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Assessment of biofuels in 2030 - Support to KEV 2021

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Preface

The author is thankful to Gerben Geilenkirchen (PBL), Hein de Wilde and Martin Scheepers (TNO), Eric van den Heuvel (Platform Hernieuwbare Brandstoffen) and Jose Muisers (RVO) for their support and constructive feedbacks.

Contents

1 Introduction

PBL (Netherlands Environmental Assessment Agency) publishes the 'Netherlands Climate and Energy Outlook' (KEV) report annually. The KEV provides an integral insight into the past, present and future of the Dutch energy system and its greenhouse gas (GHG) emissions. A great deal of attention is paid to national policies and their expected effects on the future energy use and emissions. Mobility is one of the sectors covered in the KEV.

For preparing the KEV 2021, PBL has asked TNO to study the impact of the new policy document "draft Ordinance Energy in Transport[1]", published in December 2020. This ordinance laid down the renewable energy obligations in transport as part of the implementation of the recast Renewable Energy Directive (REDII) for the period 2022-2030. More precisely, insights into the possible effects of this policy on the amounts and types of biofuels that can be introduced in the market were requested. Furthermore, TNO was asked to estimate the additional costs of biofuels compared to the fossil fuel references. So, within the framework of the REDII implementation in the Netherlands and the Climate Agreement, the following questions were addressed:

- What are the demand volumes of different biofuel categories in 2030?
- What type of biofuels can be expected and, related to that, what production processes?
- What will be the order of the magnitude of the additional costs?

In September 2021, a new ordinance proposal was published. This proposal was sent to the House of Representatives in October 2021. Some changes were introduced in this proposal. Since the KEV 2021 is based on the policy principals as of 1 May 2021, these new changes are not taken into account in this study. For the same reason, the new EU policy package, Fit-for-55, published in July 2021, is also not participated.

This is a concise assessment to support the mobility section of the PBL's KEV 2021 study related to biofuels. This document summarises the main findings of TNO. It consists of 5 chapters. Following the current Chapter 1 with the introduction, Chapter 2 introduces the key elements of the current policy process that will impact the biofuels deployment in the Netherlands. Chapter 3 focuses on the key factors that may affect the amount and type of biofuels applied in 2030. Next, Chapter 4 introduces the scenarios for further analysis. In Chapter 5, the analysis results are presented. This chapter includes both the types and amounts of biofuels that can be needed in 2030. In addition to that, an estimate of the associated costs is included. Finally, Chapter 6 presents the important observations, main limitations of this assessment and the discussion points.

[1] Besluit van tot wijziging van het Besluit energie vervoer in verband met de implementatie van Richtlijn (EU) 2018/2001 van het Europees Parlement en de Raad van 11 december 2018 ter bevordering van het gebruik van energie uit hernieuwbare bronnen en ter uitvoering van het Klimaatakkoord

2 Policy framework

This chapter introduces the key elements of the policies that are most relevant to the biofuels deployment in the transport sector in 2030.

The European Commission published the Renewable Energy Directive recast (REDII) in December 2018, setting the framework for the use of renewable transport fuels in the European Unions (EU) for the period 2021-2030. The Netherlands is in the process of transposing this directive into national laws and as part of this process the Dutch government issued a draft ordinance (IenW, 2020a) in December 2020. This draft ordinance details the renewable fuel obligations up to 2030..The key elements of this draft ordinance are summarised in Table 1. Following the consultation process, a new proposal ordinance was issued and sent to the House of Representatives in October 2021. The main changes introduced in this ordinance proposal is also highlighted in this table. It needs to be mention that this proposal is also not a final decision and some further adaptations may happen in the coming period.

Table 1 Main elements of the draft decision regarding renewable fuels in transport in the Netherlands

	Obligations according to draft ordinance in December 2018	Main differences in ordinance proposal sent to the House of Representatives in October 2021
End users subject to the obligation	Diesel, gasoline, and heavy fuel oil supplied to: - Road and rail transport - Non-road mobile machinery, - Agricultural tractors and forest machines, - Recreational boating (when not at sea). - Inland shipping, including inshore fishers	Inland shipping will not be brought under the annual obligation.
Time period covered[2]	2022-2030	
Obligation level	16.4% in 2022. increasing to 27.1% in 2030 (based on energy content, including multiple counting).	17.9 in 2022. increasing to 28% in 2030 (based on energy content, including multiple counting)
Limit to conventional biofuels	Limited to the 2020 level (around 1.7% of the total diesel and gasoline consumed in transport) Palm- and soya oil as feedstock is not allowed due to indirect land use change (iLUC) risk	Limit updated to 1.4% (as in 2020)
Limit to biofuels from Annex IX-B feedstocks[3]	Use of biofuels from used cooking oils (UCO) and animal fats (AF) is limited to the 2020 levels (around 8.4% of the total diesel and gasoline consumed in transport). This includes double counting. Thus, they are limited to 4.2% in physical terms (energy content).	Updated to 10% administratively. Without double counting, this is 5%.

[2] There has been another decision for 2021.

[3] Annex IX B feedstocks refer to used cooking oil (UCO) and animal fats

	Obligations according to draft ordinance in December 2018	Main differences in ordinance proposal sent to the House of Representatives in October 2021
Minimum sub-target for advanced biofuels from Annex IX-A feedstocks[4]	Linear growth from 1.2% in 2021 to 7% in 2030. This number includes double counting. Thus, in physical terms it is 3.5% in 2030 (energy content).	No change.
Other renewable fuels	This category includes: - Renewable electricity in road transport (counted 4 times its energy content). - Gaseous renewable fuels produced from renewable electricity such as hydrogen. - Liquid renewable fuels produced from renewable electricity (Power-to-Liquid, PtL). - Liquid biofuels from crops that do not entail a risk of agricultural land expansion (i.e., catch and cover crops). - Biofuels from Annex IX A list feedstocks above the subtarget.	No change to renewable electricity accounting. Liquid and gaseous renewable fuels from renewable electricity to be counted 2.5 times.

Next to the transposition of the REDII in national legislation (*Wet Milieubeheer*), the Dutch government is actively pursuing the introduction of a European blending obligation for aviation. As part of the EU Fit-for-55 policy package, a directive proposal was introduced for the aviation sector in July 2021. The ReFuelEU Aviation proposal introduces renewable fuel blending obligations to increase uptake of sustainable aviation fuels. As KEV 2021 considers policy measures up to 1 May 2021, this policy package is not included in the assessments.

For maritime shipping, various processes are underway, both at European and International Maritime Organisation (IMO) level. In the Sustainability Framework for Biological Raw Materials, the Dutch government will investigate the effectiveness of an obligation to blend renewable (bio) fuels in sea shipping. An opt-in system has been implemented in the Netherlands. Renewable fuels supplied to maritime shipping and aviation sectors have been counted towards the national obligation fulfilment. The draft ordinance indicates that from 2022 onwards for maritime shipping only advanced biofuels will be counted towards the blending obligation. This is to prevent any disruption in regard to the achievement of the national climate obligation. The GHG emission reductions that occur in the maritime sector do not count for the national emission reduction goals in the Netherlands. At the same time, the booking authority (www.emissieautoriteit.nl) ensures that maritime shipping, like the other sectors, contributes to the demand for advanced renewable fuels, which translates into a demand for new production capacity. More importantly, this opt-in system for maritime shipping and aviation will be terminated by 1 January 2025. The Fit-for-55 package also includes the FuelEU Maritime initiative, which proposes to include shipping in the European Emissions Trading Scheme (ETS) to reduce GHG emissions. Same as the aviation directive proposal, possible implications of this initiative is beyond this study.

[4] Annex IX A provides a long list of biomass feedstocks that are mostly consist of wastes and residues

Previously, the Dutch Climate Agreement has laid down additional ambitions and targets for renewable energy in road transport and inland shipping. The aspects most relevant to biofuels include:

- An ambition of all new passenger cars sold to be emission-free by 2030. It should be noted that as of now this is only an ambition. Underlying policies for incentivizing the uptake of zero emission cars have only been put in place for the 2020-2025 period. There was no agreement reached on the policies for the 2026-2030 period.
- A maximum of 27 PJ renewable fuels will be used in road transport on top of the 2030 scenario of the 2017 National Energy Outlook (PBL, 2017). This is in addition to the use of electricity and hydrogen. Thus, this 27 PJ is in addition to 33 PJ biofuels projected for 2030 in the 2017 outlook, adding up to a total of 60 PJ renewable fuels in 2030.
- The national government will reserve 200 million euros to increase the production and innovation of sustainable advanced biofuels and renewable synthetic biofuels.
- A minimum of 5 PJ sustainable energy carriers will be supplied to inland shipping. The carriers include electricity, hydrogen and sustainable biofuels.

The government plans to use the above mentioned €200 million to support the production of advanced biofuels and renewable synthetic fuels through the Stimulation of Sustainable Energy Production scheme (SDE++) program. In fact, in 2020, three advanced biofuel categories were included in the SDE++ policy instrument with a possibility to expand the coverage in the coming period. In 2021, two additional value chains were included to the concept advise for 2022; viz production of bio-methanol and Fischer Tropsch (FT) liquids. While SDE++ stimulates the production of renewable energy a precondition is set for advanced biofuels. These advanced biofuels will be included in the renewable obligation for fuel suppliers to guarantee that advanced biofuels that receive SDE++ will be used in the Netherlands. The table below illustrates the current state of information in the SDE++.

Table 2 Current status of advanced biofuel categories included to SDE++

Category	Feedstock type
Bioethanol	Lignocellulosic feedstocks from Annex IX A
Bio-LNG	Mono-manure
	All other feedstocks suitable for biogas generation
Drop-in biofuels via hydrotreated pyrolysis oil	Lignocellulosic feedstocks from Annex IX A
Drop-in biofuels via FT synthesis[5]	Lignocellulosic feedstocks from Annex IX A
Bio-methanol	Lignocellulosic feedstocks from Annex IX A

[5] FT liquids are considered to be 70% diesel and 30% gasoline in volume. In a standard FT synthesis the ratio is mostly X% diesel, Y% kerosene and Z% naphtha, which can be converted into gasoline.

3 Scenario set-up

Future deployment of biofuels, given the policy framework described in the previous paragraph, will depend on a number of factors, among which two aspects are considered to play a crucial role on the required amounts of (advanced) biofuels that will be needed in 2030.

- Supply of biofuels produced from feedstocks listed in Annex IX B of REDII, mainly used cooking oil (UCO) and animal fats (AF), classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.
- The amount of electrification, including H_2 use in fuel cell electric vehicles (FCEVs), in (road) transport.

3.1 Supply of biofuels from feedstocks listed in Annex IX B

In REDII, the European Commission has introduced a 1.7%[6] cap to biofuels produced from UCO and AF. One of the reasons behind this cap was to avoid/limit unintended negative consequences (i.e. mix with virgin oils or pure fats). Another reason was the estimated availability of Annex IX B feedstocks, especially when other countries are stepping up on using these feedstocks as well. The demand for these biofuels was increasing in Europe as they were stimulated in several countries, including in the Netherlands, by allowing the option of double counting. This double counting is meant to redirect the deployment from conventional to waste based biofuels. This implies that one unit can count twice towards the target. Biofuels that can be produced from UCO and AF are:

- UCO methyl ester (UCOME) and tallow methyl ester (TME)-based biodiesel, that can be blended with fossil diesel. Fatty acid methyl ester (FAME) and UCOME & TME altogether can be blended with a maximum of 7% in volume. There are also vehicles (such as buses) that can process B100 (100% vol. biodiesel)
- Hydrotreated vegetable oil (HVO), also referred to as renewable diesel, that can be blended up to 30% in diesel to still comply to EN590 fuel specification or can be used as 100% renewable fuel in engines that have been approved by the Original Equipment Manufacturers (OEMs) (mainly Euro V and Euro VI trucks).
- Hydro processed Esters and Fatty Acids (HEFA), that can be used as Sustainable aviation fuels (SAF).
- Bio-Heavy Fuel Oil (Bio-HFO) for maritime sector.

While RED II introduces a cap for biofuels from Annex IX B, Member States may, where justified, modify that limit, taking into account the availability of feedstock[7]. Thus, countries can inquire the Commission for setting a higher limitation. Among the member states, Italy, Portugal, Hungary, Netherlands and Ireland appear to supply higher biofuels from Annex IX B than the 1.7% cap[8], introduced by the European Commission. The draft ordinance suggests to keep the amount the same as it was supplied to the Dutch market in 2020. As such, only the 1.7% share allowed under the REDII will be reported to the EU within the REDII obligations.

According to the Netherlands Emission Authority (NEa), more than half of the UCO based biofuels originated from outside Europe, mainly from China and Malesia in 2019 and 2020 (NEa,2021; 2020). Approximately, 50% of the UCO utilised in Europe was imported from outside the EU (Hemelinck et al., 2021). However, many

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6 Contribution of these biofuels should not exceed 1.7% of fuels supplied to road and rail transport.
7 Any such modification shall be subject to approval by the Commission" (RED II Art 27 para 1.b)
8 UK also utilizes much higher

countries outside the E have climate targets and incentives to maximize utilization of domestic wastes and residues. As Asian countries seek to meet their own climate targets, this may lead to increased competition for UCO produced in Asia. As a consequence, increasing demand for these biofuels and the double counting mechanism may push up the market price of UCO and influence the cost competitiveness of biofuels produced from these feedstocks. It may, therefore, become more difficult for EU and the Netherlands to rely on these imports.

Moreover, the draft ordinance energy in transport states that due to sustainability concerns, the Dutch government may decide to abolish double counting of these biofuels by 2025. This can result in these fuels and feedstocks being pulled by other markets.

In 2019, the physical delivery of biofuels produced from UCO and AF was around 22 PJ[9] (NEa, 2020). According to the Climate Agreement, the amount of biofuels produced from these feedstocks shall stay at the 2020 level in 2030. The ordinance indicated a 4.2% cap in 2030, which would correspond to approximately the same amount. This introduced cap to biofuels produced from UCO and AF is considered as one of the sensitive factors that will affect the demand for other advanced biofuels from Annex IX A and/or other renewable fuels in the Netherlands. Thus, to which extent this proposed maximum limit will be used in 2030 is one of the uncertain factors introduced in our scenario descriptions.

3.2 Role of electrification

Electrification of road transport will affect biofuels in two ways. Use of electric vehicles (EVs) will result in less diesel and gasoline use. In addition, an EV vehicle is more energy efficient, which means that energy consumption of vehicles will decrease with more use of EVs. The renewable obligation is set as share of diesel and gasoline use, therefore, the reduction in final fossil fuel use will lower the demand for renewable fuels in absolute terms. Next, higher use of renewable electricity will contribute to the total share of renewable fuels in transport and therefore, will reduce the demand for biofuels. Below formula illustrates the interactions between electrification of transport (both direct electrification via battery electric vehicles (BEVs) and H_2 use in fuel cell electric vehicles (FCEVs).

$$RES\ (\%) = \frac{(RE - E\uparrow + Biofuels\downarrow)}{(Diesel + Gasoline)\downarrow}$$

Of which:
RES: Renewable energy share
RE-E: Renewable amount of electricity used by EVs and fuel cell electric vehicles

It should be noted that not all electricity used in transport can be accounted under the renewable energy obligation. Only the renewable share can be taken into account. According to the REDII, for the calculation of the share of renewable electricity in road and rail vehicles Member States shall refer to the two-year period before the year in which the electricity is supplied in their territory. In this context, the renewable amount of electricity used in road transport in 2030 should be estimated using the share of renewable electricity mix in 2028. According to KEV 2021, this is 72% in 2028. Furthermore, from the amount of total electricity supplied to transport, 47% of it is assumed to be booked. This is the amount of electricity that is considered as bookable to the Register Energy and Transport (REV) and that can receive renewable fuel units (HBEs). HBE's can only be created when the electricity

9 Recent publication from NEa indicates the total amount of these biofuels to be around 24, 4 PJ. In this study we implemented the 4.2% cap, rather than the absolute values from 2020.

is supplied specifically to road transport. As such, home charging cannot be used to create HBE's. Since most current EVs are mostly charged at home, only a small part of current electricity use in road transport is actually used to create HBE's. Research by Ecorys (2020) estimates that in the long term up to 47% of electricity use in road transport can be turned into HBE's.

3.3 Scenario set up

As introduced above, scenarios for 2030 are based on the role of electrification and H_2 use in transport, and how far the cap set for biofuels produced from Annex IX B can be fully met . Figure 1 illustrates the scenario set up.

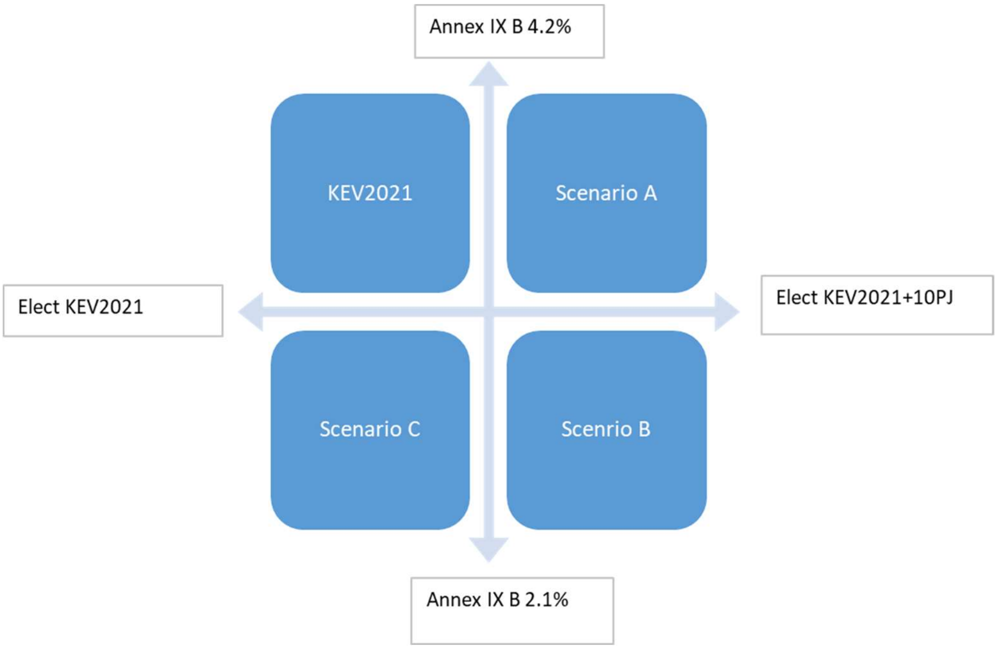

Figure 1 Illustration of the main elements of the scenario set up

In the KEV 2021 baseline scenario and scenario C the role of electrification and H_2 in road transport is fixed to the KEV 2021 projections. Thus, direct electrification of road transport comprises around 19 PJ in 2030, whereas H_2 has a limited role of 0.4 PJ in road transport (KEV 2021). In scenario A and B we assume that the direct electrification is increased by 10 PJ[10] reaching to 29 PJ in final energy consumption. This extra 10 PJ is an assumption to show how the mechanism works. It is conceivable that electrification will go faster than the KEV 2021 estimates, for instance, due to the EU Fit-for-55 package, which is not included in the KEV. We, therefore, chose a scenario with more EVs than the KEV 2021 projection. Further electrification related energy savings[11] in scenario A and B is implemented to fossil gasoline and diesel consumption in road transport. Other transport fuels, including LPG and CNG/LNG are kept the same as KEV projections in all 4 scenarios.

[10] Same assumptions are implemented for that 10 PJ extra electricity, namely 72% is renewable share and 47% can be booked in 2030

[11] The energy saving potential factor of battery electric vehicles is set to 1.94 and fuel cell electric vehicles to 1.07. This saving potential factor is applied 50/50 to gasoline and diesel.

All other scenario assumptions are based on the Dutch ordinance that also takes into account REDII. As such, renewable electricity is counted 4 times, renewable H_2[12] 2.5 times and advanced biofuels (both Annex IX A and B) 2 times.

The Annex X B biofuels, namely biofuels from UCO and AF, are assumed to meet the cap of 4.2% in 2030 in the KEV 2021 baseline scenario and scenario A. Other two scenarios consider a future, where only half of the cap for these biofuel will be met due to the market dynamics and t biofuels produced from UCO and AF are becoming less competitive in the Dutch market. Thus, in scenarios B and C the cap is halved.

The contribution of conventional biofuels are kept the same as 2020, and the associated FAME/ethanol ratio of 20%/80% is implemented also for 2030. In this study, other renewable fuels are assumed to be advanced biofuels from Annex IX A. Other renewable fuels can also include cover crops, renewable electricity and renewable fuels from non-biological origin (RFNBO). As the impacts of electrification is already included in different scenarios we excluded this option. We assumed that the amount of RFNBO can be neglected as these technologies are not mature/cost competitive yet. We assumed that the cover crops will consist of grasses and they will be part of Annex X A list.

3.4 KEV2021 as main data source

Scenarios are built on the KEV 2021 projections for 2030. The KEV 2021 projections for energy demand in the transport sector and the role of H_2 and electrification are presented in Table 3.

Table 3 Breakdown of final energy use in 2030 according to KEV 2021

		Final energy use [PJ]
Road transport	Gasoline	185.9
	Diesel	172.6
	LPG	2.1
	CNG/LNG	3.1
	Electricity	19
	H_2	0.4
Rail	Diesel	1
	Electricity	6.8
Recreational craft	Gasoline	0.9
	Diesel	1.5
Non-road mobile machinery	Gasoline	1.5
	Diesel	40.4
	LPG	0.9
Inland shipping**	Diesel	12.7
	Diesel (bunkers)	40.9

* *Biofuels are included as part of total diesel, gasoline and CNG/LNG*

** *Inland shipping includes 'work at sea'. When the KEV 2021 projections were made, it was uncertain to what extent this category would also be covered by the new regulations.*

[12] Multiple counting for H_2 was not yet decided at the time of this assessment.

4 Scenario assessment

4.1 Total renewable fuels mix in 2030

Figure 2 illustrates the amount of renewable energy in transport in 2030, according to the different scenarios. This figure also includes KEV 2020 projections for comparison. The KEV 2020 did not include the proposed increases of the renewable energy obligations for transport. Therefore, amount of renewable energy, particularly biofuels, is much lower in KEV 2020.

Results show that the total demand for renewable fuels is reduced by around 11% compared to KEV 2021 baseline, when direct electrification is increased by 10 PJ (scenario A and B). The total biofuel demand is reduced by 19%, from 52.4 PJ to 42.7 PJ, in these scenarios. These reductions result from the energy savings due to electrification of road transport and the introduction of renewable targets as percentages. The higher the direct electrification of road transport, the lower the denominator becomes. Since the biofuel targets and caps are set as shares of the denominator, their absolute contributions get lower. Total biofuel demand and the contribution of renewable electrification appear in Scenario C the same as KEV 2021 baseline. This is because the main difference between the two scenarios relate to the type of biofuels rather than the total amount.

The Climate Agreement allows for a maximum of 60 PJ of renewable fuels (excluding electrification and H_2) to be used in road transport in 2030 and a minimum of 5 PJ of renewable energy (including electrification and H_2) to be used in inland shipping. This assessment results show that this maximum of 60 PJ is by no means used as the results, which include inland shipping, are well below this figure.

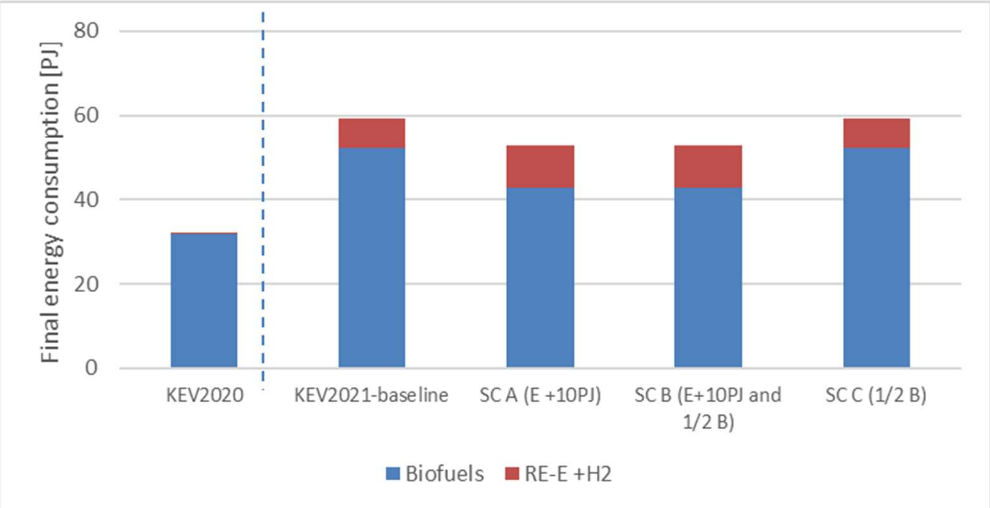

Figure 2 Role of renewable fuels in 2030 according to different scenarios (without multiple counting)

Figure 3 illustrates the total energy demand breakdown to fossil resources, renewable electricity and biofuels. Direct electricity use is disaggregated into three categories: i) amount of renewable electricity that is bookable, ii) renewable electricity that cannot be booked towards the renewable energy target, and iii) electricity from fossil origin. This third category includes, next to road transport, electricity consumption in rail transport. Figure 3 shows that in all scenarios fossil fuel use corresponds to more than 80% of the fuel supply[13]. Renewables share is 11 - 12%. Increased electrification in Scenario A and B results in 2.6% reduction of fossil fuels, compared to KEV 2021 baseline and Scenario C.

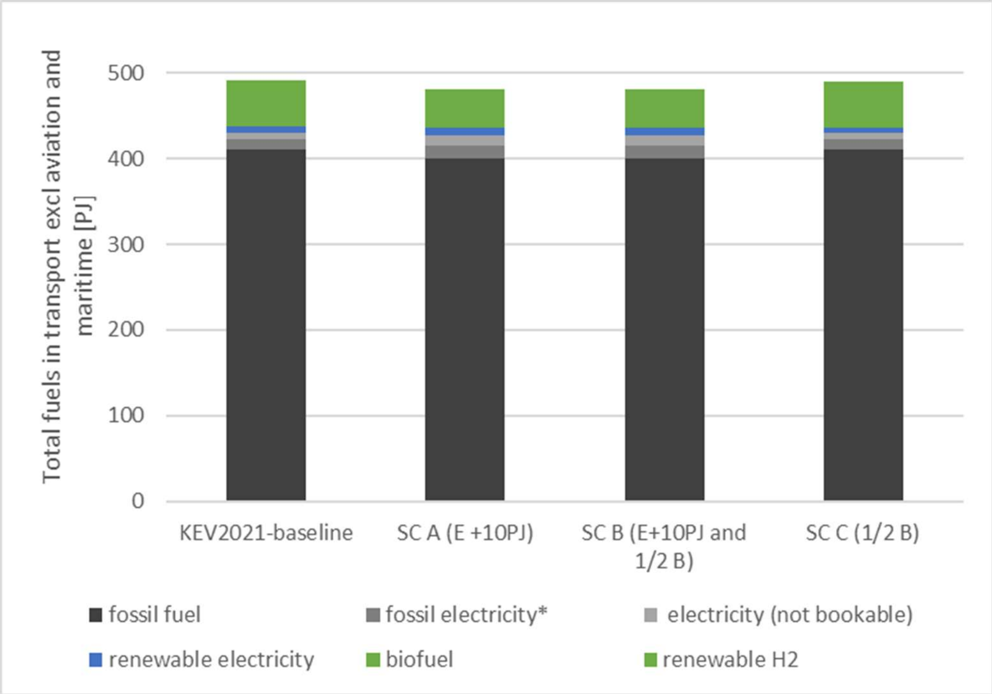

Figure 3 Total energy demand in 2030 according to different scenarios, broken down to origin of energy source.

The different renewable energy options that meet the obligations introduced in the draft ordinance energy and transport are illustrated in Figure 4. Biofuels from Annex IX A (assuming other fuels also as Annex IX A) are calculated to be in the range of 16.9 - 35 PJ in 2030. These are numbers refer to physical demand, they do not include multiple accounting. The lower range relates to Scenario A, where electrification is increased and the maximum cap for biofuels from Annex IX B is fully met. The high figure in this range refers to scenario C, where electrification is kept at the level estimated in the KEV 2021 and the Annex IX B fuels are assumed to be halved due to the market dynamics and these biofuels becoming less competitive in the Dutch market. KEV 2021 and Scenario B result in similar amount of demand for biofuels from Annex X A feedstocks. Conventional (1G) biofuels stay the same in all scenarios. Almost all scenarios indicate the significant importance of biofuels produced from the feedstocks listed in Annex IX A. This suggest the importance of quick progress in developing technologies that can utilise the type of feedstocks from Annex IX A and produce biofuels.

[13] It should be noted that electricity de facto always has a lower share in these types of energy figures than in, for example, figures on fleet or kilometres due to differences in vehicle efficiency.

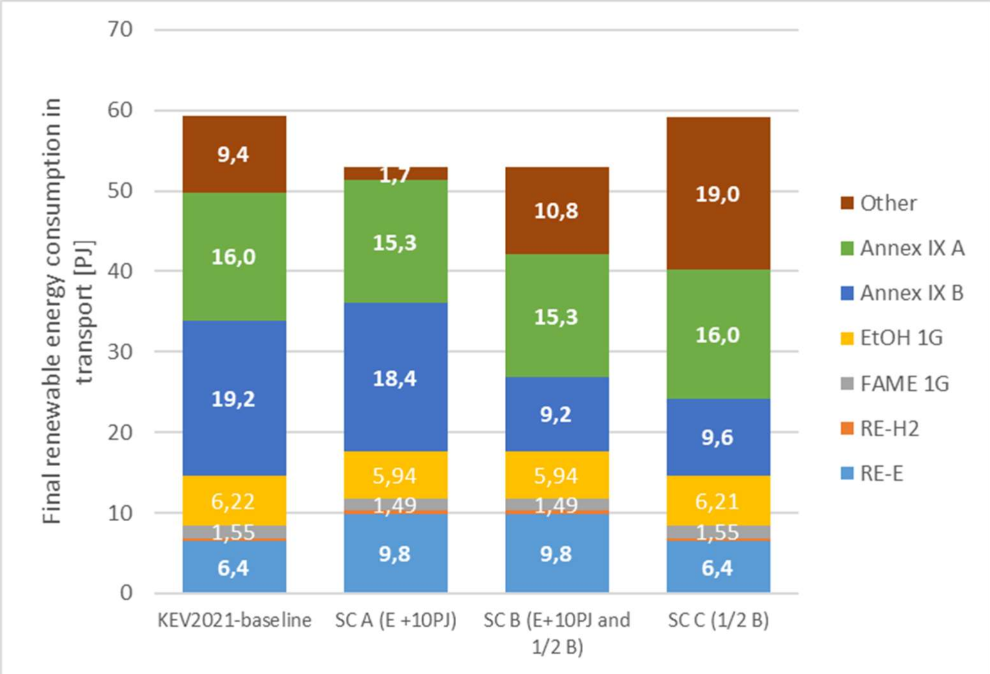

Figure 4 Breakdown of renewable energy in the transport sector in 2030

4.2 Identifying the type of biofuels

In this section, we identify the type of advanced biofuels that are likely to be on the market in 2030. This is based on the below assumptions:

i) traditional vehicles that use internal combustion engines (ICE)[14] continue to be used in 2030. No vehicle adaptations (i.e. to use DME or higher shares of methanol) are included.
ii) current blending limitations stay the same. Thus, E10 for ethanol, B7 for biodiesel and 3% vol. for methanol in 2030.
iii) biofuels are produced and consumed in the Netherlands[15]. This means that all main and by-products of a biorefinery are used in the Dutch transport sector.

Based on these assumptions we follow the below steps to identify the different types of biofuels:

- Biofuels from Annex IX B relates to UCOME[16] (UCO-Methyl Ester) and HVO. Production of HEFA and bio-HFO are excluded as aviation and maritime sectors are not included to this scenario assessment.

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[14] It could be that gas engine vehicles (already existing vehicles, would not require adaptations) could re-enter the market as biomethane based fuels are interesting from annex IX-A point of view. This option is ignored in this study.

[15] In reality this will not be the case as biofuels are tradable commodities. This assumption is implemented to reduce the uncertainties around the possible type of marketable biofuels and their prices in 2030. Next to that, the implementation of SDE++ may favor production and consumption of these biofuels in the NL.

[16] In 2017, 82% of the double counting FAME was from UCO and 9,9% from AF. This corresponds to 15,2 PJ UCOME from Annex IX A (singe counting). 85.8% of HVO was from UCO in 2019, corresponding to 4.2 PJ. Thus, around 78.8% of the biofuels from annex IX B was UCOME.

- We assume that 1G FAME will comprise around 20%[17] of the total 1G biofuels in 2030. Furthermore, the total amount of FAME and UCOME will need to comply with the 7% vol. blending wall also by 2030. Based on this limitation, we consider the remaining to be HVO and the by-products of this process, bio-naphtha & LPG.
- According to the most recent SDE++ base rate values bio-LNG production from anaerobic digestion is one of the least cost options[18]. In this study, we assume that bio-LNG use is limited to the LNG projections from KEV 2021.
- Among the advanced biofuel routes, bio-methanol (bio-MEOH) generation appears as the next cost effective option. In this study, bio-MEOH can substitute gasoline (thus not MeOH adapted engines), therefore the supply is limited with the 3% vol. blending[19].
- The amount of lignocellulosic ethanol is based on the total blending wall of 10%vol[20], where the total amount of 1G ethanol and 2G naphtha are also taken into account.
- The remaining demand is assumed to be met via synthetic fuels (drop-in biofuels) via FT synthesis.

Figure 5 presents the types of biofuels that may become available in the Dutch market in 2030. Based on the above assumptions, this study suggests that biofuels that substitute diesel will be around, 23.7-32.8 PJ. Gasoline substitution is calculated to be in the range of 14.2-17.9 PJ, according to the different scenarios. Among the different type of biofuels, drop-in diesel via FT synthesis and biodiesel from UCO & AF appear to be the largest biofuel types in all scenarios.

[17] In 2019 78% of the 1G biofuels was ethanol. In 2020. the share of 1G ethanol was increased to 98% (NEa, 2021)
[18] Least cost hear refers to the production costs.
[19] Possibility to use MTBE is not considered.
[20] Production of Ethyl Tertiary Butyl Ether (ETBE) from ethanol and 22% blending in E10 is not considered. ETBE use in 2019 was very small.

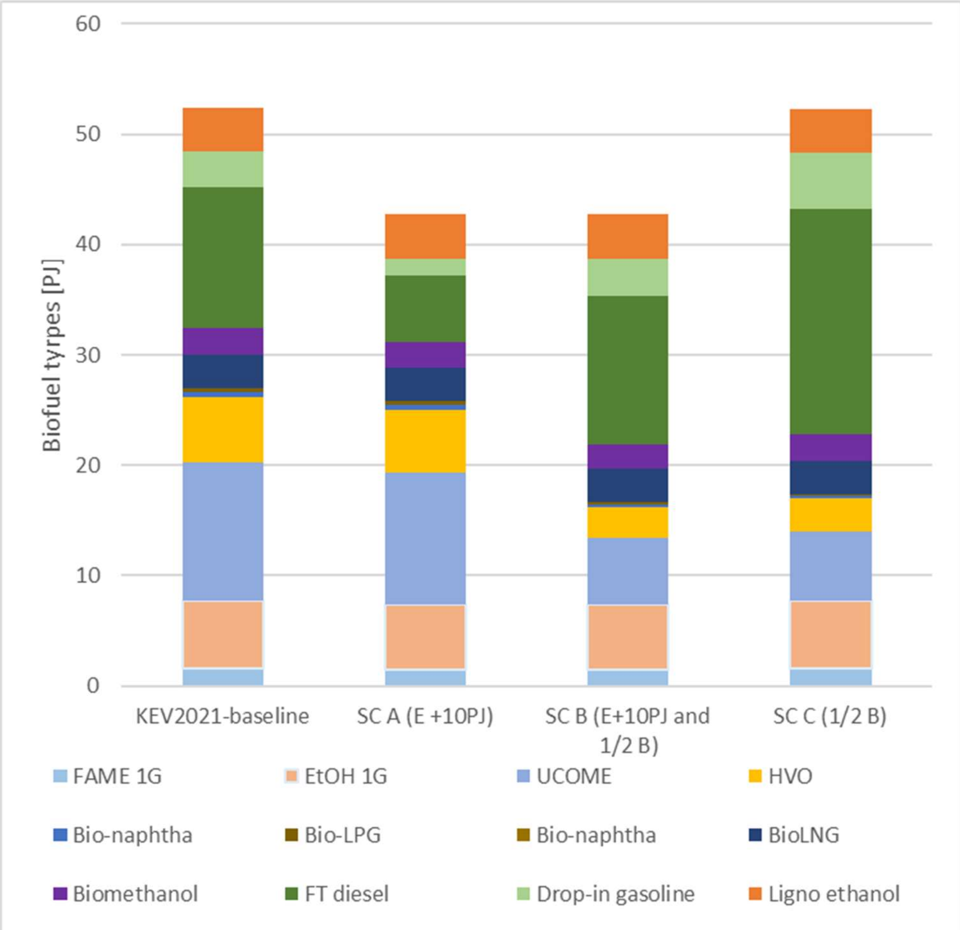

Figure 5 Biofuels in 2030. according to different scenarios

In order to define the contribution of biofuels among the different sub-sectors, namely road transport, rail, inland shipping, and non-road mobile machinery below assumptions are considered.

- Bio-LPG and bio-LNG/CNG replaces the fossil counterparts in accordance with the KEV2021 projections among different transport modes.
- 1G biofuels are largely used in road transport but, limited with the blend walls (E10 and B7).
- HVO is mainly used in heavy duty vehicles.

Table 4 presents the distribution of biofuels among the different transport sectors for KEV baseline scenario.

Table 4 Contribution of biofuels among different transport modes in 2030

Road transport		PJ
	FAME/UCO	9,6
	HVO	6.0
	Drop in diesel	5,1
	ETOH	10.2
	Bio-naphtha	0.5
	Drop in gasoline	3.2
	Bio-MeOH	2.4

	Bio-CNG/LNG	3.1
Non road mobile machinery (NRMM)		
	FAME/UCOME	2.3
	Drop-in diesel	4,5
	Bio-LPG	0.3
Inland shipping		
	FAME/UCOME	2.3
	Drop-in diesel	3.2

4.3 Total additional costs

Additional costs refer to the difference between the KEV2020 biofuels projection related cost difference and the scenarios analysed in this study. Cost difference is calculated as the total production cost difference between biofuel production costs and cost of fossil references. Biofuel production costs are based on the SDE++ base rate calculation for bio-LNG, bio-methanol, lignocellulosic ethanol and FT liquids from Concept advise for 2022. For HVO and UCOME the calculations are based on the CAPEX and OPEX data provided by Hamelinck et al (2021). We assumed that 1G biofuel production is comparable to UCOME and, therefore the same production cost data are considered. Table 5 presents the production costs used in this study in comparison to the production cost figure ranges presented in IEA (2020).

Table 5 Biofuel production costs in comparison to production cost ranges presented in IEA (2020)

	Production cost (€/GJ)	IEA production costs (€/GJ)
FAME 1G	17.8	
EtOH 1G	17.8	
UCOME	17.8	
HVO	23.9	*14-25.3*
Bio-LNG	22.2	*17-31* *(13-24 for waste)*
Bio-methanol	26.1	*17-31* *(13-24 for waste)*
FT liquids	26.4	*20.8-40)* *(14-25 for waste)*
Ligno ethanol	33.9	*28-43,9* *(14-16; corn fiber, 1.5G)*

In order to calculate the production cost differences we identified the production costs of fossil diesel, gasoline and LNG. For fossil diesel production cost estimate, we used the historical correlation between crude oil price and diesel refining costs. Fasihi et al (2016) calculated the long term (13 year) average ratio of one barrel diesel cost (crude oil consumption and refining cost) to crude oil price as 118.8% (see Figure 6). According to the KEV 2021 projections, the crude oil price will be 11.1 €/GJ in 2030. Based on this value the fossil diesel production cost is calculated as 13,2 €/GJ. The fossil gasoline production cost is based on the gasoline/diesel price ratio of 2020 (from KEV 2020 projection of pomp price, excluding taxes), which is 0.9. Thus, the gasoline production cost for 2030 is calculated as 11,9 €/GJ. LNG production costs is also based on the correlation to the TTF price (See Figure 7). KEV 2021 projected the natural gas price to 7.1 €/GJ for 2030. Based on the correlation, the LNG production cost for 2030 is calculated as 8 €/GJ.

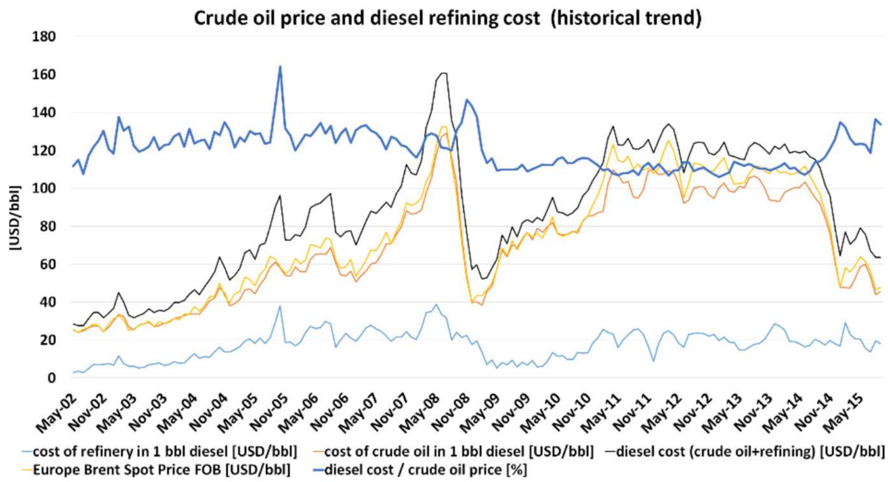

Figure 6 Historical trend regarding crude oil price and diesel refining cost [Fasihi et al (2016)]

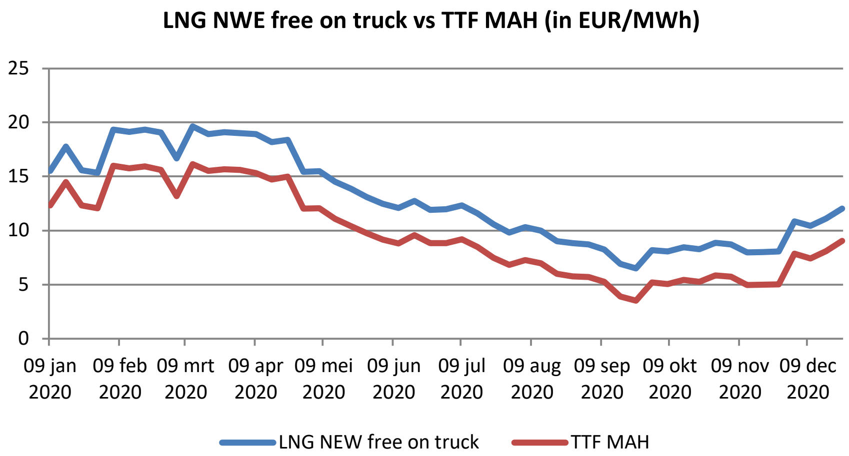

Figure 7 Correlation between LNG and TTF [SDE++2021]

* *TTF prices are the middle prices between bid and offer prices*
** *All prices are month ahead prices (MAH)*
*** *LNG prices are based on Argus small-scale NEW free on truck prices*

The additional costs are presented in Figure 8. KEV 2020 indicated the total amount of biofuels to be around 32 PJ in 2030. The total cost difference of KEV2020 biofuels is around 287 M€. The implementation of REDII in the Netherlands will result in higher costs, which are estimated to be in the range of 115-253 M€. This is in line with previous projections of PBL which estimated the additional costs of the use of biofuels resulting from the Climate Agreement to be between 135 and 270 M€ (Nijland et al., 2019). The large bandwidth presented in Figure 8 relates to the different shares of FT liquids in the studied scenarios. In scenario A, increased electrification reduces the demand for FT liquids significantly. This results in lower additional cost related to biofuels. The high value relates to a future where the supply of Annex IX B type of biofuels is much less. It is necessary to highlight that costs related to direct electrification, such as electricity price and the BEV related costs, are not included in this study. The cost comparison solely relates to biofuels.

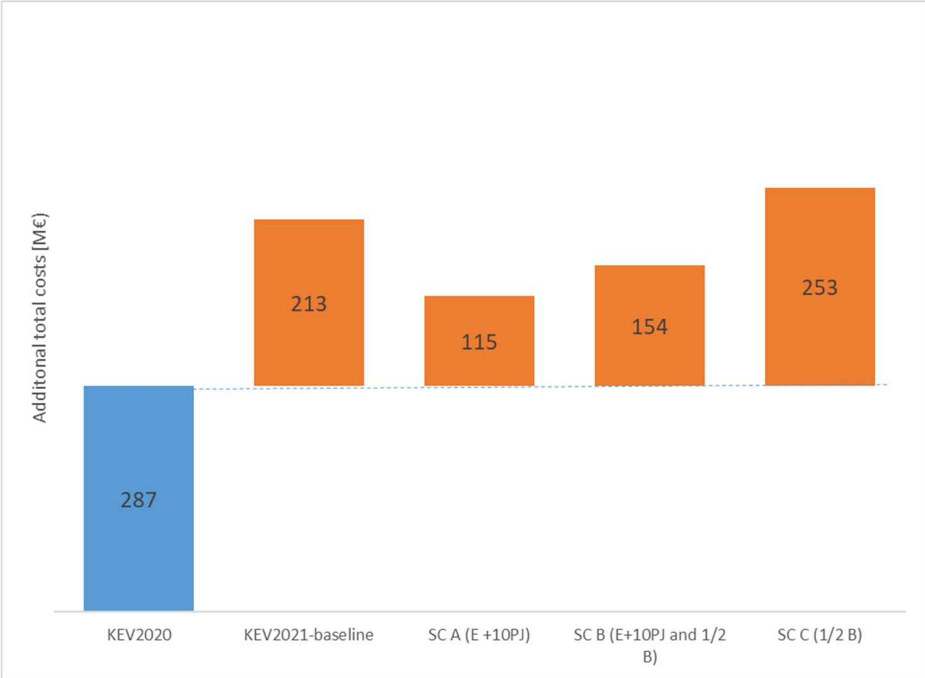

Figure 8 Total additional cost of various scenarios in comparison to KEV2020

5 Final observations, study limitations & discussions

5.1 Final observations

The Renewable Energy Directive (REDII) sets the European framework for the role of renewable fuels in transport for the time period up to 2030. As part of the Dutch transport sector decarbonisation and adaptation of this new directive into the national legislation, an ordinance was published in December 2022. This ordinance detailed the renewable fuel obligations within the time frame 2022-2030. According to this ordinance, biofuels are likely to contribute to around 80-88% of the final renewable fuel demand in 2030. This range relates to the direct electrification of road transport and also the share of renewable electricity. In fact, the biofuel demand results are very sensitive to the projections on electrification.

Advanced biofuels from Annex IX A feedstocks dominate the biofuel mix in 2030. According to the scenarios, they contribute around 40 to 67% of total biofuels. This is due to the minimum sub-obligation introduced for advanced biofuels and the caps introduced for conventional biofuels and biofuels from UCO & animal fats (Annex IX B feedstocks).

5.2 Study limitations & discussions

In this study, we assumed that the characteristics of the 2030 vehicle fleet will be the same as the current conventional fleet. Possible adaptations to the existing engines, for instance that can run on DME or methanol, are not included. The blending limits are also kept as the current implementation level. The possibility to have higher blends, such as E15 and E20. or higher blends that require flex-fuel vehicles (i.e. E85 or M85) are not considered. Including these options will change the fuel mix demand and the related costs. FT liquids comprise around 20 to 50% of the total biofuels demand in 2030. According to different scenarios and the main driver relates to the high demand for drop-in diesel substitute. Given the complexity of FT process and the associated investment risks, other supply options may become a preferred option such as vehicle adaptations to run on DME. Next to that, we assumed that the FT liquids consist of 85% diesel and 15% gasoline substitute. In practice, the FT processes are designed to produce a mix of diesel, gasoline and kerosene and the market conditions will define the business cases and related fuel mix.

In cost calculations, we assumed that the biofuels will be produced and consumed in the Netherlands. Based on this assumption, the production costs were related to the total output, for instance in case of HVO, the total production cost included the production of HVO diesel, bio-LPG and bio-naphtha. In reality, biofuels are traded commodities and their prices will depend on the demand and supply dynamics of the market.

Literature provides a large range for the production costs of biofuels. This large range relates, among others, to the feedstock type and the price, the chosen technology and the considered capacity in the calculations (economies of scale). In this study, we fixed the woody biomass price to 50 €/ton in all value chains (excluding 1G biofuels and bio-LNG). We also used the techno-economic data from SDE++. While the calculated production costs are within the range provided by IEA (2020), these values include large uncertainties. Lignocellulosic ethanol production from corn fibre, for instance, is likely to have much lower production costs. This process is named as 1.5G ethanol in literature. In case of gasification related value chains, such as methanol production or production of FT liquids, use of biogenic wastes may result in lower production costs. Moreover, other lower cost options, such production of biodiesel from palm oil mill effluents (POME[21]), are not included in this assessment.

In this study, the additional costs relate to the production cost differences between biofuels and the fossil fuels substituted (gasoline, diesel and LNG). As such, the results are highly sensitive to the fossil fuel production cost estimates.

An important limitation to this study is the exclusion of the aviation and maritime sectors. As introduced in Chapter 2. the Dutch government is investigating the possibility of introducing blending obligations for these sectors. The total final energy demand of these two sectors are higher than the inland final energy demand and any additional blending obligations to them will have strong implications. For instance a 5% blending obligation to aviation (energy based) will result in a sustainable aviation fuel (SAF) demand of around 10 PJ. Currently, HEFA appears to be the most viable option as the technology is already commercial. There is a cap to biofuels produced from UCO and AFs and one may expect that this cap will remain regardless where the biofuels produced from these feedstocks are used. Thus, if the obligation is to be partially met by HEFA for aviation, this may result in significant reductions of UCOME and HVO for road transport.

This study included the policy framework in 2020. More recent developments, for instance, the introduction of “Fit-for-55” package and their implications are not covered.

A more thorough assessment will look at the developments in Europe and globally. It will cover the sustainable biomass availability and economic mobilisation potentials, analyse the policy driven demand, the technology developments and the market dynamics of biofuels as they are tradable commodities. However, this assessment had a more limited focus. It intended to support PBL, in their KEV study and such broader, more indebt analyses was not intended.

[21] POME is a waste-based feedstock that is collected at palm oil mills during the palm oil production process. It has been acknowledged as a suitable feedstock for biofuels in the EU Renewable Energy Directive II (RED II).

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