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Assessing the potential advanced alternative fuel volumes in the Netherlands in 2030

Authors: Nikita Pavlenko and Stephanie Searle

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Introduction

The Netherlands recently released a National Climate Agreement which contains a long-term commitment to supporting sustainable biofuels and deep decarbonization.[1] The agreement lays out an ambitious path towards reducing emissions to 49% of its 1990 levels by 2030, thereby meeting its Paris Climate Accord commitment. To do this, the government intends to increase the amount electricity produced with renewable energy to 70%, along with an additional 0.64 MtoE (27 PJ) of renewable energy from advanced biofuels supplied to the road transport sector. The agreement specifies that this additional renewable energy for transport must come from sustainable wastes and residues and is in addition to separate contributions for electromobility and crop-derived fuels. The government plans to use €200 million to support advanced biofuels and electrofuels through the Stimulation of Sustainable Energy Production scheme (SDE++) program.

Meeting the transportation fuels component of the National Climate Agreement will be done primarily through the implementation of the recast EU Renewable Energy Directive (RED II), which establishes a renewable energy target of 27% by 2030 for the European Union, and a 14% sub-target for renewable energy consumption in the road and rail sectors.[2] The 2020 RED, as amended in 2015, established a 0.5% advanced biofuels sub-target.[3] The RED II expands the RED requirement, increasing the advanced biofuels sub-target to 3.5% of transport energy for 2030. The RED II implements limits on the contribution of food-based biofuels to the overall transport target of 7% or less, as well

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[1] Government of the Netherlands, "National Climate Agreement," June 28, 2019, https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord.

[2] Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast), Official Journal of the European Union, L 328/82, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

[3] Directive (EU) 2015/1513 of the European Parliament and of the Council of 9th September, 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources, Official Journal of the European Union. L 239/1, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN

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as a declining cap on the contribution of feedstocks with a high risk of indirect land-use change (ILUC).

Fuels produced from the approved feedstocks listed Annex IX of the RED II will double-count towards the 14% target. List A of the Annex includes a mix of lignocellulosic energy crops, wastes, and residues which can be used in any quantity. In contrast, List B, which includes used cooking oil (UCO), and animal fats, is capped to contributing to 1.7% of the overall target. Only advanced biofuels produced from feedstocks listed in Annex IX list A count towards the 0.5 and 3.5% advanced biofuel targets in 2020 and 2030, respectively, and they are double-counted towards the 3.5% transportation sub-target. Renewable electricity supplied to the road and rail sectors can also count towards the 14% target, and receive credit multipliers of 4 and 1.5, respectively. Multipliers for electricity supplied to transport are intended to account for the difference in energy efficiency between electric motors and internal combustion engines.

The implementation of the RED II in the Netherlands will necessitate large changes to its policy support for biofuels, which has thus far resulted in negligible quantities of fuels produced from lignocellulosic wastes and residues. Currently, the Netherlands utilizes a biofuel quota of 16.4% overall renewable energy (including multipliers) and a 1% advanced fuels sub-target to support its 2020 RED target.[4] The policy also includes a cap of 5% on the contribution of crop-based fuels in 2020. Fuel suppliers are obligated to meet these mandates and non-compliance is penalized with a variable penalty.[5] While the Netherlands already meets approximately 72% of its renewable energy transport share from wastes, this is met primarily from UCO and animal fats whose contribution is capped under the RED II Annex IX List B.[6] Furthermore, less than 10% of the biofuels used for domestic consumption are derived from domestic raw materials.[7] As the government evaluates the scale and design of its policies, there is an opportunity to increase the contribution of domestic resources to meet the Netherlands' advanced biofuels targets.

This working paper estimates the volumes of advanced, non-food based fuels that could contribute to the Netherlands' RED II obligation in 2030 using mostly domestic resources.[8] While it is possible to meet national-level targets for alternative fuels by importing feedstocks from abroad, this option fails to take into account the limited global availability of these materials. Consequently, we use domestic resource availability as a proxy for that country's share of a given limited resource. These projections are intended to inform policymaking for the 2021-2030 time period by illustrating the production cost, feedstock availability, and potential facility deployment for a variety of fuel pathways with varying levels of policy support.

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[4] Dutch Emissions Authority, "Obligations-Energy for Transport," (2020), https://www.emissionsauthority.nl/topics/obligations---energy-for-transport/annual-obligation

[5] European Renewable Ethanol (EPURE), "Overview of Biofuel Policies and Markets across the EU-28," (EPURE: Brussels, 2018), https://www.epure.org/media/1738/epure-overview-of-biofuels-polices-and-markets-across-the-eu-28-2018-update.pdf

[6] Dutch Emissions Authority, "Rapportage Energie Voor Vervoer in Nederland 2018 Naleving Verplichtingen Wet- En Regelgeving Energie Voor Vervoer [Energy for Transport Report in the Netherlands 2018 Compliance with Laws and Regulations for Energy for Transport]," (2018), https://www.rijksoverheid.nl/documenten/rapporten/2019/07/04/rapportage-energie-voor-vervoer-in-nederland-2018

[7] Ibid.

[8] Due to the slow deployment of cellulosic conversion facilities relative to feedstock supply, some nearby EU Member States will likely have agricultural residues in excess of their technology deployment rate in 2030; therefore, we assume that there will be sufficient imports to support one commercial scale cellulosic ethanol facility.

Methodology

Pathways and scenarios

This analysis only includes alternative fuels that could be produced from feedstocks available within the Netherlands, focusing on the eligible fuels and feedstocks in the RED II. We include fuel pathways that we believe are most likely to operate at a commercial scale in the Netherlands in the 2030 timeframe. The list of pathways and technologies assessed is illustrated in Table 1 alongside the crediting that each fuel pathway receives relative to the deployment targets in the RED II. While tall oil is a large contributor to the Netherlands' present RED compliance, it is not included as a relevant feedstock for this analysis as it is entirely imported.[9] It is not likely that the Netherlands will produce tall oil in the 2030 timeframe because the country does not produce wood pulp, from which tall oil is produced as a byproduct.

Table 1. Summary of Fuel Conversion Pathways & RED II Crediting for this Analysis

Technology	Feedstock	Counts towards advanced biofuel sub-target	Multiple counting
Cellulosic Ethanol	Agricultural residues	Yes	2x
	Energy crops and short-rotation woody crops		
Biodiesel and hydrotreated renewable diesel	Used cooking oil	No	
	Animal Fats		
Synthetic diesel (gasification and Fischer-Tropsch)	Agricultural residues	Yes	
	Energy crops and wood		
	Forestry residues		
	Biological fraction of municipal solid waste		
Electrolysis and fuel synthesis	Renewable electricity	No	N/A
Flue gas fermentation	Industrial flue gas	No	N/A
Electricity in road sector	Renewable electricity	No	4x
Biomethane	Livestock manure and Sewage Sludge	Yes	2x

We assess the potential volumes of these fuels at varying production cost levels. None of the pathways assessed here would be cost competitive with fossil fuels without policy support; we thus present the results in terms of the support that would be needed to make these fuel pathways economically viable. These scenarios are defined as:

- Low policy support (€0.50 per diesel-equivalent liter)
- Medium policy support (€1.00 per diesel-equivalent liter)
- High policy support (€2.00 per diesel-equivalent liter)

This analysis assumes the policy support is provided as a stable, long-term incentive over the entire time period 2021-2030. This may either take the form of a direct production incentive or a non-compliance penalty, as in the current biofuel quota. For example, the high policy support scenario reflects a €2.00 per liter incentive that is established in 2020 for the entire 2021-2030 timeframe without any need for re-authorization by policymakers. In reality, the perceived value of incentives tend to be less stable than this example and may be discounted by investors evaluating the cashflow of a proposed advanced biorefinery over a 10 or 15-year lifetime.[10]

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[9] Ibid.

[10] Nikita Pavlenko, Stephanie Searle, Chris Malins, and Sammy El Takriti, *Development and Analysis of a Durable Low-Carbon Fuel Investment Policy for California,* (ICCT: Washington, DC, 2016), https://www.theicct.org/sites/default/files/publications/California%20Contracts%20for%20Difference_white-paper_ICCT_102016.pdf

Overall methodological approach

This assessment utilizes a supply-constrained approach to estimate the production of advanced alternative fuels at the three incentive levels described above. This analysis utilizes feedstock availability, blending constraints, and technology readiness as the primary constraints on advanced alternative fuel production in the 2030 timeframe. Given that other EU Member States are in the process of implementing their own national policies and that the total supply of sustainably available biomass, particularly wastes & residues, is highly constrained, shifting biomass resources from one country to another may make other countries' decarbonization more difficult.[11] Therefore, this analysis focuses on the contribution of domestic feedstocks or fuels towards the RED II targets, except for a modest quantity of imported agricultural residues from adjacent member states.

We draw upon Searle and Christensen, and Baldino et al. to estimate the cost-constrained potential volumes for electrofuels, such as power-to-liquids and power-to-gas, and biomethane.[12]

Vehicle electrification

The contribution of renewable energy used for electric vehicle charging towards the RED II target is assumed to be influenced by policy support for electric vehicles (EVs). To estimate the quantity of electric vehicles in the Netherlands through 2030 and their energy demand the light-duty vehicle fleet turnover model developed by Lutsey is used in conjunction with the Netherlands' proposed EV sales targets for 2030.[13] Lutsey projects that the EV sales share of the light-duty fleet will be 70% by 2030, for a cumulative total of 1.9 million EVs in the Netherlands that year.[14] Based on the distribution of vehicle ages and annual kilometers-travelled estimated through the fleet turnover model, we project that the passenger EV electricity consumption will total 4.9 billion kWh (12.4 PJ) in 2030. Because only the renewable share of charging is counted towards the RED II, we use the Netherlands' renewable electricity target of 70% for the renewable share of EV charging.[15] We then quadruple-count this pathway towards the overall 14% transport energy target.

Blend limits

For fuels with blending constraints such as ethanol, we assume that advanced fuels take precedence over food-based fuels. While historically, first-generation biofuels have been the preferred method of compliance due to lower costs, in this analysis we assume advanced fuels will be used to meet the mandate independently of food-based biofuel consumption. The estimate of transport sector energy demand from 2020 through 2030

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[11] Stephanie Searle and Chris Malins, "Waste and Residue Availability for Advanced Biofuel Production in EU Member States," *Biomass and Bioenergy. No. 89*, June 2016, 2-10, https://doi.org/10.1016/j.biombioe.2016.01.008

[12] Stephanie Searle and Adam Christensen, *Decarbonization Potential of Electrofuels in the European Union,* (ICCT: Washington, DC. 2018), https://theicct.org/sites/default/files/publications/Electrofuels_Decarbonization_EU_20180920.pdf; Chelsea Baldino, Nikita Pavlenko, Stephanie Searle, and Adam Christensen, *The Potential for Low-Carbon Renewable Methane in Heating, Power and Transportation in the European Union,* (ICCT: Washington, DC 2018), https://theicct.org/sites/default/files/publications/Renewable_Gas_EU-28_20181016.pdf

[13] Nic Lutsey. *Global Climate Change Mitigation Potential from a Transition to Electric Vehicles,* (ICCT: Washington, DC, 2018), http://theicct.org/global-ev-2050-ghg-mitigation-potential

[14] Electrification of the heavy-duty vehicle sector and off-road machinery was excluded from this analysis due to data gaps on the quantity of electrified vehicles from these sectors in the Netherlands in 2030 and their projected energy consumption

[15] Government of the Netherlands, "National Climate Agreement," June 28, 2019, https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord.

is drawn from the projections for total road fuel demand, gasoline blend demand, and diesel blend demand from the 2016 EU Reference Scenario.[16]

We assume a 10% ethanol blend wall for ethanol supplied by conventional fueling stations and consumed in vehicles. For higher blends like 85% ethanol (E85), we assume that 2% of the total amount of gasoline blend supplied is E85.[17] This constrains the overall potential blend rate of ethanol in gasoline to approximately 11%.

We do not factor blend limits into our assessment of diesel substitutes. The two eligible feedstocks in this analysis that might commonly be used to produce fatty acid methyl ester (FAME) biodiesel, used cooking oil and animal fats, can instead be processed into hydrotreated renewable diesel, a drop-in fuel that can be blended without any technical or operational constraints.

Cost assessment

We assume that fuels will only be supplied if their levelized cost, including any incentives, is equal to or lesser than the untaxed price of conventional, petroleum-derived fuels. We assess three fixed incentive levels for alternative fuels, defined above. Feedstocks that can be converted into fuel using existing, commercial scale technologies such as transesterification to produce biodiesel or hydrotreating to produce renewable diesel are assumed to be viable at the lowest incentive level, as they are already in production with the aid of existing incentives.

A discounted cashflow model is used to estimate the levelized cost for producing advanced fuels with few, or no, existing commercial-scale facilities. The cost modeling for this assessment is performed using data on the capital costs of second-generation biofuel production facilities from Peters et al. and Yao et al., in conjunction with the cashflow modeling approach developed by Pavlenko et al.[18] Levelized costs for alternative fuels are then compared to the untaxed price of diesel and petrol in the Netherlands, averaged over the last 2 years, to estimate the additional financial incentive necessary to achieve cost parity.[19]

The cashflow modeling approach is used to assess the costs of producing cellulosic ethanol, gasification Fischer-Tropsch (FT) diesel, and biogas. Due to the relatively early state of commercial development and high expected costs, fast pyrolysis facilities are not included in this assessment.[20] Fuel prices are estimated for several different feedstocks ranging in value from agricultural residues to municipal solid waste (MSW).

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[16] Capros P, De Vita A, Tasios N, Siskos P, Kannavou M, Petropoulos A, Evangelopoulou S, Zampara M, et al. *EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050.* (European Commission Directorate - General for Energy, Directorate - General for Climate Action and Directorate - General for Mobility and Transport: Luxembourg, 2016), https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

[17] We use the US as an example, where approximately 2% of fueling stations offer E85; U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center (AFDC). "Alternative Fueling Station Locator" (2019), https://afdc.energy.gov/stations/#/analyze?fuel=E85

[18] Daan Peters, Sacha Alberici, Jeff Passmore, and Chris Malins. *How to Advance Cellulosic Biofuels: Assessment of Costs, Investment Options & Required Policy Support,* (ICCT: Washington, DC, 2015) https://theicct.org/sites/default/files/publications/Ecofys-Passmore%20Group_How-to-advance-cellulosic-biofuels_rev201602.pdf; Guolin Yao, Mark D. Staples, Robert Malina, and Wallace E. Tyner, "Stochastic Techno-Economic Analysis of Alcohol-to-Jet Fuel Production," *Biotechnol Biofuels 10, Vol. 18* (2017) https://doi.org/10.1186/s13068-017-0702-7; Nikita Pavlenko, Stephanie Searle, Adam Christensen, *The Cost of Supporting Alternative Jet Fuels in the European Union,* (ICCT: Washington, DC, 2019), https://theicct.org/publications/cost-supporting-alternative-jet-fuels-european-union

[19] European Environment Agency (EEA), "Oil Bulletin Prices History," https://www.eea.europa.eu/data-and-maps/data/external/oil-bulletin

[20] Chelsea Baldino, Rosalie Berg, Nikita Pavlenko and Stephanie Searle, *Advanced Alternative Fuel Pathways: Technology Overview and Status,* (ICCT: Washington, DC, 2019), https://theicct.org/publications/advanced-alternative-fuel-pathways

The feedstock costs reference weighted average EU values developed by JRC, supplemented by Searle et al.[21]

Table 2. Per-liter prices for select advanced biofuel pathways developed via the cashflow model (€ per diesel-equivalent liter)

Feedstock	Synthetic diesel cost	Conventional diesel price	Difference (necessary support)	Cellulosic ethanol	Conventional petrol price	Difference (necessary support)
Cellulosic energy crops	€ 2.28	€ 0.56	€ 1.72	€ 1.62	€ 0.62	€ 1.00
Agricultural residues	€ 2.37		€ 1.81	€ 1.56		€ 0.94
Forest residues	€ 1.82		€ 1.27	N/A	N/A	N/A
Black liquor	€ 1.82		€ 1.27	N/A	N/A	N/A
MSW	€ 1.43		€ 0.87	N/A	N/A	N/A

Note: Untaxed price of conventional diesel fuel, taken from: European Environment Agency (EEA). “Oil Bulletin Prices History.” https://www.eea.europa.eu/data-and-maps/data/external/oil-bulletin

The prices per-liter for select advanced biofuel pathways developed from the cashflow model are shown in Table 2. The relative costs for producing advanced fuels are much higher than the existing support levels for renewable fuel units (HBEs) under the Dutch Environmental Management Act. At the late 2019 HBE price level of €10.30 per GJ of supplied renewable energy, the policy provides a value of 0.21 €/liter and 0.33 €/liter for ethanol and biodiesel, respectively; this value is doubled for Annex IX fuels.[22] For Annex IX fuels, this level of policy support is similar to our Low Policy Support scenario below. Based on the results of the cost analysis, we find that the following types of advanced alternative fuel can be supported in each policy scenario:

- **Low Policy Support (€0.50 per diesel-equivalent liter):** biodiesel and renewable diesel from used cooking oil, biodiesel and renewable diesel from animal fats, and renewable electricity supplied to vehicles and rail.
- **Medium Policy Support (€1.00 per diesel-equivalent liter):** each of the pathways listed in the low policy support scenario, as well as commercial-scale cellulosic ethanol facilities processing agricultural residues, commercial-scale gasification and Fischer Tropsch facilities processing municipal solid waste, ethanol using flue gas fermentation, and biomethane from sewage sludge.
- **High Policy Support (€2.00 per diesel-equivalent liter):** each of the pathways listed in the low and medium policy support scenario, as well as cellulosic ethanol facilities processing energy crops and commercial-scale gasification Fischer Tropsch facilities processing energy crops. In this scenario, the volumes of fuels produced through pathways already viable at lower incentive levels increases due to the higher incentive. Electrofuels from renewable electricity and biomethane from sewage sludge and livestock manure are not viable without very high levels of policy support. Searle and Christensen estimate that by 2030, electrofuels are not viable at policy support levels below €4 per liter.[23] Likewise, Baldino et al. estimates that manure biomethane is also cost-prohibitive at €4 per liter policy support, as the majority of livestock manure biomethane resources are generally cost-

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[21] Pablo Ruiz, Alessandra Sgobbi, Wouiter Nijs, Christian Tiel, Francesco Dalla Longa, Tom Kober, Berien Elbersen, Geerten Hengeveld. “The JRC-EU-TIMES Mode: Bioenergy Potentials for EU and Neighboring Countries”. (JRC Science for Policy Report, European Commission Joint Research Centre: Luxembourg, 2015), https://setis.ec.europa.eu/sites/default/files/reports/biomass_potentials_in_europe.pdf; Stephanie Searle, Nikita Pavlenko, Sammy El Takriti and Kristine Bitnere. *Potential Greenhouse Gas Savings from a 2030 Greenhouse Gas Reduction Target with Indirect Emissions Accounting for the European Union.* (ICCT: Washington, DC, 2017). https://www.theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf

[22] Geert De Cock. *Using Renewable Electricity in Transport to Meet RED Targets.* (Transport & Environment: Brussels, Belgium. 2019). https://www.transportenvironment.org/sites/te/files/publications/2019_10_Renewable_electricity_in_the%20RED_final.pdf.

[23] Stephanie Searle and Adam Christensen, *Decarbonization Potential of Electrofuels in the European Union,* (ICCT: Washington, DC. 2018), https://theicct.org/sites/default/files/publications/Electrofuels_Decarbonization_EU_20180920.pdf

prohibitive to develop due to their small sizes and the anticipated costs of linking distant farms to the gas grid.[24]

Feedstock availability

This analysis makes the following assumptions about the availability of various waste and residue feedstocks.

- **Agricultural and forestry residues and wastes:** This category includes the stalks and leaves from major crops produced in the EU, such as treetops and small branches from forestry harvesting, and the biological fraction of municipal and industrial waste. Residue and waste availability for 2030 was taken from Searle and Malins, which estimates that there are no sustainably available agricultural residues or forestry wastes, and approximately 0.6 million tonnes of MSW available in the Netherlands.[25] Those agricultural residues are already used in other industries or are necessary to remain in place to prevent unacceptable levels of erosion and soil nutrient loss. Searle and Malins estimate that the quantity of agricultural residues in some member states, such as France, exceed countries' ability to scale up a cellulosic conversion industry by 2030. Therefore we assume a small share of agricultural residues are available for import, although shipping agricultural residues is generally cost-prohibitive due to their low value and high weight. This quantity is estimated to be approximately 285,000 tonnes per year, or equivalent to the volume necessary to supply one commercial scale cellulosic bio-refinery.
- **Used cooking oil:** Used cooking oil is already a major source of biofuel in the Netherlands, where it can be processed into first-generation biodiesel, or increasingly, hydrotreated and converted into drop-in renewable diesel. Owing to its substantial biorefinery capacity for hydrotreatment, the Netherlands already imports a greater quantity of used cooking oil than it produces domestically, though these imports are not factored into the analysis.[26] We project 2020 used cooking oil potential in Netherlands based on 2015 data for commercial and household used cooking oil collection to be approximately 141,000 tonnes.[27] This amount could increase in the medium and high policy support scenarios due to an increased incentive for household collection.
- **Animal fats:** We assume that the domestic supply of animal fats is fixed and not responsive to changes in demand. As of 2019, the Netherlands imports a far greater share of its animal fats used for biofuel than are produced domestically, as it already exceeds its 2020 advanced fuels target.[28] This analysis only considers the share of animal fats produced domestically reported to the Dutch Emissions Authority for 2018.
- **Ethanol from flue gas:** Ethanol can be produced from flue gases, particularly the energy-dense waste gases emitted from the steel making process which contain carbon monoxide (CO) and hydrogen (H_2). To assess the potential for this fuel

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[24] Chelsea Baldino, Nikita Pavlenko, Stephanie Searle, and Adam Christensen, *The Potential for Low-Carbon Renewable Methane in Heating, Power and Transportation in the European Union.* (ICCT: Washington, DC 2018), https://theicct.org/sites/default/files/publications/Renewable_Gas_EU-28_20181016.pdf

[25] Stephanie Searle and Chris Malins, "Waste and Residue Availability for Advanced Biofuel Production in EU Member States". *Biomass and Bioenergy. No. 89*, June 2016, 2-10

[26] Dutch Emissions Authority, "Rapportage Energie Voor Vervoer in Nederland 2018 Naleving Verplichtingen Wet- En Regelgeving Energie Voor Vervoer [Energy for Transport Report in the Netherlands 2018 Compliance with Laws and Regulations for Energy for Transport]," (2019), https://www.rijksoverheid.nl/documenten/rapporten/2019/07/04/rapportage-energie-voor-vervoer-in-nederland-2018

[27] Greenea, *Analysis of the Current Development of Household UCO Collection Systems in the EU.* (ICCT: Washington, DC, 2016), https://www.theicct.org/sites/default/files/publications/Greenea%20Report%20Household%20UCO%20Collection%20in%20the%20EU_ICCT_20160629.pdf

[28] Dutch Emissions Authority, "Rapportage Energie Voor Vervoer in Nederland 2018 Naleving Verplichtingen Wet- En Regelgeving Energie Voor Vervoer [Energy for Transport Report in the Netherlands 2018 Compliance with Laws and Regulations for Energy for Transport]," (2019), https://www.rijksoverheid.nl/documenten/rapporten/2019/07/04/rapportage-energie-voor-vervoer-in-nederland-2018

source, we extrapolated the quantity of steel mill flue gases from the World Steel Association's estimate of the Netherlands' overall steel production in 2015.[29] Separate emission factors for conventional blast oxygen furnace steelmaking and electric arc furnace methods are used, as each method generates differing quantities of CO and H_2 per tonne of steel produced.[30] Lastly, we assume that 70% of flue gases are already utilized for onsite energy recovery.[31]

» **Energy crops and short-rotation woody crops:** Sustainable energy crop potential in the Netherlands is uncertain and depends on the quantity of marginal land available and its quality. We extrapolate the energy crop potential for the Netherlands based on an EU-wide energy crop land availability assessment.[32] Per-hectare yields, ranging from 4.7 to 17.3 dry tonnes per hectare, are also taken from the same study for both marginal and fallow land. We assume that the Netherlands' share of the EU-wide estimate of suitable land was proportional to its share of total EU agricultural output—approximately 3%, or 41,000 hectares.[33]

» **Waste-derived biomethane:** Biomethane is not commonly used in transport in the Netherlands, comprising only 1.5% of the renewable energy supplied to the sector.[34] We estimate how much could be feasibly supplied to the transport sector based off of the Netherlands' estimated share of waste and residue-derived biomethane from Baldino et al.[35] That study estimates that based on the limited availability of suitable residues and high costs for new gas infrastructure, only 1.6 PJ of biomethane would be available to the transport sector at an incentive level of €2 per diesel-equivalent liter, whereas a greater volume would be available to the power sector due to the cheaper cost of onsite biogas combustion for dairy farms.

» **Cover crops:** The quantity of cover crops available for bioenergy use and their sustainability and contribution to demand for land remains uncertain. Cover crops are not explicitly included in included in Annex IX List A, though the definition of non-food cellulosic feedstocks may be broadened to include their contribution in future decisions by the European Commission. However, they do not count towards the cap on food-based fuels. If it can be demonstrated that cover crops are produced without increasing demand for cropland overall, they may be considered an advanced feedstock. We do not include the contribution of cover cropping in this analysis, though we provide an estimate of its potential contribution.

Technological readiness and facility deployment

This assessment includes a mix of existing and developing fuel conversion technologies, as summarized in Table 1. The mix of pathways included here is based on our

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[29] World Steel Association. (2016). World Steel in Figures 2016. Retrieved from: https://www.worldsteel.org/en/dam/jcr:1568363d-f735-4c2c-a1da-e5172d8341dd/World+Steel+in+Figures+2016.pdf

[30] Alexis M. Bazzanella and Florian Ausfelder. Low Carbon Energy and Feedstock for the European Chemical Industry. (Gesellschaft für Chemische Technik und Biotechnologie e.V. (DECHEMA)[Society for Chemical Engineering and Biotechnology e.V.]: Frankfurt am Main, 2017). https://dechema.de/dechema_media/Downloads/Positionspapiere/Technology_study_Low_carbon_energy_and_feedstock_for_the_European_chemical_industry-p-20002750.pdf

[31] Stephanie Searle, Nikita Pavlenko, Sammy El Takriti and Kristine Bitnere. *Potential Greenhouse Gas Savings from a 2030 Greenhouse Gas Reduction Target with Indirect Emissions Accounting for the European Union.* (ICCT: Washington, DC, 2017). https://www.theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf

[32] Ben Allen et al., "Space for Energy Crops--Assessing the Potential Contribution to Europe's Energy Future" Report produced for BirdLife Europe, European Environmental Bureau and Transport & Environment. (London: Institute for European Environmental Policy (IEEP), May 1, 2014), http://www.birdlife.org/sites/default/files/attachments/IEEP_2014_Space_for_Energy_Crops_0.pdf.

[33] Food and Agriculture Organization of the United Nations. FAOSTAT (Crops—Production Quantity), accessed December 2019), http://www.fao.org/faostat/en/#data/QC.

[34] Dutch Emissions Authority, "Rapportage Energie Voor Vervoer in Nederland 2018 Naleving Verplichtingen Wet- En Regelgeving Energie Voor Vervoer [Energy for Transport Report in the Netherlands 2018 Compliance with Laws and Regulations for Energy for Transport]," (2019), https://www.rijksoverheid.nl/documenten/rapporten/2019/07/04/rapportage-energie-voor-vervoer-in-nederland-2018

[35] Chelsea Baldino, Nikita Pavlenko, Stephanie Searle, and Adam Christensen. *The Potential for Low-Carbon Renewable Methane in Heating, Power and Transportation in the European Union.* (ICCT: Washington, DC 2018), https://theicct.org/sites/default/files/publications/Renewable_Gas_EU-28_20181016.pdf

assessment of technological readiness from a review of advanced alternative fuel conversion technologies.[36] Here we assume that each of these conversion pathways is technologically able to launch a commercial-scale facility in 2020; however, the rate of deployment for both cellulosic ethanol and gasification facilities will be constrained, which affects the overall quantity of fuel production viable from each pathway relative to feedstock supply.

We assume that existing technologies that already operate at commercial scales, such as biodiesel and hydrotreated renewable diesel, do not have any deployment constraints. The Netherlands currently possesses over one billion liters of annual renewable diesel production capacity.[37] These technologies are fully commercialized and de-risked, often with lower upfront capital expenses and greater certainty of operational parameters. Therefore, we assume that fuel producers will expand to utilize the full quantity of available feedstock.

In contrast to renewable diesel production, conversion pathways utilizing cellulosic feedstocks or MSW still suffer from uncertain commercialization prospects. These types of facilities face technological bottlenecks associated with scaling up, particularly with respect to maintaining consistent pre-treatment for feedstocks with variable or inconsistent physical properties, such as agricultural residues. Additionally, the supply chains for many cellulosic feedstocks—particularly energy crops—must be developed from the ground up in order to ensure a consistent supply of suitable feedstock to large biorefineries.

Due to the small number of advanced biorefineries utilizing lignocellulosic feedstocks and wastes, it is difficult to extrapolate any trends on the length of time it takes for a facility to be constructed and reach its full operational capacity. For these large, capital intensive projects, construction can take several years; furthermore, some of the existing cellulosic ethanol projects in the European Union and United States have suffered from lengthy delays and have not reached their full, listed nameplate production capacity.[38] For this analysis, we therefore utilize a simplified assumption about the rate of facility deployment that factors construction, ramp-up, and the gradual expansion of the industry through a learning curve, as listed in Table 3.

Table 3. Assumed design and construction times and ramp-up times for large-scale cellulosic ethanol and gasification-Fischer Tropsch facilities

	Design and construction time for first facility (years)	Design and construction time for follow-on facilities (years)	Ramp-up time (years)
Cellulosic ethanol, medium policy support	5	4	1
Cellulosic ethanol, high policy support	4	3	1
Gasification and Fischer Tropsch	5	3	1

If a feedstock and conversion pathway is considered cost-viable at a given incentive level, we assume that a single, large-scale cellulosic facility for that feedstock category

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[36] Chelsea Baldino, Rosalie Berg, Nikita Pavlenko and Stephanie Searle. *Advanced Alternative Fuel Pathways: Technology Overview and Status.* (ICCT: Washington, DC, 2019), https://theicct.org/publications/advanced-alternative-fuel-pathways

[37] US Department of Agriculture, Foreign Agricultural Service, EU-28 Biofuels Annual, (2019), https://gain.fas.usda.gov/Recent%20 GAIN%20Publications/Biofuels%20 Annual_The%20Hague_EU-28_7-15-2019.pdf

[38] Nikita Pavlenko. "Failure to Launch: Why Advanced Biorefineries Are So Slow to Ramp Up Production". ICCT, November 13, 2018. https://theicct.org/blog/staff/failure-to-launch-biorefineries-slow-ramp-up

would begin design and construction in the first wave in 2021, and that no other facilities of that type begin design and construction until the first wave of projects has begun production at full capacity. At that point, a second wave of two facilities would begin design and construction. Each facility also has a ramp-up time in which production is halved during the first year, to reflect difficulties during the first year of operation. In the high policy support scenario, we assume that the higher incentive enables construction and design times would be shortened by one year, allowing for a third wave of cellulosic ethanol facilities to begin production by 2030. The total number of facilities is capped according to the biomass availability for MSW as estimated by Searle & Malins or the energy crop availability described above.[39]

While these assumptions of facility deployment are somewhat arbitrary and overly-simplistic, it is critical to include constraints on the deployment rate of advanced biorefineries in order to reflect the observed timeline of existing demonstration-scale and commercial-scale cellulosic biofuel facilities in the United States and European Union. This simplified approach reflects the reality that the initial waves of facility deployment will be staggered, and that it may take over a decade for an entirely new industry to emulate best practices from first entrants and reach full production.

Life-cycle greenhouse gas impacts of alternative fuels

We estimate the total emissions reductions achievable from each policy support scenario based on the total quantity of fuel supplied and the specific carbon intensity of each feedstock and conversion pathway. The full lifecycle GHG intensities for bio-based feedstocks and flue gas ethanol are taken from Searle et al. and presented in Table 4.[40] The indirect emissions for wastes and residues include the increased production emissions for materials substituting for these feedstocks if they are diverted away from non-fuel existing uses; for example, the use of animal fats to produce fuel diverts them from existing uses in heat, power and oleochemical applications. For renewable electricity used for electrofuels production, we take into account the upstream infrastructure emissions attributable to new, dedicated renewable electricity generation.[41] For the baseline GHG intensity of fossil fuels, we utilize the fossil fuel comparator (petroleum diesel or gasoline) of 94.1 gCO2e/MJ in the Fuel Quality Directive, as amended in 2015.[42] We assume the GHG intensity of renewable electricity used in vehicles to be 1 gCO2e/MJ.[43] We assume that facilities using lignocellulosic energy crops use half roundwood or whole trees as a feedstock. For energy crops, we take the average indirect land use change (ILUC) estimate for perennials and short-

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[39] Stephanie Searle and Chris Malins. “Waste and Residue Availability for Advanced Biofuel Production in EU Member States”. *Biomass and Bioenergy. No. 89*, June 2016, 2-10

[40] Stephanie Searle, Nikita Pavlenko, Sammy El Takriti and Kristine Bitnere. *Potential Greenhouse Gas Savings from a 2030 Greenhouse Gas Reduction Target with Indirect Emissions Accounting for the European Union.* (ICCT: Washington, DC, 2017). https://www.theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf

[41] Stephanie Searle and Adam Christensen. *Decarbonization Potential of Electrofuels in the European Union.* (ICCT: Washington, DC. 2018). https://theicct.org/sites/default/files/publications/Electrofuels_Decarbonization_EU_20180920.pdf

[42] Council Directive (EU) 2015/652 laying down calculation methods and reporting requirements pursuant to Directive 98/60/EC of the European Paliariemnt and of the Council relating ot the quality of petrol and diesel fuels, L107/26, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L0652

[43] Robert Edwards, Heinz Hass, Jean-Francois Larive, Heiko Maas, and David Rickeard. *Well-to-Wheels Report Version 4.a: JEF Well-to-Wheels Analysis*, (European Commission Joint Research Centre, EUCAR and CONCAWE: Ispra, Italy, 2014). https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/well-wheels-report-version-4a-jec-well-wheels-analysis

rotation woody crops in Valin et al.[44] For roundwood, we take the indirect emissions estimate from Searle et al.[45]

Table 4. Assumptions on GHG intensities in analysis

Technology	Feedstock	Direct emissions (gco_2e/mj)	Indirect emissions (gco_2e/mj)	Total emissions (gco_2e/mj)
Cellulosic ethanol	Agricultural residues	14.0	16.0	22.0
	Energy crops and wood	17.0	33.8	50.8
Biodiesel and hydrotreated renewable diesel	Used cooking oil	16.0	0	16.0
	Animal fats	20.0	22	42.0
Synthetic diesel (gasification and Fischer-Tropsch)	Agricultural residues	14.0	16.0	22.0
	Energy crops and wood	17.0	33.8	50.8
	Forestry residues	14.0	17.0	31.0
	Municipal solid waste	19.0	-45.0	-26.0
Electrolysis and fuel synthesis	Renewable electricity	12.0	14.0	26.0
Flue gas fermentation	Industrial flue gas	12.0	13.0	25.0
Electricity in road sector	Renewable electricity	1.0	0.0	1.0
Electricity in rail sector	Renewable electricity	1.0	0.0	1.0
Biomethane	Sewage sludge	19.0	0.0	19.0
	Livestock Manure	-264.0	0.0	-264.0

Results

Constraining factors by pathway

Depending on the feedstock and conversion process in question, the production potential for each of the pathways assessed here is constrained by cost, feedstock availability, or the biorefinery deployment rate for certain conversion pathways. The impact of these factors changes depending on the level of policy support available in each scenario. For example, we find that in some cases the constraining factor for a given fuel pathway changes as the incentive value decreases. Table 5 summarizes these constraining factors for all pathways in each policy scenario.

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[44] Hugo Valin, Daan Peters, Maarten van den Berg, Stefan Frank, Petr Havlik, Nicklas Forsell, and Carlo Hamelinck, *The Land Use Change Impact of Biofuels Consumed in the EU: Quantification of Area and Greenhouse Gas Impacts* (Ecofys: Utrecht, 2015); https://ec.europa.eu/energy/sites/ener/files/documents/Final Report_GLOBIOM_publication.pdf.

[45] Stephanie Searle, Nikita Pavlenko, Sammy El Takriti and Kristine Bitnere. *Potential Greenhouse Gas Savings from a 2030 Greenhouse Gas Reduction Target with Indirect Emissions Accounting for the European Union.* (ICCT: Washington, DC, 2017). https://www.theicct.org/sites/default/files/publications/RED-II-Analysis_ICCT_Working-Paper_05052017_vF.pdf

Table 5. Constraining factors for production by pathway in each policy scenario

Technology	Feedstock	Low policy support (€0.50 /diesel liter eq.)	Medium policy support (€1.00 /diesel liter eq.)	High policy support (€2.00 /diesel liter eq.)
Cellulosic Ethanol	Agricultural residues	Feedstock availability	Feedstock availability	Feedstock availability
	Energy crops and wood	Cost	Feedstock availability	Feedstock availability
Biodiesel and hydrotreated renewable diesel	Used cooking oil	Cost	Feedstock availability	Feedstock availability
	Animal Fats	Feedstock availability	Feedstock availability	Feedstock availability
Synthetic diesel (gasification and Fischer-Tropsch)	Agricultural residues	Feedstock availability	Feedstock availability	Feedstock availability
	Energy crops and wood	Cost	Cost	Feedstock availability
	Forestry residues	Feedstock availability	Feedstock availability	Feedstock availability
	Municipal solid waste	Cost	Feedstock availability	Feedstock availability
Electrolysis and fuel synthesis	Renewable electricity	Cost	Cost	Cost
Flue gas fermentation	Industrial flue gas	Cost	Cost	Ethanol Blending
Electricity in road sector	Renewable electricity	Other factors outside this analysis	Other factors outside this analysis	Other factors outside this analysis
Biomethane	Livestock manure and Sewage Sludge	Cost	Cost	Cost

The lack of sustainable, domestically available agricultural residues is a major constraint on the Netherlands' potential to meet the Advanced Biofuels Annex IX List A subtarget. While the Netherlands produces a significant amount of agricultural residues, Searle & Malins projects that the entire sustainably harvestable amount will be utilized in 2030 for other uses such as livestock bedding and mushroom cultivation.[46] However, other EU member states such as France will have large quantities of sustainably available agricultural residues in excess of their own projected pace of cellulosic ethanol technology deployment. It may therefore be possible to import some quantities of these feedstocks in order to meet the advanced fuels sub-target without impacting other countries' ability to meet their own obligation for the 2030 timeframe.

In the absence of domestic agricultural residues, we estimate the bulk of ethanol production would come from energy crops and flue gases. Additionally, in the high policy support scenario, these two fuels can supply sufficient ethanol to reach the blending limit, though only the energy crop-derived share would count towards the 3.5% advanced fuels sub-target. We project that the flue gas ethanol pathway will develop more quickly than cellulosic ethanol due to the feedstock's low cost, consistent supply, physical characteristics, and minimal need to develop new supply chains and pre-treatment processes.

The production of diesel-replacements is dominated by existing, commercialized pathways such as waste oil biodiesel or hydrotreated renewable diesel, both of which are constrained by the domestic supply of used cooking oil and animal fats. While UCO and animal fats are comparatively easier to process into alternative fuels and offer greater GHG reductions than food-based biofuels, the limited availability of these resources makes these fuel pathways unlikely to scale up beyond the 1.7% cap under Annex IX List B in the RED II. Furthermore, recent fraud in UCO imports, in which the feedstock was replaced with unsustainable palm oil, have raised concerns about continued imports and even its double-counting within the regulatory framework.[47] Therefore, we estimate that

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[46] Stephanie Searle and Chris Malins. "Waste and Residue Availability for Advanced Biofuel Production in EU Member States". *Biomass and Bioenergy. No. 89*, June 2016, 2-10

[47] Sarantis Michalopoulos, "Netherlands Mulls End to Used Cooking Oil Double-Counting," *Euractiv*, September 12, 2019, https://www.euractiv.com/section/agriculture-food/news/the-netherlands-mulls-end-to-used-cooking-oil-double-counting/.

these fuels would be viable at all three support levels assessed in this analysis, though limited in their overall contribution in the absence of imports.

Synthetic diesel production from other feedstocks is constrained by availability, with MSW being the only feedstock viable at medium policy support levels and above. Based on previous work, we find that across all three scenarios, cost constraints eliminate electrofuels from deployment in the Netherlands. Searle and Christensen estimate that in the 2030 timeframe, the cost of additional renewable electricity drives power-to-liquid fuel costs well above the price that can be achieved with policy support of €2 per liter.[48]

The relationship between the incentive for alternative fuels and EV deployment is beyond the scope of this analysis. While HBE credits are available for charging network operators under the Netherlands' current RED implementation, in practice this credit is only used by a relatively small number of large charging point operators.[49] While the proceeds from selling HBE credits by charging point operators may be used to recoup their expenses and support further deployment of charging infrastructure, the majority of electric vehicle charging does not yet generate credits and is not earmarked to support projects intended to support electrification. Therefore, we assume EV deployment to be an exogenous factor in this analysis which grows equally across all three scenarios. We assume that EV sales will be primarily supported through separate policies such as sales targets, tax advantages, and support schemes for stationary renewable electricity generation. We find that the renewable share of vehicle charging is the single largest contributor to the 14% renewable energy in transport target, comprising over 12% of transport energy demand once multipliers are factored in.

Lastly, previous work suggests that further expansion in biomethane from wastes will be very cost prohibitive. While methane production from centralized waste treatment facilities is estimated to be cost viable with medium policy support, production from livestock manure is cost-prohibitive at all policy support levels. This is due to the small size and wide distribution of dairy farms, which generates poor economies of scale for anaerobic digestion of manure.

Total potential advanced alternative fuel volumes in 2030

The total amount of advanced alternative fuel that could be deployed in the Netherlands varies substantially depending on the quantity of policy support, though we find that there are substantial availability limitations on domestic feedstocks across all three scenarios. Figure 1, Figure 2, and Figure 3 illustrate the projected volumes of advanced alternative fuels in each of the policy scenarios, from low policy support to high policy support, respectively. Each of these three charts illustrates the total quantity of fuel production in thousand tonnes of oil-equivalents (ktoe). We do not show the impact of multiple counting for the RED II targets in these figures. Subsequently, Table 6 summarizes the total production volumes from each pathway across all three scenarios.

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[48] Stephanie Searle and Adam Christensen. *Decarbonization Potential of Electrofuels in the European Union.* (ICCT: Washington, DC. 2018). https://theicct.org/sites/default/files/publications/Electrofuels_Decarbonization_EU_20180920.pdf

[49] Geert De Cock, *Using Renewable Electricity in Transport to Meet RED Targets,* (Transport & Environment: Brussels, Belgium. 2019), https://www.transportenvironment.org/sites/te/files/publications/2019_10_Renewable_electricity_in_the%20RED_final.pdf.

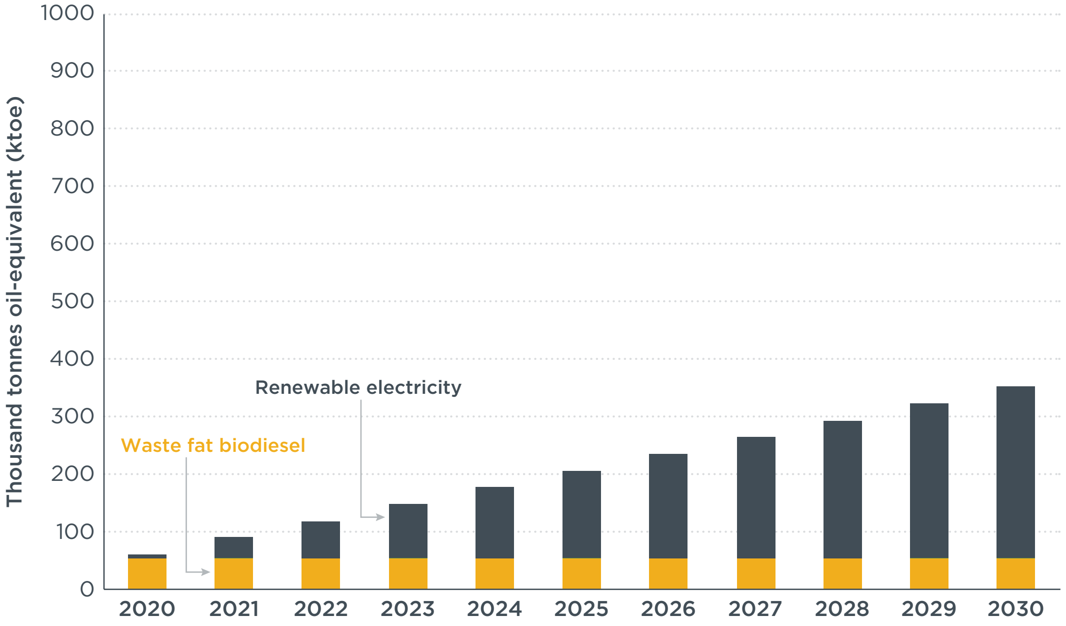

Figure 1. Projected advanced alternative fuel volumes to 2030 in the low policy support scenario (€0.50 per liter)

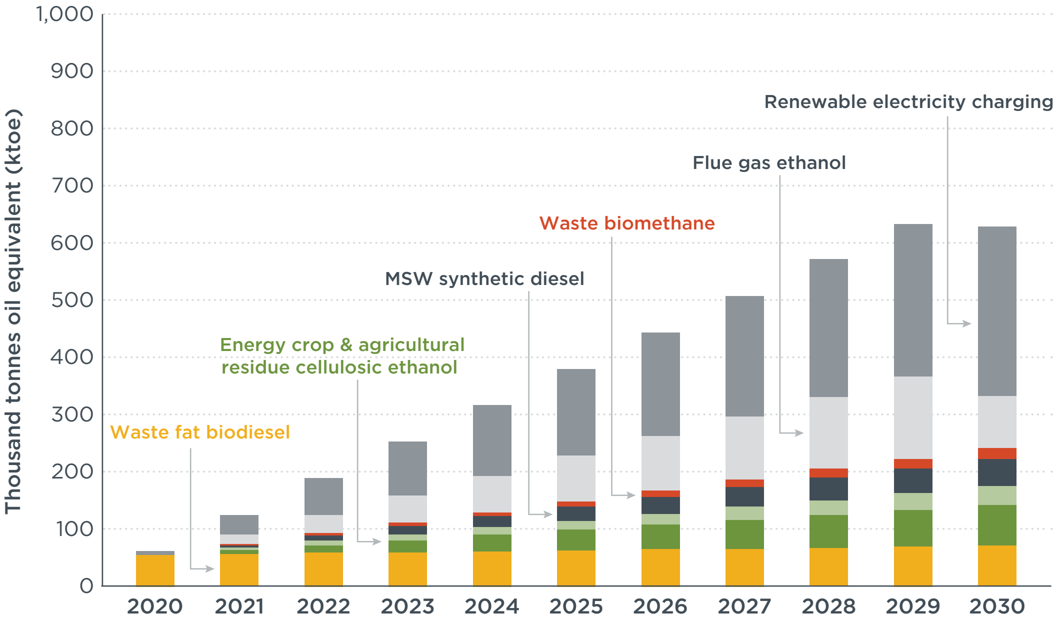

Figure 2. Projected advanced alternative fuel volumes to 2030 in the moderate policy support scenario (€1.00 per liter)

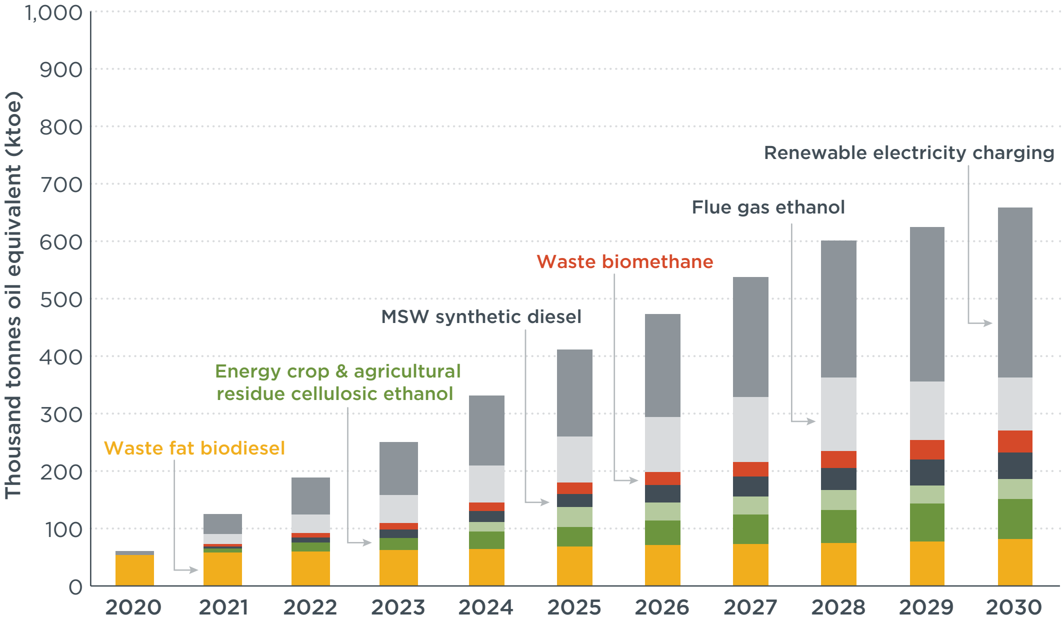

Figure 3. Projected advanced alternative fuel volumes to 2030 in the high policy support scenario (€2.00 per liter)

The scenario summary presented in Table 6 suggests that the obligation on fuel suppliers to blend 3.5% advanced biofuels from Annex IX list A cannot be met at any of the three incentive levels using domestic resources. Within those three scenarios, there is substantial variation in the quantity of Annex IX list A fuels supplied. We estimate that no amount of these fuels will be supplied with low policy support, whereas with high levels of policy support the deployment of these fuels approaches the RED II target with 1.67% of transport energy demand, or 3.4% after including multipliers. Advanced biofuel pathways only begin to penetrate the market as the incentive reaches at least €1 per liter.

While it is not possible to meet the advanced biofuels sub-target using domestic resources, the overall policy target for transport energy can be achieved through increased electric vehicle charging and rail electrification, as long as the Netherlands' separate power sector renewable energy target is met. Together, these two sectors contribute over 9% to the transport sector target after including multipliers and are the largest contributors to the 14% target. With multiple counting in place, the medium and high policy support scenario will result in renewable energy supplying over 15% of transport energy demand by 2030 from electricity and advanced fuels, without any reliance on first-generation, food-based biofuels.

Table 6. Total potential fuel production volumes by pathway in each policy scenario in 2030 (PJ)

Technology	Feedstock	Low policy support (€0.50 /diesel liter eq.)	Medium policy support (€1.00 /diesel liter eq.)	High policy support (€2.00 /diesel liter eq.)
Cellulosic ethanol	Agricultural residues	0	1.4	1.4
	Energy crops and wood	0	3.0	3.0
Biodiesel and hydrotreated renewable diesel	Used cooking oil	2.3	3.0	3.4
	Animal fats	<0.1	<0.1	<0.1
Synthetic diesel (gasification and Fischer-Tropsch)	Agricultural residues	0	0	0
	Energy crops and wood	0	0	0
	Forestry residues	0	0	0
	Municipal solid waste	0	2.0	2.0
Electrolysis and fuel synthesis	Renewable electricity	0	0	0
Flue gas fermentation	Industrial flue gas	0	5.2	5.2
Biomethane	Sewage sludge and livestock manure	0	0.8	1.6
Electricity in the road sector	Renewable electricity	12.4	12.4	12.4
Alternative fuels as share of road transport energy (without multipliers)		3.8%	6.8%	7.1%
Advanced biofuels (Annex IX list A) as share of road transport energy		0.0%	1.9%	2.1%
Used cooking oil and animal fats as share of total transport energy		0.6%	0.8%	0.9%
Advanced biofuels as share of total transport energy (Annex IX list A, including multipliers)		**0.0%**	**3.7%**	**4.2%**
Total non-food alternative fuels as share of total transport energy (including multipliers)		**14.0%**	**19.0%**	**19.7%**

Table 6 summarizes the volumes of different fuels and feedstocks that would contribute to Netherlands' overall transport energy target in energy units as well as with multipliers. The largest contributions towards meeting the List IX Annex A advanced fuels sub-target come from domestic energy cropping and the gasification of MSW, though this is largely limited by feedstock availability rather than technology deployment rate. We find that the 1.7% cap on biofuels produced from used cooking oil and animal fats is unlikely to be met using domestic resources. However, as the majority of processed waste fats in the Netherlands are imported, current usage exceeds the 1.7% cap.

We estimate that the total potential production of advanced ethanol, including flue gas ethanol, is greater than can be accommodated given blending restrictions in petrol. This is in part due to the assumption that flue gas ethanol is cost-viable at the medium policy incentive and produced up to the availability of the feedstock. We assume that the production of flue gas ethanol is reduced in this scenario in response to blend wall pressure, as it would be less valuable relative to cellulosic ethanol, which is eligible for double-counting via Annex IX List A. However, it is also possible that advanced ethanol produced from energy crops would face blending pressure. Furthermore, if significant volumes of relatively inexpensive food-based ethanol are available, these fuels would create substantial blending pressure on all advanced ethanol pathways in any of the policy scenarios modeled here.

To estimate the quantity of cover cropping for biofuel production, we utilize FAOStat data for cereals and oilseeds cropland in the Netherlands (approximately 222,000 hectares) and assume that 15% of that land is used for catch and cover crops, based on typical practices in the Netherlands.[50] Based on an assumed oat straw yield of approximately 4.8 tonnes per hectare, and collection losses and moisture content of 15%, we estimate approximately 54,000 dry tonnes of lignocellulosic cover crops would be available for fuel conversion. This would equate to approximately 13 million liters of ethanol, assuming the same yields as for producing cellulosic ethanol from agricultural residues. This equates to approximately 0.1% of 2030 road energy demand, though this value remains highly uncertain.

The simplified incentive scenarios presented here suggest that the decisions made to implement the RED II within the Netherlands will play a large role in determining the mix of feedstocks used and the progress made towards achieving the advanced fuels sub-target. This analysis suggests that while the overall transport target is primarily achieved through the expanded use of electric charging, meeting the remainder of the target requires substantial policy support. While the cost assessment presented here utilizes a high upfront incentive to support alternative fuel deployment, the incentive options available to policymakers may be more flexible or broad. We note that previous research on effective policies to support advanced biofuels suggest that economic and policy uncertainty often undermines the effectiveness of policy incentives in supporting the deployment of alternative fuel facilities, particularly those with high capital expenses.[51] To mitigate this, renewable energy unit crediting in the Dutch system could introduce a higher, fixed floor price for credits from Annex IX List A fuels to ensure greater stability for potential investors in conjunction with a higher price signal. While the current system incorporates double-counting for waste-derived fuels, the price is still dictated by the underlying value of credits generated from other pathways; furthermore, a variable credit price-level causes investors to consider a lower-bound future value for the purposes of supporting advanced biofuel projects.

This study's estimate of 640 ktoe (26.8 PJ) of total advanced fuel and electricity supplied to the transport sector in the high policy support scenario without multiple-counting is less than half of the 1.55 Mtoe (65 PJ) quantity estimated by Navigant.[52] The divergence in these results is attributable to several key methodological differences and assumptions. The largest difference is the authors' inclusion of crop-based fuels up to a hypothetical 3% cap contributing approximately 13.8 PJ to the transport sector based on speculation on the implementation of the National Climate Agreement. Their estimate includes 12.9 PJ of low-iLUC risk fuels made from food crops. Another key methodological difference is that Navigant incorporates feedstock imports, whereas this study only factors in domestic resources. Consequently, while ICCT estimates only 3.4 PJ of energy supplied from waste fats and oils produced domestically, Navigant assumes that Netherlands will use imports to produce approximately 14.8 PJ of waste oil-derived diesel; further, the authors assume that the Netherlands will meet its own national-level targets by exceeding the 1.7% Annex IX List B cap with a blending rate of 3.2% and will only count 1.7% to its EU obligation. Lastly, while this study estimates that the Netherlands cannot reach the 3.5% advanced fuels sub-target using domestic resources, Navigant estimates that this target can be more than doubled although do not provide clarity on the feedstock breakdown of Annex IX List A fuels used to meet the target. They estimate that 10 PJ of biomethane alone may be supplied from a mix of anaerobic digestion-derived biogas and electrofuels. In contrast, this study estimated a much

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[50] Food and Agriculture Organization of the United Nations. FAOSTAT (Crops—Production Quantity), accessed December 2019), http://www.fao.org/faostat/en/#data/QC.; Alliance Environment. "Evaluation Study of the Payment for Agricultural Practices Beneficial for the Climate and the Environment," (2017), https://op.europa.eu/en/publication-detail/-/publication/002a69c6-dfba-11e7-9749-01aa75ed71a1/language-en

[51] Kristine Bitnere and Stephanie Searle. *Effective Policy Design for Promoting Investment in Advanced Alternative Fuels.* (ICCT: Washington, DC, 2017). https://www.theicct.org/sites/default/files/publications/Advanced-alternative-fuels_ICCT-white-paper_21092017_vF.pdf

[52] Navigant Consulting, Inc., *Renewable Fuels for Dutch Transport Towards 2030: How to achieve the mobility goals of the Climate agreement?,* (Navigant: Utrecht, Netherlands, 2019), https://platformduurzamebiobrandstoffen.nl/wp-content/uploads/2019/12/Navigant-2019-Renewable-fuels-for-Dutch-transport-towards-2030.pdf

smaller quantity of 1.6 PJ of biomethane availability, largely due to economic constraints and by excluding biomethane from purpose-grown crops.

GHG impacts

The overall GHG performance of the alternative fuel mix in each scenario is presented in Figure 4. The assumed GHG intensities used this analysis are provided in Table 4. The overall quantity of GHG emission reductions is roughly proportional to the quantity of fuel supplied, with the GHG reductions increasing as policy support increases and supports greater quantities of advanced fuels. The inclusion of indirect emissions reduces the estimated GHG reductions significantly, but not dramatically, for this mix of pathways. We find that approximately up to 2.5 million tonnes CO_2e reduction is possible annually by 2030 in the high policy support scenario, but that only around 1.3 million tonnes CO_2e reduction would be delivered annually by 2030 in the low policy support scenario. For context, fuel combustion emissions from the transport sector in the Netherlands were 31.2 million tonnes CO_2e in 2017.[53] Emission reductions from the medium and high policy support scenarios both exceed the 2 million tonne CO2e target for the road sector established in the 2019 Dutch Climate Accord.[54] The overall GHG reductions achieved by implementation of the RED II, as proposed, will thus depend heavily on the effectiveness and design of both fuels policies and supplementary policies in the stationary power and vehicle sectors.

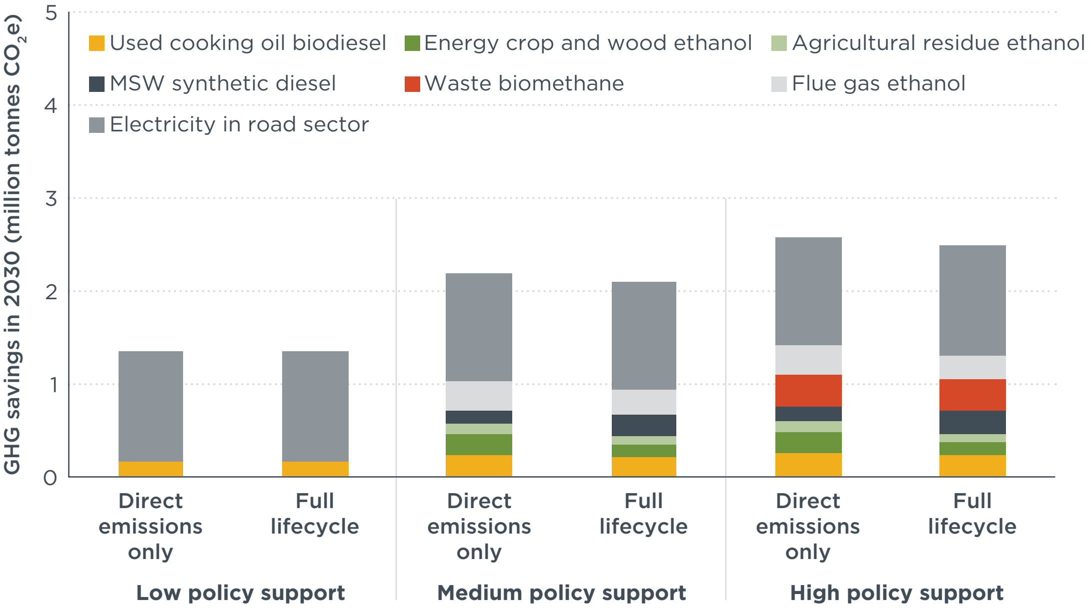

Figure 4. Direct and full lifecycle (including indirect) GHG savings from advanced alternative fuels in 2030 in each policy scenario

Conclusion

This working paper assesses the potential for Netherlands to meet the transport sector targets set by the EU RED II using advanced, non-food-based fuels from domestic resources. A combination of feedstock availability and cost assessments are used to estimate the volumes of fuels that can be supplied at three separate incentive levels. Policies supporting advanced, non-food-based fuels can deliver substantial carbon

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[53] National Institute for Public Health and the Environment, "Greenhouse Gas Emissions in the Netherlands 1990-2017," National Inventory Report 2019 (Bilthoven, NL: Ministry of Health, Welfare and Sport, April 15, 2019), https://www.rivm.nl/bibliotheek/rapporten/2019-0020.pdf.

[54] Government of the Netherlands, "National Climate Agreement," June 28, 2019, https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord.

savings—as much as 2.4 million tonnes of CO_2-equivalents annually in the high policy support scenario, after taking into account indirect emissions.

This analysis finds that the overall 14% transport sector renewable energy target can largely be met through the increased deployment of electric vehicle, likely driven by other policies, such as the deployment of new charging infrastructure and stricter vehicle efficiency or emissions standards. Based on an assumption of steady growth in electric vehicle sales and renewable electricity deployment in the power sector through 2030, we estimate that renewable electricity from vehicle charging will supply approximately 3.2% of road sector energy demand—which increases to nearly 13% after including credit multipliers.

We find that the domestic availability of wastes and residues eligible for the Annex IX List A advanced fuels sub-target are insufficient to allow the Netherlands to meet the target in the absence of imports. However, a small quantity of imported agricultural residues by 2030 would allow the Netherlands to meet its advanced fuels sub-target without impacting the ability of other Member States to meet their own target. It is therefore possible that other Member States constrained by the rate of deployment of advanced biorefineries, such as France, may export biomass for processing in the Netherlands, as is already being done for waste fats and oils. The quantity of municipal solid waste and land for energy cropping are much lower in the Netherlands than in other Member States, with only enough material to supply a small number of biorefineries. This bottleneck exists at all policy support levels. Likewise, the Netherlands lacks any sustainably available agricultural residues, one of the largest sources of feedstock for advanced biofuels in the European Union. We find that the 1.7% cap on the contribution of waste fats and oils is too high to constrain the use of domestic materials; however, it will likely impact the Netherlands' existing reliance on imported materials to achieve the broader policy target.