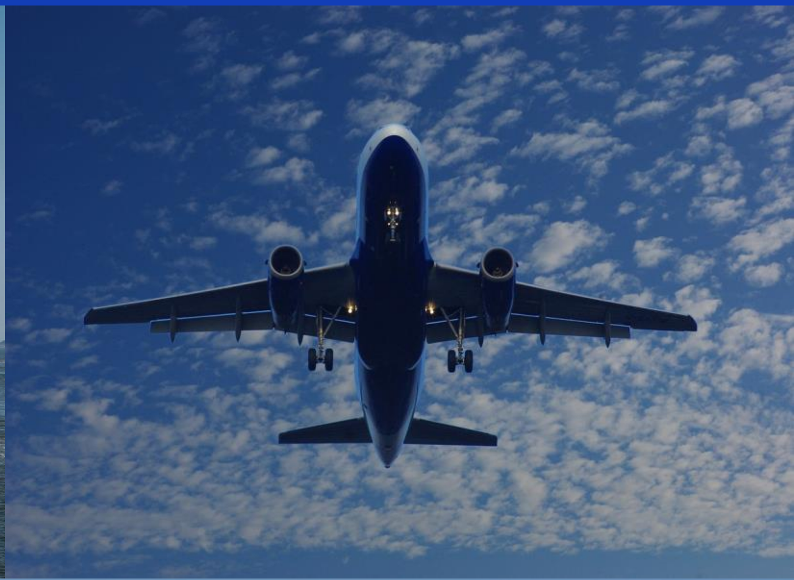
Support to KEV2023 (Update)

Renewable fuels up to 2030 - Assessment of REDIII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Renewable fuels up to 2030 - Assessment of REDIII

Support to KEV2023 (Update)

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Appendices

1 Introduction

The European Commission published the Renewable Energy Directive recast (REDII) in December 2018. This directive established, among other things, the framework for the utilisation of renewable energy in the transport sector for the period between 2021 and 2030. In the process of the transposing the relevant aspects of REDII for the transport sector and aligning with the goals of the Climate Agreement, the Dutch government introduced the Energy in Transport Ordinance[1] (IenW, 2021) in October 2021. This Ordinance outlined the renewable energy obligations extending up to the year 2030. This Ordinance was the primary foundation for projections of biofuels in the Climate and Energy outlook report published in 2022 (KEV2022)(PBL, 2022). PBL (Netherlands Environmental Assessment Agency) publishes the Netherlands Climate and Energy outlook report annually and provides a comprehensive perspective on developments within the Dutch energy system and its greenhouse gas (GHG) emissions up to 2030.

Meanwhile, the European Commission introduced the “fit-for-55” package, within which a new proposal to amend the Renewable Energy Directive (REDIII) was presented in July 2021. In March 2023, the Council and the Parliament reached a provisional agreement, which was formally endorsed by the Council in June 2023. The New legislation was published on 31 October 2023 and entered into force 20 days later.

As part of the Fit-for-55 package, regulatory proposals for the aviation and maritime transport sectors were also included. The ReFuelEU Aviation regulation proposed renewable fuel obligations for aircraft fuel suppliers at the European Union (EU) airports, while the FuelEU Maritime regulation introduced greenhouse gas (GHG) intensity reduction targets to ships above 5000 gross tonnes calling at European ports. In October 2023, the EU council adopted rules on sustainable aviation fuels (SAF) and the ReFuelEU Aviation regulation was published in the Official journal. The FuelEU Maritime proposal was signed on 13 September 2023 and was published in the Official Journal of the EU on 22 September 2023. It entered into force on 12 October 2023.

TNO has been supporting PBL in assessing KEV projections concerning biofuels by evaluating the magnitude of renewable fuel demand for the transport sector in 2030, using the transport sector projections and obligations determined by above cited legislations. This report presents the assessment results that are primarily concentrated on the final version of REDIII. The ReFuelEU aviation and FuelEU maritime regulations are also considered in this assessment albeit with a limited scope.

Firstly, a concise comparison between the Dutch Ordinance and the REDIII is provided. Secondly, the renewable fuel demand, as outlined in REDIII is quantified and compared with the KEV2022 projections for 2030. Emphasis is placed on the roles of biofuels and renewable fuels from non-biological origin (RFNBO). The key uncertainties that effect the results are also discussed. Thirdly, the FuelEU Maritime and ReFuelEU Aviation regulations are introduced, and their contributions to REDIII are quantified. Lastly, the conclusions are presented.

[1] Besluit Energie Vervoer

Box 1

This public report serves as an update, of a previous assessment for PBL in support of KEV-23 (that unintentionally has been available online for a few weeks after publication of KEV-23) Key starting points of the current report version are listed below, also indicating the differences with the prior version:

- The current version uses the final adopted versions of REDIII and other legislation while the previous assessment was based on provisional agreements.
- The current version correctly calculates the impact of electricity in transport while in the previous calculations the electricity contribution was by mistake counted two times in the calculation of the denominator.
- All assumptions in the current version have been revisited and adjusted as deemed necessary.
- In the current version, aligned with the adapted REDIII, the GHG intensity of electricity use (denominator) is set to 94 gCO_2eq/MJ, whereas the GHG emission reduction due to renewable electricity use (numerator) is rewarded with 183 gCO_2eq/MJ The methodological change introduced beyond 2030 is assessed as part of the uncertainty analysis. In the earlier calculations, based on the European Parliament recommendations, the electricity use emission intensity was set to 183 gCO_2eq/MJ.
- This current version excludes non-road mobile machinery from the transport sector (in contrast to the previous version). In addition, inland bunkering is now classified under the maritime shipping, whereas previously it was included under the domestic transport sector. These changes are fully in line with the Eurostat definitions.
- This version includes additional sensitivities to better illustrate the uncertainties.

2 Comparison of the Dutch Ordinance with the EU Renewable Energy Directive (REDIII)

Table 2.1 summarises the key elements in REDIII relevant to the transport sector, in comparison to the Dutch Ordinance issued in 2021.

One notable difference between the Dutch Ordinance and REDIII relates to the inclusion of different transport (sub)sectors and the obligations imposed on fuel types. REDIII covers all transport sectors, including aviation and maritime shipping, whereas the Dutch Ordinance covers only inland transport, excluding inland shipping, aviation and maritime shipping. Additionally, while the Ordinance sets obligations for diesel, gasoline and heavy fuel oil supplied to transport and also to stationary machinery and off-road[2], , REDIII covers all fuels and energy supplied to the transport sector.

In REDIII, the contribution of maritime bunkering to the total fuel and energy pool is capped to a specific level for member states with significant maritime bunkering activities, such as the Netherlands. The energy supplied to maritime transport is limited to 13% of the member state's gross final energy consumption. the exact text in REDIII is as follows:

Article 27 (5) "…the amount of energy supplied to the maritime transport sector shall, as a proportion of that Member State's gross final consumption of energy, be considered to be no more than 13 %."

PBL projections indicate total maritime bunkering, including inland bunkering in the Netherlands to be approximately 473 PJ in 2030. However, the 13% of gross final energy consumption in 2030[3] corresponds to 244 PJ. For this calculation 1878 PJ is considered as the reference gross final energy consumption in 2030. It is crucial to highlight that KEV2022 projections provide a bandwidth for the gross final energy consumption in 2030, ranging from 1556 to 2195 PJ. Thus, the contribution of the maritime shipping can fall within the range of 202 to 285 PJ.

[2] Transport that takes places in areas that are not publicly accessible (in general off-road areas, regardless if paved or unpaved) in the following sectors are to be reported in the respective end-use sectors of final consumption and not in transport: agriculture, forestry, fishing, construction (SHARES/EUROSTAT).

[3] The maritime bunkers may be capped on 13% of the gross final consumption of energy. The gross final consumption of energy is the denominator of the national share of renewable energy as calculated according to the RED calculation methodology (RED art 7).

Another difference relates to the target setting. While the current Ordinance establishes a renewable energy target, REDIII provides the option to opt for either a GHG emissions intensity reduction target or a renewable energy target. The Dutch government is working on implementing an obligation based on the GHG emissions intensity reduction for transport fuels[4]. Hence, in the remainder of this document, we specifically refer to the GHG intensity reduction target. It is important to note that the goal of reducing GHG intensity is about lowering emissions throughout the whole supply chain. Thus, it covers the well-to-wheel emissions.

REDIII also revises the sub-targets. An overall 5.5% sub-target is established for the combination of Annex IX list A feedstock-based biofuels and RFNBO in transport for 2030. However, within this overall transport target, the RFNBO minimum contribution is set at 1% point. Annex IX of the Renewable Energy Directive includes two lists of feedstocks eligible for producing biofuels, and these lists form the basis for the targets outlined in the directive. There has been a delegated act consultation to update these lists, with new typed of feedstocks added. Appendix A shows the complete list, highlighting the new feedstocks in blue. This list is a draft version and additions may be made.

Table 2.1: Differences between Dutch Ordinance and REDIII

	Dutch Ordinance (current based on REDII)	REDIII
End users subject to the obligation (denominator)	Transport sectors, namely • Road and rail transport • Non-road mobile machinery • Agricultural tractors and forest machines • Recreational boating (when not at sea)	Transport sectors, namely • Road and rail transport • Inland shipping • Aviation and maritime sector The amount of energy supplied to maritime transport shall, as a proportion of that Member State's gross final consumption of energy, be considered no more than 13%
Fuel type	• Diesel, gasoline, and heavy fuel	• All fuels and energy
Renewable energy (numerator)	• All types of energy from renewable sources supplied to all transport modes, including international bunkering, in the territory of each MS, excluding rail	• All types of energy from renewable sources supplied to all transport modes, including international bunkering, in the territory of each MS

[4] Overheid.nl | Consultatie Wet milieubeheer RED-III (internetconsultatie.nl)

	Dutch Ordinance (current based on REDII)	REDIII
Type and level of ambition	Overall renewable energy target (energy content) • at least 17.9% RES in 2022, increasing to 28% in 2030 (including multiple counting)	A binding GHG intensity reduction of at least 14.5% in transport by 2030, compared to the baseline set out in Article 27 or a binding share of at least 29% of renewables within the final consumption of energy in the transport sector by 2030 • MS may exempt supply of electricity or RFNBO to comply with the advanced biofuel min. share • Free to design the obligation as volumes, energy content or GHG emissions • Distinguish between different energy carriers • Distinguish between maritime transport and other sectors
Sub-target for advanced biofuels from Annex IX-A feedstocks and RFNBO	Linear growth from 1.8% in 2022 to 7% in 2030. These include double counting	A binding combined sub-target of at least 1% in 2025 and 5,5% for advanced biofuels and RFNBO in the share of renewable energy supplied to the transport sector. Multiple counting is allowed
Sub-target for RFNBO	No sub-target	Within the combined 5.5% target, a minimum requirement of 1% of RFNBO in the share of renewable energies to the transport sector in 2030. • Next to direct use as transport fuels, RFNBO intermediate use in the production of conventional fuels, or • In the production of biofuels, when GHG emissions reduction achieved by the use of H_2 is not included in the GHG emissions savings calculations of biofuels
Limit to biofuels from food and feed crops	Limited to the 2020 level, which is 1.4% of the total diesel and gasoline consumed in transport. Palm- and soy oil as feedstock is not allowed due to indirect land use change (iLUC) risk	Cap on conventional fuels to stay as 2020, and/or increase no more than 1% point higher. Conventional biofuels GHG savings to be fixed to 50%
Limit to biofuels from Annex IX-B feedstocks	Limited to the 2020 levels, which is 5% without double counting and 10% with double counting	Same as REDII (1.7% cap), with the difference that transport sector is expanded to cover also aviation and maritime

	Dutch Ordinance (current based on REDII)	REDIII
Multiple counting	• Biofuels and biogas from Annex IX list- A and B can be double counted • Renewable electricity in road transport counted 4 times its energy content. Renewable electricity in rail transport is not counted • RFNBO counted 2.5 times to the overall target • Advanced biofuels and other renewable fuels to aviation ad shipping can be counted towards the target up to 1 January 2025, with a multiplier as a possible steering instrument depending on the modality. After that, they will not be counted	Only valid for the binding target of 29% RES • Biofuels from Annex IX and RFNBO counted 2X energy content • Renewable electricity 4X when supplied to road vehicles, 1.5X when supplied to rail • Addition to the double counting, share of Annex IX A biofuels supplied to aviation and maritime shall be considered as 1.2 X their energy content • Addition to the double counting, share of RFNBO to aviation and maritime to be 1.5 X their energy content Valid under the GHG intensity target Biofuels from Annex IX A and RFNBO counted 2 X energy content to meet the 5,5% sub-obligation

3 Quantification of REDIII and comparison with KEV2022 projections

3.1 Minimum share of RFNBO and advanced biofuels from Annex IX, list A feedstocks

An essential consideration to answer this question relates to the definition and scope of the transport sector. The preceding directive (REDII) encompassed petrol, diesel, natural gas, biofuels, biogas, renewable liquid and gaseous transport fuels of non-biological origin, recycled carbon fuels and electricity supplied to the road and rail transport (Article 27.1a). , It excludes other fuels such as Liquefied Petroleum Gas (LPG), aviation kerosene or any type of fuel used for international shipping. Different from this, the REDIII, Article 27(2a) specifies that, in calculating the denominator–representing the total energy consumed in the transport sector–all fuels and electricity supplied to the transport sector must be considered. In addition, Article 25(5) refers to energy consumed in the maritime transport sector and indicates (as already explained in the previous chapter) that this amount shall be considered no more than 13% of that Member Sate’s gross final consumption of energy.

There have been some uncertainties surrounding the below aspects.

- The precise scope of the transport sector for calculating the denominator has been unclear. Should it encompass solely road and rail transport, inland shipping, aviation and maritime shipping? Or should it extend to include energy supplied to non-road machinery, recreational activities, and fisheries? Eurostat statics do not cover non-road machinery. However, non-road machinery has been part of the “Dutch obligation system “Jaarverplichting”. To be aligned with the Eurostat definition and REDIII, non-road machinery and fisheries are excluded from the denominator. This issue is revisited in the uncertainty analysis chapter.
- Additionally, there has been ambiguity regarding the fuel consumption of inland shipping, comprising both domestic inland consumption and inland bunkering. The question was raised whether inland bunkering should be categorised under inland transport or maritime shipping. Based on the Eurostat definition of “international maritime bunkers”– the international navigation may take place at sea, on inland lakes and waterways, and in coastal waters . Thus, the domestic/international split should be determined based on port of departure and port of arrival, and consumption by fishing vessels and military forces should be excluded. Therefore, in this assessment, only domestic navigation is included and the inland bunkering is considered as maritime transport.

Table 3.1 presents the breakdown of the transport sectors covered in this assessment and the relevant energy supply based on the KEV publication in 2022. This table also includes the demand for advanced biofuels from Annex IX, list A feedstocks and the RFNBOs to meet the minimum sub-targets introduced in REDIII. REDIII indicates that multiple counting can be used to meet the sub-target of 5.5%. Therefore, the demand for biofuels and RFNBO are presented as physical values within brackets.

Table 3.1: Final energy consumption in transport (based on KEV2022 forecast) and the minimum amount of advanced biofuels and RFNBO to meet the 5.5% sub-target set in REDIII in 2030.

	Bandwidth (PJ)	Reference value (PJ)
Total inland transport	400.6	400.6
Road	378.4	378.4
Rail	7.6	7.6
Domestic navigation	11.7	11.7
Recreational boating	2.4	2.4
Domestic aviation	0.4	0.4
Aviation[1]	159.3	159.3
Maritime shipping-as 13% cap to gross final energy[2]	202.3-285.4	244.2
Total transport energy (denominator)	**762.2-845.2**	**804.0**
Minimum amount of renewable fuels (5.5%)	41.9-46.5 (21.0-23.2)*	44.2 (22.1)*
To meet the 5.5% sub-target, minimum amount of RFNBO (1% point)	7.6-8.5 (3.8-4.2)*	8.0 (4.0)*
To meet the 5,5% sub-target, remaining amount as advanced biofuels from Annex IX, list A	34.3-38.0 (17.1-19.0)*	36.2 (18.1)*

1 KEV2022 includes also a bandwidth for aviation bunkering. in this study, only the refence vale is implemented.

2 KEV2022 indicates a bandwidth of 1556-2195 PJ for the gross final consumption of energy in the Netherlands in 2030 (PBL, 2022).

* REDIII included double counting to meet the sub-targets. The values within the brackets refer to the minimum actual supply needed to meet the sub-targets, thus they exclude the double counting This double counting is with the assumption that all Annex IXA biofuels and RFNBO's are used in the road sector. If biofuels from annex IXA and RFNBO's are used in aviation or shipping, the values will decrease due to the additional factor of 1.2 for biofuels and 1,5 for RFNBO.. No multipliers assumed in final energy consumption, pending a detailed elaboration of the calculation method by EUROSTAT.

3.2 Renewable energy demand to meet the GHG intensity reduction target

The calculation approach relevant to achieving the 14.5% GHG intensity reduction in 2030 is outlined below[5].

- In line with the REDIII methodology, the baseline was calculated by multiplying the overall energy (fuels and electricity) supplied to the transport sector by 94 gCO_2eq/MJ. This approach is valid until 31 December 2030. From 1 January 2031, the baseline calculation will be adapted as follows (Article 27(1(b) (i)and (ii))):
  - The amount of fuels supplied to all transport modes will be multiplied by 94 gCo_2eq/MJ
  - The amount of electricity supplied to all transport modes will be multiplied by 183 gCO_2/MJ This change of methodology and possible effects are included in the uncertainty analyses.
- For biofuels and biogas the typical emission factors from REDII Annex V were used (DIRECTIVE (EU) 2018/2001). These typical values are presented in appendix A, and their impacts are evaluated and presented in the uncertainty analyses in paragraph 3.4, considering different emission factors.
- In line with the REDIII methodology, the emissions savings for renewable electricity use in transport is based on the multiplication of renewable electricity with average GHG emission intensity of electricity production of 183 gCO_2/MJ.
- RFNBO is assumed to be renewable e-diesel[6] supplied to transport and the GHG emissions intensity is derived from JRC Well-to-Tank (WTT) assessments (JRC, 2020). It is important to note that REDIII sets the 70% life-cycle GHG emissions savings threshold for RFNBO to be eligible under REDIII. Thus, the well-to-wheel GHG emissions of this value chain shall not exceed 28.2 g CO_2eq/MJ. The impact of this assumption is evaluated in the uncertainty analyses paragraph.
- The total energy demand for transport, including aviation and maritime shipping, is based on the KEV2022 projections. The values in Table 3.1 are implemented. Further sensitivity analysis is conducted to illustrate the importance of sector coverage.
- No multiple counting is included for these calculations.
  Direct electrification is kept the same as KEV2022 projections.

Figure 3.1 shows the order of the magnitude of the renewable energy demand in 2030 to comply with the 14.5% GHG intensity reduction target. According to these calculations the total renewable energy demand (that covers biofuels, RFNBO and the direct use of renewable electricity in transport) is around 102-116 PJ. Accordingly, the biofuels demand is calculated to be around 74.4--88.1 PJ and RFNBO around 3.8-4.2 PJ. The ranges mainly relate to the uncertainty about the contribution of maritime bunkering to the total transport sector energy pool. This figure also shows the results based on the reference dataset.

These results have been communicated with RVO (Netherlands Enterprise Agency www.rvo.nl). They estimated biofuel demand at around 96 PJ assuming an average emission reduction of 70% (based on KEV2022 data and non-finalized EUROSTAT REDIII calculation methodology). It was indicated that the amount of biofuels required will decrease as the average emission reduction increases. Furthermore, the amount of biofuels required to

[5] In accordance with the current reading, the final REDIII calculation method still needs to be worked out in detail by EUROSTAT in coordination with DGENER.

[6] In this study, existing vehicle compatible option is selected, whereas H_2 us in road transport may appear as a viable option up to 2030.

meet the targets highly depends on the realization of the predicted electricity consumption in transport in 2030. The introduction of a GHG intensity reduction target complicates the evaluation of the total biofuel requirement because the average GHG intensity of the renewable fuels (referring to biofuels and RFNBO) that will enter the market in 2030 remains uncertain. This complicates the biofuel demand projection, since uncertainty in the GHG intensity of renewable fuels proportionally relates to uncertainty in the volumes required to meet the GHG reduction target. REDIII sets a threshold for the renewable fuels to qualify for the target achievement, requiring at least 50-70% reduction in GHG intensity compared to fossil fuels. We used the typical values specified in the Directive for biofuels, indicating GHG savings of 84 to 86%, relative to the fossil reference of 94 g CO_2eq/MJ. Additionally, for RFNBO, we implemented the well-to-wheel GHG emission value from JRC, representing a 99% GHG saving. These variances could explain the large uncertainty around the demand for biofuels in 2030.

Furthermore, these renewable fuel demand figures are highly sensitive to the amount of direct electrification and the share of renewable electricity. The GHG emission savings related to the renewable electricity use are calculated by multiplying the amount of renewable electricity with 183 gCO_2eq/MJ. To put this number into perspective, to achieve the equal amount of GHG emission savings, almost 4 times as much of conventional biofuels will be needed[7], when compared with the use of renewable electricity in transport. For advanced biofuels, this will be around two times, with the assumption that the well-to-wheel GHG emission savings of advanced biofuels are around 85%.

The results indicate approximately 1.5 times increase when compared with the KEV2022 projections for renewable energy in transport. The "Voortgang uitvoering Duurzaamheidskader biogrondstoffen" letter[8] indicates that the total use of renewable energy in heavy road transport, inland shipping, aviation and maritime shipping will grow to approximately 150 PJ within the context of the Fit-for-55 package. This value appears to be higher than the calculated numbers (here in the present report). At the same time, 150 PJ was an indication based on the provisional version of the REDIII and is no longer consistent with the final REDIII[9].

[7] The GHG emission savings are set to 50% for conventional biofuels.
[8] pdf (overheid.nl)
[9] Based on the communication with RVO

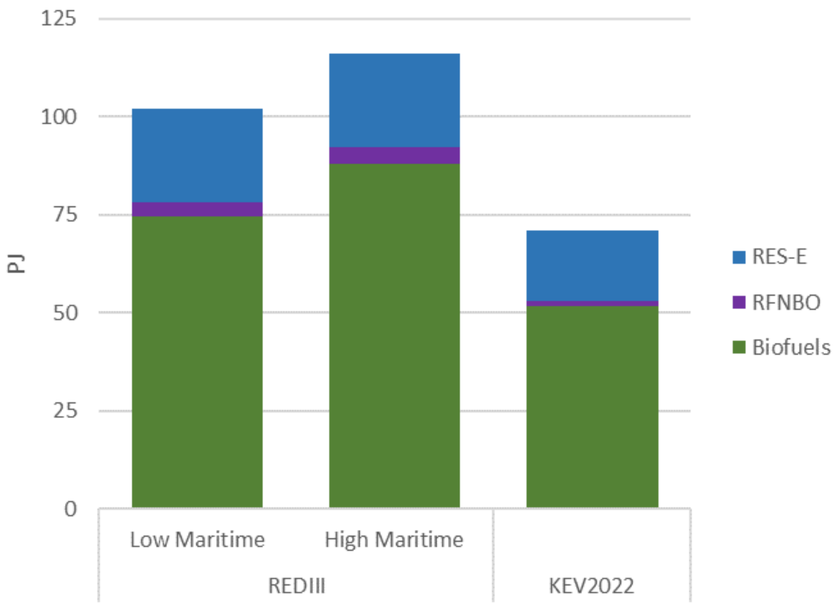

Figure 3.1: REDIII demand for renewable energy to meet the GHG intensity reduction target and comparison with the KEV2022 projections for 2030. No multiple counting is included.

As mentioned earlier, a primary distinction lies in the coverage of the transport sector. The Dutch Ordinance established renewable energy targets for the overall supply of diesel, gasoline and heavy fuel oil, excluding inland shipping, including non-road machinery. Consequently, the KEV2022 projections for 2030 relate to a total transport pool of 346.5 PJ. REDIII, however, refers to all transport modes and all energy sources. This means that the obliged transport pool includes, aviation and maritime bunkering fuel demand, with maritime bunkering capped at 13% of the gross final energy consumption in the Netherlands in 2030. So the according to REDIII defined total energy pool is much larger and is calculated as 762.2-845.2PJ (see Table 3.1).

3.3 Role of different type of biofuels

Based on the REDIII caps and sub-targets the contribution of different types of biofuels in 2030 is presented in Figure 3.2. Note that the 1.7% cap to Annex IX list B biofuels, like used cooking oil, corresponds to 13.0-14.4 PJ biofuels for the Netherlands. While the combined overall target of 5.5% correspond to 21-23.2 PJ, the biofuel demand from Annex IX A is calculated as 17.1-19.0 PJ to meet this overall target. However, the total amount of biofuels from Annex IXA will need to be much larger. This is because achieving the 14.5% GHG intensity reduction target will require additional biofuels, referred to as other biofuels in this figure. This other biofuels will likely also be based on feedstocks from Annex IX, list A, as conventional and Annex IXB biofuels are capped.

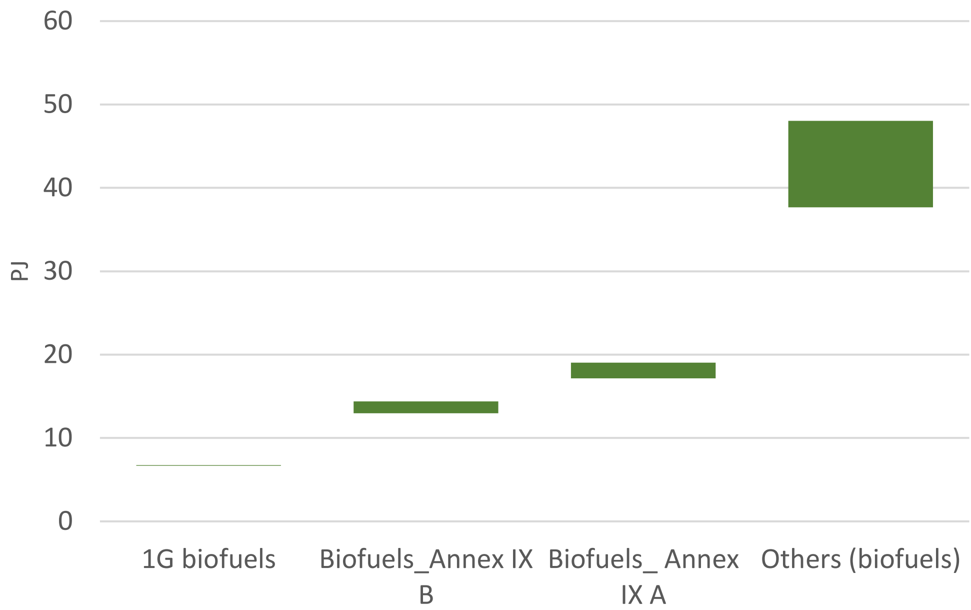

Figure 3.2: Breakdown of biofuel demand in 2030 according to REDIII reference case

Among the different types of biofuels, drop-in advanced biofuels that can substitute fossil diesel become increasingly important. Unless there are sufficient quantities of biomass feedstocks that are suitable for HVO/HEFA production but not capped, biomass gasification followed by Fischer Tropsch synthesis becomes one of the key value chains to produce advanced biofuels. Delivering such large quantities by 2030 will be challenging as there are currently no large scale commercial biomass to-liquid value chains via gasification that use lignocellulosic feedstocks. Delivering renewable e-diesel and e-kerosene will also be a challenge. Harnessing the synergies between the bio and the e-value chains can help overcoming these challenges. Renewable hydrogen use in the production of advanced biofuels can increase the carbon efficiency significantly and as a result can increase the biofuel yields. Next to that, given that there is an increasing target for RFNBO for aviation, captured biogenic CO_2 can be combined with the renewable H_2 to produce e-syngas, which can go through the Fischer Tropsch synthesis to produce e-kerosene. Thus, the Fischer Tropsch synthesis appears as a no-regret option that can convert both bio and e-syngas into kerosene and diesel.

3.4 Uncertainty analyses

The total demand for renewable fuels in 2030 can be highly sensitive to specific assumptions and the applied calculation methods. This section delves into the key sensitivities that will impact the results. All cases are based on the data introduced in table 3.1.

3.4.1 Different approaches to renewable electricity

REDIII introduces two different approaches for electricity supplied to all transport sectors within the baseline GHG intensity calculation. Approach one is applicable until 31 December 2030, and has been used in the preceding chapter. Approach two will be used from 1 January 2031. According to approach two, the amount of electricity supplied to all transport modes will be multiplied by the fossil fuel comparator of 183 gCO_2eq/MJ, whereas in approach one this comparator is set to 94 gCO_2eq/MJ.

In this section we assess the impact of this different approach on the demand for biofuels. The main reason for this change of approaches relates to granting disproportionately high GHG saving assumptions for renewable electricity in transport with approach one[10].

Figure 3.3 illustrates the biofuel demand to achieve the 14.5% GHG intensity reduction target in 2030, based on the implementation of the two different approaches. As can be seen, biofuel demand increases with the second approach, resulting in a bandwidth of 81.6-92 PJ.

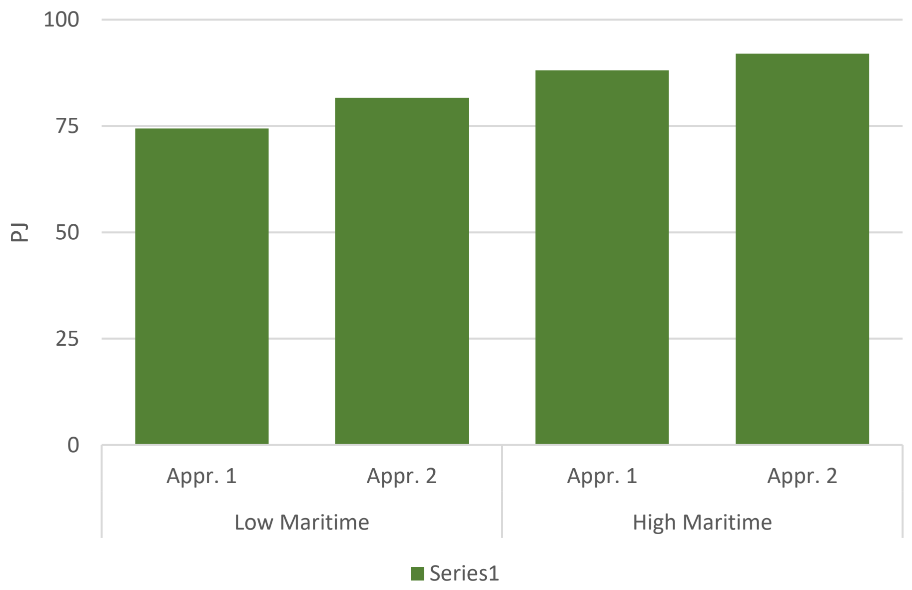

Figure 3.3: Biofuel demand in 2030 to achieve 14.5% GHG intensity reduction target. No use of multipliers

3.4.2 The maritime transport sector contribution

As emphasized earlier, the allocation of maritime transport fuel demand to the denominator (total transport sector) and the application of a 13% cap raises several questions. According to the government consultation[11], there will be a shift to sector specific emission reduction targets, to control the division of the overall transport target over land transport, inland navigation, air and sea shipping.

In light of these discussions, we constructed hypothetical "what if" scenarios. We assumed i) 50%, and ii) 100% of maritime bunkering energy demand contributing to the transport sector denominator. It is important to note that this is a speculative assumption. According to KEV2022 data, maritime bunkering including inland shipping, is projected to be approximately 477PJ in 2030.

As shown in Figure 3.4, the results are highly sensitive to the contribution of maritime bunkering to the total transport pool. A 50% cap on the energy consumption in maritime

[10] See EP f"AM_Com_LegOpinion (europa.eu)"
[11] Overheid.nl | Consultatie Wet milieubeheer RED-III (internetconsultatie.nl)

bunkering is close to the previously explained 13% cap on the gross inland energy consumption results. So as a result the demand for renewable fuels does not change significantly. However, the assessment shows that the demand for biofuels can increase to 157.8 PJ, when the full amount of energy demand in maritime bunkering is taken into consideration.

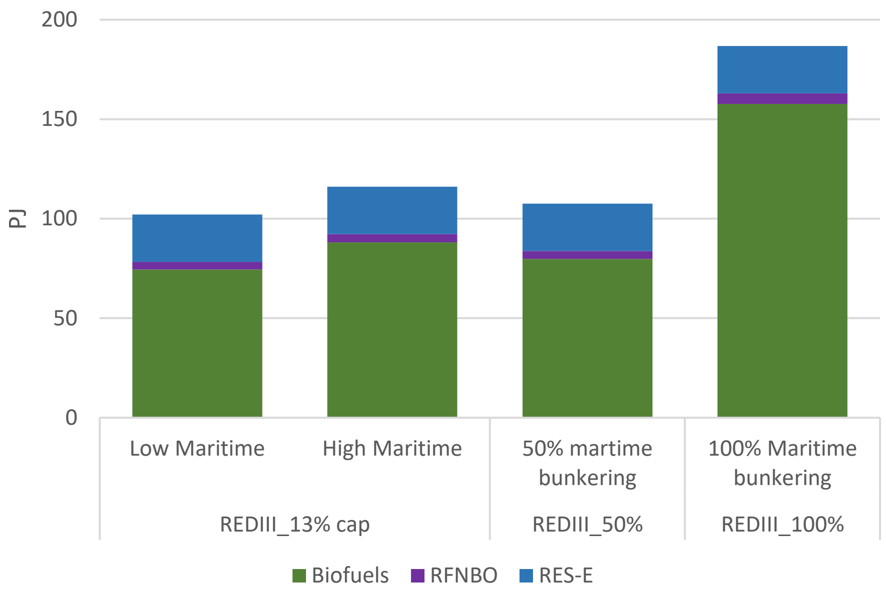

Figure 3.4: Impact of the contribution of maritime bunkering to the demand for RES fuels to meet the GHG intensity reduction target in 2030

3.4.3 Renewable fuels emission factors

One of the main reasons to implement a GHG emission intensity reduction target is to stimulate the use of renewable fuels with the largest well-to-wheel GHG emissions saving potentials. In this study the “typical emission factors” are used for biofuels (see Appendix A). According to this data, the GHG emission reductions are in the range of 84-85% for biofuels from Annex IX, list A and B, and 50% for crop-based biofuels. For RFNBO, the JRC emission factor of 0.8 gCO_2eq/MJ is used, which results in 98% emission reduction, when compared with the fossil fuel comparator. The JRC data considers renewable electricity to syndiesel via methanol route, where all upstream emissions are set to zero. However, the actual implementation of these renewable fuels may result in a different amount of demand. The companies are currently allowed to use either the standard emission factors from REDII (default values), or calculate the emission factors themselves in accordance with the calculation rules of REDII. According to NEa (2022), emission factors are increasingly reported on the basis of values calculated by companies and these values are generally lower than the default values in REDII. Figure 3.5 illustrates the observed average emission factors for diesel and petrol substitutes in the period of 2011-2021 (NEa,2022). The emission factor of the diesel substitutes appears to be stabilised around 11 gCO_2eq/MJ. To put this into perspective, the default emission factor for diesel from UCO is stated as 14 gCO_2eq/MJ in REDII. For the gasoline substitute the lowest emission factor reported appears to be 20 gCO_2eq/MJ. This is also lower than the assumption introduced in REDIII, which is 50% GHG intensity reduction for 1G biofuels, compared to fossil fuel comparators. NEa (2022) mentions the bio-naphtha emission factor as 8.9 gCO_2eq/MJ. The typical emission factor for second generation ethanol is introduced as 13.7 gCO_2eq/MJ in REDII.

Table 3.2 compares the average emission factors used in this study with the range presented in NEa. It is necessary to highlight that advanced biofuels (produced from Annex IX, list A) reported by NEa consists of biofuels produced from wastewater of palm oil mill, low grade starch slurry, used bleaching earth, etc. It does not include any value for the advanced biofuels produced from lignocellulosic feedstocks as these types of biofuels are not yet in the market. At the same time, it is uncertain whether there will be sufficient amounts of very low GHG intensity biofuels (as NEa reported) to meet the large demand in 2030.

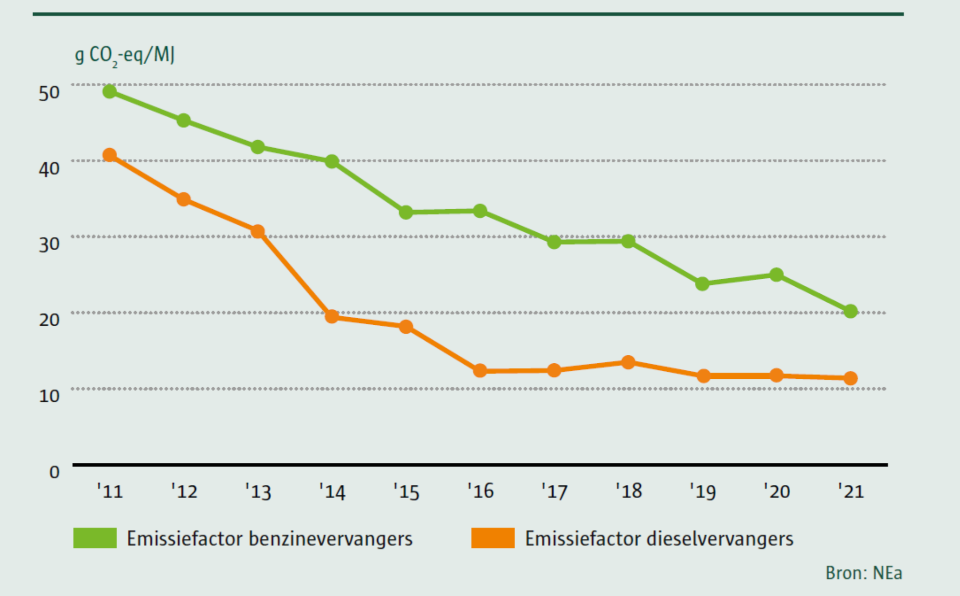

Figure 3.5: Reported emission factors for diesel and petrol substitutes between 2011-2021 (NEa, 2022)

Table 3.2: Comparison of the average emission factors used in this study with the reported emission factors from NEa between 2011-2021

gCO_2eq/MJ	NEa range	This study Average (weighted average)
Petrol substitute	49[12]-20	23.3 (25.2)
Diesel substitute	40-11	15.0 (22.4)

In this sensitivity we look into implementing higher GHG emission factors for renewable fuels (referred to as high). We increased the default values related to biofuels by 30%. For RFNBO, we assume a 85% GHG emission saving potential, compared to the fossil reference. It is important to emphasise that the GHG emission saving threshold for renewable fuels to be eligible for target achievement in REDIII is set at minimum 50-65% for biofuels, and 70% for RFNBO.

Figure 3.6 presents the results in comparison to the results based on the typical values. When biofuels with higher GHG emissions are considered, the demand for biofuels to achieve the 14.5% GHG intensity reduction target increases by approximately 10%. With these higher GHG emission factors the demand for biofuels appear to be 81.5-96.4 PJ.

[12] It is necessary to highlight that biofuels that have GHG emission intensities higher than 47 g CO_2eq/MJ are not compliant with the REDIII as it sets the threshold to min 50% GHG emission saving.

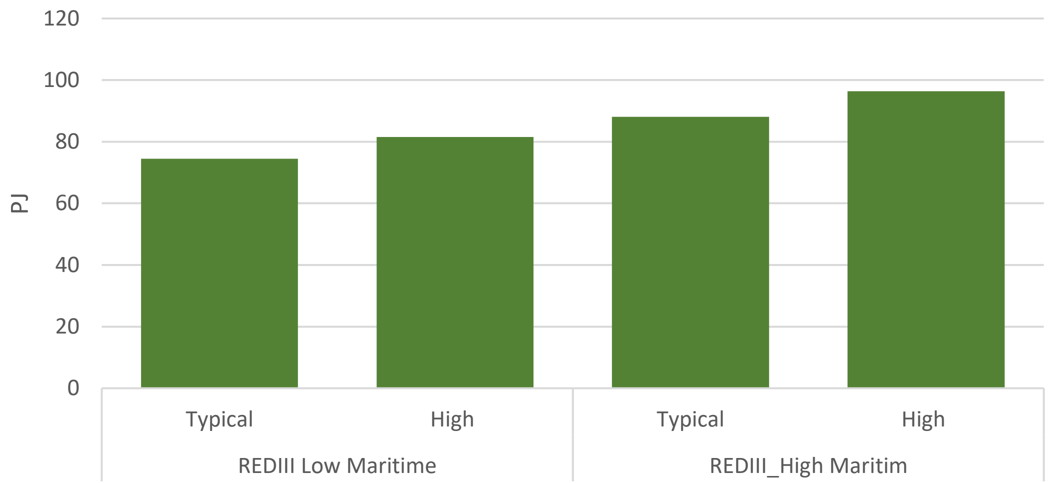

Figure 3.6: Comparison of the biofuel demand in 2030 when higher GHG intensities are implemented

3.4.4 Implementation of RFNBO

In the previous sections, the RFNBO contribution is calculated based on the supply of renewable e-diesel to the transport sector. Member states are allowed to fulfil the RFNBO sub-target also when these are utilised as intermediate product for the production of conventional fuels, or biofuels. In a previous study, Uslu et al. (2022) mapped out the options for meeting the RFNBO obligation in the transport sector, and presented the potential contribution of RFNBO as an intermediate product in the production of conventional fuels to be in the range of 8-18 PJ.

This section provides a brief assessment of the consequences of implementing this option. The assessment involves a comparison of the following options

- Meeting the minimum RFNBO sub-target of 1% by using RFNBO as transport fuel, assuming in the form of renewable e-diesel/kerosene. (REDIII)
- Fulfilling the minimum RFNBO target of 1% by utilising RFNBO, in the form of green hydrogen, as an intermediate product in the production of conventional fuels (REDIII_H2 inject.). In this case, the RFNBO use does not contribute to the CO_2-reduction target in transport

Meeting the 1% RFNBO minimum sub-target through RFNBO use as intermediate product in the refinery necessitates additional biofuels to offset this (see Figure 3.7). Achieving the 5.5% sub-target can be eased by use of RFNBO as an intermediate product, but this intermediate use does not substitute the actual use of fossil fuels in transport. Consequently, there will be an additional demand for biofuels to achieve the GHG intensity reduction target of 14.5%. According to the internet consultation on the changes to the Environmental Management Act, there will be a registry of so called “refining reduction-units” and the rules regarding the calculations from the amount of renewable hydrogen injected to CO_2-equivalent reduction will be laid down. We did not count it in in this study, since it does not represent an additional renewable energy supply to the transport sector.

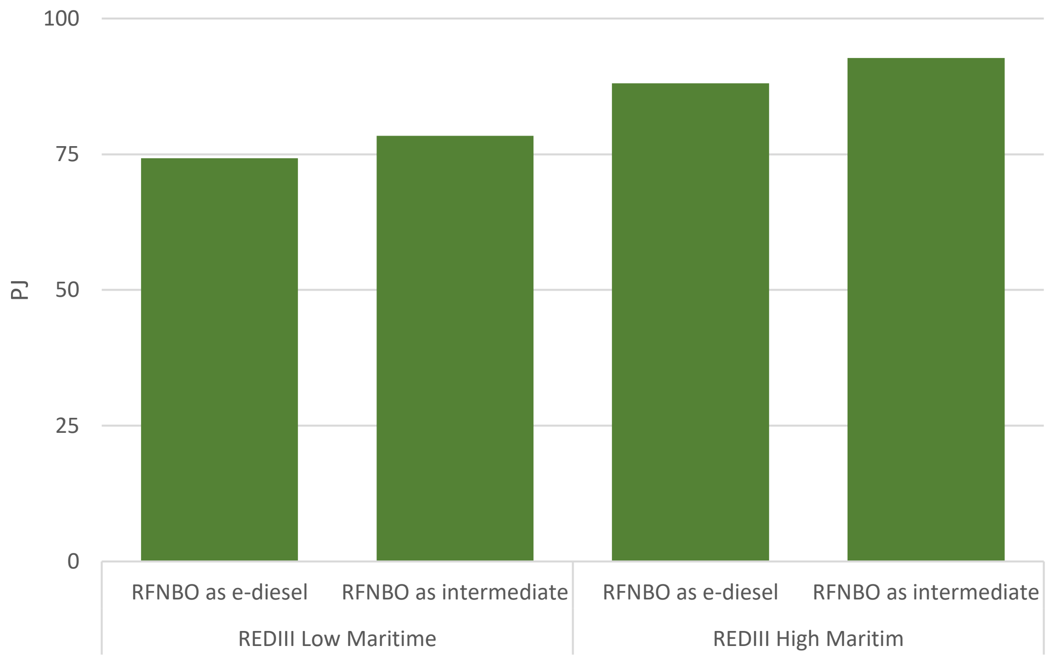

Figure 3.7: Reference demand for biofuels for the three options to achieve the 14.5% GHG intensity reduction target-RFNBO contribution (no multiple counting included). Emission factors can be found in the appendix.

3.4.5 Inclusion of non-road machinery and fisheries

In Chapter 3.1, the coverage of the transport sector is discussed and non-road machinery related energy demand is excluded from the calculations to align with the current Eurostat definition of transport sector. However, the Dutch implementation of REDII, the Jaarverplichting, has been including this sector as it is very difficult to distinguish between diesel for non-road machineries and road transport. In this sensitivity analysis, we discuss the implications of including non-road machinery related energy demand into the transport pool. With the same logic, we also include the energy demand for fisheries and compare the implications with the reference data presented in Table 3.1 and the fallowing chapters to achieve 14.5% GHG intensity reduction targets.

Results show that adding non-road machinery and the fisheries result in approximately 7% demand increase for renewable energy. More detailed numbers can be found in the below table.

Table 3.3: Final energy consumption in transport and the minimum amount of advanced biofuels and RFNBO to meet the 5.5% sub-target set in REDIII

	Bandwidth (PJ)	Bandwidth including non-road machinery+ fisheries (PJ)
Total inland transport	400.6	453.0
Road	378.4	378.4
Rail	7.6	7.6
Domestic navigation	11.7	11.7

	Bandwidth (PJ)	Bandwidth including non-road machinery+ fisheries (PJ)
Recreative	2.4	2.4
Domestic aviation	0.4	0.4
Non-road machinery		46.0
Fisheries		6.4
Aviation	159.3	159.3
Maritime shipping-as 13% cap to gross final energy[1]	202.3-285.4	202.3-285.4
Total transport energy pool	**762.2-845.2**	**814.6-897.6**
Minimum amount of renewable fuels (5.5%)	41.9-46.5 (21.0-23.2)*	44.8-49.4 (22.4-24.7)
Minimum amount of RFNBO (1% point)	7.6-8.5(3.8-4.2)*	8.1-9.0(4.1-4.5)
Remaining amount as advanced biofuels from Annex IX, list A to achieve the sub-target	34.3-38.0(17.1-19.0)*	36.7-40.4(18.3-20.)
Total biofuels to achieve 14.5 GHG intensity reduction	74.4-88.1	81.4-95.3
Total renewable energy to achieve 14.5% GHG intensity reduction	102.1-116.1	109.7-124.1

1 KEV2022 indicates a bandwidth of 1556-2195 PJ for the gross final consumption of energy in the Netherlands in 2030. (PBL, 2022); See also the explanation in the first section of Chapter 2.

* REDIII_P included double counting to meet the sub-targets. The values within the brackets refer to the minimum actual supply needed to meet the sub-targets, thus they exclude the double counting.

Box 2: Renewable energy projection used for KEV2023

While the present report shows the final assessment results of the REDIII, the previous assessment results have been shared with PBL to support the relevant sections of the KEV publication in 2023. In the previous assessment we calculated the total renewable energy demand as approximately 160 PJ and the contribution of biofuels around 130 PJ. This was due to a different interpretation by that time of the provisional REDIII and also an error detected in the calculations. In this current version, the demand for renewable energy is calculated to be in the range of approximately 102-116 PJ, of which 74 to 88 PJ relate to biofuels. As illustrated in the previous sections, these results are highly sensitive to several assumptions and the biofuel demand can increase up to 96 PJ.

4 FuelEU Maritime and ReFuelEU Aviation legislations

The previous chapters focused on the assessment of the renewable energy demand for the transport sector to achieve the targets set in REDIII. Next to this Directive, the FuelEU Maritime and the Refuel EU Aviation regulations are formally adapted. In this chapter a recap of this two regulations is introduced, followed by an indicative assessment of the demand for renewable energy by 2030.

Table 4.1 introduces the key elements of the ReFuelEU Aviation and FuelEU Maritime regulations.

Table 4.1: Main elements of the ReFuelEU Aviation and FuelEU Maritime Regulations

	ReFuelEU Aviation Regulation (as of 18 October 2023)	FuelEU Maritime Regulation (as of 13 September 2023)[13]
Type of target/obligation	Sustainable aviation fuel (SAF) target The mandate is volume based.	A GHG intensity reduction target on energy used on board by a ship
Obliged parties and sector coverage	Aircraft operators, Union airports and their respective Union airport managing bodies, and aviation fuel suppliers.	All ship owners above 5000 gross tonnage • 100% of energy on voyages between EU ports and to 50% of energy used on voyages where the arrival or departure port are outside the EU or the EU's outermost regions[14]
Targets/obligations	Minimum SAF target of 2% of overall aviation fuel supplied by 2025, 6% in 2030, 20% in 2035 and reaching 70% by 2050.	GHG intensity reduction of 2% from 2025, 6% from 2030, 14.5% from 2035, 31% from 2040, 62% from 2045, 80% in 2050. All GHG cuts are relative to a defined 2020 GHG intensity level of 91.16 gCO_2eq per MJ.

[13] Articles related to the obligation to connect to OPS and use zero-mission technologies are not included to this table as the focus has been on the use of biofuels.

[14] Ports in the nine EU outermost regions are Açores, Madeira, Canarias, Guadeloupe, French Guyana, Martinique, Mayotte, Saint Martin and Reunion

	ReFuelEU Aviation Regulation (as of 18 October 2023))	FuelEU Maritime Regulation (as of 13 September 2023)[13]
Sub-target for RFNBO/H_2	From 1 January 2030 until 31 December 2031, an average share of 1.2% , of which each year minimum of 0.7% From 1 January 2032 until 31 December 2034, an average share of 2%, of which each year a minimum share of 1.2% from 2032-2033, and minimum 2% in 2034. Minimum 5% in 2035, increasing to minimum 35% in 2050.	No sub target, but, if the Commission reports that the share of RFNB/H_2 accounts for less than 1% of the shipping sector fuel mix in 2031, a 2% RFNBOs fuel use target will be set from 2034. From 1 January 2025 to 31 December 2033, a multiplier of “2” can be used to reward the ship for the use of RFNBO.
Renewable and sustainable fuel coverage	Biofuels, recycled carbon fuels and renewable synthetic aviation fuels (e-fuels) in line with the REDIII.	All low carbon fuels both renewable and fossil
Role of biofuels from Annex IXB	No cap is set on fuel suppliers meeting targets with animal fats and UCO.	No cap is set on fuel suppliers meeting targets with animal fats and UCO.
Role of 1G biofuels	Biofuels from other then Annex IX list A and B biomass feedstocks capped to a maximum of 3%, setting a limit on the contribution of food and feed based crops. Feed and food crop-based fuels, and fuels derived from intermediate crops, palm fatty acid distillate and palm and soy-derived materials, and soap stock and its derivatives, will be excluded from SAF target.	Food and feed crop based biofuels shall be considered to have the least favourable fossil fuel type emission factor, thus, not contribute to any reduction

The use of aviation bunker fuel in 2030 according to the KEV 2022 projection was 159,7 PJ. To meet the 6% target[15] for sustainable aviation fuels by 2030, as set in the ReFuelEU Aviation regulation, at least 1.1 PJ renewable e-kerosene and 8.4 PJ biokerosene is required. Consequently, the total sustainable aviation fuel demand is calculated as approximately 9.6 PJ in 2030. This new legislation includes the possibility of using H_2 and low carbon fuels in aircrafts to meet the minimum shares. It is worthwhile to mention that the targets in this regulation are not based on the energy content of the fuels but on the volumes supplied to the aircrafts. Since liquid H_2 has a relatively lower energy density (8.5 MJ/l) compared to biofuels and e-kerosene (35 MJ/l) achieving the (share of) mandate on RFNBO via H_2 can be done with less PJ’s, which would result in larger use of fossil kerosene in comparison to achieving the mandate using bio-or e-kerosene. Bunse et al. (2023) has quantified the implications of using H_2 in the aviation sector. We did not consider H_2 use in this study.

The renewable energy demand to meet the FuelEU Maritime target is more complex to calculate. The GHG intensity reduction target is set to

- the 100% of the energy used on voyages from a port of call under the jurisdiction of a member State to a port of call under the jurisdiction of a member State.

[15] Note that this target is an EU wide target, allowing different contributions form different member states.

- The 100% of energy used at berth within a port of call under the jurisdiction of a member State.
- 50% of the energy used on voyages departing from or arriving at a port of call under the jurisdiction of a member State, where the last or the next port of call is under the jurisdiction of a third country.

The targets are set to ships that are larger than 5000 gross tonne. The port of call refers to a port where ships stop to load and unload cargo or get on and off board of passengers. Stops for the sole purpose of refuelling, obtaining supplies, relieving the crew, going into dry-doc or making repairs to the ship and its equipment, ship-to-ship transfers carried out outside ports, stops due to bad weather or stops of containerships in a neighbouring container transhipment port are excluded.

KEV2022 projections indicate the total maritime bunkering but does neither specify what share of this fuel use relates to the voyages within and outside the EU, nor the activities that are excluded. According to the MRV data[16] related to the port of register as Amsterdam and Rotterdam, 46% of the CO_2 emissions were related to the voyages between ports under the EU jurisdiction in 2019. In this assessment, we assume that 40% of the maritime bunkering fully falls under the obligation. For the remaining voyages 50% is assumed to be covered. Thus, we assume that 70% of the bunkering fall under the GHG emission intensity reduction obligation. According to KEV2022, the maritime bunkering in 2030 is around 432 PJ and the 70% of this corresponds to 302 PJ.

This assumption is quite uncertain as the total amount of bunkering in the Netherlands may change significantly up to 2030 (and even more thereafter), for the following reasons:
- Fuel prices are considered to be a determining factor for ships to bunker at a certain location and both biofuels and e-fuels can be produced at lower costs in other non-EU countries which are also located on trade routes (CE Delft,2021). Therefore, the shipowner may purchase fuel in another country along the trade route instead of the Netherlands, especially when ships already call at ports in those countries.
- The energy density of renewable fuels is lower than that of fossil fuel oil. This means that the new ships will either need to have relatively large storage tanks to carry the same amount of energy on board and, thus be able to keep the same bunkering frequency, or they will need to bunker more frequently.

In addition, we do not have information regarding how much of this refers to ships that are larger than 5000 gross tone.

For these reasons the assessments regarding the total amount of renewable and low carbon fuels is rather uncertain. The KEV2022 projections are used as the basis for this calculation. This means that the use of marine diesel oil (MDO), liquefied natural gas (LNG) and “walstroom” (electricity used from the grid when in port) are kept to the same amounts as in the KEV2022 projections for 2030. Inland bunkering is added to the maritime shipping energy demand. Table 4.2 introduces the reference data used for the calculations. We assumed that the LNG is used in Otto dual fuel slow speed engines[17], and has a 7.6% lower GHG intensity when compared with heavy fuel oil[18]. The Regulation proposal sets the target to 6% GHG intensity reduction and as explained previously, we implement this emission

[16] THETIS-MRV (europa.eu)
[17] This configuration has a relatively low CH4 (methane) slip and therefore a lower GHG intensity compared to HFO.
[18] WtW GHG emissions for HFO is set to 91.6 g CO_2eq/MJ, whereas for LNG otto dual fuel slow speed engines this was 84.63 gCO_2eq/MJ (see annex C, Table 19 in CE Delft (2022)

reduction target to 70% of the maritime bunkering and to all inland bunkering. The GHG intensity reduction can be met in various ways, using different low carbon energy carriers.

We introduce three hypothetical cases:

- In case 1, we assume that the lower cost renewable fuel supply option–Used Cooking Oil Methyl Esther (UCOME)– will be used to reduce GHG emissions intensity. This case keeps the contribution of different fuel supply options (LNG, MDO and electricity) the same amount as the KEV2022 projections, and assumed that the UCOME substitutes fuel oil[19] projections. This case results in a demand of around 23 PJ UCOME. It is important to note that this amount is larger than the 1.7% cap introduced in REDIII for biofuels produced from Annex IX B list. However, unlike the REDIII, the FuelEU Maritime regulation does not refer to any cap for this type of biofuels (see also table 4.1). This may mean that only a certain amount of biofuels used in maritime shipping can be counted towards the REDIII. The remaining can be attributed to FuelEU Maritime regulation. This option will depend on the national policy choices. Biofuels from Annex IX list B is currently not permitted for seagoing shipping in the national system and whether this will be continued or changed from 2025 is to be seen.
- In case 2, we assume that 0.5% of the maritime fuel will be mandatory from e-fuels and the rest can be met via use of UCOME. Even though there is no sub-target for e-fuels in the regulation proposal it states that if RFNBO/H_2 accounts for less than 1% of the shipping sector fuel mix in 2031, a 2% RFNBOs fuel use target will be set from 2034 onwards. In addition, a bonus of double counting is introduced for these fuels. This 0.5% target refers to 1.7 PJ of e-fuels. In this case, the UCOME demand is calculated to be around 21 PJ. It is worthwhile to mention that the use of HVO instead of UCOME will not change the total demand as both value chains have comparable GHG intensity.
- In case 3, we assume that the GHG intensity reduction target can be achieved by much larger use of LNG , this time in diesel dual fuel slow speed engine ships. In contrast to the previous cases that assumed LNG use in otto dual fuel slow speed engines. In this very hypothetical case, the LNG demand is approximately 118 PJ in 2030. This case is illustrated to simply emphasise the fact that fossil fuels with lower GHG emission factors can also serve to reducing GHG emission intensity, according to the FuelEU Maritime Regulation.

The GHG intensities used for these calculations can be found in appendix a.

Table 4.2: Maritime bunkering fuel mix coverage in 2030 broken down to different fuel types

Coverage of the FuelEU Maritime regulation	Fuel types	Base reference in 2030 (PJ)
Covered	FO (assumed as low sulphur)	222
	MDO	49
	LNG	30
	electricity	1.3
	Total	302
	Inland bunkering	40.8
Not covered	HFO	129.5

[19] In this calculations very low sulfur fuel oil is considered as the main fuel oil.

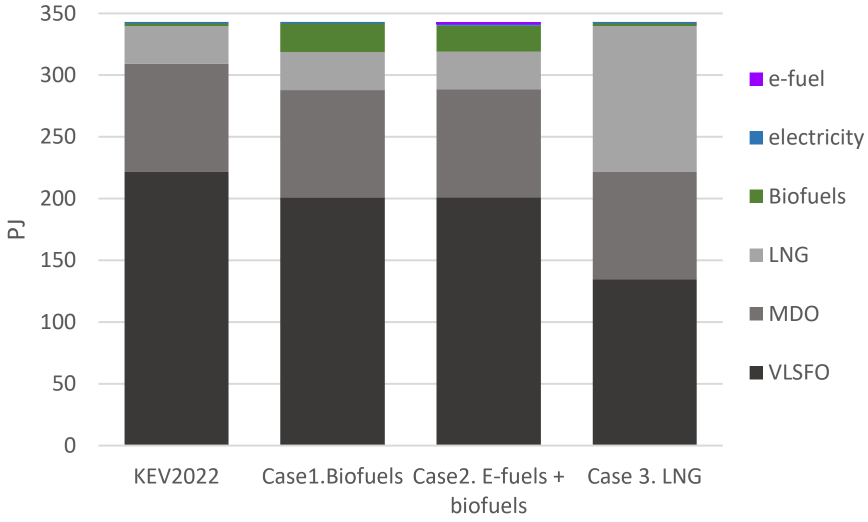

Figure 4.1: Fuel mix of the 70% of maritime shipping that is assumed to fall under the regulation to achieve 6% GHG emission intensity reduction target according to the FuelEU Maritime regulation in comparison to KEV2022 projections

5 Conclusions and discussions

The impact of the REDIII on the use of renewable fuels in transport is rather uncertain and depends on the interpretation of the REDIII and the transposition of the REDIII in national legislation.

The findings of this study indicate a substantial increase in the demand for renewable energy within the transport sector, aligning with the GHG intensity reduction target set for 2030 in REDIII. According to the assessment results, the physical supply of renewable fuels is highly uncertain as the target is based on the GHG intensity reduction rather than the energy content. In this assessment, we used the typical GHG emission factors for biofuels from REDII. For RFNBO, we employed the JRC well-to-wheel assessment data for e-diesel based on wind energy. This resulted in a projected biofuels demand between 74-88 PJ in 2030. A more conservative assumption, so a lower GHG-reduction performance, for both biofuels and RFNBO, still ensuring compliance within the sustainability threshold for eligibility, would lead to an increase in demand. For instance, when the default GHG emission factors are increased by 30% the biofuel demand projections increases to 81.5-96.4 PJ. The Netherlands Enterprise Agency (RVO) estimated biofuel demand at around 96 PJ assuming a rather conservative average emission reduction of 70%. The amount of biofuels required to meet the targets will decrease as their average emission reduction increases.

The emphasized range (81.5-96.4PJ) relates to the contribution of maritime transport to the overall transport demand, forming the basis for calculating the GHG intensity reduction target. REDIII introduces the possibility of limiting the contribution of this sector, especially in countries where the supply volume is proportionally large (like in the Netherlands). Consequently, the maritime transport sector can be capped at 13% of the gross final energy consumption in a member state. KEV projections in 2022 provided a range for gross final energy consumption in 2030. Consequently, the contribution of the maritime sector to overall transport demand also varies within a range, leading to a bandwidth for the projected biofuel demand to meet the 2030 target of 14.5% GHG.

A critical aspect in calculating the demand for biofuels and RFNBO is associated with the GHG intensity calculation method for the direct electrification of transport and the share of renewable electricity within it. There has been ongoing debate regarding the credit provided by the use of renewable electricity. In the final REDIII, two different approaches are introduced. The approach that will be valid from January 1, 2031, will reduce the extent of crediting to some degree. When this different approach is implemented, the demand for renewable fuels, particularly biofuels, increases by 7%. This underscores the sensitivity of the results to the calculations related to the contribution of electrification and renewables therein to the demand for biofuels.

Other sensitivities are related to how REDIII will be transposed in the Netherlands. In earlier implementations of the Directive, different transport sector coverage was applied compared to the current transport sector definition according to Eurostat. Specifically, non-road machinery was also included under the yearly obligation. A similar approach in the upcoming implementation could increase the total energy supply in transport, consequently leading to higher demand for renewable fuels. In this analysis, the inclusion of non-road machinery and fisheries resulted in a demand for biofuels in the range of 81-96 PJ.

Among the different types of biofuels, drop-in advanced biofuels that can substitute fossil diesel, become increasingly important. Unless there are sufficient quantities of biomass feedstocks that are suitable for HVO/HEFA production but not capped, biomass gasification followed by Fischer Tropsch synthesis becomes one of the key value chains to produce advanced biofuels. Delivering such large quantities by 2030 will be challenging as there are currently no large scale commercial biomass to-liquid value chains via gasification that use lignocellulosic feedstocks. Delivering renewable e-diesel and e-kerosene will also be a challenge. Harnessing the synergies between the bio and the e-value chains can help reducing these challenges. Renewable hydrogen use in the production of advanced biofuels can increase the carbon efficiency significantly and as a result can increase the biofuel yields. Next to that, given that there is an increasing target for RFNBO for aviation, captured biogenic CO_2 can be combined with the renewable H_2 to produce e-syngas, which can go through the Fischer Tropsch synthesis to produce e-kerosene. Thus, the Fischer Tropsch synthesis appears as a no-regret option that can convert both bio and e-syngas into kerosene and diesel.

Next to the RED, the Refuel EU Aviation Regulation, aimed at boosting Sustainable Aviation Fuel (SAF) use in aviation, has been finalized. According to the volume-based obligations set in this regulation, the SAF supply would be 9.6 PJ in 2030, of which at least 1.1 PJ should be from RFNBO, namely e-kerosene. Thus, the contribution of biokerosene can be approximately 8.4 PJ in 2030. The other regulation that has been finalized is the FuelEU Maritime regulation. Unlike Refuel EU Aviation, this regulation introduces a GHG intensity reduction target of 6% for 2030 for the maritime shipping sector. This regulation covers all energy on voyages between EU ports and half of energy used on voyages where the arrival or departure port is outside the EU. It is challenging to define what volume of the international bunkering projected in KEV2022 for 2030 refers to voyages between EU ports and outside the EU. This regulation also excludes ships below 5000 gross tonnes, and the share of the total bunkering energy supply referring to this type of ships is not known at the drafting of this report. Additionally, this GHG intensity reduction target can be achieved not only by substituting fossil fuel use with renewable fuels and energy but also by using other fossil fuels with lower well-to-wake GHG emission factors, such as liquefied natural gas (LNG) use in ship engines with limited methane slip risks. As such, the quantitative assessment results are highly uncertain. That being said, the GHG emission intensity reduction in this sector can be achieved by supplying 23 PJ of biofuel, in addition to the energy mix supply options in KEV2022. This target can also be met without biofuels. In that case, the LNG contribution will be around 1/3 of bunkering fuel that falls under the regulation.

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Appendix A
REDIII Annex IX

Annex IX Part A and Part B full list (blue coloured feedstocks refer to the delegated act proposal of 2022 **(Ares(2022)8413323)**

Part A

(a) Algae if cultivated on land in ponds or photobioreactors;
(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC;
(c) Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive;¶
(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex;
(e) Straw;
(f) Animal manure and sewage sludge;
(g) Palm oil mill effluent and empty palm fruit bunches;
(h) Tall oil pitch;
(i) Crude glycerine;
(j) Bagasse;
(k) Grape marcs and wine lees;
(l) Nut shells;
(m) Husks;
(n) Cobs cleaned of kernels of corn;
(o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil;
(p) Other non-food cellulosic material;
(q) Other ligno-cellulosic material except saw logs and veneer logs
(r) Alcoholic distillery residues and wastes (fusel oils) not fit for use in the food or feed chain;
(s) Raw methanol from kraft pulping stemming from the production of wood pulp;
(t) Non-food crops grown on severely degraded land, not suitable for food and feed crops.”.

Part B

(a) Used cooking oil;
(b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.
(c) Bakery and confectionary residues and waste not fit for use in the food and feed chain; (d) Drink production residues and waste not fit for use in the food and feed chain;
(e) Fruit and vegetable residues and waste not fit for use in the food and feed chain, excluding tails, leaves, stalks and husks;
(f) Starchy effluents with less than 20% starch content not fit for use in the food and feed chain;
(g) Brewers' Spent Grain not fit for use in the food and feed chain;
(h) Liquid whey permeate;
(i) De-oiled olive pomace;
(j) Damaged crops that are not fit for use in the food or feed chain, excluding substances that have been intentionally modified or contaminated in order to meet this definition;
(k) Municipal wastewater and derivatives other than sewage sludge;
(l) Brown grease;
(m) Cyanobacteria;
(n) Vinasse excluding thin stillage and sugar beet vinasse;
(o) Dextrose ultrafiltration retentate from sugar refining;
(p) Intermediate crops, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained."

Appendix B

Implemented GHG emission factors

Table B.1: GHG emission intensities used in REDIII assessment

	typical	default	low GHG	High GHG	References for typical and default values
	g CO_2eq/MJ	g CO_2eq/MJ	g CO_2eq/MJ	g CO_2eq/MJ	
UCO/AF-FAME	13 .3	17 .9	9 .3	23 .2	DIRECTIVE (EU) 2018/2001
HVO	13 .5	18 .9	9 .5	24 .6	
HEFA	13 .9	18 .9	9 .7	24 .6	
Bio ethanol (2G)	13 .7	15 .7	9 .6	20 .4	
Methanol	14 .9	14 .9	10 .4	19 .3	
FT-diesel	15 .2	15 .2	10 .6	19 .8	
FT-gasoline	13 .7	13 .7	9 .6	17 .8	
1G biofuels	47.0	47.0	32 .9	61 .1	REDIII
Fossil fuel	94.0				REDIII
ECF(e)-Electricity					REDII/REDIII
H_2 from wind	3.6				JRC,2020
e-diesel	0.8			14.1	JRC,2020

Table B.2: GHG emission intensities used for the FuelEU Maritime Regulation assessment

	WTW	Reference
	gCO_2eq/MJ	
VLSFO	**92 .60**	CE Delft, 2021. Table 12 Emission for different maritime fuels . derived from FuelEU Maritime Regulation
MDO/MGO	**90 .63**	
LNG (otto dual fuel medium speed	**92 .39**	
LNG (lean burn spark ignition	**88 .06**	
LNG (otto dual fuel slow speed	**84 .63**	
LNG (diesel dual fuel slow speed)	**76 .31**	

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