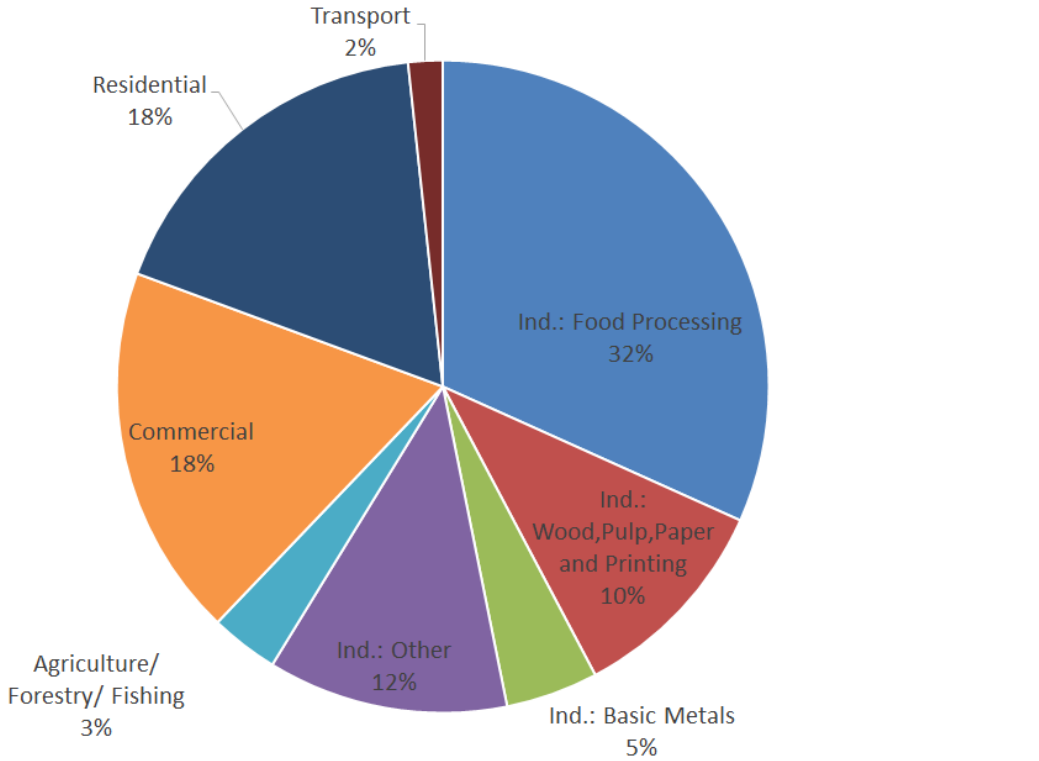
Electricity generation implications of large-scale fuel-switching from gas to electricity

This note sets out an order-of-magnitude estimate of the electricity generation implications of large scale fuel switching from 'gas' (being reticulated natural gas and liquified petroleum gas (LPG)) to electricity for so-called 'direct-users' of gas and LPG in New Zealand.[1] As is illustrated in the following figure these direct users comprise:

- Industrial consumers who use gas primarily for intermediate-to-high-temperature process heat, such as food processing or paper manufacturing
- Commercial and residential consumers who use gas primarily for space and water heating.

A relatively small amount of direct use gas is also used for other purposes, such as transport (particularly for LPG), and cooking.

Figure 1: Direct users of natural gas and LPG in 2017



Source: Concept analysis of MBIE and LPGA data

In 2017, a total of 54 PJ of gas (45 PJ natural gas, 9 PJ LPG) was consumed by direct users.

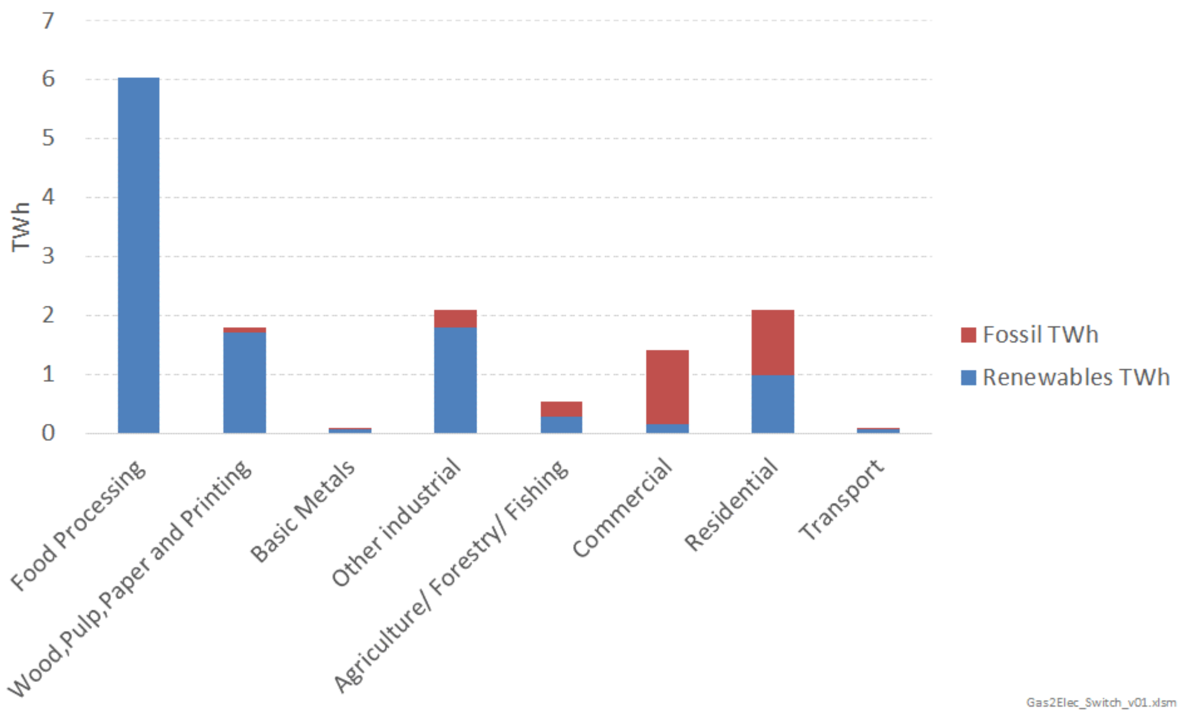
[1] "Direct use" only includes gas which is directly used by the final consumer as an energy source – it excludes gas used as a chemical feedstock for petrochemical manufacturing, and gas used as a fuel source for electricity generation.

Analysis was undertaken as to the amount of electricity generation required if this demand for energy was instead to be supplied by electricity. In undertaking this analysis, the following factors were taken into account:

- The types of energy use (e.g. high temperature process heat, space heating, water heating, etc.) for each of the above segments
- The extent to which electricity is a feasible option for some uses. In this context, the use of electricity for some of the very high-temperature industrial process requirements is not considered feasible.
- The relative efficiency of gas and electric appliances for meeting these energy use requirements based on typical industry norms. Electricity lines losses are also taken into account to translate consumer demand for energy into required generation.
- The 'shape' of consumption – in particular the daily and seasonal patterns of consumption and how these affect load factors (i.e. average utilisation over a year). This has a significant bearing on the MW capacity of electricity supply assets required to substitute for gas, and the extent to which additional electricity generation is likely to be met by renewable generation, or fossil-fuelled power generation. Thus, the relatively high load factor of industrial use means that the additional capacity (MW) required to meet this demand per annual MWh of energy are a lot less than for space heating which has a very low load factor. Further, the relatively flat within-year and within-day shape of demand for major industrial users means that the majority of industrial demand can be met by new renewable generation, whereas the winter-only demand profile (plus significant within-day shape as well) for space heating means it is likely to predominantly be met by increased fossil-fuelled generation.

The results of this analysis in terms of the amount of electricity generation required if existing direct-users of gas were to switch to electricity are shown in the following figure.

Figure 2: Estimated electricity generation required to meet direct users' energy services demand currently met by gas and LPG



In total, it is estimated that 14.2 TWh of additional generation would be required if today's existing direct users of gas were to switch to electricity (excluding those direct users for whom electricity is not feasible). It is estimated that 11.2 TWh would come from renewable generation and 3 TWh from increased fossil-fuelled generation. The relatively high proportion of space heating demand drives the need for peaking fossil-fuelled generation to meet much of the demand for commercial and residential consumers.

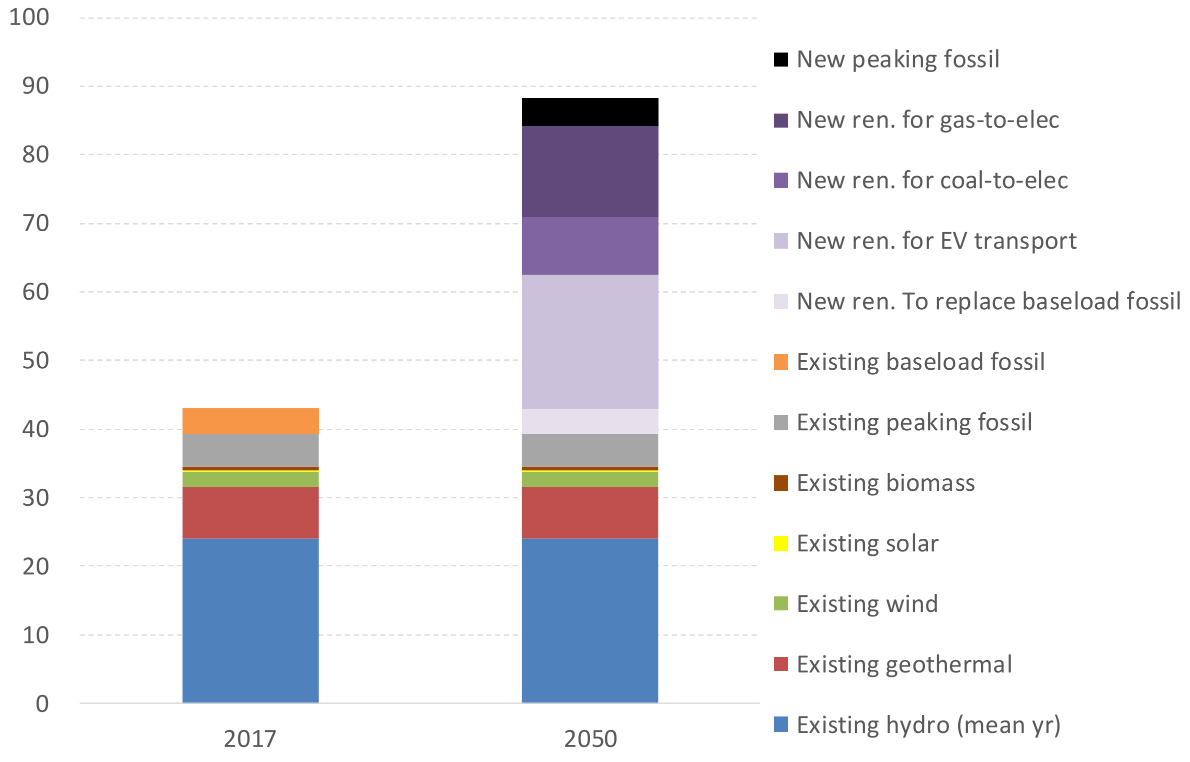
This analysis was developed further to consider the feasibility of such a transition for the years out to 2050 – being the government's target for net zero emissions.

This included considering the extent to which other factors would be increasing the demand for renewable electricity. These additional factors include:

- The growth in demand for the energy services currently met by gas due to population and economic growth during this period
- The implications of the complete electrification of transport over this same period (plus also considering the growth in demand for transport over this period)
- The implications for the electrification of energy use currently met by coal over the same period (plus considering the growth in demand for the energy services currently met by coal)
- The amount of renewables required in order to displace existing *baseload* fossil-fuelled generation. (For this analysis it is assumed that renewables aren't developed to displace fossil-fuelled generation which are providing peaking services (i.e. dry/wet year balancing, and seasonal peaking))

The results of this high-level analysis are shown in the following figure

Figure 3: High-level estimate of new electricity generation requirements to meet electrification of New Zealand's energy services currently met by fossil fuels



As can be seen, if New Zealand wishes to completely transition away from petrol/diesel for transport, and coal for industrial process heat, and gas for process-space-and-water heating, the amount of new renewable generation required would be very large – approximately doubling the annual electricity demand.

In this respect it is worth noting that:

- There are not considered to be significant potential new hydro schemes that could make a material addition to New Zealand's energy requirements
- There are some potential new geothermal resources, but these are understood to be limited to roughly a doubling of the existing resource. (Researching the scale of new potential is outside the scope of this exercise).
- There is a significant amount of new wind potential, plus there is a significant amount of new solar potential – albeit that wind generation is expected to remain cheaper than utility-scale solar for a decade or so. However, the challenge with significant proportions of variable renewable generation on the system is that it will result in extremes of surplus and scarcity. As such, were New Zealand to try and develop wind and solar to meet all the above demand (noting that it would be a sixteen-fold increase above current levels – assuming that geothermal can double output), it is likely that there would be large amounts of spill (i.e. generation of renewable electricity that could not be used at times). While some of this could be managed by batteries (including in electric vehicles), hydro balancing, and maybe even using the surplus to produce hydrogen, it is nonetheless considered that large amounts of spill could occur. To the extent large amounts of spill did occur, this would give rise to a need to develop significantly more wind and solar assets than indicated in Figure 3. Further, developing wind and solar to an extent which would give rise to very large amounts of spill would become increasingly expensive.
- The de-carbonisation of transport is based on moving to battery electric vehicles (EVs). If Hydrogen-fuelled vehicles were to become the norm (which is possible for heavy freight, but considered unlikely for the light fleet), there would be significantly more renewable electricity required.

Based on the above analysis, it is considered to be challenging to achieve fuel switching of the scale indicated by Figure 3 by 2050.

Given this observation, it is considered that New Zealand should prioritise the sections of the economy which it should de-carbonise, by focussing on those which are likely to yield the largest carbon savings per unit of cost. In this respect, it is considered that the merit-order of options (from most economic to least economic) is broadly:

- Transitioning our transport fleet to EVs.
- Displacing existing baseload gas-fired electricity generation
- Displacing coal-fired process heat
- Displacing existing direct-uses of gas.

We'd expect the relative priority would be properly signalled if effective pricing of carbon, fuel and transport/delivery were in place

Although it is out of scope for this analysis, past Concept analysis indicates that, in order to be economic, the switching from gas to renewable electricity will require significantly higher carbon prices (of the order of \$100 to \$200/tCO_2 greater in some cases) than many of the other options.

This is not just due to the wholesale fuel and appliance cost implications of the different options. It should also be noted that the economic network costs of gas and electricity are substantially different. In this respect:

- Existing gas networks have sufficient capacity to meet demand for the foreseeable future
- Electricity demand growth – particularly due to gas-to-electricity fuel switching for residential and commercial users – would likely give rise to significant new electricity network investment.

Lastly, given the above evaluation of the relative economics of New Zealand's de-carbonisation options and challenges of significantly scaling up new renewables, actions which result in 'early' fuel-switching from gas to electricity will not just be relatively costly, but could likely result in higher emissions by slowing the rate of fuel switching that would otherwise be possible from de-carbonising our more emissions-intensive coal and oil-based energy uses.