My submission to the Productivity Commission is in the areas of agriculture and road transport, which stand out in your report's energy/emissions profile.

While the technologies I will suggest can find a place within the ETS these might be best considered as complementary measures to speed up achieving the 'Zero emissions by 2050' target, in line with measures being suggested by the Bioenergy Association.

Rather than addressing ruminant methane, which is getting good new attention, my information deals with direct agricultural/forestry use of fossil fuels and fertiliser that make up the agricultural emissions of long lived gases, CO_2 and N_2O. Heavy transport vehicles and off-road equipment will not be easily replaced by electric vehicles, so are a good sector to focus on to supply renewable diesel fuel (RDF). Such fuel would also be very beneficial in speeding up the replacement of fossil fuels used in current light diesel vehicles, even if importation of that category of vehicles should stop before 2030.

This submission will focus on opportunities growing non-tree energy crops as biofuel feedstocks rather than on the biomass to biofuel conversion technologies, since my expertise is not in engineering.

During the past decade my biomass crop research for Plant & Food Research and the Chemical and Process Engineering Department of Canterbury University investigated a wide range of species (Renquist & Kerckhoffs, 2012). We identified the lignocellulosic grass called giant miscanthus (*Miscanthus x giganteus*), or Mxg, as the superior option as a feedstock for renewable diesel fuel in NZ (Renquist and Kerckhoffs, 2014). Mxg grows well in some categories of marginal land or can be used for Land Use Change (LUC) from arable feed crops to a bioenergy crop, with dramatically reduced CO_2 emissions per ha (detailed below). Since LUC is involved the benefits would be shown in the NZ GHG Inventory.

A plantation of Mxg only takes 2-3 years to reach maturity and is very likely to grow well for 25 years. There is negligible runoff or leaching of nutrients after its first year, protecting waterways. The N fertiliser requirement has proven to be near 0 in typical NZ soils since, like its tropical relative sugarcane, the plant accesses N through an association with soil microbes. Therefore emissions of the long-lived gas N20 will also be negligible. The global warming potential (GWP100) has been carefully quantified (from Cradle to Farm Gate) in a Life Cycle Assessment of NZ grown Mxg (Renquist, 2014a). The LCA also showed the large potential benefit for waterways.

The Scion-led New Zealand Biofuels Roadmap project offers a useful framework for a NZ biofuel development programme (Scion, 2018). The report (cited in your draft Productivity Commission report) includes analyses and biofuel scenarios which point to pine forests as the principal source of NZ biofuel feedstock, even though it will only be plentiful after 25 years. Trees species are certainly the best choice for replacing pasture on steep land. Tree species that can be coppiced regularly may be better than pines on some sites however.

This submission provides essential supplemental information on the role of Mxg biomass as another important biofuel feedstock. The Scion report does list Mxg as a temporary source of feedstock on arable crop land during the decades while new pine forests are growing, but Mxg use for biofuels is downplayed in several ways which need to be corrected.

The first issue is land use by non-forest biomass crop species such as Mxg. The Scion report contrasted the use of arable and non-arable land, indicating reasons to avoid more than short term use of arable land. The report even contended that "All food-producing land (current and potential, and including all dairy land) should be off limits to use for biofuels in order to satisfy export markets' definition of sustainable production."

In reality, part of the rural NZ land identified as arable can be legitimately used for sustainable biofuel feedstock production using the right species. Getting the land use guidelines for sustainable biomass crops wrong will also put at risk achieving the Carbon Zero 2050 goal.

The Plant & Food Research scientists working on sustainable biomass production published findings that categorised a large area of flat and rolling land as arable but marginal. This land-use category is termed 'summer dry' due to the too-frequent occurrence (for valuable arable crops) of seasons with low 'rainfall + soil water supply'. The study quantified a very significant potential for biofuel production (enough to fuel all primary production needs) using only 5-10% of this marginal land, which does not compete with production of food or feed grain crops (Trolove et al, 2013).

In addition there are significant areas of flat or gently rolling land that is of low fertility and which can only be farmed for valuable arable crops with the application of large amounts of fertiliser – with associated problems of leaching nutrients into the water table and N_2O emissions from the soil.

There is a large area of arable land in both of the above categories that can be better used for sustainable biomass production, helping solve water quality problems along with those from fossil fuel use. There are a few biomass species to which this applies, but in addition there is a major advantage in using Mxg.

When a plantation of Mxg is developed on what was marginal arable land the landowner will also be contributing substantially to CO_2 sequestration in the soil due to its massive rhizome system. As the plantation develops, the rhizomes accumulate a large amount of soil organic carbon (SOC), documented in several studies with Mxg in the EU. The SOC sequestration is actually larger than the entire GWP100 footprint calculated in the NZ LCA, making Mxg production actually carbon negative during its early years. While there is likely to be a sound business case to plant Mxg (making this a Complementary measure) it would also make sense to incentivise it with credits within the ETS.

With regard to dairy land, that Scion suggested to be off limits to biofuel feedstock, it is now clear that government policy will be restricting dairy grazing on unsuitable soil types by tight standards for nutrient leaching and by reduced irrigation supply to protect water quality. Within the land area likely to be excluded from future dairy grazing (especially within the Canterbury plains) are many sites where Mxg can produce sustainable biomass. Fonterra researcher Jeff Brown has reported relevant results with Mxg in Canterbury (Brown, 2017).

There is a clear opportunity to scale up biomass and biofuel production more readily and sooner with Mxg than other feedstock options.

The second issue raised in the Scion report is that Mxg is too new as a NZ species (and therefore too risky) to be grown at scale during the next several years.
The following 6 points counter that claim:

- I evaluated the crop production requirements of Mxg during the 6 years that I had hands-on involvement in planting, growing and harvesting the crop and investigating its qualities for use in bioenergy. My 2010 research planting of Mxg was still yielding very well in 2017 (>25 tonnes of dry matter per hectare from a spring harvest);
- Propagation of Mxg nursery plants via tissue culture has proven itself as a mature technology and was used from 2010 onwards; propagation from rhizome pieces is also being used to greatly expand the NZ plantation area;
- The number of Mxg plantings being used commercially (second growing season or older in 2018) is at least 12; there were also 5 new commercial plantings this season;
- The regions where Mxg is commercially grown are Auckland, Waikato, Central North Island, Taupo, Mid Canterbury, South Canterbury and Otago (plus my large research trials in Hawke's Bay);
- The 8 years of NZ experience with the crop has confirmed that Mxg grows in the same way and requires the same crop management as in the EU (where it has been studied for over 25 years).
- A 2009 planting of Mxg (the first in NZ) is still in production.

My expert advice is that the above advancements in Mxg crop production in NZ means that its use for biofuels will not need to be delayed in order to overcome biofuel feedstock production problems. It can be brought on line as fast as or faster than the use of forest harvest wastes, and in much greater quantity than is possible using all NZ lignocellulosic waste streams as biofuel feedstocks.

One technical fuel note is that renewable diesel fuel (or 'drop in' diesel) is not the same as biodiesel. The latter is made from oilseed crops that have low yields and greater emissions and environmental impacts on soil than a true biomass species such as Mxg. Biodiesel from waste tallow is better, but cannot be scaled up like RDF technology.

Scion Report will need updating

Despite the Scion report release date being 2018, the fuel use study it relied on is already outdated by the new government policy of NZ to be net carbon zero by 2050. The target in the scenarios is to substitute for 30% of current use of all fossil fuels (diesel, petrol and jet). Given the strong support for switching the light vehicle fleet to EVs (along with transport mode shifting and a potential import ban on petrol vehicles) there may be little need to produce 'drop in' petrol. Fuel needs in 2050 in the Scion report were based on the BusinessNZ Energy Committee (BECS2050) study, which determined that a large amount of fossil fuel (about half of all current use) will still be imported or refined after 2050. The cost of offsetting that much fossil fuel to achieve and sustain net carbon zero would be huge. New government policies will aim to eliminate fossil fuel use by that date (with aviation perhaps excepted). So the fuel substitution could be targeted at the markets using diesel and achieve much more than 30%.

The Scion report has many conversion technology options, but pyrolysis may suit forestry best. However, it requires natural gas for upgrading and gas is not likely to be either available or allowed by 2050. The alternative is to generate H_2 using gasification at each of the estimated 43 conversion plants. In that case, direct use of biomass gasification may be a better option.

Offset options for pastoral farmers

If Mxg crop land is within existing dairy farms it offers one means by which dairy farmers can feasibly reduce their net GHG emissions. This could be part of a policy approach requiring those farms to lead NZ’s uptake of GHG-reducing fuels by switching to renewable diesel fuel (RDF) if they cannot reduce ruminant methane. Fuel switching to ‘drop in’ RFD will likely be the low-hanging fruit for farmers who need to show some action. They could also profit from their region’s new fuel use by growing the feedstock. If they grow Mxg their crop land would be both carbon negative in the early years and only have tiny N_2O emissions since the crop grows without using N fertiliser. If pastoral farms use some paddocks to grow feed grain crops that are not essential to them, then growing Mxg would be a good alternative. Mxg has very low emissions and energy footprint (Renquist, 2014a), much lower than feed grain crops (triticale was the best cereal option), as shown in my Life Cycle Assessment of three species (2014b). The energy use avoided is for manufacture of N fertiliser and fuel for annual planting. Mxg only needs replanting after about 25 years (EU findings).

As well as its value for offsetting pastoral emissions there is new evidence the Mxg will have commercial value to pastoral farmers even before there is a market for RDF. The properties of Mxg straw (lighter and drier than other options) make it an ideal animal bedding material (Peter Brown of Miscanthus New Zealand Ltd). Any use that makes Mxg saleable also includes the feature of more regular revenue than a tree planting. Fonterra research with Mxg indicated that growing this 3.5m tall grass to provide wind shelter for cows in Canterbury increased grass growth and milk production while still producing a useful end product (Brown, 2017). The impacts of an Mxg plantation on nutrient movement make it ideal for riparian plantings as well.

Giant miscanthus as the preferred non-tree biomass species

There are other biomass species with high dry mass production. Lucerne yields are similar to those of Mxg, but require four harvests per year to equal the single harvest of Mxg. Jerusalem artichoke stems have high yields but retain moisture until required harvest time, making the species better for ensiling for use producing biogas. Mxg also has some advantages over pine trees. Mxg reaches peak DM yield in 3 years and from that time will yield >24 tonnes dry mass per ha per year (roughly double the annual dry mass gain of a pine plantation). Mxg straw is also much drier than wood or sawdust.

Mxg not only has the lowest GHG and energy footprints but also the unique benefit of the massive rhizome system. As noted above, the storage of soil carbon in the early years is actually greater than total carbon emissions, making Mxg biomass production carbon negative. Growing Mxg in appropriate sites currently used for arable feed crops would make a large contribution to reducing both GHG emissions energy use (compared to arable feed crops) and; it would also significantly reduce N leaching to the water table, a triple win.

Conversion to biofuels

Biofuel investor comments: The scale of biomass production required is 50,000 tonnes dry mass per year per plant, or roughly 2000 ha of Mxg. There is no need for government investment in the infrastructure or commercialisation of the RDF technology. The distribution infrastructure is already present in NZ since RDF can substitute for regular diesel. The type of government assistance that will make all the difference in achieving Carbon Zero 2050 is funding to get the commercial players, who are already seriously interested, over the line. Then once they are, government assistance in fast-tracking and smoothing-the-way for resource consent approval for the actual production plants would help a lot. This RDF fuel is not just carbon neutral, it could be carbon negative.

I have no commercial interest in any biofuel feedstock or biofuel technology. I am aware, however, of promising biomass conversion technologies for producing renewable diesel fuel directly from biomass (particularly one being demonstrated in Canada at this time). That technology also produces enough biochar to sequester substantial carbon if it is soil-stored rather than burned in place of coal (as indicated in the Scion report scenarios). Therefore the technology will also have a very low emissions footprint (indications are that it is potentially even carbon negative). This is in addition to the Mxg biomass being carbon negative during early years of each new plantation.

The indicated optimal processing plant scale is well suited to locating them in several regions, rather than requiring one or two very large plants, with resulting long feedstock transport distances. This suits the demand for heavy freight, since 80% of it exists within each region. From the standpoint of when the crop output may be achieved, I suggest conservative policy target dates for the production of Mxg biomass and RDF for the primary sector and heavy transport within regions to be 2025-2029. This would help meet the NZ 2030 target for the Paris Agreement, instead of buying credits from overseas.

Many thanks to the Productivity Commission and staff for giving this your consideration.

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