Transportation Carbon Intensity Targets for the European Union – *Road and Aviation Sectors*

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Chapter 1

Executive Summary

Decarbonizing the transport sector is a critical element of the European Union's (EU) net-zero climate ambitions. In July, 2021, the European Commission released a suite of proposals aimed to achieve 55% greenhouse gas (GHG) reductions by 2030 compared to 1990 levels. One key piece is a revision to the Renewable Energy Directive (REDII revision), which ramps up the ambition level for increasing the use of renewables across the European economy. The REDII revision proposal introduces a 13% GHG reduction target for fuels used across the entire transport sector in 2030. This is a significant change from the previous 14% energy mandate in the REDII and not only increases the ambition level of the policy but also fundamentally changes how it will work. The Commission's proposal includes other elements to promote advanced, sustainable fuel pathways within the GHG target: a 2.2% energy mandate for advanced biofuels and a 2.6% energy mandate for renewable fuels of non-biological origin (RFNBOs, including renewable hydrogen and e-fuels) in 2030. At the same time, the Commission has proposed a 5% sustainable aviation fuel mandate and a 0.7% sub-mandate for RFNBOs in aviation in 2030 as part of its proposed ReFuel EU regulation.

This study aims to model the behavior of how obligated parties might comply with targets in the Commission's proposal, as well as in 9 other scenarios representing similar policy options. We create a partial equilibrium model using the GAMS modeling language to represent decisions made by fuel blenders, suppliers, and consumers in order to comply with the GHG target and other mandates and caps in the policy. It simulates a market in which obligated parties may trade GHG reduction credits generated from the use of renewable fuel and use those GHG reduction credits to achieve compliance with the policy targets. Our model covers the aviation and road sectors, including both light-duty and heavy-duty vehicles. While the REDII revision covers maritime fuels, and the Commission has also proposed separate measures for maritime fuels, the maritime sector is outside the scope of our model.

Table 1.1 presents the scenarios included in our study. Scenario 1 represents the Commission's REDII revision proposal. Scenarios 2-6 vary the GHG target, mandate, and food-based biofuel cap levels. Scenario 7 represents a scenario with pessimistic penetration of electric vehicles (EVs), and thus, direct renewable electricity use in transport. Scenarios 8-10 model renewable energy mandates, replacing the GHG target, for similar ambition levels as scenarios 1-7. Another factor we investigate is intermediate crops (crops grown during the winter or off-season). Intermediate crops are currently exempt from the food-based biofuel cap, even if they are produced from food and feed crops, and in scenarios 4, 5, and 10 we investigate removing that exemption.

#	Description	GHG Reduction Target	Renewable Energy Mandate	Food-and-Feed Based Biofuel Cap	Advanced Biofuel Energy Mandate	RFNBO Energy Mandate	SAF Mandate	Aviation e-Fuel Mandate	Multipliers	EV Annual Growth	Intermediate Crops Exempt from Food Cap
#1	REDII revision proposal	13%	0%	7%	2.2%	2.6%	5%	0.7%	1.2x SAF and Maritime only	Central	Yes
#2	Lower GHG target	11%	0%	7%	2.2%	2.6%	5%	0.7%	1.2x SAF and Maritime only	Central	Yes
#3	No food-based biofuels	9%	0%	0%	2.2%	2.6%	5%	0.7%	1.2x SAF and Maritime only	Central	Yes
#4	No food-based or intermediate crops	8%	0%	0%	2.2%	2.6%	5%	0.7%	1.2x SAF and Maritime only	Central	No
#5	No intermediate crops	13%	0%	7%	2.2%	2.6%	5%	0.7%	1.2x SAF and Maritime only	Central	No
#6	Higher subtargets	13%	0%	7%	2.75%	2.6%	5%	2.5%	1.2x SAF and Maritime only	Central	Yes
#7	Low EV growth	13%	0%	7%	2.2%	2.6%	5%	0.7%	1.2x SAF and Maritime only	Low	Yes
#8	Renewable energy target	0%	26%	7%	4.4%	2.6%	5%	0.7%	REDII multipliers	Central	Yes
#9	High renewable energy target	0%	29.5%	7%	4.4%	2.6%	5%	0.7%	REDII multipliers	Central	Yes
#10	Energy target, no food-based or intermediate	0%	19%	0%	4.4%	2.6%	5%	0.7%	REDII multipliers	Central	No

TABLE 1.1: Policy scenario matrix.

Figure 1.1 summarizes the types of fuels used to meet the policy requirements for each scenario. Some of the differences between the scenarios are as expected, for example a lower total amount of renewable energy when the GHG target is reduced (Scenario 2) and no food-based biofuels when the food-based cap is set to 0% (Scenarios 3, 4, and 10). One striking result is the large amount of intermediate crop biofuel in most scenarios in which it is exempt from the food-based biofuel cap. When the policy becomes more ambitious, for example increasing the energy mandate level from Scenario 8 to 9, we see that intermediate crop biofuel fills in most of the total increased renewable fuel demand. In particular, we find a large increase in soy hydrotreated vegetable oil (HVO). Simply reducing the target level, for example from Scenario 1 to 2, sharply reduces the amount of intermediate crop biofuel used. The REDII/III requires intermediate crop biofuel not to "trigger demand for additional land" in order to be considered exempt from the food-based biofuel cap, but the European Commission has not released guidance on how voluntary schemes should interpret that condition. In the absence of meaningful restrictions, we find that intermediate crops are the cheapest compliance option to meet a GHG target or a renewable energy mandate, once the sub-mandates and caps have been complied with.

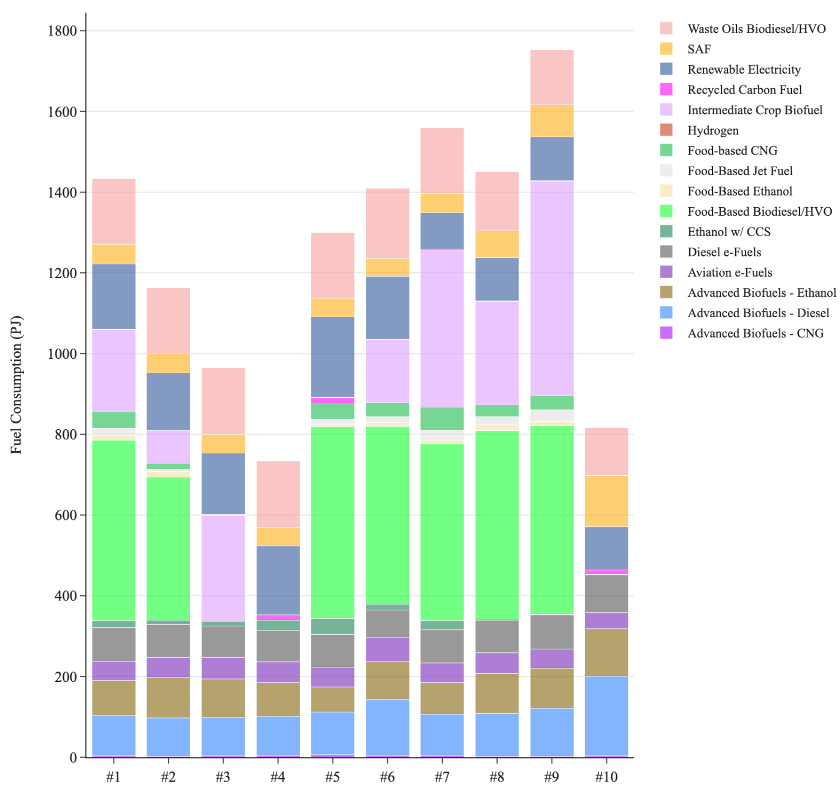

FIGURE 1.1: Energy consumption by fuel category by policy scenario. Values shown here are mean values from the sensitivity experiments.

The majority of intermediate crops globally are major commodity crops and their use in biofuel can be expected to cause indirect land use change (ILUC), just as with food-based biofuels. When we consider ILUC emissions, the very high total GHG emissions from intermediate crop soy biofuel significantly detract from the GHG savings of the policy as a whole. We can see this in Table 1.2, which shows the total GHG savings for each scenario, as well as the average cost of carbon abatement, the GHG credit price, and the total share of renewable energy in the road and aviation sectors. We calculate total GHG savings and the carbon abatement cost including ILUC emissions but assume the policy and the GHG credit prices are implemented without them. Accounting for ILUC, we find the highest GHG savings in scenarios 4, 5, and 10, where intermediate crops are not exempt from the food-based biofuel cap. Excluding all food-based biofuels also significantly increases GHG savings (Scenario 3 compared to Scenario 1, and Scenario 10 compared to Scenario 8).

Scn	**GHG Credit Price (€/tCO2e)**	**Renewable Share (%)**	**GHG Reduction (million tCO2e)**	**Cost of Carbon Abatement (€/tCO2e)**
#1 - REDII revision proposal	364	15.6%	29.2	1281
#2 - Lower GHG target	255	12.6%	37.4	855
#3 - No food-based biofuels	323	10.5%	38.2	823
#4 - No food-based or intermediate crops	480	8%	66.4	460
#5 - No intermediate crops	588	14.2%	58	682
#6 - Higher subtargets	338	15.3%	35.4	1033
#7 - Low EV growth	433	17%	-2.3	NA
#8 - Renewable energy target	-	15.6%	9.5	3871
#9 - High renewable energy target	-	18.9%	-13.1	NA
#10 - Energy target, no food-based or intermediate	-	8.8%	60.3	590

TABLE 1.2: Environmental summary statistics.

One important finding of this study is that a GHG target results in much greater GHG savings than a renewable energy mandate. Scenario 8, representing a 26% renewable energy mandate (including all the current REDII multipliers) leads to a similar total amount of renewable fuel as Scenario 1 (the REDII revision proposal), but delivers only around one-third the overall GHG savings. Consequently, the carbon abatement cost of Scenario 8 is around three times as high as that of Scenario 1. This study shows that a GHG target is also a much more cost effective means to achieve climate mitigation than a renewable energy mandate.

The analysis presented here demonstrates that setting targets too high leads to unintended consequences. In all cases shown here, higher targets lead to greater amounts of intermediate crop biofuel, leading to net increases in GHG emissions. This is because much of the increase in intermediate crop biofuel is soy HVO, which is not subject to blending constraints and has higher lifecycle GHG emissions than fossil fuels. An ambitious renewable energy mandate, shown in Scenario 9, has the perverse impact of increasing GHG emissions compared to having no renewable energy policy; the increase in renewable energy is met almost entirely with an increased amount of intermediate crop biofuel. The same effect is seen in Scenario 7, where EV penetration falls short of expectations, resulting in a more ambitious target for all other types of eligible fuels, including intermediate crop biofuel. Simply reducing the GHG target level from 13%, as in the REDII revision proposal, to 11% has the unexpected effect of increasing total GHG savings from the policy because the lower target creates less of an incentive for intermediate crop biofuel.

Renewable fuel policy is complex, and the impacts of policy changes are not always intuitive. Quantitative modeling, such as the study presented here, can be a useful tool in objectively analyzing a broad set of effects from policy changes.

Chapter 2

Introduction and Policy Context

The EU has ambitious climate goals, including goals for a 55% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990 levels and a net-zero GHG economy in 2050, as introduced in the Green Deal [1]. In July 2021, the European Commission released a number of policy proposals aimed at achieving the 55% GHG reduction goal by 2030, known as the Fit for 55 package [2]. The purpose of this study is to analyze how major elements of the Fit for 55 package will impact renewable transport fuels.

There are three policy proposals concerning renewable transport fuels in the Fit for 55 package: the revised Renewable Energy Directive (REDII revision), ReFuel EU, and FuelEU Maritime [3, 4, 5]. All of these pieces are European Commission proposals; they may be amended by the European Parliament and the Council before they are finalized.

The REDII revision proposal introduces 2030 renewable energy targets for the EU economy as a whole and for several sectors individually, including transport. For transport, it replaces the previous 14% renewable energy target in the REDII with a 13% GHG target for 2030 [6]. This target is significantly more ambitious than the 14% renewable energy target for three reasons: 1) most renewable fuels deliver less than 100% GHG savings, so more than 1% renewable energy is needed to deliver 1% GHG savings, 2) the REDII included several multipliers for various types of fuel, most of which are deleted in the REDII revision, and 3) the REDII revision expands the energy pool for which the 13% GHG target applies to aviation and maritime fuels, whereas the REDII targets only applied to road and rail transport fuels. The REDII revision changes the advanced biofuel energy target to 2.2% in 2030, with no multipliers. Only biofuels produced from feedstocks listed in Annex IX, list A of the REDII are eligible for the advanced biofuel target. It introduces a new target for Renewable Fuels of Non-Biological Origin (RFNBOs) of 2.6% in 2030. The REDII revision maintains the 7% cap on food- and feed-based biofuels from the REDII, and intermediate crops are exempt from the cap.

The ReFuel EU proposal is for a regulation. It introduces a 5% target for Sustainable Aviation Fuels (SAF) in 2030, with a smaller target in 2025 and other interim targets increasing to 63% in 2050. This applies to the share of fuel supplied to EU airports. SAF includes biofuels produced from feedstocks listed in Annex IX (both parts A and B) as well as RFNBOs. ReFuel EU also includes a 0.7% sub-target for RFNBOs used in aviation in 2030, increasing to 28% in 2050.

FuelEU Maritime is also a proposal for a regulation, introducing a 6% GHG target for energy used onboard vessels. It applies to energy used on ships within the EU as well as half that used in international travel to and from the EU. There are no eligibility constraints for fuel pathways for this target, but the GHG intensity of food- and feed-based biofuels is set to the same as the highest-GHG fossil fuel that can be used in shipping, and so effectively cannot contribute to the target.

In this study, we analyze the impact the REDII revision and ReFuel EU will have on renewable fuel use in the EU in 2030. Our model is limited to the road and aviation sectors and so does not include maritime or rail; we thus do not analyze the 6% GHG target for the maritime sector proposed in FuelEU Maritime. We develop a partial equilibrium model to assess the behavior of blenders and consumers in response to the targets described above in the REDII revision and ReFuel EU. We also assess a number of scenarios representing potential policy changes to the Fit for 55 proposals. We present the quantities of various types of renewable fuel projected to be used for compliance with the targets in each scenario, the GHG target credit price, and the overall costs and GHG impacts of the policies. We also present a sensitivity analysis on credit price and fuel price impacts. This study is aimed to help inform the ongoing policy debate over the Fit for 55 package.

Chapter 3

Model Description

A model of the European Union's transportation fuel market was developed in the GAMS modeling language. The model is a partial equilibrium model and as such it was calibrated to a baseline set of data. We developed our baseline data in close collaboration with the International Council on Clean Transportation (ICCT), and of note, the baseline penetration of electric vehicles has been harmonized to align with the European Commission's Climate Impact Plan (See Appendix D for baseline data and emission factors) [7]. Calibration was verified and counterfactual *policy scenarios* were developed to gauge the market response. The transportation market has several different *agents* that have specific roles to play. These agents make rational economic decisions based on information that they can access. The model contains representative consumers, a blender agent, and supply agents for different blendstock fuels. Details of each of these agent problems are provided in the following sections.

Formulation of equilibrium problems is conceptually simple but can be tedious in practice. GAMS used Extended Mathematical Programming (EMP) in order to reformulate the collection of agent optimization problems (or their first order or KKT conditions) into a single complementarity model. Using EMP to reformulate the suite of agent models eliminates the errors in a critical and problematic step. The model is ultimately solved with the PATH algorithm.

It is important to be clear what this model is and what it is not. This model is able to gauge how the market might shift away from a market equilibrium if new policy were implemented. Starting at a point with an assumed equilibrium means that the law of one price (on an energy basis) applies to all blended feedstocks (i.e., no arbitrage opportunities). This implies that there might exist some exogenous implied subsidy for fuels that might have high production cost, and yet, appear in the market with a non-zero quantity. These implied subsidies can manifest themselves from overlapping policies or simply from some other internal business strategy. Either way, these implied subsidies have the effect of shifting the entire supply curve downward.

Models of this type are able to resolve incentives, cost impacts, etc., but partial equilibrium models are not explicitly a business forecasting tool because it is unclear if the implied subsidy that exists at the calibration point would be available for all future business entities (we do not place upper bounds on any blendstock quantities). Said another way, this is a model that can resolve incentives and preferences of the *policy* but does not explicitly resolve firm-level decisions. Any entity evaluating a new policy would need to ensure that their internal cash flow models result in a profit considering some market support. In sum, models of this type are able to help answer the question *How much support might a fuel pathway expect from the new policy?* but not *What is the future production capacity of a fuel pathway?*. The subsections that follow describe each agents' optimization problem.

3.1 Consumer agents

There are three *classes* of consumer in this model; 1) a light-duty vehicle (LDV) consumer, 2) a heavy-duty vehicle (HDV) consumer, and 3) an aviation consumer. All consumer agents are modeled as cost minimizers that purchase vehicle kilometers (VKTs) that are produced by several different vehicles. The LDV consumer can purchase gasoline LDVs, diesel LDVs, or electric vehicles. The HDV consumer can purchase diesel HDVs, compressed natural gas (CNG) HDVs, or hydrogen fueled HDVs. There are no *vehicle* choices for the aviation consumer, instead one representative aircraft engine is used to generate vehicle-kilometers.

The production of VKT by these vehicle classes is modeled by a constant elasticity of substitution (CES) style production function. The CES style production function allows for vehicle preferences to change between categories and is used to capture the aggregate preferences for all consumers, economy-wide; we utilize the calibrated share form of the CES function as described by Rutherford [8]. The consumer agent problem can be described mathematically as the following optimization problem (Equation 3.1).

$$\begin{aligned} \min_{VKT_v} \quad & \sum_{v,f} \left[\frac{\left(P_f - P_f^{GHG}\right)}{\gamma_v} + Z_v^{opex} + Z_v^{capital} \right] VKT_v \\ \text{s.t.} \quad & \sum_{v} \left[\theta_v \left(\frac{VKT_v}{\overline{VKT}_v} \right)^{\rho} \right]^{\frac{1}{\rho}} = \frac{D}{\bar{d}} \end{aligned} \tag{3.1}$$

Where

- $v \in V$ represents different vehicle technologies
- $f \in F$ represents blended fuels that are used in each vehicle
- P_f represents final price for the underlying blended fuel, the consumer is assumed to be a price taker from the blender agent (€$/MJ$)
- P_f^{GHG} represents final value (cost or benefit) of the GHG credits associated with a finished (blended) fuel, the consumer is assumed to be a price taker from the blender agent (€$/MJ$)
- VKT_v are decision variables that represent the number of kilometers driven per year (billion $km/year$)
- γ_v is the fuel economy of the vehicle (km/MJ)
- ρ is the substitution parameter (which is related to the elasticity of substitution, $\rho = (\sigma - 1)/\sigma$)
- θ_v is the market value share for vehicle v
- Z_v^{opex} is data that represent non-fuel vehicle operating costs (€$/km$)
- $Z_v^{capital}$ is data that represent vehicle capital costs (€$/km$)
- D is the aggregate vehicle market value for an agent ($billion$ €)

The final demand is described by an isoelastic function shown in Equation 3.2 and is a function of the aggregate price index (PD) which is exactly the dual variable of the CES production constraint in Equation 3.1. The aggregate price index is equal to 1 at the benchmark when using the calibrated share form of the CES production function.

$$D = \bar{d}\left[\frac{PD}{1}\right]^{-\epsilon} \tag{3.2}$$

Where

- $\bar{d}$ is the baseline aggregate vehicle market value ($billion$ €)
- PD is the aggregate price index
- ϵ is the demand elasticity

3.2 Blender agent

The business structure of the blender agent(s) should mimic that seen in the real market. However, the details of these business structures are difficult to know and varied. The framework used in this study includes one blender agent that is responsible for all fuel blending. All the agents in this model have price-taking behavior, and as such, the single blender formulation is equivalent to a more nuanced multi-blender model. The single blender is therefore responsible for providing fuel to the consumer agents that meet all the necessary policy requirements. The blender agent will blend fuel to minimize costs. The blender agent is assumed to purchase quantities of energy from blendstock suppliers. The blender agent problem can be described mathematically as the following base optimization problem (Equation 3.3); policy constraints will be discussed individually.

The single blender model implies that the price of the GHG credit is equivalent to the marginal price on the credit market clearing condition in Equation 3.14 (i.e., zero net credits).

$$
\begin{aligned}
\min_{Q^{blend}_{bs,f}} \quad & \sum_{bs \in BSF(bs,f)} \left[Q^{blend}_{bs,f} P_{bs} \right] \\
\text{s.t.} \quad & P_f = \sum_{bs,f} \frac{Q^{blend}_{bs,f}}{Q_f} P_{bs} \\
& Q_f = \sum_{v,a} \frac{VKT_{v,a}}{\gamma_v} \\
& Q_f = \sum_{bs} Q^{blend}_{bs,f} \\
& E_f = \frac{\sum_{bs,f} Q^{blend}_{bs,f}}{\sum_{bs',f} \frac{Q^{blend}_{bs',f}}{\rho^v_{bs'}}} \\
& \sum_{bs,bst,f} \frac{\frac{Q^{blend}_{bs,f}}{\rho^v_{bs}}}{\frac{Q_f}{E_f}} \leq BLEND^{UP}_{bst,f} \\
& \sum_{bs,bst,f} \frac{\frac{Q^{blend}_{bs,f}}{\rho^v_{bs}}}{\frac{Q_f}{E_f}} \geq BLEND^{LO}_{bst,f} \\
& \sum_{bs,bst,f} \frac{\frac{Q^{blend}_{bs,f}}{\rho^v_{bs}}}{\frac{Q_f}{E_f}} = BLEND^{FX}_{bst,f}
\end{aligned}
\tag{3.3}
$$

Where

- $bs \in BS$ represents different fuel blendstocks
- $f \in F$ represents blended fuels that are used in each vehicle
- $BSF(bs, f)$ represents the two dimensional set that maps fuel blendstock to a finished blended fuel
- $bst \in BST$ represents common categories of blendstock types (i.e., all ethanols, all FAME, etc.)
- ρ^v_{bs} is the energy density of a blendstock ($MJ/$physical unit)
- P_f is the final price for the blended fuel (€$/MJ$)
- $Q^{blend}_{bs,f}$ are (primary) decision variables that represent the portion of energy from a blendstock used in a finished fuel (billion MJ)
- Q_f are decision variables that represent the total energy of a blended fuel ($billionMJ$)
- E_f are decision variables that represent the energy density of a blended fuel ($MJ/$physical unit)

- $BLEND_{bst,f}^{UP,LO,FX}$ are technology based limits on blending fuels (i.e., E10 blends, B7 blends, etc.)

3.2.1 Policy constraints

The optimization problems described in Equation 3.3 include all the technology-based logic to describe how blending fuels should be performed. Blenders will also be subject to a number of shared policy related constraints that will impact blending behaviors. We describe each of these formulations separately. If the policy is active in the policy scenario it is simply added to the list of technology-based constraints listed in Equation 3.3.

Food-based biofuels eligibility

The fraction of *road-based* transport energy that can come from food-based biofuels is controlled by Equation 3.4. The parameter λ_{food} will change depending on different policy scenarios.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in FOOD}} Q_{bs,f}^{blend} \leq \lambda_{food} \sum_{f} Q_f \tag{3.4}$$

All fuels that are part of the set $FOOD$ in the summation on the left-hand side of Equation 3.4 are presented in Table 3.1. Fuels that are derived from cover crops are exempt from the food-based fuel limit. *Note*: All instances of the abbreviation "CCS" in Table 3.1 (and elsewhere in this report) refer to Carbon Capture and Sequestration technolgies.

Impacted Fuels
CNG (silage maize)
FAME (palm), FAME (rapeseed), FAME (soy)
HVO (palm), HVO (rapeseed), HVO (soy)
Ethanol (corn), Ethanol (corn w/CCS), Ethanol (sugar)
Ethanol (sugarbeet), Ethanol (sugarbeet w/CCS)
Ethanol (wheat), Ethanol (wheat w/CCS)
SAF Alcohol-to-Jet (corn)
SAF HEFA (palm), SAF HEFA (rapeseed), SAF HEFA (soy)
SAF Alcohol-to-Jet

TABLE 3.1: Fuels included in the food-based biofuel constraint.

Annex IX, Part B fuels eligibility

The fraction of *road-based* transport energy that can come from Annex IX, Part B fuels is controlled by Equation 3.5. The parameter λ_{waste} will change depending on different policy scenarios.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in WASTE}} Q_{bs,f}^{blend} \leq \lambda_{waste} \sum_{f} Q_f \tag{3.5}$$

All fuels that are part of the set $WASTE$ in the summation on the left-hand side of Equation 3.5 are presented in Table 3.2.

Impacted Fuels
FAME (tallow), FAME (used cooking oil)
HVO (tallow), HVO (used cooking oil)
SAF (tallow), SAF (used cooking oil)

TABLE 3.2: Fuels included in the Annex IX, Part B fuels constraint.

Intermediate crop-based fuels eligibility

The fraction of *total* transport energy that can come from fuels derived from intermediate crops (i.e., those that were planted as covercrops in a field rotation) is controlled by Equation 3.6. Scenarios 4, 5, and 10 set the parameter λ_{cover} to zero (i.e., intermediate crop-based biofuels are forbidden); this is meant to reflect scenarios where intermediate crops are not exempt from the food-and-feed-based biofuel cap and so there is no incentive for their consumption.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in COVER}} Q^{blend}_{bs,f} \leq \lambda_{cover} \sum_{f} Q_f \tag{3.6}$$

All fuels that are part of the set $COVER$ in the summation on the left-hand side of Equation 3.6 are presented in Table 3.3.

Impacted Fuels
Ethanol (corn intermediate crop), FAME (soy intermediate crop), HVO (soy intermediate crop)
SAF HEFA (soy intermediate crop), SAF Alcohol-to-Jet (corn intermediate crop)

TABLE 3.3: Fuels included in the intermediate crop-based biofuel constraint.

Palm oil fuels eligibility

The fraction of *total* transport energy that can come from palm oil-based fuels is controlled by Equation 3.7. For all scenarios in this report we set the parameter λ_{palm} to zero (i.e., palm oil fuels are forbidden).

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in PALM}} Q^{blend}_{bs,f} \leq \lambda_{palm} \sum_{f} Q_f \tag{3.7}$$

All fuels that are part of the set $PALM$ in the summation on the left-hand side of Equation 3.7 are presented in Table 3.4.

Impacted Fuels
FAME (palm), HVO (palm), SAF HEFA (palm)

TABLE 3.4: Fuels included in the palm oil-based biofuel constraint.

Renewable fuels mandate

The fraction of *road-based* transport energy that *must* come from all alternative fuels is controlled by Equation 3.8. The parameter λ_{alt} will change depending on different policy scenarios. This mandate also considers a multiplier policy parameter, specified as m_{bs}. This multiplier is designed to give preference to certain blendstock fuels.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in ALTFUEL}} m_{bs} Q_{bs,f}^{blend} \geq \lambda_{alt} \sum_{f \in ROAD} Q_f \tag{3.8}$$

All fuels that are part of the set $ALTFUEL$ in the summation on the left-hand side of Equation 3.8 are presented in Table 3.5.

Impacted Fuels
CNG (biowaste), CNG (manure), CNG (silage maize)
FAME (rapeseed), FAME (soy), FAME (soy intermediate crop)
FAME (tallow), FAME (used cooking oil)
HVO (crude tall oil), HVO (rapeseed)
HVO (soy), HVO (soy intermediate crop)
HVO (tallow), HVO (used cooking oil)
Cellulosic Diesel (agricultural residues), Cellulosic Diesel (energy crops)
Cellulosic Diesel (municipal solid waste)
Diesel e-Fuels
Renewable Electricity
Ethanol (corn), Ethanol (corn intermediate crop), Ethanol (corn w/CCS)
Ethanol (sugar), Ethanol (sugarbeet), Ethanol (sugarbeet w/CCS)
Ethanol (wheat), Ethanol (wheat w/CCS), Ethanol (flue gas)
Cellulosic Ethanol (agricultural residues), Cellulosic Ethanol (agricultural residues w/CCS)
Cellulosic Ethanol (energy crops), Cellulosic Ethanol (energy crops w/CCS)
Green Hydrogen
SAF Alcohol-to-Jet (agricultural residues), SAF Fischer-Tropsch (agricultural residues)
SAF Alcohol-to-Jet (corn), SAF Alcohol-to-Jet (corn intermediate crop)
SAF Alcohol-to-Jet (energy crops), SAF Fischer-Tropsch (energy crops)
SAF Alcohol-to-Jet (flue gas), SAF Fischer-Tropsch (municipal solid waste)
SAF e-Fuels
SAF HEFA (rapeseed), SAF HEFA (soy), SAF HEFA (soy intermediate crop)
SAF Alcohol-to-Jet, SAF (tallow), SAF (used cooking oil)

TABLE 3.5: Fuels included in the alternative fuel mandate.

Advanced biofuels mandate

The fraction of *road-based* transport energy that *must* come from all advanced biofuels is controlled by Equation 3.9. The parameter λ_{adv} will change depending on different policy scenarios. This mandate also considers a multiplier policy parameter, specified as m_{bs}. This multiplier is designed to give preference to certain blendstock fuels towards the overall Renewable Fuels Mandate.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in ADVFUEL}} m_{bs} Q^{blend}_{bs,f} \geq \lambda_{adv} \sum_{f} Q_f \tag{3.9}$$

All fuels that are part of the set $ADVFUEL$ in the summation on the left-hand side of Equation 3.9 are presented in Table 3.6.

Impacted Fuels
CNG (biowaste), CNG (manure)
HVO (crude tall oil)
Cellulosic Diesel (agricultural residues)
Cellulosic Diesel (energy crops)
Cellulosic Diesel (municipal solid waste)
Cellulosic Ethanol (agricultural residues), Cellulosic Ethanol (agricultural residues w/CCS)
Cellulosic Ethanol (energy crops), Cellulosic Ethanol (energy crops w/CCS)
SAF Alcohol-to-Jet (agricultural residues), SAF Fischer-Tropsch (agricultural residues)
SAF Alcohol-to-Jet (energy crops), SAF Fischer-Tropsch (energy crops)
SAF Fischer-Tropsch (municipal solid waste)

TABLE 3.6: Fuels included in the advanced biofuel mandate.

Alternative aviation fuels mandate

The fraction of *aviation* transport energy that *must* come from alternative aviation fuels (or *sustainable aviation fuels* or "SAF") is controlled by Equation 3.10. The parameter λ_{jet} will change depending on different policy scenarios. This mandate also considers a multiplier policy parameter, specified as m_{bs}. This multiplier is designed to give preference to certain blendstock fuels towards the overall Renewable Fuels Mandate.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in ALTJET}} m_{bs} Q^{blend}_{bs,f} \geq \lambda_{jet} \sum_{f \in AVIATION} Q_f \tag{3.10}$$

All fuels that are part of the set $ALTJET$ in the summation on the left-hand side of Equation 3.10 are presented in Table 3.7. Only biofuels in Annex IX parts A and B and RFNBOs will qualify under the mandate.

Impacted Fuels
SAF Alcohol-to-Jet (agricultural residues), SAF Fischer-Tropsch (agricultural residues)
SAF Alcohol-to-Jet (energy crops), SAF Fischer-Tropsch (energy crops)
SAF Alcohol-to-Jet (flue gas), SAF Fischer-Tropsch (municipal solid waste)
SAF e-Fuels, SAF (tallow), SAF (used cooking oil)

TABLE 3.7: Fuels included in the advanced biofuel mandate.

Aviation e-Fuels mandate

The fraction of *aviation* transport energy that *must* come from aviation e-Fuels is controlled by Equation 3.11. The parameter λ_{efuel} will change depending on different policy scenarios. This mandate also considers a multiplier policy parameter, specified as m_{bs}. This multiplier is designed to give preference to certain blendstock fuels towards the overall Renewable Fuels Mandate.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in JETEFUEL}} m_{bs} Q^{blend}_{bs,f} \geq \lambda_{efuel} \sum_{f \in AVIATION} Q_f \tag{3.11}$$

All fuels that are part of the set $JETEFUEL$ in the summation on the left-hand side of Equation 3.10 are presented in Table 3.8.

Impacted Fuels
SAF e-Fuels

TABLE 3.8: Fuels included in the aviation e-fuel mandate.

Renewable fuel of non-biological origin mandate

The fraction of *road-based* transport energy that *must* come from renewable fuels of non-biological origin is controlled by Equation 3.12. The parameter λ_{rfnbo} will change depending on different policy scenarios. This mandate also considers a multiplier policy parameter, specificed as m_{bs}. This multiplier is designed to give preference to certain blendstock fuels towards the Renewable Fuels Mandate.

$$\sum_{\substack{bs,f \in BSF(bs,f) \\ bs \in RFNBO}} m_{bs} Q^{blend}_{bs,f} \geq \lambda_{rfnbo} \sum_{f} Q_f \tag{3.12}$$

All fuels that are part of the set $RFNBO$ in the summation on the left-hand side of Equation 3.10 are presented in Table 3.9.

Impacted Fuels
Diesel e-Fuels
Green Hydrogen
SAF e-Fuels

TABLE 3.9: Fuels included in the renewable fuels of non-biological origin (RFNBO) mandate.

Carbon intensity standard (GHG target)

A fuel carbon intensity (CI) standard can be included in this model as a policy mechanism for incentivizing alternative fuels/vehicles. A fuel will generate *credits* for fuels that are cleaner than this standard and will generate *deficits* if the fuel has a higher carbon intensity than the standard. Equation Block 3.13 dictates how these credits (positive values of Q^{GHG}) and deficits (negative values of Q^{GHG}) are generated; also included is an equation that describes the embedded value of the GHG credits for each finished (i.e., blended) fuel.

$$
\begin{aligned}
P_f^{GHG} &= \sum_{bs,f \in BSF(bs,f)} \frac{Q_{bs,f}^{blend}}{Q_f} \lambda^{GHG} \left[CI^{std} - CI_{bs} \right] \\
Q_{bs,f}^{GHG} &= \sum_{std,bs \in STD(std,bs)} \left[CI^{std} - CI_{bs} \right] Q_{bs,f}^{blend}
\end{aligned}
\tag{3.13}
$$

Where

- $std \in STD$ represents the different carbon intensity standards
- $STD(std, bs)$ represents a two dimensional set that maps the applicible carbon intensity standard to the blendstock fuel
- λ^{GHG} represents GHG credit price final value (cost or benefit) of the GHG credits associated with a finished (blended) fuel (€$/tCO2e$)
- P_f^{GHG} represents final value (cost or benefit) of the GHG credits associated with a finished (blended) fuel (€$/MJ$)

The price of the GHG credit (λ^{GHG}) is the price at which the supply of credit exactly clears the demand for credits (i.e., the dual variable of the market clearing condition). This market clearing condition is described in Equation 3.14.

$$
\sum_{bs,f \in BSF(bs,f)} Q_{bs,f}^{GHG} = 0 \tag{3.14}
$$

3.3 Supply agents

The agents that are responsible for supplying blendstocks to the blender are not modeled as individual optimizers. Instead, the supply of blendstocks is assumed to fit an isoelastic supply curve. This curve is represented by Equation 3.15.

$$
\frac{P_{bs}}{\bar{p}_b s} = \left[\frac{Q_{bs}}{\bar{q}_{bs}} \right]^{1/\eta_{bs}} \tag{3.15}
$$

Where

- P_{bs} is the price at which a quantity of blendstock fuel can be supplied (€$/MJ$)
- Q_{bs} is the quantity of blendstock that is demanded under a policy shock ($billion\ MJ$)
- $\bar{p}_{bs}$ is the baseline price at which the baseline quantity of blendstock fuel is supplied (€$/MJ$)
- $\bar{q}_{bs}$ is the baseline quantity of blendstock fuel (€$/MJ$)
- η_{bs} is the supply elasticity for a particular blendstock fuel

3.4 Additional modeling details

3.4.1 Carbon intensities

GHG intensities of all fuel pathways are provided in Table D.1 in Appendix D. Unless otherwise noted, the GHG intensities are taken as the typical values for each pathway from REDII, or the threshold GHG savings required for eligible biofuels (i.e. 65% compared to the liquid fossil fuel comparator of 94 gCO2e/MJ), whichever is lower. We follow the REDII revision proposal in assigning a GHG intensity of 94 gCO2e/MJ for all liquid and gaseous fossil fuels in model execution, as well as the GHG intensity of 183 gCO2e/MJ identified for the fossil electricity comparator. For post-hoc analysis of the GHG impacts of the scenarios, we add ILUC emissions following Valin et al. [9], except where otherwise noted; these ILUC emission estimates are not included in the GHG intensities for the purposes of model execution.

3.4.2 Supply elasticities

The price curves in this study were calculated according to Equation 3.15. To be clear, $\bar{p}_{bs}$ represents the baseline price at which a renewable fuel could be sold assuming no policy support; for all blendstocks the baseline price takes on that of the EU wholesale price of diesel, gasoline, kerosene, or CNG (depending on which fossil fuel the renewable fuel pathway would be substituting); these prices are a direct consequence of the no-arbitrage assumption. $\bar{q}_{bs}$ represents the quantity of each fuel pathway that would be demanded at $\bar{p}_{bs}$ and can be thought of as the quantity of each fuel pathway we would expect to be demanded in the absence of any alternative fuel policy support; these values were estimated since this baseline represents a counterfactual from current market conditions (i.e., there are various ways that alternative fuels are currently incentivized in the EU).

We estimated the long-run elasticity (i.e., an elasticity that represents a supply system that does not encounter resource constraints), η_{bs}, using current consumed quantities (Q_{bs}) and prices (P_{bs}) in the EU, where this data is available, as well as the values for $\bar{p}_{bs}$ and the estimated values for $\bar{q}_{bs}$. It was assumed that the available fuel price data better represents the current *average* market price rather than the marginal production price at the volumes currently supplied. An iterative solution method was used in order to solve Equation 3.16 for η_{bs}.

$$\int_{\bar{q}_{bs}}^{Q_{bs}} P_{bs} dQ_{bs} = \bar{p}_{bs}\bar{q}_{bs}\left[\frac{\eta_{bs}}{\eta_{bs}+1}\right]\left[Q_{bs}^{\frac{1}{\eta_{bs}}+1} - 1\right] \tag{3.16}$$

3.5 Sensitivity tests

There are many hard-to-know modeling parameters that appear in economic models such as this one. Thus it is imperative that any analysis also include an appropriate number of sensitivity experiments. In this work we generate samples for elasticities (supply, demand, and substitution) using a latin hypercube sampling technique to ensure that we sample across the entire space [10]. We generated 10,000 samples and solve the model for each of these tests, recording each successful solve. Solve success rates (i.e., the faction of the 10,000 samples where a new equilibrium point was successfully found by the PATH solver) are presented in Table 3.10. The solve success rate was used as a high level metric to inform how well the solution finding processes worked for all scenarios. Numerical problems can arise when a policy scenario results in large deviations from the initial equilibrium starting point and in many cases we needed to implement a solution finding routine that included many sub-solves. These sub-solves took many incremental steps toward the true solution, only the final solution, if it was found, was recorded as a solution. Practically speaking, if the solve success rate was not high enough we tuned how many sub-solves the routine performed. Our goal was to reach 50% solve success rate for all scenarios, however even after experimenting with several solver settings, there were some scenarios that proved to be more difficult.

Scn	**Solve Success Rate (%)**
#1 - REDII revision proposal	70.14
#2 - Lower GHG target	63.36
#3 - No food-based biofuels	44.52
#4 - No food-based or intermediate crops	41.94
#5 - No intermediate crops	53.58
#6 - Higher subtargets	58.91
#7 - Low EV growth	71.82
#8 - Renewable energy target	39.48
#9 - High renewable energy target	45.58
#10 - Energy target, no food-based or intermediate	44.75

TABLE 3.10: Solve success rate by scenario.

Chapter 4

Policy Scenario Matrix

GAMS developed 10 policy scenarios in close concert with researchers at the International Council on Clean Transportation in order to illustrate important factors about how the model responds to various data and structural changes. Table 1.1 details the nature of those 10 policy scenarios. Further details about the model assumption set are provided:

- Gasoline can contain at most 10% ethanol (by volume)
- Diesel can contain at most 7% FAME (biodiesel) (by volume)
- 0% of total transport energy can come from palm oil based fuels
- At most 1.7% of total transport energy can come from Annex IX, Part B fuels
- At least 5% of aviation transport energy must come from sustainable aviation alternatives (SAF), assuming that half of the 2.6% RFNBO target is met using green hydrogen in petroleum refining
- At least 1.3% of total transport energy must come from renewable fuels of non-biological origin (RFNBO)
- The resource potential of HVO (crude tall oil) must be less than 44.5 billion MJ [11]
- The resource potential of CNG (manure) must be less than 361 billion MJ [12]
- The resource potential of CNG (biowaste) must be less than 95 billion MJ [12]
- The resource potential of fuels from flue gas processes, assuming the same resource potential as previously estimated for the U.S., must be less than 36.3 billion MJ [13]

We assume 5% to be the average cap on food-based biofuels in the EU in practice. The REDII caps the contribution of food based fuels in 2030 at either 7% of the final energy consumption in the road and rail sectors in each Member State or at one percentage point higher than the share of such fuels in the year 2020. Because several Member States are expected to consume less than 7% food-based biofuels in 2020 and some Member States may choose to set a cap lower, we assume the average contribution of food-based biofuels to be 5%. For example, Germany has proposed setting its national food based cap at 4.4% in 2030 [14]. Our assumption of 5% food based fuels in 2030 is also roughly consistent with the shares reported for the modeling scenarios in the Commission's Climate Target Plan [15]. So while we present 7% as the food-based biofuel cap in applicable scenarios, this is actually reflected as a 5% maximum blending of food-based biofuels in the modeling. Similarly, we reduce the 2.6% RFNBO target to 1.3% in the modeling. In addition to direct use of RFNBOs in transport, green hydrogen used in petroleum refining is eligible to count towards the 2.6% RFNBO target. This pathway is not included in our model. It is unclear how much of the RFNBO target may be met with green hydrogen used in petroleum refining; we assume half.

The credit multipliers here are described as *1.2x SAF and Maritime only* and *REDII multipliers*, all credit multipliers (m_{bs}) are included in Appendix B. *1.2x SAF and Maritime only* reflects the REDII revision proposal, including only the 1.2x multiplier of advanced biofuels (Annex IX, Part A) and RFNBOs used in the aviation and maritime sectors towards the REDII revision targets. *REDII multipliers* reflects the full set of multipliers in current policy in the REDII, including the same 1.2x multiplier for aviation and maritime, as well as the 2x multiplier for advanced biofuels and Annex IX, Part B fuels and the 4x multiplier for renewable electricity used in vehicles.

Chapter 5

Fuel Consumption Impacts

One of the primary model outputs is the quantity the blendstock fuels that are supported by each policy proposal. These quantities are shown in an aggregate form, side-by-side, in Figure 1.1. The accompanying tabular data, which includes distributional information by blendstock, is located in Appendix E. The category aggregation is performed such that each blendstock belongs to only one category; only alternative fuels are presented in this graph. The aggregation schema is provided in Table 5.1.

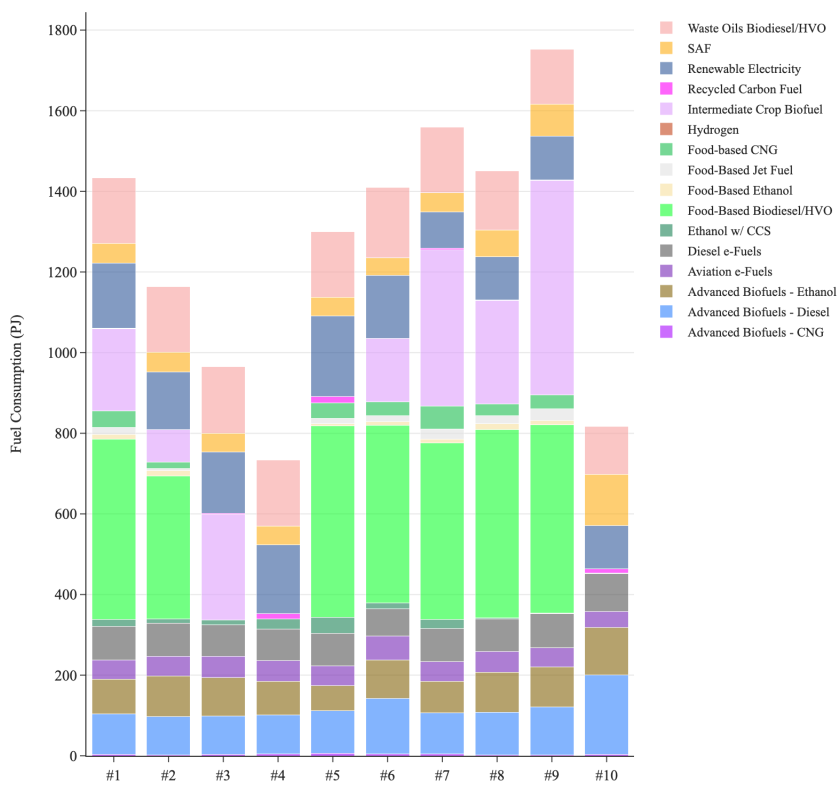

FIGURE 5.1: Energy consumption by fuel category by policy scenario. Values shown here are mean values from the sensitivity experiments.

Blendstock	**Aggregation Category**
CNG (manure)	Advanced Biofuels - CNG
CNG (biowaste)	Advanced Biofuels - CNG
HVO (crude tall oil)	Advanced Biofuels - Diesel
Cellulosic Diesel (agricultural residues)	Advanced Biofuels - Diesel
Cellulosic Diesel (energy crops)	Advanced Biofuels - Diesel
Cellulosic Diesel (municipal solid waste)	Advanced Biofuels - Diesel
Cellulosic Ethanol (agricultural residues)	Advanced Biofuels - Ethanol
Cellulosic Ethanol (energy crops)	Advanced Biofuels - Ethanol
SAF e-Fuels	Aviation e-Fuels
Diesel e-Fuels	Diesel e-Fuels
Cellulosic Ethanol (agricultural residues w/CCS)	Ethanol w/ CCS
Cellulosic Ethanol (energy crops w/CCS)	Ethanol w/ CCS
Ethanol (corn w/CCS)	Ethanol w/ CCS
Ethanol (wheat w/CCS)	Ethanol w/ CCS
Ethanol (sugarbeet w/CCS)	Ethanol w/ CCS
FAME (soy)	Food-Based Biodiesel/HVO
FAME (rapeseed)	Food-Based Biodiesel/HVO
FAME (palm)	Food-Based Biodiesel/HVO
HVO (soy)	Food-Based Biodiesel/HVO
HVO (rapeseed)	Food-Based Biodiesel/HVO
HVO (palm)	Food-Based Biodiesel/HVO
CNG (silage maize)	Food-based CNG
Ethanol (corn)	Food-Based Ethanol
Ethanol (wheat)	Food-Based Ethanol
Ethanol (sugar)	Food-Based Ethanol
Ethanol (sugarbeet)	Food-Based Ethanol
SAF Alcohol-to-Jet (corn)	Food-Based Jet Fuel
SAF Alcohol-to-Jet	Food-Based Jet Fuel
SAF HEFA (rapeseed)	Food-Based Jet Fuel
SAF HEFA (soy)	Food-Based Jet Fuel
SAF HEFA (palm)	Food-Based Jet Fuel
Hydrogen (fossil sources)	Hydrogen
Green Hydrogen	Hydrogen
Ethanol (corn intermediate crop)	Intermediate Crop Biofuel
SAF Alcohol-to-Jet (corn intermediate crop)	Intermediate Crop Biofuel
FAME (soy intermediate crop)	Intermediate Crop Biofuel
HVO (soy intermediate crop)	Intermediate Crop Biofuel
SAF HEFA (soy intermediate crop)	Intermediate Crop Biofuel
Ethanol (flue gas)	Recycled Carbon Fuel
SAF Alcohol-to-Jet (flue gas)	Recycled Carbon Fuel
Renewable Electricity	Renewable Electricity
SAF Alcohol-to-Jet (agricultural residues)	SAF
SAF Alcohol-to-Jet (energy crops)	SAF
SAF Fischer-Tropsch (agricultural residues)	SAF
SAF Fischer-Tropsch (energy crops)	SAF
SAF Fischer-Tropsch (municipal solid waste)	SAF
SAF (used cooking oil)	SAF
SAF (tallow)	SAF
FAME (used cooking oil)	Waste Oils Biodiesel/HVO
FAME (tallow)	Waste Oils Biodiesel/HVO
HVO (used cooking oil)	Waste Oils Biodiesel/HVO
HVO (tallow)	Waste Oils Biodiesel/HVO

TABLE 5.1: Aggregation schema used to generate Figure 1.1.

Chapter 6

Vehicle Kilometers Traveled (VKT)

Another primary model output is the vehicle kilometers travel by each consumer. As a brief reminder, each consumer will respond to price signals, and as such, the desire to travel will float up or down depending on the fuel incentives created by the individual policy scenarios. The following sections break out the total kilometers traveled by vehicle type for each consumer in the model.

6.1 LDV consumer VKT

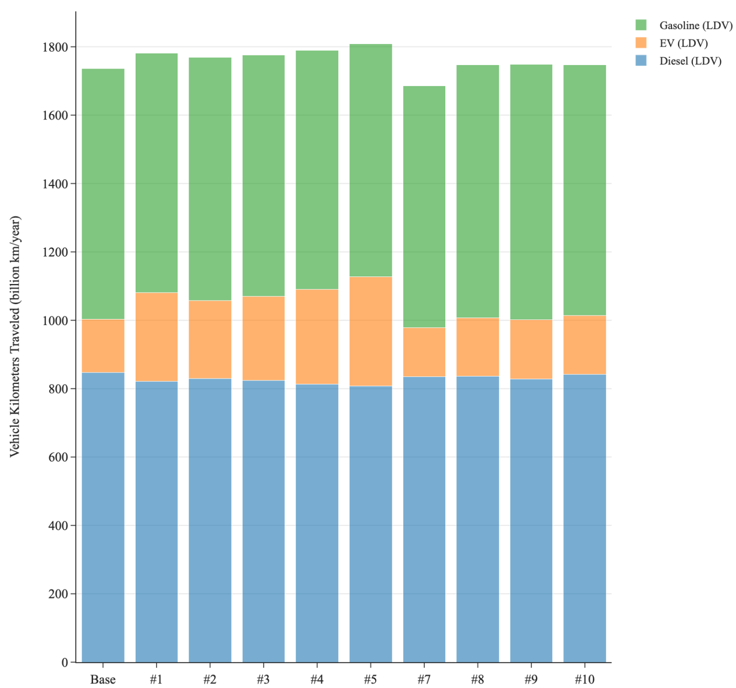

FIGURE 6.1: LDV kilometers traveled by policy scenario. Values shown here are mean values from the sensitivity experiments.

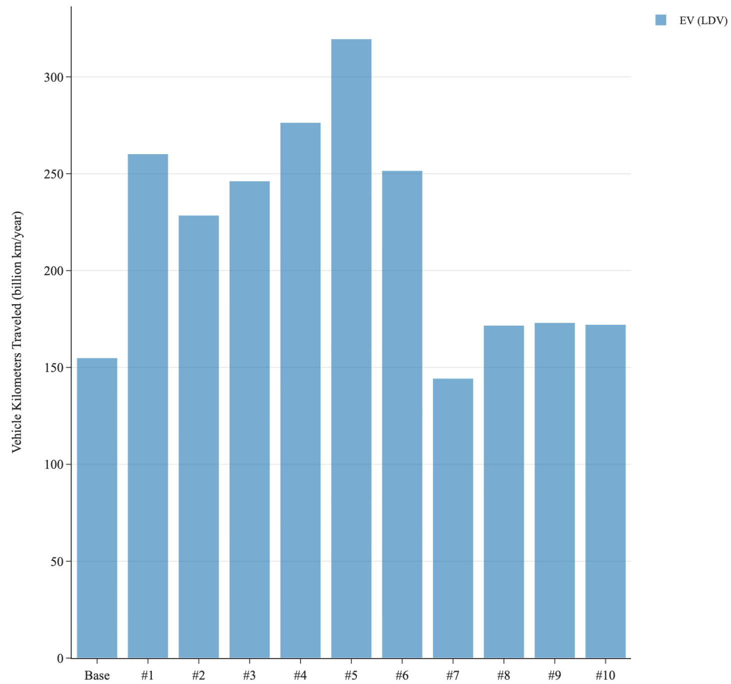

FIGURE 6.2: EV *only* kilometers traveled by policy scenario. Values shown here are mean values from the sensitivity experiments.

Chapter 7

GHG Credit Prices

As a reminder, policy scenarios #8-10 do not have an active GHG reduction standard, thus they will not have a GHG credit price. A summary of the mean GHG credit price by policy scenario is shown in Figure 7.1. The following sections show distribution of credit prices for each of the policy scenarios. Again, the distribution of prices results from the sensitivity tests described in Section 3.5. It is important to understand the impact that uncertainty has on aggregate policy parameters; these parameters represent the main market signal that influence how compliance is achieved. The following figures show that these aggregate parameters have well defined peaks (with varying degrees of spread) even when considering uncertain market conditions.

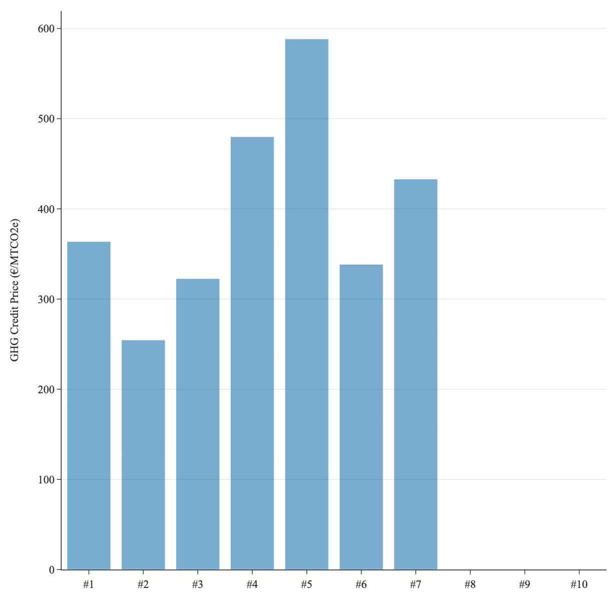

FIGURE 7.1: Mean GHG credit price by policy scenario.

7.1 Scenario #1: REDII revision proposal

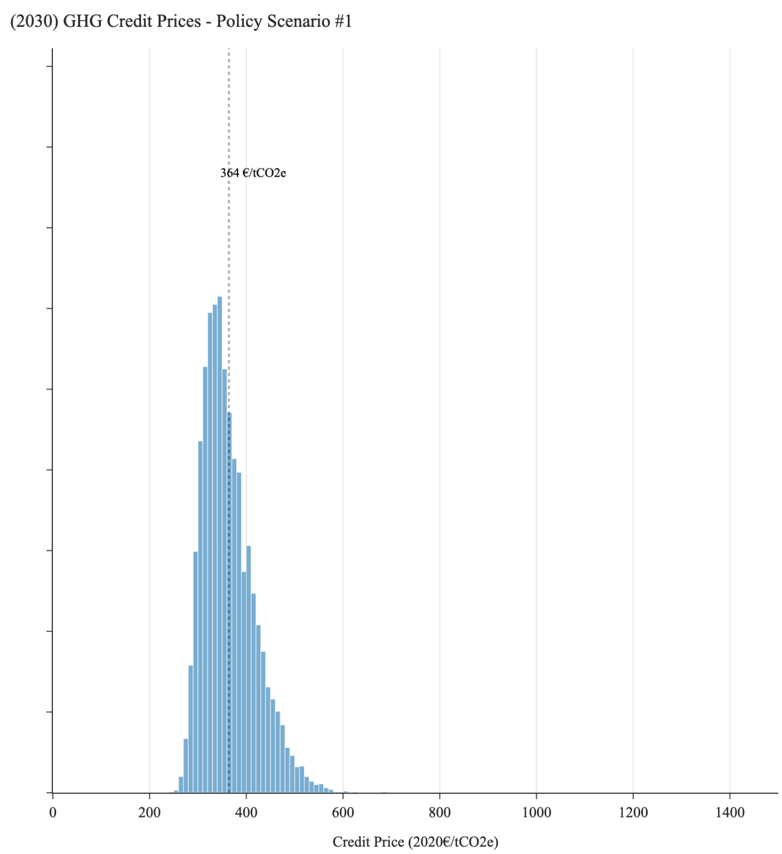

FIGURE 7.2: Distribution of GHG credit prices for scenario #1.

7.2 Scenario #2: Lower GHG target

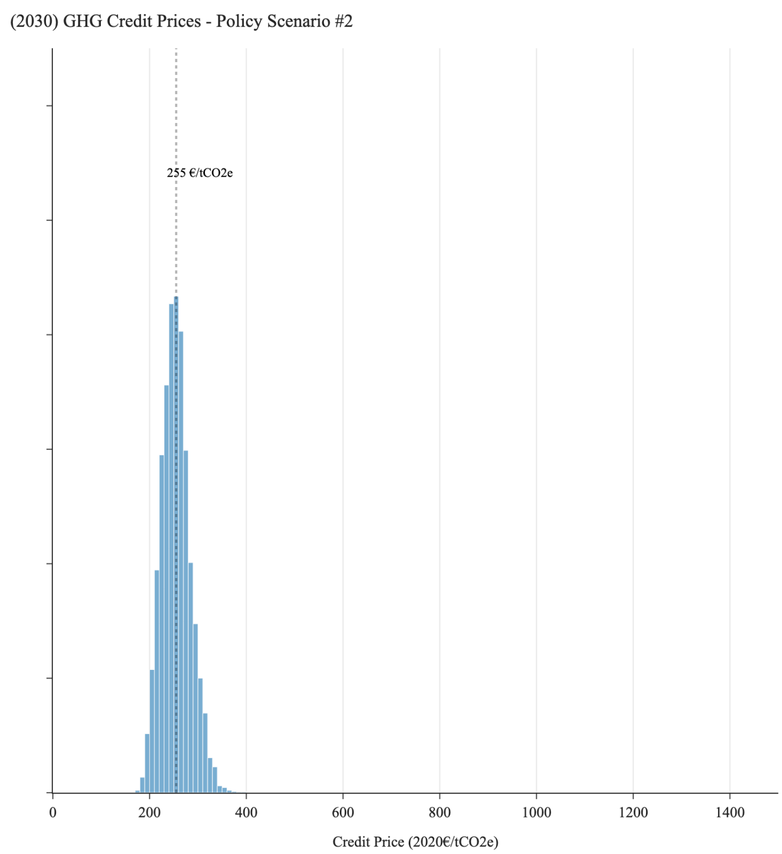

FIGURE 7.3: Distribution of GHG credit prices for scenario #2.

7.3 Scenario #3: No food-based biofuels

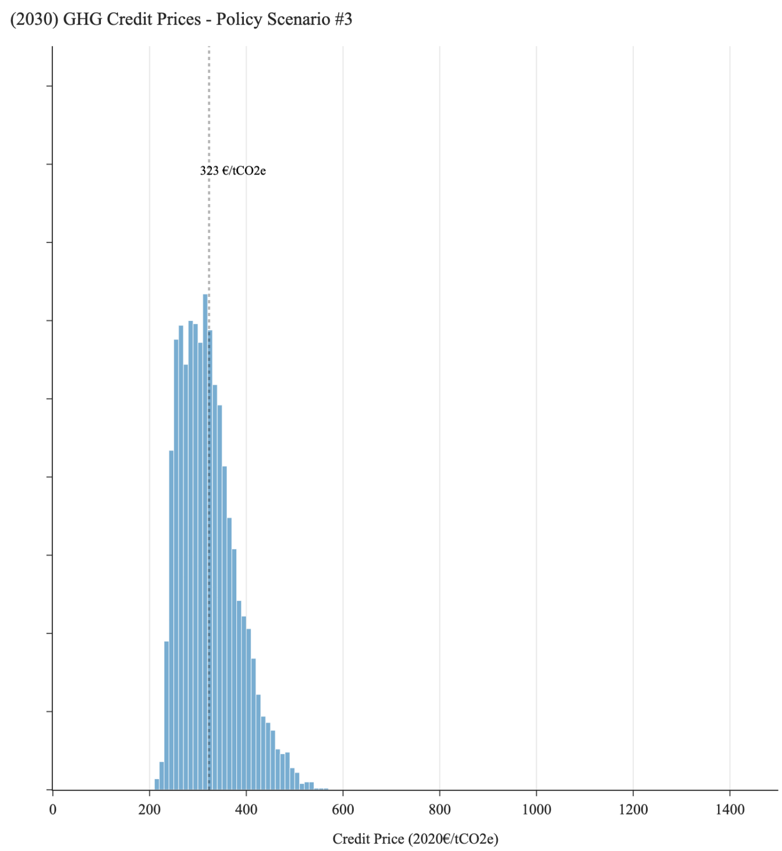

FIGURE 7.4: Distribution of GHG credit prices for scenario #3.

7.4 Scenario #4: No food-based or intermediate crops

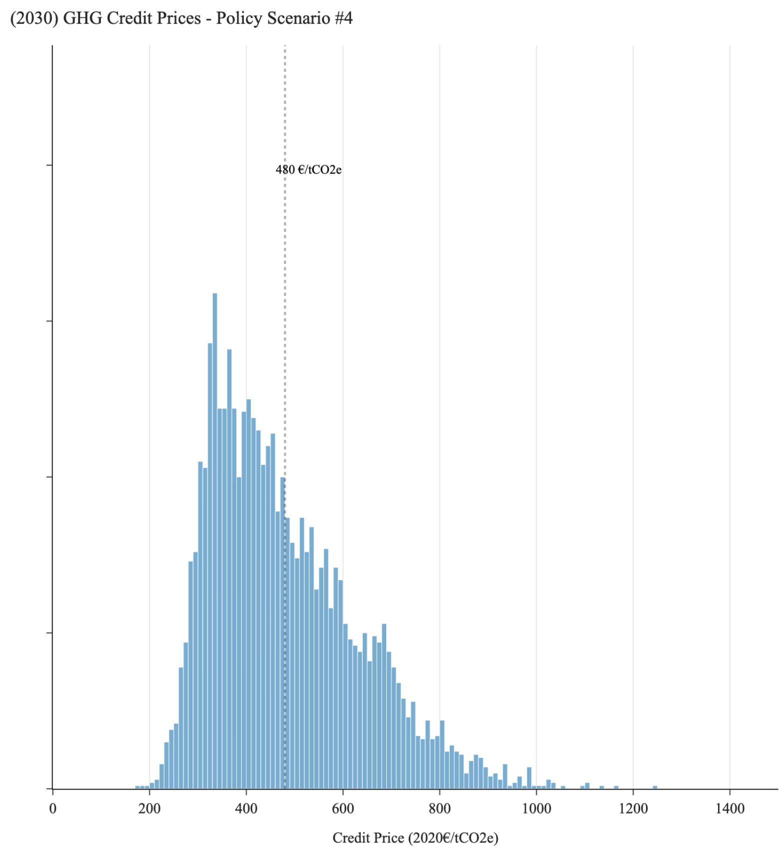

FIGURE 7.5: Distribution of GHG credit prices for scenario #4.

7.5 Scenario #5: No intermediate crops

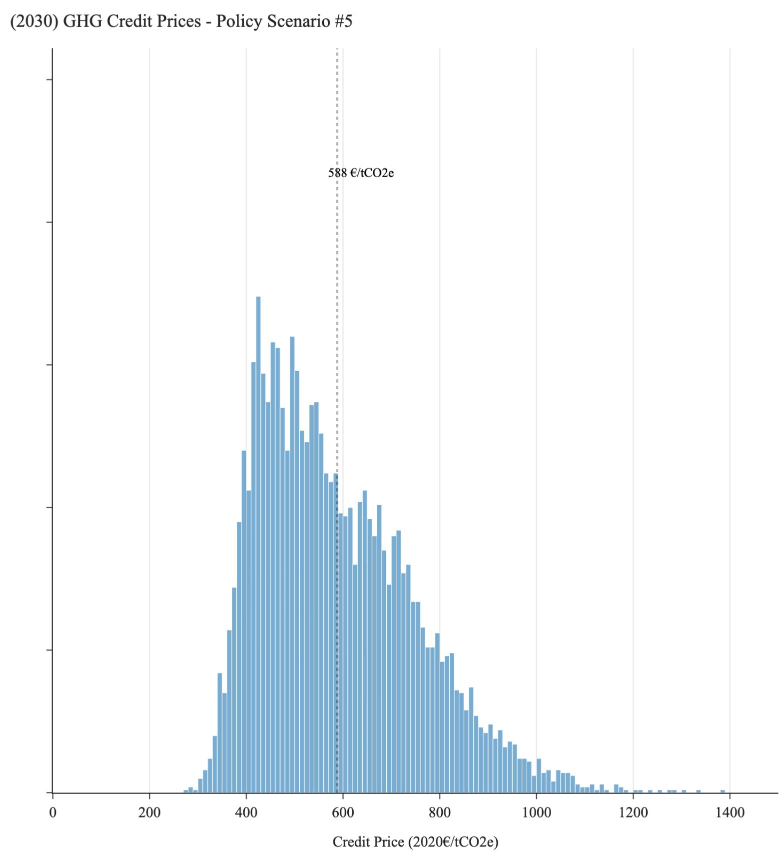

FIGURE 7.6: Distribution of GHG credit prices for scenario #5.

7.6 Scenario #6: Higher subtargets

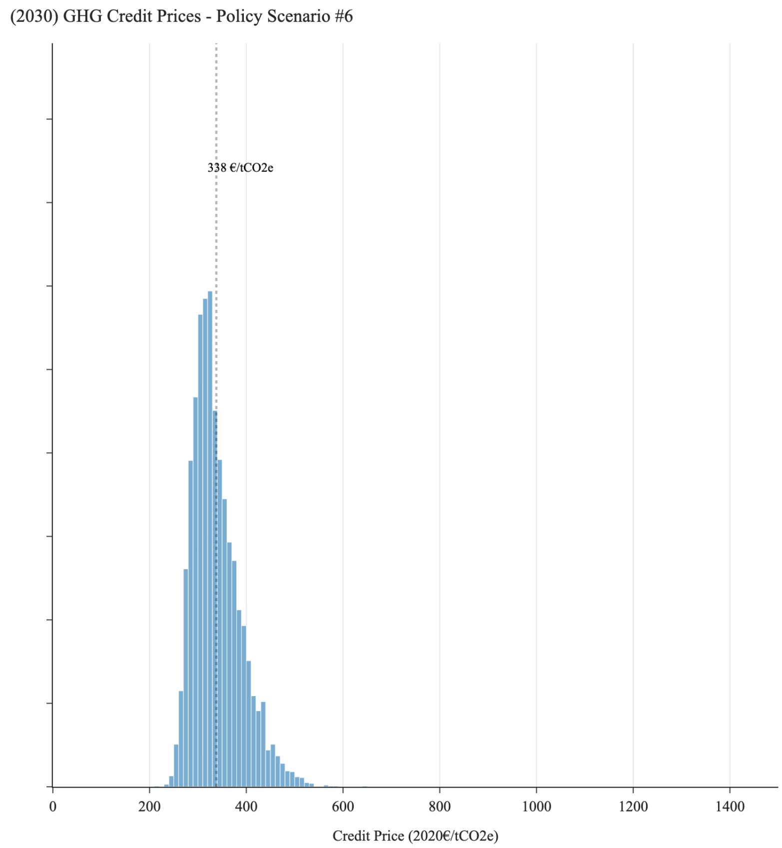

FIGURE 7.7: Distribution of GHG credit prices for scenario #6.

7.7 Scenario #7: Low EV growth

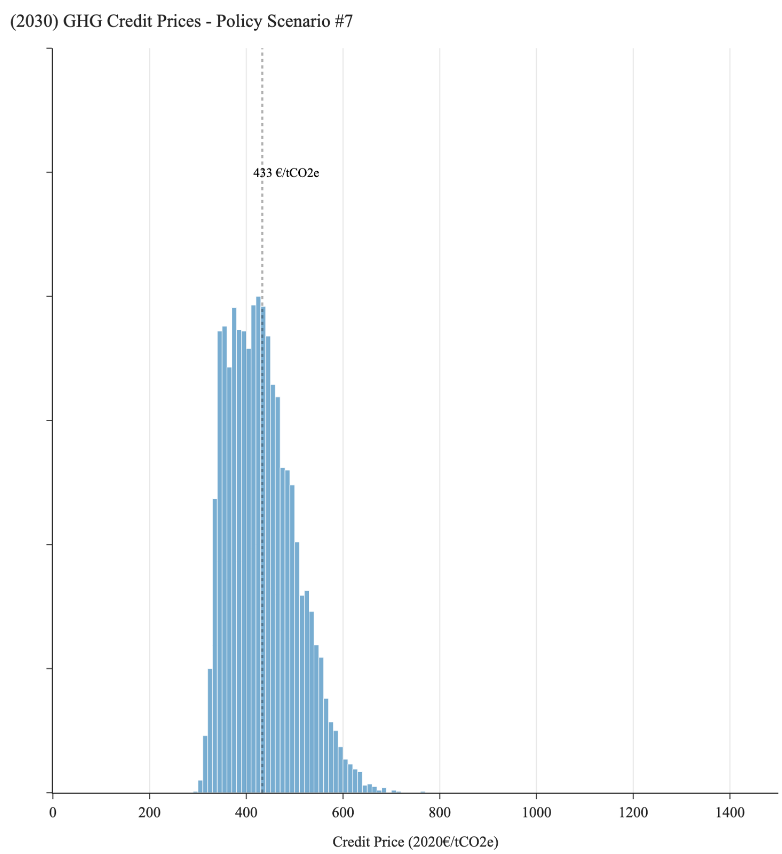

FIGURE 7.8: Distribution of GHG credit prices for scenario #7.

Chapter 8

Overall Program Cost

Overall program costs are captured by the objective function; we report objective function values for the LDV consumer, HDV consumer Aviation Consumer. The cost impacts are presented in Table 8.1.

Scn	**LDV Consumer (billion €)**	**HDV Consumer (billion €)**	**Aviation Consumer (billion €)**
#1 - REDII revision proposal	10.7 (+1.3%)	26.6 (+13.4%)	0.1 (+0.1%)
#2 - Lower GHG target	9.7 (+1.2%)	22.2 (+11.2%)	0 (+0%)
#3 - No food-based biofuels	8.6 (+1.1%)	22.7 (+11.5%)	0.1 (+0.1%)
#4 - No food-based or intermediate crops	5.9 (+0.7%)	24.5 (+12.4%)	0.1 (+0.1%)
#5 - No intermediate crops	9.1 (+1.1%)	30.3 (+15.3%)	0.1 (+0.2%)
#6 - Higher subtargets	10.9 (+1.3%)	25.5 (+12.9%)	0.2 (+0.2%)
#7 - Low EV growth	13.9 (+1.8%)	27.2 (+13.8%)	0.1 (+0.1%)
#8 - Renewable energy target	12.4 (+1.5%)	24.2 (+12.2%)	0 (+0%)
#9 - High renewable energy target	14 (+1.7%)	29.4 (+14.9%)	0.2 (+0.2%)
#10 - Energy target, no food-based or intermediate	12.9 (+1.6%)	22.5 (+11.4%)	0.2 (+0.2%)

TABLE 8.1: Consumer cost impact analysis (presented as a difference from baseline costs). Parenthetical values show the % difference from the 2030 baseline

Chapter 9

Discussion

This study assesses the expected compliance with major transport fuels elements of the Fit for 55 package, including the REDII revision and ReFuelEU proposals, as well as nine other policy scenarios that represent changes that could potentially be made to transport fuel policies in this package. From assessing the European Commission's policy proposals as well as the other scenarios, there are a number of key observations we can make that could help inform future policy decisions.

9.1 Intermediate crops

In this study, we find that intermediate crop biofuel largely fills in the gap between the overall target (whether this is GHG target or an energy mandate) and the sum of sub-mandates and caps. Comparing Scenarios 1 and 2, we see that reducing the GHG target results largely in a reduction in intermediate crop biofuel. Conversely, comparing Scenarios 8 and 9, increasing the renewable energy mandate results largely in an increase in intermediate crop biofuel. The reason this occurs is because we expect intermediate crop biofuel to be a relatively inexpensive compliance option for fuel blenders, but its contribution to the REDII and REDII revision targets is not capped. Article 2, paragraph 40 of the REDII defines food- and feed-based biofuels as "starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land."

While intermediate crops in the EU are generally grown for environmental protection purposes, outside the EU, they are generally grown as business-as-usual cash crops for purely economic reasons; these crops are generally used for food and feed [16, 17]. For example, in Brazil, two-thirds of all maize produced is grown as a winter crop; in 2020, winter corn reached 77 million tons [18]. The FAO projects that one-third of the increase in soybean harvested area over the coming decade will be from winter cropping [19]. While intermediate crops are only grown on 2% of cropland in the United States, 80% of this is wheat and rye, staple food crops [20]. The use of these crops for EU biofuels would displace them from their existing uses in food and feed, increasing overall demand for food and feed crops, raising food and feed prices, and causing ILUC, exactly the same as for food and feed crops grown as main crops. We thus apply the same ILUC factors to intermediate crop biofuels as we do for the corresponding food-based biofuel pathways. While the REDII states that to be exempt from the food- and feed-based biofuel cap, intermediate crops should "not trigger demand for additional land," the European Commission has not issued guidance on how voluntary schemes should interpret this clause. In the absence of any guidance, we assume that voluntary schemes would only verify that intermediate crops were indeed grown during the winter or off-season and would not apply the same level of rigor as, for example, the Commission's proposed rules for certifying low-ILUC biofuel feedstocks in the draft delegated act on voluntary schemes [21].

In particular, in scenarios with higher targets we see an increase in intermediate crop soy HVO, presumably because this fuel is not subject to blend walls, as ethanol and biodiesel (FAME) are. In Scenario 1, 97% of all intermediate crop fuel is from soy (the remainder is from maize). This effect corresponds to lower GHG savings and higher costs of carbon abatement for the policy scenarios overall. This is because soy biofuel has very high ILUC emissions, according to the estimates we take from the 2015 study commissioned by the European Commission Valin et al. [9], with total GHG emissions for soy biofuel far exceeding that of petroleum fuels. For example, when the GHG target in the REDII revision proposal is reduced from 13% in Scenario 1 to 11% in Scenario 2, the total GHG savings from the policy increases from 29 to 37 million tons CO2e in 2030 and the average cost of carbon abatement declines from around 1300 to 850 e/MTCO2e. Much of this is due to a decline in intermediate crop soy biofuel from 5.6 to 2.3 billion liters in Scenarios 1 and 2, respectively. In the scenarios modeling a renewable energy target, increasing that target from 26% to 29.5% (Scenarios 8 and 9, respectively) eliminates all GHG savings from the policy and actually leads to a GHG increase because of the large increase in intermediate crop soy biofuel, from 6.9 to 14.2 billion liters. The three scenarios with by far the highest GHG savings and the lowest cost of carbon abatement are all those in which intermediate crops are included in the food-based biofuel cap (and without an incentive for intermediate crop biofuel, we see zero volumes): Scenarios 4, 5, and 10. In scenarios 4 and 5, the GHG savings from the Commission's current proposal are roughly doubled, even though the target levels are lower (9% and 8%, respectively), because of the sharp reduction in soy biofuel.

9.2 Food-and-feed based biofuels

Similar to our findings on intermediate crop biofuels, we find that reducing the cap on food- and feed-based biofuels increases GHG savings, reduces costs, and reduces the average cost of carbon abatement. We can see this in Scenario 3, which is the same as the Commission's REDII revision proposal but excluding food-based biofuels and reducing the GHG target accordingly; this increases GHG savings from 29 to 38 million tons CO2e. Excluding food-based biofuels reduces the average cost of carbon abatement by around 35%.

9.3 GHG target level

We find that the GHG savings are substantially higher and the average cost of carbon abatement lower in scenarios with a GHG target compared to a renewable energy mandate. Scenarios 1 and 8 achieve similar quantities of renewable energy and use the same set of submandates and caps – but Scenario 1, representing the GHG target, achieves around three times the GHG savings of the renewable energy mandate (Scenario 8). The average cost of carbon abatement for the GHG target is around one-third that of the renewable energy mandate. These differences are muted if food-based biofuels and intermediate crop biofuels are excluded: Scenarios 4 and 10 achieve similar levels of renewable energy without these categories, but Scenario 4, representing the GHG target, achieves around 10% greater GHG savings and around a 20% lower cost of carbon abatement, compared to the renewable energy mandate in Scenario 10. In scenarios with a GHG target, we see greater amounts of very low carbon fuels – for example, as shown in Figure 5, all the GHG target scenarios (Scenarios 1-7) have significant amounts of ethanol with carbon capture and storage (CCS), a technology that can be used to substantially reduce CO2 emissions from both conventional and cellulosic ethanol production, while we see no significant volumes for these pathways in the renewable energy mandate scenarios (Scenarios 8-10).

9.4 Aviation fuels

We find that SAF and aviation e-fuel volumes exceed the targets in every scenario. The share of SAF in total jet fuel is over 6% in 2030 in all of our scenarios, compared to the target of 5% for 2030 in the proposed ReFuel EU regulation. Over-compliance with the aviation e-fuel mandate is even more dramatic; in all of our scenarios, the share of e-fuels in total jet fuel is over 2.7%, compared to the target of 0.7% in 2030. This suggests that the transport-wide targets are generally more ambitious than the ReFuel EU targets.

9.5 Electric vehicles

We find a significant response of electric vehicle penetration in response to the GHG target scenarios in our study, but not the renewable energy mandate scenarios, as shown in Figure 6.2. The REDII revision proposal includes an amendment to require EU Member States to "establish a mechanism allowing fuel suppliers in their territory to exchange credits for supplying renewable energy to the transport sector" (amendment to Article 25). Public charging stations are identified as the parties that should receive credits. This requirement creates an incentive for charging station companies to expand their networks and reduce their rates, which should contribute to further electric vehicle sales and use. While renewable electricity used in vehicles counts towards the renewable energy in transport mandate in the REDII, there is no required mechanism to incentivize further penetration of electric vehicles. In our model, the renewable energy mandate in Scenarios 8-10 only incentivizes electric vehicles very slightly compared to a baseline scenario by increasing electricity prices to a lesser extent than gasoline and diesel prices. Our results show that a GHG target is a much more effective way to increase electric vehicle penetration through low carbon fuels policy than a renewable energy mandate. Electric vehicle kilometers driven more than doubles in the scenario with the highest credit price (Scenario 5) compared to the baseline scenario.

9.6 Regarding carbon abatement costs

Aggregate metrics, such as the average carbon abatement costs, can be used to compare results across many differently structured models. In the policy scenarios that we designed we vary the levels of both the GHG targets and the energy mandates. We calculate the average cost of carbon abatement as the difference in consumer costs when compared to the baseline divided by the total reduction in GHG emissions. The average cost of carbon abatement is shown in Table 9.1.

Overall, the GHG credit prices, shown in Table 1.2, mirror the trends in consumer costs and the average cost of carbon abatement, shown in Table 9.1. However, in all cases the GHG credit prices are lower than the average cost of carbon abatement. The difference between these two values is that the GHG credit price represents only the marginal cost of compliance with the GHG target, while the average cost of carbon abatement represents the overall average cost (including all policy constraints). Constraints such as the advanced biofuel and RFNBO mandates, in particular, are expensive to meet. Additionally, the GHG credit prices are calculated without considering ILUC, while we calculate the average cost of carbon abatement with ILUC included in the GHG calculation. Thus, for the average cost of carbon abatement, we are dividing costs over a smaller quantity of GHG savings. This term better reflects the true cost of climate mitigation compared to the GHG credit price.

Scn	**Consumer Cost Increase (billion €)**	**GHG Reduction (million tCO2e)**	**Average Cost of Carbon Abatement (€/tCO2e)**
#1 - REDII revision proposal	37.4 +(3.4%)	29.2	1281
#2 - Lower GHG target	32 +(2.9%)	37.4	855
#3 - No food-based biofuels	31.4 +(2.9%)	38.2	823
#4 - No food-based or intermediate crops	30.5 +(2.8%)	66.4	460
#5 - No intermediate crops	39.6 +(3.6%)	58	682
#6 - Higher subtargets	36.6 +(3.3%)	35.4	1033
#7 - Low EV growth	41.1 +(3.8%)	-2.3	NA
#8 - Renewable energy target	36.6 +(3.3%)	9.5	3871
#9 - High renewable energy target	43.6 +(4%)	-13.1	NA
#10 - Energy target, no food-based or intermediate	35.6 +(3.2%)	60.3	590

TABLE 9.1: Effective cost of reducing carbon emissions across all scenarios.

Appendix A

Fuel Categories

The following category labels were used in this work.

Fuel Category	**Member**
All Finished Fuels	Finished Diesel Fuel, Finished CNG, Electricity Finished Gasoline, Finished Hydrogen, Finished Jet Fuel
All LDV Fuels	Renewable Electricity Gasoline (BOB) Ethanol (corn), Ethanol (corn intermediate crop), Ethanol (corn w/CCS) Ethanol (sugar), Ethanol (sugarbeet) Ethanol (sugarbeet w/CCS) Ethanol (wheat), Ethanol (wheat w/CCS) Cellulosic Ethanol (agricultural residues) Cellulosic Ethanol (agricultural residues w/CCS) Cellulosic Ethanol (energy crops), Cellulosic Ethanol (energy crops w/CCS), Ethanol (flue gas)
All HDV Fuels	CNG (fossil sources) CNG (biowaste), CNG (manure), CNG (silage maize) Diesel (fossil sources) FAME (palm), FAME (rapeseed) FAME (soy), FAME (soy intermediate crop) FAME (tallow), FAME (used cooking oil), HVO (crude tall oil) HVO (palm), HVO (rapeseed) HVO (soy), HVO (soy intermediate crop) HVO (tallow), HVO (used cooking oil) Cellulosic Diesel (agricultural residues), Cellulosic Diesel (energy crops), Cellulosic Diesel (municipal solid waste) Diesel e-Fuels Hydrogen (fossil sources), Green Hydrogen
All Jet Fuels	Kerosene (fossil sources) SAF Alcohol-to-Jet (agricultural residues) SAF Fischer-Tropsch (agricultural residues) SAF Alcohol-to-Jet (corn) SAF Alcohol-to-Jet (corn intermediate crop) SAF Alcohol-to-Jet (energy crops) SAF Fischer-Tropsch (agricultural residues) SAF Alcohol-to-Jet (flue gas) SAF Fischer-Tropsch (municipal solid waste) SAF HEFA (palm), SAF e-Fuels SAF HEFA (rapeseed), SAF HEFA (soy), SAF HEFA (soy intermediate crop) SAF Alcohol-to-Jet SAF (tallow), SAF (used cooking oil)

TABLE A.1: All modeled fuels.

Appendix B

Credit Multipliers

Values for the parameter m_{bs} in Equations 3.8, 3.9, 3.10, 3.11, and 3.12 are listed in the following tables.

Fuel	Alternative	Advanced	Alternative Jet	RFNBO	Aviation e-Fuels
Cellulosic Diesel (agricultural residues)	1	1	-	-	-
Cellulosic Diesel (energy crops)	1	1	-	-	-
Cellulosic Diesel (municipal solid waste)	1	1	-	-	-
Cellulosic Ethanol (agricultural residues w/CCS)	1	1	-	-	-
Cellulosic Ethanol (agricultural residues)	1	1	-	-	-
Cellulosic Ethanol (energy crops w/CCS)	1	1	-	-	-
Cellulosic Ethanol (energy crops)	1	1	-	-	-
CNG (biowaste)	1	1	-	-	-
CNG (fossil sources)	-	-	-	-	-
CNG (manure)	1	1	-	-	-
CNG (silage maize)	1	-	-	-	-
Diesel (fossil sources)	-	-	-	-	-
Diesel Power-to-Liquids	1	-	-	1	-
Ethanol (corn intermediate crop)	1	-	-	-	-
Ethanol (corn w/CCS)	1	-	-	-	-
Ethanol (corn)	1	-	-	-	-
Ethanol (flue gas)	1	-	-	-	-
Ethanol (sugar)	1	-	-	-	-
Ethanol (sugarbeet w/CCS)	1	-	-	-	-
Ethanol (sugarbeet)	1	-	-	-	-
Ethanol (wheat w/CCS)	1	-	-	-	-
Ethanol (wheat)	1	-	-	-	-
FAME (palm)		-	-	-	-
FAME (rapeseed)	1	-	-	-	-
FAME (soy intermediate crop)	1	-	-	-	-
FAME (soy)	1	-	-	-	-
FAME (tallow)	1	-	-	-	-
FAME (used cooking oil)	1	-	-	-	-
Gasoline (BOB)	-	-	-	-	-
Green Hydrogen	1	-	-	1	-
HVO (crude tall oil)	1	1	-	-	-
HVO (palm)	-	-	-	-	-
HVO (rapeseed)	-	-	-	-	-
HVO (soy intermediate crop)	1	-	-	-	-
HVO (soy)	1	-	-	-	-
HVO (tallow)	1	-	-	-	-
HVO (used cooking oil)	1	-	-	-	-
Hydrogen (fossil sources)	-	-	-	-	-
Renewable Electricity	1	-	-	-	-
SAF (tallow)	1	-	1	-	-
SAF (used cooking oil)	1	-	1	-	-
SAF Alcohol-to-Jet (agricultural residues)	1	1	1.2	-	-
SAF Alcohol-to-Jet (corn intermediate crop)	1	-	-	-	-
SAF Alcohol-to-Jet (corn)	1	-	-	-	-
SAF Alcohol-to-Jet (energy crops)	1	1	1.2	-	-
SAF Alcohol-to-Jet (flue gas)	1	-	1	-	-
SAF Alcohol-to-Jet	1	-	-	-	-
SAF Fischer-Tropsch (agricultural residues)	1	1	1.2	-	-
SAF Fischer-Tropsch (energy crops)	1	1	1.2	-	-
SAF Fischer-Tropsch (municipal solid waste)	1	1	1.2	-	-
SAF HEFA (palm)	-	-	-	-	-
SAF HEFA (rapeseed)	1	-	-	-	-
SAF HEFA (soy intermediate crop)	1	-	-	-	-
SAF HEFA (soy)	1	-	-	-	-
SAF Power-to-Liquids	1	-	1	1.2	1

TABLE B.1: Credit multiplier (m_{bs}) ***1.2x SAF and Maritime only***.

Fuel	Alternative	Advanced	Alternative Jet	RFNBO	Aviation e-Fuels
Cellulosic Diesel (agricultural residues)	2	2	-	-	-
Cellulosic Diesel (energy crops)	2	2	-	-	-
Cellulosic Diesel (municipal solid waste)	2	2	-	-	-
Cellulosic Ethanol (agricultural residues w/CCS)	2	2	-	-	-
Cellulosic Ethanol (agricultural residues)	2	2	-	-	-
Cellulosic Ethanol (energy crops w/CCS)	2	2	-	-	-
Cellulosic Ethanol (energy crops)	2	2	-	-	-
CNG (biowaste)	2	2	-	-	-
CNG (fossil sources)	-	-	-	-	-
CNG (manure)	2	2	-	-	-
CNG (silage maize)	1	-	-	-	-
Diesel (fossil sources)	-	-	-	-	-
Diesel Power-to-Liquids	1	-	-	1	-
Ethanol (corn intermediate crop)	1	-	-	-	-
Ethanol (corn w/CCS)	1	-	-	-	-
Ethanol (corn)	1	-	-	-	-
Ethanol (flue gas)	1	-	-	-	-
Ethanol (sugar)	1	-	-	-	-
Ethanol (sugarbeet w/CCS)	1	-	-	-	-
Ethanol (sugarbeet)	1	-	-	-	-
Ethanol (wheat w/CCS)	1	-	-	-	-
Ethanol (wheat)	1	-	-	-	-
FAME (palm)		-	-	-	-
FAME (rapeseed)	1	-	-	-	-
FAME (soy intermediate crop)	1	-	-	-	-
FAME (soy)	1	-	-	-	-
FAME (tallow)	2	-	-	-	-
FAME (used cooking oil)	2	-	-	-	-
Gasoline (BOB)	-	-	-	-	-
Green Hydrogen	1	-	-	1	-
HVO (crude tall oil)	2	2	-	-	-
HVO (palm)	-	-	-	-	-
HVO (rapeseed)	-	-	-	-	-
HVO (soy intermediate crop)	1	-	-	-	-
HVO (soy)	1	-	-	-	-
HVO (tallow)	2	-	-	-	-
HVO (used cooking oil)	2	-	-	-	-
Hydrogen (fossil sources)	-	-	-	-	-
Renewable Electricity	4	-	-	-	-
SAF (tallow)	2.4	-	1	-	-
SAF (used cooking oil)	2.4	-	1	-	-
SAF Alcohol-to-Jet (agricultural residues)	2.4	2.4	1	-	-
SAF Alcohol-to-Jet (corn intermediate crop)	1	-	-	-	-
SAF Alcohol-to-Jet (corn)	1	-	-	-	-
SAF Alcohol-to-Jet (energy crops)	2.4	2.4	1	-	-
SAF Alcohol-to-Jet (flue gas)	1	-	1	-	-
SAF Alcohol-to-Jet	1	-	-	-	-
SAF Fischer-Tropsch (agricultural residues)	2.4	2.4	1	-	-
SAF Fischer-Tropsch (energy crops)	2.4	2.4	1	-	-
SAF Fischer-Tropsch (municipal solid waste)	2.4	2.4	1	-	-
SAF HEFA (palm)	-	-	-	-	-
SAF HEFA (rapeseed)	1	-	-	-	-
SAF HEFA (soy intermediate crop)	1	-	-	-	-
SAF HEFA (soy)	1	-	-	-	-
SAF Power-to-Liquids	1.2	-	1	1.2	1

TABLE B.2: Credit multiplier (m_{bs}) ***REDII multipliers***

Appendix C

Elasticities

Fuel	Lower Bound	Upper Bound
Gasoline (BOB)	6	10
Diesel (fossil sources)	6	10
Kerosene (fossil sources)	6	10
CNG (fossil sources)	6	10
FAME (soy)	5.64	10.48
FAME (rapeseed)	5.64	10.48
FAME (palm)	5.64	10.48
FAME (used cooking oil)	10.73	19.93
FAME (tallow)	10.73	19.93
FAME (soy intermediate crop)	5.64	10.48
HVO (soy intermediate crop)	7.56	14.03
HVO (soy)	7.56	14.03
HVO (rapeseed)	7.56	14.03
HVO (palm)	8.51	15.81
HVO (used cooking oil)	7.86	14.59
HVO (tallow)	7.58	14.08
HVO (crude tall oil)	7.33	13.61
Cellulosic Diesel (agricultural residues)	3.97	7.38
Cellulosic Diesel (energy crops)	3.82	7.1
Cellulosic Diesel (municipal solid waste)	5.13	9.52
Diesel Power-to-Liquids	3.62	6.72
Hydrogen (fossil sources)	27.58	51.22
Green Hydrogen	6.86	12.73
Renewable Electricity	1.68	3.12
CNG (manure)	2.29	4.26
CNG (silage maize)	5.09	9.46
CNG (biowaste)	2.29	4.26
Cellulosic Ethanol (agricultural residues)	6.63	12.32
Cellulosic Ethanol (energy crops)	6.63	12.32
Cellulosic Ethanol (agricultural residues w/CCS)	3.95	7.34
Cellulosic Ethanol (energy crops w/CCS)	3.99	7.4
Ethanol (corn)	7.07	13.12
Ethanol (wheat)	7.07	13.12
Ethanol (sugar)	7.07	13.12
Ethanol (sugarbeet)	7.07	13.12
Ethanol (corn w/CCS)	8.1	15.04
Ethanol (wheat w/CCS)	8.14	15.11
Ethanol (sugarbeet w/CCS)	7.86	14.6
Ethanol (flue gas)	9.92	18.42
Ethanol (corn intermediate crop)	7.07	13.12
SAF Alcohol-to-Jet (corn)	5.93	11.01
SAF Alcohol-to-Jet	6.04	11.21
SAF Alcohol-to-Jet (agricultural residues)	2.88	5.35
SAF Alcohol-to-Jet (energy crops)	2.82	5.24
SAF Fischer-Tropsch (agricultural residues)	3.03	5.63
SAF Fischer-Tropsch (energy crops)	2.93	5.45
SAF Fischer-Tropsch (municipal solid waste)	3.74	6.94
SAF (used cooking oil)	7.44	13.81
SAF (tallow)	5.37	9.98
SAF HEFA (rapeseed)	4.82	8.95
SAF HEFA (soy)	4.82	8.95
SAF HEFA (palm)	5.28	9.8
SAF Power-to-Liquids	2.87	5.34
SAF Alcohol-to-Jet (flue gas)	4.29	7.96
SAF Alcohol-to-Jet (corn intermediate crop)	5.25	9.75
SAF HEFA (soy intermediate crop)	4.82	8.95

TABLE C.1: Supply elasticities, η_{bs}

Consumer	Lower Bound	Upper Bound	Source
HDV Consumer	-0.08	-0.02	Assumed similar to [22]-
LDV Consumer	-0.08	-0.02	[22]
Aviation Consumer	-1.2	-0.8	[23]

TABLE C.2: Demand elasticity, ϵ

Consumer	Lower Bound	Upper Bound
HDV Consumer	1.1	3
LDV Consumer	1.1	8

TABLE C.3: Elasticity of substitution, σ

Appendix D

Baseline Data

Fuel	Quantity (billion MJ)	Policy Emission Factor (gCO2e/MJ)	Emission Factor w/ILUC (gCO2e/MJ)	Source
Gasoline (BOB)	3144.5	94	94	[24]
Diesel (fossil sources)	7874.97	94	94	[24]
Kerosene (fossil sources)	1844.03	94	94	[25]
CNG (fossil sources)	72	94	94	[26]
FAME (soy)	0.4844	32.9	182.9	[27, 28]
FAME (rapeseed)	0.9055	32.9	97.9	[27, 28]
FAME (palm)	0.6857	32.9	263.9	[27, 28]
FAME (used cooking oil)	0.005	11.2	11.2	[27, 28]
FAME (tallow)	0.005	15.3	15.3	[27, 28]
FAME (soy intermediate crop)	0.2422	32.9	182.9	[27]
HVO (soy intermediate crop)	0.0025	32.9	182.9	[29]
HVO (soy)	0.005	32.9	182.9	[29]
HVO (rapeseed)	0.005	32.9	97.9	[29]
HVO (palm)	0.005	32.9	263.9	[29]
HVO (used cooking oil)	0.0905	11.9	11.9	[29]
HVO (tallow)	0.0283	16	16	[29]
HVO (crude tall oil)	0.0283	12	12	[29]
Cellulosic Diesel (agricultural residues)	0.0001	7.7	23.7	[29, 30]
Cellulosic Diesel (energy crops)	0.0001	10.4	-1.6	[29, 30]
Cellulosic Diesel (municipal solid waste)	0.0001	15	15	[29, 31]
Diesel e-Fuels	0.0001	1	1	[32, 33]
Hydrogen (fossil sources)	0.0001	13.2	13.2	[34, 35]
Green Hydrogen	0.0001	1.8	1.8	[35, 36, 37]
Renewable Electricity	1.6271	-89	-89	[32]
CNG (manure)	0.0001	-84	-84	[12, 38]
CNG (silage maize)	0.001	28	49	[12, 38]
CNG (biowaste)	0.0001	13	13	[12, 38]
Cellulosic Ethanol (agricultural residues)	0.0001	13.7	29.7	[39]
Cellulosic Ethanol (energy crops)	0.0001	14	2	[39]
Cellulosic Ethanol (agricultural residues w/CCS)	0.0001	-93.7	-77.7	[39, 40, 41, 42]
Cellulosic Ethanol (energy crops w/CCS)	0.0001	-85.2	-97.2	[39, 40, 41, 42]
Ethanol (corn)	0.2218	32.9	46.9	[43]
Ethanol (wheat)	0.2368	32.9	66.9	[43]
Ethanol (sugar)	0.0823	28.1	45.1	[43]
Ethanol (sugarbeet)	0.0606	30.7	45.7	[43]
Ethanol (flue gas)	0.0001	19.6	19.6	[31, 39]
Ethanol (corn intermediate crop)	0.1109	32.9	46.9	[43]
Ethanol (corn w/CCS)	0.0111	28.4	42.4	[40, 41, 42]
Ethanol (wheat w/CCS)	0.0118	30	64	[40, 41, 42]
Ethanol (sugarbeet w/CCS)	0.0041	16.4	31.4	[40, 41, 42]
SAF Alcohol-to-Jet (corn)	0.0001	32.9	46.9	[29, 30]

SAF Alcohol-to-Jet	0.0001	24	41	[29, 30]
SAF Alcohol-to-Jet (agricultural residues)	0.0001	29.3	45.3	[29, 30]
SAF Alcohol-to-Jet (energy crops)	0.0001	32.9	20.9	[29, 30]
SAF Fischer-Tropsch (agricultural residues)	0.0001	7.7	23.7	[29, 30]
SAF Fischer-Tropsch (energy crops)	0.0001	10.4	-1.6	[29, 30]
SAF Fischer-Tropsch (municipal solid waste)	0.0001	5.2	5.2	[29, 30]
SAF (used cooking oil)	0.0001	13.9	13.9	[29, 30]
SAF (tallow)	0.0001	22.5	22.5	[29, 30]
SAF HEFA (rapeseed)	0.005	32.9	97.9	[29, 30]
SAF HEFA (soy)	0.005	32.9	182.9	[29, 30]
SAF HEFA (palm)	0.005	32.9	263.9	[29, 30]
SAF e-Fuels	0.0001	1	1	[32, 33]
SAF Alcohol-to-Jet (flue gas)	0.0001	19.6	19.6	[31, 39]
SAF Alcohol-to-Jet (corn intermediate crop)	0.0001	32.9	46.9	[43]
SAF HEFA (soy intermediate crop)	0.0025	32.9	182.9	[29]

TABLE D.1: Baseline data.

Scn	**Gasoline (%/yr)**	**Diesel (%/yr)**	**CNG (%/yr)**	**JET (%/yr)**	**EV (%/yr)**	**Hydrogen (%/yr)**
#1 - REDII revision proposal	-5.15	-0.85	6.9	0.81	51	10
#2 - Lower GHG target	-5.15	-0.85	6.9	0.81	51	10
#3 - No food-based biofuels	-5.15	-0.85	6.9	0.81	51	10
#4 - No food-based or intermediate crops	-5.15	-0.85	6.9	0.81	51	10
#5 - No intermediate crops	-5.15	-0.85	6.9	0.81	51	10
#6 - Higher subtargets	-5.15	-0.85	6.9	0.81	51	10
#7 - Low EV growth	-5.15	-0.85	6.9	0.81	41	10
#8 - Renewable energy target	-5.15	-0.85	6.9	0.81	51	10
#9 - High renewable energy target	-5.15	-0.85	6.9	0.81	51	10
#10 - Energy target, no food-based or intermediate	-5.15	-0.85	6.9	0.81	51	10

TABLE D.2: Fuel annual growth rates used to project the baseline data into future years.

Appendix E

Detailed Fuel Quantity Results

Fuel	Scn	Mean	10%	25%	50%	75%	95%
Cellulosic Diesel (agricultural residues)	#1 - REDII revision proposal	6.5199	0.149	0.4025	1.7469	7.4034	30.3504
Cellulosic Diesel (agricultural residues)	#2 - Lower GHG target	5.9906	0.1345	0.3628	1.5634	6.5037	29.4068
Cellulosic Diesel (agricultural residues)	#3 - No food-based biofuels	6.1267	0.1352	0.3638	1.6405	6.8241	29.1182
Cellulosic Diesel (agricultural residues)	#4 - No food-based or intermediate crops	6.329	0.1473	0.3867	1.6954	6.7339	30.5114
Cellulosic Diesel (agricultural residues)	#5 - No intermediate crops	7.5959	0.1775	0.4775	2.0548	8.4936	36.1614
Cellulosic Diesel (agricultural residues)	#6 - Higher subtargets	12.0734	0.2119	0.5931	2.8111	13.0793	60.5245
Cellulosic Diesel (agricultural residues)	#7 - Low EV growth	6.9178	0.1572	0.4089	1.8428	7.9502	32.1287
Cellulosic Diesel (agricultural residues)	#8 - Renewable energy target	6.0338	0.1302	0.3375	1.5015	6.5175	29.1477
Cellulosic Diesel (agricultural residues)	#9 - High renewable energy target	6.8397	0.1525	0.4009	1.8617	7.7568	31.5026
Cellulosic Diesel (agricultural residues)	#10 - Energy target, no food-based or intermediate	18.726	0.2457	0.7237	3.5118	17.6953	100.7752
Cellulosic Diesel (energy crops)	#1 - REDII revision proposal	4.2536	0.1084	0.2707	1.0966	4.3988	20.8192
Cellulosic Diesel (energy crops)	#2 - Lower GHG target	3.9228	0.0975	0.2479	0.9576	3.8375	19.706
Cellulosic Diesel (energy crops)	#3 - No food-based biofuels	4.0391	0.0975	0.2489	0.9785	3.911	20.4411
Cellulosic Diesel (energy crops)	#4 - No food-based or intermediate crops	4.1857	0.103	0.2602	1.0273	4.2578	20.9648
Cellulosic Diesel (energy crops)	#5 - No intermediate crops	4.8961	0.1164	0.3024	1.2449	5.2525	23.5198
Cellulosic Diesel (energy crops)	#6 - Higher subtargets	7.947	0.1475	0.3961	1.6626	7.3036	43.0481
Cellulosic Diesel (energy crops)	#7 - Low EV growth	4.3672	0.1118	0.2796	1.134	4.5948	20.9259
Cellulosic Diesel (energy crops)	#8 - Renewable energy target	4.2473	0.0999	0.2385	0.9991	4.1122	21.4728
Cellulosic Diesel (energy crops)	#9 - High renewable energy target	4.6297	0.1164	0.287	1.2222	4.8303	22.5246
Cellulosic Diesel (energy crops)	#10 - Energy target, no food-based or intermediate	12.4737	0.1733	0.4711	2.1285	10.769	68.22
Cellulosic Diesel (municipal solid waste)	#1 - REDII revision proposal	45.4448	2.4646	8.279	33.6712	68.9046	136.1391
Cellulosic Diesel (municipal solid waste)	#2 - Lower GHG target	40.972	2.2443	7.4635	30.5602	61.4436	125.9464
Cellulosic Diesel (municipal solid waste)	#3 - No food-based biofuels	40.3908	2.2427	7.7812	31.1038	61.1103	120.4588
Cellulosic Diesel (municipal solid waste)	#4 - No food-based or intermediate crops	41.233	2.3484	8.5469	35.1087	63.553	109.6136
Cellulosic Diesel (municipal solid waste)	#5 - No intermediate crops	48.5105	2.5127	8.7296	36.1312	74.7945	141.9107
Cellulosic Diesel (municipal solid waste)	#6 - Higher subtargets	73.4252	4.8187	18.3117	69.881	113.0542	182.5373
Cellulosic Diesel (municipal solid waste)	#7 - Low EV growth	46.0138	2.4232	7.9655	32.742	71.7224	138.2388
Cellulosic Diesel (municipal solid waste)	#8 - Renewable energy target	51.8729	2.728	9.2816	37.6748	79.4098	154.4433
Cellulosic Diesel (municipal solid waste)	#9 - High renewable energy target	63.992	2.8353	9.9471	39.5158	100.6916	194.4852
Cellulosic Diesel (municipal solid waste)	#10 - Energy target, no food-based or intermediate	122.2733	8.8444	36.9897	134.0173	193.6215	237.0057
Cellulosic Ethanol (agricultural residues w/CCS)	#1 - REDII revision proposal	7.1063	0.1553	0.4077	1.9037	8.6864	31.6968
Cellulosic Ethanol (agricultural residues w/CCS)	#2 - Lower GHG target	3.8063	0.0947	0.2367	1.0297	4.2626	16.0602
Cellulosic Ethanol (agricultural residues w/CCS)	#3 - No food-based biofuels	6.416	0.1357	0.3669	1.6938	7.4861	28.8177
Cellulosic Ethanol (agricultural residues w/CCS)	#4 - No food-based or intermediate crops	12.2217	0.2622	0.7645	3.6014	16.1443	54.2747
Cellulosic Ethanol (agricultural residues w/CCS)	#5 - No intermediate crops	18.5352	0.3856	1.1456	6.1049	26.6374	77.587
Cellulosic Ethanol (agricultural residues w/CCS)	#6 - Higher subtargets	6.5382	0.142	0.3579	1.6794	7.597	28.9298
Cellulosic Ethanol (agricultural residues w/CCS)	#7 - Low EV growth	9.9666	0.2035	0.5332	2.6878	12.657	44.5658
Cellulosic Ethanol (agricultural residues w/CCS)	#8 - Renewable energy target	0.492	0.0167	0.0371	0.126	0.3848	1.9927
Cellulosic Ethanol (agricultural residues w/CCS)	#9 - High renewable energy target	0.4753	0.0167	0.0374	0.1157	0.3664	1.8379
Cellulosic Ethanol (agricultural residues w/CCS)	#10 - Energy target, no food-based or intermediate	0.736	0.0183	0.0413	0.136	0.448	3.2829
Cellulosic Ethanol (agricultural residues)	#1 - REDII revision proposal	43.3939	1.3032	5.2266	29.3668	80.4546	115.0745
Cellulosic Ethanol (agricultural residues)	#2 - Lower GHG target	50.3682	1.6179	6.6747	38.2533	94.6115	120.4955
Cellulosic Ethanol (agricultural residues)	#3 - No food-based biofuels	47.4707	1.5772	6.3688	35.0809	89.3477	118.6614
Cellulosic Ethanol (agricultural residues)	#4 - No food-based or intermediate crops	41.8501	1.4129	5.9198	30.2318	74.017	111.9634
Cellulosic Ethanol (agricultural residues)	#5 - No intermediate crops	31.7554	0.7429	3.1584	17.7074	55.5303	100.6217
Cellulosic Ethanol (agricultural residues)	#6 - Higher subtargets	47.3241	1.5485	6.0657	34.0953	89.311	118.112
Cellulosic Ethanol (agricultural residues)	#7 - Low EV growth	39.3678	1.0355	4.0265	23.76	71.1814	113.6199
Cellulosic Ethanol (agricultural residues)	#8 - Renewable energy target	49.6445	1.3513	5.8372	33.3513	94.0232	126.7188
Cellulosic Ethanol (agricultural residues)	#9 - High renewable energy target	49.7988	1.3527	5.4077	32.1065	95.5704	127.9321
Cellulosic Ethanol (agricultural residues)	#10 - Energy target, no food-based or intermediate	59.3418	1.9371	9.1985	51.9433	111.1868	128.0854
Cellulosic Ethanol (energy crops w/CCS)	#1 - REDII revision proposal	6.6845	0.1459	0.3726	1.7743	7.6714	29.2684
Cellulosic Ethanol (energy crops w/CCS)	#2 - Lower GHG target	3.7163	0.0914	0.2347	0.9876	3.9792	16.1189
Cellulosic Ethanol (energy crops w/CCS)	#3 - No food-based biofuels	5.8064	0.1294	0.3252	1.4829	6.3907	25.8286
Cellulosic Ethanol (energy crops w/CCS)	#4 - No food-based or intermediate crops	12.0794	0.2473	0.7029	3.4924	15.7816	53.4316
Cellulosic Ethanol (energy crops w/CCS)	#5 - No intermediate crops	17.2247	0.3318	0.9578	5.1006	23.9245	74.3633
Cellulosic Ethanol (energy crops w/CCS)	#6 - Higher subtargets	6.1306	0.1324	0.338	1.5786	7.0674	27.2986
Cellulosic Ethanol (energy crops w/CCS)	#7 - Low EV growth	9.1058	0.1916	0.4906	2.3561	10.8687	40.7948

Cellulosic Ethanol (energy crops w/CCS)	#8 - Renewable energy target	0.5433	0.0192	0.0401	0.125	0.3909	2.0475
Cellulosic Ethanol (energy crops w/CCS)	#9 - High renewable energy target	0.4744	0.018	0.0388	0.123	0.3793	1.7641
Cellulosic Ethanol (energy crops w/CCS)	#10 - Energy target, no food-based or intermediate	0.8045	0.0196	0.0446	0.1472	0.4781	3.4561
Cellulosic Ethanol (energy crops)	#1 - REDII revision proposal	42.6171	1.2534	4.907	27.6846	78.8966	114.7596
Cellulosic Ethanol (energy crops)	#2 - Lower GHG target	49.3158	1.5923	6.5028	36.8914	93.1049	120.3748
Cellulosic Ethanol (energy crops)	#3 - No food-based biofuels	48.3166	1.6546	6.5764	37.9831	89.4415	118.103
Cellulosic Ethanol (energy crops)	#4 - No food-based or intermediate crops	41.8583	1.3829	5.8741	30.8699	75.5261	110.6503
Cellulosic Ethanol (energy crops)	#5 - No intermediate crops	30.8323	0.709	2.8999	16.3223	54.411	97.4509
Cellulosic Ethanol (energy crops)	#6 - Higher subtargets	47.4803	1.565	6.0353	35.1367	89.9017	117.6169
Cellulosic Ethanol (energy crops)	#7 - Low EV growth	39.5213	1.0501	4.0476	23.4185	71.8754	113.7036
Cellulosic Ethanol (energy crops)	#8 - Renewable energy target	49.952	1.343	5.9472	35.1768	94.9399	126.8636
Cellulosic Ethanol (energy crops)	#9 - High renewable energy target	48.9671	1.2582	5.103	32.0193	93.3755	127.6663
Cellulosic Ethanol (energy crops)	#10 - Energy target, no food-based or intermediate	58.274	1.8432	8.9361	50.2257	109.9931	128.0055
CNG (biowaste)	#1 - REDII revision proposal	0.706	0.0482	0.0937	0.282	0.8383	2.8262
CNG (biowaste)	#2 - Lower GHG target	0.686	0.0463	0.09	0.2746	0.79	2.7564
CNG (biowaste)	#3 - No food-based biofuels	0.692	0.0471	0.0931	0.2888	0.8284	2.7379
CNG (biowaste)	#4 - No food-based or intermediate crops	0.6942	0.0465	0.0941	0.2921	0.7975	2.7275
CNG (biowaste)	#5 - No intermediate crops	0.7663	0.0511	0.101	0.3157	0.9076	2.9589
CNG (biowaste)	#6 - Higher subtargets	1.0819	0.0595	0.1228	0.3859	1.1747	4.6199
CNG (biowaste)	#7 - Low EV growth	0.7264	0.0492	0.0988	0.2995	0.8654	2.8888
CNG (biowaste)	#8 - Renewable energy target	0.7325	0.0482	0.0967	0.3039	0.8517	2.9851
CNG (biowaste)	#9 - High renewable energy target	0.7765	0.0529	0.1085	0.3374	0.9709	2.996
CNG (biowaste)	#10 - Energy target, no food-based or intermediate	1.3861	0.0695	0.1419	0.4698	1.5327	6.1512
CNG (fossil sources)	#1 - REDII revision proposal	111.0269	49.8092	88.8595	122.0902	138.6659	159.984
CNG (fossil sources)	#2 - Lower GHG target	135.6742	101.6382	123.9195	139.4305	150.0749	173.0864
CNG (fossil sources)	#3 - No food-based biofuels	147.4836	130.2311	139.8354	147.0637	155.8358	178.1036
CNG (fossil sources)	#4 - No food-based or intermediate crops	143.749	124.0682	136.5476	143.973	152.592	172.8015
CNG (fossil sources)	#5 - No intermediate crops	121.7669	86.5524	109.649	126.7134	137.4392	158.364
CNG (fossil sources)	#6 - Higher subtargets	109.0374	48.098	86.6971	120.4136	138.0874	155.7133
CNG (fossil sources)	#7 - Low EV growth	99.8012	28.0698	71.4707	111.9781	133.2629	153.8808
CNG (fossil sources)	#8 - Renewable energy target	117.3384	21.0466	81.9688	135.3152	156.9795	184.8021
CNG (fossil sources)	#9 - High renewable energy target	112.7118	4.3363	63.0222	133.6847	161.096	191.2244
CNG (fossil sources)	#10 - Energy target, no food-based or intermediate	158.7571	133.1624	149.5151	160.5957	173.1329	197.8794
CNG (manure)	#1 - REDII revision proposal	2.7484	0.1348	0.2864	1.0494	3.6936	10.8387
CNG (manure)	#2 - Lower GHG target	1.86	0.1013	0.2095	0.7204	2.437	7.3353
CNG (manure)	#3 - No food-based biofuels	2.4022	0.1189	0.2526	0.8878	3.0731	9.8975
CNG (manure)	#4 - No food-based or intermediate crops	3.8678	0.1642	0.3606	1.3611	4.8901	15.7144
CNG (manure)	#5 - No intermediate crops	5.6036	0.2111	0.4618	1.872	7.3236	22.5889
CNG (manure)	#6 - Higher subtargets	3.3516	0.1484	0.3188	1.2006	4.3881	14.0235
CNG (manure)	#7 - Low EV growth	3.4656	0.1549	0.3355	1.2655	4.6021	14.1073
CNG (manure)	#8 - Renewable energy target	0.7274	0.0489	0.0966	0.3067	0.8617	2.8746
CNG (manure)	#9 - High renewable energy target	0.7748	0.0541	0.108	0.3246	0.9335	3.0206
CNG (manure)	#10 - Energy target, no food-based or intermediate	1.3589	0.07	0.1419	0.4745	1.5169	5.9246
CNG (silage maize)	#1 - REDII revision proposal	40.619	2.5095	5.808	21.6089	62.6481	135.7987
CNG (silage maize)	#2 - Lower GHG target	15.002	0.979	2.0947	6.7757	20.759	56.9027
CNG (silage maize)	#3 - No food-based biofuels	0	0	0	0	0	0
CNG (silage maize)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
CNG (silage maize)	#5 - No intermediate crops	38.9436	2.3857	5.609	19.8699	56.8256	137.5975
CNG (silage maize)	#6 - Higher subtargets	34.2646	2.0635	4.7895	17.6222	52.7521	116.3108
CNG (silage maize)	#7 - Low EV growth	57.2242	3.2531	8.1265	31.562	92.2904	180.4327
CNG (silage maize)	#8 - Renewable energy target	28.4067	2.0218	4.6345	16.528	46.8443	84.8413
CNG (silage maize)	#9 - High renewable energy target	34.3238	2.466	6.1403	21.4209	60.4049	93.7522
CNG (silage maize)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Diesel (fossil sources)	#1 - REDII revision proposal	6139.6869	6012.0244	6066.5444	6136.3384	6206.9718	6315.1442
Diesel (fossil sources)	#2 - Lower GHG target	6371.3752	6268.2848	6312.4622	6362.9305	6426.9315	6523.215
Diesel (fossil sources)	#3 - No food-based biofuels	6555.1684	6444.3306	6489.3259	6546.352	6617.2481	6718.925
Diesel (fossil sources)	#4 - No food-based or intermediate crops	6777.917	6684.6695	6731.2694	6770.8682	6831.0366	6909.291
Diesel (fossil sources)	#5 - No intermediate crops	6251.0284	6151.8783	6197.5436	6243.9847	6306.0406	6395.3345
Diesel (fossil sources)	#6 - Higher subtargets	6174.7659	6052.3304	6102.539	6166.5083	6238.7089	6353.9728
Diesel (fossil sources)	#7 - Low EV growth	6001.9664	5860.0014	5918.603	5995.7413	6078.1835	6198.6645
Diesel (fossil sources)	#8 - Renewable energy target	6134.1864	6004.6524	6054.9318	6122.0695	6206.1431	6334.3929
Diesel (fossil sources)	#9 - High renewable energy target	5857.0653	5687.6239	5745.4567	5838.4199	5945.6153	6132.7447
Diesel (fossil sources)	#10 - Energy target, no food-based or intermediate	6752.0926	6596.6437	6647.0747	6730.8612	6841.2719	7026.0841
Diesel e-Fuels	#1 - REDII revision proposal	82.7626	6.3694	37.2809	102.1885	127.1915	128.0671
Diesel e-Fuels	#2 - Lower GHG target	82.308	6.4397	37.4454	99.0454	127.8001	128.5342
Diesel e-Fuels	#3 - No food-based biofuels	77.8298	5.2495	29.3361	90.8508	127.3634	128.3827
Diesel e-Fuels	#4 - No food-based or intermediate crops	78.8534	5.8844	31.0323	93.3028	127.2604	128.0165
Diesel e-Fuels	#5 - No intermediate crops	81.6613	6.5009	34.9519	99.9602	126.4343	127.2141
Diesel e-Fuels	#6 - Higher subtargets	66.6904	5.7532	33.2518	90.8654	94.2771	97.7864
Diesel e-Fuels	#7 - Low EV growth	82.1277	6.3296	34.5199	101.5195	126.849	127.6151
Diesel e-Fuels	#8 - Renewable energy target	80.5653	4.6964	34.8278	94.5901	128.6393	129.3152
Diesel e-Fuels	#9 - High renewable energy target	84.3879	5.7296	35.8298	106.1358	128.6413	129.2203
Diesel e-Fuels	#10 - Energy target, no food-based or intermediate	93.9065	15.8285	66.6729	115.7698	128.3713	129.1368
Electricity	#1 - REDII revision proposal	161.6905	129.267	142.9011	162.4126	179.8828	198.4107
Electricity	#2 - Lower GHG target	142.0044	120.3816	129.2606	141.8132	154.0969	167.9396
Electricity	#3 - No food-based biofuels	152.9878	124.9115	135.3771	151.8708	168.7059	190.5014
Electricity	#4 - No food-based or intermediate crops	171.7501	147.4895	161.288	175.3207	184.6355	191.867

Electricity	#5 - No intermediate crops	198.5555	163.5031	183.0925	203.5785	216.5153	227.4726
Electricity	#6 - Higher subtargets	156.3454	127.3734	139.8272	156.9995	172.863	188.5061
Electricity	#7 - Low EV growth	89.695	66.7183	75.1285	88.1547	102.2662	121.6563
Electricity	#8 - Renewable energy target	106.7182	103.5664	104.6451	106.3753	108.3187	111.4462
Electricity	#9 - High renewable energy target	107.5738	103.9979	105.3052	107.3281	109.4816	112.5152
Electricity	#10 - Energy target, no food-based or intermediate	106.9832	103.704	104.7904	106.6662	108.7639	111.7844
Ethanol (corn intermediate crop)	#1 - REDII revision proposal	6.2582	0	0.0007	0.8727	6.4509	32.6477
Ethanol (corn intermediate crop)	#2 - Lower GHG target	2.1665	0	0	0.092	2.1035	11.2479
Ethanol (corn intermediate crop)	#3 - No food-based biofuels	12.4201	0	0.0001	0.7524	14.631	64.2174
Ethanol (corn intermediate crop)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (corn intermediate crop)	#5 - No intermediate crops	0	0	0	0	0	0
Ethanol (corn intermediate crop)	#6 - Higher subtargets	3.2981	0	0	0.0045	2.1745	18.8839
Ethanol (corn intermediate crop)	#7 - Low EV growth	11.0999	0	0.0158	2.5173	13.6384	54.1658
Ethanol (corn intermediate crop)	#8 - Renewable energy target	11.5756	0	0.0114	2.2818	13.2764	56.694
Ethanol (corn intermediate crop)	#9 - High renewable energy target	18.3366	0	0.0936	4.419	23.7482	88.5534
Ethanol (corn intermediate crop)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (corn w/CCS)	#1 - REDII revision proposal	0.8661	0	0	0.0701	0.6857	4.6992
Ethanol (corn w/CCS)	#2 - Lower GHG target	0.8542	0	0	0.0209	0.5513	4.6807
Ethanol (corn w/CCS)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (corn w/CCS)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (corn w/CCS)	#5 - No intermediate crops	0.4948	0	0	0.0015	0.2397	2.7686
Ethanol (corn w/CCS)	#6 - Higher subtargets	0.6577	0	0	0.0002	0.3249	3.8293
Ethanol (corn w/CCS)	#7 - Low EV growth	0.655	0	0	0.0454	0.4877	3.4083
Ethanol (corn w/CCS)	#8 - Renewable energy target	0.7105	0	0	0.0567	0.5157	3.5557
Ethanol (corn w/CCS)	#9 - High renewable energy target	0.4932	0	0	0.0132	0.2825	2.7149
Ethanol (corn w/CCS)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (corn)	#1 - REDII revision proposal	3.7066	0	0	0.4565	4.1359	18.7723
Ethanol (corn)	#2 - Lower GHG target	4.1871	0	0	0.1831	4.1246	23.0023
Ethanol (corn)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (corn)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (corn)	#5 - No intermediate crops	1.5568	0	0	0.0047	0.9746	9.1458
Ethanol (corn)	#6 - Higher subtargets	2.8584	0	0	0.002	2.1374	17.5387
Ethanol (corn)	#7 - Low EV growth	2.6007	0	0.0001	0.2428	2.6211	12.9569
Ethanol (corn)	#8 - Renewable energy target	5.7331	0	0.0007	0.8533	6.2504	29.0331
Ethanol (corn)	#9 - High renewable energy target	4.0227	0	0.0002	0.2502	3.6519	21.3892
Ethanol (corn)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (flue gas)	#1 - REDII revision proposal	1.3011	0	0	0.0312	0.4315	7.1264
Ethanol (flue gas)	#2 - Lower GHG target	0.135	0	0	0.0014	0.046	0.7246
Ethanol (flue gas)	#3 - No food-based biofuels	2.5444	0	0	0.0211	0.7063	17.9098
Ethanol (flue gas)	#4 - No food-based or intermediate crops	11.039	0	0.0063	2.1031	22.9697	36.2322
Ethanol (flue gas)	#5 - No intermediate crops	12.3659	0	0.0693	4.4068	27.1125	36.1466
Ethanol (flue gas)	#6 - Higher subtargets	0.5793	0	0	0.0001	0.0741	2.5371
Ethanol (flue gas)	#7 - Low EV growth	3.2192	0	0.0008	0.1408	1.6595	22.7751
Ethanol (flue gas)	#8 - Renewable energy target	0.3791	0	0	0.0088	0.0853	1.394
Ethanol (flue gas)	#9 - High renewable energy target	0.8771	0	0.0001	0.0171	0.187	3.9204
Ethanol (flue gas)	#10 - Energy target, no food-based or intermediate	6.3438	0	0	0.0145	2.963	36.2223
Ethanol (sugar)	#1 - REDII revision proposal	2.9936	0	0.0001	0.3956	3.0649	15.2348
Ethanol (sugar)	#2 - Lower GHG target	2.6687	0	0	0.1361	2.542	14.8539
Ethanol (sugar)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (sugar)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (sugar)	#5 - No intermediate crops	1.7042	0	0	0.0149	1.1892	9.5726
Ethanol (sugar)	#6 - Higher subtargets	2.1986	0	0	0.0031	1.4811	13.1161
Ethanol (sugar)	#7 - Low EV growth	2.3761	0	0.0004	0.2768	2.228	12.1582
Ethanol (sugar)	#8 - Renewable energy target	2.2828	0	0.0003	0.3259	2.2259	11.5704
Ethanol (sugar)	#9 - High renewable energy target	1.7028	0	0.0001	0.0932	1.3216	9.3592
Ethanol (sugar)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (sugarbeet w/CCS)	#1 - REDII revision proposal	1.8793	0	0.0003	0.1928	1.4748	10.1223
Ethanol (sugarbeet w/CCS)	#2 - Lower GHG target	1.0361	0	0	0.0411	0.6984	5.615
Ethanol (sugarbeet w/CCS)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (sugarbeet w/CCS)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (sugarbeet w/CCS)	#5 - No intermediate crops	2.4097	0	0	0.0448	1.1667	14.1783
Ethanol (sugarbeet w/CCS)	#6 - Higher subtargets	1.2384	0	0	0.0023	0.5538	7.515
Ethanol (sugarbeet w/CCS)	#7 - Low EV growth	2.0203	0	0.0014	0.2075	1.4853	10.9089
Ethanol (sugarbeet w/CCS)	#8 - Renewable energy target	0.2154	0	0	0.0201	0.1784	1.1126
Ethanol (sugarbeet w/CCS)	#9 - High renewable energy target	0.1572	0	0	0.0049	0.0952	0.8475
Ethanol (sugarbeet w/CCS)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (sugarbeet)	#1 - REDII revision proposal	1.5567	0	0	0.194	1.5145	7.7043
Ethanol (sugarbeet)	#2 - Lower GHG target	1.5763	0	0	0.0704	1.4152	8.3649
Ethanol (sugarbeet)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (sugarbeet)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (sugarbeet)	#5 - No intermediate crops	0.7721	0	0	0.0036	0.4594	4.3311
Ethanol (sugarbeet)	#6 - Higher subtargets	1.1801	0	0	0.001	0.7542	6.6674
Ethanol (sugarbeet)	#7 - Low EV growth	1.1532	0	0.0001	0.1172	1.0034	5.8524
Ethanol (sugarbeet)	#8 - Renewable energy target	1.7703	0	0.0002	0.2321	1.7505	8.5855
Ethanol (sugarbeet)	#9 - High renewable energy target	1.2213	0	0	0.0681	0.9414	6.0093
Ethanol (sugarbeet)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (wheat w/CCS)	#1 - REDII revision proposal	0.7438	0	0	0.0554	0.5842	3.7596

Ethanol (wheat w/CCS)	#2 - Lower GHG target	0.7688	0	0	0.0176	0.5267	4.3612
Ethanol (wheat w/CCS)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (wheat w/CCS)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (wheat w/CCS)	#5 - No intermediate crops	0.3863	0	0	0.0008	0.1642	2.0312
Ethanol (wheat w/CCS)	#6 - Higher subtargets	0.5692	0	0	0.0002	0.2688	3.2672
Ethanol (wheat w/CCS)	#7 - Low EV growth	0.5404	0	0	0.0329	0.3938	2.7145
Ethanol (wheat w/CCS)	#8 - Renewable energy target	0.8006	0	0	0.0633	0.6182	3.9433
Ethanol (wheat w/CCS)	#9 - High renewable energy target	0.5292	0	0	0.0145	0.3155	2.6215
Ethanol (wheat w/CCS)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Ethanol (wheat)	#1 - REDII revision proposal	3.9882	0	0.0001	0.4865	4.3042	19.9962
Ethanol (wheat)	#2 - Lower GHG target	4.4477	0	0	0.1981	4.4291	23.961
Ethanol (wheat)	#3 - No food-based biofuels	0	0	0	0	0	0
Ethanol (wheat)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Ethanol (wheat)	#5 - No intermediate crops	1.7356	0	0	0.005	1.027	9.9556
Ethanol (wheat)	#6 - Higher subtargets	3.0868	0	0	0.0021	2.1459	18.2218
Ethanol (wheat)	#7 - Low EV growth	2.7679	0	0.0001	0.2571	2.7025	14.3561
Ethanol (wheat)	#8 - Renewable energy target	5.9873	0	0.0008	0.977	6.7592	29.36
Ethanol (wheat)	#9 - High renewable energy target	4.3296	0	0.0002	0.2614	3.7817	23.7276
Ethanol (wheat)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
FAME (palm)	#1 - REDII revision proposal	0	0	0	0	0	0
FAME (palm)	#2 - Lower GHG target	0	0	0	0	0	0
FAME (palm)	#3 - No food-based biofuels	0	0	0	0	0	0
FAME (palm)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
FAME (palm)	#5 - No intermediate crops	0	0	0	0	0	0
FAME (palm)	#6 - Higher subtargets	0	0	0	0	0	0
FAME (palm)	#7 - Low EV growth	0	0	0	0	0	0
FAME (palm)	#8 - Renewable energy target	0	0	0	0	0	0
FAME (palm)	#9 - High renewable energy target	0	0	0	0	0	0
FAME (palm)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
FAME (rapeseed)	#1 - REDII revision proposal	200.0936	68.944	113.627	196.8335	278.5885	368.0959
FAME (rapeseed)	#2 - Lower GHG target	195.3554	63.3436	103.137	189.2894	277.9872	364.272
FAME (rapeseed)	#3 - No food-based biofuels	0	0	0	0	0	0
FAME (rapeseed)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
FAME (rapeseed)	#5 - No intermediate crops	245.7224	84.564	144.7975	253.5526	342.6647	418.9545
FAME (rapeseed)	#6 - Higher subtargets	207.1873	69.5727	116.4476	206.1804	290.5439	375.1526
FAME (rapeseed)	#7 - Low EV growth	162.0906	52.2484	84.3872	144.2927	227.869	340.4345
FAME (rapeseed)	#8 - Renewable energy target	195.9102	66.278	112.9097	192.5206	270.9869	365.0134
FAME (rapeseed)	#9 - High renewable energy target	147.5566	33.3044	63.1373	124.6384	219.6333	343.8952
FAME (rapeseed)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
FAME (soy intermediate crop)	#1 - REDII revision proposal	117.3278	32.5994	57.7715	104.4759	163.6241	256.401
FAME (soy intermediate crop)	#2 - Lower GHG target	66.2724	12.7821	21.8478	46.0026	93.3631	192.9669
FAME (soy intermediate crop)	#3 - No food-based biofuels	194.8028	67.232	118.1469	196.9349	267.8791	339.6939
FAME (soy intermediate crop)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
FAME (soy intermediate crop)	#5 - No intermediate crops	0	0	0	0	0	0
FAME (soy intermediate crop)	#6 - Higher subtargets	98.3917	25.1013	44.0423	82.1004	136.9058	233.2036
FAME (soy intermediate crop)	#7 - Low EV growth	190.2836	55.9673	104.8941	187.8212	269.7027	356.9846
FAME (soy intermediate crop)	#8 - Renewable energy target	139.1732	41.2866	76.5213	137.253	192.2136	268.9885
FAME (soy intermediate crop)	#9 - High renewable energy target	222.9909	60.5928	116.4617	213.7118	328.3391	433.8087
FAME (soy intermediate crop)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
FAME (soy)	#1 - REDII revision proposal	123.0282	28.5822	49.7722	101.1811	178.618	295.3628
FAME (soy)	#2 - Lower GHG target	119.0024	28.0909	47.4801	97.9361	173.9739	285.2927
FAME (soy)	#3 - No food-based biofuels	0	0	0	0	0	0
FAME (soy)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
FAME (soy)	#5 - No intermediate crops	153.7935	34.3635	62.9493	131.3622	229.891	355.2115
FAME (soy)	#6 - Higher subtargets	128.0734	28.9722	51.307	106.8978	188.7211	306.2545
FAME (soy)	#7 - Low EV growth	101.6023	22.1714	39.0674	79.0793	144.1509	263.1524
FAME (soy)	#8 - Renewable energy target	118.6005	27.3363	47.3536	96.5139	171.2452	285.5095
FAME (soy)	#9 - High renewable energy target	91.2785	15.4158	30.2774	64.4347	130.0019	261.3282
FAME (soy)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
FAME (tallow)	#1 - REDII revision proposal	9.4035	0.07	0.4232	2.0722	8.9808	46.6275
FAME (tallow)	#2 - Lower GHG target	25.4599	1.678	4.0055	13.0376	36.3922	91.4953
FAME (tallow)	#3 - No food-based biofuels	31.2445	2.0827	4.6671	16.0783	46.3015	110.1717
FAME (tallow)	#4 - No food-based or intermediate crops	26.3179	1.4659	3.5303	12.213	37.3303	100.8845
FAME (tallow)	#5 - No intermediate crops	12.9169	0.3717	1.0972	4.0435	14.5025	59.2516
FAME (tallow)	#6 - Higher subtargets	12.1901	0.1657	0.7782	3.3604	13.4527	58.2246
FAME (tallow)	#7 - Low EV growth	5.3854	0.0057	0.0642	0.5803	3.557	28.4258
FAME (tallow)	#8 - Renewable energy target	9.7184	0.0363	0.2771	1.7663	9.2167	49.4168
FAME (tallow)	#9 - High renewable energy target	5.1049	0.0005	0.0163	0.2903	2.7327	28.7649
FAME (tallow)	#10 - Energy target, no food-based or intermediate	30.6354	1.2645	3.8489	14.3763	47.0608	108.7594
FAME (used cooking oil)	#1 - REDII revision proposal	18.3231	0.2394	1.176	5.9999	24.2272	79.7834
FAME (used cooking oil)	#2 - Lower GHG target	39.6232	3.2541	8.4348	26.9063	62.8743	116.7651
FAME (used cooking oil)	#3 - No food-based biofuels	53.9191	4.7938	12.5353	42.1444	88.6971	140.0689
FAME (used cooking oil)	#4 - No food-based or intermediate crops	57.787	5.2947	14.2395	46.7	93.2109	147.5069
FAME (used cooking oil)	#5 - No intermediate crops	37.1333	1.8478	6.4059	22.7909	57.9898	118.6787
FAME (used cooking oil)	#6 - Higher subtargets	22.8482	0.4671	2.0304	8.9265	31.8401	93.7193
FAME (used cooking oil)	#7 - Low EV growth	12.057	0.032	0.2624	2.0867	12.0219	62.844
FAME (used cooking oil)	#8 - Renewable energy target	9.094	0.0333	0.2651	1.7515	8.6282	46.8114

FAME (used cooking oil)	#9 - High renewable energy target	5.187	0.0005	0.016	0.2865	2.9698	30.6834
FAME (used cooking oil)	#10 - Energy target, no food-based or intermediate	30.5092	1.177	3.5766	14.2608	46.228	109.8295
Finished CNG	#1 - REDII revision proposal	155.1004	137.0721	143.7237	151.8515	163.6336	192.0693
Finished CNG	#2 - Lower GHG target	153.2223	138.093	143.9464	151.1022	160.4501	183.6323
Finished CNG	#3 - No food-based biofuels	150.5778	136.631	142.246	148.8161	157.599	179.7048
Finished CNG	#4 - No food-based or intermediate crops	148.311	134.9764	140.5523	146.6037	154.8	175.0798
Finished CNG	#5 - No intermediate crops	167.0804	135.1254	143.0456	154.9643	177.5803	246.0031
Finished CNG	#6 - Higher subtargets	147.7356	129.1676	141.1672	148.8485	157.7905	179.2002
Finished CNG	#7 - Low EV growth	161.2175	136.5407	143.5664	154.222	172.1456	217.484
Finished CNG	#8 - Renewable energy target	147.205	102.0322	130.6232	151.9239	165.0995	192.5921
Finished CNG	#9 - High renewable energy target	148.587	97.6238	125.5391	153.8528	170.6842	198.7597
Finished CNG	#10 - Energy target, no food-based or intermediate	161.5021	139.3273	151.8643	162.2312	174.1915	199.1095
Finished Diesel Fuel	#1 - REDII revision proposal	7121.7473	7045.0397	7092.0909	7131.24	7164.1385	7199.2318
Finished Diesel Fuel	#2 - Lower GHG target	7145.9274	7071.2782	7118.2431	7156.481	7186.9356	7218.4357
Finished Diesel Fuel	#3 - No food-based biofuels	7137.199	7065.0485	7108.8547	7146.7502	7177.5163	7210.6969
Finished Diesel Fuel	#4 - No food-based or intermediate crops	7116.6236	7049.7721	7093.7141	7124.4752	7150.147	7186.4922
Finished Diesel Fuel	#5 - No intermediate crops	7075.1542	6989.4634	7041.6896	7086.422	7120.8473	7162.3227
Finished Diesel Fuel	#6 - Higher subtargets	7142.7321	7078.751	7113.5223	7146.4132	7174.4735	7217.0376
Finished Diesel Fuel	#7 - Low EV growth	7142.3192	7058.8126	7110.6544	7153.354	7186.0627	7221.8303
Finished Diesel Fuel	#8 - Renewable energy target	7167.5196	7078.543	7130.2777	7171.4337	7212.236	7281.9627
Finished Diesel Fuel	#9 - High renewable energy target	7143.2347	7053.924	7099.8366	7146.8729	7190.5873	7255.7768
Finished Diesel Fuel	#10 - Energy target, no food-based or intermediate	7163.8354	7083.4204	7130.2076	7166.5189	7200.6112	7260.733
Finished Gasoline	#1 - REDII revision proposal	1767.6812	1701.7765	1735.7388	1771.3599	1803.4774	1835.0982
Finished Gasoline	#2 - Lower GHG target	1795.7434	1739.9099	1769.2057	1798.9735	1822.99	1857.4088
Finished Gasoline	#3 - No food-based biofuels	1783.6046	1723.5381	1755.3188	1787.907	1815.6227	1844.584
Finished Gasoline	#4 - No food-based or intermediate crops	1767.865	1714.6468	1742.2134	1769.2786	1795.0259	1826.7915
Finished Gasoline	#5 - No intermediate crops	1719.9674	1660.7489	1686.2593	1718.3979	1753.5589	1795.4849
Finished Gasoline	#6 - Higher subtargets	1768.3173	1707.9253	1739.3424	1772.1797	1802.2904	1828.7877
Finished Gasoline	#7 - Low EV growth	1786.33	1725.0261	1757.0569	1790.8541	1818.342	1849.195
Finished Gasoline	#8 - Renewable energy target	1868.0741	1827.901	1845.6372	1861.2168	1884.0377	1943.6223
Finished Gasoline	#9 - High renewable energy target	1886.7264	1848.5905	1860.1198	1877.287	1904.8365	1965.5009
Finished Gasoline	#10 - Energy target, no food-based or intermediate	1851.0494	1810.8647	1832.0797	1849.2956	1866.2635	1915.0998
Finished Hydrogen	#1 - REDII revision proposal	0.0015	0.001	0.0012	0.0014	0.0017	0.0024
Finished Hydrogen	#2 - Lower GHG target	0.0011	0.0008	0.0009	0.001	0.0012	0.0015
Finished Hydrogen	#3 - No food-based biofuels	0.0013	0.0009	0.001	0.0012	0.0015	0.0022
Finished Hydrogen	#4 - No food-based or intermediate crops	0.0033	0.0011	0.0013	0.0019	0.0032	0.0092
Finished Hydrogen	#5 - No intermediate crops	0.0055	0.0014	0.0018	0.0027	0.0049	0.0156
Finished Hydrogen	#6 - Higher subtargets	0.0014	0.0009	0.0011	0.0013	0.0016	0.0021
Finished Hydrogen	#7 - Low EV growth	0.0019	0.0011	0.0014	0.0017	0.0022	0.0034
Finished Hydrogen	#8 - Renewable energy target	0.0006	0.0005	0.0006	0.0006	0.0006	0.0007
Finished Hydrogen	#9 - High renewable energy target	0.0006	0.0006	0.0006	0.0006	0.0006	0.0007
Finished Hydrogen	#10 - Energy target, no food-based or intermediate	0.0006	0.0005	0.0006	0.0006	0.0006	0.0007
Finished Jet Fuel	#1 - REDII revision proposal	1592.6557	1339.6942	1497.8049	1650.7734	1721.9253	1781.8971
Finished Jet Fuel	#2 - Lower GHG target	1620.8518	1357.2046	1521.9284	1686.0178	1757.0101	1818.3697
Finished Jet Fuel	#3 - No food-based biofuels	1612.7035	1353.5038	1513.5101	1671.5341	1751.6693	1813.1459
Finished Jet Fuel	#4 - No food-based or intermediate crops	1619.4545	1370.3811	1530.0254	1671.2998	1748.5954	1812.8501
Finished Jet Fuel	#5 - No intermediate crops	1559.6158	1324.9085	1476.9297	1603.9198	1679.6026	1750.8065
Finished Jet Fuel	#6 - Higher subtargets	1473.6782	1253.3849	1375.8314	1491.5278	1598.6281	1697.0874
Finished Jet Fuel	#7 - Low EV growth	1582.551	1338.065	1492.7047	1638.4157	1708.6103	1770.0993
Finished Jet Fuel	#8 - Renewable energy target	1629.406	1342.2125	1506.42	1699.1317	1790.2942	1857.8807
Finished Jet Fuel	#9 - High renewable energy target	1616.4975	1323.8679	1499.5611	1690.5665	1776.4421	1843.1412
Finished Jet Fuel	#10 - Energy target, no food-based or intermediate	1610.7239	1356.0707	1495.0973	1647.9284	1775.953	1853.7528
Gasoline (BOB)	#1 - REDII revision proposal	1644.5858	1583.2704	1614.8677	1648.0083	1677.8892	1707.308
Gasoline (BOB)	#2 - Lower GHG target	1670.6963	1618.7483	1646.0041	1673.699	1696.0431	1728.065
Gasoline (BOB)	#3 - No food-based biofuels	1660.6304	1603.9071	1633.5435	1664.2821	1690.2235	1721.1692
Gasoline (BOB)	#4 - No food-based or intermediate crops	1648.8165	1596.8887	1623.5618	1649.5187	1674.4198	1710.9743
Gasoline (BOB)	#5 - No intermediate crops	1600.1946	1545.0999	1568.8338	1598.7344	1631.4469	1670.4533
Gasoline (BOB)	#6 - Higher subtargets	1645.1776	1588.9911	1618.2203	1648.771	1676.7849	1701.437
Gasoline (BOB)	#7 - Low EV growth	1661.9359	1604.901	1634.7013	1666.145	1691.7186	1720.4232
Gasoline (BOB)	#8 - Renewable energy target	1737.9877	1700.612	1717.1131	1731.6078	1752.8396	1808.2749
Gasoline (BOB)	#9 - High renewable energy target	1755.341	1719.8608	1730.5873	1746.5589	1772.19	1828.63
Gasoline (BOB)	#10 - Energy target, no food-based or intermediate	1725.5494	1684.817	1704.7611	1720.8959	1737.9307	1805.2226
Green Hydrogen	#1 - REDII revision proposal	0.0015	0.001	0.0012	0.0014	0.0017	0.0024
Green Hydrogen	#2 - Lower GHG target	0.0011	0.0008	0.0009	0.001	0.0012	0.0015
Green Hydrogen	#3 - No food-based biofuels	0.0013	0.0009	0.001	0.0012	0.0015	0.0022
Green Hydrogen	#4 - No food-based or intermediate crops	0.0033	0.0011	0.0013	0.0019	0.0032	0.0092
Green Hydrogen	#5 - No intermediate crops	0.0055	0.0014	0.0018	0.0027	0.0049	0.0156
Green Hydrogen	#6 - Higher subtargets	0.0014	0.0009	0.0011	0.0013	0.0016	0.0021
Green Hydrogen	#7 - Low EV growth	0.0019	0.0011	0.0014	0.0017	0.0022	0.0034
Green Hydrogen	#8 - Renewable energy target	0.0006	0.0005	0.0006	0.0006	0.0006	0.0007
Green Hydrogen	#9 - High renewable energy target	0.0006	0.0006	0.0006	0.0006	0.0006	0.0007
Green Hydrogen	#10 - Energy target, no food-based or intermediate	0.0006	0.0005	0.0006	0.0006	0.0006	0.0007
HVO (crude tall oil)	#1 - REDII revision proposal	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#2 - Lower GHG target	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#3 - No food-based biofuels	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#4 - No food-based or intermediate crops	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#5 - No intermediate crops	44.476	44.476	44.476	44.476	44.476	44.476

HVO (crude tall oil)	#6 - Higher subtargets	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#7 - Low EV growth	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#8 - Renewable energy target	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#9 - High renewable energy target	44.476	44.476	44.476	44.476	44.476	44.476
HVO (crude tall oil)	#10 - Energy target, no food-based or intermediate	44.476	44.476	44.476	44.476	44.476	44.476
HVO (palm)	#1 - REDII revision proposal	0	0	0	0	0	0
HVO (palm)	#2 - Lower GHG target	0	0	0	0	0	0
HVO (palm)	#3 - No food-based biofuels	0	0	0	0	0	0
HVO (palm)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
HVO (palm)	#5 - No intermediate crops	0	0	0	0	0	0
HVO (palm)	#6 - Higher subtargets	0	0	0	0	0	0
HVO (palm)	#7 - Low EV growth	0	0	0	0	0	0
HVO (palm)	#8 - Renewable energy target	0	0	0	0	0	0
HVO (palm)	#9 - High renewable energy target	0	0	0	0	0	0
HVO (palm)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
HVO (rapeseed)	#1 - REDII revision proposal	61.957	4.577	10.8627	36.5758	95.7895	199.1316
HVO (rapeseed)	#2 - Lower GHG target	20.3516	1.496	3.0942	9.4994	27.1904	75.9741
HVO (rapeseed)	#3 - No food-based biofuels	0	0	0	0	0	0
HVO (rapeseed)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
HVO (rapeseed)	#5 - No intermediate crops	37.3762	2.969	6.6374	20.3145	51.9759	127.2915
HVO (rapeseed)	#6 - Higher subtargets	53.2649	3.9121	9.1149	30.934	80.4613	174.519
HVO (rapeseed)	#7 - Low EV growth	88.8398	6.365	15.6484	54.0066	137.4683	280.812
HVO (rapeseed)	#8 - Renewable energy target	74.6921	5.5832	13.8006	46.3161	118.8786	230.0257
HVO (rapeseed)	#9 - High renewable energy target	114.4685	7.5359	20.0607	73.6352	180.531	349.0697
HVO (rapeseed)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
HVO (soy intermediate crop)	#1 - REDII revision proposal	71.7134	4.7194	12.7667	45.7644	113.4117	219.2031
HVO (soy intermediate crop)	#2 - Lower GHG target	11.6332	0.7204	1.4884	4.8146	14.4256	45.1058
HVO (soy intermediate crop)	#3 - No food-based biofuels	49.3992	1.8492	5.285	19.8019	68.7808	194.2716
HVO (soy intermediate crop)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
HVO (soy intermediate crop)	#5 - No intermediate crops	0	0	0	0	0	0
HVO (soy intermediate crop)	#6 - Higher subtargets	49.8531	2.9212	7.7992	28.8927	76.5023	164.2193
HVO (soy intermediate crop)	#7 - Low EV growth	165.6138	18.6947	47.8732	142.6391	265.3928	390.7415
HVO (soy intermediate crop)	#8 - Renewable energy target	94.3034	9.0268	25.0017	76.8496	151.3445	234.5288
HVO (soy intermediate crop)	#9 - High renewable energy target	257.429	37.0193	99.7211	255.2708	405.7349	520.564
HVO (soy intermediate crop)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
HVO (soy)	#1 - REDII revision proposal	61.8217	4.6489	11.2693	37.3438	93.4526	197.4806
HVO (soy)	#2 - Lower GHG target	20.4619	1.5494	3.1432	9.5704	26.3595	79.2306
HVO (soy)	#3 - No food-based biofuels	0	0	0	0	0	0
HVO (soy)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
HVO (soy)	#5 - No intermediate crops	38.1483	3.1427	6.7932	21.0544	53.1524	133.814
HVO (soy)	#6 - Higher subtargets	51.9931	4.0859	9.3132	30.1712	78.3679	168.4891
HVO (soy)	#7 - Low EV growth	86.21	6.1974	15.2626	52.2737	133.2804	278.702
HVO (soy)	#8 - Renewable energy target	77.0884	5.9138	15.2806	50.8682	120.5398	225.3898
HVO (soy)	#9 - High renewable energy target	112.7329	7.3875	20.8509	70.6417	172.5136	359.2513
HVO (soy)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
HVO (tallow)	#1 - REDII revision proposal	27.721	2.6326	5.61	14.3205	38.0681	100.2313
HVO (tallow)	#2 - Lower GHG target	20.4718	2.338	4.5878	11.051	26.4905	74.2708
HVO (tallow)	#3 - No food-based biofuels	13.044	1.6868	2.9981	6.9304	15.7371	46.9276
HVO (tallow)	#4 - No food-based or intermediate crops	10.5975	1.2992	2.3407	5.1454	12.3382	39.3913
HVO (tallow)	#5 - No intermediate crops	17.189	1.496	3.1544	7.8448	21.1091	67.6989
HVO (tallow)	#6 - Higher subtargets	29.3557	2.7975	5.8866	15.3997	40.7689	105.0012
HVO (tallow)	#7 - Low EV growth	28.571	2.4276	5.4066	13.9783	39.2854	105.2319
HVO (tallow)	#8 - Renewable energy target	35.4192	3.9213	8.2391	21.0744	51.4828	115.5248
HVO (tallow)	#9 - High renewable energy target	34.6602	3.7048	7.6056	20.2948	50.957	113.5088
HVO (tallow)	#10 - Energy target, no food-based or intermediate	14.3142	1.2992	2.7584	7.1652	18.6271	52.4183
HVO (used cooking oil)	#1 - REDII revision proposal	107.2142	37.7159	67.9819	112.0881	147.6262	174.5711
HVO (used cooking oil)	#2 - Lower GHG target	78.251	20.5946	37.7627	73.6682	114.4692	158.4506
HVO (used cooking oil)	#3 - No food-based biofuels	66.7586	13.6107	26.0029	57.8883	102.1562	151.5255
HVO (used cooking oil)	#4 - No food-based or intermediate crops	68.9271	13.2011	26.7765	61.0532	106.2628	154.8346
HVO (used cooking oil)	#5 - No intermediate crops	94.7065	28.6662	53.9786	96.3408	134.0294	168.3622
HVO (used cooking oil)	#6 - Higher subtargets	110.1968	36.5138	67.9895	118.5165	153.5513	175.1948
HVO (used cooking oil)	#7 - Low EV growth	115.7968	45.2292	80.1259	122.4599	155.7758	176.4514
HVO (used cooking oil)	#8 - Renewable energy target	92.1385	24.7817	49.7004	95.017	132.0236	167.2274
HVO (used cooking oil)	#9 - High renewable energy target	90.4357	22.7638	46.4826	92.6655	130.9878	166.5992
HVO (used cooking oil)	#10 - Energy target, no food-based or intermediate	44.4287	5.2594	11.6546	31.5126	69.4097	125.3339
Hydrogen (fossil sources)	#1 - REDII revision proposal	0	0	0	0	0	0
Hydrogen (fossil sources)	#2 - Lower GHG target	0	0	0	0	0	0
Hydrogen (fossil sources)	#3 - No food-based biofuels	0	0	0	0	0	0
Hydrogen (fossil sources)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
Hydrogen (fossil sources)	#5 - No intermediate crops	0	0	0	0	0	0
Hydrogen (fossil sources)	#6 - Higher subtargets	0	0	0	0	0	0
Hydrogen (fossil sources)	#7 - Low EV growth	0	0	0	0	0	0
Hydrogen (fossil sources)	#8 - Renewable energy target	0	0	0	0	0	0
Hydrogen (fossil sources)	#9 - High renewable energy target	0	0	0	0	0	0
Hydrogen (fossil sources)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
Kerosene (fossil sources)	#1 - REDII revision proposal	1469.7781	1198.6157	1357.8751	1535.286	1609.8671	1673.472
Kerosene (fossil sources)	#2 - Lower GHG target	1515.8604	1235.0494	1401.2367	1591.26	1661.0802	1720.2585

Kerosene (fossil sources)	#3 - No food-based biofuels	1508.6786	1236.8625	1393.338	1576.2614	1658.6622	1717.9331
Kerosene (fossil sources)	#4 - No food-based or intermediate crops	1519.9957	1258.0793	1417.9464	1583.03	1658.5139	1721.5683
Kerosene (fossil sources)	#5 - No intermediate crops	1447.9824	1195.0223	1348.7137	1500.3126	1578.007	1649.1856
Kerosene (fossil sources)	#6 - Higher subtargets	1349.4238	1124.2274	1247.5116	1364.5231	1481.5545	1590.6573
Kerosene (fossil sources)	#7 - Low EV growth	1439.44	1170.1396	1331.6038	1497.1281	1580.8889	1651.4272
Kerosene (fossil sources)	#8 - Renewable energy target	1478.9847	1141.6234	1335.1266	1552.1045	1668.6743	1742.7948
Kerosene (fossil sources)	#9 - High renewable energy target	1425.273	1047.7889	1265.9576	1501.6848	1634.3347	1719.1857
Kerosene (fossil sources)	#10 - Energy target, no food-based or intermediate	1440.3828	1094.3672	1281.8941	1481.978	1662.6441	1753.0878
Renewable Electricity	#1 - REDII revision proposal	161.6905	129.267	142.9011	162.4126	179.8828	198.4107
Renewable Electricity	#2 - Lower GHG target	142.0044	120.3816	129.2606	141.8132	154.0969	167.9396
Renewable Electricity	#3 - No food-based biofuels	152.9878	124.9115	135.3771	151.8708	168.7059	190.5014
Renewable Electricity	#4 - No food-based or intermediate crops	171.7501	147.4895	161.288	175.3207	184.6355	191.867
Renewable Electricity	#5 - No intermediate crops	198.5555	163.5031	183.0925	203.5785	216.5153	227.4726
Renewable Electricity	#6 - Higher subtargets	156.3454	127.3734	139.8272	156.9995	172.863	188.5061
Renewable Electricity	#7 - Low EV growth	89.695	66.7183	75.1285	88.1547	102.2662	121.6563
Renewable Electricity	#8 - Renewable energy target	106.7182	103.5664	104.6451	106.3753	108.3187	111.4462
Renewable Electricity	#9 - High renewable energy target	107.5738	103.9979	105.3052	107.3281	109.4816	112.5152
Renewable Electricity	#10 - Energy target, no food-based or intermediate	106.9832	103.704	104.7904	106.6662	108.7639	111.7844
SAF (tallow)	#1 - REDII revision proposal	1.8463	0.0038	0.0103	0.0656	0.5887	11.1442
SAF (tallow)	#2 - Lower GHG target	2.0296	0.0042	0.0112	0.0723	0.7282	12.412
SAF (tallow)	#3 - No food-based biofuels	1.7515	0.0024	0.0056	0.0458	0.5495	10.4257
SAF (tallow)	#4 - No food-based or intermediate crops	1.6334	0.0012	0.0031	0.0377	0.4629	9.6631
SAF (tallow)	#5 - No intermediate crops	1.4002	0.0011	0.0036	0.0332	0.3552	7.9695
SAF (tallow)	#6 - Higher subtargets	0.5899	0.003	0.0062	0.0197	0.1113	2.8283
SAF (tallow)	#7 - Low EV growth	1.7381	0.0031	0.0089	0.0564	0.5077	10.5317
SAF (tallow)	#8 - Renewable energy target	3.2746	0.0588	0.1538	0.5684	2.3571	17.1832
SAF (tallow)	#9 - High renewable energy target	3.9485	0.0745	0.1926	0.7413	3.0672	21.1991
SAF (tallow)	#10 - Energy target, no food-based or intermediate	4.2099	0.089	0.2302	0.9852	3.5921	20.0481
SAF (used cooking oil)	#1 - REDII revision proposal	19.0728	0.0578	0.296	7.1337	35.3693	65.8981
SAF (used cooking oil)	#2 - Lower GHG target	18.7341	0.0442	0.2039	6.3218	34.2397	66.1654
SAF (used cooking oil)	#3 - No food-based biofuels	17.5125	0.0291	0.113	4.0345	32.057	65.3862
SAF (used cooking oil)	#4 - No food-based or intermediate crops	18.7452	0.0266	0.1036	5.4081	35.4578	66.8962
SAF (used cooking oil)	#5 - No intermediate crops	18.9006	0.0377	0.1799	5.8882	36.2059	64.8491
SAF (used cooking oil)	#6 - Higher subtargets	6.5291	0.0365	0.11	0.6682	9.2897	31.1077
SAF (used cooking oil)	#7 - Low EV growth	19.4077	0.061	0.3163	7.4946	36.4119	65.8123
SAF (used cooking oil)	#8 - Renewable energy target	35.977	1.2544	5.923	26.9204	56.3057	109.4267
SAF (used cooking oil)	#9 - High renewable energy target	46.0083	1.8077	8.5944	34.8055	68.211	142.6108
SAF (used cooking oil)	#10 - Energy target, no food-based or intermediate	61.1023	2.5707	9.7625	41.4049	100.9579	177.7163
SAF Alcohol-to-Jet (agricultural residues)	#1 - REDII revision proposal	1.3962	0.0486	0.1115	0.3854	1.3862	6.1801
SAF Alcohol-to-Jet (agricultural residues)	#2 - Lower GHG target	1.6012	0.0542	0.1249	0.4329	1.5873	7.2826
SAF Alcohol-to-Jet (agricultural residues)	#3 - No food-based biofuels	1.4031	0.0481	0.1153	0.3975	1.3786	6.1589
SAF Alcohol-to-Jet (agricultural residues)	#4 - No food-based or intermediate crops	1.2279	0.0406	0.0941	0.3054	1.0969	5.2066
SAF Alcohol-to-Jet (agricultural residues)	#5 - No intermediate crops	1.0914	0.0389	0.0916	0.2997	1.0183	4.8209
SAF Alcohol-to-Jet (agricultural residues)	#6 - Higher subtargets	1.9243	0.0572	0.1372	0.4922	1.8208	8.5498
SAF Alcohol-to-Jet (agricultural residues)	#7 - Low EV growth	1.2629	0.0456	0.1022	0.3502	1.2546	5.4377
SAF Alcohol-to-Jet (agricultural residues)	#8 - Renewable energy target	1.8038	0.0656	0.1471	0.5611	2.0632	7.7852
SAF Alcohol-to-Jet (agricultural residues)	#9 - High renewable energy target	1.8525	0.0678	0.1572	0.5938	2.1044	8.0826
SAF Alcohol-to-Jet (agricultural residues)	#10 - Energy target, no food-based or intermediate	3.9322	0.0925	0.2296	0.9251	3.4835	18.2411
SAF Alcohol-to-Jet (corn intermediate crop)	#1 - REDII revision proposal	0.6915	0.0325	0.0687	0.2162	0.7	2.7364
SAF Alcohol-to-Jet (corn intermediate crop)	#2 - Lower GHG target	0.0899	0.0103	0.0181	0.045	0.1139	0.3175
SAF Alcohol-to-Jet (corn intermediate crop)	#3 - No food-based biofuels	0.4056	0.0194	0.0414	0.121	0.3473	1.6828
SAF Alcohol-to-Jet (corn intermediate crop)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF Alcohol-to-Jet (corn intermediate crop)	#5 - No intermediate crops	0	0	0	0	0	0
SAF Alcohol-to-Jet (corn intermediate crop)	#6 - Higher subtargets	0.4348	0.0251	0.0509	0.1526	0.4588	1.6706
SAF Alcohol-to-Jet (corn intermediate crop)	#7 - Low EV growth	2.0893	0.0615	0.1466	0.5087	1.8788	9.0103
SAF Alcohol-to-Jet (corn intermediate crop)	#8 - Renewable energy target	1.1966	0.0423	0.0931	0.314	1.0889	5.298
SAF Alcohol-to-Jet (corn intermediate crop)	#9 - High renewable energy target	4.0301	0.0792	0.2011	0.7371	3.2498	19.2785
SAF Alcohol-to-Jet (corn intermediate crop)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
SAF Alcohol-to-Jet (corn)	#1 - REDII revision proposal	0.8838	0.0411	0.0892	0.288	0.9226	3.4218
SAF Alcohol-to-Jet (corn)	#2 - Lower GHG target	0.2269	0.0183	0.0345	0.0953	0.26	0.8706
SAF Alcohol-to-Jet (corn)	#3 - No food-based biofuels	0	0	0	0	0	0
SAF Alcohol-to-Jet (corn)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF Alcohol-to-Jet (corn)	#5 - No intermediate crops	0.5436	0.0295	0.0614	0.1881	0.569	2.1113
SAF Alcohol-to-Jet (corn)	#6 - Higher subtargets	0.7049	0.0362	0.0756	0.2492	0.7642	2.694
SAF Alcohol-to-Jet (corn)	#7 - Low EV growth	1.3499	0.0507	0.1135	0.3736	1.3005	5.3409
SAF Alcohol-to-Jet (corn)	#8 - Renewable energy target	1.2108	0.0483	0.1049	0.3507	1.1498	5.0578
SAF Alcohol-to-Jet (corn)	#9 - High renewable energy target	1.9033	0.0597	0.1298	0.4533	1.6783	7.8423
SAF Alcohol-to-Jet (corn)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
SAF Alcohol-to-Jet (energy crops)	#1 - REDII revision proposal	1.103	0.0423	0.092	0.3025	1.0437	4.8608
SAF Alcohol-to-Jet (energy crops)	#2 - Lower GHG target	1.2844	0.048	0.1096	0.36	1.2444	5.61
SAF Alcohol-to-Jet (energy crops)	#3 - No food-based biofuels	1.144	0.0423	0.0921	0.3015	1.0693	4.8961
SAF Alcohol-to-Jet (energy crops)	#4 - No food-based or intermediate crops	0.9483	0.034	0.0742	0.2325	0.8539	4.1276
SAF Alcohol-to-Jet (energy crops)	#5 - No intermediate crops	0.8324	0.0331	0.0711	0.2153	0.7316	3.4647
SAF Alcohol-to-Jet (energy crops)	#6 - Higher subtargets	1.5778	0.0491	0.1127	0.3893	1.3508	6.9661
SAF Alcohol-to-Jet (energy crops)	#7 - Low EV growth	0.9956	0.0391	0.0874	0.2809	0.9293	4.2772
SAF Alcohol-to-Jet (energy crops)	#8 - Renewable energy target	1.4444	0.0595	0.128	0.448	1.5967	6.1878
SAF Alcohol-to-Jet (energy crops)	#9 - High renewable energy target	1.5912	0.0603	0.1369	0.4871	1.7358	6.8547

SAF Alcohol-to-Jet (energy crops)	#10 - Energy target, no food-based or intermediate	3.0612	0.0838	0.1989	0.73	2.7808	14.2628
SAF Alcohol-to-Jet (flue gas)	#1 - REDII revision proposal	0.3223	0.0211	0.0416	0.1225	0.3498	1.2413
SAF Alcohol-to-Jet (flue gas)	#2 - Lower GHG target	0.0546	0.0076	0.013	0.0299	0.0711	0.1819
SAF Alcohol-to-Jet (flue gas)	#3 - No food-based biofuels	0.1975	0.0131	0.0264	0.0719	0.1986	0.7584
SAF Alcohol-to-Jet (flue gas)	#4 - No food-based or intermediate crops	1.8168	0.0279	0.0721	0.2523	1.1007	9.4473
SAF Alcohol-to-Jet (flue gas)	#5 - No intermediate crops	3.5014	0.067	0.181	0.6907	2.9939	19.1705
SAF Alcohol-to-Jet (flue gas)	#6 - Higher subtargets	0.2192	0.0167	0.0324	0.0864	0.2388	0.8379
SAF Alcohol-to-Jet (flue gas)	#7 - Low EV growth	0.8278	0.036	0.0776	0.2584	0.8146	3.528
SAF Alcohol-to-Jet (flue gas)	#8 - Renewable energy target	0.1774	0.0143	0.0265	0.0727	0.1947	0.6985
SAF Alcohol-to-Jet (flue gas)	#9 - High renewable energy target	0.4731	0.0242	0.0515	0.1544	0.4742	2.0142
SAF Alcohol-to-Jet (flue gas)	#10 - Energy target, no food-based or intermediate	3.5148	0.0597	0.1589	0.5876	2.6047	20.9375
SAF Alcohol-to-Jet	#1 - REDII revision proposal	2.8604	0.0881	0.2084	0.8008	3.0823	12.5361
SAF Alcohol-to-Jet	#2 - Lower GHG target	0.612	0.0339	0.0695	0.2177	0.6905	2.5299
SAF Alcohol-to-Jet	#3 - No food-based biofuels	0	0	0	0	0	0
SAF Alcohol-to-Jet	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF Alcohol-to-Jet	#5 - No intermediate crops	3.2442	0.098	0.2373	0.9117	3.4952	14.4353
SAF Alcohol-to-Jet	#6 - Higher subtargets	2.1715	0.0743	0.1734	0.6157	2.33	9.4142
SAF Alcohol-to-Jet	#7 - Low EV growth	4.8851	0.1231	0.2988	1.1857	4.7989	21.1172
SAF Alcohol-to-Jet	#8 - Renewable energy target	1.5185	0.0569	0.1224	0.4201	1.4744	6.435
SAF Alcohol-to-Jet	#9 - High renewable energy target	2.3812	0.0644	0.15	0.5868	2.1171	10.1905
SAF Alcohol-to-Jet	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
SAF e-Fuels	#1 - REDII revision proposal	48.0178	11.8348	12.2562	32.3242	84.6708	113.1534
SAF e-Fuels	#2 - Lower GHG target	49.0348	12.1037	12.5573	35.674	84.5028	113.7489
SAF e-Fuels	#3 - No food-based biofuels	52.5424	12.1479	12.6596	41.9426	90.8257	114.2022
SAF e-Fuels	#4 - No food-based or intermediate crops	51.5462	12.1064	12.6305	39.8869	89.3735	113.6268
SAF e-Fuels	#5 - No intermediate crops	48.0818	11.5147	12.0175	33.4122	85.0594	112.4956
SAF e-Fuels	#6 - Higher subtargets	60.219	34.0265	37.4681	42.213	87.3313	113.369
SAF e-Fuels	#7 - Low EV growth	48.1482	11.737	12.1598	32.6304	85.8986	112.98
SAF e-Fuels	#8 - Renewable energy target	51.1501	12.3605	12.8514	40.2086	87.3655	114.804
SAF e-Fuels	#9 - High renewable energy target	47.7879	12.0363	12.5101	30.7014	85.7886	114.1008
SAF e-Fuels	#10 - Energy target, no food-based or intermediate	39.7635	11.3701	12.4493	21.9597	61.4633	112.0895
SAF Fischer-Tropsch (agricultural residues)	#1 - REDII revision proposal	3.2208	0.0951	0.2309	0.9102	3.4959	15.0717
SAF Fischer-Tropsch (agricultural residues)	#2 - Lower GHG target	3.2296	0.0949	0.23	0.9087	3.5422	15.1158
SAF Fischer-Tropsch (agricultural residues)	#3 - No food-based biofuels	3.112	0.0938	0.2232	0.8619	3.3496	14.493
SAF Fischer-Tropsch (agricultural residues)	#4 - No food-based or intermediate crops	3.0328	0.091	0.2187	0.8358	3.2384	14.2186
SAF Fischer-Tropsch (agricultural residues)	#5 - No intermediate crops	3.0165	0.0936	0.2219	0.8392	3.1634	13.9542
SAF Fischer-Tropsch (agricultural residues)	#6 - Higher subtargets	4.2491	0.1125	0.2718	1.108	4.3149	19.7472
SAF Fischer-Tropsch (agricultural residues)	#7 - Low EV growth	3.1023	0.0948	0.2267	0.8809	3.2841	14.5381
SAF Fischer-Tropsch (agricultural residues)	#8 - Renewable energy target	3.0358	0.0945	0.2311	0.8811	3.3834	13.8756
SAF Fischer-Tropsch (agricultural residues)	#9 - High renewable energy target	3.1861	0.1004	0.2463	0.9584	3.5941	14.0268
SAF Fischer-Tropsch (agricultural residues)	#10 - Energy target, no food-based or intermediate	6.4477	0.133	0.3358	1.4326	6.3034	31.5419
SAF Fischer-Tropsch (energy crops)	#1 - REDII revision proposal	2.1954	0.0737	0.173	0.6196	2.3374	10.0239
SAF Fischer-Tropsch (energy crops)	#2 - Lower GHG target	2.2797	0.0763	0.1794	0.6402	2.4407	10.4755
SAF Fischer-Tropsch (energy crops)	#3 - No food-based biofuels	2.2096	0.0738	0.1722	0.6093	2.374	10.3849
SAF Fischer-Tropsch (energy crops)	#4 - No food-based or intermediate crops	2.0812	0.0692	0.1562	0.5428	2.1105	10.0161
SAF Fischer-Tropsch (energy crops)	#5 - No intermediate crops	2.0717	0.0729	0.1721	0.5965	2.1995	9.476
SAF Fischer-Tropsch (energy crops)	#6 - Higher subtargets	2.9532	0.0851	0.2048	0.7339	2.848	14.1703
SAF Fischer-Tropsch (energy crops)	#7 - Low EV growth	2.1375	0.0743	0.1745	0.6162	2.3043	9.745
SAF Fischer-Tropsch (energy crops)	#8 - Renewable energy target	2.1369	0.0726	0.1642	0.6154	2.2782	9.7596
SAF Fischer-Tropsch (energy crops)	#9 - High renewable energy target	2.2404	0.0786	0.1808	0.6599	2.4278	10.2186
SAF Fischer-Tropsch (energy crops)	#10 - Energy target, no food-based or intermediate	4.7992	0.1111	0.2741	1.0605	4.2059	21.9709
SAF Fischer-Tropsch (municipal solid waste)	#1 - REDII revision proposal	20.1051	0.6736	2.0876	10.0286	33.8959	64.828
SAF Fischer-Tropsch (municipal solid waste)	#2 - Lower GHG target	19.7354	0.6735	2.0847	10.5054	33.347	62.5357
SAF Fischer-Tropsch (municipal solid waste)	#3 - No food-based biofuels	19.0307	0.6619	1.9528	9.6969	32.6289	60.3988
SAF Fischer-Tropsch (municipal solid waste)	#4 - No food-based or intermediate crops	18.427	0.6231	1.8675	9.3938	31.2957	59.8106
SAF Fischer-Tropsch (municipal solid waste)	#5 - No intermediate crops	19.8496	0.6483	1.9496	9.457	33.048	64.7399
SAF Fischer-Tropsch (municipal solid waste)	#6 - Higher subtargets	26.0571	0.791	2.4176	12.7059	38.6379	89.9734
SAF Fischer-Tropsch (municipal solid waste)	#7 - Low EV growth	19.8681	0.6379	1.8914	9.766	33.2691	65.0815
SAF Fischer-Tropsch (municipal solid waste)	#8 - Renewable energy target	19.1714	0.5456	1.5806	8.4116	29.9021	66.9714
SAF Fischer-Tropsch (municipal solid waste)	#9 - High renewable energy target	21.5902	0.6518	1.7966	9.5714	31.4069	82.9366
SAF Fischer-Tropsch (municipal solid waste)	#10 - Energy target, no food-based or intermediate	43.5104	0.9029	2.903	16.9064	66.2959	166.4394
SAF HEFA (palm)	#1 - REDII revision proposal	0	0	0	0	0	0
SAF HEFA (palm)	#2 - Lower GHG target	0	0	0	0	0	0
SAF HEFA (palm)	#3 - No food-based biofuels	0	0	0	0	0	0
SAF HEFA (palm)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF HEFA (palm)	#5 - No intermediate crops	0	0	0	0	0	0
SAF HEFA (palm)	#6 - Higher subtargets	0	0	0	0	0	0
SAF HEFA (palm)	#7 - Low EV growth	0	0	0	0	0	0
SAF HEFA (palm)	#8 - Renewable energy target	0	0	0	0	0	0
SAF HEFA (palm)	#9 - High renewable energy target	0	0	0	0	0	0
SAF HEFA (palm)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
SAF HEFA (rapeseed)	#1 - REDII revision proposal	6.8495	0.6941	1.2837	3.2172	8.6436	24.1976
SAF HEFA (rapeseed)	#2 - Lower GHG target	2.4554	0.3415	0.5927	1.361	3.1875	8.035
SAF HEFA (rapeseed)	#3 - No food-based biofuels	0	0	0	0	0	0
SAF HEFA (rapeseed)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF HEFA (rapeseed)	#5 - No intermediate crops	4.6218	0.5127	0.918	2.2604	5.8069	16.5044
SAF HEFA (rapeseed)	#6 - Higher subtargets	5.8452	0.6309	1.1527	2.8293	7.3771	20.6313

SAF HEFA (rapeseed)	#7 - Low EV growth	9.4428	0.8347	1.592	4.1519	11.6652	33.92
SAF HEFA (rapeseed)	#8 - Renewable energy target	8.8067	0.7639	1.4671	3.9179	10.6667	32.9898
SAF HEFA (rapeseed)	#9 - High renewable energy target	12.2522	0.9203	1.784	4.8867	13.8662	47.1154
SAF HEFA (rapeseed)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
SAF HEFA (soy intermediate crop)	#1 - REDII revision proposal	7.5777	0.5281	1.0644	3.0495	8.3724	29.3116
SAF HEFA (soy intermediate crop)	#2 - Lower GHG target	1.2143	0.174	0.2912	0.6419	1.5411	4.1245
SAF HEFA (soy intermediate crop)	#3 - No food-based biofuels	4.7162	0.3213	0.6349	1.6372	4.7693	18.8535
SAF HEFA (soy intermediate crop)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF HEFA (soy intermediate crop)	#5 - No intermediate crops	0	0	0	0	0	0
SAF HEFA (soy intermediate crop)	#6 - Higher subtargets	5.1509	0.3939	0.7614	2.1197	5.7385	20.1035
SAF HEFA (soy intermediate crop)	#7 - Low EV growth	18.4993	0.9621	2.063	6.4456	20.7436	77.3596
SAF HEFA (soy intermediate crop)	#8 - Renewable energy target	11.1712	0.6844	1.3799	3.9536	12.4801	47.6823
SAF HEFA (soy intermediate crop)	#9 - High renewable energy target	30.2344	1.2455	2.8354	9.887	33.2933	129.8587
SAF HEFA (soy intermediate crop)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0
SAF HEFA (soy)	#1 - REDII revision proposal	6.7348	0.6953	1.2481	3.2281	8.4381	24.0724
SAF HEFA (soy)	#2 - Lower GHG target	2.4096	0.3527	0.5919	1.3339	3.1402	7.9645
SAF HEFA (soy)	#3 - No food-based biofuels	0	0	0	0	0	0
SAF HEFA (soy)	#4 - No food-based or intermediate crops	0	0	0	0	0	0
SAF HEFA (soy)	#5 - No intermediate crops	4.4782	0.5219	0.9294	2.3085	5.6796	15.7273
SAF HEFA (soy)	#6 - Higher subtargets	5.6283	0.6179	1.1043	2.7785	7.1654	19.4258
SAF HEFA (soy)	#7 - Low EV growth	9.3564	0.8339	1.5967	4.1933	11.3083	34.897
SAF HEFA (soy)	#8 - Renewable energy target	8.3462	0.7854	1.4914	3.9582	10.2201	31.2766
SAF HEFA (soy)	#9 - High renewable energy target	11.7451	0.9124	1.7942	4.9303	13.2954	44.4605
SAF HEFA (soy)	#10 - Energy target, no food-based or intermediate	0	0	0	0	0	0

TABLE E.1: Detailed fuel quantity results (all units are in billion MJ).

Bibliography

[1] European Commission. *Communication from the Commission: The European Green Deal*. Dec. 2019. URL: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

[2] European Commission. *Delivering the European Green Deal*. URL: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en.

[3] European Commission. *Proposal for a Directive of the European Parliament and of the council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*. July 2021. URL: https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf.

[4] European Commission. *Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport*. July 2021. URL: https://ec.europa.eu/info/sites/default/files/refueleu_aviation_-_sustainable_aviation_fuels.pdf.

[5] European Commission. *Proposal for a Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC*. July 2021. URL: https://ec.europa.eu/info/sites/default/files/fueleu_maritime_-_green_european_maritime_space.pdf.

[6] European Commission. *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources*. July 2021. URL: https://ec.europa.eu/energy/topics/renewable-energy/directive-targets-and-rules/renewable-energy-directive_en.

[7] European Commission. *Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people*. URL: https://ec.europa.eu/clima/sites/clima/files/eu-climate-action/docs/impact_en.pdf.

[8] Thomas Rutherford. *Lecture notes on constant elasticity functions*. Nov. 2002. URL: http://www.gamsworld.org/mpsge/debreu/ces.pdf.

[9] Hugo Valin et al. "The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts". In: (2015). Publisher: Ecofys Netherlands BV. URL: https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf.

[10] Mohamed Amine Bouhlel et al. "A Python surrogate modeling framework with derivatives". In: *Advances in Engineering Software* (2019), p. 102662. ISSN: 0965-9978. DOI: https://doi.org/10.1016/j.advengsoft.2019.03.005.

[11] D Peters and V Stojcheva. "Crude Tall Oil Low ILUC Risk Assessment—Comparing Global Supply and Demand". In: *ECOFYS Netherlands BV: Utrecht, The Netherlands* (2017), pp. 1–23.

[12] Chelsea Baldino et al. "The potential for low carbon renewable methane as a transport fuel in France, Italy, and Spain". In: *Working Paper* 2018-28 (2018). URL: https://theicct.org/sites/default/files/publications/Biogas_potential_FR_IT_ES_20181109.pdf.

[13] LanzaTech. *Technical background on the LanzaTech process*. URL: http://www.arpae-summit.com/paperclip/exhibitor_docs/14AE/LanzaTech_Inc._131.pdf.

[14] *CO2 reduction and biofuels in Germany's transport sector - implementing the RED II directive*. en. Nov. 2020. URL: https://www.cleanenergywire.org/factsheets/co2-reduction-and-biofuels-germanys-transport-sector-implementing-red-ii-directive (visited on 08/05/2021).

[15] European Commission. *2030 Climate Target Plan*. en. Text. Sept. 2020. URL: https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en (visited on 08/05/2021).

[16] Bert Smit et al. *Adoption of cover crops for climate change mitigation in the EU*. Tech. rep. Joint Research Centre (Seville site), 2019. URL: https://op.europa.eu/en/publication-detail/-/publication/0638ab96-f939-11e9-8c1f-01aa75ed71a1.

[17] Kaley Hart et al. *Evaluation study of the payment for agricultural practices beneficial for the climate and the environment*. Tech. rep. Joint Research Centre (Seville site), Nov. 2017. URL: https://op.europa.eu/en/publication-detail/-/publication/0638ab96-f939-11e9-8c1f-01aa75ed71a1.

[18] Soybean and Corn Advisor. *Conab - 2020/21 Brazilian Soy Production up 7.1%, Corn up 2.6%*. URL: http://www.soybeansandcorn.com/news/Oct9_20-Conab-202021-Brazilian-Soy-Production-up-7_1-Corn-up-2_6.

[19] Food and Agriculture Organization of the United Nations. *FAO/OECD: Latin America and the Caribbean will account for 25 % of global agricultural and fisheries exports by 2028*. URL: http://www.fao.org/americas/noticias/ver/en/c/1200912/.

[20] Allison Borchers et al. "Multi-cropping practices: recent trends in double-cropping". In: (2014). URL: https://www.ers.usda.gov/webdocs/publications/43862/46871_eib125.pdf?v=41787.

[21] European Commission. *DRAFT rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land-use change-risk criteria*. URL: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12723-Sustainable-biofuels-bioliquids-and-biomass-fuels-voluntary-schemes-implementing-rules-_en.

[22] Energy Information Administration. *Gasoline prices tend to have little effect on demand for car travel*. URL: https://www.eia.gov/todayinenergy/detail.php?id=19191.

[23] InterVISTAS Consulting Inc. *Estimating Air Travel Demand Elasticities*. Tech. rep. Dec. 2007. URL: https://www.iata.org/en/iata-repository/publications/economic-reports/estimating-air-travel-demand-elasticities---by-intervistas/.

[24] European Commission. *Weekly Oil Bulletin*. URL: https://ec.europa.eu/energy/data-analysis/weekly-oil-bulletin_en.

[25] Dan Rutherford et al. "Potential tankering under an EU sustainable aviation fuels mandate". In: (2021). URL: https://theicct.org/publications/tankering-eu-SAF-mandate-apr2021.

[26] Eurostat. *Prices of natural gas and electricity*. URL: https://ec.europa.eu/eurostat.

[27] Neste Oil. *Biodiesel prices (SME & FAME)*. URL: https://www.neste.com/investors/market-data/biodiesel-prices-sme-fame#2e6c0fc6.

[28] USDA Economic Research Service. *Oil Crops Yearbook*. URL: https://www.ers.usda.gov/data-products/oil-crops-yearbook/.

[29] Nikita Pavlenko, Stephanie Searle, and Adam Christensen. "The cost of supporting alternative jet fuels in the European Union". In: *International Council on Clean Transportation (ICCT), Washington DC, USA* (2019). URL: https://theicct.org/sites/default/files/publications/Alternative_jet_fuels_cost_EU_2020_06_v3.pdf.

[30] International Civil Aviation Organization. *CORSIA Eligible Fuels – Life Cycle Assessment Methodology*. Tech. rep. June 2019. URL: https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA%20Supporting%20Document_CORSIA%20Eligible%20Fuels_LCA%20Methodology.pdf.

[31] Stephanie Searle et al. "Potential greenhouse gas savings from a 2030 greenhouse gas reduction target with indirect emissions accounting for the European Union". In: (2017). URL: https://theicct.org/publications/potential-greenhouse-gas-savings-2030-greenhouse-gas-reduction-target-indirect.

[32] Stephanie Searle and Adam Christensen. "Decarbonization potential of electrofuels in the European Union". In: (2018). URL: https://theicct.org/publications/decarbonization-potential-electrofuels-eu.

[33] P. Schmidt et al. *Power to Liquids: Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel*. Tech. rep. German Environment Agency (Umwelt Bundesamt), 2016.

[34] Chelsea Baldino et al. *Hydrogen for heating? Decarbonization options for households in the United Kingdom in 2050*. 2020. URL: https://theicct.org/sites/default/files/publications/Hydrogen-heating-UK-dec2020.pdf.

[35] Michael Penev, Jarett Zuboy, and Chad Hunter. "Economic analysis of a high-pressure urban pipeline concept (HyLine) for delivering hydrogen to retail fueling stations". In: *Transportation Research Part D: Transport and Environment* 77 (2019). Publisher: Elsevier, pp. 92–105.

[36] Adam Christensen. "Assessment of hydrogen production costs from electrolysis: United States and Europe". In: *International Council on Clean Transportation: Washington, DC, USA* (2020), pp. 1–73. URL: https://theicct.org/publications/assessment-hydrogen-production-costs-electrolysis-united-states-and-europe.

[37] M Mann and P Spath. *Life Cycle Assessment of Renewable Hydrogen Production via Wind/Electrolysis: Milestone Completion Report*. Tech. rep. National Renewable Energy Lab., Golden, CO.(US), 2004.

[38] Robert Edwards et al. "WELL-TO-WHEELS Report Version 4. a JEC WELL-TO-WHEELS ANALYSIS". In: *Institute for Energy and Transport, Joint Research Centre, Luxembourg: Publications Office of the European Union* 2014 (2014). URL: https://www.researchgate.net/profile/Laura-Lonza/publication/280566047_JEC_Well-to-Wheels_Report_Version_4a/links/55ba1d6808aec0e5f43e8a97/JEC-Well-to-Wheels-Report-Version-4a.pdf.

[39] Adam Brown et al. "Advanced Biofuels—Potential for Cost Reduction". In: *IEA Bioenergy* 88 (2020). URL: https://www.ieabioenergy.com/wp-content/uploads/2020/02/IEABioenergy-2pSummary-CostAdvancedBiofuels.pdf.

[40] F Mueller-Langer et al. "Techno-economic assessment of hydrogen production processes for the hydrogen economy for the short and medium term". In: *International journal of hydrogen energy* 32.16 (2007). Publisher: Elsevier, pp. 3797–3810. URL: https://www.sciencedirect.com/science/article/abs/pii/S0360319907003011.

[41] Nils Johnson, Nathan Parker, and Joan Ogden. "How negative can biofuels with CCS take us and at what cost? Refining the economic potential of biofuel production with CCS using spatially-explicit modeling". In: *Energy Procedia* 63 (2014). Publisher: Elsevier, pp. 6770–6791. URL: https://www.sciencedirect.com/science/article/pii/S1876610214025272.

[42] Argonne National Laboratory. *The Greenhouse Gases, Regulated Emissions, and Energy use in Technologies Model (GREET)*. 2019. URL: https://greet.es.anl.gov/.

[43] Stergios Zacharakis and Chrysa Glystra. "European ETBE premium to MTBE reaches historic high". In: *S&P Global Platts* (Jan. 2020). URL: https://www.spglobal.com/platts/en/market-insights/latest-news/agriculture/012320-european-etbe-premium-to-mtbe-reaches-historic-high.