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Market modeling of a Sustainable Biofuels Mandate in New Zealand

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Introduction

New Zealand is considering introducing a Sustainable Biofuels Mandate. The goal is to increase the use of lower-carbon fuels in the transport sector and contribute to the country's broader climate action plan. In June 2021, the Ministry of Business, Innovation & Employment and the Ministry of Transport released a consultation paper that outlines the key aims of a future Sustainable Biofuels Mandate.[1] As proposed in the paper, the mandate would take the form of a transport fuel greenhouse gas (GHG) intensity reduction target and the suggested reduction targets are 1.2% in 2023, 2.3% in 2024, and 3.5% in 2025. A review is planned in 2024 to consider extending the mandate to later years, and the proposed mandate would cover all transport modes, including aviation. Importantly, the consultation paper also expresses an intention to avoid negative sustainability impacts from the policy, in particular regarding competition with food and feed production, biodiversity impacts, and the conversion of land containing large stocks of carbon.

Following the key aims presented in the government's consultation paper, this paper presents a market modeling analysis of a Sustainable Biofuels Mandate in New Zealand. We consider three scenarios for how the government could implement the sustainability aims of the consultation paper by focusing on various limits that could be placed on food- and feed-based biofuels. We assess the combination of biofuel pathways that could be used to meet the mandate in 2025 in each scenario, as well as the GHG impacts and costs.

Methodology

This work was conducted using a partial equilibrium model in the GAMS modeling language to represent decisions made by fuel blenders, suppliers, and consumers, and this model is described in detail in a paper from earlier this year (hereafter, "the

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1 New Zealand Ministry of Transport, "Increasing the Use of Biofuels in Transport: Consultation Paper on the Sustainable Biofuels Mandate," April 2021, https://www.mbie.govt.nz/dmsdocument/15020-increasing-the-use-of-biofuels-in-transport-consultation-paper-on-the-sustainable-biofuels-mandate-pdf

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Christensen study").[2] The model represents a GHG credit market in which alternative fuels generate credits based on their GHG reductions, and the credits can then be traded among and used by obligated parties to comply with a fuel GHG intensity reduction target. A real-world example of a policy that has been implemented using this general structure is California's Low Carbon Fuel Standard.[3]

The model used in our study includes light-duty and heavy-duty vehicles and the aviation sector. It does not include the maritime sector. All modeling inputs except for those listed below are taken from the Christensen study and were calibrated for the European Union context; this includes elasticities and fuel-pathway costs and GHG intensities. The modeling inputs specific to New Zealand that were changed for this exercise are:

» Demand for diesel, gasoline, and jet fuel in New Zealand in 2025. This was calculated from the estimate of gasoline demand in 2020 from a Sapere report released earlier this year[4] compared with projected GHG emissions from gasoline, diesel, and jet fuel in 2020/2021 and 2025/2026 from a 2017 review by the New Zealand Ministry of Transport; we assumed that the ratio of GHG emissions (in tons CO_2e) to gasoline demand (in tons oil equivalent) would remain constant over time and applied this ratio for the 2020/2021 data to projected GHG emissions in 2025/2026.[5]

» Average fuel efficiency of diesel and gasoline vehicles in New Zealand. This was calculated from the above estimate of 2020 and 2025 diesel and gasoline demand compared with projected fleet-wide vehicle kilometers traveled from the New Zealand Ministry of Transport.[6] In this calculation, we included fuel consumption from plug-in hybrid vehicles.

We also made the following assumptions:

» Only biofuels are eligible to meet the policy targets, following the consultation paper.[7] We did not include renewable electricity used in vehicles, hydrogen, e-fuels (also known as power-to-liquids), or fuels derived from fossil fuel wastes. We included a small quantity of compressed natural gas (CNG) consumed in the transport sector, but assumed it is not eligible to contribute toward the policy target.

» A biodiesel (fatty acid methyl ester – FAME) limit of 7% in diesel, and no vehicles designed for high blends.

» No blend limits for hydrotreated vegetable oil (HVO – renewable diesel) in diesel or bio-jet fuel in jet fuel. The bio-jet pathways included in this analysis, which include the jet fractions of hydrotreating and alcohol-to-jet processes, can all be considered drop-in or near drop-in.

» An ethanol limit of 10% in gasoline, and no vehicles designed for high blends.

» No fully battery electric vehicles. We made this assumption for modeling simplicity, even though the Ministry of Transport projects a significant number of kilometers

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2 Adam Christensen, "Transportation Carbon Intensity Targets for the European Union – Road and Aviation Sectors," (ICCT: Washington, D.C., 2021), https://theicct.org/sites/default/files/publications/GAMS%20EU%20fuels%20modeling%20consultant%20report%20Aug2021.pdf

3 "Low Carbon Fuel Standard," California Air Resources Board, accessed December 10, 2021, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.

4 Corina Comendant and Toby Stevenson, "Biofuel Insights: An Independent Report Prepared for EECA," Sapere, March 2021, https://www.eeca.govt.nz/assets/EECA-Resources/Research-papers-guides/Liquid-Biofuel-Research-Report-March-2021.pdf.

5 New Zealand Ministry of Transport, "Transport Outlook: Future State. A Starting Discussion on the Future of Transport in New Zealand," spreadsheet data accompanying the report, https://www.transport.govt.nz/area-of-interest/infrastructure-and-investment/transport-outlook/

6 Ibid.

7 New Zealand Ministry of Transport, "Increasing the Use of Biofuels in Transport."

driven by fully battery electric vehicles in 2025.[8] This assumption means our analysis is likely to overestimate the volumes of ethanol and biodiesel (FAME) that could be blended into gasoline and diesel fuel, respectively, and thus slightly underestimate the overall costs of the program, since these fuels are generally less expensive than their drop-in alternatives.

» No volumes of cellulosic biofuel (i.e., biofuel produced from materials including agricultural and forestry residues and municipal solid waste) would be available in 2025 due to the relatively long timelines for construction of and ramping up production in these facilities.[9]

» No exceptional treatment of biofuels produced from food and feed crops grown as rotational crops, also known as intermediate crops or cover crops. These are a second or third crop grown in a year that is not the main crop. Such crops are assumed to receive the same policy treatment as other food and feed crops in the policy scenarios.

» Indirect land use change (ILUC) emissions are not included in the calculation of fuel pathway GHG intensities for the purposes of policy implementation. We do, however, include ILUC emissions in assessing policy impacts; these are included in the reported GHG impacts and the average carbon abatement costs in Table 1.

» Our model is based in U.S. dollars (USD). In Table 1, we converted costs to New Zealand dollars (NZD) assuming an exchange rate of 1.45 NZD/USD, a rate retrieved on September 30, 2021.

Scenarios

We modeled the following three scenarios:

» **Scenario 1:** 3.5% fuel GHG reduction target. No food- or feed-based biofuels.

» **Scenario 2:** 3.5% fuel GHG reduction target. Food- and feed-based biofuels are capped at 50% of total biofuel consumption when measured on a per-energy content basis (i.e., 50% of all megajoules or petajoules), and high-ILUC-risk feedstocks are excluded.

» **Scenario 3:** 3.5% fuel GHG reduction target. No restrictions on food- and feed-based biofuels.

Here we define high-ILUC-risk feedstocks as those crops for which the share of expansion onto high carbon stock land is greater than 5%, according to shares listed in the Annex to the European Commission Delegated Regulation on high- and low-ILUC-risk biofuel feedstocks.[10] This 5% is different from the 10% threshold used in the Delegated Regulation. The rationale for this is that, when all major sources of carbon emissions are accounted for, including soil carbon and below-ground biomass, 4%–8% expansion onto high carbon stock land would result in land use change emissions high enough to offset the GHG benefits of displacing petroleum, when also accounting for direct emissions from producing and transporting the biofuel and feedstock.[11]

8 New Zealand Ministry of Transport, "Transport Outlook: Future State."

9 Nikita Pavlenko, "Failure to Launch: Why Advanced Biorefineries Are So Slow to Ramp Up Production," (blog), International Council on Clean Transportation, November 13, 2018, https://theicct.org/blog/staff/failure-to-launch-biorefineries-slow-ramp-up

10 European Commission, "Commission Delegated Regulation of 13.3.2019 supplementing Directive (EU) 2018/2001 as regards the determination of high indirect land-use change-risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed and the certification of low indirect land use change-risk biofuels, bioliquids and biomass fuels," (2019), https://ec.europa.eu/energy/sites/ener/files/documents/2_en_act_part1_v3.pdf

11 Stephanie Searle, "International Council on Clean Transportation comments on the draft Delegated Regulation supplementing Directive (EU) 2018/2001 regarding the determination of high ILUC-risk feedstock," February 21, 2019, https://theicct.org/news/comments-draft-delegated-regulation-supplementing-directive-eu-20182001-regarding-determination.

Results

The main results of this analysis are presented in Figure 1 and Table 1, below. Figure 1 shows the quantities of various types of biofuel used to comply with the policy targets in each of the scenarios. These quantities are shown in million liters of gasoline equivalent, to account for the differences in the energy density of the different types of biofuels. While the biofuel pathways are aggregated into categories in Figure 1, detailed results for individual pathways within each of the categories are given in Table 2.

In Scenario 1, primarily biodiesel and HVO produced from wastes (tallow, used cooking oil or UCO, and crude tall oil) are used to meet the 3.5% fuel GHG intensity reduction target; food-based biofuels are not eligible. In Scenario 2, food-based biofuels are capped at 50% of total biofuel consumption by energy content, and high-ILUC-risk feedstocks are ineligible. Here, there are significant amounts of food-based biodiesel and ethanol, and waste-based biodiesel and HVO make up most of the remaining 50% of policy compliance. In Scenario 3, where there are no limits on food-based biofuels, 78% of the biofuels used for policy compliance are food- and feed-based, and waste-based HVO comprises most of the remainder.

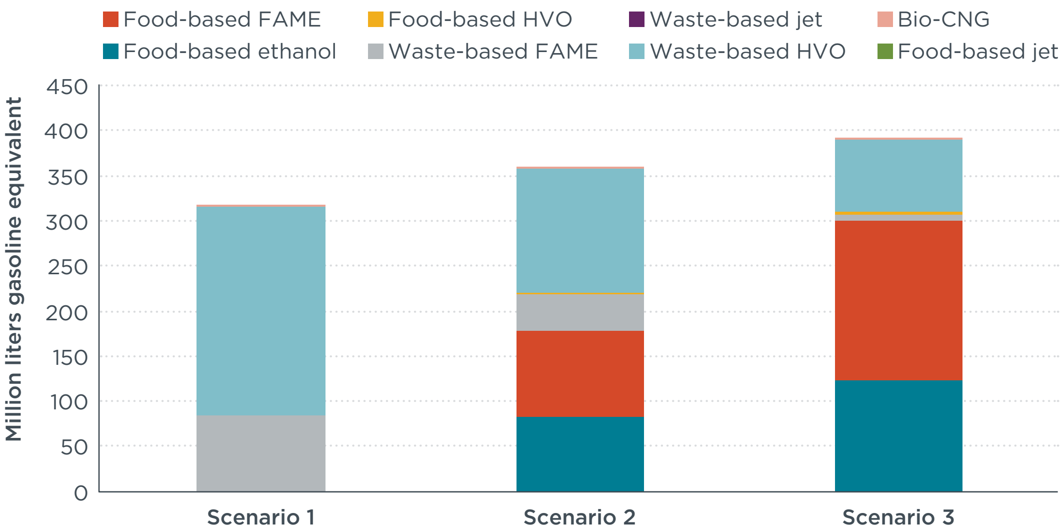

Figure 1. Energy content by fuel pathway in 2025 for each scenario, in million liters gasoline equivalent.

The total amount of energy delivered by biofuel increases with each scenario. This is because Scenario 3, and to a lesser extent Scenario 2, include food-based biofuels that have, on average, lower GHG reduction scores compared to those used in Scenario 1, even when ILUC emissions are not included in policy implementation. Bio-jet fuel is present in very small amounts all scenarios, comprising only around 0.1% of total biofuel energy consumed.

Table 1 presents the GHG and cost results for each of the scenarios. Although ILUC GHG emissions are not included in the GHG intensities used to determine the compliance of each fuel pathway with the fuel GHG intensity reduction targets, we did include ILUC GHG emissions in assessing the total GHG impacts of each policy option. The GHG intensities of each fuel pathway, with and without ILUC, are given in Table 2 and are based on the European Union context; further detail is given in the Christensen study.[12]

GHG reductions are greatest for Scenario 1 (813,000 tons CO_2e reduction) and 31% lower for Scenario 2 (562,000 tons CO_2e reduction). This is because Scenario 2 includes 50% food-based biofuels, which have significant ILUC emissions. Scenario 3 does not achieve any GHG reductions, and actually GHG emissions increase by 69,000 tons CO_2e. This is

12 Adam Christensen, "Transportation Carbon Intensity Targets for the European Union."

because there are no limits on food-based biofuels in Scenario 3, and Scenario 3 allows the use of palm- and soy-based biofuels, which increase GHG emissions compared to fossil fuels.

Table 1. GHG and cost results, and food- and feed-based biofuel shares, by scenario.

	Scenario 1	Scenario 2	Scenario 3
GHG difference compared to no action (thousand tons CO_2e)	-813	-562	+69
Share of food- and feed-based biofuels	0%	50%	78%
Total policy cost to consumers (million NZD)	70	38	22
Average cost of carbon abatement (NZD/tCO_2e)	86	68	N/A (there is no carbon abatement)
GHG credit price (NZD/tCO_2e)	131	112	91

The total policy cost to consumers is greatest in Scenario 1 and least in Scenario 3 because supplying high quantities of waste-based biofuels is more expensive than supplying food-based biofuels. However, the average cost of carbon abatement when considering ILUC emissions is only slightly lower, about 20%, in Scenario 2 compared to Scenario 1. The GHG credit price is the price at which GHG credits would be traded for use in compliance with the GHG targets; this represents essentially the marginal cost of delivering 1 tCO_2e reduction using biofuels in each scenario. The GHG credits are an integral part of policy implementation, but as we assume ILUC emissions are not considered in policy implementation, the ILUC emissions do not factor into the GHG credit prices. The GHG credit price is highest for Scenario 1 and declines modestly in Scenarios 2 and 3. For reference, the GHG credit price in California's Low Carbon Fuel Standard is around 200 USD/tCO_2e.

In short, Scenario 1 delivers the greatest GHG reductions, and this comes at a greater cost than Scenario 2. Because Scenario 3 increases GHG emissions as well as costs compared to no policy action, our analysis finds no benefits with this policy option.

Table 2. Detailed quantity results by specific fuel pathway for each scenario and GHG intensities used in the analysis.

	Scenario 1 quantity (TJ)	Scenario 2 quantity (TJ)	Scenario 3 quantity (TJ)	GHG intensity for policy implementation (no ILUC – gCO_2e/MJ)	GHG intensity for policy impacts (with ILUC – gCO_2e/MJ)
CNG – sewage	0.4	0.2	0.2	13	13
CNG – fossil	0.2	0.0	0.0	94	69
CNG – manure	1.8	1.2	0.7	-84	-84
CNG – silage maize	0.0	1.0	1.6	28	49
Diesel – fossil	77,048.8	78,288.4	78,596.1	94	95
Ethanol – maize	0.0	859.3	1,288.1	33	47
Ethanol – maize with CCS	0.0	65.8	102.2	28	42
Ethanol – sugarcane	0.0	383.2	556.2	28	45
Ethanol – sugarbeet	0.0	257.3	379.9	31	46
Ethanol – sugarbeet with CCS	0.0	37.6	52.3	16	31
Ethanol – wheat	0.0	913.7	1,367.2	33	67
Ethanol – wheat with CCS	0.0	66.4	104.0	30	64
Biodiesel – palm	0.0	0.0	1,837.0	33	264
Biodiesel – rapeseed	0.0	2,978.4	2,413.1	33	98
Biodiesel – soy	0.0	0.0	1,304.5	33	183
Biodiesel – tallow	1,181.8	584.9	81.6	15	15
Biodiesel – UCO	1,455.8	707.6	100.3	11	11
Gasoline – fossil	84,161.7	81,582.1	80,316.5	94	93
HVO – crude tall oil	1,303.6	786.2	437.9	12	12
HVO – palm	0.0	0.0	57.5	33	264
HVO – rapeseed	0.0	26.0	43.5	33	98
HVO – soy	0.0	0.0	43.5	33	183
HVO – tallow	1,264.4	767.1	426.7	16	16
HVO – UCO	4,663.8	2,785.1	1,588.2	12	12
Jet fuel – fossil	15,232.4	15,253.0	15,272.6	94	89
Jet fuel – corn	0.0	0.6	0.9	33	47
Jet fuel – palm	0.0	0.0	0.7	33	264
Jet fuel – rapeseed	0.0	0.4	0.6	33	98
Jet fuel – soy	0.0	0.0	0.6	33	183
Jet fuel – sugarcane	0.0	0.8	1.2	24	41
Jet fuel – tallow	2.3	1.5	1.0	23	23
Jet fuel – UCO	12.6	6.8	3.3	14	14