 2001/02 EECA Database.

As noted by Patterson and McDonald (2009) the quality of the transport data remains a significant issue, and if anything has probably deteriorated since the last EECA Database Update in 2004. Of particular concern is the lack of up-to-date data of delivered energy use by transport mode. The quality of the industrial data also remains an area of concern, although the *Heat Plant Survey* compiled by the Bio-Energy Association (2006) now provides very comprehensive data on boiler energy use, but unfortunately this does not extend to other industrial energy end-use processes.

Table 9.1 Assessment of the Data Sources Used in OPENZ

Data Areas	Main sources	Data Quality	Critical Gaps	Future Needs and Updating
End-Use Energy Data	EECA End Use Database.	Good in most areas and 24 year track record.	Some industrial sectors and processes. Transport mode data.	ANZSIC coding of *Heat Plant Survey*. Regular and reliable updating of End-Use Database, and continuation of underpinning surveys.
Energy End-Use Cost Economics	Many and varied. *Society of Chemical Engineers Cost Calculator* for Industrial Processes.	Very good for household sector. Fair/Good for most other sectors. Some industrial processes very uncertain.	Some industrial processes (eg, aluminium smelting), Transport and Primary Sectors.	Comprehensive and systematic coverage of all Sectors, to a significantly higher standard than OPENZ V1. Incorporate international database costings (i.e., MARKAL)
Energy Savings Options Cost Economics	Henderson (1994) adjusted for 2006/07 base year.	Average. Basis to costings not always explicit, but are well informed and are reasonable where they have been cross-checked.	Difficult to accurately measure to what extent those options proposed by Henderson (1994) have already been captured.	De novo update of Henderson (1994) particularly to capture new technologies, not featured in 1994. New costs and energy quantities need to be estimated.
Energy Supply Data	MED commissioned reports (for new supply options) and *Energy DataFile* (existing supply options).	Very Good.	Too aggregated for the evaluation of some energy policy options, but satisfactory for energy efficiency and carbon emissions policy options.	More disaggregation of existing supply processes, if the policy problem being investigated warrants it.
Energy Supply Cost Economics	MED commissioned reports, and other varied sources.	Correct 'merit order' for existing and new options, implied by the costings. However, only generic and stylised costing for existing supply processes.	Need for more detailed and realistic costings of existing supply processes.	Depends on the future policy evaluation use of OPENZ - see above.
Greenhouse Gas Emissions	NZ Energy Greenhouse Gas Emissions Inventory and IPCC (2006)	Excellent.	None.	Continued availability of existing sources.
Long-term Forecasts of 'Sectoral GDP 'and exogenous 'Energy Prices'.	Market Economics Ltd (for 37 Sector GDPs); and Donovan *et al.* (for 'exogenous' Energy Prices).	Good. Largely dependent on the validity of econometric forecasts ,which some experts question.	None.	Need to validate/compare MEL's forecasts with other more aggregative sources.

The simplest action to improve the quality of the data in *OPENZ* and the *EECA End-Use Database*, would be to ensure that the *Heat Plant Survey* data is coded in terms of ANZSIC sectoral codes. Without this crucial field of data, sometimes quite arbitrary choices need to be made in allocating energy end-use data to economic sectors, introducing quite unnecessary error.[96]

9.2. Energy End Use Economics

It is crucial in economic optimisations performed by OPENZ that there be reliable data on the economic cost of energy end-use conversion processes. That is, data is required on the capital, maintenance, operational and energy costs of each energy conversion or energy savings process considered by OPENZ.

9.2.1 Energy Conversion Processes Economics

There are approximately 460 energy-use conversion processes considered by OPENZ (Delivered Energy → End Use, via specified technologies). It was beyond the time constraints of the existing project to undertake detailed costings of these processes and the generic specification of technologies particularly in the industrial sector which made matters even more difficult. It also needs to be commented that there is a remarkable lack of published data on the cost economics of these end-use conversion processes, with published energy efficiency manuals tending to focus more on the engineering and technological aspects rather than project economics. What data is available (for example from published MARKAL databases) is most often not applicable to the EECA database structure and/or the specific of the New Zealand situation.

The most reliable cost economics were obtained for the household sector; and aspects of the industrial sector where *Heat Plant Survey Database* data could be cross-matched with costings from the *Society of Chemical Engineers Capital Cost Calculator* (Jesen and Earl, 2006).

It is therefore strongly recommended to EECA in the future updating of OPENZ, that considerable effort be put into quantifying the cost economics of end-use conversion processes. The Ministry of Economic Development puts considerable effort into commissioning and funding economic feasibility studies of energy supply options, (e.g. East Harbour Management Services, 2004, 2005). The same type of effort needs to be put into maintaining robust datasets of the cost economics of end-use conversion processes, particularly if EECA wishes to use OPENZ to justify from an economic standpoint new energy efficiency policy and implementation initiatives.

9.2.2 Energy Savings Options Economics

On the end-use side, there are many and numerous energy savings options. Some of these are captured by energy and/or technology switching which is adequately handled in terms of the end-use data fed into OPENZ from the EECA database, and the associated costings of these processes.

[96] Incidentally, although the EECA database made estimates of industrial boiler use data, prior to the *Heat Plant Survey* being available, the two sets of data produced very similar quantitative results for 2006/07 (ie. data extrapolated from the 2001/02 EECA database to 2006/07, produced very similar data to the 2006 Heat Plant Survey). In this restricted sense, the Heat Plant Survey provided a good validation of the EECA database data.

However, other energy savings mechanisms (e.g. behavioral or non-technology specific mechanism such as 'integrated building design'), cannot be adequately captured in terms of the EECA Database structure. Therefore, additional data needs to be collected on potential energy savings and costing of these mechanisms. The only comprehensive set of data available was that from Henderson's (1994) analysis *'Supply Curves of Economic Potential for Improving Energy Efficiency in New Zealand'*. Although Henderson's (1994) data could be reasonably easily updated for the 2006/07 base-year, it has three main shortcomings in terms of underpinning OPENZ:

1. It was 12-15 years out-of-date meaning that many of the costs, energy quantities and energy management mechanisms may have significantly changed. Although due care was taken to appropriately update the costings and 'energy quantities saved' in particular considerable uncertainties remain. Most critical was estimating, how much of these energy savings identified by Henderson (1994) have already been captured over the 1994 to 2006 period. Some were obvious (like reducing the speed limit to 100km/hour), but most were more difficult to estimate.
2. It is difficult to know exactly how robust many of Henderson's (1994) cost economics were, as the documentation is rather sparse and it seems that it mainly relied on interviews and feedback from sector experts, based on initial spreadsheet calculations.
3. The costings of energy saving mechanisms in Henderson (1994) are 'hard-wired' and therefore difficult to dynamically integrate into OPENZ. For example, Henderson (1994) makes assumptions about delivered energy costs, which in many cases (e.g. electricity) are endogenously determined by OPENZ. It is difficult sometimes to 'un-hardwire' these features.

Therefore, as per the energy conversion economics, it is strongly recommended to EECA in the updating of OPENZ, that considerable effort be put into: (a) defining new energy savings mechanisms that have emerged since 1994; (b) a *de novo* determination of the cost economics of these savings, aligned to potential levels of energy savings.

9.3 Energy Supply Data

Although OPENZ does not have a detailed focus on energy supply, this is a necessary and critical component of the operation of OPENZ. It is a central tenant of OPENZ, that energy policy development and implementation, cannot solely focus on either supply or demand – it must focus on both. This applies in a sense general to all energy policy issues as well as specifically to energy efficiency policy. For example, moving to so called 'more energy efficient' or 'lower carbon footprint' hybrid cars, this may not necessarily be the case – for example, if additional coal is used to produce the electricity for these hybrid cars. Such extravagant claims can only be made if the whole production chain from electricity production to end-use is taken into account, which is what OPENZ attempts to achieve.

For the purpose of OPENZ therefore the supply-side data must be robust enough to give reliable answers to questions like the hybrid car example given above. This doesn't necessarily require detailed supply-side data, but it must be reliable to generically quantify supply-side options. In this way OPENZ, characterizes and quantifies 26 existing and 40 new energy supply side processes, including secondary energy production from primary sources.

The data for these 20 existing energy supply processes, although highly aggregated, is considered to be accurate and reliable having been obtained from published sources readily available in printed form and on internet datafiles, provided by the Ministry of Economic

Development. The main source of data was the MED's *Energy Datafile*, which integrates and collates a wide range of supply-side energy data drawn from sources documented in that publication, although it is sometimes not clear how this data was reconciled, verified and checked.

9.4 Energy Supply Economics

The cost economics of *existing energy supply options* were most difficult to estimate, because of the broadness of the categories and because ultimately much of this data to some degree is commercially sensitive. Nevertheless, there is enough publically available data (e.g. Wilkinson, 2005) that enables these cost estimates to be reasonably reliable and provide the correct 'merit order' for OPENZ to select the least expensive options, when using economic criteria to drive it. Perhaps, in the future development of OPENZ, closer collaboration between EECA and MED staff could facilitate data transfer from MED sources.

One issue that could be assessed in the future development of OPENZ, is the effect of possible 'aggregation error' in OPENZ. OPENZ for example operates on the basis of a weighted mean cost of hydroelectricity generation, where there may, for example, be considerable inter-station differentials in costs. Whether aggregating all of these hydro stations together, vis-à-vis treating them separately, could be the focus of an investigation into the level of aggregation error implicated in the use of OPENZ.

The cost of *new energy supply processes* (e.g. production of transport fuels from lignite) are based primarily on cost estimation undertaken by studies commissioned by the Ministry of Economic Development (eg, East Harbour Management Services, 2005), as well as to a lesser-extent by international studies collated by agencies such as the International Energy Agency. These studies are all technology explicit, detailed and they clearly set out costing produced under varying sets of assumptions such as for discount rates. Again, it is considered that these costings for new energy supply processes provide the correct 'merit order' for OPENZ.

There is little doubt that the range and detail of both existing and new energy supply processes covered by OPENZ could be significantly increased. One avenue for doing this could be to investigate the possibility and practicality of using MARKAL databases that are used for other developed countries like New Zealand, which cover a much wider range of energy supply processes. It is however doubtful if this would need to be undertaken if OPENZ, was continue to be used for just end-use efficiency studies. It would nevertheless be a more pressing concern if OPENZ was going to be used to investigate energy policy issues that have a more supply-side emphasis – e.g. evaluating the future use of renewable sources of energy or the development of Southland lignite resources.

9.5 Greenhouse Gas Emissions

OPENZ covers the greenhouse gas emissions from energy production and end-use processes. In calculating the greenhouse gas emissions, for all these processes, emission factors from the MED's (2008) publication *'New Zealand Energy Greenhouse Gas Emissions 1990-2007'*, and from the IPCC (2006) are used.

These emissions data are 'technology specific' which was highly compatible with the way *OPENZ* and the related *Energy End Use Database* is constructed – e.g. the MED's (2008a) publication shows that N_2O and CH_4 emissions depends, to some extent, on the end-use of the delivered energy, the technology (e.g. stationery vs. mobile engines) and the sector where it is used.

Therefore, the greenhouse gas emissions data used by OPENZ is considered to be very accurate and consequently there is no need for EECA to put any extra effort into further improving the accuracy of these data.

9.6 Other Data

This discussion has focused on the core energy and economic data used in OPENZ, and has very much focused on quantifying the core processes in OPENZ. There is, however, other more general data considered by OPENZ which is discussed in Chapter 2 to do with:
1. Forecast of Future GDP of sectors.
2. National Gas Use for Methanol and Urea Production.
3. Size of Natural Gas Reserves
4. Size of Rebound Effects
5. Future Carbon Prices
6. Imported verses Indigenous Supply of Energy (Degree of Energy Self-Sufficiency)
7. Land Available for Biomass Energy Farming
8. Technology Penetration Rates
9. Discount Rates
10. Future Energy Prices, for energy sources not endogenously calculated by OPENZ
11. Policy Targets and Constraints

Some of these factors (e.g. discount rates, policy targets) although they are quantifiable and that sense are ‘data’, they fundamentally are determined by commercial and policy assumptions selected and specified by the OPENZ User. Therefore, we will not consider this data further in this report, other than what is already commented upon in Chapter 2. In addition, most of these type of data are collected, investigated and researched by other agencies, the universities and the CRIs; and are not directly in EECA’s domain of control or interest. Perhaps EECA could however make some recommendations to the Ministry of Science and Innovation (MSI) concerning research priorities in these areas – eg, there is a dearth of good information about technology penetration rates and the behavioural, innovation and market dynamics that underpin such rates. This may well be an potential area of research investment for the MSI, perhaps more broadly focused on the conundrum of how to facilitate the technological re-design and transformation of our historical ‘legacies’ of energy production and use. Very little is known about this issue, other than efforts such as those by Ruth and Amato (2002) and others who have investigated how we can transform from ‘old’ technological infrastructures to ‘smarter’ ‘more energy efficient’ infrastructures.

One area which is however of more practical importance to the OPENZ update is the forecasting of future GDP at the 37 sector level. The Treasury and other organisations do produce forecasts, some of which are free and publically available, but most aren’t. A particular need of OPENZ is that GDP forecasts are produced at the 37 sector level, if data in the EECA database is to be fully utilized. It is recommended that these 37 sector GDP data be obtained from Market Economics Ltd, as to our knowledge they are the only providers of this level of sectoral forecasts. It is however recommended that EECA does correlate the more detailed Market Economics Ltd forecasts with other reliable and official sources such as those from The Treasury.

Another area that EECA should focus is on obtaining robust 'forecasts' of future energy prices (for energy sources not determined endogenously by OPENZ). For these forecasts we heavily relied on Donovan *et al's* (2009) report to the Auckland Regional Council and MED's *Energy Outlook*. EECA may wish to commission Donovan *et al* (2009) to provide up-to-date price forecasts for future versions of OPENZ for those prices not covered by MED, although we don't see this as a high priority.

10. Conclusions and Future Research Directions

The development of OPENZ as a practical tool for assessing energy savings potentials in New Zealand was successful, although there are a number of ways it can be improved and extended upon into the future.

The most important empirical findings were:

- By 2025/26 it was shown that New Zealand has considerable scope to reduce its primary energy consumption. It was found that by 2025/26 it is technically possible to make energy savings of 61% compared with the Business-As-Usual baseline. This reduces to 42% energy savings when just considering 'economic' options, and 27% when further allowances are made for realistic rates of technology uptake.[97]
- By just focussing on minimising 'Greenhouse Gas Emissions', rather than on minimising 'Primary Energy Inputs', some interesting policy relevant results were obtained. That is, it was found that greenhouse gas emissions could actually decrease, over the 20 year study period, in spite of the economy expanding by 48%. Specifically, it was found that greenhouse gas emissions could drop from 38,584 kt CO_2e in 2006/07 to 35,790 kt CO_2e in 2025/26. One of the main features of this optimisation was the heavy dependence on electricity from sources that had no or very low levels of greenhouse gas emissions (hydro, wind, geothermal).

The initial runs of OPENZ revealed some other important policy relevant results. Probably most important was the finding that in order to reduce New Zealand's energy related greenhouse gases by 7.2% over the 20 year period, this would require expenditure equivalent to 1.75% of projected GDP[98]. This same scenario would reduce primary energy consumption by 1.1% over the 20 year period. In spite of producing some interesting policy-relevant results, the initial development of OPENZ has only really 'scratched the surface' of the potential of the model for evaluating energy policy issues in New Zealand. It is argued in the report that the future development of OPENZ, needs to consider other energy policy goals apart from just energy efficiency and greenhouse gas emissions. For example, its future development should include goals such as: energy self-sufficiency, resilience of the system to supply-side shocks, economic competitiveness, fair pricing and so forth. Furthermore, the future development of OPENZ, needs to simultaneously consider all of these policy goals, rather than just one policy goal. This is for the obvious reason that government policy makers and stakeholders, are unlikely to take notice of OPENZ results that single-mindedly take account of only one policy goal such as energy efficiency. Particularly, in the immediate future, OPENZ could be deployed to evaluate some specific policy questions concerning the current and proposed future 'Emissions Trading Systems'. For example, what would be the impact of increasing carbon prices, and where are critical price thresholds in terms of motivating switches to more energy efficient supply and demand technologies? Current modelling tools in New Zealand have a poor ability to answer such questions in a technology-explicit fashion.

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[97] These percentage energy savings (compared with the BAU) are calcaulted on the basis of primary energy inputs being measured in 'heat content units'. If adjusted for energy quality as advocated by this author (using transformties or quality co-efficients), then the measured energy savingsfor 2025/26 are significantly less: 55% for the 'technical energy savings potential', 30% for the 'economic energy savings potential' and 11% for the 'realisable energy savings potential'.

[98] These data are for the 'Greenhouse Gas Emission Reductions optimisation', which assumes 'realistic' levels of technology uptake that approximate historical uptake rates for new technologies.

The development of OPENZ represents one significant methodological development in terms of energy modelling in New Zealand. However, the process of developing OPENZ did reveal a number of deficiencies in current methods and data, which need to be addressed in the future development of OPENZ in other related analytical/modelling endeavours:

- OPENZ development highlighted the lack of consensus on an operational definition of terms 'energy efficiency' and 'energy savings'. Both terms only have general meanings which give insufficient guidance in terms of providing specific operational measures. Fundamentally there are issues in terms of how to commensurate energy types in terms of a common energy quality adjusted unit. Incidentally, the same type of methodological problem also occurs when commensurating (adding-up) greenhouse gas emissions, but in that case there is clear consensus on the solution to the problem.
- There are significant data deficiencies in a number of areas, although these data deficiencies are not considered critical enough to change the broad nature of the results obtained from this study (initial runs of OPENZ). Firstly, there is a serious lack of good data on current levels of cogeneration in the industrial and commercial sectors. Secondly, there was a significant reliance on using data that was updated from Henderson (1994). There is a critical need to undertake surveys and primary data collection to validate both Henderson's (1994) original data and the updated data which appears in OPENZ. Thirdly, and related to the second point, the costings of capital equipment and operating costs, for many of the options in the industrial, commercial and transport sectors needs to be improved – this doesn't apply to the household sector and industrial boiler-based activities where there is particularly good data.
- There could be better integration of OPENZ with macro-economic models. There are significant interlinkages between the energy supply and demand sectors and the rest of the economy. These interlinkages are currently largely ignored in OPENZ which means that the impact for the instance of reducing CO_2 emissions cannot be assessed in an integrated fashion – e.g. the increased investments in wind farms, will have several important flow-on (multiplier) effects through the economy in terms of increasing the activity of engineering firms, contractors, equipment suppliers and so forth. The best avenue for better integrating OPENZ with macro-economic models, is to integrate it with existing Computable General Equilibrium models which already exist in New Zealand or alternatively integrate OPENZ to a greater extent with the Economic Futures model.
- OPENZ has been developed in relative isolation from other energy models in New Zealand and overseas. A better communication and dialogue with those other energy modelling effort could be fruitful. For instance, the MARKAL model developed for many other countries has some similarities to OPENZ and utilises similar data – therefore, it may be, for example, useful to explore how the very extensive databases associated with MARKAL could be utilised to provide data where there are currently significant data deficiencies in OPENZ.
- OPENZ has the requisite data for generating supply curves of 'energy savings' and supply curves for 'reducing greenhouse gas emissions.' In the future development of OPENZ, these supply curves could routinely be produced by OPENZ, in order to provide both a comparison with other studies and to provide an easily understood way of presenting the results.
- The initial focus of OPENZ was on end-use demand, with 460 end-use 'technologies/processes' specified and 201 end-use 'energy savings' measues specified. There were however, only 76 supply side 'technologies/processes'. These 76 supply side technologies could, in the future development of OPENZ, be considered in a more disaggregated fashion, with for example explicit coverage of some of the larger individual hydro-electric plants.

- OPENZ is currently formulated on the basis that it uses known and currently commercially available technologies. This probably is a reasonable basis for a model which has a 20 year time horizon, as it is unlikely that other new technologies will play a significant role over the next 20 years. However, notwithstanding that comment, more attention in the future could be given to ‘new and emerging technologies’ such as those covered by the IEA (2008).

In sum, the development of OPENZ provides for the first time in New Zealand, a practical energy policy analysis model that has a focus on providing energy end-use services and it is fully technology-specific in all areas of supply and demand. Although this ‘bottom-up’ approach has its critics (e.g. Denne, *et. al*, 2005a) and limitations, it is hoped that at the very least this modelling approach of OPENZ will impose a ‘realism’ on the analysis, which is currently lacking in most other more macro-level model in New Zealand.

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APPENDICES

Appendix A

Energy Quality Problem

One of the main problems with operational definitions of energy efficiency in the area of macro-economic modelling is the 'energy quality problem' (Leach, 1975; Edwards, 1976; Webb and Ricketts, 1980). Without the ability to validly compare energy of different types on a common basis, energy-based macro-economic modelling is constrained its use in guiding policy decisions with respect to energy efficiency and other related matters.

Different forms of energy have different qualities or grades, which are not taken into account of enthalpic (ΔH) measurements. Enthalpic measurements (ΔH) only measure the heat content of energy forms, and do not necessarily make any distinction between low grade energy sources (such as incident solar energy) and higher grade energy sources (such as oil or natural gas). From this basis, it was consequently been argued that energy when measured in enthalpic terms (ΔH) cannot be 'added up' because it has different grades. This particular problem has variously been called the 'oranges and lemons' or aggregation problem of Energy Analysis (Leach, 1975). Finally, it has been argued that because energy measured in enthalpy (ΔH) terms, is not additive, Energy Analysis is without a numeraire, and therefore has no basis for its proposed evaluative role.

The energy quality problem is peculiar to macro-studies and does not present itself in Thermodynamics. This is because Thermodynamics is only concerned with energy transformation in simple systems, whereas macro-studies is concerned with energy transformations in complex systems (multiple inputs-multiple outputs and interdependent pathways). Any attempt to determine the efficient or optimal use of the analyst is confronted with comparing unlike (unequal quality) inputs and outputs. Whereas, in simple thermodynamic systems this problem does not arise as only straightforward energy conversions from one input to one output are being dealt with

A.1 Energy Quality Problem in this Project

The current project to estimate the 'energy savings potential' brings sharply into focus the issue of energy measurement and its appropriate commensuration in terms of energy quality.

By way of illustration, the same type of commensuration issue occurs when 'adding-up' Greenhouse Gas Emissions. Analogously it is incorrect to 'add-up' tonnes of CH_4, CO_2 and N_2O as they have different 'global warming potentials'. Here there are a number of ratios that enable the commensuration of these greenhouse gases (CH_4, CO_2, N_2O) in terms of their 'global warming potentials':

$CO_2 = 1$
$CH_4 = 21$
$N_2O = 310$

As with energy quality as measured by Patterson (1983, 1996) and Odum et al (2000), these relationships can be represented by a system of over-determined simultaneous linear equations:

$b_1 1 = b_2 21$
$b_1 1 = b_3 10$

Conventionally $b_1=1$ is the numeraire, with the solution being multiples of CO_2 equivalents. As with the energy quality determination by Patterson (1996), the choice of the numeraire is arbitrary, as the relativities (ratios) between $b_1:b_2:b_3$ remain constant – viz, the commensuration could equally well be in terms of N_2O equivalents. In optimisation analysis, for example, exactly the same optimal solution will result irrespective if CO_2 equivalents or N_2O equivalents are used as the numeraire, which illustrates the arbitrariness of the choice of numeraire.

In sum, having an objective function that minimises Greenhouse Gas Emissions, *necessarily* requires conversion of tonnes of CO_2 + tonnes of CH_4 + tonnes of N_2O, in terms of 'global warming equivalents'. The same issue arises when 'minimising energy inputs'. That is, energy inputs (say coal, wood and electricity) cannot validly be added up when they are measured in heat content terms, and therefore they *necessarily* must be adjusted for energy quality before they are optimised.

A further yet related issue, is that it is *a priori* unclear whether 'primary energy inputs' or 'delivered energy' inputs should be minimised in the optimisation modelling. If one was to 'minimise the sum of the primary energy inputs' in terms of their 'heat content' this would result in quite a different solution to the optimisation problem to 'minimising the sum of the delivered energy inputs'. Very importantly, if the 'primary energy inputs' and the 'delivered energy inputs' are converted to (energy) quality equivalents before minimisation, this problem of inconsistent results will not occur. This is because the 'quality equivalent' methodology specifically commensurates 'primary energy' and 'delivered energy' flows in terms of their conversion efficiencies, which means by definition ∑'primary energy (quality equivalents) = ∑'delivered energy (quality equivalents)'.

Zhou and Ang (2008) also draw attention to the problem of measuring energy efficiency in linear optimisation (linear programming) models. As they put it:

> "*different definitions of energy efficiency would lead to different indicators being used to monitor changes in energy efficiency, which can yield very different (optimisation) results and policy implications*."

A.2 Range of Numeraires to Resolve the Energy Quality Problem

To resolve the energy quality problem, energy analysts have attempted to establish a number of appropriate numeraires for converting the conventional enthalpy based statistics to a common unit. The IFIAS workshop on energy analysis in Stockholm explicitly addressed this question. It recommended that all energy data should be based on thermo-dynamic quantities of enthalpy *(H)*, Gibbs free energy *(G)*, and entropy *(S)*.

The attraction of these thermodynamic quantities are that they are state functions, which means they give unique and objective measures for each prescribed set of conditions (prescribed by temperature, pressure, concentration, chemical formula, nuclear species, magnetisation, etc.). Thus for any actual change in physical conditions that results from some dynamic process, the associated change in the values of the state functions can be measured or imputed. Similarly, for a specified change in physical conditions, the minimum energy requirement can be calculated.

Other non-thermodynamic measurements of energy have been devised with respect to addressing the energy quality problem. Namely, the use of OECD thermal equivalents which are now quite commonly used in the compilation of national energy statistics – and fossil fuel equivalents devised by Odum and Odum (1976). Fossil fuel equivalents attempt to take account of the energy requirements for interconversion between one energy form and another. The use of the latter two equivalents is recognised as introducing a number of 'subjectivities' into the process of measuring energy quality. Hence there is a tendency in the literature to prefer the use of thermodynamic quantities for equivalencing energy types of different qualities because they are perceived to be more 'objective'.

Enthalpy (Heat Content)

Most energy analyses and official statistics use enthalpy measurements of energy, although it is frequently acknowledged that the use of enthalpy measurements ignores the energy quality problem. It is often contended that enthalpy figures are good enough for the sake of obtaining 'ballpark' estimates, and further refinements are unnecessary given the indicative long term nature of many energy analyses.

Enthalpic change (ΔH) measurements are essentially a quantification of the heat content of an energy form. Heat content (ΔH) defined in this way is often used to measure energy, as in one sense it represents the maximum *quantity* of energy available for conversion to any other form of energy (ie all forms of energy as measured in enthalpic potential forms are 100 per cent convertible to heat (ΔH) but not 100 per cent convertible to other forms of energy such as mechanical work). However, the use of enthalpic (ΔH) measurements of energy does not take account of the *quality* of energy. No distinction is make between low quality (low efficiency) energy sources such as solar energy and higher quality (higher efficiency) energy sources such as natural gas. For example, in this instance a much greater proportion of natural gas can be converted to a useful out-put such as mechanical energy than solar energy.

Despite the well know deficiency of enthalpy (ΔH) measures with respect to measuring energy quality (Odum & Odum, 1976; Berndt, 1978; Ahern, 1980); many compilers of national energy statistics still incorrectly use such measurements. This not only gives a misleading picture of national energy supply-use patterns, but frequently leads to false analyses of macro-level statistics. For example, macro-level energy productivity studies such as that undertaken by Berndt (1978) are misleading as they treat different energy inputs as homogeneous in quality terms. They are only strictly homogeneous in terms of heat equivalents, but not in terms of any sensible system-wide measure that takes account of a whole multiplicity of energy end-uses in addition to heat.

Gibbs Free Energy

This thermodynamic measure of energy quality is based on the second law of thermodynamics and on the idea that energy quality and be gauged by the ability of an energy form to produce mechanical work. Although the change in Gibbs free energy (ΔH) measurement of energy takes account of energy quality in a very narrow thermodynamic sense; it cannot be applied to real-world systems which have multiple energy outputs. To do so, would wrongfully assume that the only ultimate useful (or effective) energy output is work. This clearly is not the case in modern economic systems where many other effective energy outputs such as light, sound, heat and various other outputs are required as well as work.

Practical problems also emerge in the calculation of the Gibbs free energy (ΔG) measurement, although they present no theoretical barrier to the putative role of ΔG as a measurement of energy quality. When the reactants and products are diverse, as in the making of ferro-concrete from aggregate, steel and cement; the data simply is not available for all materials involved. Where the system is extremely complex, as in the growth of plants or in human nutrition, not enough is known to estimate the entropic contribution to free energy to better than one order of magnitude, even when we can measure the enthalpic (ΔH) contribution fairly accurately.

Exergy and Available Work

The measurement of exergy and available work are closely related to Gibbs free energy and accordingly can also be said to be based on second law considerations, albeit a rather narrow interpretation of that law. The difference between available work and Gibbs free energy is that in the former, pressure and temperature refer to the surroundings; whereas in the case of Gibbs free energy, they refer to the reference state. Hence it is argued by proponents of available work that this is a more realistic measurement of work, as it takes account of the physical conditions that exist in reality.

Exergy is a very similar measurement of energy, being defined by Ahern (1980) as ‘the work that is available in a gas, fluid or mass as a result of its non-equilibrium condition relative to some reference condition’. The reference condition usually used is sea-level atmospheric conditions, which is considered to be the sink for terrestrial energy systems.

Whilst both available work and exergy seem more appropriate measurements than Gibbs free energy change (ΔG), in that they explicitly refer to environment conditions encountered in the economic production processes dealt with in energy analysis; they still have the same fundamental weakness of not taking account of other end-uses apart from work. However, by explicitly allowing for a ‘reference condition’, we are therefore seeing the movement away from ‘objective’ thermodynamic measurements of energy, as the energy analyst is confronted with real-world economic systems which are the context for their studies.

Temperature

The idea of using the temperature of heat sources and the temperature required to produce a desired output, has been suggested in the literature (Groscurth et. al, 1989) as an appropriate criterion for measuring energy quality. This criterion seemingly underlies Lovins (1977, 1979) end-use matching concept. The rationale behind this idea of using temperature as the quality-numeraire seems to lie in Kelvin’s formula for setting the upper limit of a Carnot engine’s conversions of heat to work:

$$M = \Delta H\,[(t_1 - t_2)/t_1]$$

where: M is the mechanical work done by the conversation process (J); t_1 is the temperature of the heat input into the conversion process (K); t_2 is the temperature of the heat output from the conversion process (K).

Temperature differences between the heat source (t_1) and the heat sink (t_2), therefore limit the efficiency by which heat can be converted to mechanical work. Similar temperature defined potentialities can be shown to quantify the level of conversion efficiency between other sources and end-uses of energy and hence the attractiveness of using temperature as a numeraire for measuring the relative quality of different energy sources.

Despite the apparent simplicity and attractiveness of using temperature differences in process optimisation (Linnhoff et. al, 1982) the use of temperature does have a number of shortcomings in terms of being an appropriate measure of energy quality in energy – these are outlined by Patterson (1993). The most serious shortcoming is the implicit assumption in the Kelvin formula, especially if these methods are being applied to heat-to-work conversion processes. These include the unrealistic assumption that such processes operate in a perfectly reversible fashion (or equivalently stated they can be said to operate at an infinitely slow rate)[99]. Furthermore, although the upper limits of many processes can be defined according to temperature differentials between heat source and sink, there is at least some doubt that such differentials can be sensibly applied to all energy conversion processes of socio-economic interest.

OECD Thermal Equivalents

OECD thermal equivalents represent an attempt, albeit a very partial one, to move away from thermodynamic measures of energy quality (Anon, 1987). The OECD thermal equivalents measure the relative efficiency of converting primary energy resources (coal, gas, hydro, oil, geothermal) to electricity.

They have two crucial shortcomings in terms of being satisfactory quality numeraires in energy analysis studies. Firstly, they only encompass one part of the energy conversion system that operates in modern economies – that is, those processes that convert primary energy resources to electricity. Obviously, in modern energy economies there are many more energy conversion processes operating, and there are many other required outputs apart from electricity.

A comprehensive system-side quality numeraire should take account of all of these processes and ultimately reflect the ability of primary energy inputs to be converted to the whole range of desired end-uses (heat, lighting, chemical reduction, mechanical drive and so forth). Secondly OECD thermal equivalents do not take account of the indirect energy inputs required to convert primary energy inputs into electricity, eg the energy embodied in the construction of a hydro-electricity dam. If these indirect energy inputs were introduced into the calculation the 'energy quality problem' would immediately reappear as invariably such indirect inputs are of many different types and qualities.

Fossil Fuel Equivalents

Odum (1983) made the first attempt to establish a methodology for measuring energy quality in complex economic systems; whereas the approaches described so far are only applicable to simple energy transformation to one output. Essentially, Odum attempts to measure the quality of an energy form by its embodies energy content, i.e. the amount of direct and indirect energy required to produce it. Higher quality energy (as measured by embodied energy content) is also

[99] Finite-time thermodynamics methods have been developed in order to some extent overcome this problem.

considered to have greater amplifier effects, i.e. it can be fed-back into the system to increase the flow of energy into the system.

Odum constructs a hypothetical energy hierarchy to measure the energy conversion efficiency from an energy form of 'low quality' through to energy forms of 'higher quality'. These conversation ratios are standardised by equating one of the energy forms to unity, and hence all other energy forms in the chain are expressed in terms of 'equivalents' of that energy form. The term fossil fuel equivalent (FFE) is often used by Odum (1983) as he usually expresses the equivalents in terms of a notational fossil fuel. Accordingly Odum and Odum (1976) have derived the following hierarchy for the United States economy:

Sunlight	0.0005 FFE
Wood	0.05 FFE
Fossil Fuel	1.00 FFE (by definition)
Energy in Elevated Water	3.00 FFE
Electricity	4.00 FFE

There are however some technical problems in operationalising Odums' approach, which have lead to its non-acceptance outside the eco-energetics school of energy analysis:

1. There is an implicit assumption, that simple straight chains of transformation exist in reality, or at the very least that such chains have relevance to the analysis of real-world systems. The justification for this assumption is not provided by Odum in his various publications (Odum & Odum, 1976; Odum, 1983). For example, the hierarchical chain implicit in the above data is: Sunlight → Wood → Fossil Fuel → Energy in Elevated Water → Electricity. Obviously, in complex economic systems such straight chains do not exist; rather economic systems are complex networks of energy transformation with feedback loops, which are not accounted for in the empirical side of Odum's approach
2. There is an *a priori* assumption, that certain energy forms are of higher quality than others. Odum's approach provides no rigorous means of determining these energy rankings, in terms of a set of pre-specified criteria.

Another possible criticism of Odum's approach to energy quality measurement is that it fails to consider explicitly the eventual end-uses of energy, such as heating, mechanical drive, chemical reduction, lighting and so forth. Odum's flow diagrams usually stop at the delivered energy level and provide little characterisation of the end-use purpose for which his energy is used.

Summary

The thermodynamic measures of energy quality have been found to be deficient numeraires in the context of energy analysis studies. This is because fundamentally they ultimately place value only on one form of energy – either heat or some work measurement. Similarly, the OECD thermal equivalent only places value on electricity. This practice of placing value on one chosen energy form is purely arbitrary and without justification in terms of energy analysis' focus on quantifying energy flows in complex economic systems. In such systems, there is a simultaneous requirement for many end-uses of energy; such as heat, mechanical energy, refrigeration, pumping, space cooling, chemical reduction, lighting, sound propagation and so forth. In this context, it is simply inappropriate to measure the quality of an energy form by its ability to be converted to any one energy output, when obviously very many different types of energy are required.

In energy analysis there is a requirement for a systems-based approach to energy quality, given the complex interlinking conversion processes that are used in economic systems to convert primary energy forms to end uses of energy. This has been attempted by Odum (1983), but unfortunately despite his stated concern with feedbacks and interlinkages of energy supply pathways, his operational methodology falls short in this crucial respect. Odum's (1983) energy quality measurements are not only based on straight chains rather than complex webs, but he presents no scientifically reproducible way of uniquely determining the quality coefficients of the energy forms in these chains.

A.3 Quality Equivalent Methodology

The quality equivalent methodology developed by Patterson (1983, 1993) and emulated by Collins (2001) and Odum (2000), presents a way of commensurating energy in terms of the energy quality of energy inputs and outputs in complex energy systems. As pointed out earlier this method, avoids the need to (arbitrarily) select either ∑primary energy input or ∑delivered energy input as the objective function, as in both instances the same optimal solution is obtained.

A.3.1 Explanation of Quality Equivalent Methodology

The purpose of the quality equivalent methodology[100] is to define an energy unit which allows energy inputs and outputs to be compared on a common basis. This energy unit is called a quality equivalent and is defined by solving a system of simultaneous linear equations. These equations, which are termed a reference system, quantify the flow of energy in national energy systems, e.g. the 2006/07 New Zealand energy system. As such, there is a description of the flow of energy from primary energy sources to delivered energy and eventually to end uses of energy.

Reference System Equations

The flow of energy in any complex system, such as a national energy system, can be quantified by a system of simultaneous linear equations represented by:

$$X\beta + e = 0$$

Where

X = matrix (*m x n)* of *m* processes describing the conversion of energy between *n* types of energy. The energy flows are measured in ΔH terms, with inputs entered as negatives entries and outputs as positive entries.

ß = column vector (*n* x 1) of quality coefficients of each energy type. The quality coefficients are measured in terms of $E/\Delta H$ units, and are determined by solving the simultaneous equations.

100 Fuller explanations of the quality equivalent methodology are contained in Patterson (1993b) and also in an earlier publication in *Energy Policy* by Patterson (1983).

e = residual vector (*m* x 1). The residual expressed in quality equivalents *(E)* for each process. For a process with an efficiency equalling the system's average $e = 0$ and for a process efficiency greater than the system's average $e > 0$

This system of simultaneous equations needs to be solved so as to determine the quality coefficients for each of the energy types – i.e. to obtain a solution vector *ß*. This presents a number of problems. First, the system of equations is nearly always overdetermined, as there are more conversation processes *(m)* than energy types *(n)*. Therefore, deterministic solution methods, such as those used in Leontief-style input output analysis, are not suitable solution methods. Second, the system of equations is homogeneous, as the right hand side of the equations is a vector of zero entries. For this reason, the trivial solution of *ß* = 0 is always a possible solution but not meaningful. The key to solving the equation is to avoid the trivial solution by setting one of the quality coefficients to unity and transferring the resultant vector to the other side of the system of equations. The solved quality coefficients *ß* are expressed in terms of multiples of the variable which has been transferred to the right-hand side. These multiples are called quality equivalents. Any one of the specific coefficients in the reference system can be used as the quality equivalent unit. For a properly specified system of equations, it does not matter which coefficient is set to unity as the relativities between the quality coefficients remain constant.

Quality Equivalent Unit and Quality Coefficients[1]

The concept of the quality equivalent unit is pivotal in the QEM. The quality equivalent unit is the 'measuring rod', which allows energy forms to be compared on a common basis in terms of their energy quality. Energy inputs and outputs have been traditionally measured in terms of their heat content (ΔH) which takes no account of energy quality. To convert energy inputs and outputs measured in heat units (ΔH) to quality equivalent units (E), they need to be multiplied by the quality coefficients ($E/\Delta H$) obtained from solving the above specified system of equations.

In general, the quality coefficients ($E/\Delta H$) provide a measurement of the quality of energy inputs and outputs. The specific meaning that can be attached to the numerical value of each quality coefficient, depends on the type of energy input/output. For primary energy inputs, the quality coefficient ($E_{out}/\Delta H_{in}$) is the relative efficiency at which a primary energy input (ΔH_{in}) is converted to energy end-users (E_{out}) in the reference system. The higher the energy quality of a primary energy input, the more end use energy it will produce. For example a primary energy input such as natural gas is usually more efficient or productive at producing end uses of energy, than lower quality energy inputs such as coal. That is, one unit of natural gas (ΔH_{in}) will produce more end use energy (E_{out}), than one unit of coal (ΔH_{in}). Therefore, natural gas will have a higher quality coefficient ($E_{out}/\Delta H_{in}$) than that for coal.

For an end use of energy, its quality coefficient ($E_{out}/\Delta H_{in}$) is the total embodied energy required to produce that end use. For example, a typical high quality end use, such as light energy, requires a greater input of direct and indirect energy (ΔH_{in}) to produce one useful output of energy (E_{out}).

[1] These concepts have direct analogues in economic thinking: quality equivalent (E) = monetary value ($); quality coefficient (E/unit of energy) = relative price ($/unit of commodity).

A simple numerical example

Algegraic equations can be used to describe the conversion of inputs (ΔH) to outputs (ΔH) of energy for each process in the reference system. In the following equations, the inputs are arranged on the left-hand side and the output on the right-hand side:

1 b_1 14.50 + $b_7$010 + $b_8$0.20 + e_1 = $b_4$13.50
2 $b_6$6.00 + $b_8$0.02 + e_2 = $b_4$2.00
3 $b_5$2.00 + $b_7$0.80 + $b_8$0.01 + e_3 = $b_4$0.50
4 $b_2$16.00 + $b_8$0.01 + e_4 + $b_6$14.00
5 $b_3$125.00+$b_7$0.20 + e_5 + $b_5$100.00
6 $b_4$6.300 + $b_8$0.04 + e_6 = $b_7$6.00
7 $b_6$4.00 + $b_8$0.03 + e_7 + $b_7$3.00
8 $b_5$8.00 + $b_8$0.10 + e_8 = $b_7$4.80
9 $b_6$4.00 + $b_7$0.04 + e_9 = $b_8$0.60
10 $b_5$80.00 + $b_7$0.04 + e_{10} = $b_8$8.00
11 $b_4$10.00 + $b_8$0.04 + e_{11} = $b_9$1.00

This system of simultaneous equations can be solved and expressed in terms of multiples of any of the energy forms (in this particular case delivered electricity equivalents).

1 b_1 = 0.8823 (hydroelectricity
2 b_2 = 0.3755 (wellstream gas)
3 b_3 = 0.2509 (crude oil)
4 b_4 = 1.0000 (delivered electricity)
5 b_5 = 0.3152 (oil products
6 b_6 = 0.4314 (delivered gas)
7 b_7 = 0.7813 (heat)
8 b_8 = 3.1403 (transport)
9 b_9 = 10.125 (lighting)

It becomes evident from solving the equations that not all processes are equally efficient, as demonstrated by the existence of non-zero residuals ($e \neq 0$). The relative efficiency (Φ) of each process can be calculated by dividing the outputs (E_{out}) by the inputs (E_{in}) of each process.

Processes that have relative efficiencies of greater than one (Φ > 1) are more efficient than the system's average; and those that have relative efficiencies less than one (Φ <1) are less efficient than the system's average. By using these relative efficiencies, it is possible to rigorously match end uses and sources of energy, in accordance with the type of ideas promoted by Lovins (1977). For example, the most efficient way of providing heat is by using oil products (Φ_8 = 1.3224); whereas, the least efficient way of providing heat is by using electricity (Φ_6 = 0.7652).

A.3.2 Mathematics of the Quality Equivalent Methodology

The energy quality problem stated above can be formulated by redefining e as:

$$\boldsymbol{e}=\mathbf{X}\boldsymbol{\beta} \tag{6}$$

where $\boldsymbol{e}$ is an $(m \times 1)$ vector and

(7)

$$e_i = \sum_{j=1}^{n} x_{ij} b_j.$$

Without any loss of generality it is now possible to restate Eq. (1) so as to find the minimum value of

(8)

$$E = \sum_{i=1}^{m} e_i^2 = \sum_{i=1}^{m} \left(\sum_{j=1}^{n} x_{ij} b_j \right)^2$$

subject to the constraint:

(9)

$$\sum_{j=i}^{n} b_j^2 = c^2 \neq 0$$

As it turns out, the value of *c* does not matter.

The solution is obtained by the method of Lagrange multipliers by defining:

(10)

$$E(\beta\lambda) = \sum_{i=1}^{m} \left(\sum_{j=1}^{n} x_{ij} b_j \right)^2 - \lambda \left(\sum_{j=1}^{n} b_j^2 - c^2 \right).$$

Here λ is a free variable (that is, a Lagrange multiplier). Eq. (10) may now be differentiated.

(11)

$$\frac{\partial E}{\partial b_k} = 2 \sum_{i=1}^{m} x_{ik} \left(\sum_{j=1}^{n} x_{ij} b_j \right) - 2\lambda b_k = 0$$

for a minimum based on a system of *n* equations and *n* unknowns with λ subject to:

(12)

$$\frac{\partial E}{\partial \lambda} = \sum_{j=1}^{n} b_j^2 - c^2 = 0$$

which satisfies the constraint. By re-arrangement, Eq. (11) may be expressed as

(13)

$$\frac{1}{2} \frac{\partial E}{\partial b_k} = \sum_{j=1}^{n} \left(\sum_{i=1}^{m} x_{ij} x_{ik} \right) b_j - \lambda b_k = 0.$$

If we now define the symmetric matrix

$$\mathbf{Y}=\mathbf{X}^{\mathrm{T}}\mathbf{X} \tag{14}$$

$$\text{or} \quad y_{ij}k = \sum_{i=1}^{n} x_{ij}x_{ik}, \tag{15}$$

The optimal solution for the b_j are obtained when

$$\mathbf{Y}\boldsymbol{\beta}=\lambda\boldsymbol{\beta}, \tag{16}$$

That is, when $\boldsymbol{\beta}$ is an eigenvector of the matrix **Y**.

So $\boldsymbol{\lambda}$ is an eigenvalue of **Y** with eigenvector $\boldsymbol{\beta} \neq \mathbf{0}$. By contrast, $|\boldsymbol{\beta}| = c$ is arbitrary. The only important quantities are $\beta_1\beta_2\ldots\beta_n$. All eigenvalues of the symmetric matrix **Y** $\lambda_1\lambda_2\ldots\lambda_n$ are real with eigenvectors $\beta_1, \beta_2,\ldots\beta_n$. A minimum is obtained by choosing the smallest eigenvalue and corresponding eigenvector so that:

$$\sum_{i=1}^{m} e_i^2 = \sum_{i=1}^{m}\left(\sum_{j=1}^{n} x_{ij}b_j\right)^2 = \text{minimum} \tag{17}$$

with

$$\sum_{j=1}^{n} b_j^2 = 1. \tag{18}$$

A.3.3 Derivation of Quality Coefficients for the New Zealand Energy System

A system of simultaneous linear equations is solved for the 2006/07 NZ Economy's energy system, in order to derive *quality coefficients* for each of the *primary energy inputs* and the *delivered energy inputs*[101]. This system of simultaneous linear equations measures the actual energy from primary sources to delivered energy and eventually to end-uses.

The quality coefficients (expressed in 'crude oil equivalents') thereby derived are:

Primary Energy

0.8174 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Hydro-Electricity
0.2184 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Wellhead Geothermal
1.2490 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Biogas
1.8753 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Wind
0.1665 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Fodder Beet
0.1665 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Forage
0.1978 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Maize
0.1978 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Eucalyptus

[101] Strictly speaking, as quality coefficients are a directly implicit function of the structure of the Energy System, they should be derived separately (and simultaneously) for each of the years included in the dynamic optimisation, not just for 2006/07.

0.1978 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Radiata Pine
0.1978 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Purpose Grown Wood
0.5418 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Mine Coal
1.0000 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Wellhead Crude Oil
1.1922 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Wellhead Natural Gas
0.6911 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Wellhead LPG
0.5418 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Coal
1.0002 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Crude Oil
1.0633 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Fuel Oil
1.3114 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Natural Gas
0.7096 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported LPG
1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Petrol
1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Diesel
1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Imported Aviation Fuel
0.6742 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Black Liquor
0.1978 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Wood Residues
0.2082 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Waste Heat

Delivered Energy[102]

1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Aviation Fuel
0.5418 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Coal
1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Diesel
2.0816 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Electricity
1.0633 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Fuel Oil
0.4457 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Geothermal
1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	LPG
1.3114 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Natural Gas & Methane
1.2298 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Petrol
1.1465 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Ethanol
1.1465 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Methanol

Energy End-Uses[103]

4.7349 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Al_2O_3 Reduction
2.3357 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Electronics & Other Uses
4.9448 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Fe_3O_4 Reduction
2.7242 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Heat (>300 C), Process Req.
4.6957 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Heat (100-300 C), Cooking
2.4953 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Heat (100-300 C),Process Req.
16.809 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Lighting
5.2029 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Heat (<100 C), Clothes Drying
1.7274 PJ Crude Oil Equivalents	per	1 PJ (ΔH	Heat (<100 C), Process Req.
1.7101 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Heat (<25 C), Space Heating
2.1530 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Heat (<70 C), Water Heating
9.0437 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Motive Power, Mobile
2.8712 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Motive Power, Stationary

[102] Because of the way the energy accounting has been set up, some of the ‘primary energy inputs’ are also ‘delivered energy inputs’ (Black Liquor, Wood Residues, Waste Heat). It is therefore important in the linear optimisation that these energy inputs be included in both objective functions that include ‘primary energy inputs’ and ‘delivered energy inputs’.

[103] The ‘quality coefficients of the energy end-uses’ are not directly required for operationalisation of the optimisation model. However, without them, the quality coefficients of ‘primary/delivered energy inputs’ (necessary for formulating the objective function), could not be determined.

2.8364 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Pumping
1.9018 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Refrigeration
1.0964 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Space Cooling
2.8712 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Transport, Air
10.907 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Transport, Land
5.8658 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Transport, Rail
8.7059 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Transport, Sea
2.5661 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Dishwasher: (<100 C), Water Heating
1.9446 PJ Crude Oil Equivalents	per	1 PJ (ΔH)	Spa Pools: (<100 C), Water Heating

A.4 Summary and Recommendations

The ‘project brief’ requested that the ‘energy savings potential’ for NZ be estimated from 2006/07 to 2025/26. The operational difficulty in defining ‘energy savings potential’ comes sharply into focus when attempting to mathematically and operationally define the objective function for this optimisation modelling exercise. The main methodological issue [104] concerns the valid aggregation of, energy measured in common ‘quality units’ – viz., the ‘energy quality problem’ or ‘commensuration problem’. There are also incidentally other methodological issues concerning the measurement of ‘energy savings potential’ and ‘energy efficiency’ which have less relevance to this optimisation modelling approach, but are critically reviewed by Patterson (1996).

It is therefore recommended that:

- In defining the objective function of ‘minimising primary energy inputs’ in OPENZ, that quality equivalent units be used. This has a number of methodological advantages, including being analytically equivalent to ‘minimising delivered energy inputs’. Alternatively, EECA could consider using ‘Exergy’ units in the objective function, which is more widely used than ‘quality equivalent units, but as Patterson (1991, 1996) argues is more limited as it commensurates ‘energy quality’ based on some arbitrary ‘work potential’.
- EECA consider using ‘minimisation of GHG emissions’ as the objective function because: (a) it is more easily defined that minimising ‘primary energy inputs’ because the commensuration problem is more easily resolved by the use of CO_2 equivalents to take account of ‘global warming potential’; (b) it avoids the ambiguity and methodological problems associated with using ‘energy savings potential’ and ‘energy efficiency’ measures[105] ; (c) it could be argued that minimising ‘greenhouse gas emissions’ is now a far more pressing and important policy goal than the minimisation of ‘energy inputs’.
- In the future development of OPENZ that other policy goals (in addition to ‘energy efficiency’ and ‘reducing GHG emissions’) should be considered to reflect in government policy and more specifically in the New Zealand Energy Strategy. These for example could include: energy security, reducing CO_2 emissions, fair pricing, resilience of the supply system, reducing the cost of supply ($), industrial competitiveness, self-sufficiency and so

[104] The ‘energy quality problem’ is a well known problem in measuring energy efficiency, along with other methodological problems such as the boundary problem, joint production problem and technical versus gross energy efficiency issue – refer to Patterson (1996) for further discussion.

[105] For example, quite different results can ensue depending on which energy numeraire is used in the objective function, and most numeraires will give a different ‘energy efficiency’ results depending on whether ‘primary energy inputs’ or ‘delivered energy inputs’ are using in the ‘objective function’.

forth. Although the implicit focus of this potential modelling exercise is energy efficiency, it would be unwise not to consider these other energy policy goals. It is therefore recommended in the further development and application of OPENZ that EECA at least pay some attention to these other policy goals. For example, it is argued that it would be helpful to ‘minimise energy inputs’ (≡ maximise energy savings), subject to the constraint that CO_2 emissions not exceed the 2006/07 base year level or some other government target. This is for the obvious reason, that government policy makers are unlikely to take seriously any theoretical ‘energy savings potential’ that involves CO_2 emissions that exceed a Government target.

Appendix B

Further Methodological Details

B.1 Mathematics of Optimisation Models

The mathematical technique of optimisation forms the core of the OPENZ model. Optimisation is a mathematical technique that can be perhaps traced back to the work (Steepest Decent) of the German Mathematician Gauss in the early 1800's. As an operational method, linear optimisation (linear programming) was developed initially by Danzig around the Second World War period. With the contemporaneous development of the first computers during this period, the technique rapidly grew across a number of domains, with early applications focussing on logistics, military, air industry and oil industry problems.

Nowadays linear optimisation is heavily used in micro-economics, company management, planning, production, transportation and in many other areas. The software is readily available and widely used. A recent survey showed that 85% of *Fortune 500 Companies* regularly use linear optimisation in their decision-making (Floudas and Pandalos, 2001). Perhaps particularly with the worldwide movement away from centralised government planning of the economy and the more indistinct nature of public policy objectives compared with business objectives (eg profit maximisation), optimisation analysis is less frequently used by government agencies. An interesting account however is given by Burton (1985) of how such methods can be used in policy analysis using regional development as a point of illustration in NZ.

The technique involves solving a system of simultaneous linear equations, in order to optimise (maximise, minimise) some objective function. Formally therefore the linear maximisation problem can be stated as follows:

$$\text{Maximise } z = c_1 x_1 + c_2 x_2 + \cdots + c_n x_n \qquad (2.1)$$

Subject to:

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$$
$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \leq b_2$$
$$\vdots \qquad \vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \leq b_m$$
$$x_1, x_2, \cdots, x_n \geq 0$$

Where:
z = objective function
a = technical coefficients
x = activity level of processes, from *l . . .n*
b = constraints, from *1 . . .m*

c = objective function quantity – e.g., Cost ($) or CO_2 (tonnes)
$x_1, x_2 \ldots x_n \geq 0$ = non-negativity constraint of each process activity

In matrix notation the problem can be more compactly written:

$$\text{Max } \mathbf{z} = \mathbf{cx} \tag{2.2}$$

Subject to: $\mathbf{Ax} = \mathbf{b}$
$\mathbf{x} \geq \mathbf{o}$

There are a small number of generic departures from this formal statement *(standard form)* of the linear optimisation problem:

(i) the constraints be a mixture of less than or equal to **(≤)** greater than, or equal to **(≥)** and/or equality **(=)** constraints. Therefore, $\mathbf{Ax} = \mathbf{b}$ is not strictly always the case, and instead for example $\mathbf{Ax} \leq \mathbf{b}$ could apply;
(ii) the problem is not always a maximisation problem, instead it could be a minimisation problem;
(iii) under some circumstances the non-negativity constraint may not be applicable.

Every linear optimisation problem, referred to as the primal problem, can be converted to a dual problem. The dual problem provides the upper bound of the optimal value to the primal problem. In matrix notation the *primal problem* can be expressed as:

$$\text{Max: } \mathbf{c}^t\mathbf{x} \tag{2.3}$$

Subject to: $\mathbf{Ax} \leq \mathbf{b}$
$\mathbf{x} \geq \mathbf{o}$

where:
$\mathbf{c}^t$ is the transpose of $\mathbf{c}$

The corresponding *dual problem* is:

$$\text{Min; } \mathbf{b}^t\,\mathbf{y} \tag{2.4}$$

Subject: to $\mathbf{A}^t\mathbf{y} \geq \mathbf{c}$
$\mathbf{y} \geq \mathbf{o}$

where:
$\mathbf{b}^t$ is the transpose of $\mathbf{b}$

In this problem **y** is used instead of **x**, as the variable vector.

B.2 Mathematical Assumptions of Linear Optimisation Problems

The first assumption is that the relationships that represent the processes and the objective function are *linear*.[106] This is not always the case as relationships, particularly for example in biological and ecological systems are perhaps intrinsically non-linear. Non-linear systems are however far more difficult to reliably solve, although the software is commonly available even in the 'Excel Solver' used in this OPENZ model. Fortunately many of the energy processes quantified in the OPENZ, are linear or close-to-linear, e.g. one thousand 100 watt light bulbs, use 1000 times the energy of one just 100 watt light bulb, which is a strict linear relationship.

One common tactic for dealing with non-linear relationships, is to use linear approximations of the non-linear relationships. To some extent in the OPENZ model, this is what we did to quantify the supply of electricity supply options by defining a series of 'block-wise' linear relationships to track the supply of 'blocks' of electricity in the electricity supply curve. This is standard practice, in constructing supply curves for energy supply (eg, Smith, 2000).

There are a number of other important (generic) assumptions of the linear optimisation model that have particular pertinence to the solvability of the systems of linear equations of the type outlined by (2.1).

- *Degeneracy*. Essentially this happens where there is a 'tie' for the optimum solution. From a practical standpoint, this degeneracy condition emerges when there is at least one redundant constraint. Unfortunately, there are no reliable techniques for identifying redundant constraints directly from the *tableau* **Ax=b**. There are some instances in the solution of equations for OPENZ that this degeneracy condition does emerge – for example, there are a number of processes that are equally energy efficient that leads to a 'tie', when minimisation of energy inputs is the specified objective function.
- *Alternative Optimums (Optima).* When the objective function is parallel to a *binding constraint* (ie, a constraint that is satisfied equally by the optimal solution), the objective function will assume the same optimal value at more than one point. In practice, knowledge of alternative optimum is useful as it gives the decision-maker the 'opportunity to select the solution' that 'best suits their situation', trusting that their choice will not affect the value of the objective function.
- *Unbounded Solution.* This means that the objective function value can increase, indefinitely, as there is a lack of binding constraints or bounds. That is, the solution space is unbounded. An example of an unbounded model could be maximising profit, with no realistic constraints specified (e.g. market size) to constrain the problem. The general rule for recognising unboundedness is as follows. If at any iteration in the solution process, *if* the constraint coefficients of a *non-basic* variable are non-positive, *then* the solution space is unbounded this that direction. If, in addition, the objective of that variable is negative in the case of maximisation or negative in the case of minimisation, then the objective value is unbounded.

[106] Further (to the linearity assumption), other formally stated assumptions of the linear optimisation problem are:
(1) *Proportionality*. A change in a variable results in a proportionate change in that variable's contribution to the value of the function.
(2) *Addivity*. The function value is the sum of the contribution of each item.
(3) *Divisibility*. The decision variables can be divided into non-integral values, taking on fractional values. This is unrealistic in some circumstances – e.g., you cannot have 50% of a bridge or 50% of a hydro-electric dam. In these circumstances, the technique of integer programming (restricting the solution to integer values or 'whole numbers') is used to overcome this problem.

- *Infeasible Solution.* This is the most frequently encountered problem in linear optimisation, although the most easily resolved. If all constraints are not simultaneously solved, the optimisation problem is said to have no feasible solution. For example, in the OPENZ model it may not be feasible to supply all of New Zealand's energy needs in 2025, given the various constraints (capacity, technological penetration rates, available energy resources, policy constraints setting CO2 targets and so forth). Such 'infeasibility' problems, instead of being considered to be a 'difficulty' actually provide useful insights into the nature of the problem. For example, in the OPENZ model it means that policy makers, need to consider what constraints they may need relaxed (e.g., perhaps CO_2 target) in order to achieve a 'feasible' (realistic) solution. In a sense, if the model is realistic, you almost always expect at some stage in the optimisation modelling process, that an 'infeasible' solution will exist. Suspicions may oppositely arise if you never in a model like OPENZ encounter an infeasible solution. Theoretically, duality theory (primal vs. dual solution) provides a neat relationship between an 'unbounded' and an 'infeasible' solution. Duality theory states that if the primal problem is unbounded, then the dual is infeasible. Oppositely, if the dual is unbounded, the primary must be infeasible.

B.3 Optimisation Concepts and Terms

Optimisation theory and practice involves a number of concepts and terms – for further details refer to Floudas and Pandalos (2001). The main concepts include:

Objective Function: A mathematical function that can be optimised (maximised or minimised). In a less formal sense, it refers to something that you may wish to either maximise or minimise. For example, a company may wish to maximise its profit. Another example, is a commuter to work may wish to minimise his/her commuting time. In many real-world situations, it is not a simple matter of maximising or minimising just one goal or objective. In this context, an objective function can mathematically describe several goals.

Constraint: This is a condition that a solution of the optimisation problem must satisfy. In OPENZ, a constraint could be that the demand for natural gas must not exceed the supply of natural gas. Or at market equilibrium the supply and demand for natural gas must be equal.

Binding Constraint: This refers to a constraint that will change the value of the objective function. Tightening a binding constraint can only worsen the objective function value, and loosening a binding constraint value can only improve the objective function value.

Non-binding Constraints: This refers to a constraint that has no impact on the solution of the optimisation problem. That is, they have no affect on the optimal solution found and they can effectively be eliminated from the problem.

Bound: This is a limitation on the activity level of a process. For example in OPENZ, there is an upper limitation on the production capacity of the Marsden Point Refinery. Strictly speaking, a bound is a limitation on the vector **x** – for example, $\mathbf{x} \geq \mathbf{0}$ means that no process can have a negative activity.

Standard Form: This is the 'standard' way a linear optimisation problem is described in terms of a core matrix **Ax**, a set of constraints ($\leq \mathbf{b}$, $\geq \mathbf{b}$, $=\mathbf{b}$) and a set of bounds ($\mathbf{x} \leq$, $\mathbf{x} \geq \mathbf{0}$, $\mathbf{x} = \mathbf{0}$). Many software packages require that the problem be described and structured in this way.

Tableau: A structured table or matrix of numbers that describe the optimisation problem. The tableau therefore provides a numerical expression of the problem in terms of the standard form. Defining the optimisation problem in terms of a 'tableau' is usually the first step in the optimisation modelling process.

Shadow Price: The shadow price for a constraint is the amount that the objective function value changes per unit of change in the constraint. The reported shadow price is valued up to the allowable increase or allowable decrease in the constraint.

Slack Variable: A variable added to the problem to eliminate 'less-than' constraints.

Surplus Variable: A variable added to the problem to eliminate 'greater-than' constraints.

Artificial Variable: A variable added to the linear optimisation to assist the solution of the problem.

B.4 Linkages to a Model of the NZ Economy

B.4.1 Economic Futures Model

The Economic Futures Model (EFM) is a dynamic input output model of the NZ Economy. As such, the model is run through the use of scenarios. The model maps the growth path of each scenario, for 48 sectors and households over 25 years. A key feature of the model is that it can be used to evaluate not only the *direct* economic growth in final consumption, but also the associated *indirect* (i.e. through supply-chain) and *induced* (i.e. through consumer spending) economic effects (McDonald and Patterson, 2008). The Economic Futures Model was selected for use in this 'energy savings potential' project because it provides GDP Growth projections down to the 48 sector level, which is a similar level of detail that will be used in the 'Full OPENZ model' that is based on the 37 sectors in the EECA Energy End-Use Database. The EFM provides a very similar picture of GDP growth on an economy-wide basis (up until 2030) to the Treasury (2005) budget projections, but the EFM preferred in this study because it disaggregates down to 48 sectors.

The model is run through the use of scenarios. The model maps the growth paths (Gross Domestic Product) of each scenario, for 48 sectors and households over 25 years. It provides a 'Business as Usual (BAU) scenario, for input into the OPENZ model. The baseline BAU represents the scenario in which an economy continues to function in the same way as it has over recent times. Scenarios are established by generating projections of final consumption (i.e. household consumption, export consumption and gross fixed capital formation (GFKF)) over a 25 year period. In the case of the baseline BAU, household consumption is based on population projections and private and public consumption profiles by age-sex cohort. In addition, exports and GFKF are based on econometric analysis of national growth rates over the last 15-20 years. At the discretion of the client, this analysis may be augmented with a qualitative analysis of prevailing or imminent economic conditions, as gathered through literature searches, industry reports, media commentaries and dedicated workshops, interviews and/or surveys of key regional stakeholders. The inclusion of qualitative data into the modelling framework both 'ground truths' and 'calibrates' the model against real-world observations.

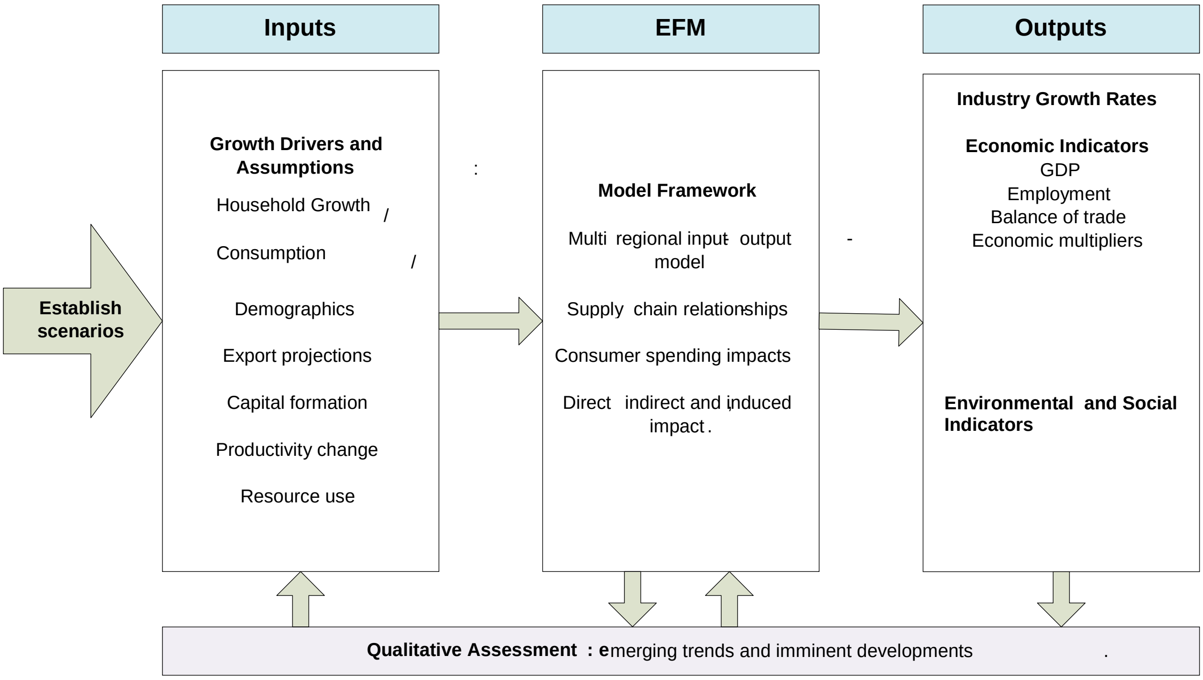
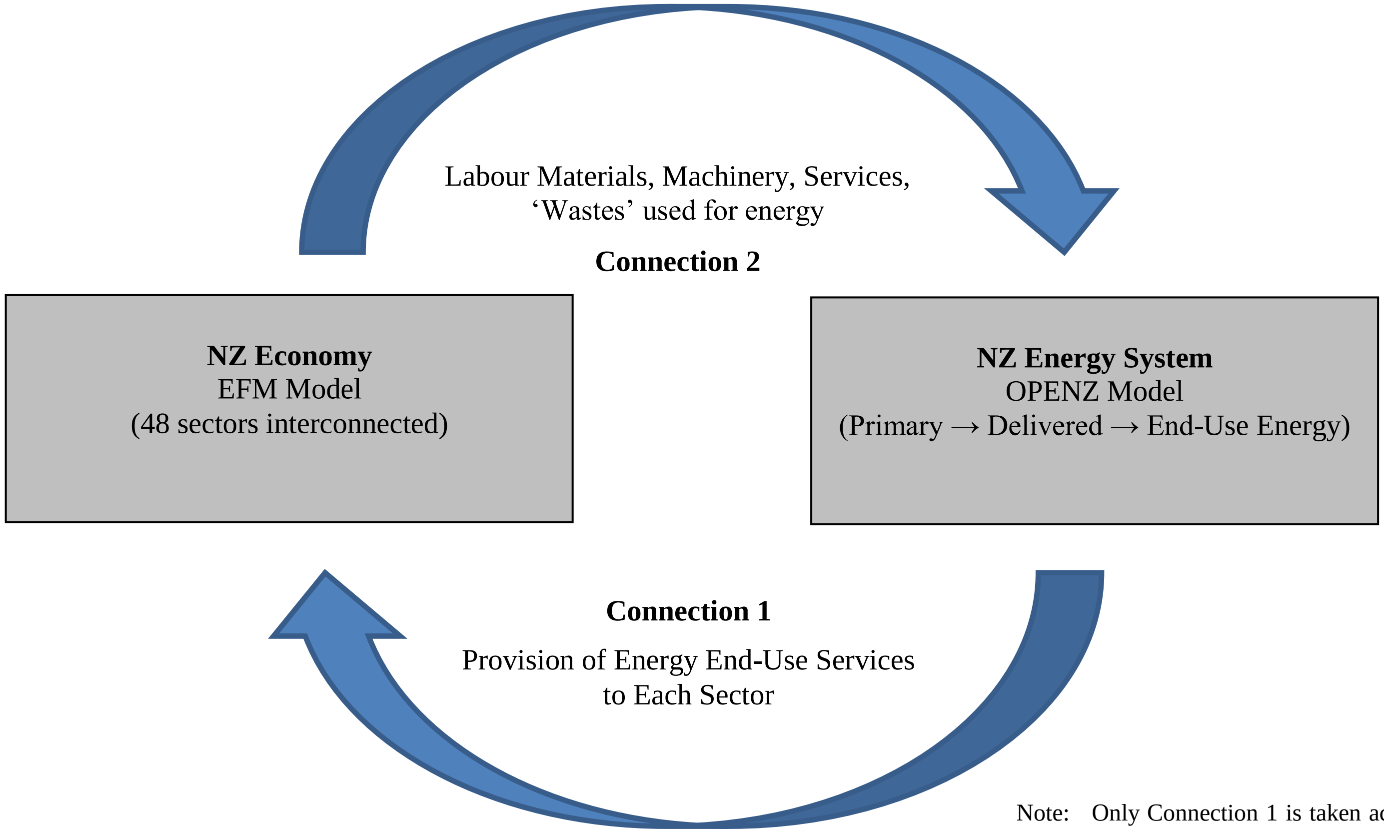


Figure B.1 The Economic Futures Model Methodology

Figure B.1 is a diagrammatic representation of the process by which the EFM is created. It shows the variables that are fed into the model and the outputs subsequently. Growth rates for household consumption, exports and GFKF are the principal drivers of the model, but may as previously stated be augmented with qualitative analysis. Quantitative projections of household consumption are based on Statistics New Zealand's national population projections by age-sex cohort, profiles of) private and public consumption[107] per person, and household consumption figures for the base year from the underlying multi-regional input-output table. Growth in exports and GFKF are based on statistical time series analysis.

[107] Allowances are made for the likely decline in private consumption associated with the so-called 'demographic dividend' effect (Bloom *et al*., 2002) and, conversely, the likely increase in public consumption resulting from expenditure of elderly care (Guest *et al*., 2003).



Note: Only Connection 1 is taken account of in the current modelling framework.

Figure B.2 Modelling the Interconnections between the NZ Economy and the NZ Energy System

Selection of the time series technique applied depends on the underlying dynamic behaviour of the sector output being analysed. Where historical observations fluctuate around a long-run mean, stationary time series methods are applied (e.g. the AMRA process). Where historical observations indicate a consistent upwards or downwards movement, non-stationary time series methods are used (e.g. Holt's method).

B.4.2 Modelling the Connections between the Economy and the Energy System

Figure B.2 shows that there are two main connections between the 'NZ Economy' and the 'NZ Energy System':

(1) *NZ Economy → NZ Energy System.* Sectoral growth/decline drives the demand for 'energy end services'. The more physical production there is in a sector, the higher the demand for 'energy end-use services' to produce this increased sectoral output. Conversely, the less physical production there is in a sector, the lower the demand for 'energy end-use services' to produce this decreased sectoral output.

(2) *NZ Energy System → NZ Economy.* As there are new developments (building a hydro-electric dam, retro-fitting houses with improved insulation) in the energy system, there is a demand for labour, goods and services from the economy. The demand for these inputs will have all sorts of 'flow on' effects in the economy which can be estimated by using economic models like the EFM.

In principle, we should be able to model both of these types of connections in an integrated fashion by simultaneously using the OPENZ and the EFM models, within one modelling framework.

Modelling Connection (1) in the Current Project

In the OPENZ modelling framework, it is assumed that the demand '*Energy End-Use Services'* is driven by the amount of sectoral production as measured by GDP – the more production, the greater the demand for end-use services, and vice versa. For example, if the GDP production of the Dairy Farming Sector increases by 15%, it is assumed that the demand for end-use services (milk chilling, pumping, hot water heating) all increase by exactly 15%. There are a number of assumptions implicit in this approach: (1) *Direct Linear Relationship* between GDP output of a sector and end-use demand. For example, if the 'brick manufacturing' sector increases its GDP production by 20%, then the demand for all of the end use services that it requires also increases by 20%. This is a very reasonable assumption, in industries like brick making, where there is a strong correlation between physical production (of bricks) and GDP output ($). In some sectors, particularly service sectors, this correlation may not be quite so strong because they produce 'non-physical' services, rather than physical products; (2) *Energy End-Use Mix Remains Constant*, in a given sector. For example, if the brick industry increases in size over the 2006-2026 period, then the 55% of end-use energy (high temperature heat) required for baking bricks remains constant.

This ‘end-use mix’ assumption probably holds true if the product mix of the sector remains constant[108]. If, for example, the brick industry diversified into making garden furniture, then it would not require so much high temperature heat (>300°C) and the 55% of end-use energy being for high temperature heat may drop to say 35% of the total end-use energy. However if the ‘brick industry’ continues to only produce ‘bricks’ then the physical requirement for 55% of its end-use energy for high temperature heat (>300°C) would remain more-or-less constant; required for baking bricks remains constant. (3) *It is assumed no energy for labour or substitution* for energy services or vice versa (Patterson 1989). Proportionately more mechanical drive energy could be required to produce products if for example there is energy for labour substitution, by using more machinery. It is unlikely that this last assumption continues to have much significant effect in the NZ economy as the major phases of mechanisation in NZ industry has already occurred (Patterson, 1989).

All of these assumptions (particularly 1 and 2), apply strongly to sectors based on physical production of goods, but not quite so well in service-based sectors. Even for sectors that are based on physical production, there may be better indicators of the increase in their end-use energy demand – eg number of cows or kg of milk-fat production for the Dairy farming sector. Such alternative indicators to GDP have been used in the various updates of the EECA End-Use Database (Patterson and McDonald and McGregor, 2004; Patterson and McDonald, 2009).

Modelling Connection (2) and Flow-on Economic Effects in Future Projects.

The full assessment of the ‘economic energy savings potential’, needs to consider the economic flow-on effects of the energy savings options. As mentioned above, these ‘flow-on’ effects can be significant as jobs and income are generated for example in investments such as wind farms. A model such as the Economic Futures Model is required to quantify these multiplier (flow-on) effects. In the current project, the cost ($) of the various inputs (labour, materials, machinery) is taken account of, in the cost ($) objective function; but the multiplier effect of the purchases of these inputs are not considered. It is therefore strongly recommended in future work that the EFM (or alternative economic model such as a CGE model), be integrated into the analysis in a more ‘connected up’ way – viz, connections (1) and (2) should not just be exogenous data, but be endogenised into one modelling framework.

[108] To a large extent the problem of product-mix changes can be minimised by the appropriate use of Input-Output matrices in modelling and classifying economic activities in the economy. Two practices are pertinent in this regard: (1) The conventional practice of clumping together industries, that produce similar or the same products – eg it is unlikely in the above example that analysts would add ‘garden furniture manufacturing’ and ‘brick making’. They are much more likely to add together ‘brick making’ and ‘pottery’, which have similar physical inputs; (2). The use of commodity-by-commodity (or even commodity-by-sector Input-Output matrices). When the input-output matrix is constructed in terms of commodities, this means that the ‘product-mix’ shifts are largely irrelevant. Unfortunately however in constructing commodity-based input-output tables, statisticians often apply the ‘product technology’ and ‘industry technology’ assumptions which both have their limitations. (Avonds, 2007).

Table 2.1 Projection of the 'Industrial Sector' End-Use Services Demand (Terajoules) Using GDP Scalars, 2006/7 to 2013/14 [1]

End-Use Code	End-Use Category	Years								
		2006/07	2007/08	2008/09	2009/10	2009/11	2010/11	2011/12	2012/13	2013/14
EU1	Al2O3 Reduction	7,693	7,906	8,124	8,349	8,580	8,783	8,991	9,204	9,422
EU2	Electronics and Other Electrical Uses	280	287	295	304	312	319	327	335	343
EU3	Fe3O4 Reduction	2,121	2,180	2,240	2,302	2,366	2,422	2,479	2,538	2,598
EU4	High Temperature Heat (>300 C), Process Requirements	10,467	10,757	11,054	11,360	11,674	11,950	12,233	12,523	12,820
EU5	Intermediate Heat (100-300 C), Cooking	0	0	0	0	0	0	0	0	0
EU6	Intermediate Heat (100-300 C), Process Requirements	48,215	49,548	50,917	52,325	53,771	55,045	56,349	57,685	59,052
EU7	Lighting	147	151	155	159	163	167	171	175	180
EU8	Low Temperature Heat (<100 C), Clothes Drying	0	0	0	0	0	0	0	0	0
EU9	Low Temperature Heat (<100 C), Process Requirements	3,339	3,431	3,526	3,624	3,724	3,812	3,903	3,995	4,090
EU10	Low Temperature Heat (<100 C), Space Heating	522	537	551	567	582	596	610	625	640
EU11	Low Temperature Heat (<100 C), Water Heating	2,462	2,530	2,600	2,672	2,746	2,811	2,877	2,946	3,015
EU12	Motive Power, Mobile	691	710	730	750	770	789	807	826	846
EU13	Motive Power, Stationary	14,262	14,656	15,061	15,477	15,905	16,282	16,668	17,063	17,467
EU14	Pumping	2,803	2,880	2,960	3,042	3,126	3,200	3,276	3,353	3,433
EU15	Refrigeration	5,565	5,719	5,877	6,040	6,207	6,354	6,504	6,658	6,816
EU16	Space Cooling	0	0	0	0	0	0	0	0	0
EU17	Transport, Air	49	50	51	53	54	55	57	58	60
EU18	Transport, Land	1,358	1,395	1,434	1,474	1,514	1,550	1,587	1,625	1,663
EU19	Transport, Rail	0	0	0	0	0	0	0	0	0
EU20	Transport, Sea	0	0	0	0	0	0	0	0	0
EU21	Dishwasher: Low Temperature Heat (<100 C), Water Heating	0	0	0	0	0	0	0	0	0
EU22	Spa Pools: Low Temperature Heat (<100 C), Water Heating	0	0	0	0	0	0	0	0	0
	Gross Domestic Product Scalar [2]	1.0000	1.0276	1.0560	1.0852	1.1152	1.1417	1.1687	1.1964	1.2248

Notes:

1. In the Potentials Modelling (reported in Section 8) End-Use Energy Demand Projections, continue to 2025/26. Space restriction preclude their conclusion in this Table.
2. This is the 'Target year GDP' divided by the '2006/07 GDP'. These GDP scalars are obtained from the 'Economic Futures Model'.
3. All End-Use Categories Increase by the same percentage/ratio change from year to year.
4. When analysing at the 37 sector level, the Industrial Sector level the End-Use Categories, will not have same percentage/ratio changes from year to year.
   A 37 sector analysis will be undertaken in the 'full model' stage of this project, opposed to this 'prototype' model

B.4.3 How Energy Use Demand is Driven by Sector GDP Growth

In modelling process all important ‘demand for energy end-use services’ (water heating, lighting, mechanical drive, process heat, chemical reduction etc.) is driven by GDP growth/decline in each sector.

There are a few points to be noted, concerning the ‘energy end-use services’ demand (2006/07 – 2013/14), as described by Table 2.1 illustrative example:

- It should be noted that each of the 31 energy end-uses increase by exactly the same percentage (ratio) per year. This is due to the ‘fixed energy use mix assumption’ outlined in section B.2.1.
- There are a number of ways of overcoming or reducing the effect of this constant ‘end-use mix assumption’. Firstly, as noted in the previous noted, the use of commodity-based rather than sector-based input-output matrices, will minimise the change in ‘product mix’ and hence change in ‘end-use mix’. Secondly, an analysis at a finer level of sectoral disaggregation will minimise this effect. For example, compared to the analysis undertaken in Table B.1 which is at the 5 sector aggregation, a 37 sector analysis will get closer you get to actually measuring products/commodities. Hence, the closer you get to eliminating the ‘product mix’ assumption and related problem of ‘end-use mix’ to change from year to year.

B.5 Classification Systems Used

B.5.1 Energy Classification and Definitions

OPENZ cover the following ***broad categories*** of energy in the New Zealand economy:

Primary Energy Inputs
Primary energy inputs of energy refer to the inputs of energy sources external to the economy or reference system of interest. That is, these energy inputs are either obtained from natural sources (e.g. falling water, fossil fuel in the ground, wood, geothermal steam from the wellsite), or from other countries (e.g. crude oil electricity flows across national borders). By definition these represent inward flows of energy across the system’s boundaries.

End Use Energy
These are useful energy inputs which result from end-use processes in a given economy or reference system. They include those proportions of energy actually useful to consumers. For example in cooking it includes the energy absorbed into the cooking load, but not the waste heat lost to the surrounding environment. The terms “effective”, “useful” and “final” energy are synonymous and as such are used interchangeably in the literature (World Energy Conference, 1987: D’Ermo, 1988). The term “available energy” should be avoided because of its confusion with the available energy concept used in Thermodynamics (World Energy Conference, 1987).

Unlike the primary and consumer levels, the classification of the different types of effective energy forms is more difficult and no generally accepted classification system exists. Quite often temperature is used to characterize effective outputs into different temperature bands (United Nations, 1984: Groscurth, Kummel and van Gool, 1989). Typical end-uses of energy included in such classification systems are: process heat, water heating, space heating, space cooling, refrigeration, lighting, electronics, pumping, mechanical drive, transport types and electro-chemistry end-uses.

Delivered Energy Inputs and Outputs
Delivered energy forms are intermediate between the primary energy inputs and the effective energy outputs, in the energy conversion processes that make up the reference system. Being produced from the primary energy sources, delivered energy is specifically the energy measured at its point of delivery to the location of its end-use. Delivered energy is synonymous with the term “delivered energy” which is sometime used. Although by definition delivered energy inputs can never cross the system boundary, delivered energy outputs can. For example, excess production of refined oil may be exported.

The term “secondary energy” is often used as a further distinction with the delivered energy class. Secondary energy refers to a delivered energy form that has been produced from another form of delivered energy, e.g. electricity produced from delivered coal, or manufactured gas produced from delivered coal.

B.5.1.1 Specific Definitions

Primary Energy Inputs

The following primary energy forms were considered:
(1) Hydroelectricity. This is electricity at the damsite where it is generated from falling water. This does not include the inefficiencies involved in converting falling water to electricity, due to the lack of reliable data. Hence, the systems boundary in this care is set at the point of generation.
(2) Crude Oil. This is crude oil as it is imported into New Zealand, after being obtained from overseas oil wells; and oil as it is directly obtained from indigenous oil wells.
(3) Refined Oil. This is refined oil which has been refined from crude oil, prior to its importation into New Zealand.
(4) Wellstream Gas. This is natural gas as it lies in the gas well, prior to any processing or transmission to end-use points.
(5) Mine Coal. This is coal as it lies in the coal mine site.
(6) Wellstream Geothermal. This is geothermal steam at the point where it is about to leave the earth’s crust.
(7) Primary wood. This refers to wood and/or wood residues at the point where they are produced (e.g. at forest sites or at industrial sites where wood residues are produced).
(8) Black Liquor. This is a by-product from the paper industry containing dissolved lignin, sodium sulphate and sodium carbonate amongst other chemicals. After concentration and evaporation it is combusted in a recovery boiler for steam production.

Delivered Energy Forms

The following consumer energy forms were considered:
(1) Delivered Electricity. This is electricity at the point where it has been transmitted to the point of end-use (e.g. the household, industrial and commercial premised).
(2) Delivered Gas. This is natural gas and town gas at the point where it has been refined and transmitted to the point of end-use or to the point of secondary energy conversion to electricity or synthetic petroleum.

(3) Delivered Oil. This refers to oil products (principally gasoline and diesel) after refining and at the point of end-use or at the point of secondary energy conversion to electricity.
(4) Delivered Coal. This is coal where it has been delivered to the point of end-use or to the point of secondary energy conversion to electricity.
(5) Delivered Wood (w_5). This is wood where it has been delivered to the point of end-use.
(6) Delivered Geothermal. This is geothermal steam where it has been piped to the point of end-use or to the point of secondary energy conversion to electricity.

End-Use Energy Forms

The following effective energy forms were considered, encompassing the whole range of end-uses of energy in the economy:
(1) Process Heat (≥300°C). This refers to those end-uses of heat in industrial processes where it is required at temperatures of greater than or equal to 300°C. This includes the heat requirements of processes in the iron and steel, cement, engineering and kilning industries, where heat temperatures exceeding 1000°C are often required.
(2) Process Heat (<300°C). This refers to those end-uses of heat in industrial processes where it is required at temperatures of below 300°C. This includes most of the heat used in the chemical, paper, food and textile industries.
(3) Cooking (100°-300°C). This refers to the heating of cooking loads in households, restaurants, cafes and other similar situations. It includes heat actually entering the cooking load.
(4) Water Heating (50°-70°C). This refers to the heating of water in the household and commercial sectors to relatively low temperatures.
(5) Space Heating (20°-25°C). This refers to the heating of rooms primarily in the household and commercial sectors to an acceptable environmental temperature of about 20°-25°C.
(6) Space Cooling (20°-25°C). This refers to the cooling of rooms primarily in the household and commercial sectors to an acceptable environmental temperature of about 20°-25°C.
(7) Refrigeration (<3°C). This refers to the removal of heat from refrigeration spaces (cabinets, rooms, stores), so as to attain a temperature below 3°C.
(8) Lighting. This refers to the generation of electromagnetic radiation (0.4µm-0.7µm) that can be perceived by the human eye.
(9) Electronics and Other Minor Electrical Uses. This refers to electrical energy used by electronic equipment such as televisions, radios and computers. The systems boundary is drawn at the point of electricity entering this equipment as no reliable data is available on the end-use efficiency of such equipment.
(10) Pumping. This refers to energy being applied to move a fluid along a system of pipes and valves. The systems boundary is drawn at the point of the fluid entering the pumping system under pressure, and where losses due to the electric motors operating the system are taken into account. This does not include losses in the pumping system itself; such as head losses, friction losses, and losses due to valve and joint enlargement which are all extremely difficult to quantify.
(11) Stationary Motive Power. This is mechanical energy generated mainly in industrial situation from stationery engines and motors.
(12) Land Transport. This refers to that mechanical energy required to power road and land vehicles taking full account of friction and other losses. These vehicles include automobiles, trucks, buses, motor cycles, tractors and other related vehicle types, which operate on roads and/or land surfaces.
(13) Rail Transport. This refers to that mechanical energy required to power railroad stock, taking full account of friction and other losses.

(14) Sea Transport. This refers to that mechanical energy required to power vessels that are designed to move across the surface of water bodies, taking full account of friction and other losses.
(15) Air Transport. This refers to that mechanical energy required to power aircraft, taking full account of friction and other losses. This includes both domestic aircraft, as well as aircraft traveling overseas but receiving fuel in New Zealand.
(16) Reduction of Aluminum. This refers to the electro-chemical reduction of aluminium oxides (primarily $A1_2O_3$) to elemental aluminium.
(17) Reduction of Iron Oxides. This refers to the chemical reduction of Fe_3O_4 to elemental iron.

B.5.2 ANZSIC Sectors

Table B.2 outlines the 37 sectors used in OPENZ and their corresponding ANZSIC Classifications. The following sectors at the 5 digit ANZSIC level are specifically excluded from OPENZ as they are not covered 2006/07 database: 63010 International Sea Transport, 64010 Scheduled International Air Transport, 65010 Pipeline Transport, 65090 Transport nec, 66300 Services to Air Transport, 66410 Travel Agency Services, 66440 Customs Agency Services, 67010 Grain Storage, and 67090 Storage nec. These exclusions (energy supply industries and international travel) are consistent with coverage of the 1994/95 and 2001/02 EECA databases. The following sectors are implicitly covered in OPENZ in the 'Energy Supply Module": 36100 Electricity Supply, 36200 Gas Supply.

Table B.2 2006/07 EECA Database Sector Categories, as Defined by 5 Digit *ANZSIC(96) Sectors*

Database Sector Categories	5 Digit ANZSIC(96) Sectors
Agriculture [a]	1110 to 2190, 95250
Fishing and Hunting	2200, 4110 to 4200
Forestry and Logging	3010 to 3030
Mining and Quarrying	11010 to 15200
Slaughtering and Meat Processing	21110 to 21130
Dairy Products	21210 to 21220
Other Food Processing Sectors	21290 to 21900, 51240
Textile, Apparel and Leathergoods	22110 to 22620
Wood Processing and Wood Products	23110 to 23290, 29190 to 29210, 29230 to 29290
Paper and Paper Products, Printing and Publishing	23310 to 24210, 24300
Chemicals, Related Products and Plastics	25100 to 25660
Concrete, Clay, Glass and Related Minerals Manufacture	26100 to 26400
Basic Metal Industries	27110 to 27330
Fabricated Metal Products, Machinery and Equipment	27410 to 29110, 29220, 78330
Other Manufacturing Industries	29410 to 29490
Construction	41110 to 42590
Wholesale Trade – Food	47110 to 47190
Retail Trade – Food	51101 to 51230, 51250 to 51290, 57200 to 57400
Motels, Hotels and Guest Houses	57100

Database Sector Categories	5 Digit ANZSIC(96) Sectors
Wholesale and Retail Trade – Non Food	45110 to 46240, 47210 to 47990, 52100 to 52590, 53110 to 53210, 53240 to 53290, 95110
Transport and Storage	61100 to 67090, 77410 to 77420
Communication	71110 to 71200
Financing, Insurance, Real Estate and Business Services	24220 to 24230, 73100 to 77301, 77430, 78210 to 78320, 78340 to 78640, 78670 to 78690
Sanitary and Cleaning Services	37020, 78650 to 78660, 96340
Education Services: Pre-School, Primary and Secondary	84100 to 84240, 84400, 93190
Education Services: Tertiary Education	84310 to 84320
Health and Welfare Services	86110 to 86130, 87100 to 87210
Other Social and Related Community Services	52610 to 52690, 53220 to 53230, 78100, 86210 to 86400, 87220 to 93120, 93210 to 93300, 95190 to 95240, 95260 to 96290, 97000
Central Government Administration	81110, 81200, 96310 to 96330
Local Government Administration	81130
Central Government Defence Services	82000
Water Works and Supply	37010
Household (Other)	Nil
Household (Private Transport)	Nil

Appendix C

Energy Price Default Settings in OPENZ

Default price projections for the 'exogenously determined' prices are outlined in the tables in Appendix C. Where possible the base year delivered energy prices for all sectors were obtained from data in the *Energy Data File* published by the Ministry of Economic Development (2008). Unfortunately there were a number of significant omissions in the price data in the *Energy Data File* (e.g. coal prices), that required these prices to be obtained from other sources including other published reports or internet sources. The most valuable alternative source of price data were the various reports by East Harbour Services Management (2004, 2005) and Donovan *et al.* (2009).

The future delivered energy costs were almost entirely drawn from Donovan *et al.'s* (2009) report to the Auckland Regional Council that provides a very thorough analysis of future energy prices from 2008 to 2060. This analysis by Donovan *et al.* (2009) utilizes various pricing models, in conjunction with sophisticated statistical analyses as well as judgemental inputs from industry experts. Donovan *et al.'s* (2009) price forecast, were normalised, so that they corresponded with actual delivered energy inputs for the base year.

Table C.1 Aviation Fuel Prices : Default Settings in the OPENZ Model for the Aggregated Sectors[1]

March Year Ending	Household (GJ/ $2006/07)[2]	Commercial (GJ/ $2006/07)[3]	Industrial (GJ/ $2006/07)[3]	Transport (GJ/ $2006/07)[3]
2007	48.41	41.31	37.86	34.42
2008	50.03	42.94	39.49	36.05
2009	49.24	42.14	38.70	35.26
2010	50.86	43.76	40.32	36.88
2011	52.48	45.38	41.94	38.50
2012	54.10	47.00	43.56	40.12
2013	55.72	48.63	45.18	41.74
2014	57.35	50.25	46.80	43.36
2015	58.97	51.87	48.42	44.98
2016	60.59	53.49	50.04	46.60
2017	62.21	55.11	51.66	48.22
2018	63.83	56.73	53.28	49.84
2019	65.45	58.35	54.91	51.46
2020	67.07	59.97	56.53	53.08
2021	68.69	61.59	58.15	54.70
2022	70.31	63.21	59.77	56.32
2023	71.93	64.83	61.39	57.94
2024	73.55	66.45	63.01	59.56
2025	75.17	68.07	64.63	61.19
2026	76.79	69.69	66.25	62.81

Notes:
1. Aggregated Sectors as Defined in the EECA End-Use Database
2. GST Inclusive
3. GST Exclusuve

Table C.2 Coal Prices: Default Settings for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)	Industrial (GST excl.)	Transport (GST excl.)	Imported
2007	10.69	6.84	4.06	5.45	4.06
2008	10.73	6.88	4.10	5.49	4.10
2009	10.78	6.92	4.15	5.53	4.15
2010	10.82	6.96	4.19	5.58	4.19
2011	10.86	7.00	4.23	5.62	4.23
2012	10.90	7.05	4.27	5.66	4.27
2013	10.95	7.09	4.32	5.70	4.32
2014	10.99	7.13	4.36	5.75	4.36
2015	11.03	7.17	4.40	5.79	4.40
2016	11.07	7.22	4.44	5.83	4.44
2017	11.11	7.26	4.49	5.87	4.49
2018	11.16	7.30	4.53	5.91	4.53
2019	11.20	7.34	4.57	5.96	4.57
2020	11.24	7.39	4.61	6.00	4.61
2021	11.28	7.43	4.65	6.04	4.65
2022	11.33	7.47	4.70	6.08	4.70
2023	11.37	7.51	4.74	6.13	4.74
2024	11.41	7.55	4.78	6.17	4.78
2025	11.45	7.60	4.82	6.21	4.82
2026	11.49	7.64	4.87	6.25	4.87

Table C.3 Diesel Prices: Default Settings for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)	Industrial (GST excl.)	Transport (GST excl.)
40.69	37.07	36.69	36.69	36.69
41.10	37.48	37.10	37.10	37.10
40.00	36.38	36.00	36.00	36.00
41.00	37.38	37.01	37.01	37.01
42.01	38.38	38.01	38.01	38.01
43.01	39.39	39.01	39.01	39.01
44.01	40.39	40.02	40.02	40.02
45.02	41.40	41.02	41.02	41.02
46.02	42.40	42.03	42.03	42.03
47.03	43.40	43.03	43.03	43.03
48.03	44.41	44.03	44.03	44.03
49.03	45.41	45.04	45.04	45.04
50.04	46.42	46.04	46.04	46.04
51.04	47.42	47.05	47.05	47.05
52.05	48.43	48.05	48.05	48.05
53.05	49.43	49.06	49.06	49.06
54.06	50.43	50.06	50.06	50.06
55.06	51.44	51.06	51.06	51.06
56.06	52.44	52.07	52.07	52.07
57.07	53.45	53.07	53.07	53.07

Table C.4 Fuel Oil Prices: Default Setting for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)	Industrial (GST excl.)	Transport (GST excl.)
2007	18.32	18.32	14.55	14.55
2008	18.73	18.73	14.96	14.96
2009	18.53	18.53	14.76	14.76
2010	19.02	19.02	15.26	15.26
2011	19.51	19.51	15.75	15.75
2012	20.00	20.00	16.24	16.24
2013	20.50	20.50	16.73	16.73
2014	20.99	20.99	17.22	17.22
2015	21.48	21.48	17.71	17.71
2016	21.97	21.97	18.20	18.20
2017	22.46	22.46	18.69	18.69
2018	22.95	22.95	19.19	19.19
2019	23.44	23.44	19.68	19.68
2020	23.94	23.94	20.17	20.17
2021	24.43	24.43	20.66	20.66
2022	24.92	24.92	21.15	21.15
2023	25.41	25.41	21.64	21.64
2024	25.90	25.90	22.13	22.13
2025	26.39	26.39	22.63	22.63
2026	26.88	26.88	23.12	23.12

Table C.5 LPG (Bottled) Prices: Default Setting for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)
2007	60.59	60.59
2008	62.67	62.67
2009	61.66	61.66
2010	63.08	63.08
2011	64.49	64.49
2012	65.91	65.91
2013	67.32	67.32
2014	68.74	68.74
2015	70.15	70.15
2016	71.57	71.57
2017	72.98	72.98
2018	74.40	74.40
2019	75.81	75.81
2020	77.23	77.23
2021	78.64	78.64
2022	80.06	80.06
2023	81.48	81.48
2024	82.89	82.89
2025	84.31	84.31
2026	85.72	85.72

Table C.6 LPG (Motive Power/Transport) Prices: Default Setting for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)	Industrial (GST excl.)	Transport (GST excl.)
2007	50.87	56.02	55.37	55.37
2008	52.94	58.10	57.45	57.45
2009	51.93	57.09	56.44	56.44
2010	53.35	58.51	57.86	57.86
2011	54.77	59.92	59.27	59.27
2012	56.18	61.34	60.69	60.69
2013	57.60	62.75	62.10	62.10
2014	59.01	64.17	63.52	63.52
2015	60.43	65.58	64.93	64.93
2016	61.84	67.00	66.35	66.35
2017	63.26	68.42	67.76	67.76
2018	64.67	69.83	69.18	69.18
2019	66.09	71.25	70.59	70.59
2020	67.50	72.66	72.01	72.01
2021	68.92	74.08	73.42	73.42
2022	70.33	75.49	74.84	74.84
2023	71.75	76.91	76.26	76.26
2024	73.16	78.32	77.67	77.67
2025	74.58	79.74	79.09	79.09
2026	75.99	81.15	80.50	80.50

Table C.7 Petrol Prices: Default Settings for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)	Industrial (GST excl.)	Transport (GST excl.)
2007	44.52	39.58	39.58	39.58
2008	46.39	41.45	41.45	41.45
2009	45.49	40.54	40.54	40.54
2010	46.16	41.21	41.21	41.21
2011	46.83	41.89	41.89	41.89
2012	47.51	42.56	42.56	42.56
2013	48.18	43.24	43.24	43.24
2014	48.86	43.91	43.91	43.91
2015	49.53	44.59	44.59	44.59
2016	50.21	45.26	45.26	45.26
2017	50.88	45.94	45.94	45.94
2018	51.56	46.61	46.61	46.61
2019	52.23	47.29	47.29	47.29
2020	52.91	47.96	47.96	47.96
2021	53.58	48.64	48.64	48.64
2022	54.26	49.31	49.31	49.31
2023	54.93	49.99	49.99	49.99
2024	55.61	50.66	50.66	50.66
2025	56.28	51.34	51.34	51.34
2026	56.96	52.01	52.01	52.01

Table C.8 Wood Prices: Default Setting for the for the OPENZ Model

March Year	Residential (GST incl.)	Commercial (GST excl.)	Industrial (GST excl.)	Transport (GST excl.)
2007	4.11	0.00	0.00	na
2008	4.11	0.00	0.00	na
2009	4.11	0.00	0.00	na
2010	4.11	0.00	0.00	na
2011	4.11	0.00	0.00	na
2012	4.11	0.00	0.00	na
2013	4.11	0.00	0.00	na
2014	4.11	0.00	0.00	na
2015	4.11	0.00	0.00	na
2016	4.11	0.00	0.00	na
2017	4.11	0.00	0.00	na
2018	4.11	0.00	0.00	na
2019	4.11	0.00	0.00	na
2020	4.11	0.00	0.00	na
2021	4.11	0.00	0.00	na
2022	4.11	0.00	0.00	na
2023	4.11	0.00	0.00	na
2024	4.11	0.00	0.00	na
2025	4.11	0.00	0.00	na
2026	4.11	0.00	0.00	na

Table C.9 Imported LNG Prices Default Setting for the for the OPENZ Model

March Year	Inputs into Energy Supply Industires
2007	10.00
2008	10.24
2009	10.47
2010	10.71
2011	10.94
2012	11.18
2013	11.42
2014	11.65
2015	11.89
2016	12.12
2017	12.36
2018	12.60
2019	12.83
2020	13.07
2021	13.30
2022	13.54
2023	13.77
2024	14.01
2025	14.25
2026	14.48

Appendix D

Costings for the Household Sector Processes

Appendix D contains further data on the costings of the household sector 'technology-explicit end-use processes'. Table D.1 describes the base data supplied by EECA staff. Table D.2 described the annualised capital costs determined using the base data from Table D.1

Table D.1 (Part 1) Base Data for Capital and Equipment Costings for the Household Sector in the OPENZ Model

Process Code	New/Existing	Energy Input	Energy Output	Technology	Unit Power Rating (W)	Unit Thermal Efficiency	Unit Capital Cost ($)	Units Required per Household	Total Costs ($) of Capital Per Household	Unit Lifetime
H317 A	Existing	Coal	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	2300	0.15	8,000	1	8,000	50
H318	Existing	Coal	Low Temperature Heat (<25 C), Space Heating	Burner (Direct Heat)	1,500	0.55	4,000	1	4,000	20
H319	Existing	Coal	Low Temperature Heat (<25 C), Space Heating	Open Fire	1,500	0.10	10,000	1	10,000	50
H320	Existing	Coal	Low Temperature Heat (<25 C), Space Heating	Open Fire, with Wetback	5,000	0.40	15,000	1	15,000	50
H322	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	1,500	0.90	10,000	1	10,000	7
H323 A	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	2,300	0.16	4,000	1	4,000	15
H323 B	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Electric Stovetop	1,200	0.80	1,500	1	1,500	15
H323 D	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Microwave	800	1.00	400	1	400	8
H324_A	Existing	Electricity	Lighting	Tungsten Incandescent Lights	100	0.06	1	25	23	1
H324_B	Existing	Electricity	Lighting	Compact Fluorescent Light	25	0.25	7	25	163	7
H324_C	Existing	Electricity	Lighting	Halogen Lights	75	0.08	4	25	100	2
H324_D	New	Electricity	Lighting	LED Lights	30	0.40	80	25	2,000	30
H324_E	Existing	Electricity	Lighting	'Non-Compact' Fluorescent Light	50	0.10	10	25	250	5
H325	Existing	Electricity	Low Temperature Heat (<100 C), Clothes Drying	Clothes Dryer	1,000	0.25	659	1	659	20
H326	Existing	Electricity	Low Temperature Heat (<25 C), Space Heating	Existing Heat Pumps	2,283	2.00	2,107	1	2,107	15
H326_A	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Heat Pump 1.03 kW reverse cycle	1,030	3.03	1,395	1	1,395	15
H326_B	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Heat Pump 1.88 kW reverse cycle	1,880	2.62	2,127	1	2,127	15
H326_C	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Heat Pump 3.94 kW reverse cycle	3,940	2.38	2,800	1	2,800	15
H327_A	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Resistance Heater	1,200	1.00	50	2	100	20
H363	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Night Store	3,850	1.00	1,200	1	1,200	30
H327	Existing	Electricity	Low Temperature Heat (<25 C), Space Heating	Resistance Heater & Nightstore	1,465	1.00	165	1	165	21
H355	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Ceiling Insulation	na	na	1,500	1	1,500	50
H356	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Wall Insulation	na	na	9,913	1	9,913	50
H357	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Floor Insulation	na	na	1,973	1	1,973	50
H358	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Double Glazing	na	na	9,968	1	9,968	50
H328	New	Electricity	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with No Wrap)	4,000	0.70	1,000	1	1,000	20
H328_A	New	Electricity	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with Wrap)	4,000	0.90	1,080	1	1,080	20
H328_C	Existing	Electricity	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder	4,000	0.80	1,040	1	1,040	20
H347	Existing	Electricity	Dishwasher: Low Temp Heat (<100 C), Water Heating	Dish Washer	1,200	0.40	1,299	1	1,299	20
H329	Existing	Electricity	Motive Power, Stationary	Electric Motor	600	0.75	800	2	1,600	8
H330	Existing	Electricity	Refrigeration	Refrigeration Systems	420	0.85	1,674	1.55	2,595	20
H331	Existing	Wellhead Geothermal	Low Temperature Heat (<25 C), Space Heating	Direct Heat	2,000	1.00	1,000	1	1,000	10
H332	Existing	Wellhead Geothermal	Low Temperature Heat (50-70 C), Water Heating	Direct Heat	2,000	1.00	1,000	1	1,000	10
H333_A	New	LPG	Low Temperature Heat (<25 C), Space Heating	LPG space heating (unflued)	2,500	0.80	250	1	250	20
H333_B	New	LPG	Low Temperature Heat (<25 C), Space Heating	LPG space heating (flued)	4,500	0.70	1,500	1	1,500	20
H344_B	New	LPG	Low Temperature Heat (50-70 C), Water Heating	Instantaneous gas water heater	3,000	0.84	4,500	1	4,500	20
H333	Existing	LPG	Low Temperature Heat (<25 C), Space Heating	Burner (Direct Heat)	3,500	0.75	875	1	875	20
H334	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Ovens	2,300	0.06	1,750	1	1,750	15

Table D.1 (Part 2) Base Data for Capital and Equipment Costings for the Household Sector in the OPENZ Model

Process Code	New/Existing	Energy Input	Energy Output	Technology	Unit Power Rating (W)	Unit Thermal Efficiency	Unit Capital Cost ($)	Units Required per Household	Total Costs ($) of Capital Per Household	Unit Lifetime
H334_A	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Cooktops	1,300	0.40	1,400	1	1,400	15
H334_B	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Oven & Cooktops	2,300	0.23	1,750	1	1,750	15
H335_A	New	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Direct space heating, unflued, bayonet fitting or fixed wall mount	2,500	0.95	1,000	1	1,000	20
H335_B	New	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Direct space heating, flued	4,500	0.80	2,500	1	2,500	20
H360	New	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Central Heating	24,000	0.90	11,000	1	11,000	20
H355	Existing	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Burner (Direct Heat)	3,500	0.80	1,750	1	1,750	20
H337	Existing	Wood	Intermediate Heat (100-300 C), Cooking	Wood Cooking Oven	8,000	0.15	5,000	1	5,000	20
H338_A	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1,500	0.30	4,500	1	4,500	20
H338_B	New	Wood	Low Temp Heat (<100 C), Space Heating & Water Heat	Enclosed wood burner with wet back, space heating	14,000	0.70	5,000	1	5,000	20
H345	New	Wood	Low Temperature Heat (<25 C), Space Heating	Wood pellet stoves	8,000	0.75	5,000	1	5,000	20
H339	Existing	Wood	Low Temperature Heat (<25 C), Space Heating	Open Fire	1,500	0.10	10,000	1	10,000	50
H340	Existing	Wood	Low Temperature Heat (<25 C), Space Heating	Open Fire, with Wetback	5,000	0.40	15,000	1	15,000	40
H342_A	New	Solar (+Elect)	Low Temperature Heat (50-70 C), Water Heating	Solar water heater, electricity boosted & elect pump	4,000	0.95	7,000	1	7,000	25
H342_B	New	Solar (+Gas)	Low Temperature Heat (50-70 C), Water Heating	Solar water, heater gas boosted & elect pump	4,000	0.89	7,000	1	7,000	25
H342	Existing	Solar (Elect +Gas)	Low Temperature Heat (50-70 C), Water Heating	Solar water, heater gas/elec boosted & elect pump	4,000	0.94	7,000	1	7,000	25
H343	Existing	Electricity	Spa Pools: Low Temp Heat (<100 C), Water Heating	Water Heater	6,000	0.40	6,500	1	6,500	15
H344_A	new	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Instantaneous gas water heater	3,000	0.84	4,500	1	4,500	20
H380_A	New	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with No Wrap)	4,000	0.65	1,000	1	1,000	20
H380_B	New	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with Wrap)	4,000	0.85	1,080	1	1,080	20
H380	Existing	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Existing Technology Mix	4,000	0.75	1,040	1	1,040	20
H346_A	New	Electricity	Space Cooling[1]	Heat Pump (for Cooling, reverse Cycle)	890	2.87	1,359	1	1,359	15
H346_B	New	Electricity	Space Cooling[1]	Heat Pump (for Cooling, reverse Cycle)	1,800	2.62	2,127	1	2,127	15
H346_C	New	Electricity	Space Cooling[1]	Heat Pump (for Cooling, reverse Cycle)	4,150	2.38	2,800	1	2,800	15
H346	Existing	Electricity	Space Cooling[1+E31]	Heat Pumps	2,280	2.00	2,095	1	2,095	15
H338	Existing	Petrol	Motive Power	Internal Combustion (Lawnmower)	2,500	0.30	500	1	500	12
H363	no data	Electricity	Low Temperature Heat (<25 C), Space Heating	Ceiling heating Distributed	no data	no data	no data	1	no data	no data
H400	Existing	Diesel	Transport, Land	Internal Combustion Engine (Land Transport)	100,000	0.12	35,000	1	35,000	10
H401	Existing	LPG	Transport, Land	Internal Combustion Engine (Land Transport)	100,000	0.12	37,000	1	37,000	10

Table D.1 (Part 3) Base Data for Capital and Equipment Costings for the Household Sector in the OPENZ Model

Process Code	New/Existing	Energy Input	Energy Output	Technology	Unit Power Rating (W)	Unit Thermal Efficiency	Unit Capital Cost ($)	Units Required per Household	Total Costs ($) of Capital Per Household	Unit Lifetime
H402	Existing	Natural Gas	Transport, Land	Internal Combustion Engine (Land Transport)	100,000	0.13	37,000	1	37,000	10
H403	Existing	Petrol	Transport, Land	Internal Combustion Engine (Land Transport)	100,000	0.12	35,000	1	35,000	10
H404	Existing	Electricity	Transport, Land	Electric Motor (Land Transport)	90,000	0.95	100,000	1	100,000	10
H405	New	Electricity/Petrol	Transport, Land	Hybrid Electric Motor & Internal Combustion Engine (Land Transport)	57,000	0.62	45,000	1	45,000	10
H406	New	Ethanol 10% with Petrol	Transport, Land	Internal Combustion Engine (Land Transport)	90,000	0.12	35,000	1	35,000	10
H407	New	Pure Ethanol	Transport, Land	Internal Combustion Engine (Land Transport)	90,000	0.09	60,000	1	60,000	10
H408	New	Methanol 15% with Petrol	Transport, Land	Internal Combustion Engine (Land Transport)	90,000	0.12	35,000	1	35,000	10

Notes

1. Space Heat and Space Cooling use the same reverse cycle heat pump. Since 'space heating ' is the predominant use & 'space cooing' is the co-incident use, it could be assumed that capital cost=zero for 'space cooling'. Alternatively, 'space heating/cooling' could be pro-rated, which would result in the 'capital cost of space cooling' being very close to zero because of its very low relative use. All of this has on effect on the 'optimal mix', as there are no alternative ways of providing 'space cooling'.

Table D.2 (Part1) Capital and Equipmet Costings for the Household Sector in the OPENZ Model

Process Code	New/Existing	Energy Input	Energy Output	Technology	Annualised Total Capital Cost ($) per Household	End-Use Energy Demand per Household (MJ)	Annualised Total Capital Cost per Energy End-Use ($/GJ)	Annualised Total Capital Cost per Delivered Energy ($/GJ)
H317 A	Existing	Coal	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	807	1,095	737	111
H318	Existing	Coal	Low Temperature Heat (<25 C), Space Heating	Burner (Direct Heat)	470	7,496	63	34
H319	Existing	Coal	Low Temperature Heat (<25 C), Space Heating	Open Fire	1,009	7,496	135	13
H320	Existing	Coal	Low Temperature Heat (<25 C), Space Heating	Open Fire, with Wetback	1,513	7,496	202	81
H322	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	2,054	4,842	424	380
H323 A	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	526	1,095	480	76
H323 B	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Electric Stovetop	197	1,095	180	144
H323 D	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Microwave	75	1,095	68	68
H324_A	Existing	Electricity	Lighting	Tunsten Incandescent Lights	25	224	111	7
H324_B	Existing	Electricity	Lighting	Compact Fluorescent Light	32	224	145	36
H324_C	Existing	Electricity	Lighting	Halogen Lightis	57	224	256	21
H324_D	New	Electricity	Lighting	LED Lights	212	224	947	379
H324_E	Existing	Electricity	Lighting	'Non-Compact' Fluorescent Light	66	224	295	31
H325	Existing	Electricity	Low Temperature Heat (<100 C), Clothes Drying	Clothes Dryer	77	216	359	90
H326	Existing	Electricity	Low Temperature Heat (<25 C), Space Heating	Existing Heat Pumps	277	7,496	37	74
H326_A	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Heat Pump 1.03 kW reverse cycle	183	7,496	24	74
H326_B	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Heat Pump 1.88 kW reverse cycle	280	7,496	37	98
H326_C	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Heat Pump 3.94 kW reverse cycle	368	7,496	49	117
H327_A	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Resistance Heater	12	7,496	2	2
H363	New	Electricity	Low Temperature Heat (<25 C), Space Heating	Night Store	127	7,496	17	17
H327	Existing	Electricity	Low Temperature Heat (<25 C), Space Heating	Resistance Heater & Nightstore	19	7,496	3	3
H355	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Ceiling Insulation	151	na	na	na
H356	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Wall Insulation	1,000	na	na	na
H357	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Floor Insulation	199	na	na	na
H358	Existing	All Types	Low Temperature Heat (<25 C), Space Heating	Double Glazing	1,005	na	na	na
H328	New	Electricity	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with No Wrap)	117	10,278	11	8
H328_A	New	Electricity	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with Wrap)	127	10,278	12	11
H328_C	Existing	Electricity	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder	122	10,278	12	10
H347	Existing	Electricity	Dishwasher: Low Temp Heat (<100 C), Water Heating	Dish Washer	153	10,278	15	6
H329	Existing	Electricity	Motive Power, Stationary	Electric Motor	300	156	1927	1446
H330	Existing	Electricity	Refrigeration	Refrigeration Systems	305	3,767	81	69
H331	Existing	Wellhead Geothermal	Low Temperature Heat (<25 C), Space Heating	Direct Heat	163	1,095	149	149
H332	Existing	Wellhead Geothermal	Low Temperature Heat (50-70 C), Water Heating	Direct Heat	163	10,278	16	16
H333_A	New	LPG	Low Temperature Heat (<25 C), Space Heating	LPG space heating (unflued)	29	7,496	4	3
H333_B	New	LPG	Low Temperature Heat (<25 C), Space Heating	LPG space heating (flued)	176	7,496	24	16
H344_B	New	LPG	Low Temperature Heat (50-70 C), Water Heating	Instantaneous gas water heater	529	10,278	51	43
H333	Existing	LPG	Low Temperature Heat (<25 C), Space Heating	Burner (Direct Heat)	103	7,496	14	10
H334	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Ovens	230	1,095	210	13
H334_A	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Cooktops	184	1,095	168	67
H334_B	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Oven & Cooktops	230	1,095	210	48
H335_A	New	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Direct space heating, unflued, bayonet fitting or fixed wall mount	117	7,496	16	15
H335_B	New	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Direct space heating, flued	294	7,496	39	31
H360	New	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Central Heating	1,292	7,496	172	155

Table D.2 (Part2) Capital and Equipmet Costings for the Household Sector in the OPENZ Model

Process Code	New/Existing	Energy Input	Energy Output	Technology	Annualised Total Capital Cost ($) per Household	End-Use Energy Demand per Household (MJ)	Annualised Total Capital Cost per Energy End-Use ($/GJ)	Annualised Total Capital Cost per Delivered Energy ($/GJ)
H355	Existing	Natural Gas	Low Temperature Heat (<25 C), Space Heating	Burner (Direct Heat)	206	7,496	27	22
H337	Existing	Wood	Intermediate Heat (100-300 C), Cooking	Wood Cooking Oven	587	1,095	537	80
H338_A	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	529	7,496	71	21
H338_B	New	Wood	Low Temp Heat (<100 C), Space Heating & Water Heat	Enclosed wood burner with wet back, space heating	587	7,496	78	55
H345	New	Wood	Low Temperature Heat (<25 C), Space Heating	Wood pellet stoves	587	7,496	78	59
H339	Existing	Wood	Low Temperature Heat (<25 C), Space Heating	Open Fire	1,009	7,496	135	13
H340	Existing	Wood	Low Temperature Heat (<25 C), Space Heating	Open Fire, with Wetback	1,534	7,496	205	82
H342_A	New	Solar (+Elect)	Low Temperature Heat (50-70 C), Water Heating	Solar water heater, electricity boosted & elect pump	771	10,278	75	71
H342_B	New	Solar (+Gas)	Low Temperature Heat (50-70 C), Water Heating	Solar water, heater gas boosted & elect pump	771	10,278	75	67
H342	Existing	Solar (Elect +Gas)	Low Temperature Heat (50-70 C), Water Heating	Solar water, heater gas/elec boosted & elect pump	771	10,278	75	70
H343	Existing	Electricity	Spa Pools: Low Temp Heat (<100 C), Water Heating	Water Heater	855	3,156	271	108
H344_A	new	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Instantaneous gas water heater	529	10,278	51	43
H380_A	New	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with No Wrap)	117	10,278	11	7
H380_B	New	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Hot Water Cylinder (with Wrap)	127	10,278	12	10
H380	Existing	Natural Gas	Low Temperature Heat (50-70 C), Water Heating	Existing Technology Mix	122	10,278	12	9
H346_A	New	Electricity	Space Cooling (see note A)	Heat Pump (for Cooling, reverse Cycle)	179	4,501	40	114
H346_B	New	Electricity	Space Cooling (see note A)	Heat Pump (for Cooling, reverse Cycle)	280	4,501	62	163
H346_C	New	Electricity	Space Cooling (see note A)	Heat Pump (for Cooling, reverse Cycle)	368	4,501	82	194
H346	Existing	Electricity	Space Cooling (see note A)	Heat Pumps	275	4,501	61	122
H338	Existing	Petrol	Motive Power	Internal Combustion (Lawnmower)	73	277	265	79
H363	no data	Electricity	Low Temperature Heat (<25 C), Space Heating	Ceiling heating Distributed	no data	no data	no data	no data
H400	Existing	Diesel	Transport, Land	Internal Combustion Engine (Land Transport)	5,696	9,147	623	75
H401	Existing	LPG	Transport, Land	Internal Combustion Engine (Land Transport)	6,022	9,147	658	79
H402	Existing	Natural Gas	Transport, Land	Internal Combustion Engine (Land Transport)	6,022	9,147	658	86
H403	Existing	Petrol	Transport, Land	Internal Combustion Engine (Land Transport)	5,696	9,147	623	75
H404	Existing	Electricity	Transport, Land	Electric Motor (Land Transport)	16,275	9,147	1779	1690
H405	New	Electicity/Petrol	Transport, Land	Hybrid Electric Motor & Internal Combustion Engine (Land Transport)	7,324	9,147	801	495
H406	New	Ethanol 10% with Petrol	Transport, Land	Internal Combustion Engine (Land Transport)	5,696	9,147	623	75
H407	New	Pure Ethanol	Transport, Land	Internal Combustion Engine (Land Transport)	9,765	9,147	1068	96
H408	New	Methanol 15% with Petrol	Transport, Land	Internal Combustion Engine (Land Transport)	5,696	9,147	623	75

Note
1. Assumed Discount Rate of 10%. OPENZ can consider other Discount Rates by changing the 'Default Setting'

Appendix E

Detailed Results: Supply of Delivered Energy
- By Technology Explicit Processes

E.1 Technical Energy Savings Potential

The following pages contain four tables that describe and summarise the supply of delivered energy:

- Supply of Electricity by Technology Explicit Processes (Table E.1.1)
- Supply of Transport Fuels by Technology Explicit Processes (Table E.1.2)
- Primary Energy Sources of Generated Electricity (Table E.1.3)
- Delivered Energy Consumption (Table E.1.4)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table E.1.1 Supply of Electricity by Technology Explicit Processes: *Technical Energy Savings Potential*

Code	Existing/ New	Primary Energy Input	Energy Output	Technology	Petajoules of Generated Electricity (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
E1	Existing	Hydro	Generated Electricity	Dam, Hydro Turbine	92.33	92.33	92.33	92.33	92.33	92.33
E2	Existing	Wellhead Geothermal	Generated Electricity	Steam Turbine	12.22	12.22	12.22	12.22	12.22	12.22
E3	Existing	Biogas	Generated Electricity	Various	0.84	0.00	0.00	0.00	0.00	0.00
E4	Existing	Wood	Generated Electricity	Various	1.14	0.00	0.00	0.00	0.00	0.00
E5	Existing	Wind	Generated Electricity	Wind Turbine	2.29	2.29	2.29	2.29	2.29	2.29
E7	Existing	Natural Gas	Generated Electricity	Huntly Steam Turbine	8.68	0.00	0.00	0.00	0.00	0.00
E8	Existing	Coal	Generated Electricity	Huntly Steam Turbine	18.02	0.00	0.00	0.00	0.00	0.00
E12	Existing	Natural Gas	Generated Electricity	Cogeneration	24.81	0.00	0.00	0.00	0.00	0.00
E13	Existing	Waste Heat	Generated Electricity	Cogeneration	0.25	0.00	0.00	0.00	0.00	0.00
E15	New	Purpose Grown Wood	Generated Electricity	Various	0.00	0.29	0.36	0.36	0.36	0.36
E20	New	Mine Coal (Southland Lignite)	Generated Electricity	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	0.00	11.36	14.20	9.47	4.62	1.07
E25	New	Mine Coal (Lignite: Southland)	Generated Electricity	Supercritical Pulverised Boiler, with no Flue Gas Desulphurisation	0.00	3.41	1.45	0.00	0.00	0.00
E27	New	Mine Coal (Sub-Bituminous: North Island)	Generated Electricity	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	0.00	9.21	0.00	0.00	0.00	0.00
E31	New	Purpose Grown Wood	Generated Electricity	Various	0.00	0.82	1.02	1.02	1.02	1.02
E35	New	Purpose Grown Wood	Generated Electricity	Various	0.00	0.82	1.02	1.02	1.02	1.02
E40	New	Purpose Grown Wood	Generated Electricity	Various	0.00	3.06	3.82	3.82	3.82	3.82
Total					**160.59**	**135.80**	**128.72**	**122.54**	**117.69**	**114.14**

NB: Table E1.1.1 measures Petajoules of generated electricity. Process G1 converts ‘generated electricity’ to ‘delivered electricity’ at an efficiency of 92%

Table E.1.2 Supply of Transport Fuels by Technology Explicit Processes: ***Technical Energy Savings Potential***

Code	Existing /New	Primary Energy Input	Energy Output	Technology	Petajoules of Generated Electricity (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
T1	Existing	Crude Oil	Petrol	Oil Refinery	68.93	82.77	81.21	64.11	46.14	31.39
T2	Existing	Imported Petrol	Petrol	Tanker Delivery	47.03	0.00	0.00	0.00	0.00	0.00
T3	Existing	Crude Oil	Diesel	Oil Refinery	71.21	45.61	31.06	31.68	31.90	31.81
T4	Existing	Imported Diesel	Diesel	Tanker Delivery	46.46	0.00	0.00	0.00	0.00	0.00
T5	Existing	Crude Oil	Aviation Fuel	Oil Refinery	17.94	17.81	18.13	18.38	18.57	18.65
T7	Existing	Wellhead LPG	LPG	Tanker Delivery	8.41	10.80	10.80	8.05	8.80	9.98
T8	Existing	Imported LPG	LPG	Tanker Delivery	0.20	1.36	0.12	0.00	0.00	0.00
T9	New	Fodder Beat	Ethanol	Fermentation	0.00	8.42	16.72	25.02	30.00	30.00
T11	New	Radiata Pine	Methanol	Gasification	0.00	0.84	1.45	2.18	2.90	3.45
T14	New	Maize	Ethanol	Enzyme Hydrolysis followed by Fermentation	0.00	0.00	0.00	0.00	0.00	4.30
T15	New	Eucalyptus	Diesel	FAME (transesterification)	0.00	24.00	30.00	30.00	30.00	30.00
T16	New	Eucalyptus	Diesel	HTU	0.00	24.00	30.00	30.00	30.00	30.00
T17	New	Eucalyptus	Diesel	Gastification	0.00	21.98	9.55	9.05	8.54	8.16
Total[A]					**260.18**	**237.58**	**229.04**	**218.46**	**206.86**	**197.75**

Table E.1.3 Primary Energy Sources of Generated Electricity (PJ)
Technical Energy Savings Potential

Year	Total	Hydro	Natural Gas	Coal	Geothermal	Wind	Fuel Oil	Biogas	Wood	Waste Heat
2007	160.59	92.33	33.49	18.02	12.22	2.29	0.00	0.84	1.14	0.25
2008	130.58	99.11	2.27	10.09	15.26	2.29	0.00	0.00	1.40	0.15
2009	138.19	98.46	0.00	16.47	18.29	2.29	0.00	0.00	2.51	0.15
2010	136.85	92.33	0.00	22.15	16.19	2.29	0.00	0.00	3.73	0.15
2011	135.80	92.33	0.00	23.98	12.22	2.29	0.00	0.00	4.97	0.00
2012	133.33	92.33	0.00	20.27	12.22	2.29	0.00	0.00	6.22	0.00
2013	131.70	92.33	0.00	18.63	12.22	2.29	0.00	0.00	6.22	0.00
2014	130.21	92.33	0.00	17.15	12.22	2.29	0.00	0.00	6.22	0.00
2015	128.72	92.33	0.00	15.65	12.22	2.29	0.00	0.00	6.22	0.00
2016	127.43	92.33	0.00	14.36	12.22	2.29	0.00	0.00	6.22	0.00
2017	126.02	92.33	0.00	12.95	12.22	2.29	0.00	0.00	6.22	0.00
2018	124.33	92.33	0.00	11.26	12.22	2.29	0.00	0.00	6.22	0.00
2019	122.54	92.33	0.00	9.47	12.22	2.29	0.00	0.00	6.22	0.00
2020	121.24	92.33	0.00	8.17	12.22	2.29	0.00	0.00	6.22	0.00
2021	119.92	92.33	0.00	6.85	12.22	2.29	0.00	0.00	6.22	0.00
2022	118.80	92.33	0.00	5.73	12.22	2.29	0.00	0.00	6.22	0.00
2023	117.69	92.33	0.00	4.62	12.22	2.29	0.00	0.00	6.22	0.00
2024	116.48	92.33	0.00	3.41	12.22	2.29	0.00	0.00	6.22	0.00
2025	115.28	92.33	0.00	2.21	12.22	2.29	0.00	0.00	6.22	0.00
2026	114.14	92.33	0.00	1.07	12.22	2.29	0.00	0.00	6.22	0.00
Growth Rate (2007- 2026)	**-28.9%**	**0.0%**	**n.a.**	**-94.1%**	**0.0%**	**0.0%**	**n.a.**	**n.a.**	**444.4%**	**n.a.**
Average Growth Rate (2007- 2026)	**-1.8%**	**0.0%**	**n.a.**	**-13.8%**	**0.0%**	**0.0%**	**n.a.**	**n.a.**	**9.3%**	**n.a.**

NB: Table E1.1.3 measures Petajoules of generated electricity. Process G1 converts 'generated electricity' to 'delivered electricity' at an efficiency of 92%

Table E.1.4 Delivered Energy Consumption (PJ, Heat Units):
Technical Energy Savings Potential

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethanol	Methanol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	530.48	130.29	97.04	113.35	17.46	38.20	7.29	9.18	52.43	38.84	24.09	2.10	0.21
2009	533.86	127.98	89.28	118.13	17.58	35.36	6.67	10.28	59.10	39.86	25.00	4.21	0.42
2010	537.79	126.48	83.21	121.70	17.69	33.40	6.50	11.12	65.69	40.07	25.00	6.31	0.63
2011	541.64	124.96	83.28	119.15	17.81	31.89	5.75	12.19	72.25	40.09	25.00	8.42	0.84
2012	543.84	122.67	85.07	114.31	17.89	31.18	5.45	11.78	78.81	40.12	25.00	10.52	1.05
2013	545.66	121.16	86.89	109.45	17.98	30.26	5.16	11.86	83.94	40.14	25.00	12.62	1.18
2014	551.36	119.80	86.86	108.66	18.05	29.67	5.10	11.56	90.69	40.00	25.00	14.70	1.27
2015	550.88	118.42	83.33	110.17	18.13	29.47	5.15	10.99	97.51	34.55	25.00	16.72	1.45
2016	552.43	117.23	79.77	111.53	18.20	29.46	5.15	9.99	104.05	31.66	25.00	18.77	1.63
2017	553.40	115.94	75.96	112.84	18.26	29.57	5.20	8.60	110.54	28.81	25.00	20.85	1.81
2018	554.74	114.38	72.11	114.15	18.32	29.68	5.25	8.18	116.70	26.02	25.00	22.94	2.00
2019	556.33	112.73	68.22	115.45	18.38	29.71	5.30	8.16	122.88	23.29	25.00	25.02	2.18
2020	557.90	111.54	64.32	116.73	18.44	28.87	5.35	8.51	129.05	20.62	25.00	27.11	2.36
2021	559.45	110.33	60.40	118.00	18.49	28.04	5.40	8.80	135.25	18.01	25.00	29.20	2.54
2022	560.62	109.30	56.24	119.20	18.53	27.32	5.45	8.67	141.44	16.75	25.00	30.00	2.72
2023	562.67	108.28	52.02	120.39	18.57	26.50	5.50	8.96	147.56	17.00	25.00	30.00	2.90
2024	565.73	107.16	47.75	121.54	18.60	25.92	5.55	9.67	153.39	17.24	25.00	30.81	3.09
2025	569.13	106.05	43.42	122.66	18.63	25.36	5.60	9.83	159.26	17.49	25.00	32.56	3.27
2026	572.89	105.01	39.21	123.75	18.65	24.80	5.65	10.18	165.15	17.73	25.00	34.30	3.45
Growth Rate	-0.48%	-28.95%	-66.19%	5.17%	3.95%	-45.54%	-31.72%	18.18%	225.49%	-56.26%	10.78%	n.a.	n.a.
Average Growth Rate	-0.03%	-1.78%	-5.55%	0.27%	0.20%	-3.15%	-1.99%	0.88%	6.41%	-4.26%	0.54%	n.a.	n.a.

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even those this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

E.2 Economic Energy Savings Potential

The following pages contain four tables that describe and summarise the supply of delivered energy:

- Supply of Electricity by Technology Explicit Processes (Table E.2.1)
- Supply of Transport Fuels by Technology Explicit Processes (Table E.2.2)
- Primary Energy Sources of Generated Electricity (Table E.2.3)
- Delivered Energy Consumption (Table E.2.4)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table E.2.1 Supply of Electricity by Technology Explicit Processes: *Economic Energy Savings Potential*

Code	Existing/ New	Primary Energy Input	Energy Output	Technology	Petajoules of Generated Electricity (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
E1	Existing	Hydro	Generated Electricit	Dam, Hydro Turbine	92.33	92.33	92.33	92.33	92.33	92.33
E2	Existing	Wellhead Geothermal	Generated Electricit	Steam Turbine	12.22	12.22	12.22	12.22	12.22	12.22
E3	Existing	Biogas	Generated Electricit	Various	0.84	0.84	0.84	0.84	0.84	0.84
E4	Existing	Wood	Generated Electricit	Various	1.14	1.14	1.14	0.00	0.00	0.00
E5	Existing	Wind	Generated Electricit	Wind Turbine	2.29	2.29	2.29	2.29	2.29	2.29
E7	Existing	Natural Gas	Generated Electricit	Huntly Steam Turbine	8.68	0.00	0.00	0.00	0.00	0.00
E8	Existing	Coal	Generated Electricit	Huntly Steam Turbine	18.02	10.08	2.75	0.00	0.00	0.00
E11	Existing	Coal	Generated Electricit	Cogeneration	0.00	2.10	2.10	2.10	2.10	2.10
E12	Existing	Natural Gas	Generated Electricit	Cogeneration	24.81	0.00	0.00	0.00	0.00	0.00
E13	Existing	Waste Heat	Generated Electricit	Cogeneration	0.25	0.15	0.15	0.15	0.15	0.15
E14	New	Wellhead Geothermal	Generated Electricit	Steam Turbine	0.00	0.58	0.72	0.72	0.72	0.72
E15	New	Purpose Grown Wood	Generated Electricit	Various	0.00	0.29	0.36	0.36	0.36	0.36
E16	New	Wellhead Geothermal	Generated Electricit	Steam Turbine	0.00	4.77	5.96	5.96	5.96	5.96
E17	New	Wind	Generated Electricit	Wind Turbine	0.00	11.84	14.80	14.80	14.80	14.80
E18	New	Natural Gas	Generated Electricit	Combined Cycle Advanced Gas Turbine	0.00	9.09	11.36	0.00	0.00	0.00
Total					**160.59**	**147.72**	**147.03**	**131.77**	**131.77**	**131.77**

NB: Table E1.1.1 measures Petajoules of generated electricity. Process G1 converts 'generated electricity' to 'delivered electricity' at an efficiency of 92%

Table E.2.2 Supply of Transport Fuels by Technology Explicit Processes: ***Economic Energy Savings Potential***

Code	Existing/ New	Primary Energy Input	Delevered Energy	Technology	Petajoules of Delivered Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
T1	Existing	Crude Oil	Petrol	Oil Refinery	68.93	82.77	43.57	34.42	24.48	25.34
T2	Existing	Imported Petrol	Petrol	Tanker Delivery	47.03	13.56	0.00	0.00	0.00	0.00
T3	Existing	Crude Oil	Diesel	Oil Refinery	71.21	93.90	101.64	110.02	119.09	68.37
T4	Existing	Imported Diesel	Diesel	Tanker Delivery	46.46	28.29	28.98	28.95	0.00	0.00
T5	Existing	Crude Oil	Aviation Fuel	Oil Refinery	17.94	17.81	18.13	18.38	18.57	18.65
T6	Existing	Imported Aviation Fuel	Aviation Fuel	Tanker Delivery	0.00	0.00	0.00	0.00	0.00	0.00
T7	Existing	Wellhead LPG	LPG	Tanker Delivery	8.41	0.82	0.35	0.00	0.00	0.00
T8	Existing	Imported LPG	LPG	Tanker Delivery	0.20	0.00	0.00	0.00	0.00	0.00
T9	New	Fodder Beat	Ethanol	Fermentation	0.00	0.07	0.15	0.22	0.30	0.30
T19	New	Mine Coal (Lignite: Southland)	Diesel	Fischer-Tropsch	0.00	0.00	0.00	0.00	27.06	44.69
T20	New	Mine Coal (Lignite: Southland)	Petrol	Fischer-Tropsch	0.00	0.00	44.69	44.69	44.69	44.69
Total[A]					260.18	237.23	237.51	236.68	234.18	202.04

Table E.2.3 Primary Energy Sources of Generated Electricity (PJ): *Economic Energy Savings Potential*

Year	Total	Hydro	Natural Gas	Coal	Geotherm al	Wind	Fuel Oil	Biogas	Wood	Waste Heat
2007	160.59	92.33	33.49	18.02	12.22	2.29	0.00	0.84	1.14	0.25
2008	140.47	92.33	27.08	3.25	13.56	2.29	0.00	0.84	0.97	0.15
2009	144.64	92.33	25.08	2.10	14.90	8.21	0.00	0.84	1.03	0.15
2010	145.99	92.33	6.82	17.10	16.23	11.17	0.00	0.84	1.36	0.15
2011	147.72	92.33	9.09	12.18	17.57	14.13	0.00	0.84	1.43	0.15
2012	147.84	92.33	11.36	5.66	18.91	17.09	0.00	0.84	1.50	0.15
2013	147.88	92.33	11.36	5.70	18.91	17.09	0.00	0.84	1.50	0.15
2014	147.70	92.33	11.36	5.52	18.91	17.09	0.00	0.84	1.50	0.15
2015	147.03	92.33	11.36	4.85	18.91	17.09	0.00	0.84	1.50	0.15
2016	146.62	92.33	11.36	4.44	18.91	17.09	0.00	0.84	1.50	0.15
2017	145.89	92.33	11.36	3.73	18.91	17.09	0.00	0.84	1.48	0.15
2018	145.22	92.33	0.00	14.45	18.91	17.09	0.00	0.84	1.46	0.15
2019	144.60	92.33	0.00	2.10	18.91	29.92	0.00	0.84	0.36	0.15
2020	144.07	92.33	0.00	2.10	18.91	29.39	0.00	0.84	0.36	0.15
2021	143.54	92.33	0.00	2.10	18.91	28.86	0.00	0.84	0.36	0.15
2022	143.08	92.33	0.00	2.10	18.91	28.40	0.00	0.84	0.36	0.15
2023	142.62	92.33	0.00	2.10	18.91	27.94	0.00	0.84	0.36	0.15
2024	142.17	92.33	0.00	2.10	18.91	27.49	0.00	0.84	0.36	0.15
2025	141.87	92.33	0.00	2.10	18.91	27.19	0.00	0.84	0.36	0.15
2026	141.56	92.33	0.00	2.10	18.91	26.87	0.00	0.84	0.36	0.15
Growth Rate	-11.85%	0.00%	n.a	-88.35%	54.66%	1071.10%	0.00%	0.00%	-68.48%	-40.90%
Average Growth Rate	-0.66%	0.00%	n.a	-10.70%	2.32%	13.83%	0.00%	0.00%	-5.90%	-2.73%

NB: Table E1.1.3 measures Petajoules of generated electricity. Process G1 converts 'generated electricity' to 'delivered electricity' at an efficiency of 92%

Table E.2.4 Delivered Energy Consumption (PJ, Heat Units): *Economic Energy Savings Potential*

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	535.11	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	0.00	22.57	0.00	0.00
2008	497.36	133.22	102.10	116.13	17.46	47.15	8.22	3.44	45.54	0.00	24.09	0.03	0.01
2009	502.98	133.92	100.00	118.89	17.58	50.42	8.21	1.66	47.26	0.00	25.00	0.04	0.00
2010	510.80	134.89	98.49	122.30	17.69	53.71	8.57	1.48	48.61	0.00	25.00	0.06	0.00
2011	518.42	136.18	96.84	125.76	17.81	56.73	8.92	0.93	50.17	0.00	25.00	0.07	0.00
2012	523.86	136.06	94.89	128.94	17.89	59.60	9.27	0.84	51.28	0.00	25.00	0.09	0.00
2013	529.66	136.05	93.20	131.66	17.98	62.47	9.62	0.74	52.83	0.00	25.00	0.11	0.00
2014	535.47	135.88	91.25	134.80	18.05	65.34	9.96	0.56	54.49	0.00	25.00	0.13	0.00
2015	541.09	135.27	89.30	137.93	18.13	68.21	10.31	0.59	56.21	0.00	25.00	0.15	0.00
2016	546.62	134.89	87.33	141.05	18.20	71.08	10.66	0.27	57.98	0.00	25.00	0.17	0.00
2017	551.99	134.21	85.13	144.13	18.26	73.80	11.00	0.31	59.96	0.00	25.00	0.18	0.00
2018	557.45	133.61	82.90	147.20	18.32	76.49	11.35	0.34	62.03	0.00	25.00	0.20	0.00
2019	562.99	133.03	80.66	150.05	18.38	79.18	11.69	0.38	64.38	0.00	25.00	0.22	0.00
2020	568.89	132.54	78.66	152.80	18.44	81.88	12.04	0.42	66.88	0.00	25.00	0.24	0.00
2021	575.00	132.06	76.87	155.76	18.49	84.57	12.38	0.46	69.16	0.00	25.00	0.26	0.00
2022	580.28	131.64	74.95	158.17	18.53	87.28	12.72	0.50	71.21	0.00	25.00	0.28	0.00
2023	585.93	131.21	73.16	160.89	18.57	89.99	13.01	0.55	73.26	0.00	25.00	0.30	0.00
2024	591.59	130.80	71.34	163.57	18.60	92.63	13.33	0.59	75.40	0.00	25.00	0.31	0.00
2025	597.36	130.52	69.51	166.21	18.63	95.26	13.67	0.64	77.61	0.00	25.00	0.31	0.00
2026	603.13	130.23	76.14	160.33	18.65	97.89	14.00	0.69	79.89	0.00	25.00	0.30	0.00
Growth Rate	12.71%	-11.89%	-34.34%	36.26%	3.95%	114.93%	69.23%	-92.04%	57.45%	0.00%	10.78%	n.a	n.a
Average Growth Rate	0.63%	-0.66%	-2.19%	1.64%	0.20%	4.11%	2.81%	-12.47%	2.42%	0.00%	0.54%	n.a	n.a

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even those this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

E.3 Realisable Energy Savings Potential

The following pages contain four tables that describe and summarise the supply of delivered energy:

- Supply of Electricity by Technology Explicit Processes (Table E.3.1)
- Supply of Transport Fuels by Technology Explicit Processes (Table E.3.2)
- Primary Energy Sources of Generated Electricity (Table E.3.3)
- Delivered Energy Consumption (Table E.3.4)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded being recorded here.

Table E.3.1 Supply of Electricity by Technology Explicit Processes: *Realisable Energy Savings Potential*

Code	Existing/ New	Primary Energy Input	Energy Output	Technology	Petajoules of Generated Electricity (for each year)					
					2007	2011	2015	2019	2023	2026
E1	Existing	Hydro	Generated Electricity	Dam, Hydro Turbine	92.33	92.33	92.33	92.33	92.33	92.33
E2	Existing	Wellhead Geothermal	Generated Electricity	Steam Turbine	12.22	12.22	12.22	12.22	12.22	12.22
E3	Existing	Biogas	Generated Electricity	Various	0.84	0.84	0.84	0.84	0.84	0.84
E4	Existing	Wood	Generated Electricity	Various	1.14	0.87	0.77	0.85	1.00	0.00
E5	Existing	Wind	Generated Electricity	Wind Turbine	2.29	2.29	2.29	2.29	2.29	2.29
E6	Existing	Fuel Oil	Generated Electricity	Steam Turbine	0.00	0.00	0.00	0.00	0.00	0.00
E7	Existing	Natural Gas	Generated Electricity	Huntly Steam Turbine	8.68	0.00	0.00	0.00	0.00	0.00
E8	Existing	Coal	Generated Electricity	Huntly Steam Turbine	18.02	25.25	25.25	23.84	25.25	25.25
E11	Existing	Coal	Generated Electricity	Cogeneration	0.00	2.10	2.10	2.10	2.10	2.10
E12	Existing	Natural Gas	Generated Electricity	Cogeneration	24.81	0.00	0.00	0.00	0.00	0.00
E13	Existing	Waste Heat	Generated Electricity	Cogeneration	0.25	0.15	0.15	0.15	0.15	0.15
E14	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	0.58	0.72	0.72	0.72	0.72
E15	New	Purpose Grown Wood	Generated Electricity	Various	0.00	0.29	0.36	0.36	0.36	0.36
E16	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	4.77	5.96	5.96	5.96	5.96
E17	New	Wind	Generated Electricity	Wind Turbine	0.00	11.84	14.80	14.80	14.80	14.80
E18	New	Natural Gas	Generated Electricity	Combined Cycle Advanced Gas Turbine	0.00	9.09	11.36	0.00	0.00	0.00
E20	New	Mine Coal (Southland Lignite)	Generated Electricity	Supercritical Pulverised Boiler, including Flue Gas Desulphurisation	0.00	0.00	0.00	0.00	5.72	12.67
E22	New	Hydro	Generated Electricity	Dam, Hydro Turbine	0.00	0.68	0.94	0.94	0.94	0.94
E23	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	0.00	0.00	7.66	7.66	7.66
E24	New	Wind	Generated Electricity	Wind Turbine	0.00	0.00	0.93	13.97	13.97	13.97
Total					**160.59**	**163.29**	**171.02**	**179.03**	**186.31**	**192.26**

NB: Table E1.1.1 measures Petajoules of generated electricity. Process G1 converts 'generated electricity' to 'delivered electricity' at an efficiency of 92%

Table E.3.2 Supply of Transport Fuels by Technology Explicit Processes: *Realisable Energy Savings Potential*

Code	Existing/ New	Primary Energy Inp	Delivered Energy	Technology	Petajoules of Delivered Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
T1	Existing	Crude Oil	Petrol	Oil Refinery	68.93	82.77	62.64	64.06	65.48	66.37
T2	Existing	Imported Petrol	Petrol	Tanker Delivery	47.03	24.72	0.00	0.00	0.00	0.00
T3	Existing	Crude Oil	Diesel	Oil Refinery	71.21	93.90	101.64	110.02	119.09	74.35
T4	Existing	Imported Diesel	Diesel	Tanker Delivery	46.46	25.17	25.85	24.72	0.00	0.00
T5	Existing	Crude Oil	Aviation Fuel	Oil Refinery	17.94	18.32	19.23	20.17	21.12	21.85
T6	Existing	Imported Aviation Fuel	Aviation Fuel	Tanker Delivery	0.00	0.00	0.00	0.00	0.00	0.00
T7	Existing	Wellhead LPG	LPG	Tanker Delivery	8.41	5.07	2.91	2.16	2.25	2.47
T8	Existing	Imported LPG	LPG	Tanker Delivery	0.20	0.00	0.00	0.00	0.00	0.00
T9	New	Fodder Beat	Ethanol	Fermentation	0.00	0.26	0.52	0.79	1.05	1.24
T10	New	Radiata Pine	Methanol	Gasification	0.00	0.39	0.73	1.09	1.45	1.72
T16	New	Eucalyptus	Diesel	HTU	0.00	0.00	0.00	0.00	0.00	30.00
T19	New	Mine Coal (Lignite: Southland)	Diesel	Fischer-Tropsch	0.00	0.00	0.00	0.00	23.27	44.69
T20	New	Mine Coal (Lignite: Southland)	Petrol	Fischer-Tropsch	0.00	0.00	44.69	44.69	44.69	44.69
Total[A]					260.18	250.62	258.21	267.70	278.39	287.39

Table E.3.3 Primary Energy Sources of Generated Electricity (PJ)
Realisable Energy Savings Potential

Year	Total	Hydro	Natural Gas	Coal	Geothermal	Wind	Fuel Oil	Biogas	Wood	Waste Heat
2007	160.59	92.33	33.49	18.02	12.22	2.29	0.00	0.84	1.14	0.25
2008	151.57	92.33	27.08	14.82	13.56	2.29	0.00	0.84	0.50	0.15
2009	157.43	92.33	29.35	10.66	14.90	8.21	0.00	0.84	0.99	0.15
2010	160.43	92.33	6.82	27.35	16.23	15.60	0.00	0.84	1.11	0.15
2011	163.29	93.01	9.09	27.35	17.57	14.13	0.00	0.84	1.16	0.15
2012	165.53	92.33	11.36	23.66	18.91	17.09	0.00	0.84	1.20	0.15
2013	167.31	92.33	11.36	25.46	18.91	17.09	0.00	0.84	1.18	0.15
2014	169.24	92.33	11.36	27.35	18.91	17.15	0.00	0.84	1.16	0.15
2015	171.02	93.27	11.36	27.35	18.91	18.02	0.00	0.84	1.13	0.15
2016	173.00	93.27	11.36	27.35	18.91	20.03	0.00	0.84	1.11	0.15
2017	174.85	93.27	0.00	27.35	21.10	31.06	0.00	0.84	1.08	0.15
2018	176.92	93.27	0.00	27.35	23.13	31.06	0.00	0.84	1.12	0.15
2019	179.03	93.27	0.00	25.94	26.57	31.06	0.00	0.84	1.21	0.15
2020	180.89	93.27	0.37	27.35	26.57	31.06	0.00	0.84	1.29	0.15
2021	182.68	93.27	0.00	29.42	26.57	31.06	0.00	0.84	1.38	0.15
2022	184.20	93.27	0.00	31.04	26.57	31.06	0.00	0.84	1.28	0.15
2023	186.31	93.27	0.00	33.07	26.57	31.06	0.00	0.84	1.36	0.15
2024	188.32	93.27	0.00	36.08	26.57	31.06	0.00	0.84	0.36	0.15
2025	190.28	93.27	0.00	38.03	26.57	31.06	0.00	0.84	0.36	0.15
2026	192.26	93.27	0.00	40.02	26.57	31.06	0.00	0.84	0.36	0.15
Growth Rate	19.7%	1.0%	n.a	122.1%	117.4%	1253.5%	n.a	n.a	-68.5%	-40.9%
Average Growth Rate	1.0%	0.1%	n.a	4.3%	4.2%	14.7%	n.a	n.a	-5.9%	-2.7%

NB: Table E1.1.3 measures Petajoules of generated electricity. Process G1 converts ‘generated electricity’ to ‘delivered electricity’ at an efficiency of 92%

Table E.3.4 Delivered Energy Consumption (PJ, Heat Units):
Realisable Energy Savings Potential

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	530.63	133.22	102.10	116.13	17.46	47.15	8.22	3.44	45.54	33.27	24.09	0.03	0.01
2009	536.30	133.92	100.00	118.89	17.58	50.42	8.21	1.66	47.26	33.32	25.00	0.04	0.00
2010	541.41	134.89	98.49	122.30	17.69	53.71	8.57	1.48	48.61	30.61	25.00	0.06	0.00
2011	549.07	136.18	96.84	125.76	17.81	56.73	8.92	0.93	50.17	30.66	25.00	0.07	0.00
2012	554.68	136.06	94.89	128.94	17.89	59.60	9.27	0.84	51.28	30.82	25.00	0.09	0.00
2013	560.65	136.05	93.20	131.66	17.98	62.47	9.62	0.74	52.83	30.99	25.00	0.11	0.00
2014	566.62	135.88	91.25	134.80	18.05	65.34	9.96	0.56	54.49	31.15	25.00	0.13	0.00
2015	572.40	135.27	89.30	137.93	18.13	68.21	10.31	0.59	56.21	31.32	25.00	0.15	0.00
2016	578.10	134.89	87.33	141.05	18.20	71.08	10.66	0.27	57.98	31.48	25.00	0.17	0.00
2017	583.64	134.21	85.13	144.13	18.26	73.80	11.00	0.31	59.96	31.65	25.00	0.18	0.00
2018	589.26	133.61	82.90	147.20	18.32	76.49	11.35	0.34	62.03	31.82	25.00	0.20	0.00
2019	594.97	133.03	80.66	150.05	18.38	79.18	11.69	0.38	64.38	31.99	25.00	0.22	0.00
2020	601.05	132.54	78.66	152.80	18.44	81.88	12.04	0.42	66.88	32.15	25.00	0.24	0.00
2021	607.32	132.06	76.87	155.76	18.49	84.57	12.38	0.46	69.16	32.32	25.00	0.26	0.00
2022	612.77	131.64	74.95	158.17	18.53	87.28	12.72	0.50	71.21	32.49	25.00	0.28	0.00
2023	618.59	131.21	73.16	160.89	18.57	89.99	13.01	0.55	73.26	32.66	25.00	0.30	0.00
2024	624.41	130.80	71.34	163.57	18.60	92.63	13.33	0.59	75.40	32.83	25.00	0.31	0.00
2025	630.36	130.52	69.51	166.21	18.63	95.26	13.67	0.64	77.61	33.00	25.00	0.31	0.00
2026	636.30	130.23	76.14	160.33	18.65	97.89	14.00	0.69	79.89	33.17	25.00	0.30	0.00
Growth Rate	**10.54%**	**-11.89%**	**-34.34%**	**36.26%**	**3.95%**	**114.93%**	**69.23%**	**-92.04%**	**57.45%**	**-18.19%**	**10.78%**	**n.a**	**n.a**
Average Growth Rate	**0.53%**	**-0.66%**	**-2.19%**	**1.64%**	**0.20%**	**4.11%**	**2.81%**	**-12.47%**	**2.42%**	**-1.05%**	**0.54%**	**n.a**	**n.a**

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even those this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

E.4 Greenhouse Gas Reductions Potential

The following pages contain four tables that describe and summarise the supply of delivered energy:

- Supply of Electricity by Technology Explicit Processes (Table E.4.1)
- Supply of Transport Fuels by Technology Explicit Processes (Table E.4.2)
- Primary Energy Sources of Generated Electricity (Table E.4.3)
- Delivered Energy Consumption (Table E.4.4)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table E.4.1 Supply of Electricity by Technology Explicit Processes: *Greenhouse Gas Reductions Potential*

Code	Existing/ New	Primary Energy Input	Energy Output	Technology	Petajoules of Generated Electricity (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
E1	Existing	Hydro	Generated Electricity	Dam, Hydro Turbine	92.33	92.33	92.33	92.33	92.33	92.33
E2	Existing	Wellhead Geothermal	Generated Electricity	Steam Turbine	12.22	12.22	12.22	12.22	12.22	12.22
E3	Existing	Biogas	Generated Electricity	Various	0.84	0.00	0.00	0.00	0.00	0.00
E4	Existing	Wood	Generated Electricity	Various	1.14	0.00	0.00	0.00	0.00	0.00
E5	Existing	Wind	Generated Electricity	Wind Turbine	2.29	2.29	2.29	2.29	2.29	2.29
E6	Existing	Fuel Oil	Generated Electricity	Steam Turbine	0.00	0.00	0.00	0.00	0.00	0.00
E7	Existing	Natural Gas	Generated Electricity	Huntly Steam Turbine	8.68	0.00	0.00	0.00	0.00	0.00
E8	Existing	Coal	Generated Electricity	Huntly Steam Turbine	18.02	0.00	0.00	0.00	0.00	0.00
E11	Existing	Coal	Generated Electricity	Cogeneration	0.00	0.00	0.00	0.00	0.00	0.00
E12	Existing	Natural Gas	Generated Electricity	Cogeneration	24.81	0.00	0.00	0.00	0.00	0.00
E13	Existing	Waste Heat	Generated Electricity	Cogeneration	0.25	0.15	0.15	0.15	0.15	0.15
E14	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	0.00	0.00	0.00	0.72	0.72
E16	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	0.00	0.00	5.95	5.96	5.96
E17	New	Wind	Generated Electricity	Wind Turbine	0.00	8.77	4.26	6.02	7.63	8.94
E22	New	Hydro	Generated Electricity	Dam, Hydro Turbine	0.00	0.75	0.94	0.94	0.94	0.94
E23	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	0.00	3.07	7.66	7.66	7.66
E24	New	Wind	Generated Electricity	Wind Turbine	0.00	11.17	13.97	13.97	13.97	13.97
E32	New	Hydro	Generated Electricity	Dam, Hydro Turbine	0.00	11.51	14.38	14.38	14.38	14.38
E33	New	Wellhead Geothermal	Generated Electricity	Steam Turbine	0.00	0.49	0.82	0.82	0.82	0.82
E34	New	Wind	Generated Electricity	Wind Turbine	0.00	6.67	8.33	8.33	8.33	8.33
E36	New	Hydro	Generated Electricity	Dam/ Hydro Turbine	0.00	1.77	2.21	2.21	2.21	2.21
E37	New	Wind	Generated Electricity	Wind Turbine	0.00	4.29	5.36	5.36	5.36	5.36
E38	New	Hydro	Generated Electricity	Dam, Hydro Turbine	0.00	6.55	8.19	8.19	8.19	8.19
E39	New	Wind	Generated Electricity	Wind Turbine	0.00	2.72	3.40	3.40	3.40	3.40
E41	New	Hydro	Generated Electricity	Dam, Hydro Turbine	0.00	6.55	8.19	8.19	8.19	8.19
Total					**160.59**	**168.25**	**180.13**	**192.44**	**194.78**	**196.08**

NB: Table E1.1.1 measures Petajoules of generated electricity. Process G1 converts ‘generated electricity’ to ‘delivered electricity’ at an efficiency of 92%

Table E.4.2 Supply of Transport Fuels by Technology Explicit Processes: *Greenhouse Gas Reductions Potential*

Code	Existing/ New	Primary Energy In	Delivered Energy	Technology	Petajoules of Delivered Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
T1	Existing	Crude Oil	Petrol	Oil Refinery	68.93	82.77	89.59	96.98	101.75	98.32
T2	Existing	Imported Petrol	Petrol	Tanker Delivery	47.03	23.22	14.59	6.24	0.00	0.00
T3	Existing	Crude Oil	Diesel	Oil Refinery	71.21	43.11	46.66	48.98	51.51	55.45
T4	Existing	Imported Diesel	Diesel	Tanker Delivery	46.46	0.00	0.00	0.00	0.00	0.00
T5	Existing	Crude Oil	Aviation Fuel	Oil Refinery	17.94	18.32	19.23	20.17	21.12	21.85
T6	Existing	Imported Aviation I	Aviation Fuel	Tanker Delivery	0.00	0.00	0.00	0.00	0.00	0.00
T7	Existing	Wellhead LPG	LPG	Tanker Delivery	8.41	8.58	7.74	7.67	6.52	6.90
T8	Existing	Imported LPG	LPG	Tanker Delivery	0.20	0.00	0.00	0.00	0.00	0.00
T9	New	Fodder Beat	Ethanol	Fermentation	0.00	3.89	7.78	11.66	15.55	18.47
T11	New	Radiata Pine	Methanol	Gasification	0.00	0.39	0.79	1.18	1.57	1.87
T13	New	Forage	Methane (Nat Gas)	Methane Fermentation	0.00	24.00	30.00	30.00	30.00	30.00
T15	New	Eucalyptus	Diesel	FAME (transesterification)	0.00	24.00	0.00	0.00	0.00	30.00
T16	New	Eucalyptus	Diesel	HTU	0.00	24.00	10.01	9.74	9.47	30.00
T17	New	Eucalyptus	Diesel	Gasification	0.00	22.29	30.00	30.00	30.00	9.26
T18	New	Eucalyptus	Diesel	Pyrolysis	0.00	0.00	30.00	30.00	30.00	0.00
Total[A]					260.18	274.58	286.39	292.61	297.49	302.11

Table E.4.3 Primary Energy Sources of Generated Electricity (PJ): *Greenhouse Gas Reductions Potential*

Year	Total	Hydro	Natural Gas	Coal	Geothermal	Wind	Fuel Oil	Biogas	Wood	Waste Heat
2007	160.59	92.33	33.49	18.02	12.22	2.29	0.00	0.84	1.14	0.25
2008	144.42	99.11	27.61	0.00	15.26	2.29	0.00	0.00	0.00	0.15
2009	156.89	105.89	10.90	0.00	18.29	21.65	0.00	0.00	0.00	0.15
2010	164.42	112.68	0.00	0.00	20.27	31.33	0.00	0.00	0.00	0.15
2011	168.25	119.46	0.00	0.00	12.72	35.92	0.00	0.00	0.00	0.15
2012	175.03	126.24	0.00	0.00	12.22	36.42	0.00	0.00	0.00	0.15
2013	175.43	126.24	0.00	0.00	12.22	36.81	0.00	0.00	0.00	0.15
2014	177.19	126.24	0.00	0.00	13.57	37.23	0.00	0.00	0.00	0.15
2015	180.13	126.24	0.00	0.00	16.12	37.63	0.00	0.00	0.00	0.15
2016	183.40	126.24	0.00	0.00	18.95	38.06	0.00	0.00	0.00	0.15
2017	186.63	126.24	0.00	0.00	21.77	38.47	0.00	0.00	0.00	0.15
2018	189.60	126.24	0.00	0.00	24.29	38.92	0.00	0.00	0.00	0.15
2019	192.44	126.24	0.00	0.00	26.66	39.39	0.00	0.00	0.00	0.15
2020	193.58	126.24	0.00	0.00	27.40	39.80	0.00	0.00	0.00	0.15
2021	193.98	126.24	0.00	0.00	27.40	40.19	0.00	0.00	0.00	0.15
2022	194.31	126.24	0.00	0.00	27.40	40.52	0.00	0.00	0.00	0.15
2023	194.78	126.24	0.00	0.00	27.40	40.99	0.00	0.00	0.00	0.15
2024	195.22	126.24	0.00	0.00	27.40	41.43	0.00	0.00	0.00	0.15
2025	195.65	126.24	0.00	0.00	27.40	41.86	0.00	0.00	0.00	0.15
2026	196.08	126.24	0.00	0.00	27.40	42.30	0.00	0.00	0.00	0.15
Growth Rate (2007- 2026)	**22.1%**	**36.7%**	**n.a.**	**n.a.**	**124.1%**	**1743.2%**	**n.a.**	**n.a.**	**n.a.**	**-40.9%**
Average Growth Rate (2007- 2026)	**1.1%**	**1.7%**	**n.a.**	**n.a.**	**4.3%**	**16.6%**	**n.a.**	**n.a.**	**n.a.**	**-2.7%**

NB: Table E1.1.3 measures Petajoules of generated electricity. Process G1 converts ‘generated electricity’ to ‘delivered electricity’ at an efficiency of 92%

Table E.4.4 Delivered Energy Consumption (PJ, Heat Units): *Greenhouse Gas Reductions Potential*

Year	Total[1]	Elect.	Petrol	Diesel	Av. Fuel	Coal	Fuel Oil	LPG	Natural Gas & Methane	Wood	Black Liquor	Ethan-ol	Metha-nol
2007	575.65	147.80	115.96	117.67	17.94	45.55	8.27	8.61	50.74	40.54	22.57	0.00	0.00
2008	541.70	141.77	107.79	111.73	17.58	44.39	7.74	8.35	48.29	30.43	22.57	0.97	0.10
2009	545.91	144.34	107.32	112.37	17.82	44.36	7.82	8.70	50.76	26.83	23.44	1.94	0.20
2010	551.36	151.27	106.84	113.49	18.07	45.00	7.73	8.40	48.16	24.88	24.30	2.92	0.29
2011	559.01	154.79	106.25	115.21	18.32	45.78	7.85	8.60	49.39	23.53	25.00	3.89	0.39
2012	567.55	161.03	105.31	116.74	18.55	45.83	7.93	8.78	50.68	22.34	25.00	4.86	0.49
2013	570.96	161.39	105.16	118.25	18.78	46.06	8.02	8.16	51.72	21.99	25.00	5.83	0.59
2014	576.04	163.01	104.91	119.34	19.00	46.40	8.12	7.96	52.94	21.87	25.00	6.80	0.69
2015	582.50	165.72	104.73	120.50	19.23	46.76	8.22	7.78	54.14	21.85	25.00	7.78	0.79
2016	590.03	168.73	104.62	121.64	19.47	47.14	8.32	7.89	55.66	21.92	25.00	8.75	0.88
2017	597.41	171.70	104.46	122.61	19.70	47.48	8.42	7.98	57.27	22.08	25.00	9.72	0.98
2018	604.34	174.43	104.28	123.64	19.93	47.84	8.53	7.85	58.75	22.31	25.00	10.69	1.08
2019	611.35	177.05	104.07	124.71	20.17	48.23	8.65	7.73	60.29	22.61	25.00	11.66	1.18
2020	616.70	178.10	103.83	125.86	20.40	48.67	8.77	7.24	61.93	22.98	25.00	12.64	1.28
2021	622.32	178.46	103.57	127.11	20.64	49.31	8.89	6.70	64.22	23.43	25.00	13.61	1.37
2022	629.75	178.77	103.26	129.12	20.88	50.06	9.02	6.52	67.24	23.82	25.00	14.58	1.47
2023	637.74	179.19	102.93	131.33	21.12	50.82	9.16	6.61	70.18	24.28	25.00	15.55	1.57
2024	645.55	179.60	102.23	133.56	21.36	51.60	9.31	6.74	73.14	24.81	25.00	16.52	1.67
2025	653.10	180.00	100.99	135.80	21.60	52.40	9.46	6.88	76.29	25.43	25.00	17.50	1.77
2026	660.75	180.40	99.74	138.06	21.85	53.22	9.55	7.01	79.47	26.12	25.00	18.47	1.87
Growth Rate	**14.78%**	**22.05%**	**-13.98%**	**17.33%**	**21.76%**	**16.85%**	**15.47%**	**-18.57%**	**56.62%**	**-35.57%**	**10.78%**	**n.a.**	**n.a.**
Average Growth Rate	**0.73%**	**1.05%**	**-0.79%**	**0.84%**	**1.04%**	**0.82%**	**0.76%**	**-1.08%**	**2.39%**	**-2.29%**	**0.54%**	**n.a.**	**n.a.**

Note 1: As per conventional practice by many statistical agencies, these PJ (Heat Units) are added-up without any adjustment for energy quality. Even those this practice is criticised in this report, it is undertaken here to aid comparison with other published data.

Appendix F

Detailed Results: Supply of Energy End-Uses - By Technology Explicit Processes

F.1 Technical Energy Savings Potential

The following pages contain five tables that present the manner (technology type, delivered energy type) by which the energy end-uses are supplied in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table F.1.1)
- Industrial Sector (Table F.1.2)
- Commercial Sector (Table F.1.3)
- Primary Sector (Table F.1.4)
- Transport and Storage Sector (Table F.1.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table F.1.1 Supply of Energy End-Uses: *Household Sector, Technical Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H347	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Dish Washer	0.25	0.26	0.28	0.30	0.32	0.33
H322	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	7.36	7.76	8.32	8.87	9.41	9.82
H317 A	Existing	Coal	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.00	0.00	0.00	0.00	0.00	0.00
H323 A	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.30	0.00	0.00	0.00	0.00	0.00
H323 B	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Electric Stovetop	0.87	0.82	0.50	0.18	0.00	0.00
H323 D	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Microwave	0.26	0.36	0.47	0.58	0.56	0.39
H334	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Ovens	0.02	0.19	0.38	0.57	0.76	0.90
H334_A	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Cooktops	0.01	0.04	0.08	0.12	0.16	0.19
H334_B	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Oven & Cooktops	0.24	0.33	0.44	0.54	0.64	0.72
H337	Existing	Wood	Intermediate Heat (100-300 C), Cooking	Wood Cooking Oven	0.01	0.01	0.01	0.01	0.00	0.02
H324_A	Existing	Electricity	Lighting	Tungsten Incandescent Lights	0.33	0.18	0.09	0.00	0.00	0.00
H324_B	Existing	Electricity	Lighting	Compact Fluorescent Light	0.08	0.12	0.15	0.19	0.23	0.25
H324_C	Existing	Electricity	Lighting	Halogen Lightis	0.00	0.03	0.05	0.08	0.01	0.00
H324_D	New	Electricity	Lighting	LED Lights	0.00	0.03	0.05	0.08	0.11	0.13
H324_E	Existing	Electricity	Lighting	'Non-Compact' Fluorescent Light	0.01	0.03	0.06	0.08	0.11	0.10
H325	Existing	Electricity	Low Temperature Heat (<100 C), Clothes Drying	Clothes Dryer	0.21	0.22	0.24	0.25	0.27	0.28
H355	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Ceiling Insulation	0.00	0.06	0.12	0.19	0.25	0.30
H356	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Wall Insulation	0.00	0.10	0.20	0.30	0.40	0.48
H357	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Floor Insulation	0.00	0.15	0.31	0.46	0.62	0.73
H358	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Double Glazing	0.00	0.17	0.34	0.52	0.69	0.82
H318	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.11	0.16	0.00	0.00	0.00	0.00
H319	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire	0.08	0.00	0.00	0.00	0.00	0.00
H320	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	0.02	0.03	0.03	0.00	0.00	0.00
H326	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Existing Heat Pumps	1.80	2.53	3.30	2.86	0.90	0.00
H326_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.03 kW reverse cycle	0.03	0.22	0.45	0.67	0.90	1.06
H326_B	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.88 kW reverse cycle	0.03	0.22	0.45	0.67	0.90	1.06
H326_C	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 3.94 kW reverse cycle	0.03	0.22	0.45	0.67	0.90	0.70
H327_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	0.03	0.22	0.00	0.00	0.00	0.00
H363	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Night Store	0.03	0.22	0.00	0.00	0.00	0.00
H327	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater & Nightstore	4.99	0.66	0.00	0.00	0.00	0.00

NB: For processes H355, H356, H357, H358 the yearly data is not measured in Petajoules. Rather, it represents the proportion of extra households adopting that form of insulation. It should be noted this is extra/additional to the existing proportions: H355=0.64, H356=0.45, H357=0.18, H358=0.09.

Table F.1.1 Supply of Energy End-Uses: ***Household Sector, Technical Energy Savings Potential (continued)***

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
H333_A	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (unflued)	0.03	0.22	0.45	0.00	0.00	0.00
H333_B	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (flued)	0.03	0.22	0.00	0.00	0.00	0.00
H333	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.69	2.38	1.04	0.00	0.00	0.00
H335_A	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, unflued, bayonet fitting or fixed wall mount	0.03	0.22	0.45	0.67	0.90	1.06
H335_B	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, flued	0.03	0.22	0.45	0.67	0.90	1.06
H360	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Central Heating	0.03	0.22	0.45	0.67	0.90	1.06
H355	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	2.06	2.90	3.78	4.67	5.55	6.22
H331	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.05	0.07	0.09	0.12	0.14	0.15
H338_A	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.83	1.16	1.52	1.87	1.98	1.80
H345	New	Wood	Low Temperature Heat (<100 C), Space Heating	Wood pellet stoves	0.03	0.22	0.45	0.67	0.90	1.06
H339	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire	0.47	0.48	0.29	0.10	0.00	0.00
H340	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	0.11	0.15	0.20	0.24	0.29	0.32
H338_B	New	Wood	Low Temperature Heat (<100 C), Space Heating + I	Enclosed wood burner with wet back, space heating	0.03	0.22	0.45	0.67	0.90	1.06
H328	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	0.05	0.00	0.00	0.00	0.00	0.00
H328_A	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	0.05	0.38	0.75	1.13	1.51	0.87
H328_C	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	13.54	10.27	7.28	4.33	1.33	0.00
H344_B	New	LPG	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	0.05	0.38	0.75	1.13	1.51	1.79
H344_A	new	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	0.05	0.38	0.75	1.13	1.51	1.79
H380_A	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	0.05	0.38	0.75	1.13	1.51	1.79
H380_B	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	0.05	0.38	0.75	1.13	1.51	1.79
H380	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Existing Technology Mix	2.21	3.10	4.05	5.00	5.95	6.66
H342_A	New	Solar (+Elect)	Low Temperature Heat (<100 C), Water Heating	Solar water heater, electricity boosted & elect pump	0.05	0.38	0.75	1.13	1.51	1.79
H342_B	New	Solar (+Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas boosted & elect pump	0.05	0.38	0.75	1.13	1.51	1.79
H342	Existing	Solar (Elect +Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas/elec boosted & elect pump	0.31	0.60	0.92	1.24	1.56	1.80
H332	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Water Heating	Direct Heat	0.05	0.07	0.09	0.12	0.14	0.15

Table F.1.1 Supply of Energy End-Uses: *Household Sector, Technical Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H338	Existing	Petrol	Motive Power, Mobile	Internal Combustion (Lawnmower)	0.42	0.44	0.48	0.51	0.54	0.56
H329	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.24	0.25	0.27	0.28	0.30	0.32
H330	Existing	Electricity	Refrigeration	Refrigeration Systems	5.97	6.29	6.74	7.19	7.63	7.96
H343	Existing	Electricity	Spa Pools: Low Temperature Heat (<100 C), Water Heating	Water Heater	0.28	0.30	0.32	0.34	0.36	0.38
H346_A	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.01	0.01	0.02	0.02
H346_B	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.01	0.01	0.02	0.02
H346_C	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.01	0.01	0.02	0.02
H346	Existing	Electricity	Space Cooling	Heat Pumps	0.05	0.04	0.04	0.03	0.02	0.01
H408	New	Methanol 15% \	Transport, Land	Internal Combustion Engine (Land Transport)	0.00	0.58	1.16	1.74	2.32	2.76
H400	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	1.66	2.02	0.00	0.00	0.00	0.00
H405	New	Electicity & Petr	Transport, Land (Cars)	Hybrid Electric Motor & Internal Combustion Engine (Land Transport)	0.07	0.58	1.16	1.74	2.32	2.76
H404	Existing	Electricity	Transport, Land (Cars)	Electric Motor (Land Transport)	0.07	0.58	1.16	1.74	2.32	2.76
H406	New	Ethanol 10% wi	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.58	1.16	1.74	2.32	2.76
H401	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.09	0.12	0.15	0.17	0.19
H402	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.01	0.02	0.02	0.03	0.03
H403	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	11.01	8.40	8.44	6.46	4.47	2.97
H407	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.58	1.16	1.74	2.32	2.76

Table F.1.2 Supply of Energy End-Uses: *Industrial Sector, Technical Energy Savings Potential*

Code	Existing/New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind19	Existing	Electricity	Al2O3 Reduction	Electric Furnace	8.00	8.68	9.05	9.47	9.93	10.29
Ind20	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.29	0.31	0.34	0.38	0.41	0.44
Ind3	Existing	Coal	Fe3O4 Reduction	Furnace/Kiln	2.10	2.25	2.30	2.38	2.46	2.52
Ind50	Existing	Natural Gas	Fe3O4 Reduction	Furnace/Kiln	0.11	0.15	0.19	0.24	0.28	0.31
Ind4	Existing	Coal	High Temperature Heat (>300 C), Process	Boiler Systems	0.05	0.07	0.09	0.11	0.00	0.00
Ind21	Existing	Electricity	High Temperature Heat (>300 C), Process	Electric Furnace	2.44	1.34	0.17	0.00	0.00	0.00
Ind23	Existing	Electricity	High Temperature Heat (>300 C), Process	Resistance Heater	0.59	0.82	1.07	0.42	0.00	0.00
Ind32	Existing	Fuel Oil	High Temperature Heat (>300 C), Process	Boiler Systems	0.04	0.05	0.07	0.00	0.00	0.00
Ind41	Existing	LPG	High Temperature Heat (>300 C), Process	Boiler Systems	0.11	0.15	0.20	0.24	0.00	0.00
Ind51	Existing	Natural Gas	High Temperature Heat (>300 C), Process	Boiler Systems	2.84	3.93	5.13	6.33	7.51	7.84
Ind13	Existing	Diesel	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.10	0.00	0.00	0.00	0.00	0.00
Ind24	Existing	Electricity	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	1.14	0.15	0.07	0.00	0.00	0.00
Ind35	Existing	Fuel Oil	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.00	0.00	0.00	0.00	0.00	0.00
Ind56	Existing	Natural Gas	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.38	0.53	0.69	0.85	0.94	1.02
Ind2	Existing	Black Liquor	Intermediate Heat (100-300 C), Process	Boiler Systems	13.54	15.00	15.00	15.00	15.00	15.00
Ind6	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	6.27	0.00	0.00	0.00	0.00	0.00
Ind12	Existing	Diesel	Intermediate Heat (100-300 C), Process	Boiler Systems	0.67	0.00	0.00	0.00	0.00	0.00
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.25	0.00	0.00	0.00	0.00	0.00
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.00	0.00	0.00	0.00	0.00	0.00
Ind40	Existing	Geothermal	Intermediate Heat (100-300 C), Process	Direct Heat	6.12	8.48	11.07	13.66	14.88	14.19
Ind43	Existing	LPG	Intermediate Heat (100-300 C), Process	Boiler Systems	0.49	0.67	0.00	0.00	0.00	0.00
Ind44	Existing	LPG	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.26	0.36	0.00	0.00	0.00	0.00
Ind53	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	12.27	16.99	22.18	27.37	32.56	36.45
Ind54	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.25	0.34	0.45	0.55	0.66	0.74
Ind69	Existing	Wood	Intermediate Heat (100-300 C), Process	Boiler Systems	9.47	9.39	6.25	2.33	0.00	0.00
Ind5	Existing	Coal	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	1.22	0.74	0.00	0.00	0.00	0.00
Ind11	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.24	0.00	0.00	0.00	0.00	0.00
Ind22	Existing	Electricity	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.10	0.00	0.00	0.00	0.00	0.00
Ind33	Existing	Fuel Oil	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.05	0.00	0.00	0.00	0.00	0.00
Ind42	Existing	LPG	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.25	0.35	0.34	0.00	0.00	0.00
Ind52	Existing	Natural Gas	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	2.88	3.99	5.20	6.04	6.58	7.02
Ind68	Existing	Wood	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.08	0.11	0.15	0.18	0.21	0.24

Table F.1.2 Supply of Energy End-Uses: ***Industrial Sector, Technical Energy Savings Potential (continued)***

Code	Existing/New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind7	Existing	Coal	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.05	0.00	0.00	0.00	0.00	0.00
Ind55	Existing	Natural Gas	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	1.17	1.46	0.56	0.44	0.32	0.23
Ind71	Existing	Wood	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.55	0.00	1.00	1.24	1.47	1.65
Ind9	Existing	Coal	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.11	0.10	0.00	0.00	0.00	0.00
Ind37	Existing	Fuel Oil	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.03	0.00	0.00	0.00	0.00	0.00
Ind59	Existing	Natural Gas	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.14	0.00	0.25	0.31	0.37	0.42
Ind73	Existing	Wood	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.22	0.25	0.38	0.41	0.44	0.46
Ind25	Existing	Electricity	Lighting	Lights	0.15	0.16	0.18	0.19	0.21	0.22
Ind8	Existing	Coal	Low Temperature Heat (<100 C), Process	Boiler Systems	0.08	0.00	0.00	0.00	0.00	0.00
Ind14	Existing	Diesel	Low Temperature Heat (<100 C), Process	Boiler Systems	0.14	0.00	0.00	0.00	0.00	0.00
Ind26	Existing	Electricity	Low Temperature Heat (<100 C), Process	Heat Pump (for Heating	2.13	2.42	2.31	2.29	2.27	2.26
Ind27	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.06	0.00	0.00	0.00	0.00	0.00
Ind28	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.29	0.00	0.00	0.00	0.00	0.00
Ind36	Existing	Fuel Oil	Low Temperature Heat (<100 C), Process	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Ind45	Existing	LPG	Low Temperature Heat (<100 C), Process	Boiler Systems	0.16	0.00	0.00	0.00	0.00	0.00
Ind57	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Boiler Systems	0.27	0.38	0.49	0.61	0.72	0.81
Ind58	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Burner (Direct Heat)	0.36	0.50	0.65	0.81	0.96	1.08
Ind72	Existing	Wood	Low Temperature Heat (<100 C), Process	Boiler Systems	0.04	0.00	0.07	0.09	0.10	0.12
Ind60	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.72	0.58	0.63	0.69	0.74	0.78
Ind10	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.48	1.21	1.02	0.87	0.76	0.71
Ind38	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Ind46	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.04	0.06	0.07	0.09	0.11	0.12
Ind61	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.16	1.60	2.09	2.58	3.07	3.44

Table F.1.2 Supply of Energy End-Uses: *Industrial Sector, Technical Energy Savings Potential (continued)*

Code	Existing/New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind15	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.40	0.55	0.67	0.71	0.75	0.78
Ind47	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.11	0.15	0.20	0.24	0.29	0.32
Ind64	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.21	0.08	0.00	0.00	0.00	0.00
Ind16	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.43	0.00	0.00	0.00	0.00	0.00
Ind29	Existing	Electricity	Motive Power, Stationary	Electric Motor	14.39	15.74	16.94	18.26	19.66	20.76
Ind39	Existing	Fuel Oil	Motive Power, Stationary	Stationary Engine	0.00	0.00	0.00	0.00	0.00	0.00
Ind65	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.01	0.00	0.00	0.00	0.00	0.00
Ind30	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	2.91	3.20	3.52	3.88	4.27	4.59
Ind31	Existing	Electricity	Refrigeration	Refrigeration Systems	6.08	6.45	7.17	7.96	8.84	9.56
Ind1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.05	0.05	0.06	0.07	0.07	0.08
Ind17	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.02	0.00	0.00	0.00	0.00
Ind76	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.02	0.05	0.04
Ind75	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.03	0.05	0.05
Ind77	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.00	0.00	0.00	0.00
Ind48	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.02	0.00	0.00	0.00
Ind79	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.00	0.00	0.00	0.00
Ind74	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.03	0.05	0.05
Ind66	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.00	0.00	0.00	0.00	0.00
Ind78	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.03	0.00	0.00
Ind18	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.23	1.42	1.57	1.75	1.95	2.11
Ind49	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.01	0.01	0.02	0.02	0.02
Ind62	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind63	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.02	0.03	0.04	0.04
Ind67	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.07	0.00	0.00	0.00	0.00	0.00

Table F.1.3 Supply of Energy End-Uses: *Commercial Sector, Technical Energy Savings Potential*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	2.99	3.15	3.41	3.68	3.97	4.19
Com10	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Elements	0.13	0.18	0.23	0.28	0.34	0.38
Com11	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.36	0.24	0.19	0.13	0.09	0.07
Com27	Existing	LPG	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.13	0.18	0.24	0.29	0.35	0.39
Com33	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.09	0.12	0.16	0.19	0.23	0.26
Com2	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	0.15	0.00	0.00	0.00	0.00	0.00
Com12	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.24	0.00	0.00	0.00	0.00	0.00
Com34	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	1.95	0.66	0.70	0.74	0.78	0.80
Com13	Existing	Electricity	Lighting	Lights	0.81	0.85	0.93	1.00	1.07	1.13
Com3	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.99	1.38	1.80	2.22	2.08	1.24
Com4	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.48	0.66	0.87	1.03	0.00	0.00
Com15	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump (for Heating)	4.42	6.15	8.02	9.90	11.78	13.19
Com16	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	5.64	3.72	1.82	0.00	0.00	0.00
Com23	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.08	0.00	0.00	0.00	0.00	0.00
Com24	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.01	0.00	0.00	0.00	0.00	0.00
Com26	Existing	Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.08	0.11	0.14	0.18	0.21	0.23
Com28	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.31	0.43	0.57	0.70	0.83	0.93
Com35	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.92	1.28	1.67	2.07	2.46	2.75
Com5	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.46	0.64	0.84	1.03	1.23	1.38
Com17	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Heat Pump (for Heating)	0.45	0.62	0.81	1.00	1.19	1.33
Com18	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	2.63	2.20	1.81	1.45	1.11	0.88
Com25	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Com29	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.00	0.01	0.01	0.01	0.01	0.01
Com36	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.66	0.92	1.21	1.49	1.77	1.98
Com37	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	0.34	0.47	0.61	0.75	0.89	1.00
Com30	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com38	Existing	Natural Gas	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00

Table F.1.3 Supply of Energy End-Uses: ***Commercial Sector, Technical Energy Savings Potential*** **(continued)**

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
Com19	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.31	1.38	1.50	1.61	1.73	1.83
Com21	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	0.56	0.59	0.63	0.68	0.73	0.77
Com22	Existing	Electricity	Refrigeration	Refrigeration Systems	4.37	4.72	5.26	5.84	6.47	6.98
Com8	Existing	Electricity	Space Cooling	Heat Pump (for Cooling)	4.44	4.68	5.08	5.50	5.94	6.29
Com14	Existing	Electricity	Street Lighting	Street Lights	0.05	0.05	0.06	0.06	0.06	0.06
Com1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.20	0.20	0.21	0.22	0.23	0.24
Com6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.04	0.06	0.08	0.10	0.11	0.13
Com44	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.05	0.07	0.10	0.12
Com43	New	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.05	0.07	0.10	0.12
Com45	New	Ethanol 10% with F	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com31	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.01	0.01	0.01	0.01
Com47	New	Methanol 15% with	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com42	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.05	0.07	0.10	0.12
Com41	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.34	0.38	0.31	0.24	0.17	0.12
Com46	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.05	0.07	0.10	0.12
Com7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.65	1.40	1.52	1.63	1.75	1.84
Com32	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.01
Com39	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com48	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.02	0.02	0.02	0.02	0.02	0.03

Table F.1.4 Supply of Energy End-Uses: *Primary Sector, Technical Energy Savings Potential*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
P9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.05	0.05	0.05	0.06	0.06	0.06
P10	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.18	0.25	0.25	0.19	0.13	0.09
P17	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.24	0.06	0.00	0.00	0.00	0.00
P21	Existing	Natural Ga	Intermediate Heat (100-300 C), Process	Boiler Systems	0.26	0.35	0.46	0.57	0.67	0.75
P1	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P18	Existing	Fuel Oil	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.00	0.00	0.00	0.00	0.00	0.00
P2	Existing	Diesel	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P11	Existing	Electricity	Lighting	Lights	0.05	0.05	0.05	0.06	0.06	0.07
P12	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.32	0.35	0.39	0.43	0.48	0.51
P1	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.86	1.32	0.85	0.39	0.00	0.00
P22	Existing	Natural Ga	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.48	2.04	2.66	3.29	3.85	3.99
P3	Existing	Diesel	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.12	0.00	0.00	0.00	0.00	0.00
P13	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.24	1.19	1.36	1.55	1.77	1.95
P23	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.18	0.25	0.33	0.41	0.48	0.54
P4	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	1.08	1.07	1.11	1.16	1.22	1.27
P14	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.34	1.60	1.71	1.83	1.95	2.05
P24	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.02	0.00	0.00	0.00	0.00	0.00
P5	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.26	0.00	0.00	0.00	0.00	0.00
P15	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.93	2.14	2.42	2.73	3.09	3.39
P16	Existing	Electricity	Refrigeration	Refrigeration Systems	1.46	1.59	1.80	2.02	2.28	2.50

Table F.1.4 Supply of Energy End-Uses: *Primary Sector, Technical Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
P25	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.19	0.08	0.04	0.00	0.00	0.00
P27	New	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.01	0.03	0.04	0.04	0.06
P28	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.01	0.03	0.04	0.05	0.06
P29	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.01	0.03	0.04	0.05	0.06
P30	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P31	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.03	0.04	0.04	0.01
P32	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.03	0.00	0.00	0.00	0.00	0.00
P26	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.09	0.00	0.00	0.00	0.00	0.00
P7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.99	1.17	1.29	1.42	1.57	1.69
P19	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.29	0.13	0.00	0.00	0.00	0.00
P8	Existing	Diesel	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.61	0.84	1.09	1.21	1.35	1.46

Table F.1.5 Supply of Energy End-Uses: Transport and Storage Sector, *Technical Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Trans8	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.19	0.20	0.21	0.23	0.25	0.26
Trans9	Existing	Electricity	Lighting	Lights	0.04	0.04	0.05	0.05	0.05	0.06
Trans10	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.28	0.30	0.32	0.35	0.37	0.40
Trans1	Existing	Aviation Fuel	Transport, Air	Aircraft	4.85	5.09	5.50	5.93	6.40	6.78
Trans3	Existing	Diesel	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.78	0.83	0.87	0.92	0.98	1.03
Trans11	Existing	Electricity	Transport, Land (Buses)	Electric Motor	0.06	0.08	0.11	0.13	0.16	0.17
Trans15	Existing	LPG	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans18	Existing	Natural Gas	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.01	0.01	0.02	0.02	0.02	0.03
Trans20	Existing	Petrol	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.03	0.00	0.00	0.00	0.00	0.00
Trans4	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.12	0.00	0.00	0.00	0.00	0.00
Trans25	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.08	0.15	0.22	0.31	0.31
Trans24	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.08	0.15	0.23	0.31	0.37
Trans26	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.08	0.05	0.00	0.00	0.00
Trans16	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.10	0.14	0.18	0.00	0.00	0.00
Trans28	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.08	0.00	0.00	0.00	0.00
Trans23	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.08	0.15	0.23	0.31	0.37
Trans21	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.53	0.18	0.00	0.00	0.00	0.00
Trans27	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.08	0.15	0.23	0.06	0.00
Trans5	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.02	8.91	9.60	10.34	11.14	11.78
Trans17	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.06	0.09	0.11	0.14	0.16	0.18
Trans19	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.02	0.03	0.03	0.04	0.05	0.05
Trans22	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.49	0.00	0.00	0.00	0.00	0.00

Table F.1.5 Supply of Energy End-Uses: Transport and Storage Sector, *Technical Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Trans7	Existing	Diesel	Transport, Rail (Freight)	Locomotive (Rail)	0.12	0.00	0.00	0.00	0.00	0.00
Trans13	Existing	Electricity	Transport, Rail (Freight)	Electric Motor	0.98	1.15	1.24	1.34	1.45	1.53
Trans2	Existing	Coal	Transport, Rail (Passenger)	Locomotive (Rail)	0.01	0.00	0.00	0.00	0.00	0.00
Trans6	Existing	Diesel	Transport, Rail (Passenger)	Locomotive (Rail)	0.02	0.00	0.00	0.00	0.00	0.00
Trans12	Existing	Electricity	Transport, Rail (Passenger)	Electric Motor	0.13	0.16	0.17	0.18	0.20	0.21
Trans14	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.71	0.74	0.80	0.86	0.93	0.99

F.2 Economic Energy Savings Potential

The following pages contain five tables that present the manner (technology type, delivered energy type) by which the energy end-uses are supplied in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table F.2.1)
- Industrial Sector (Table F.2.2)
- Commercial Sector (Table F.2.3)
- Primary Sector (Table F.2.4)
- Transport and Storage Sector (Table F.2.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table F.2.1 Supply of Energy End-Uses: ***Household Sector, Economic Energy Savings Potential***

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H347	Existing	Electricity	Dishwasher: Low Temperature Heat (<100 C)	Dish Washer	0.25	0.26	0.28	0.30	0.32	0.33
H322	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	7.36	7.76	8.32	8.87	9.41	9.82
H317 A	Existing	Coal	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.00	0.00	0.00	0.00	0.00	0.00
H323 A	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.30	0.00	0.00	0.00	0.00	0.00
H323 B	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Electric Stovetop	0.87	1.22	1.33	1.30	1.27	1.25
H323 D	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Microwave	0.26	0.36	0.47	0.58	0.69	0.78
H334	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Ovens	0.02	0.00	0.00	0.00	0.00	0.00
H334_A	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Cooktops	0.01	0.04	0.08	0.12	0.16	0.19
H334_B	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Oven & Cooktops	0.24	0.14	0.00	0.00	0.00	0.00
H337	Existing	Wood	Intermediate Heat (100-300 C), Cooking	Wood Cooking Oven	0.01	0.00	0.00	0.00	0.00	0.00
H324_A	Existing	Electricity	Lighting	Tungsten Incandescent Lights	0.33	0.18	0.09	0.00	0.00	0.00
H324_B	Existing	Electricity	Lighting	Compact Fluorescent Light	0.08	0.12	0.15	0.19	0.23	0.25
H324_C	Existing	Electricity	Lighting	Halogen Lightis	0.00	0.03	0.05	0.08	0.01	0.00
H324_D	New	Electricity	Lighting	LED Lights	0.00	0.03	0.05	0.08	0.11	0.10
H324_E	Existing	Electricity	Lighting	'Non-Compact' Fluorescent Light	0.01	0.03	0.06	0.08	0.11	0.13
H325	Existing	Electricity	Low Temperature Heat (<100 C), Clothes Drying	Clothes Dryer	0.21	0.22	0.24	0.25	0.27	0.28
H355	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Ceiling Insulation	0.00	0.00	0.00	0.00	0.00	0.00
H356	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Wall Insulation	0.00	0.00	0.00	0.00	0.00	0.00
H357	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Floor Insulation	0.00	0.00	0.00	0.00	0.00	0.00
H358	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Double Glazing	0.00	0.00	0.00	0.00	0.00	0.00
H318	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.11	0.00	0.00	0.00	0.00	0.00
H319	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire	0.08	0.00	0.00	0.00	0.00	0.00
H320	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	0.02	0.00	0.00	0.00	0.00	0.00
H326	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Existing Heat Pumps	1.80	2.10	0.00	0.00	0.00	0.00
H326_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.03 kW reverse cycle	0.03	0.22	0.45	0.67	0.90	1.06
H326_B	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.88 kW reverse cycle	0.03	0.22	0.45	0.67	0.90	1.06
H326_C	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 3.94 kW reverse cycle	0.03	0.00	0.00	0.00	0.00	0.00
H327_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	0.03	0.22	0.45	0.67	0.90	1.06
H363	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Night Store	0.03	0.00	0.00	0.00	0.00	0.00
H327	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater & Nightstore	4.99	7.01	7.88	6.84	5.80	5.01

NB: For processes H355, H356, H357, H358 the yearly data is not measured in Petajoules. Rather, it represents the proportion of extra households adopting that form of insulation. It should be noted this is extra/additional to the existing proportions: H355=0.64, H356=0.45, H357=0.18, H358=0.09.

Table F.2.1 Supply of Energy End-Uses: Household Sector, *Economic Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H333_A	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (unflued)	0.03	0.00	0.00	0.00	0.00	0.00
H333_B	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (flued)	0.03	0.00	0.00	0.00	0.00	0.00
H333	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.69	0.00	0.00	0.00	0.00	0.00
H335_A	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, unflued, bayonet fitting or fixed wall mount	0.03	0.22	0.45	0.67	0.90	1.06
H335_B	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, flued	0.03	0.00	0.00	0.00	0.00	0.00
H360	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Central Heating	0.03	0.00	0.00	0.00	0.00	0.00
H355	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	2.06	2.90	3.78	4.67	5.55	6.22
H331	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.05	0.00	0.00	0.00	0.00	0.00
H338_A	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.83	0.00	0.00	0.00	0.00	0.00
H345	New	Wood	Low Temperature Heat (<100 C), Space Heating	Wood pellet stoves	0.03	0.00	0.00	0.00	0.00	0.00
H339	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire	0.47	0.00	0.00	0.00	0.00	0.00
H340	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	0.11	0.00	0.00	0.00	0.00	0.00
H338_B	New	Wood	Low Temperature Heat (<100 C), Space Heating + Low Temperature Heat (<100 C), Water Heating	Enclosed wood burner with wet back, space heating	0.03	0.22	0.45	0.67	0.90	1.06
H328	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	0.05	0.00	0.00	0.00	0.00	0.00
H328_A	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	0.05	0.38	0.75	1.13	1.51	1.79
H328_C	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	13.54	10.82	8.27	5.70	3.13	1.20
H344_B	New	LPG	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	0.05	0.00	0.00	0.00	0.00	0.00
H344_A	new	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	0.05	0.38	0.75	1.13	1.51	1.79
H380_A	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	0.05	0.38	0.75	1.13	1.51	1.79
H380_B	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	0.05	0.38	0.75	1.13	1.51	1.79
H380	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Existing Technology Mix	2.21	3.10	4.05	5.00	5.95	6.66
H342_A	New	Solar (+Elect)	Low Temperature Heat (<100 C), Water Heating	Solar water heater, electricity boosted & elect pump	0.05	0.38	0.75	1.13	1.51	1.79
H342_B	New	Solar (+Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas boosted & elect pump	0.05	0.38	0.75	1.13	1.51	1.79
H342	Existing	Solar (Elect +Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas/elec boosted & elect pump	0.31	0.60	0.92	1.24	1.56	1.80
H332	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Water Heating	Direct Heat	0.05	0.07	0.09	0.12	0.14	0.15

Table F.2.1 Supply of Energy End-Uses: *Household Sector, Economic Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H338	Existing	Petrol	Motive Power, Mobile	Internal Combustion (Lawnmower)	0.42	0.44	0.48	0.51	0.54	0.56
H329	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.24	0.25	0.27	0.28	0.30	0.32
H330	Existing	Electricity	Refrigeration	Refrigeration Systems	5.97	6.29	6.74	7.19	7.63	7.96
H343	Existing	Electricity	Spa Pools: Low Temperature Heat (<100 C), Water Heating	Water Heater	0.28	0.30	0.32	0.34	0.36	0.38
H346_A	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.01	0.01	0.02	0.02
H346_B	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.01	0.01	0.02	0.02
H346_C	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.00	0.00	0.00	0.00
H346	Existing	Electricity	Space Cooling	Heat Pumps	0.05	0.05	0.04	0.04	0.04	0.03
H408	New	Methanol 15% w	Transport, Land	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
H400	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	1.66	2.33	3.04	3.75	4.46	3.98
H405	New	Electicity & Petr	Transport, Land (Cars)	Hybrid Electric Motor & Internal Combustion Engine (Land Transport)	0.07	0.58	1.16	1.74	2.32	2.76
H404	Existing	Electricity	Transport, Land (Cars)	Electric Motor (Land Transport)	0.07	0.00	0.00	0.00	0.00	0.00
H406	New	Ethanol 10% wi	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
H401	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.00	0.00	0.00	0.00	0.00
H402	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.01	0.02	0.02	0.03	0.03
H403	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	11.01	10.50	10.17	9.83	9.47	10.23
H407	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00

Table F.2.2 Supply of Energy End-Uses: *Industrial Sector, Economic Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
Ind19	Existing	Electricity	Al2O3 Reduction	Electric Furnace	8.00	8.68	9.05	9.47	9.93	10.29
Ind20	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.29	0.31	0.34	0.38	0.41	0.44
Ind3	Existing	Coal	Fe3O4 Reduction	Furnace/Kiln	2.10	2.39	2.50	2.61	2.74	2.84
Ind50	Existing	Natural Gas	Fe3O4 Reduction	Furnace/Kiln	0.11	0.00	0.00	0.00	0.00	0.00
Ind4	Existing	Coal	High Temperature Heat (>300 C), Process	Boiler Systems	0.05	0.07	0.09	0.11	0.13	0.15
Ind21	Existing	Electricity	High Temperature Heat (>300 C), Process	Electric Furnace	2.44	1.49	0.36	0.00	0.00	0.00
Ind23	Existing	Electricity	High Temperature Heat (>300 C), Process	Resistance Heater	0.59	0.82	1.07	0.58	0.00	0.00
Ind32	Existing	Fuel Oil	High Temperature Heat (>300 C), Process	Boiler Systems	0.04	0.05	0.07	0.09	0.10	0.11
Ind41	Existing	LPG	High Temperature Heat (>300 C), Process	Boiler Systems	0.11	0.00	0.00	0.00	0.00	0.00
Ind51	Existing	Natural Gas	High Temperature Heat (>300 C), Process	Boiler Systems	2.84	3.93	5.13	6.33	7.28	7.57
Ind13	Existing	Diesel	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.10	0.00	0.00	0.00	0.00	0.00
Ind24	Existing	Electricity	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	1.14	0.15	0.07	0.00	0.00	0.00
Ind35	Existing	Fuel Oil	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.00	0.00	0.00	0.00	0.00	0.00
Ind56	Existing	Natural Gas	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.38	0.53	0.69	0.84	0.94	1.02
Ind2	Existing	Black Liquor	Intermediate Heat (100-300 C), Process	Boiler Systems	13.54	15.00	15.00	15.00	15.00	15.00
Ind6	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	6.27	8.69	11.34	13.99	16.65	18.64
Ind12	Existing	Diesel	Intermediate Heat (100-300 C), Process	Boiler Systems	0.67	0.00	0.00	0.00	0.00	0.00
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.25	0.35	0.45	0.56	0.66	0.74
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.00	0.00	0.00	0.01	0.01	0.01
Ind40	Existing	Geothermal	Intermediate Heat (100-300 C), Process	Direct Heat	6.12	8.48	11.07	13.66	16.25	18.19
Ind43	Existing	LPG	Intermediate Heat (100-300 C), Process	Boiler Systems	0.49	0.00	0.00	0.00	0.00	0.00
Ind44	Existing	LPG	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.26	0.00	0.00	0.00	0.00	0.00
Ind53	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	12.27	8.96	7.06	5.39	3.90	2.90
Ind54	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.25	0.34	0.45	0.55	0.66	0.74
Ind69	Existing	Wood	Intermediate Heat (100-300 C), Process	Boiler Systems	9.47	9.42	9.57	9.75	9.97	10.16

Table F.2.2 Supply of Energy End-Uses: *Industrial Sector, Economic Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind5	Existing	Coal	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	1.22	1.69	2.21	2.72	3.24	3.63
Ind11	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.24	0.00	0.00	0.00	0.00	0.00
Ind22	Existing	Electricity	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.10	0.00	0.00	0.00	0.00	0.00
Ind33	Existing	Fuel Oil	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.05	0.00	0.00	0.00	0.00	0.00
Ind42	Existing	LPG	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.25	0.00	0.00	0.00	0.00	0.00
Ind52	Existing	Natural Gas	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	2.88	3.38	3.33	3.32	3.34	3.39
Ind68	Existing	Wood	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.08	0.11	0.15	0.18	0.21	0.24
Ind7	Existing	Coal	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.05	0.07	0.09	0.11	0.13	0.14
Ind55	Existing	Natural Gas	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	1.17	1.39	1.47	1.56	1.66	1.73
Ind71	Existing	Wood	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.55	0.00	0.00	0.00	0.00	0.00
Ind9	Existing	Coal	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.11	0.16	0.21	0.25	0.30	0.34
Ind37	Existing	Fuel Oil	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.03	0.05	0.06	0.07	0.09	0.10
Ind59	Existing	Natural Gas	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.14	0.00	0.00	0.00	0.00	0.00
Ind73	Existing	Wood	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.22	0.15	0.11	0.08	0.05	0.02
Ind25	Existing	Electricity	Lighting	Lights	0.15	0.16	0.18	0.19	0.21	0.22
Ind8	Existing	Coal	Low Temperature Heat (<100 C), Process	Boiler Systems	0.08	0.11	0.15	0.18	0.22	0.25
Ind14	Existing	Diesel	Low Temperature Heat (<100 C), Process	Boiler Systems	0.14	0.19	0.25	0.31	0.00	0.00
Ind26	Existing	Electricity	Low Temperature Heat (<100 C), Process	Heat Pump (for Heating)	2.13	2.41	2.37	2.36	2.73	2.78
Ind27	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.06	0.00	0.00	0.00	0.00	0.00
Ind28	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.29	0.00	0.00	0.00	0.00	0.00
Ind36	Existing	Fuel Oil	Low Temperature Heat (<100 C), Process	Boiler Systems	0.02	0.02	0.03	0.04	0.04	0.05
Ind45	Existing	LPG	Low Temperature Heat (<100 C), Process	Boiler Systems	0.16	0.00	0.00	0.00	0.00	0.00
Ind57	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Boiler Systems	0.27	0.00	0.00	0.00	0.00	0.00
Ind58	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Burner (Direct Heat)	0.36	0.50	0.65	0.81	0.96	1.08
Ind72	Existing	Wood	Low Temperature Heat (<100 C), Process	Boiler Systems	0.04	0.05	0.07	0.09	0.10	0.12
Ind60	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.72	0.58	0.63	0.69	0.74	0.78
Ind10	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.48	2.05	2.67	3.30	3.93	4.27
Ind38	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.02	0.03	0.04	0.01	0.00
Ind46	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.04	0.00	0.00	0.00	0.00	0.00
Ind61	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.16	0.79	0.48	0.21	0.00	0.00

Table F.2.2 Supply of Energy End-Uses: ***Industrial Sector, Economic Energy Savings Potential (continued)***

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind15	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.40	0.55	0.72	0.89	1.04	1.11
Ind47	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.11	0.00	0.00	0.00	0.00	0.00
Ind64	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.21	0.23	0.14	0.06	0.00	0.00
Ind16	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.43	0.00	0.00	0.00	0.00	0.00
Ind29	Existing	Electricity	Motive Power, Stationary	Electric Motor	14.39	15.74	16.94	18.26	19.65	20.75
Ind39	Existing	Fuel Oil	Motive Power, Stationary	Stationary Engine	0.00	0.00	0.00	0.01	0.01	0.01
Ind65	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.01	0.00	0.00	0.00	0.00	0.00
Ind30	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	2.91	3.20	3.52	3.88	4.27	4.59
Ind31	Existing	Electricity	Refrigeration	Refrigeration Systems	6.08	6.45	7.17	7.96	8.84	9.56
Ind1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.05	0.05	0.06	0.07	0.07	0.08
Ind17	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.03	0.03	0.04	0.05	0.05
Ind76	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind75	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind77	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.03	0.05	0.04
Ind48	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Ind79	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind74	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.03	0.05	0.05
Ind66	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.05	0.03	0.02	0.00	0.00
Ind78	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind18	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.23	1.45	1.61	1.77	1.97	2.13
Ind49	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Ind62	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind63	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.03	0.04	0.04
Ind67	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.07	0.00	0.00	0.00	0.00	0.00

Table F.2.3 Supply of Energy End-Uses: *Commercial Sector, Economic Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	2.99	3.15	3.41	3.68	3.97	4.19
Com10	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Elements	0.13	0.00	0.00	0.00	0.00	0.00
Com11	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.36	0.50	0.65	0.71	0.78	0.84
Com27	Existing	LPG	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.13	0.10	0.00	0.00	0.00	0.00
Com33	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.09	0.12	0.16	0.19	0.23	0.26
Com2	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	0.15	0.21	0.28	0.34	0.41	0.46
Com12	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.24	0.00	0.00	0.00	0.00	0.00
Com34	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	1.95	0.44	0.42	0.39	0.37	0.34
Com13	Existing	Electricity	Lighting	Lights	0.81	0.85	0.93	1.00	1.07	1.13
Com3	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.99	1.38	1.80	2.22	2.64	2.96
Com4	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.48	0.66	0.87	1.07	1.27	1.42
Com15	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump (for Heating)	4.42	2.00	0.00	0.00	0.00	0.00
Com16	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	5.64	7.85	9.83	10.14	10.16	10.20
Com23	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.08	0.11	0.14	0.17	0.21	0.23
Com24	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.01	0.01	0.02	0.02	0.03	0.03
Com26	Existing	Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.08	0.00	0.00	0.00	0.00	0.00
Com28	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.31	0.43	0.57	0.41	0.60	0.75
Com35	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.92	1.28	1.67	2.07	2.46	2.75
Com5	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.46	0.64	0.84	1.03	1.23	1.38
Com17	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Heat Pump (for Heating)	0.45	0.00	0.00	0.00	0.00	0.00
Com18	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	2.63	2.83	2.63	2.46	2.31	2.22
Com25	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Com29	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.00	0.00	0.00	0.00	0.00	0.00
Com36	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.66	0.92	1.21	1.49	1.77	1.98
Com37	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	0.34	0.47	0.61	0.75	0.89	1.00
Com30	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com38	Existing	Natural Gas	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00

Table F.2.3 Supply of Energy End-Uses: *Commercial Sector, Economic Energy Savings Potential* *(continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com19	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.31	1.38	1.50	1.61	1.73	1.83
Com21	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	0.56	0.59	0.63	0.68	0.73	0.77
Com22	Existing	Electricity	Refrigeration	Refrigeration Systems	4.37	4.72	5.26	5.84	6.47	6.98
Com8	Existing	Electricity	Space Cooling	Heat Pump (for Cooling)	4.44	4.68	5.08	5.50	5.94	6.29
Com14	Existing	Electricity	Street Lighting	Street Lights	0.05	0.05	0.06	0.06	0.06	0.06
Com1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.20	0.20	0.21	0.22	0.23	0.24
Com6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.04	0.06	0.08	0.10	0.11	0.13
Com44	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com43	New	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com45	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com31	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com47	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com42	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.05	0.07	0.10	0.12
Com41	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.34	0.46	0.47	0.47	0.48	0.48
Com46	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.65	1.41	1.52	1.64	1.76	1.85
Com32	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com39	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com48	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.02	0.02	0.02	0.02	0.02	0.03

Table F.2.4 Supply of Energy End-Uses: *Primary Sector, Economic Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
P9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.05	0.05	0.05	0.06	0.06	0.06
P10	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.18	0.00	0.00	0.00	0.00	0.00
P17	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.24	0.33	0.44	0.54	0.64	0.72
P21	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	0.26	0.33	0.27	0.22	0.17	0.13
P1	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P18	Existing	Fuel Oil	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.00	0.00	0.00	0.00	0.00	0.00
P2	Existing	Diesel	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P11	Existing	Electricity	Lighting	Lights	0.05	0.05	0.05	0.06	0.06	0.07
P12	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.32	0.35	0.39	0.43	0.48	0.51
P1	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.86	2.56	3.34	3.68	3.85	3.99
P3	Existing	Diesel	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.12	0.00	0.00	0.00	0.00	0.00
P22	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.48	0.80	0.17	0.00	0.00	0.00
P13	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.24	1.19	1.36	1.55	1.77	1.95
P4	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land	1.08	1.33	1.44	1.57	1.70	1.81
P23	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land	0.18	0.00	0.00	0.00	0.00	0.00
P5	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.26	0.00	0.00	0.00	0.00	0.00
P14	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.34	1.60	1.71	1.83	1.95	2.05
P24	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.02	0.00	0.00	0.00	0.00	0.00
P15	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.93	2.14	2.42	2.73	3.09	3.39
P16	Existing	Electricity	Refrigeration	Refrigeration Systems	1.46	1.59	1.80	2.02	2.28	2.50

Table F.2.4 Supply of Energy End-Uses: *Primary Sector, Economic Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
P1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.07	0.07	0.08	0.09	0.10	0.10
P6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.03	0.04	0.00	0.00	0.00	0.00
P29	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
P30	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P27	New	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
P32	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P28	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.01	0.03	0.04	0.05	0.06
P25	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.19	0.08	0.12	0.12	0.13	0.13
P31	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.99	1.17	1.29	1.42	1.57	1.69
P26	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.09	0.00	0.00	0.00	0.00	0.00
P8	Existing	Diesel	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.61	0.58	0.58	0.58	0.59	0.62
P19	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.29	0.39	0.51	0.63	0.76	0.85

Table F.2.5 Supply of Energy End-Uses: Transport and Storage Sector, *Economic Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Trans8	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.19	0.20	0.21	0.23	0.25	0.26
Trans9	Existing	Electricity	Lighting	Lights	0.04	0.04	0.05	0.05	0.05	0.06
Trans10	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.28	0.30	0.32	0.35	0.37	0.40
Trans1	Existing	Aviation Fuel	Transport, Air	Aircraft	4.85	5.09	5.50	5.93	6.40	6.78
Trans3	Existing	Diesel	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.78	0.84	0.88	0.93	0.98	1.03
Trans11	Existing	Electricity	Transport, Land (Buses)	Electric Motor	0.06	0.08	0.11	0.13	0.16	0.17
Trans15	Existing	LPG	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans18	Existing	Natural Gas	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.02	0.02	0.02	0.03
Trans20	Existing	Petrol	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.03	0.00	0.00	0.00	0.00	0.00
Trans4	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.12	0.17	0.22	0.27	0.32	0.36
Trans25	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Trans24	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Trans26	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.08	0.15	0.23	0.31	0.32
Trans16	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.10	0.00	0.00	0.00	0.00	0.00
Trans28	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans23	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.08	0.15	0.23	0.31	0.37
Trans21	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.53	0.46	0.32	0.18	0.05	0.00
Trans27	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans5	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.02	9.02	9.74	10.52	11.30	11.96
Trans17	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.06	0.00	0.00	0.00	0.00	0.00
Trans19	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.05	0.05
Trans22	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.49	0.00	0.00	0.00	0.00	0.00

Table F.2.5 Supply of Energy End-Uses: Transport and Storage Sector, *Economic Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Trans7	Existing	Diesel	Transport, Rail (Freight)	Locomotive (Rail)	0.12	0.00	0.00	0.00	0.00	0.00
Trans13	Existing	Electricity	Transport, Rail (Freight)	Electric Motor	0.98	1.15	1.24	1.34	1.45	1.53
Trans2	Existing	Coal	Transport, Rail (Passenger)	Locomotive (Rail)	0.01	0.01	0.01	0.02	0.02	0.02
Trans6	Existing	Diesel	Transport, Rail (Passenger)	Locomotive (Rail)	0.02	0.00	0.00	0.00	0.00	0.00
Trans12	Existing	Electricity	Transport, Rail (Passenger)	Electric Motor	0.13	0.15	0.16	0.17	0.18	0.19
Trans14	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.71	0.74	0.80	0.86	0.93	0.99

F.3 Realisable Energy Savings Potential

The following pages contain five tables that present the manner (technology type, delivered energy type) by which the energy end-uses are supplied in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table F.3.1)
- Industrial Sector (Table F.32)
- Commercial Sector (Table F.3.3)
- Primary Sector (Table F.3.4)
- Transport and Storage Sector (Table F.3.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table F.3.1 Supply of Energy End-Uses: *Household Sector, Realisable Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H347	Existing	Electricity	Dishwasher: Low Temperature Heat (<100 C)	Dish Washer	0.25	0.26	0.28	0.30	0.32	0.33
H322	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	7.36	7.76	8.32	8.87	9.41	9.82
H317 A	Existing	Coal	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.00	0.00	0.00	0.00	0.00	0.00
H323 A	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.30	0.17	0.05	0.00	0.00	0.00
H323 B	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Electric Stovetop	0.87	0.93	1.01	1.10	1.18	1.25
H323 D	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Microwave	0.26	0.28	0.30	0.33	0.35	0.37
H334	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Ovens	0.02	0.09	0.19	0.21	0.18	0.15
H334_A	New	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Cooktops	0.01	0.02	0.04	0.06	0.08	0.10
H334_B	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Gas Oven & Cooktops	0.24	0.26	0.28	0.30	0.32	0.34
H337	Existing	Wood	Intermediate Heat (100-300 C), Cooking	Wood Cooking Oven	0.01	0.01	0.01	0.01	0.01	0.01
H324_A	Existing	Electricity	Lighting	Tungsten Incandescent Lights	0.33	0.24	0.22	0.20	0.18	0.16
H324_B	Existing	Electricity	Lighting	Compact Fluorescent Light	0.08	0.09	0.10	0.11	0.11	0.12
H324_C	Existing	Electricity	Lighting	Halogen Lightis	0.00	0.01	0.03	0.04	0.05	0.06
H324_D	New	Electricity	Lighting	LED Lights	0.00	0.01	0.03	0.04	0.05	0.06
H324_E	Existing	Electricity	Lighting	'Non-Compact' Fluorescent Light	0.01	0.02	0.03	0.04	0.06	0.06
H325	Existing	Electricity	Low Temperature Heat (<100 C), Clothes Drying	Clothes Dryer	0.21	0.22	0.24	0.25	0.27	0.28
H355	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Ceiling Insulation	0.00	0.00	0.00	0.00	0.00	0.00
H356	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Wall Insulation	0.00	0.00	0.00	0.00	0.00	0.00
H357	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Floor Insulation	0.00	0.00	0.00	0.00	0.00	0.00
H358	Existing	All Types	Low Temperature Heat (<100 C), Space Heating	Double Glazing	0.00	0.00	0.00	0.00	0.00	0.00
H318	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.11	0.12	0.13	0.14	0.15	0.16
H319	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire	0.08	0.00	0.00	0.00	0.00	0.00
H320	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	0.02	0.00	0.00	0.00	0.00	0.00
H326	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Existing Heat Pumps	1.80	1.93	2.11	2.28	2.46	2.59
H326_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.03 kW reverse cycle	0.03	0.11	0.22	0.34	0.45	0.53
H326_B	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 1.88 kW reverse cycle	0.03	0.11	0.22	0.34	0.45	0.53
H326_C	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump 3.94 kW reverse cycle	0.03	0.11	0.22	0.34	0.45	0.05
H327_A	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	0.03	0.11	0.22	0.34	0.45	0.53
H363	New	Electricity	Low Temperature Heat (<100 C), Space Heating	Night Store	0.03	0.11	0.22	0.34	0.18	0.00
H327	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater & Nightstore	4.99	5.36	5.84	6.33	6.82	7.18

NB: For processes H355, H356, H357, H358 the yearly data is not measured in Petajoules. Rather, it represents the proportion of extra households adopting that form of insulation. It should be noted this is extra/additional to the existing proportions: H355=0.64, H356=0.45, H357=0.18, H358=0.09.

Table F.3.1 Supply of Energy End-Uses: ***Household Sector, Realisable Energy Savings Potential (continued)***

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H333_A	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (unflued)	0.03	0.11	0.22	0.00	0.00	0.00
H333_B	New	LPG	Low Temperature Heat (<100 C), Space Heating	LPG space heating (flued)	0.03	0.00	0.00	0.00	0.00	0.00
H333	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	1.69	1.47	0.37	0.00	0.00	0.00
H335_A	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, unflued, bayonet fitting or fixed wall mount	0.03	0.11	0.22	0.34	0.45	0.53
H335_B	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Direct space heating, flued	0.03	0.11	0.22	0.34	0.45	0.53
H360	New	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Central Heating	0.03	0.00	0.00	0.00	0.00	0.00
H355	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	2.06	2.21	2.41	2.62	2.82	2.97
H331	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.05	0.00	0.00	0.00	0.00	0.00
H338_A	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.83	0.89	0.97	0.65	0.00	0.00
H345	New	Wood	Low Temperature Heat (<100 C), Space Heating	Wood pellet stoves	0.03	0.11	0.22	0.34	0.45	0.53
H339	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire	0.47	0.00	0.00	0.00	0.00	0.00
H340	Existing	Wood	Low Temperature Heat (<100 C), Space Heating	Open Fire, with Wetback	0.11	0.00	0.00	0.00	0.00	0.00
H338_B	New	Wood	Low Temperature Heat (<100 C), Space Heating + Low Temperature Heat (<100 C), Water Heating	Enclosed wood burner with wet back, space heating	0.03	0.11	0.22	0.34	0.45	0.53
H328	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	0.05	0.00	0.00	0.00	0.00	0.00
H328_A	New	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	0.05	0.19	0.38	0.57	0.75	0.89
H328_C	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	13.54	13.00	12.63	12.24	11.85	11.55
H344_B	New	LPG	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	0.05	0.00	0.00	0.00	0.00	0.00
H344_A	new	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Instantaneous gas water heater	0.05	0.19	0.38	0.57	0.75	0.89
H380_A	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with No Wrap)	0.05	0.19	0.38	0.57	0.75	0.89
H380_B	New	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder (with Wrap)	0.05	0.19	0.38	0.57	0.75	0.89
H380	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Existing Technology Mix	2.21	2.37	2.59	2.80	3.02	3.18
H342_A	New	Solar (+Elect)	Low Temperature Heat (<100 C), Water Heating	Solar water heater, electricity boosted & elect pump	0.05	0.19	0.38	0.57	0.75	0.89
H342_B	New	Solar (+Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas boosted & elect pump	0.05	0.19	0.38	0.57	0.75	0.89
H342	Existing	Solar (Elect +Gas)	Low Temperature Heat (<100 C), Water Heating	Solar water, heater gas/elec boosted & elect pump	0.31	0.41	0.54	0.68	0.81	0.91
H332	Existing	Wellhead Geothermal	Low Temperature Heat (<100 C), Water Heating	Direct Heat	0.05	0.06	0.06	0.07	0.07	0.07

Table F.3.1 Supply of Energy End-Uses: ***Household Sector, Realisable Energy Savings Potential (continued)***

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H338	Existing	Petrol	Motive Power, Mobile	Internal Combustion (Lawnmower)	0.42	0.44	0.48	0.51	0.54	0.56
H329	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.24	0.25	0.27	0.28	0.30	0.32
H330	Existing	Electricity	Refrigeration	Refrigeration Systems	5.97	6.29	6.74	7.19	7.63	7.96
H343	Existing	Electricity	Spa Pools: Low Temperature Heat (<100 C)	Water Heater	0.28	0.30	0.32	0.34	0.36	0.38
H346_A	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.00	0.01	0.01	0.01
H346_B	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.00	0.01	0.01	0.01
H346_C	New	Electricity	Space Cooling	Heat Pump (for Cooling, reverse Cycle)	0.00	0.00	0.00	0.00	0.00	0.00
H346	Existing	Electricity	Space Cooling	Heat Pumps	0.05	0.05	0.05	0.05	0.05	0.05
H408	New	Methanol 15% with P	Transport, Land	Internal Combustion Engine (Land Transport)	0.00	0.29	0.58	0.87	1.16	1.38
H400	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	1.66	1.78	1.94	2.10	2.26	2.38
H405	New	Electicity & Petrol	Transport, Land (Cars)	Hybrid Electric Motor & Internal Combustion Engine (Land Transport)	0.07	0.29	0.58	0.87	1.16	1.38
H404	Existing	Electricity	Transport, Land (Cars)	Electric Motor (Land Transport)	0.07	0.07	0.09	0.12	0.13	0.13
H406	New	Ethanol 10% with Pe	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.29	0.58	0.87	1.16	1.38
H401	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.07	0.08	0.08	0.09	0.09
H402	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.01	0.01	0.01	0.01	0.01
H403	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	11.01	10.63	10.52	10.42	10.31	10.23
H407	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00

Table F.3.2 Supply of Energy End-Uses: *Industrial Sector, Realisable Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind19	Existing	Electricity	Al2O3 Reduction	Electric Furnace	8.00	8.68	9.05	9.47	9.93	10.29
Ind20	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.29	0.31	0.34	0.38	0.41	0.44
Ind3	Existing	Coal	Fe3O4 Reduction	Furnace/Kiln	2.10	2.34	2.50	2.61	2.74	2.84
Ind50	Existing	Natural Gas	Fe3O4 Reduction	Furnace/Kiln	0.11	0.05	0.00	0.00	0.00	0.00
Ind4	Existing	Coal	High Temperature Heat (>300 C), Process	Boiler Systems	0.05	0.06	0.06	0.07	0.08	0.08
Ind21	Existing	Electricity	High Temperature Heat (>300 C), Process	Electric Furnace	2.44	2.32	2.25	2.10	1.97	1.88
Ind23	Existing	Electricity	High Temperature Heat (>300 C), Process	Resistance Heater	0.59	0.66	0.75	0.84	0.93	1.00
Ind32	Existing	Fuel Oil	High Temperature Heat (>300 C), Process	Boiler Systems	0.04	0.04	0.05	0.05	0.06	0.07
Ind41	Existing	LPG	High Temperature Heat (>300 C), Process	Boiler Systems	0.11	0.12	0.00	0.00	0.00	0.00
Ind51	Existing	Natural Gas	High Temperature Heat (>300 C), Process	Boiler Systems	2.84	3.16	3.60	4.04	4.47	4.80
Ind13	Existing	Diesel	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.10	0.00	0.00	0.00	0.00	0.00
Ind24	Existing	Electricity	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	1.14	0.25	0.27	0.30	0.34	0.38
Ind35	Existing	Fuel Oil	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.00	0.00	0.00	0.00	0.00	0.00
Ind56	Existing	Natural Gas	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.38	0.42	0.48	0.54	0.60	0.64
Ind2	Existing	Black Liquor	Intermediate Heat (100-300 C), Process	Boiler Systems	13.54	15.00	15.00	15.00	15.00	15.00
Ind6	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	6.27	7.00	7.96	8.93	9.89	10.62
Ind12	Existing	Diesel	Intermediate Heat (100-300 C), Process	Boiler Systems	0.67	0.00	0.00	0.00	0.47	1.13
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.25	0.28	0.32	0.36	0.39	0.42
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.00	0.00	0.00	0.00	0.00	0.00
Ind40	Existing	Geothermal	Intermediate Heat (100-300 C), Process	Direct Heat	6.12	6.83	7.77	8.71	9.65	10.36
Ind43	Existing	LPG	Intermediate Heat (100-300 C), Process	Boiler Systems	0.49	0.00	0.00	0.00	0.00	0.00
Ind44	Existing	LPG	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.26	0.00	0.00	0.00	0.00	0.09
Ind53	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	12.27	12.94	14.91	17.26	19.35	20.76
Ind54	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.25	0.28	0.31	0.35	0.39	0.42

Table F.3.2 Supply of Energy End-Uses: *Industrial Sector, Realisable Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind69	Existing	Wood	Intermediate Heat (100-300 C), Process	Boiler Systems	9.47	9.23	9.39	9.48	9.66	9.77
Ind5	Existing	Coal	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	1.22	1.36	1.55	1.74	1.92	2.07
Ind11	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.24	0.26	0.30	0.27	0.20	0.18
Ind22	Existing	Electricity	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.10	0.11	0.01	0.00	0.00	0.00
Ind33	Existing	Fuel Oil	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.05	0.06	0.07	0.00	0.00	0.00
Ind42	Existing	LPG	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.25	0.08	0.00	0.00	0.00	0.00
Ind52	Existing	Natural Gas	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	2.88	3.21	3.65	4.10	4.54	4.87
Ind68	Existing	Wood	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.08	0.09	0.10	0.12	0.13	0.14
Ind7	Existing	Coal	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.05	0.05	0.06	0.07	0.08	0.08
Ind55	Existing	Natural Gas	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	1.17	1.30	1.48	1.60	1.71	1.79
Ind71	Existing	Wood	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.55	0.10	0.02	0.00	0.00	0.00
Ind9	Existing	Coal	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.11	0.13	0.14	0.16	0.18	0.19
Ind37	Existing	Fuel Oil	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.03	0.04	0.04	0.05	0.05	0.06
Ind59	Existing	Natural Gas	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.14	0.00	0.00	0.00	0.00	0.00
Ind73	Existing	Wood	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.22	0.19	0.19	0.20	0.21	0.21
Ind25	Existing	Electricity	Lighting	Lights	0.15	0.16	0.18	0.19	0.21	0.22
Ind8	Existing	Coal	Low Temperature Heat (<100 C), Process	Boiler Systems	0.08	0.09	0.10	0.12	0.13	0.14
Ind14	Existing	Diesel	Low Temperature Heat (<100 C), Process	Boiler Systems	0.14	0.16	0.18	0.20	0.00	0.00
Ind26	Existing	Electricity	Low Temperature Heat (<100 C), Process	Heat Pump (for Heating)	2.13	2.37	2.70	2.88	3.33	3.48
Ind27	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.06	0.00	0.02	0.00	0.00	0.00
Ind28	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.29	0.00	0.00	0.00	0.00	0.00
Ind36	Existing	Fuel Oil	Low Temperature Heat (<100 C), Process	Boiler Systems	0.02	0.02	0.02	0.02	0.03	0.03
Ind45	Existing	LPG	Low Temperature Heat (<100 C), Process	Boiler Systems	0.16	0.00	0.00	0.00	0.00	0.00
Ind57	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Boiler Systems	0.27	0.21	0.00	0.00	0.00	0.00
Ind58	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Burner (Direct Heat)	0.36	0.40	0.46	0.52	0.57	0.61
Ind72	Existing	Wood	Low Temperature Heat (<100 C), Process	Boiler Systems	0.04	0.04	0.05	0.06	0.00	0.00
Ind60	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.72	0.58	0.63	0.69	0.74	0.78
Ind10	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.48	1.65	1.88	2.11	2.33	2.50
Ind38	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.02	0.02	0.02	0.03	0.03
Ind46	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.04	0.00	0.00	0.00	0.00	0.00
Ind61	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.16	1.19	1.29	1.41	1.58	1.73

Table F.3.2 Supply of Energy End-Uses: *Industrial Sector, Realisable Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind15	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.40	0.44	0.51	0.57	0.63	0.67
Ind47	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.11	0.10	0.09	0.08	0.08	0.08
Ind64	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.21	0.23	0.27	0.30	0.33	0.36
Ind16	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.43	0.00	0.00	0.00	0.00	0.00
Ind29	Existing	Electricity	Motive Power, Stationary	Electric Motor	14.39	15.74	16.94	18.26	19.66	20.75
Ind39	Existing	Fuel Oil	Motive Power, Stationary	Stationary Engine	0.00	0.00	0.00	0.00	0.00	0.00
Ind65	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.01	0.00	0.00	0.00	0.00	0.00
Ind30	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	2.91	3.20	3.52	3.88	4.27	4.59
Ind31	Existing	Electricity	Refrigeration	Refrigeration Systems	6.08	6.45	7.17	7.96	8.84	9.56
Ind1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.05	0.05	0.06	0.07	0.07	0.08
Ind17	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.02	0.02	0.03	0.03	0.03
Ind76	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind75	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind77	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind48	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Ind79	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind74	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind66	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.07	0.08	0.08	0.09	0.09
Ind78	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind18	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.23	1.37	1.56	1.75	1.94	2.08
Ind49	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Ind62	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind63	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.02	0.02	0.02	0.02
Ind67	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.07	0.06	0.03	0.03	0.04	0.07

Table F.3.3 Supply of Energy End-Uses: *Commercial Sector, Realisable Energy Savings Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	2.99	3.15	3.41	3.68	3.97	4.19
Com10	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Elements	0.13	0.08	0.16	0.17	0.19	0.20
Com11	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.36	0.40	0.45	0.50	0.54	0.58
Com27	Existing	LPG	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.13	0.14	0.10	0.12	0.15	0.17
Com33	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.09	0.10	0.11	0.12	0.13	0.14
Com2	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	0.15	0.17	0.19	0.21	0.23	0.25
Com12	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.24	0.00	0.00	0.00	0.00	0.00
Com34	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	1.95	0.49	0.51	0.53	0.54	0.56
Com13	Existing	Electricity	Lighting	Lights	0.81	0.85	0.93	1.00	1.07	1.13
Com3	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.99	1.09	1.23	1.36	1.49	1.59
Com4	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.48	0.52	0.59	0.65	0.72	0.77
Com15	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump (for Heating)	4.42	4.45	4.48	4.55	4.68	4.83
Com16	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	5.64	6.22	6.98	7.74	8.51	9.08
Com23	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.08	0.09	0.10	0.11	0.12	0.12
Com24	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.01	0.01	0.01	0.01	0.01	0.02
Com26	Existing	Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.08	0.00	0.00	0.00	0.00	0.00
Com28	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.31	0.34	0.39	0.43	0.47	0.50
Com35	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.92	1.02	1.14	1.26	1.39	1.48
Com5	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.46	0.51	0.57	0.63	0.69	0.74
Com17	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Heat Pump (for Heating)	0.45	0.36	0.24	0.15	0.08	0.05
Com18	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	2.63	2.90	3.25	3.61	3.96	4.23
Com25	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Com29	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.00	0.00	0.00	0.00	0.00	0.00
Com36	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.66	0.73	0.82	0.91	1.00	1.07
Com37	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	0.34	0.37	0.41	0.46	0.51	0.54
Com30	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (	0.00	0.00	0.00	0.00	0.00	0.00
Com38	Existing	Natural Gas	Motive Power, Mobile	Internal Combustion Engine (	0.00	0.00	0.00	0.00	0.00	0.00

Table F.3.3 Supply of Energy End-Uses: *Commercial Sector, Realisable Energy Savings Potential* (continued)

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com19	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.31	1.38	1.50	1.61	1.73	1.83
Com21	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	0.56	0.59	0.63	0.68	0.73	0.77
Com22	Existing	Electricity	Refrigeration	Refrigeration Systems	4.37	4.72	5.26	5.84	6.47	6.98
Com8	Existing	Electricity	Space Cooling	Heat Pump (for Cooling)	4.44	4.68	5.08	5.50	5.94	6.29
Com14	Existing	Electricity	Street Lighting	Street Lights	0.05	0.05	0.06	0.06	0.06	0.06
Com1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.20	0.20	0.21	0.22	0.23	0.24
Com6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.04	0.05	0.05	0.06	0.06	0.07
Com44	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com43	New	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com45	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com31	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com47	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com42	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.04	0.05	0.06
Com41	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.34	0.49	0.52	0.55	0.58	0.60
Com46	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.65	1.41	1.52	1.64	1.76	1.85
Com32	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com39	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com48	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.02	0.02	0.02	0.02	0.02	0.03

Table F.3.4 Supply of Energy End-Uses: *Primary Sector, Realisable Energy Savings Potential*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
P9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.05	0.05	0.05	0.06	0.06	0.06
P10	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.18	0.10	0.06	0.02	0.00	0.00
P17	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.24	0.27	0.31	0.36	0.40	0.43
P21	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	0.26	0.29	0.33	0.38	0.41	0.42
P1	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P18	Existing	Fuel Oil	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.00	0.00	0.00	0.00	0.00	0.00
P2	Existing	Diesel	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P11	Existing	Electricity	Lighting	Lights	0.05	0.05	0.05	0.06	0.06	0.07
P12	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.32	0.35	0.39	0.43	0.48	0.51
P1	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.86	2.10	2.42	2.74	3.05	3.29
P3	Existing	Diesel	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.12	0.00	0.00	0.00	0.00	0.00
P22	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.48	1.26	1.10	0.94	0.79	0.69
P13	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.24	1.19	1.36	1.55	1.77	1.95
P4	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	1.08	1.22	1.41	1.57	1.70	1.81
P23	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.18	0.10	0.03	0.00	0.00	0.00
P5	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.26	0.09	0.00	0.00	0.00	0.00
P14	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.34	1.51	1.71	1.83	1.95	2.05
P24	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.02	0.00	0.00	0.00	0.00	0.00
P15	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.93	2.14	2.42	2.73	3.09	3.39
P16	Existing	Electricity	Refrigeration	Refrigeration Systems	1.46	1.59	1.80	2.02	2.28	2.50

Table F.3.4 Supply of Energy End-Uses: ***Primary Sector, Realisable Energy Savings Potential (continued)***

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
P1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.07	0.07	0.08	0.09	0.10	0.10
P6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.03	0.03	0.00	0.00	0.00	0.00
P29	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
P30	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P27	New	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
P32	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P28	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.01	0.01	0.02	0.03	0.03
P25	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.19	0.10	0.13	0.14	0.15	0.16
P31	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.99	1.12	1.29	1.42	1.57	1.69
P26	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.09	0.05	0.00	0.00	0.00	0.00
P8	Existing	Diesel	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.61	0.66	0.72	0.79	0.88	0.96
P19	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.29	0.32	0.37	0.42	0.47	0.51

Table F.3.5 Supply of Energy End-Uses: Transport and Storage Sector, *Realisable Energy Savings Potential*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Trans8	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.19	0.20	0.21	0.23	0.25	0.26
Trans9	Existing	Electricity	Lighting	Lights	0.04	0.04	0.05	0.05	0.05	0.06
Trans10	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.28	0.30	0.32	0.35	0.37	0.40
Trans1	Existing	Aviation Fuel	Transport, Air	Aircraft	4.85	5.09	5.50	5.93	6.40	6.78
Trans3	Existing	Diesel	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.78	0.86	0.92	0.99	1.06	1.12
Trans11	Existing	Electricity	Transport, Land (Buses)	Electric Motor	0.06	0.06	0.07	0.08	0.09	0.09
Trans15	Existing	LPG	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans18	Existing	Natural Gas	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.01	0.01	0.01	0.01
Trans20	Existing	Petrol	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.03	0.00	0.00	0.00	0.00	0.00
Trans4	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.12	0.13	0.15	0.17	0.18	0.19
Trans25	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Trans24	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Trans26	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.04	0.06	0.08	0.10
Trans16	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.10	0.01	0.00	0.00	0.00	0.00
Trans28	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.00	0.00	0.00	0.00
Trans23	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.04	0.06	0.08	0.10
Trans21	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.53	0.58	0.62	0.63	0.64	0.66
Trans27	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans5	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.02	8.83	9.74	10.52	11.32	11.99
Trans17	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.06	0.00	0.00	0.00	0.00	0.00
Trans19	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.02	0.02	0.00	0.00	0.03	0.03
Trans22	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.49	0.16	0.00	0.00	0.00	0.00

Table F.3.5 Supply of Energy End-Uses: Transport and Storage Sector, *Realisable Energy Savings Potential (continued)*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Trans7	Existing	Diesel	Transport, Rail (Freight)	Locomotive (Rail)	0.12	0.08	0.04	0.00	0.00	0.00
Trans13	Existing	Electricity	Transport, Rail (Freight)	Electric Motor	0.98	1.07	1.21	1.34	1.45	1.53
Trans2	Existing	Coal	Transport, Rail (Passenger)	Locomotive (Rail)	0.01	0.01	0.01	0.01	0.01	0.01
Trans6	Existing	Diesel	Transport, Rail (Passenger)	Locomotive (Rail)	0.02	0.01	0.00	0.00	0.00	0.00
Trans12	Existing	Electricity	Transport, Rail (Passenger)	Electric Motor	0.13	0.14	0.16	0.17	0.19	0.20
Trans14	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.71	0.74	0.80	0.86	0.93	0.99

F.4 Greenhouse Gas Reductions Potential

The following pages contain five tables that present the manner (technology type, delivered energy type) by which the energy end-uses are supplied in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table F.4.1)
- Industrial Sector (Table F.4.2)
- Commercial Sector (Table F.4.3)
- Primary Sector (Table F.4.4)
- Transport and Storage Sector (Table F.4.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

The *Greenhouse Gas Reductions Potentials* quantified here are more precisely 'Realisable' *Greenhouse Gas Reductions Potentials.* This is because they assume the same end-use technology uptake rates as the 'Realisable Energy Savings Potentials', which reflect realistic levels of uptake.

Table F.4.1 Supply of Energy End-Uses: *Household Sector, Greenhouse Gas Reductions Potential*

Code	Existing/New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H347	Existing	Electricity	Dish Washer	Dishwasher: Low Temperature Heat (<100 C), Water	0.25	0.26	0.28	0.30	0.32	0.33
H322	Existing	Electricity	Electronics	Electronics and Other Electrical Uses	7.36	7.76	8.32	8.87	9.41	9.82
H317 A	Existing	Coal	Cooking Ovens	Intermediate Heat (100-300 C), Cooking	0.00	0.00	0.00	0.00	0.00	0.00
H323 A	Existing	Electricity	Cooking Ovens	Intermediate Heat (100-300 C), Cooking	0.30	0.32	0.35	0.38	0.18	0.16
H323 B	Existing	Electricity	Electric Stovetop	Intermediate Heat (100-300 C), Cooking	0.87	0.93	1.01	1.10	1.18	1.25
H323 D	Existing	Electricity	Microwave	Intermediate Heat (100-300 C), Cooking	0.26	0.28	0.30	0.33	0.35	0.37
H334	New	Natural Gas	Gas Ovens	Intermediate Heat (100-300 C), Cooking	0.02	0.00	0.00	0.00	0.00	0.00
H334_A	New	Natural Gas	Gas Cooktops	Intermediate Heat (100-300 C), Cooking	0.01	0.02	0.04	0.06	0.08	0.10
H334_B	Existing	Natural Gas	Gas Oven & Cooktops	Intermediate Heat (100-300 C), Cooking	0.24	0.20	0.17	0.13	0.32	0.34
H337	Existing	Wood	Wood Cooking Oven	Intermediate Heat (100-300 C), Cooking	0.01	0.01	0.01	0.01	0.01	0.01
H324_A	Existing	Electricity	Tungsten Incandescent Lights	Lighting	0.33	0.24	0.22	0.20	0.18	0.16
H324_B	Existing	Electricity	Compact Fluorescent Light	Lighting	0.08	0.09	0.10	0.11	0.11	0.12
H324_C	Existing	Electricity	Halogen Lightis	Lighting	0.00	0.01	0.03	0.04	0.05	0.06
H324_D	New	Electricity	LED Lights	Lighting	0.00	0.01	0.03	0.04	0.05	0.06
H324_E	Existing	Electricity	'Non-Compact' Fluorescent Light	Lighting	0.01	0.02	0.03	0.04	0.06	0.06
H325	Existing	Electricity	Clothes Dryer	Low Temperature Heat (<100 C), Clothes Drying	0.21	0.22	0.24	0.25	0.27	0.28
H355	Existing	All Types	Ceiling Insulation	Low Temperature Heat (<100 C), Space Heating	0.00	0.05	0.11	0.00	0.22	0.26
H356	Existing	All Types	Wall Insulation	Low Temperature Heat (<100 C), Space Heating	0.00	0.08	0.16	0.06	0.33	0.39
H357	Existing	All Types	Floor Insulation	Low Temperature Heat (<100 C), Space Heating	0.00	0.12	0.24	0.00	0.49	0.58
H358	Existing	All Types	Double Glazing	Low Temperature Heat (<100 C), Space Heating	0.00	0.14	0.27	0.00	0.54	0.65
H318	Existing	Coal	Burner (Direct Heat)	Low Temperature Heat (<100 C), Space Heating	0.11	0.12	0.00	0.00	0.00	0.00
H319	Existing	Coal	Open Fire	Low Temperature Heat (<100 C), Space Heating	0.08	0.00	0.00	0.00	0.00	0.00
H320	Existing	Coal	Open Fire, with Wetback	Low Temperature Heat (<100 C), Space Heating	0.02	0.02	0.00	0.00	0.00	0.00
H326	Existing	Electricity	Existing Heat Pumps	Low Temperature Heat (<100 C), Space Heating	1.80	1.93	2.11	2.28	2.46	2.59
H326_A	New	Electricity	Heat Pump 1.03 kW reverse cycle	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H326_B	New	Electricity	Heat Pump 1.88 kW reverse cycle	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H326_C	New	Electricity	Heat Pump 3.94 kW reverse cycle	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H327_A	New	Electricity	Resistance Heater	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H363	New	Electricity	Night Store	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H327	Existing	Electricity	Resistance Heater & Nightstore	Low Temperature Heat (<100 C), Space Heating	4.99	5.36	5.84	6.33	6.82	7.18

NB: For processes H355, H356, H357, H358 the yearly data is not measured in Petajoules. Rather, it represents the proportion of extra households adopting that form of insulation. It should be noted this is extra/additional to the existing proportions: H355=0.64, H356=0.45, H357=0.18, H358=0.09.

Table F.4.1 Supply of Energy End-Uses: *Household Sector, Greenhouse Gas Reductions Potential (continued)*

Code	Existing/New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
H333_A	New	LPG	LPG space heating (unflued)	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.00	0.00
H333_B	New	LPG	LPG space heating (flued)	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.00	0.00	0.00	0.00
H333	Existing	LPG	Burner (Direct Heat)	Low Temperature Heat (<100 C), Space Heating	1.69	1.82	1.42	0.71	0.00	0.00
H335_A	New	Natural Gas	Direct space heating, unflued, bayonet fitting or fixed wall mount	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H335_B	New	Natural Gas	Direct space heating, flued	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H360	New	Natural Gas	Central Heating	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.22	0.34	0.45	0.53
H355	Existing	Natural Gas	Burner (Direct Heat)	Low Temperature Heat (<100 C), Space Heating	2.06	2.21	2.41	2.62	2.61	2.07
H331	Existing	Wellhead Geotherr	Direct Heat	Low Temperature Heat (<100 C), Space Heating	0.05	0.06	0.06	0.07	0.07	0.07
H338_A	Existing	Wood	Burner (Direct Heat)	Low Temperature Heat (<100 C), Space Heating	0.83	0.13	0.00	0.00	0.00	0.00
H345	New	Wood	Wood pellet stoves	Low Temperature Heat (<100 C), Space Heating	0.03	0.11	0.00	0.00	0.00	0.00
H339	Existing	Wood	Open Fire	Low Temperature Heat (<100 C), Space Heating	0.47	0.00	0.00	0.00	0.00	0.00
H340	Existing	Wood	Open Fire, with Wetback	Low Temperature Heat (<100 C), Space Heating	0.11	0.12	0.00	0.00	0.02	0.03
H338_B	New	Wood	Enclosed wood burner with wet back, space heating	Low Temperature Heat (<100 C), Space Heating + Low Temperature Heat (<100 C), Water Heating	0.03	0.11	0.22	0.00	0.45	0.53
H328	New	Electricity	Hot Water Cylinder (with No Wrap)	Low Temperature Heat (<100 C), Water Heating	0.05	0.19	0.38	0.47	0.00	0.00
H328_A	New	Electricity	Hot Water Cylinder (with Wrap)	Low Temperature Heat (<100 C), Water Heating	0.05	0.19	0.38	0.57	0.75	0.89
H328_C	Existing	Electricity	Hot Water Cylinder	Low Temperature Heat (<100 C), Water Heating	13.54	14.53	15.85	17.17	16.87	13.46
H344_B	New	LPG	Instantaneous gas water heater	Low Temperature Heat (<100 C), Water Heating	0.05	0.00	0.00	0.00	0.00	0.00
H344_A	new	Natural Gas	Instantaneous gas water heater	Low Temperature Heat (<100 C), Water Heating	0.05	0.19	0.00	0.00	0.00	0.89
H380_A	New	Natural Gas	Hot Water Cylinder (with No Wrap)	Low Temperature Heat (<100 C), Water Heating	0.05	0.00	0.00	0.00	0.00	0.00
H380_B	New	Natural Gas	Hot Water Cylinder (with Wrap)	Low Temperature Heat (<100 C), Water Heating	0.05	0.19	0.13	0.00	0.24	0.89
H380	Existing	Natural Gas	Existing Technology Mix	Low Temperature Heat (<100 C), Water Heating	2.21	0.71	0.00	0.00	0.00	2.13
H342_A	New	Solar (+Elect)	elect pump	Low Temperature Heat (<100 C), Water Heating	0.05	0.19	0.38	0.57	0.75	0.89
H342_B	New	Solar (+Gas)	Solar water, heater gas boosted & elect pump	Low Temperature Heat (<100 C), Water Heating	0.05	0.19	0.38	0.00	0.75	0.89
H342	Existing	Solar (Elect +Gas)	Solar water, heater gas/elec boosted & elect pump	Low Temperature Heat (<100 C), Water Heating	0.31	0.41	0.54	0.68	0.81	0.91
H332	Existing	Wellhead Geothermal	Direct Heat	Low Temperature Heat (<100 C), Water Heating	0.05	0.06	0.06	0.07	0.07	0.07

Table F.4.1 Supply of Energy End-Uses: *Household Sector, Greenhouse Gas Reductions Potential (continued)*

Code	Existing/New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
H338	Existing	Petrol	Internal Combustion (Lawnmower)	Motive Power, Mobile	0.42	0.44	0.48	0.51	0.54	0.56
H329	Existing	Electricity	Electric Motor	Motive Power, Stationary	0.24	0.25	0.27	0.28	0.30	0.32
H330	Existing	Electricity	Refrigeration Systems	Refrigeration	5.97	6.29	6.74	7.19	7.63	7.96
H343	Existing	Electricity	Water Heater	Spa Pools: Low Temperature Heat (<100 C), Water Heating	0.28	0.30	0.32	0.34	0.36	0.38
H346_A	New	Electricity	Heat Pump (for Cooling, reverse Cycle)	Space Cooling	0.00	0.00	0.00	0.01	0.01	0.01
H346_B	New	Electricity	Heat Pump (for Cooling, reverse Cycle)	Space Cooling	0.00	0.00	0.00	0.01	0.01	0.01
H346_C	New	Electricity	Heat Pump (for Cooling, reverse Cycle)	Space Cooling	0.00	0.00	0.00	0.01	0.01	0.01
H346	Existing	Electricity	Heat Pumps	Space Cooling	0.05	0.05	0.05	0.05	0.04	0.04
H408	New	Methanol 15% with Petrol	Internal Combustion Engine (Land Transport)	Transport, Land	0.00	0.29	0.58	0.87	1.16	1.38
H400	Existing	Diesel	Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	1.66	1.26	0.87	0.47	0.07	0.00
H405	New	Electicity & Petrol	Hybrid Electric Motor & Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	0.07	0.29	0.58	0.87	1.16	1.38
H404	Existing	Electricity	Electric Motor (Land Transport)	Transport, Land (Cars)	0.07	0.29	0.58	0.87	1.16	1.38
H406	New	Ethanol 10% with Petrol	Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	0.00	0.29	0.58	0.87	1.16	1.38
H401	Existing	LPG	Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	0.06	0.07	0.08	0.08	0.09	0.09
H402	Existing	Natural Gas	Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	0.01	0.01	0.01	0.01	0.01	0.01
H403	Existing	Petrol	Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	11.01	10.63	10.52	10.42	10.31	9.99
H407	New	Pure Ethanol	Internal Combustion Engine (Land Transport)	Transport, Land (Cars)	0.00	0.29	0.58	0.87	1.16	1.38

Table F.4.2 Supply of Energy End-Uses: *Industrial Sector, Greenhouse Gas Reductions Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind19	Existing	Electricity	Al2O3 Reduction	Electric Furnace	8.00	8.68	9.05	9.47	9.93	10.29
Ind20	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.29	0.31	0.34	0.38	0.41	0.44
Ind3	Existing	Coal	Fe3O4 Reduction	Furnace/Kiln	2.10	2.27	2.36	2.46	2.57	2.66
Ind50	Existing	Natural Gas	Fe3O4 Reduction	Furnace/Kiln	0.11	0.12	0.13	0.15	0.17	0.18
Ind4	Existing	Coal	High Temperature Heat (>300 C), Process	Boiler Systems	0.05	0.00	0.00	0.00	0.00	0.00
Ind21	Existing	Electricity	High Temperature Heat (>300 C), Process	Electric Furnace	2.44	2.72	3.09	3.47	2.10	2.03
Ind23	Existing	Electricity	High Temperature Heat (>300 C), Process	Resistance Heater	0.59	0.66	0.75	0.84	0.93	1.00
Ind32	Existing	Fuel Oil	High Temperature Heat (>300 C), Process	Boiler Systems	0.04	0.00	0.00	0.00	0.00	0.00
Ind41	Existing	LPG	High Temperature Heat (>300 C), Process	Boiler Systems	0.11	0.00	0.00	0.00	0.00	0.00
Ind51	Existing	Natural Gas	High Temperature Heat (>300 C), Process	Boiler Systems	2.84	2.99	2.88	2.79	4.47	4.80
Ind13	Existing	Diesel	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.10	0.00	0.00	0.00	0.00	0.00
Ind24	Existing	Electricity	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	1.14	0.68	0.76	0.85	0.94	1.02
Ind35	Existing	Fuel Oil	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.00	0.00	0.00	0.00	0.00	0.00
Ind56	Existing	Natural Gas	Ind Ovens _Intermediate Heat (100-300 C), Process	Industrial Ovens	0.38	0.00	0.00	0.00	0.00	0.00
Ind2	Existing	Black Liquor	Intermediate Heat (100-300 C), Process	Boiler Systems	13.54	15.00	15.00	15.00	15.00	15.00
Ind6	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	6.27	7.00	7.96	8.93	9.89	10.62
Ind12	Existing	Diesel	Intermediate Heat (100-300 C), Process	Boiler Systems	0.67	0.74	0.84	0.95	1.05	1.13
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.25	0.28	0.32	0.36	0.39	0.42
Ind34	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.00	0.00	0.00	0.00	0.00	0.00
Ind40	Existing	Geothermal	Intermediate Heat (100-300 C), Process	Direct Heat	6.12	6.83	7.77	8.71	9.65	10.36
Ind43	Existing	LPG	Intermediate Heat (100-300 C), Process	Boiler Systems	0.49	0.54	0.62	0.69	0.77	0.82
Ind44	Existing	LPG	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.26	0.29	0.33	0.37	0.41	0.44
Ind53	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	12.27	13.68	15.57	17.46	19.35	20.76
Ind54	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Burner (Direct Heat)	0.25	0.28	0.31	0.35	0.39	0.42

Table F.4.2 Supply of Energy End-Uses: *Industrial Sector, Greenhouse Gas Reductions Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind69	Existing	Wood	Intermediate Heat (100-300 C), Process	Boiler Systems	9.47	6.92	6.93	7.27	7.91	8.59
Ind5	Existing	Coal	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	1.22	1.32	1.28	1.28	1.33	1.39
Ind11	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	0.24	0.26	0.30	0.34	0.37	0.40
Ind22	Existing	Electricity	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	0.10	0.11	0.13	0.15	0.16	0.17
Ind33	Existing	Fuel Oil	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	0.05	0.00	0.00	0.00	0.00	0.00
Ind42	Existing	LPG	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	0.25	0.28	0.32	0.36	0.40	0.43
Ind52	Existing	Natural Gas	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	2.88	3.21	3.65	4.10	4.54	4.87
Ind68	Existing	Wood	Kiln/Furnance_ High Temperature Heat (>300 C), Proc	Furnace/Kiln	0.08	0.00	0.00	0.00	0.00	0.00
Ind7	Existing	Coal	Kiln/Furnance_Intermediate Heat (100-300 C), Proces	Furnace/Kiln	0.05	0.05	0.06	0.01	0.00	0.00
Ind55	Existing	Natural Gas	Kiln/Furnance_Intermediate Heat (100-300 C), Proces	Furnace/Kiln	1.17	1.30	1.48	1.66	1.79	1.88
Ind71	Existing	Wood	Kiln/Furnance_Intermediate Heat (100-300 C), Proces	Furnace/Kiln	0.55	0.10	0.02	0.00	0.00	0.00
Ind9	Existing	Coal	Kiln/Furnance_Low Temperature Heat (<100 C), Proce	Furnace/Kiln	0.11	0.13	0.14	0.16	0.18	0.19
Ind37	Existing	Fuel Oil	Kiln/Furnance_Low Temperature Heat (<100 C), Proce	Furnace/Kiln	0.03	0.04	0.04	0.05	0.05	0.06
Ind59	Existing	Natural Gas	Kiln/Furnance_Low Temperature Heat (<100 C), Proce	Furnace/Kiln	0.14	0.00	0.00	0.00	0.00	0.00
Ind73	Existing	Wood	Kiln/Furnance_Low Temperature Heat (<100 C), Proce	Furnace/Kiln	0.22	0.19	0.19	0.20	0.21	0.21
Ind25	Existing	Electricity	Lighting	Lights	0.15	0.16	0.18	0.19	0.21	0.22
Ind8	Existing	Coal	Low Temperature Heat (<100 C), Process	Boiler Systems	0.08	0.00	0.00	0.00	0.00	0.00
Ind14	Existing	Diesel	Low Temperature Heat (<100 C), Process	Boiler Systems	0.14	0.00	0.00	0.00	0.00	0.00
Ind26	Existing	Electricity	Low Temperature Heat (<100 C), Process	Heat Pump (for Heating	2.13	2.37	2.70	3.02	3.35	3.60
Ind27	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.06	0.07	0.08	0.09	0.10	0.10
Ind28	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.29	0.32	0.37	0.41	0.46	0.49
Ind36	Existing	Fuel Oil	Low Temperature Heat (<100 C), Process	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Ind45	Existing	LPG	Low Temperature Heat (<100 C), Process	Boiler Systems	0.16	0.13	0.00	0.00	0.00	0.00
Ind57	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Boiler Systems	0.27	0.00	0.00	0.00	0.00	0.00
Ind58	Existing	Natural Gas	Low Temperature Heat (<100 C), Process	Burner (Direct Heat)	0.36	0.40	0.39	0.27	0.15	0.07
Ind72	Existing	Wood	Low Temperature Heat (<100 C), Process	Boiler Systems	0.04	0.00	0.00	0.00	0.00	0.00
Ind60	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.72	0.58	0.63	0.69	0.74	0.78
Ind10	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.48	1.51	1.65	1.82	2.03	2.21
Ind38	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.02	0.02	0.02	0.03	0.03
Ind46	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.04	0.04	0.05	0.06	0.06	0.07
Ind61	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	1.16	1.29	1.47	1.65	1.83	1.96

Table F.4.2 Supply of Energy End-Uses: *Industrial Sector, Greenhouse Gas Reductions Potential (continued)*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Ind15	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.40	0.44	0.51	0.57	0.63	0.67
Ind47	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.11	0.12	0.14	0.15	0.17	0.18
Ind64	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.21	0.21	0.22	0.23	0.24	0.25
Ind16	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.43	0.00	0.00	0.00	0.00	0.00
Ind29	Existing	Electricity	Motive Power, Stationary	Electric Motor	14.39	15.74	16.94	18.26	19.66	20.76
Ind39	Existing	Fuel Oil	Motive Power, Stationary	Stationary Engine	0.00	0.00	0.00	0.00	0.00	0.00
Ind65	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.01	0.00	0.00	0.00	0.00	0.00
Ind30	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	2.91	3.20	3.52	3.88	4.27	4.59
Ind31	Existing	Electricity	Refrigeration	Refrigeration Systems	6.08	6.45	7.17	7.96	8.84	9.56
Ind1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.05	0.05	0.06	0.07	0.07	0.08
Ind17	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
Ind76	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind75	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind77	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind48	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.01	0.02	0.02	0.02	0.02
Ind79	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind74	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind66	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.06	0.07	0.06	0.05	0.04	0.04
Ind78	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.01	0.01	0.01	0.02
Ind18	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.23	1.37	1.56	1.75	1.94	2.08
Ind49	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Ind62	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Ind63	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.02	0.02	0.02	0.02
Ind67	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.07	0.06	0.03	0.03	0.04	0.07

Table F.4.3 Supply of Energy End-Uses: *Commercial Sector, Greenhouse Gas Reductions Potential*

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	2.99	3.15	3.41	3.68	3.97	4.19
Com10	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Elements	0.13	0.14	0.16	0.17	0.19	0.20
Com11	Existing	Electricity	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.36	0.40	0.45	0.50	0.54	0.58
Com27	Existing	LPG	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.13	0.09	0.10	0.12	0.15	0.17
Com33	Existing	Natural Gas	Intermediate Heat (100-300 C), Cooking	Cooking Ovens	0.09	0.10	0.11	0.12	0.13	0.14
Com2	Existing	Coal	Intermediate Heat (100-300 C), Process	Boiler Systems	0.15	0.00	0.00	0.00	0.00	0.00
Com12	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.24	0.26	0.30	0.33	0.36	0.38
Com34	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	1.95	0.39	0.40	0.41	0.41	0.42
Com13	Existing	Electricity	Lighting	Lights	0.81	0.85	0.93	1.00	1.07	1.13
Com3	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.99	1.09	0.73	0.40	0.12	0.00
Com4	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.48	0.02	0.00	0.00	0.00	0.00
Com15	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Heat Pump (for Heating)	4.42	4.87	5.46	6.06	6.66	7.11
Com16	Existing	Electricity	Low Temperature Heat (<100 C), Space Heating	Resistance Heater	5.64	6.22	6.98	7.74	8.51	9.08
Com23	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.08	0.09	0.10	0.11	0.12	0.10
Com24	Existing	Fuel Oil	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.01	0.01	0.01	0.01	0.01	0.00
Com26	Existing	Geothermal	Low Temperature Heat (<100 C), Space Heating	Direct Heat	0.08	0.09	0.10	0.11	0.12	0.13
Com28	Existing	LPG	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.31	0.34	0.39	0.43	0.47	0.50
Com35	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Burner (Direct Heat)	0.92	1.02	1.14	1.26	1.39	1.48
Com5	Existing	Coal	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.46	0.37	0.26	0.16	0.09	0.06
Com17	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Heat Pump (for Heating)	0.45	0.49	0.55	0.61	0.67	0.72
Com18	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	2.63	2.90	3.25	3.61	3.96	4.23
Com25	Existing	Fuel Oil	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.02	0.00	0.00	0.00	0.00	0.00
Com29	Existing	LPG	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.00	0.01	0.01	0.01	0.01	0.01
Com36	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Boiler Systems	0.66	0.73	0.82	0.91	1.00	1.07
Com37	Existing	Natural Gas	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	0.34	0.37	0.41	0.46	0.51	0.54
Com30	Existing	LPG	Motive Power, Mobile	Internal Combustion Engine (	0.00	0.00	0.00	0.00	0.00	0.00
Com38	Existing	Natural Gas	Motive Power, Mobile	Internal Combustion Engine (	0.00	0.00	0.00	0.00	0.00	0.00

Table F.4.3 Supply of Energy End-Uses: *Commercial Sector, Greenhouse Gas Reductions Potential* (continued)

Code	Existing/ New	Delivered Energy	End-Use Energy	Technology	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
Com19	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.31	1.38	1.50	1.61	1.73	1.83
Com21	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	0.56	0.59	0.63	0.68	0.73	0.77
Com22	Existing	Electricity	Refrigeration	Refrigeration Systems	4.37	4.72	5.26	5.84	6.47	6.98
Com8	Existing	Electricity	Space Cooling	Heat Pump (for Cooling)	4.44	4.68	5.08	5.50	5.94	6.29
Com14	Existing	Electricity	Street Lighting	Street Lights	0.05	0.05	0.06	0.06	0.06	0.06
Com1	Existing	Aviation Fuel	Transport, Air	Aircraft	0.20	0.20	0.21	0.22	0.23	0.24
Com6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.04	0.05	0.05	0.06	0.06	0.07
Com44	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.04	0.05	0.06
Com43	New	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.04	0.05	0.06
Com45	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com31	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.01	0.01	0.01	0.01
Com47	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com42	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.04	0.05	0.06
Com41	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.34	0.45	0.44	0.43	0.42	0.42
Com46	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.01	0.02	0.04	0.05	0.06
Com7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	1.65	1.41	1.52	1.64	1.76	1.85
Com32	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com39	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Com48	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.02	0.02	0.02	0.02	0.02	0.03

Table F.4.4 Supply of Energy End-Uses: *Primary Sector, Greenhouse Gas Reductions Potential*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
P9	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.05	0.05	0.05	0.06	0.06	0.06
P10	Existing	Electricity	Intermediate Heat (100-300 C), Process	Resistance Heater	0.18	0.21	0.24	0.27	0.00	0.00
P17	Existing	Fuel Oil	Intermediate Heat (100-300 C), Process	Boiler Systems	0.24	0.27	0.31	0.36	0.40	0.43
P21	Existing	Natural Gas	Intermediate Heat (100-300 C), Process	Boiler Systems	0.26	0.18	0.15	0.13	0.41	0.42
P1	Existing	Diesel	Kiln/Furnance_ High Temperature Heat (>300 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P18	Existing	Fuel Oil	Kiln/Furnance_Intermediate Heat (100-300 C), Process	Furnace/Kiln	0.00	0.00	0.00	0.00	0.00	0.00
P2	Existing	Diesel	Kiln/Furnance_Low Temperature Heat (<100 C), Process	Furnace/Kiln	0.15	0.17	0.18	0.20	0.22	0.24
P11	Existing	Electricity	Lighting	Lights	0.05	0.05	0.05	0.06	0.06	0.07
P12	Existing	Electricity	Low Temperature Heat (<100 C), Process	Resistance Heater	0.32	0.35	0.39	0.43	0.48	0.51
P1	Existing	Coal	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.86	1.55	1.43	1.31	1.21	1.14
P3	Existing	Diesel	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	0.12	0.14	0.16	0.18	0.20	0.21
P22	Existing	Natural Gas	Low Temperature Heat (<100 C), Space Heating	Boiler Systems	1.48	1.67	1.93	2.18	2.44	2.63
P13	Existing	Electricity	Low Temperature Heat (<100 C), Water Heating	Hot Water Cylinder	1.24	1.19	1.36	1.55	1.77	1.95
P4	Existing	Diesel	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	1.08	1.12	1.20	1.30	1.40	1.49
P23	Existing	Petrol	Motive Power, Mobile	Internal Combustion Engine (Land Transport)	0.18	0.21	0.24	0.27	0.30	0.33
P5	Existing	Diesel	Motive Power, Stationary	Stationary Engine	0.26	0.07	0.00	0.00	0.00	0.00
P14	Existing	Electricity	Motive Power, Stationary	Electric Motor	1.34	1.51	1.71	1.83	1.95	2.05
P24	Existing	Petrol	Motive Power, Stationary	Stationary Engine	0.02	0.02	0.00	0.00	0.00	0.00
P15	Existing	Electricity	Pumping	Pump Systems (for Fluids, etc.)	1.93	2.14	2.42	2.73	3.09	3.39
P16	Existing	Electricity	Refrigeration	Refrigeration Systems	1.46	1.59	1.80	2.02	2.28	2.50

Table F.4.4 Supply of Energy End-Uses: ***Primary Sector, Greenhouse Gas Reductions Potential (continued)***

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	2011	2015	2019	2023	2026
P6	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.03	0.00	0.00	0.00	0.00	0.00
P29	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.01	0.01	0.02	0.03	0.03
P30	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P27	New	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
P32	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P28	New	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.02	0.00	0.00	0.00	0.00	0.00
P25	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.19	0.13	0.13	0.14	0.15	0.16
P31	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
P7	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.99	1.12	1.29	1.42	1.57	1.69
P26	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.09	0.05	0.00	0.00	0.00	0.00
P8	Existing	Diesel	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.61	0.69	0.80	0.90	1.01	1.09
P19	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.29	0.29	0.29	0.31	0.34	0.38

Table F.4.5 Supply of Energy End-Uses: Transport and Storage Sector, *Greenhouse Gas Reductions Potential*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
Trans8	Existing	Electricity	Electronics and Other Electrical Uses	Electronics	0.19	0.20	0.21	0.23	0.25	0.26
Trans9	Existing	Electricity	Lighting	Lights	0.04	0.04	0.05	0.05	0.05	0.06
Trans10	Existing	Electricity	Motive Power, Stationary	Electric Motor	0.28	0.30	0.32	0.35	0.37	0.40
Trans1	Existing	Aviation Fuel	Transport, Air	Aircraft	4.85	5.09	5.50	5.93	6.40	6.78
Trans3	Existing	Diesel	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.78	0.86	0.93	1.00	1.08	1.14
Trans11	Existing	Electricity	Transport, Land (Buses)	Electric Motor	0.06	0.06	0.07	0.08	0.09	0.09
Trans15	Existing	LPG	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.00	0.00	0.00	0.00	0.00	0.00
Trans18	Existing	Natural Gas	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.01	0.00	0.00	0.00	0.00	0.00
Trans20	Existing	Petrol	Transport, Land (Buses)	Internal Combustion Engine (Land Transport)	0.03	0.00	0.00	0.00	0.00	0.00
Trans4	Existing	Diesel	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.12	0.00	0.00	0.00	0.00	0.00
Trans25	New	Electicity & Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.04	0.06	0.08	0.10
Trans24	Existing	Electricity	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.04	0.06	0.08	0.10
Trans26	New	Ethanol 10% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.04	0.06	0.08	0.10
Trans16	Existing	LPG	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.10	0.11	0.13	0.14	0.15	0.16
Trans28	New	Methanol 15% with Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.04	0.06	0.08	0.10
Trans23	Existing	Natural Gas	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.01	0.02	0.04	0.06	0.08	0.10
Trans21	Existing	Petrol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.53	0.55	0.48	0.41	0.34	0.30
Trans27	New	Pure Ethanol	Transport, Land (Cars)	Internal Combustion Engine (Land Transport)	0.00	0.02	0.04	0.06	0.08	0.10
Trans5	Existing	Diesel	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	8.02	8.83	9.74	10.52	11.35	12.02
Trans17	Existing	LPG	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.06	0.07	0.00	0.00	0.00	0.00
Trans19	Existing	Natural Gas	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.02	0.02	0.00	0.00	0.00	0.00
Trans22	Existing	Petrol	Transport, Land (Freight)	Internal Combustion Engine (Land Transport)	0.49	0.10	0.00	0.00	0.00	0.00

Table F.4.5 Supply of Energy End-Uses: Transport and Storage Sector, *Greenhouse Gas Reductions Potential (continued)*

Code	Existing/ New	Delivered Energy	Technology	End-Use Energy	Petajoules of End-Use Energy (for each year)					
					2007	**2011**	**2015**	**2019**	**2023**	**2026**
Trans7	Existing	Diesel	Transport, Rail (Freight)	Locomotive (Rail)	0.12	0.08	0.04	0.00	0.00	0.00
Trans13	Existing	Electricity	Transport, Rail (Freight)	Electric Motor	0.98	1.07	1.21	1.34	1.45	1.53
Trans2	Existing	Coal	Transport, Rail (Passenger)	Locomotive (Rail)	0.01	0.00	0.00	0.00	0.00	0.00
Trans6	Existing	Diesel	Transport, Rail (Passenger)	Locomotive (Rail)	0.02	0.02	0.01	0.01	0.01	0.01
Trans12	Existing	Electricity	Transport, Rail (Passenger)	Electric Motor	0.13	0.14	0.16	0.17	0.19	0.21
Trans14	Existing	Fuel Oil	Transport, Sea	Internal Combustion Engine (Sea Transport)	0.71	0.74	0.80	0.86	0.93	0.99

Appendix G

Detailed Results: Energy Saving Measures

G.1 Technical Energy Savings Potential

The following pages contain five tables that present the 'energy saving measures' in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table G.1.1)
- Industrial Sector (Table G.1.2)
- Commercial Sector (Table G.1.3)
- Primary Sector (Table G.1.4)
- Transport and Storage Sector (Table G.1.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table G.1.1 Energy Savings Measures: *Household Sector, Technical Energy Savings Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Tran39	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km a US projection)	0.00	2.26	4.88	7.86	11.25	14.07
Tran38	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	0.00	1.52	3.27	5.27	7.53	9.43
Tran29	Diesel & Petrol	Transport, Land (Cars)	Reduce Average Car Engine Size from 2000 to 1700cc (fuel consumption from 9.2 to8.7 1/100 km	0.00	1.08	2.33	3.76	5.38	6.73
Tran30	Diesel & Petrol	Transport, Land (Cars)	Car Pool to Increase Occupancy from 1.25 to 2 per vehicle in Commuting	0.00	0.94	2.02	3.26	4.66	5.83
Tran40	Diesel & Petrol	Transport, Land (Cars)	Driver Education Programmes, tune-up, tyres, exhaust testing (assume = "O&M")	0.00	0.82	1.76	2.83	4.05	5.07
Tran31	Diesel & Petrol	Transport, Land (Cars)	Use bicycles more for Commuting	0.00	0.80	1.73	2.79	3.99	4.99
Tran32	Diesel & Petrol	Transport, Land (Cars)	Telecommute 4 out of 5 days per week	0.00	0.67	1.44	2.32	3.32	4.15
Total				**0.00**	**8.09**	**17.42**	**28.08**	**40.18**	**50.27**

Table G.1.2 Energy Savings Measures: ***Industrial Sector, Technical Energy Savings Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Ind102	Natural Gas & LPG	Elect & Process Heat	Cogeneration	0.00	1.64	3.60	5.92	8.64	10.97
Ind82	Electricity	Motive Power Stat	Motor Efficiency/ sizing improvements	0.00	0.54	1.18	1.93	2.82	3.58
Ind94	Electricity	Motors Various	Variable Speed Pumps /fans (eg, freezers and chillers)	0.00	0.25	0.56	0.92	1.34	1.70
Ind85	Electricity	General Basic Metals	Improvements incl. Cogeneration from Waste Heat at NZ Steel	0.00	0.21	0.47	0.77	1.13	1.43
Ind91	Electricity	General Industrial	Generally Improved Operations and Maintenance (housekeeping, process controls and management)	0.00	0.20	0.43	0.71	1.04	1.32
Ind87	Electricity	General Basic Metals	Improved Efficiency from Existing Cells at NZ Aluminium Smelters (better material and design)	0.00	0.18	0.39	0.64	0.93	1.18
Ind88	Electricity	Motive Power Stat	Improved Transmissions (cogged V-belts etc.)	0.00	0.16	0.36	0.59	0.86	1.10
Ind113	Natural Gas & LPG	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.13	0.28	0.46	0.67	0.85
Ind97	Electricity	Refrigeration	Plate Freezing in the Meat Industry	0.00	0.12	0.26	0.43	0.63	0.80
Ind133	Coal	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.12	0.26	0.42	0.62	0.78
Ind81	Electricity	Refrigeration	Controlled Door Opening in Cold and Cool Stores	0.00	0.10	0.23	0.38	0.55	0.70
Ind80	Electricity	General Wood Processing & Wood	Refining and Rejects Handling in Forest Products	0.00	0.09	0.21	0.34	0.49	0.63
Ind117	Oil Products	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.08	0.18	0.30	0.43	0.55
Ind106	Natural Gas & LPG	Med Temp Process	Improved Boiler Efficiency	0.00	0.08	0.17	0.27	0.40	0.51
Ind90	Electricity	Refrigeration	Better Insulation of Cold and Cool stores (floor, wall and ceiling)	0.00	0.07	0.15	0.25	0.37	0.47
Ind84	Electricity	General Basic Metals	Install New Cells (larger, magnetically compresses at NZ Aluminium Smelters	0.00	0.07	0.15	0.25	0.36	0.46
Ind107	Natural Gas & LPG	High Temp Process Heat	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	0.00	0.03	0.07	0.11	0.16	0.20

Table G.1.2 Energy Savings Measures: ***Industrial Sector, Technical Energy Savings Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Ind131	Coal	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.03	0.07	0.11	0.16	0.20
Ind81	Electricity	Refrigeration	Cool Chain Concept in Food Industry	0.00	0.03	0.07	0.11	0.16	0.20
Ind109	Natural Gas & LPG	Med Temp Process Heat	MVR Evaporators in Food Processing	0.00	0.03	0.06	0.11	0.16	0.20
Ind120	Oil Products	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.03	0.06	0.10	0.15	0.19
Ind127	Coal	Water Heating	WH Recovery	0.00	0.03	0.06	0.10	0.15	0.19
Ind116	Oil Products	Water Heating	WH Recovery	0.00	0.03	0.06	0.10	0.14	0.18
Ind128	Coal	Water Heating	Grey Water Heat Recovery	0.00	0.03	0.06	0.09	0.14	0.17
Ind105	Natural Gas & LPG	Water Heating	WH Recovery	0.00	0.02	0.05	0.09	0.12	0.16
Ind130	Coal	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.02	0.04	0.07	0.10	0.13
Ind129	Coal	Med Temp Process Heat	MVR Evaporators in Food Processing	0.00	0.02	0.04	0.07	0.10	0.12
Ind119	Oil Products	Med Temp Process Heat	MVR Evaporators in Food Processing	0.00	0.02	0.04	0.06	0.09	0.12
Ind134	Coal	Water Heating	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	0.00	0.01	0.03	0.05	0.08	0.10
Ind93	Electricity	High Temp Process Heat	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	0.00	0.01	0.03	0.04	0.06	0.08
Ind83	Electricity	Lighting	Upgrade Fluorescents (reflectors-triphoshors,CFLs)	0.00	0.01	0.02	0.04	0.06	0.07
Ind110	Natural Gas & LPG	Water Heating	Grey Water Heat Recovery	0.00	0.01	0.02	0.04	0.06	0.07
Ind132	Coal	Water Heating	Distributional Efficiency (local heaters, pipe and cylinder insulation)	0.00	0.01	0.02	0.03	0.04	0.06
Ind99	Electricity	High Temp Process Heat	Induction Heating in Metal Fabrication Industries (electricity substitution)	0.00	0.01	0.02	0.03	0.04	0.05
Ind111	Natural Gas & LPG	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.01	0.02	0.03	0.04	0.05
Ind112	Natural Gas & LPG	Water Heating	Instantaneous Water Heating	0.00	0.01	0.01	0.02	0.03	0.04
Ind115	Natural Gas & LPG	Water Heating	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	0.00	0.01	0.01	0.02	0.03	0.03
Ind95	Electricity	Water Heating	Grey Water Heat Recovery	0.00	0.00	0.01	0.02	0.03	0.03
Ind96	Electricity	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.00	0.01	0.02	0.02	0.03
Ind124	Oil Products	High Temp Process Heat	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	0.00	0.00	0.01	0.02	0.02	0.03
Ind86	Electricity	Electronics & Electrical End	Improved Operation of Electronic Equipment	0.00	0.00	0.01	0.01	0.02	0.02

Table G.1.2 Energy Savings Measures: ***Industrial Sector, Technical Energy Savings Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Ind80	Electricity	Lighting	Upgrade Gas Discharge lamps (replace HG with High press Na.)	0.00	0.00	0.01	0.01	0.01	0.02
Ind114	Natural Gas & LPG	Water Heating	Distributional Efficiency (local heaters, pipe and cylinder insulation)	0.00	0.00	0.00	0.01	0.01	0.01
Ind103	Natural Gas & LPG	Fe2O3 Reduction	Improved O&M steel	0.00	0.00	0.00	0.01	0.01	0.01
Ind121	Oil Products	Water Heating	Grey Water Heat Recovery	0.00	0.00	0.00	0.01	0.01	0.01
Ind122	Oil Products	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.00	0.00	0.01	0.01	0.01
Ind89	Electricity	Electronics & Electrical End-Uses	Higher Efficiency Electronic Equipment	0.00	0.00	0.00	0.00	0.01	0.01
Ind125	Oil Products	Water Heating	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	0.00	0.00	0.00	0.00	0.01	0.01
Total				**0.00**	**4.46**	**9.80**	**16.11**	**23.49**	**29.81**

Table G.1.3 Energy Savings Measures: ***Commercial Sector, Technical Energy Savings Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com57	Electricity	Electronics & Electrical End-Uses	Operational (office equipment management, switch off, optimum location)	0.00	0.57	1.24	2.02	2.91	3.65
Com63	Electricity	Lighting	Medium Cost Lamp Upgrade (Reflectors-triphoshor tubes,CFLs)	0.00	0.33	0.72	1.16	1.68	2.11
Com66	Electricity	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.24	0.52	0.85	1.23	1.54
Com53	Electricity	General Commercial	New Buildings/ Integrated Design	0.00	0.23	0.51	0.82	1.18	1.49
Com72	Electricity	Water Heating	Instantaneous Water Heaters	0.00	0.23	0.49	0.80	1.16	1.45
Com96	Natural Gas & LPG	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.19	0.41	0.66	0.95	1.20
Com69	Electricity	Electronics & Electrical End-Uses	Purchase (selection of efficient equipment)	0.00	0.17	0.37	0.59	0.86	1.08
Com56	Electricity	Space Heating	Recommissioning	0.00	0.16	0.34	0.55	0.79	1.00
Com92	Natural Gas & LPG	Water Heating	Condensing Boilers/European Design Practices	0.00	0.15	0.32	0.52	0.75	0.94
Com68	Electricity	Space Heating	Re-engineering	0.00	0.14	0.29	0.48	0.69	0.86
Com86	Natural Gas & LPG	Space Heating	Integrated Design	0.00	0.13	0.27	0.44	0.64	0.80
Com126	Coal	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.13	0.27	0.44	0.64	0.80
Com55	Electricity	Lighting	Design Changes (Task lighting, Uplighting,daylighting)	0.00	0.12	0.27	0.44	0.63	0.80
Com84	Electricity	Lighting	High Cost Lamp Upgrade (low loss ballasts, diffusers, high pressure sodium lamps)	0.00	0.12	0.25	0.41	0.59	0.74
Com58	Electricity	Space Cooling	Recommissioning	0.00	0.09	0.19	0.31	0.45	0.57
Com65	Electricity	Lighting	Automatic Controls (occupancy, time-switching, daylight linked)	0.00	0.09	0.19	0.30	0.44	0.55
Com119	Coal	Space Heating	Integrated Design	0.00	0.08	0.18	0.29	0.42	0.53
Com71	Electricity	Water Heating	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absorption chillers, heat recovery)	0.00	0.08	0.17	0.28	0.41	0.51
Com87	Natural Gas & LPG	Space Heating	Recommissioning	0.00	0.08	0.16	0.27	0.38	0.48
Com51	Electricity	Space Cooling	New Buildings/ Integrated Design	0.00	0.07	0.16	0.26	0.38	0.47
Com97	Natural Gas & LPG	General Commercial	Cogeneration, especially in hospitals and pools	0.00	0.07	0.16	0.26	0.37	0.47
Com51	Electricity	Space Cooling	New Buildings/ Integrated Design	0.00	0.07	0.16	0.26	0.38	0.47

Table G.1.3 Energy Savings Measures: ***Commercial Sector, Technical Energy Savings Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com97	Natural Gas & LPG	General Commercial	Cogeneration, especially in hospitals and pools	0.00	0.07	0.16	0.26	0.37	0.47
Com59	Electricity	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.07	0.16	0.25	0.36	0.46
Com62	Electricity	Water Heating	Improved Operations and Maintenance (eg, Temperature Settings, Distribution Controls, Drips, Leaks)	0.00	0.07	0.16	0.25	0.36	0.46
Com52	Electricity	Space Cooling	Internal Heat Gain Reduction	0.00	0.07	0.15	0.25	0.36	0.45
Com61	Electricity	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.07	0.14	0.23	0.33	0.42
Com49	Electricity	Lighting	Low Cost Lamp Upgrade: 38mm to 26mm)	0.00	0.06	0.13	0.22	0.31	0.39
Com54	Electricity	Motive Power	Motor Sizing	0.00	0.06	0.13	0.21	0.30	0.38
Com98	Natural Gas & LPG	Space Heating	Re-engineering	0.00	0.06	0.13	0.21	0.30	0.38
Com48	Electricity	Lighting	Delamping /Fine- tuning	0.00	0.05	0.12	0.19	0.27	0.35
Com120	Coal	Space Heating	Recommissioning	0.00	0.05	0.11	0.18	0.25	0.32
Com67	Electricity	Lighting	Improved Operations and Maintenance (after hours use, cleaning staff scheduling, occupant switching, re-commissioning, luminaire cleaning, lamp replacement scheduling)	0.00	0.05	0.11	0.18	0.25	0.32
Com74	Electricity	Cooking	Induction Cooking in Commercial Kitchens	0.00	0.05	0.10	0.16	0.23	0.29
Com64	Electricity	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.04	0.09	0.15	0.22	0.27
Com78	Electricity	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.04	0.09	0.14	0.21	0.26
Com76	Electricity	Space Heating	Exhaust Heat Recovery	0.00	0.04	0.09	0.14	0.20	0.25
Com127	Coal	Space Heating	Re-engineering	0.00	0.04	0.09	0.14	0.20	0.25
Com75	Electricity	Space Cooling	Improved Envelope Design	0.00	0.03	0.07	0.12	0.17	0.21
Com60	Electricity	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.03	0.06	0.10	0.15	0.19
Com93	Natural Gas & LPG	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.03	0.06	0.10	0.14	0.18
Com130	Coal	General Commercial	Economisers	0.00	0.02	0.05	0.09	0.13	0.16
Com91		Water Heating	Instantaneous Water Heaters	0.00	0.02	0.05	0.08	0.12	0.15
Com123	Coal	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.02	0.04	0.07	0.09	0.12
Com81	Electricity	Pumping	Variable Speed Drives on Pumps in Hospitals and Polls	0.00	0.02	0.04	0.07	0.09	0.12
Com95	Natural Gas & LPG	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.02	0.04	0.06	0.09	0.12

Table G.1.3 Energy Savings Measures: ***Commercial Sector, Technical Energy Savings Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com50	Electricity	Space Cooling	Appropriate Chiller Size and Technology	0.00	0.02	0.04	0.06	0.09	0.11
Com70	Electricity	Space Cooling	Ventilation Efficiency	0.00	0.02	0.04	0.06	0.09	0.11
Com77	Electricity	Space Cooling	Cooling Efficiencies	0.00	0.02	0.04	0.06	0.09	0.11
Com100	Natural Gas & LPG	Space Heating	Exhaust Air Recovery	0.00	0.02	0.04	0.06	0.09	0.11
Com101	Natural Gas & LPG	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.02	0.04	0.06	0.09	0.11
Com99	Natural Gas & LPG	Water Heating	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absorption chillers, heat recovery)	0.00	0.01	0.03	0.05	0.07	0.09
Com82	Electricity	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.01	0.03	0.05	0.07	0.09
Com125	Coal	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.01	0.03	0.04	0.06	0.08
Com131	Coal	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.01	0.03	0.04	0.06	0.08
Com88	Natural Gas & LPG	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.01	0.03	0.04	0.06	0.08
Com94	Natural Gas & LPG	Water Heating	Generally Improved O&M (housekeeping, process control and management)	0.00	0.01	0.03	0.04	0.06	0.08
Com79	Electricity	Space Cooling	Improved Operations and Maintenance	0.00	0.01	0.03	0.04	0.06	0.07
Com129	Coal	Space Heating	Exhaust Air Recovery	0.00	0.01	0.02	0.04	0.06	0.07
Com124	Coal	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.01	0.02	0.04	0.05	0.07
Com73	Electricity	Space Cooling	Improved Controls	0.00	0.01	0.02	0.04	0.05	0.06
Com102	Natural Gas & LPG	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.01	0.01	0.02	0.03	0.04
Com128	Coal	Water Heating	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absorption chillers, heat recovery)	0.00	0.01	0.01	0.02	0.03	0.04
Com121	Coal	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.01	0.01	0.02	0.03	0.03
Com90	Natural Gas & LPG	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.00	0.01	0.02	0.02	0.03
Com83	Electricity	Water Heating	Grey Water Heat Exchanges in Commercial Kitchens and Laundries	0.00	0.00	0.01	0.01	0.02	0.03

Table G.1.3 Energy Savings Measures: ***Commercial Sector, Technical Energy Savings Potential (continued***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Com132	Coal	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.00	0.01	0.01	0.02	0.03
Com122	Coal	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.00	0.00	0.01	0.01	0.01
Com111	Fuel Oil	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.00	0.00	0.00	0.01	0.01
Total				**0.00**	**4.72**	**10.24**	**16.61**	**23.91**	**30.03**

Table G.1.4 Energy Savings Measures: ***Primary Sector, Technical Energy Savings Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
P38	Oil Products	Motive Power Mobile	"Tractor facts"programe(operator education)	0.00	0.14	0.30	0.50	0.73	0.93
P37	Oil Products	Med Temp Process Heat	Efficiency Improvement for Kiln Drying of Forest/Agricultural products	0.00	0.04	0.08	0.13	0.19	0.25
P39	Coal	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.03	0.07	0.11	0.16	0.20
P35	Natural Gas & LPG	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.00	0.02	0.04	0.05	0.07
P36	Oil Products	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.01	0.02	0.03	0.04	0.05
Total				**0.00**	**0.21**	**0.49**	**0.80**	**1.18**	**1.50**

Table G.1.5 Energy Savings Measures: Transport and Storage Sector, *Technical Energy Savings Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Tran42	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of light goods vehicles from 20% to 30%	0.00	2.71	5.84	9.42	13.48	16.86
Tran43	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of heavy goods vehicles from 50% to 60%	0.00	1.71	3.67	5.92	8.47	10.60
Tran44	Diesel & Petrol	Transport, Land (Freight)	Shift road freight to rail	0.00	1.58	3.41	5.50	7.87	9.84
Tran34	Avaition	Air Transport	Shift passenger transport from air to rail-ship	0.00	1.03	2.21	3.57	5.11	6.39
Tran33	Diesel & Petrol	Transport, Land (Cars)	Increase load factor of passenger air services from 60% to 70%	0.00	0.66	1.42	2.28	3.26	4.08
Tran41	Diesel & Petrol	Transport, Land (Buses)	Increase load factor of passengers bus services from 30% to 40%	0.00	0.35	0.75	1.21	1.73	2.17
Tran35	Diesel & Fuel Oil	Sea Transport	Increase load factor of coastal freight services from 50% to 60%	0.00	0.17	0.37	0.60	0.86	1.08
Tran36	Diesel & Elect	Transport, Rail (Passenger)	Increase load factor of passenger rail services from 30% to 40%	0.00	0.02	0.04	0.06	0.09	0.11
Tran37	Diesel & Elect	Transport, Rail (Freight)	Increase load factor of rail freight services from 30% to 40%	0.00	0.00	0.00	0.00	0.00	0.00
Total				**0.00**	**8.23**	**17.72**	**28.57**	**40.87**	**51.14**

G.2 Economic Energy Savings Potential

The following pages contain five tables that present the ‘energy saving measures’ in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table G.2.1)
- Industrial Sector (Table G.2.2)
- Commercial Sector (Table G.2.3)
- Primary Sector (Table G.2.4)
- Transport and Storage Sector (Table G.2.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table G.2.1 Energy Savings Measures: *Household Sector, Economic Energy Savings Potential*

Code	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
			2007	**2011**	**2015**	**2019**	**2023**	**2026**
Tran39	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km a US projection)	0.00	2.26	4.88	7.86	11.25	14.07
Tran38	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	0.00	1.52	3.27	5.27	7.53	9.43
Tran40	Transport, Land (Cars)	Driver Education Programmes, tune-up, tyres, exhaust testing (assume = "O&M")	0.00	0.82	1.76	2.83	4.05	5.07
Total			**0.00**	**4.60**	**9.90**	**15.96**	**22.83**	**28.57**

Table G.2.2 Energy Savings Measures: *Industrial Sector, Economic Energy Savings Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Ind102	Natural Gas & LPG	Elect & Process Heat	Cogeneration	0.00	1.64	3.60	5.92	8.64	10.97
Ind82	Electricity	Motive Power Stat	Motor Efficiency/ sizing improvements	0.00	0.54	1.18	1.93	2.82	3.58
Ind136	Wood	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.22	0.48	0.79	1.16	1.47
Ind85	Electricity	General Basic Metals	Improvements incl. Cogeneration from Waste Heat at NZ Steel	0.00	0.21	0.47	0.77	1.13	1.43
Ind91	Electricity	General Industrial	Generally Improved Operations and Maintenance (housekeeping, process controls and management)	0.00	0.20	0.43	0.71	1.04	1.32
Ind137	Wood	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.19	0.43	0.70	1.02	1.30
Ind87	Electricity	General Basic Metals	Improved Efficiency from Existing Cells at NZ Aluminium Smelters (better material and design)	0.00	0.18	0.39	0.64	0.93	1.18

Table G.2.2 Energy Savings Measures: ***Industrial Sector, Economic Energy Savings Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Ind81	Electricity	Refrigeration	Controlled Door Opening in Cold and Cool Stores	0.00	0.10	0.23	0.38	0.55	0.70
Ind80	Electricity	General Wood Processing & Wood Products	Refining and Rejects Handling in Forest Products	0.00	0.09	0.21	0.34	0.49	0.63
Ind84	Electricity	General Basic Metals	Install New Cells (larger, magnetically compresses at NZ Aluminium Smelters	0.00	0.07	0.15	0.25	0.36	0.46
Ind81	Electricity	Refrigeration	Cool Chain Concept in Food Industry	0.00	0.03	0.07	0.11	0.16	0.20
Ind105	Natural Gas & LPG	Water Heating	WH Recovery	0.00	0.00	0.00	0.00	0.12	0.16
Ind83	Electricity	Lighting	Upgrade Fluorescents (reflectors-triphoshors,CFLs)	0.00	0.01	0.02	0.04	0.06	0.07
Ind86	Electricity	Electronics & Electrical End-Uses	Improved Operation of Electronic Equipment	0.00	0.00	0.01	0.01	0.02	0.02
Ind80	Electricity	Lighting	Upgrade Gas Discharge lamps (replace HG with High press Na.)	0.00	0.00	0.01	0.01	0.01	0.02
Ind103	Natural Gas & LPG	Fe2O3 Reduction	Improved O&M steel	0.00	0.00	0.00	0.01	0.01	0.01
Total				**0.00**	**3.49**	**7.67**	**12.61**	**18.52**	**23.51**

Table G.2.3 Energy Savings Measures: *Commercial Sector, Economic Energy Savings Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com57	Electricity	Electronics & Electrical End-Uses	Operational (office equipment management, switch off, optimum location)	0.00	0.57	1.24	2.02	2.91	3.65
Com63	Electricity	Lighting	Medium Cost Lamp Upgrade (Reflectors-triphoshor tubes,CFLs)	0.00	0.33	0.72	1.16	1.68	2.11
Com66	Electricity	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.24	0.52	0.85	1.23	1.54
Com53	Electricity	General Commercial	New Buildings/ Integrated Design	0.00	0.23	0.51	0.82	1.18	1.49
Com56	Electricity	Space Heating	Recommissioning	0.00	0.16	0.34	0.55	0.79	1.00
Com86	Natural Gas & LPG	Space Heating	Integrated Design	0.00	0.13	0.27	0.44	0.64	0.80
Com55	Electricity	Lighting	Design Changes (Task lighting, Uplighting,daylighting)	0.00	0.12	0.27	0.44	0.63	0.80
Com58	Electricity	Space Cooling	Recommissioning	0.00	0.09	0.19	0.31	0.45	0.57
Com65	Electricity	Lighting	Automatic Controls (occupancy, time-switching, daylight linked)	0.00	0.09	0.19	0.30	0.44	0.55
Com119	Coal	Space Heating	Integrated Design	0.00	0.08	0.18	0.29	0.42	0.53
Com87	Natural Gas & LPG	Space Heating	Recommissioning	0.00	0.08	0.16	0.27	0.38	0.48
Com51	Electricity	Space Cooling	New Buildings/ Integrated Design	0.00	0.07	0.16	0.26	0.38	0.47
Com97	Natural Gas & LPG	General Commercial	Cogeneration, especially in hospitals and pools	0.00	0.07	0.16	0.26	0.37	0.47
Com59	Electricity	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.07	0.16	0.25	0.36	0.46
Com62	Electricity	Water Heating	Improved Operations and Maintenance (eg, Temperature Settings, Distribution Controls, Drips, Leaks)	0.00	0.07	0.16	0.25	0.36	0.46
Com52	Electricity	Space Cooling	Internal Heat Gain Reduction	0.00	0.07	0.15	0.25	0.36	0.45

Table G.2.3 Energy Savings Measures: ***Commercial Sector, Economic Energy Savings Potential (continuation)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Com61	Electricity	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.07	0.14	0.23	0.33	0.42
Com49	Electricity	Lighting	Low Cost Lamp Upgrade: 38mm to 26mm)	0.00	0.06	0.13	0.22	0.31	0.39
Com54	Electricity	Motive Power_Stationary	Motor Sizing	0.00	0.06	0.13	0.21	0.30	0.38
Com48	Electricity	Lighting	Delamping /Fine- tuning	0.00	0.05	0.12	0.19	0.27	0.35
Com120	Coal	Space Heating	Recommissioning	0.00	0.05	0.11	0.18	0.25	0.32
Com67	Electricity	Lighting	Improved Operations and Maintenance (after hours use, cleaning staff scheduling, occupant switching, re-commissioning, luminaire cleaning, lamp replacement scheduling)	0.00	0.05	0.11	0.18	0.25	0.32
Com64	Electricity	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.04	0.09	0.15	0.22	0.27
Com60	Electricity	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.03	0.06	0.10	0.15	0.19
Com50	Electricity	Space Cooling	Appropriate Chiller Size and Technology	0.00	0.02	0.04	0.06	0.09	0.11
Com134	Wood	Space Heating	Integrated Design	0.00	0.02	0.04	0.06	0.09	0.11
Com88	Natural Gas & LPG	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.01	0.03	0.04	0.06	0.08
Com135	Wood	Space Heating	Recommissioning	0.00	0.01	0.02	0.04	0.05	0.07
Com136	Wood	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.00	0.01	0.01	0.02	0.03
Total				**0.00**	**2.96**	**6.42**	**10.42**	**14.99**	**18.83**

Table G.2.4 Energy Savings Measures: ***Primary Sector, Economic Energy Savings Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
P35	Natural Gas & LPG	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.01	0.02	0.04	0.05	0.07
P36	Oil Products	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.01	0.02	0.03	0.04	0.05
P39	Coal	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.03	0.07	0.11	0.16	0.20
P37	Oil Products	Med Temp Process Heat	Efficiency Improvement for Kiln Drying of Forest/Agricultural products	0.00	0.04	0.08	0.13	0.19	0.25
Total				**0.00**	**0.09**	**0.19**	**0.31**	**0.45**	**0.57**

Table G.2.5 Energy Savings Measures: Transport and Storage Sector, *Economic Energy Savings Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Tran42	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of light goods vehicles from 20% to 30%	0.00	2.71	5.84	9.42	13.48	16.86
Tran39	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km a US projection)	0.00	2.26	4.88	7.86	11.25	14.07
Tran43	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of heavy goods vehicles from 50% to 60%	0.00	1.71	3.67	5.92	8.47	10.60
Tran44	Diesel & Petrol	Transport, Land (Freight)	Shift road freight to rail	0.00	1.58	3.41	5.50	7.87	9.84
Tran38	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	0.00	1.52	3.27	5.27	7.53	9.43
Tran34	Aviation	Air Transport	Shift passenger transport from air to rail-ship	0.00	1.03	2.21	3.57	5.11	6.39
Tran40	Diesel & Petrol	Transport, Land (Cars)	Driver Education Programmes, tune-up, tyres, exhaust testing (assume = "O&M")	0.00	0.82	1.76	2.83	4.05	5.07
Tran33	Diesel & Petrol	Transport, Land (Cars)	Increase load factor of passenger air services from 60% to 70%	0.00	0.66	1.42	2.28	3.26	4.08
Tran41	Diesel & Petrol	Transport, Land (Buses)	Increase load factor of passengers bus services from 30% to 40%	0.00	0.35	0.75	1.21	1.73	2.17
Tran45	Diesel & Petrol	Transport, Land (Cars & Freight)	Improve road surfaces and alignment	0.00	0.27	0.59	0.95	1.36	1.71
Tran35	Diesel & Fuel Oil	Sea Transport	Increase load factor of coastal freight services from 50% to 60%	0.00	0.17	0.37	0.60	0.86	1.08
Tran36	Diesel & Elect	Transport, Rail (Passenger)	Increase load factor of passenger rail services from 30% to 40%	0.00	0.02	0.04	0.06	0.09	0.11
Total				**0.00**	**13.10**	**28.21**	**45.48**	**65.07**	**81.41**

G.3 Realisable Energy Savings Potential

The following pages contain five tables that present the 'energy saving measures' in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table G.3.1)
- Industrial Sector (Table G.32)
- Commercial Sector (Table G.3.3)
- Primary Sector (Table G.3.4)
- Transport and Storage Sector (Table G.3.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

Table G.3.1 Energy Savings Measures: *Household Sector, Realisable Energy Savings Potential*

Code	Delivered Energ	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Tran39	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km a US projection)	0.00	1.13	2.44	3.93	5.62	7.04
Tran38	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	0.00	0.76	1.63	2.63	3.77	4.71
Tran40	Diesel & Petrol	Transport, Land (Cars)	Driver Education Programmes, tune-up, tyres, exhaust testing (assume = "O&M")	0.00	0.41	0.88	1.42	2.03	2.54
Total				**0.00**	**2.30**	**4.95**	**7.98**	**11.42**	**14.28**

Table G.3.2 Energy Savings Measures: ***Industrial Sector, Realisable Energy Savings Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Ind102	Natural Gas & LPG	Elect & Process Heat	Cogeneration	0.00	0.82	1.80	2.96	4.32	5.48
Ind82	Electricity	Motive Power Stat	Motor Efficiency/ sizing improvements	0.00	0.27	0.59	0.97	1.41	1.79
Ind136	Wood	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.11	0.24	0.40	0.58	0.73
Ind85	Electricity	General Basic Metals	Improvements incl. Cogeneration from Waste Heat at NZ Steel	0.00	0.11	0.23	0.39	0.56	0.71
Ind91	Electricity	General Industrial	Generally Improved Operations and Maintenance (housekeeping, process controls and management)	0.00	0.10	0.22	0.36	0.52	0.66
Ind137	Wood	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.10	0.21	0.35	0.51	0.65
Ind87	Electricity	General Basic Metals	Improved Efficiency from Existing Cells at NZ Aluminium Smelters (better material and design)	0.00	0.09	0.19	0.32	0.46	0.59
Ind88	Electricity	Motive Power Stat	Improved Transmissions (cogged V-belts etc.)	0.00	0.00	0.00	0.00	0.43	0.55
Ind81	Electricity	Refrigeration	Controlled Door Opening in Cold and Cool Stores	0.00	0.05	0.11	0.19	0.28	0.35
Ind80	Electricity	General Wood Processing & Wood Products	Refining and Rejects Handling in Forest Products	0.00	0.05	0.10	0.17	0.25	0.31
Ind84	Electricity	General Basic Metals	Install New Cells (larger, magnetically compresses at NZ Aluminium Smelters	0.00	0.03	0.08	0.12	0.18	0.23
Ind81	Electricity	Refrigeration	Cool Chain Concept in Food Industry	0.00	0.01	0.03	0.05	0.08	0.10
Ind105	Natural Gas & LPG	Water Heating	WH Recovery	0.00	0.00	0.00	0.00	0.06	0.08
Ind83	Electricity	Lighting	Upgrade Fluorescents (reflectors-triphoshors,CFLs)	0.00	0.01	0.01	0.02	0.03	0.04
Ind86	Electricity	Electronics & Electrical End-Uses	Improved Operation of Electronic Equipment	0.00	0.00	0.00	0.01	0.01	0.01
Ind80	Electricity	Lighting	Upgrade Gas Discharge lamps (replace HG with High press Na.)	0.00	0.00	0.00	0.00	0.01	0.01
Ind103	Natural Gas & LPG	Fe2O3 Reduction	Improved O&M steel	0.00	0.00	0.00	0.00	0.01	0.01
Total				**0.00**	**1.75**	**3.84**	**6.31**	**9.69**	**12.30**

Table G.3.3 Energy Savings Measures: ***Commercial Sector, Realisable Energy Savings Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com58	Electricity	Space Cooling	Recommissioning	0.00	0.29	0.62	1.01	1.45	1.82
Com64	Electricity	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.17	0.36	0.58	0.84	1.05
Com67	Electricity	Lighting	Improved Operations and Maintenance (after hours use, cleaning staff scheduling, occupant switching, re-commissioning, luminaries cleaning, lamp replacement scheduling)	0.00	0.12	0.26	0.43	0.61	0.77
Com54	Electricity	Motive Power Stationary	Motor Sizing	0.00	0.12	0.25	0.41	0.59	0.74
Com57	Electricity	Electronics & Electrical End-Uses	Operational (office equipment management, switch off, optimum location)	0.00	0.08	0.17	0.28	0.40	0.50
Com69	Electricity	Electronics & Electrical End-Uses	Purchase (selection of efficient equipment)	0.00	0.00	0.00	0.00	0.34	0.43
Com87	Natural Gas & LPG	Space Heating	Recommissioning	0.00	0.06	0.14	0.22	0.32	0.40
Com56	Electricity	Space Heating	Recommissioning	0.00	0.06	0.14	0.22	0.32	0.40
Com59	Electricity	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.04	0.10	0.16	0.22	0.28
Com66	Electricity	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.04	0.09	0.15	0.22	0.27
Com120	Coal	Space Heating	Recommissioning	0.00	0.04	0.09	0.15	0.21	0.27
Com88	Natural Gas & LPG	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.04	0.08	0.13	0.19	0.24
Com52	Electricity	Space Cooling	Internal Heat Gain Reduction	0.00	0.04	0.08	0.13	0.19	0.24
Com98	Natural Gas & LPG	Space Heating	Re-engineering	0.00	0.04	0.08	0.13	0.19	0.23
Com63	Electricity	Lighting	Medium Cost Lamp Upgrade (Reflectors-triphoshor tubes,CFLs)	0.00	0.04	0.08	0.13	0.18	0.23
Com60	Electricity	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.04	0.08	0.13	0.18	0.23
Com53	Electricity	General Commercial	New Buildings/ Integrated Design	0.00	0.04	0.08	0.13	0.18	0.23
Com62	Electricity	Water Heating	Improved Operations and Maintenance (eg, Temperature Settings, Distribution Controls, Drips, Leaks)	0.00	0.03	0.07	0.12	0.17	0.21
Com50	Electricity	Space Cooling	Appropriate Chiller Size and Technology	0.00	0.03	0.07	0.11	0.16	0.20
Com55	Electricity	Lighting	Design Changes (Task lighting, Uplighting,daylighting)	0.00	0.03	0.06	0.10	0.15	0.19
Com49	Electricity	Lighting	Low Cost Lamp Upgrade: 38mm to 26mm)	0.00	0.03	0.06	0.10	0.14	0.17
Com121	Coal	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.03	0.05	0.09	0.13	0.16

Table G.3.3 Energy Savings Measures: ***Commercial Sector, Realisable Energy Savings Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com68	Electricity	Space Heating	Re-engineering	0.00	0.02	0.05	0.09	0.13	0.16
Com65	Electricity	Lighting	Automatic Controls (occupancy, time-switching, daylight linked)	0.00	0.02	0.05	0.07	0.11	0.14
Com139	Wood	Space Heating	Re-engineering	0.00	0.00	0.00	0.00	0.09	0.11
Com61	Electricity	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.01	0.03	0.05	0.07	0.09
Com51	Electricity	Space Cooling	New Buildings/ Integrated Design	0.00	0.01	0.02	0.03	0.04	0.06
Com135	Wood	Space Heating	Recommissioning	0.00	0.01	0.02	0.03	0.04	0.05
Com89	Natural Gas & LPG	Water Heating	Direct Water Heating	0.00	0.01	0.01	0.02	0.03	0.04
Com140	Wood	Space Heating	Exhaust Air Recovery	0.00	0.00	0.00	0.00	0.00	0.03
Com136	Wood	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.01	0.01	0.02	0.03	0.03
Com138	Wood	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.00	0.00	0.00	0.01	0.01
Com137	Wood	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.00	0.00	0.01	0.01	0.01
Total				**0.00**	**1.48**	**3.21**	**5.21**	**7.94**	**10.00**

Table G.3.4 Energy Savings Measures: ***Primary Sector, Realisable Energy Savings***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
P37	Oil Products	Med Temp Process Heat	Efficiency Improvement for Kiln Drying of Forest/Agricultural products	0.00	0.02	0.04	0.07	0.10	0.12
P39	Coal	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.02	0.03	0.05	0.08	0.10
P35	Natural Gas & LPG	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.01	0.01	0.02	0.03	0.03
P36	Oil Products	Low Temp Process Heat	Building insulation (space heated buildings, pig and poultry farms, greenhouses)	0.00	0.00	0.01	0.01	0.02	0.03
Total				0.00	0.04	0.09	0.15	0.22	0.29

Table G.3.5 Energy Savings Measures: Transport and Storage Sector, *Realisable Energy Savings Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Tran42	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of light goods vehicles from 20% to 30%	0.00	1.36	2.92	4.71	6.74	8.43
Tran43	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of heavy goods vehicles from 50% to 60%	0.00	0.85	1.84	2.96	4.24	5.30
Tran44	Diesel & Petrol	Transport, Land (Freight)	Shift road freight to rail	0.00	0.79	1.71	2.75	3.93	4.92
Tran34	Aviation	Air Transport	Shift passenger transport from air to rail-ship	0.00	0.51	1.11	1.79	2.55	3.20
Tran33	Diesel & Petrol	Transport, Land (Cars)	Increase load factor of passenger air services from 60% to 70%	0.00	0.33	0.71	1.14	1.63	2.04
Tran41	Diesel & Petrol	Transport, Land (Buses)	Increase load factor of passengers bus services from 30% to 40%	0.00	0.17	0.38	0.61	0.87	1.08
Tran45	Diesel & Petrol	Transport, Land (Cars & Freight)	Improve road surfaces and alignment	0.00	0.14	0.30	0.48	0.68	0.85
Tran35	Diesel & Fuel Oil	Sea Transport	Increase load factor of coastal freight services from 50% to 60%	0.00	0.09	0.19	0.30	0.43	0.54
Tran36	Diesel & Elect	Transport, Rail (Passenger)	Increase load factor of passenger rail services from 30% to 40%	0.00	0.01	0.02	0.03	0.04	0.06
Total				**0.00**	**4.25**	**9.16**	**14.76**	**21.12**	**26.42**

G.4 Greenhouse Gas Reductions Potential

The following pages contain five tables that present the 'energy saving measures' in each sector for 6 selected years. The five tables cover each aggregated sector:

- Household Sector (Table G.4.1)
- Industrial Sector (Table G.4.2)
- Commercial Sector (Table G.4.3)
- Primary Sector (Table G.4.4)
- Transport and Storage Sector (Table G.4.5)

It should be noted that OPENZ reporting provides data for 20 years, not just 6 years – only space restrictions restrict all years being recorded here.

The *Greenhouse Gas Reductions Potentials* quantified here are more precisely 'Realisable' *Greenhouse Gas Reductions Potentials.* This is because they assume the same end-use technology uptake rates as the 'Realisable Energy Savings Potentials', which reflect realistic levels of uptake.

Table G.4.1 Energy Savings Measures: ***Household Sector, Greenhouse Gas Reductions Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Tran39	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km a US projection)	0.00	1.13	2.44	3.93	5.62	7.04
Tran38	Diesel & Petrol	Transport, Land (Cars)	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	0.00	0.76	1.63	2.63	3.77	4.71
Tran29	Diesel & Petrol	Transport, Land (Cars)	Reduce Average Car Engine Size from 2000 to 1700cc (fuel consumption from 9.2 to8.7 1/100 km	0.00	0.54	1.17	1.88	2.69	3.37
Tran30	Diesel & Petrol	Transport, Land (Cars)	Car Pool to Increase Occupancy from 1.25 to 2 per vehicle in Commuting	0.00	0.47	1.01	1.63	2.33	2.92
Tran40	Diesel & Petrol	Transport, Land (Cars)	Driver Education Progrmmes, tune-up, tyres, exhaust testing (assume = "O&M")	0.00	0.41	0.88	1.42	2.03	2.54
Tran31	Diesel & Petrol	Transport, Land (Cars)	Use bicycles more for Commuting	0.00	0.40	0.86	1.39	1.99	2.49
Total				0.00	3.71	7.99	12.88	18.43	23.06

Table G.4.2 Energy Savings Measures: *Industrial Sector, Greenhouse Gas Reductions Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Ind102	Natural Gas & LPG	Elect & Process Heat	Cogeneration	0.00	0.82	1.80	2.96	4.32	5.48
Ind82	Electricity	Motive Power Stat	Motor Efficiency/ sizing improvements	0.00	0.27	0.59	0.97	1.41	1.79
Ind94	Electricity	Motors Various	Variable Speed Pumps /fans (eg, freezers and chillers)	0.00	0.13	0.28	0.46	0.67	0.85
Ind136	Wood	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.11	0.24	0.40	0.58	0.73
Ind85	Electricity	General Basic Metals	Improvements incl. Cogeneration from Waste Heat at NZ Steel	0.00	0.11	0.23	0.39	0.56	0.71
Ind91	Electricity	General Industrial	Generally Improved Operations and Maintenance (housekeeping, process controls and management)	0.00	0.10	0.22	0.36	0.52	0.66
Ind137	Wood	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.10	0.21	0.35	0.51	0.65
Ind87	Electricity	General Basic Metals	Improved Efficiency from Existing Cells at NZ Aluminium Smelters (better material and design)	0.00	0.09	0.19	0.32	0.46	0.59
Ind88	Electricity	Motive Power Stat	Improved Transmissions (cogged V-belts etc.)	0.00	0.08	0.18	0.30	0.43	0.55
Ind113	Natural Gas & LPG	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.06	0.14	0.23	0.34	0.43
Ind97	Electricity	Refrigeration	Plate Freezing in the Meat Industry	0.00	0.06	0.13	0.22	0.32	0.40
Ind133	Coal	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.06	0.13	0.21	0.31	0.39
Ind81	Electricity	Refrigeration	Controlled Door Opening in Cold and Cool Stores	0.00	0.05	0.11	0.19	0.28	0.35
Ind80	Electricity	General Wood Processing & Wood Products	Refining and Rejects Handling in Forest Products	0.00	0.05	0.10	0.17	0.25	0.31
Ind117	Oil Products	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.04	0.09	0.15	0.22	0.28
Ind106	Natural Gas & LPG	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.04	0.08	0.14	0.20	0.25
Ind90	Electricity	Refrigeration	Better Insulation of Cold and Cool stores (floor, wall and ceiling)	0.00	0.03	0.08	0.13	0.18	0.23
Ind84	Electricity	General Basic Metals	Install New Cells (larger, magnetically compresses at NZ Aluminium Smelters	0.00	0.03	0.08	0.12	0.18	0.23
Ind107	Natural Gas & LPG	High Temp Process Heat	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	0.00	0.02	0.03	0.05	0.08	0.10
Ind131	Coal	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.01	0.03	0.05	0.08	0.10
Ind81	Electricity	Refrigeration	Cool Chain Concept in Food Industry	0.00	0.01	0.03	0.05	0.08	0.10
Ind109	Natural Gas & LPG	Med Temp Process Heat	MVR Evaporators in Food Processing	0.00	0.01	0.03	0.05	0.08	0.10
Ind120	Oil Products	Med Temp Process Heat	Improved Boiler Efficiency	0.00	0.01	0.03	0.05	0.08	0.10
Ind127	Coal	Water Heating	WH Recovery	0.00	0.01	0.03	0.05	0.07	0.09
Ind116	Oil Products	Water Heating	WH Recovery	0.00	0.01	0.03	0.05	0.07	0.09

Table G.4.2 Energy Savings Measures: ***Industrial Sector, Greenhouse Gas Reductions Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Ind128	Coal	Water Heating	Grey Water Heat Recovery	0.00	0.01	0.03	0.05	0.07	0.09
Ind105	Natural Gas & LPG	Water Heating	WH Recovery	0.00	0.01	0.03	0.04	0.06	0.08
Ind138	Geothermal	General Industrial	Generally Improved O&M (housekeeping, process control and management)	0.00	0.01	0.02	0.04	0.06	0.07
Ind130	Coal	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.01	0.02	0.04	0.05	0.07
Ind129	Coal	Med Temp Process Heat	MVR Evaporators in Food Processing	0.00	0.01	0.02	0.03	0.05	0.06
Ind119	Oil Products	Med Temp Process Heat	MVR Evaporators in Food Processing	0.00	0.01	0.02	0.03	0.05	0.06
Ind134	Coal	Water Heating	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	0.00	0.01	0.02	0.03	0.04	0.05
Ind93	Electricity	High Temp Process Heat	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	0.00	0.01	0.01	0.02	0.03	0.04
Ind83	Electricity	Lighting	Upgrade Fluorescents (reflectors-triphoshors,CFLs)	0.00	0.01	0.01	0.02	0.03	0.04
Ind110	Natural Gas & LPG	Water Heating	Grey Water Heat Recovery	0.00	0.01	0.01	0.02	0.03	0.04
Ind132	Coal	Water Heating	Distributional Efficiency (local heaters, pipe and cylinder insulation)	0.00	0.00	0.01	0.01	0.02	0.03
Ind99	Electricity	High Temp Process Heat	Induction Heating in Metal Fabrication Industries (electricity substitution)	0.00	0.00	0.01	0.01	0.02	0.03
Ind111	Natural Gas & LPG	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.00	0.01	0.01	0.02	0.02
Ind112	Natural Gas & LPG	Water Heating	Instantaneous Water Heating	0.00	0.00	0.01	0.01	0.01	0.02
Ind115	Natural Gas & LPG	Water Heating	WHR Recovery + CO2 Refrigerant (WHR for water at pasteurising temps)	0.00	0.00	0.01	0.01	0.01	0.02
Ind95	Electricity	Water Heating	Grey Water Heat Recovery	0.00	0.00	0.01	0.01	0.01	0.02
Ind96	Electricity	Water Heating	Insulation of Hot Water Tanks and Pipes	0.00	0.00	0.00	0.01	0.01	0.01
Ind124	Oil Products	High Temp Process Heat	Infra-red heating in metal fabrication, printing & apparel industries (electricity substitution)	0.00	0.00	0.00	0.01	0.01	0.01
Ind86	Electricity	Electronics & Electrical End-Uses	Improved Operation of Electronic Equipment	0.00	0.00	0.00	0.01	0.01	0.01
Ind80	Electricity	Lighting	Upgrade Gas Discharge lamps (replace HG with High press Na.)	0.00	0.00	0.00	0.00	0.01	0.01
Ind114	Natural Gas & LPG	Water Heating	Distributional Efficiency (local heaters, pipe and cylinder insulation)	0.00	0.00	0.00	0.00	0.01	0.01
Ind103	Natural Gas & LPG	Fe2O3 Reduction	Improved O&M steel	0.00	0.00	0.00	0.00	0.01	0.01
Ind121	Oil Products	Water Heating	Grey Water Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.01
Total				**0.00**	**2.45**	**5.37**	**8.83**	**12.88**	**16.35**

Table G.4.3 Energy Savings Measures: *Commercial Sector, Greenhouse Gas Reductions Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com57	Electricity	Electronics & Electrical End-Uses	Operational (office equipment management, switch off, optimum location)	0.00	0.29	0.62	1.01	1.45	1.82
Com63	Electricity	Lighting	Medium Cost Lamp Upgrade (Reflectors-triphoshor tubes,CFLs)	0.00	0.17	0.36	0.58	0.84	1.05
Com66	Electricity	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.12	0.26	0.43	0.61	0.77
Com53	Electricity	General Commercial	New Buildings/ Integrated Design	0.00	0.12	0.25	0.41	0.59	0.74
Com72	Electricity	Water Heating	Instantaneous Water Heaters	0.00	0.11	0.25	0.40	0.58	0.73
Com96	Natural Gas & LPG	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.09	0.20	0.33	0.48	0.60
Com69	Electricity	Electronics & Electrical End-Uses	Purchase (selection of efficient equipment)	0.00	0.08	0.18	0.30	0.43	0.54
Com56	Electricity	Space Heating	Recommissioning	0.00	0.08	0.17	0.28	0.40	0.50
Com92	Natural Gas & LPG	Water Heating	Condensing Boilers/European Design Practices	0.00	0.07	0.16	0.26	0.37	0.47
Com68	Electricity	Space Heating	Re-engineering	0.00	0.07	0.15	0.24	0.34	0.43
Com86	Natural Gas & LPG	Space Heating	Integrated Design	0.00	0.06	0.14	0.22	0.32	0.40
Com126	Coal	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.06	0.14	0.22	0.32	0.40
Com55	Electricity	Lighting	Design Changes (Task lighting, Uplighting,daylighting)	0.00	0.06	0.14	0.22	0.32	0.40
Com84	Electricity	Lighting	High Cost Lamp Upgrade (low loss ballasts, diffusers, high pressure sodium lamps)	0.00	0.06	0.13	0.20	0.29	0.37
Com58	Electricity	Space Cooling	Recommissioning	0.00	0.04	0.10	0.16	0.22	0.28
Com65	Electricity	Lighting	Automatic Controls (occupancy, time-switching, daylight linked)	0.00	0.04	0.09	0.15	0.22	0.27
Com119	Coal	Space Heating	Integrated Design	0.00	0.04	0.09	0.15	0.21	0.27

Table G.4.3 Energy Savings Measures: ***Commercial Sector, Greenhouse Gas Reductions Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Com71	Electricity	Water Heating	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absorption chillers, heat recovery)	0.00	0.04	0.09	0.14	0.20	0.26
Com87	Natural Gas & LPG	Space Heating	Recommissioning	0.00	0.04	0.08	0.13	0.19	0.24
Com51	Electricity	Space Cooling	New Buildings/ Integrated Design	0.00	0.04	0.08	0.13	0.19	0.24
Com97	Natural Gas & LPG	General Commercial	Cogeneration, especially in hospitals and pools	0.00	0.04	0.08	0.13	0.19	0.23
Com59	Electricity	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.04	0.08	0.13	0.18	0.23
Com62	Electricity	Water Heating	Improved Operations and Maintenance (eg, Temperature Settings, Distribution Controls, Drips, Leaks)	0.00	0.04	0.08	0.13	0.18	0.23
Com52	Electricity	Space Cooling	Internal Heat Gain Reduction	0.00	0.04	0.08	0.13	0.18	0.23
Com61	Electricity	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.03	0.07	0.12	0.17	0.21
Com49	Electricity	Lighting	Low Cost Lamp Upgrade: 38mm to 26mm)	0.00	0.03	0.07	0.11	0.16	0.20
Com54	Electricity	Motive Power Stationary	Motor Sizing	0.00	0.03	0.06	0.10	0.15	0.19
Com98	Natural Gas & LPG	Space Heating	Re-engineering	0.00	0.03	0.06	0.10	0.15	0.19
Com48	Electricity	Lighting	Delamping /Fine- tuning	0.00	0.03	0.06	0.10	0.14	0.17
Com120	Coal	Space Heating	Recommissioning	0.00	0.03	0.05	0.09	0.13	0.16
Com67	Electricity	Lighting	Improved Operations and Maintenance (after hours use, cleaning staff scheduling, occupant switching, re-commissioning, luminaire cleaning, lamp replacement scheduling)	0.00	0.02	0.05	0.09	0.13	0.16
Com74	Electricity	Cooking	Induction Cooking in Commercial Kitchens	0.00	0.02	0.05	0.08	0.12	0.15
Com64	Electricity	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.02	0.05	0.07	0.11	0.14
Com78	Electricity	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.02	0.04	0.07	0.10	0.13
Com76	Electricity	Space Heating	Exhaust Heat Recovery	0.00	0.02	0.04	0.07	0.10	0.13
Com127	Coal	Space Heating	Re-engineering	0.00	0.02	0.04	0.07	0.10	0.13

Table G.4.3 Energy Savings Measures: ***Commercial Sector, Greenhouse Gas Reductions Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Com138	Wood	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.02	0.04	0.06	0.09	0.11
Com75	Electricity	Space Cooling	Improved Envelope Design	0.00	0.02	0.04	0.06	0.08	0.11
Com60	Electricity	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.01	0.03	0.05	0.07	0.09
Com93	Natural Gas & LPG	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.01	0.03	0.05	0.07	0.09
Com130	Coal	General Commercial	Economisers	0.00	0.01	0.03	0.04	0.06	0.08
Com91		Water Heating	Instantaneous Water Heaters	0.00	0.01	0.03	0.04	0.06	0.07
Com123	Coal	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.01	0.02	0.03	0.05	0.06
Com81	Electricity	Pumping	Variable Speed Drives on Pumps in Hospitals and Polls	0.00	0.01	0.02	0.03	0.05	0.06
Com95	Natural Gas & LPG	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.01	0.02	0.03	0.05	0.06
Com50	Electricity	Space Cooling	Appropriate Chiller Size and Technology	0.00	0.01	0.02	0.03	0.04	0.06
Com70	Electricity	Space Cooling	Ventilation Efficiency	0.00	0.01	0.02	0.03	0.04	0.06
Com77	Electricity	Space Cooling	Cooling Efficiencies	0.00	0.01	0.02	0.03	0.04	0.06
Com100	Natural Gas & LPG	Space Heating	Exhaust Air Recovery	0.00	0.01	0.02	0.03	0.04	0.05
Com101	Natural Gas & LPG	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.01	0.02	0.03	0.04	0.05
Com134	Wood	Space Heating	Integrated Design	0.00	0.01	0.02	0.03	0.04	0.05
Com99	Natural Gas & LPG	Water Heating	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absorption chillers, heat recovery)	0.00	0.01	0.02	0.02	0.04	0.04
Com82	Electricity	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.01	0.01	0.02	0.03	0.04
Com125	Coal	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.01	0.01	0.02	0.03	0.04

Table G.4.3 Energy Savings Measures: ***Commercial Sector, Greenhouse Gas Reductions Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Com131	Coal	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.01	0.01	0.02	0.03	0.04
Com88	Natural Gas & LPG	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.01	0.01	0.02	0.03	0.04
Com94	Natural Gas & LPG	Water Heating	Generally Improved O&M (housekeeping, process control and management)	0.00	0.01	0.01	0.02	0.03	0.04
Com79	Electricity	Space Cooling	Improved Operations and Maintenance	0.00	0.01	0.01	0.02	0.03	0.04
Com129	Coal	Space Heating	Exhaust Air Recovery	0.00	0.01	0.01	0.02	0.03	0.04
Com124	Coal	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.01	0.01	0.02	0.03	0.03
Com135	Wood	Space Heating	Recommissioning	0.00	0.01	0.01	0.02	0.03	0.03
Com139	Wood	Space Heating	Re-engineering	0.00	0.01	0.01	0.02	0.03	0.03
Com73	Electricity	Space Cooling	Improved Controls	0.00	0.01	0.01	0.02	0.03	0.03
Com102	Natural Gas & LPG	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.00	0.01	0.01	0.02	0.02
Com128	Coal	Water Heating	Heat Generation (Solar, condensing boilers, cogeneration with other services- eg, absorption chillers, heat recovery)	0.00	0.00	0.01	0.01	0.01	0.02
Com144	Geothermal	Space Heating	Integrated Design	0.00	0.00	0.01	0.01	0.01	0.02
Com121	Coal	Water Heating	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.00	0.00	0.01	0.01	0.01	0.02
Com90	Natural Gas & LPG	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.00	0.01	0.01	0.01	0.01
Com136	Wood	Space Heating	Correct Heating Choice (radiant/convector/air)	0.00	0.00	0.00	0.01	0.01	0.01
Com137	Wood	Space Heating	Plant Control (eg, compensator control with reset)	0.00	0.00	0.00	0.01	0.01	0.01
Com140	Wood	Space Heating	Exhaust Air Recovery	0.00	0.00	0.00	0.01	0.01	0.01
Com142	Wood	Space Heating	Zone Control (eg, thermostatic radiator valves)	0.00	0.00	0.00	0.01	0.01	0.01

Table G.4.3 Energy Savings Measures: ***Commercial Sector, Greenhouse Gas Reductions Potential (continued)***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Com83	Electricity	Water Heating	Grey Water Heat Exchanges in Commercial Kitchens and Laundries	0.00	0.00	0.00	0.01	0.01	0.01
Com132	Coal	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.00	0.00	0.01	0.01	0.01
Com145	Geothermal	Space Heating	Recommissioning	0.00	0.00	0.00	0.01	0.01	0.01
Com152	Geothermal	Space Heating	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	0.00	0.00	0.00	0.01	0.01	0.01
Com143	Wood	Space Heating	Improved Operations and Maintenance (after-hours use, cleaning staff scheduling, occupant switching, re-commissioning, filters, AMV's, controls,sensors,dampers)	0.00	0.00	0.00	0.00	0.01	0.01
Com122	Coal	Water Heating	Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.00	0.00	0.00	0.00	0.00	0.01
Total				**0.00**	**2.41**	**5.23**	**8.49**	**12.22**	**15.34**

Table G.4.4 Energy Savings Measures: ***Primary Sector, Greenhouse Gas Reductions Potential***

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	2011	2015	2019	2023	2026
Tran42	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of light goods vehicles from 20% to 30%	0.00	2.71	5.84	9.42	13.48	16.86
Tran43	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of heavy goods vehicles from 50% to 60%	0.00	1.71	3.67	5.92	8.47	10.60
Tran44	Diesel & Petrol	Transport, Land (Freight)	Shift road freight to rail	0.00	1.58	3.41	5.50	7.87	9.84
Tran34	Avaition	Air Transport	Shift passenger transport from air to rail-ship	0.00	1.03	2.21	3.57	5.11	6.39
Tran33	Diesel & Petrol	Transport, Land (Cars)	Increase load factor of passenger air services from 60% to 70%	0.00	0.66	1.42	2.28	3.26	4.08
Tran41	Diesel & Petrol	Transport, Land (Buses)	Increase load factor of passengers bus services from 30% to 40%	0.00	0.35	0.75	1.21	1.73	2.17
Tran35	Diesel & Fuel Oil	Sea Transport	Increase load factor of coastal freight services from 50% to 60%	0.00	0.17	0.37	0.60	0.86	1.08
Tran36	Diesel & Elect	Transport, Rail (Passenger)	Increase load factor of passenger rail services from 30% to 40%	0.00	0.02	0.04	0.06	0.09	0.11
Tran37	Diesel & Elect	Transport, Rail (Freight)	Increase load factor of rail freight services from 30% to 40%	0.00	0.00	0.00	0.00	0.00	0.00
Total				**0.00**	**8.23**	**17.72**	**28.57**	**40.87**	**51.14**

Table G.4.5 Energy Savings Measures: Transport and Storage Sector, *Greenhouse Gas Reductions Potential*

Code	Delivered Energy	End-Use	Energy Savings Measure	Petajoules Delivered Energy Saved (for each year)					
				2007	**2011**	**2015**	**2019**	**2023**	**2026**
Tran42	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of **light goods** vehicles from 20% to 30%	0.00	1.36	2.92	4.71	6.74	8.43
Tran43	Diesel & Petrol	Transport, Land (Freight)	Increase load factor of **heavy goods** vehicles from 50% to 60%	0.00	0.85	1.84	2.96	4.24	5.30
Tran44	Diesel & Petrol	Transport, Land (Freight)	Shift road freight to rail	0.00	0.79	1.71	2.75	3.93	4.92
Tran34	Aviation Fuel	Air Transport	Shift passenger transport from air to rail-ship	0.00	0.51	1.11	1.79	2.55	3.20
Tran33	Diesel & Petrol	Transport, Land (Cars)	Increase load factor of **passenger air** services from 60% to 70%	0.00	0.33	0.71	1.14	1.63	2.04
Tran41	Diesel & Petrol	Transport, Land (Buses)	Increase load factor of **passengers bus** services from 30% to 40%	0.00	0.17	0.38	0.61	0.87	1.08
Tran45	Diesel & Petrol	Transport, Land (Cars & Freight)	Improve road surfaces and alignment	0.00	0.14	0.30	0.48	0.68	0.85
Tran35	Diesel & Fuel Oil	Sea Transport	Increase load factor of **coastal freight** services from 50% to 60%	0.00	0.09	0.19	0.30	0.43	0.54
Tran36	Diesel & Elect	Transport, Rail (Passenger)	Increase load factor of **passenger rail** services from 30% to 40%	0.00	0.01	0.02	0.03	0.04	0.06
Tran37	Diesel & Elect	Transport, Rail (Freight)	Increase load factor of **rail freight** services from 30% to 40%	0.00	0.00	0.00	0.00	0.00	0.00
Total				**0.00**	**4.25**	**9.16**	**14.76**	**21.12**	**26.42**

Appendix H

Detailed Results: Energy Savings Supply Curves for 2025/26

Table H.1 Industrial Sector: Energy Savings Cost Curve Data for 2025/2026

Supply Curve Code	OPENZ Code	Energy Savings Measure	Amount Saved (PJ/yr)	Cost ($\$_{2006/07}$ /GJ)	Total Cost ($\$_{2006/07}$ million)
A	Ind80	Refining and Rejects Handling in Forest Products	0.63	0.00	0.00
A	Ind81	Controlled Door Opening in Cold and Cool Stores	0.70	0.28	0.20
A	Ind103	Improved O&M steel	0.01	0.69	0.01
A	Ind136	Improved Boiler Efficiency	1.47	0.88	1.30
B	Ind102	Cogeneration	10.97	1.80	19.69
C	Ind137	Generally Improved O&M (housekeeping, process control and management)	1.30	3.45	4.49
D	Ind82	Motor Efficiency/ sizing improvements	3.58	6.89	24.64
E	Ind105	WH Recovery	0.16	7.96	1.26
F	Ind83	Upgrade Fluorescents (reflectors-triphoshors,CFLs)	0.07	16.29	1.21
C	Ind91	Generally Improved Operations and Maintenance (housekeeping, process controls and	1.32	16.96	22.38
G	Ind85	Efficiency Improvements at NZ Steel	1.43	18.98	27.12
G	Ind84	Efficiency Improvements at Aluminium Smelters	0.46	19.22	8.89
	Ind86	Improved Operation of Electronic Equipment	0.02	20.55	0.41
	EU11	Low Temperature Heat (<100 C), Water Heating	-1.30	45.57	-59.22
	EU27	Ind Ovens _Intermediate Heat (100-300 C), Process Requirements	-0.08	105.94	-8.27
	EU24	Kiln/Furnace_ High Temperature Heat (>300 C), Process Requirements	-1.43	116.78	-167.46

Source: Economic Potential Optimisation

Table H.2 Commercial Sector: Energy Savings Cost Curve Data for 2025/2026

Supply Curve Code	OPENZ Code	Energy Savings Measure	Amount Saved (PJ/yr)	Cost ($\$_{2006/07}$ /GJ)	Total Cost ($\$_{2006/07}$ million)
A	Com49	Low Cost Lamp Upgrade	0.39	0.00	0.00
	Com50	Appropriate Chillier Size and Technology	0.11	0.00	0.00
B	Com51	New Buildings/ Integrated Design	0.47	0.00	0.00
B	Com52	Internal Heat Gain Reduction	0.45	0.00	0.00
B	Com53	New Buildings/ Integrated Design	1.49	1.01	1.50
B	Com104	Integrated Design	0.00	1.01	0.00
B	Com119	Integrated Design	0.53	1.01	0.54
B	Com134	Integrated Design	0.11	1.01	0.11
C	Com54	Motor Sizing	0.38	1.12	0.42
D	Com55	Design Changes (Task lighting, Uplighting,daylighting)	0.80	1.15	0.92
E	Com87	Heat Plant Recommissioning	0.48	1.49	0.71
E	Com56	Heat Plant Recommissioning	1.00	1.52	1.51
E	Com105	Heat Plant Recommissioning	0.00	1.52	0.00
E	Com120	Heat Plant Recommissioning	0.32	1.52	0.48
E	Com135	Heat Plant Recommissioning	0.07	1.52	0.10
F	Com57	Operational (office equipment management, switch off, optimum location)	3.65	2.26	8.24
E	Com58	Heat Plant Recommissioning	0.57	2.74	1.55
G	Com59	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.46	3.77	1.72
G	Com88	Flow Controls (Spray Nozzles, Shower Heads etc.)	0.08	3.77	0.29
H	Com60	Heat Distribution Efficiency (local heaters, pipes and cylinder insulation)	0.19	9.43	1.77
I	Com136	Correct Heating Choice (radiant/convector/air)	0.03	15.26	0.41
M	Com62	Improved Operations and Maintenance (eg, Temperature Settings, Distribution Controls, Drips, Leaks)	0.46	17.00	7.77
J	Com63	Medium Cost Lamp Upgrade (Reflectors-triphoshor tubes,CFLs)	2.11	18.06	38.01
	Com64	Plant Control (eg, compensator control with reset)	0.27	18.39	4.98
L	Com65	Automatic Controls (occupancy, time-switching, daylight linked)	0.55	19.07	10.47
K	Com66	Improved envelope design (insulation, glazing, shading, window size, thermal mass, passive solar)	1.54	20.58	31.67
M	Com67	Improved Operations and Maintenance (after hours use, cleaning staff scheduling, occupant switching,	0.32	21.77	6.90
N	Com97	Cogeneration, especially in hospitals and pools	0.47	23.99	11.21

Source: Economic Potential Optimisation

Table H.3 Household Sector: Energy Savings Cost Curve Data for 2025/2026

Supply Curve Code	OPENZ Code	Energy Savings Measure	Amount Saved (PJ/yr)	Cost ($_{2006/07}$ /GJ)	Total Cost ($_{2006/07}$ million)
B	EU5	Intermediate Heat (100-300 C), Cooking	3.39	-111.56	-378.25
C	EU10	Low Temperature Heat (<100 C), Space Heating	9.97	-30.20	-301.24
D	EU7a	Lighting	5.18	-29.13	-150.95
E	EU18b	Transport, Land (Passenger Cars)	18.53	-11.99	-222.30
F	H412	Passive Solar Refits	0.05	0.32	0.02
G	H411	"New House Market"	0.07	1.40	0.10

Source: Economic Potential Optimisation

Table H.4 Transport and Storage Sector: Energy Savings Cost Curve Data for 2025/2026

Supply Curve Code	OPENZ Code	Energy Savings Measure	Amount Saved (PJ/yr)	Cost ($_{2006/07}$/GJ)	Total Cost ($_{2006/07}$ million)
A	EU18a	Transport, Land (Freight)	1.65	-96.41	-159.13
B	EU18c	Transport, Land (Passenger Buses)	0.56	-56.57	-31.79
C	EU19a	Transport, Rail (Freight)	1.64	-49.39	-81.19
D	EU19b	Transport, Rail (Passenger)	0.31	-33.87	-10.62
E	Tran33	Increase load factor of passenger air services from 60% to 70%	4.08	0.00	0.00
F	Tran34	Shift passenger transport from air to rail-ship	6.39	0.00	0.00
G	Tran35	Increase load factor of coastal freight services from 50% to 60%	1.08	0.00	0.00
H	Tran36	Increase load factor of passenger rail services from 30% to 40%	0.11	0.00	0.00
H	Tran37	Increase load factor of rail freight services from 30% to 40%	0.00	0.00	0.00
I	Tran38	Improve Average Car Economy (fuel consumption from 9.2 to 7.8 /100km)	9.43	0.00	0.00
I	Tran39	Improve Average Car Economy (fuel consumption from 9.2 to 7.11/100km)	14.07	0.00	0.00
J	Tran40	Driver Education Progrmmes, tune-up, tyres, exhaust testing	5.07	0.00	0.00
K	Tran41	Increase load factor of passengers bus services from 30% to 40%	2.17	0.00	0.00
L	Tran42	Increase load factor of light goods vehicles from 20% to 30%	16.86	0.00	0.00
M	Tran43	Increase load factor of heavy goods vehicles from 50% to 60%	10.60	0.00	0.00
N	Tran44	Shift road freight to rail	9.84	0.00	0.00
O	Tran45	Improve road surfaces and alignment	1.71	0.00	0.00
P	Tran32	Telecommute 4 out of 5 days per week	4.15	2.27	9.43
Q	EU18b	Transport, Land (Passenger Cars)	5.34	60.09	320.65
R	Tran31	Use bicycles more for Commuting	4.99	114.26	569.72
S	Tran30	Car Pool to Increase Occupancy from 1.25 to 2 per vehicle in Commuting	5.83	212.81	1,241.32

Source: Technical Potential Optimisation

Table H.5 Primary Sector: Energy Savings Cost Curve Data for 2025/2026

Supply Curve Code	OPENZ Code	Energy Savings Measure	Amount Saved (PJ/yr)	Cost ($_{2006/07}$/GJ)	Total Cost ($_{2006/07}$ million)
A	EU18a	Transport, Land (Freight)	0.28	-93.74	-26.02
B	P36	Building insulation (space heated buildings, pig and poultry farms, greenh	0.05	0.32	0.02
C	P37	Efficiency Improvement for Kiln Drying of Forest/Agricultural products	0.25	1.08	0.27
B	P39	Building insulation (space heated buildings, pig and poultry farms, greenh	0.20	1.08	0.22
B	P35	Building insulation (space heated buildings, pig and poultry farms, greenh	0.07	1.40	0.10
	EU6	Intermediate Heat (100-300 C), Process Requirements	-0.12	65.51	-7.56
	EU18b	Transport, Land (Passenger Cars)	-0.04	283.22	-11.33

Source: Economic Potential Optimisation

Appendix I

Data Quality in the 2006/07 EECA Database

Table I.2 Assessment of the Quality of Energy Data Used in the EECA Database 2006/07 Update

Data Source	Data Quality Assessment	Comment
MED Energy Data		
Energy Supply and Demand Matrix	Very Good	Excellent overall summary of energy use in New Zealand. Internally consistent. The 'Unallocated Row' remains a problem although we understand that this shortcoming is being investigated by MED.
Electricity Statistics	Excellent	Particularly useful sectoral data, at a fine level of disaggregation.
Other Sources of Data in the Energy Data File	Excellent	Based on a wide range of surveys. Excellent time series which shows up obvious data anomalies.
Network Company Electricity Data	Not relevant	This data was not available for the 2006/07 Update, as opposed to the 2001/02 Update. Due to the non-availability of this data, the regional electricity data could not be cross-checked.
Sectoral Natural Gas Use (Table E:8)	Good	Some inconsistencies with the 2006/07 data in 'Energy Supply and Demand Matrix'. Lack of sectoral disaggregation.
Spatial Coverage of Energy Use		
Natural Gas Reticulation Covers	Excellent	
Energy Use in Household Space Heating	Excellent – Very Good	Based on a full census. However, some respondents seemed to have answered some questions incorrectly (eg, yes, to natural gas use in the South Island).
Canterbury Region Energy Survey	Excellent – Very Good	Credible and detailed survey by experienced analysts. Using a 'very standard methodology' (Hooper, pers com.), based mainly on actual sales of energy. Still awaiting a description of the methodology from (Hooper, pers com) Some data had to be estimated.
Waikato Regional Energy Survey 2003	Excellent – Very Good	Electricity data obtained from line companies. Other energy data estimated from surveys (coal and wood), resource consents and regional fuel tax data. The methodology is well documented in Wilton (2005).
Auckland Regional Energy Survey 2008	Unfortunately, the methodology is not written up, which prevents a proper assessment of its accuracy.	Based on actual sales data. Appears to be a similar methodology to that used for Waikato and Canterbury.
Regional Energy Use by Buses Survey	Fair- Good	Only covered six centres. Based on a one-day telephone/email survey in 2004.
Reports on Sectoral Energy Use		
Energy Wise Monitoring Quarterlies		Not available as per last update. Series Discontinued.
Sectoral Energy Reports	Excellent – Very Good	22 such reports compared with 11 last time. Reports of a generally high standard undertaken by well respected energy consultants. Main limitation is that the coverage across all sectors in the economy is 'patchy', with some well covered (eg, dairy farming) and some not at all. Some are now quite dated, eg the HEEP report for 2003.
Heat Plant Survey (Bioenergy Assoc. of New Zealand	(Potentially) Excellent	Rich and comprehensive measurement of industrial heat use in NZ, which was not available for the last update. Its usefulness (in terms of using this data in the EECA database) however is severely constrained by the lack of ANZSIC coding.
Manufacturing Energy Use Survey	Very Good	First 'full' survey of energy use in the manufacturing sector by SNZ in the last 20 years. Its lack of sectoral disaggregation beyond the ANZSIC 2 digit level is a limitation in terms of updating the database, as is its survey year of March Year 2006.
EECA Energy Data and Databases		
Audit Database	Fair (for updating purposes)	Too few businesses to make valid regional or national inferences about sectoral energy use.