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Assessment of the Feedstock Availability for Covering EU Alternative Fuels Demand

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Featured Application: The paper provides a meta-analysis to assess the potential demand for alternative fuels for transport in Europe in 2030. The demand is compared with the projected estimations for feedstock availability. The analysis shows that, currently, feedstock is not the major limiting factor for alternative fuel uptake in transport.

Abstract: Modern economies rely on the efficiency of their transportation sector; however, the environmental impact of the sector remains a growing concern. Among the various proposed solutions, the production and deployment of alternative fuels is a major option. However, concerns exist that the actual availability of sustainable feedstock might lower the current level of ambition. This paper addresses this issue by reviewing recent studies and policy targets, to match forecasts for expected demand and feedstock availability for road, aviation, and maritime sectors in the EU in 2030. The existing literature is fragmented and based on a variety of different approaches, and a consistent assessment of the potential overall demand for transport is still missing. In spite of the challenges posed by the numerous uncertainties, this research provides an estimate of potential European demand for alternative fuels that ranges between 20 and 33 Mtoe. We aimed to answer the question about the availability of sustainable feedstock to cover this potential demand. The analysis confirmed, even under very conservative assumptions, that feedstock may not be the major barrier today. Other issues, such as the feedstock costs, the price volatilities, the existing logistical infrastructures, etc., are relevant aspects contributing to the puzzle. Whilst feedstock is present across European regions, a critical element which requires detailed analysis at the implementation value chain level is the effectiveness of its sustainable mobilisation alongside the synergies and trade-offs that may arise.

Keywords: road; maritime; aviation; transport; alternative fuels; feedstock; biomass; biofuels

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1. Introduction

Any modern economy relies on the effectiveness on its transport sector. In Europe, the transport industry employs around 10 million people and accounts for about 5% of the gross domestic product (GDP) [1]. Despite political aspirations, modern transport still heavily depends on fossil resources which pollute heavily and are the reason for the increasing commitments to decarbonisation. There are various possible strategies to reduce the adverse environmental impacts of transport: increasing system efficiency, modal shift, technological improvement for the vectors, and alternative fuels for substituting part of the current oil consumption [2–4]. Unfortunately, not all of the available solutions can be successfully implemented across all transport modes at the present time. The road and maritime freight sector, as well as the aviation sector, are currently more rigid against some options, such as electrification or the use of hydrogen, due to the high energy density required to perform the service.

The recast of the Renewable Energy Directive (referred as REDII) was adopted in 2018 [5]: it sets a new overall target for the European Union for renewable energy consumption by 2030 and includes a sub-target for the transport sector. Highlighting that the REDII is already under revision, the expected goal for renewables in the EU transport sector has been set at a minimum of 14% in road and rail transport by 2030. Within this target, a gradually increasing sub-target for alternative fuels produced from advanced feedstocks (the ones listed in REDII Annex IX, Part A: lignocellulosic feedstocks, biomass fraction of mixed municipal waste, etc.) has been planned for the period of 2020–2030: a minimum of 0.2% by 2022, 1% in 2025, and at least 3.5% by 2030. The member states can double-count advanced biofuels, produced from advanced feedstocks, towards both the 3.5% target (thus 1.75% actual volume) and the 14% target. It is worthwhile to stress that the revision of this double-counting mechanism is currently under discussion. Other non-food/feed competing biofuels, which derive from feedstocks that are unsuitable for food or feed applications (the ones listed in REDII Annex IX, Part B—e.g., used cooking oil and animal fat), can also be double-counted towards the 14% target but are capped at 1.7% in 2030. The reason for this cap is linked to the attempt to lower indirect land-use change effects on other sectors, such as food and animal feeding. It is worthwhile to highlight that the REDII targets road transportation only, while no obligations are set for the aviation and maritime sectors. However, for the very first time, the REDII contains a specific multiplier to stimulate the uptake of biofuels in both maritime and aviation sectors. These are the major innovations contained in the REDII that are related to the promotion of alternative fuels for transport.

At the European level, the aviation and the maritime sectors have recently been identified as key players for meeting the targets set in the European Green Deal [6]. The European Commission launched the "fit-for-55" package [7], which contains two legislative proposals that promote the uptake of alternative fuels; alternative fuels are perceived as a short- or medium-term means to reduce greenhouse gas impacts. If, on one hand, the potential benefits from substituting fossil oil with alternative fuels are evident, then, on the other, the sustainability concerns risk reducing these benefits: the presence and availability of sustainable feedstock is a crucial point. Regarding the use of alternative sustainable fuels in aviation, the United Nation's International Civil Aviation Organization (ICAO) in 2016 adopted a global market-based scheme to limit international aviation CO_2 equivalent (CO_{2e}) greenhouse gas emissions (GHG): the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [8]. CORSIA requires operators to offset their GHG emissions that exceed 2019 levels (estimated by ICAO and ATAG at 915 million tonnes of CO_2); alternative fuels are one of the main "intra-sector" instruments for achieving carbon neutrality [8,9]. Besides the expected reduction provided by the use of alternative fuels, it is worth remarking that CORSIA is fundamentally an offsetting scheme, allowing operators to use carbon credits from extra-sector initiative, to balance their emissions. At the European level, being part of the fit-for-55 package, the ReFuel EU aviation legislative proposal [10] also aims to contribute to increasing the supply and demand for sustainable aviation fuels. The proposal sets an increasing sustainable aviation fuel (SAF) blending mandate, with a specific sub-mandate for eFuels.

Similarly, the Maritime Environment Protection Committee (MEPC) of the International Maritime Organisation (IMO) adopted an initial strategy in 2018 [11] on the reduction of GHG emissions from ships, setting out a vision for 2050. The Initial IMO Strategy on the reduction of GHG emissions from ships compels the maritime sector to peak GHG emissions and phase them out as soon as possible in this century. Furthermore, the Initial IMO Strategy sets an ambition to decline the carbon intensity of international shipping by at least 40% by 2030, pursuing efforts towards 70% by 2050, when compared with 2008. By 2050, total GHG emissions must be cut by at least 50% compared with 2008. At the European level, the FuelEU Maritime [12] (launched as part of the Fit-for-55 package) aims to increase the use of sustainable alternative fuels in European shipping and ports. Differently from its aviation counterpart, FuelEU Maritime does not set a specific quantitative target, but rather aims to address current market barriers that hamper the use of alternative fuels and remove the uncertainty about which technical options are market ready.

All these parallel initiatives are expected to create pressure on the alternative fuel market, mostly in terms of sustainable feedstock availability. So far policy for biomass supply to the advanced biofuels sectors targets biowastes and residues from forest and agricultural activities and has refined sustainability criteria for land use change and feedstock types accordingly [13]. The diversity of raw materials however and the lack of focused support for the mobilisation of the preferred biowaste and residual streams will add an extra layer to their year-round availability.

This research aimed to estimate the potential demand for alternative fuels for road, aviation, and maritime sectors and compare it with the meta-analysis of three recent assessments for feedstock availability. The existing literature appears fragmented and to be based on a variety of different approaches, therefore a consistent evaluation of the overall potential transport demand is still missing. This paper aimed to answer the research question about the availability of sustainable feedstock to cover this potential demand.

2. Materials and Methods

The analysis was based on existing literature and other sources. The data needed to perform the analysis was grouped into two classes: the inputs for defining the potential demand of alternative fuels per transports mode, and the input for feedstock availability. We report the specific criteria used to select the sources and to extract the needed information in a consistent manner.

2.1. Inputs for Estimating Alternative Fuel Potential Demand

Concerning the input for the definition of a potential demand for alternative fuels, several sources were revised. In particular, the main references for the road sector were:

- Legislative acts and proposals: [7,9–12].
- Other studies: [4,14–19].

A meta-analysis was performed based on these literature sources to estimate the expected demand per transport sector and the overall unconstrained one. The proposed pieces of legislation contain inception reports addressing the current status of the sector in terms of fuel use, on-going initiatives, etc. From these reports several key points were extracted: e.g., current fuel demand, existing consumption for alternative fuels, expected shift towards other feedstocks, etc.

Similarly, literature sources were selected from among the many available, using some specific criteria. In particular, a preliminary screening based on a set of ex-ante conditions, was carried out; the examined works had to provide fuel-mix projections covering at least part of the 2030–2050 period and explicitly include the contribution of conventional and advanced alternative fuels. The publications were used while taking into consideration the level of the proposed analyses: high-level perspective analyses and/or sub-sectorial.

The gathered information was harmonised (e.g., data were converted to common units, etc.), to allow for effective comparisons. We need to point out that with the term "unconstrained", we refer to an estimation which does not account for any intersectoral mutual or limiting effect that is, therefore, able to show an upper limit for the potential demand.

2.2. Inputs for Estimating Feedstock Availability

A meta-analysis of three recent studies for biomass availability was performed to understand the range of sustainable domestic (EU27 and UK) biomass feedstock that could be available to contribute towards the 2030 policy targets. The three studies are:

- Directorate General for Research and Innovation (DG RTD). 2017. Research and Innovation perspective of the mid- and long-term Potential for Advanced Biofuels in Europe [20].

- European Commission Joint Research Centre (JRC). 2015 (2019). ENSPRESO—an open data, EU-28 wide, transparent, and coherent database of wind, solar and biomass energy potentials [21].
- Concawe Sustainable Biomass Availability (2021) [22]—focus on selected feedstocks from Annex IX of RED II [5] (Part A and B). This study does not include food and feed crops, and other sustainable feedstocks accepted by RED but not included in Annex IX.
- Other literature sources, i.e., [23].

All three studies were commissioned to inform on biomass availability in the EU, but their aims, assumptions and modelling scenarios differed. The JRC EU TIMES study was commissioned to deliver consistent datasets for biomass potentials that would complement the datasets that the model had for the other RES technologies, e.g., wind, solar, etc. The DG RTD study was commissioned with the aim to illustrate how various R&I practices would broaden the biomass supply base and to estimate what this would mean in terms of additional biomass, cost reductions, and respectively higher shares for advanced biofuels transport in the future. The Concawe study aimed to provide an estimation of the sustainable biomass potential availability for domestic (EU27 and UK) feedstocks of agricultural, forest, and waste origin included by 2030 and 2050 and to provide an evaluation of the advanced biofuel potential.

It is relevant to highlight that all the studies followed consistent and harmonised methodological approaches for the same types of agriculture, forest, and biowaste feedstocks and for all EU member states and the United Kingdom.

2.3. Feedstock-Technology Conversion

To derive the feedstock needed to obtain a specific alternative fuel, a process conversion factor needs to be taken into account. These were obtained from the SGAB [24], IEA Bioenergy [25], and the Concawe study [22].

2.4. Limitations to the Proposed Methodology

The presented methodology was defined in relation with the work scope, which was to estimate the potential demand for alternative fuels for road, aviation, and maritime sectors, filling the existing gap in the fragmented literature. The mentioned fragmentation is particularly relevant across the three transport sub-segments: road, maritime and aviation. This is one of the limits of the analysis carried out, which is based on existing studies: no specific "in-house" modelling has been carried out for defining the fuel demands. The available studies, those meeting the minimum standards defined above, consisted of a limited number of sources. This is, on one hand, a limitation but, on the other, is normal, considering the very specific field of investigation and the regional (EU27-UK) dimension of the analysis. The sources also widely differed in terms of approach and inputs, therefore a harmonisation step was necessary. Within these limits, the followed methodology allowed us to derive a consistent set of information.

3. Results

The estimated alternative fuel demand per transport mode was estimated based on the available data and taking into account the current legislative framework. The total demand was compared with the estimated feedstock availability to understand if there were adequate biomass supply opportunities to meet the demand and to highlight any potential bottlenecks.

3.1. Estimated Demand for Road Transport

The estimation of the alternative fuels demand for the road sector required, first, to distinguish between cars: light- (LDV) and heavy-duty (HDV) sub-sectors. This was needed as the energy demand, the type of fuel, and, most importantly, the available alternative fuels can significantly differ in the 2030 scenario.

The study [14] presents a meta-analysis over 18 selected publications, resulting in 56 scenarios. The authors found that based on pre-COVID-19 estimations, the 2030 demand for alternative fuels ranged between 7.0 and 17.7 Mtoe for passenger cars and light-duty vehicles (LDV) and between 8.1 and 9.5 Mtoe for heavy-duty vehicles (HDV). The resulting total for the presented estimations varied between 15.1 and 27.2 Mtoe in 2030. These results are in line with other studies, as the Concawe 2021 report [15] defines an expected biofuel use in the road sector in 2030 of about 20–22 Mtoe.

The type of fuels that can be used to cover these estimated demands was based on the current trends: according to [26], biodiesel and HVO represented 82% of the EU biofuels consumption in 2018, followed by bioethanol for 17%, and biogas derived fuels for less than 1%. These shares appropriately represent the pool of fuels used for the LDV sub-sector; while in the HDV sub-sector, the contribution of ethanol, so far, is negligible. For this reason, for the HDV sector, a consumption of 98% biodiesel and HVO is considered, complemented by 2% biomethane, either in the form of compressed biomethane (CBM) or liquified biomethane (LBM).

3.2. Estimated Demand for Aviation

The ICAO Long-Term Aspirational Goal Task Group (LTAG-TG) has been working to revise the long-term goal for sector decarbonisation; the on-going activity [27] clearly shows that sustainable aviation fuels will play a crucial role in sector GHG impact mitigation. At the European level, the ReFuelEU aviation proposal sets a clear target for the sector. The mandatory shares of sustainable aviation fuels have been proposed as progressively increasing from 2025 onwards, including a sub-target for synthetic fuels. According to the proposed definition, synthetic fuels are fuels that are renewable and of non-biological origin (as defined in Directive (EU) 2018/2001: "liquid or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass"). A part of the aviation synthetic fuels could also be referred to as eFuels or Power-to-Liquids (see Table 1).

Table 1. Proposed mandates as per the ReFuelEU aviation [10].

Year	2025	2030	2035
SAF min. share %	2	4.3	15
Synthetic aviation fuels	0	0.7	5
Total (Mtoe)	2	5	20

In order to assess the expected demand for SAFs, the consumption in 2030 was needed. Due to the COVID-19 pandemic, ICAO estimated a demand reduction of 60% in the total world passengers in 2020 [28]. According to the latest data reported from the same source, the recovery rate is still uncertain, for both domestic (EU27) and international flights. The impact assessment accompanying the ReFuelEU proposal quantified the 5% mandate at 2.3 Mtoe, clarifying that the early stage of the SAF ramp-up would be supplied by advanced biofuels (ATJ route) and Part B biofuels (HEFA route). Given the current technological and commercial maturity levels of the two technologies, a 70% (HEFA)-30% (ATJ) ratio was considered.

A figure of 2.3 Mtoe corresponds to the 5% of the demand volume: 46 Mtoe (lower than the pre-COVID-19 EU figure which was 55 Mt in 2018 [16]). Considering the expected growing trend for the sector, and the still controversial signals about the recovery, we decided to estimate the mandate volume against the more conservative figure of 55 Mt. This resulted in 2,365 Mt (4.3% of SAFs), approximately equal to 2.39 Mtoe.

3.3. Estimated Demand for Maritime

The maritime sector is generally defined as domestic shipping and inland waterways. However, a more detailed definition can be found in the Monitoring, Reporting and Verification (MRV) of CO_2 emissions for maritime sector [29]. In the technical report

"A Clean Planet for All", issued by the EC in 2019 [30], the expected demand for the maritime sector in 2030, under the baseline scenario, accounted for about 60 Mtoe.

In contrast to the other sectors, the definition of a clear target in terms of alternative fuels is more complex for the EU maritime. Inland waterways might benefit from the expected extension of the infrastructures needed for the electrification of transports, while other more energy-dense solutions currently seem more suitable for bulk freight vessels. Prussi et al. [4] investigated the main elements needed to foster a higher penetration of alternative fuels. According to the study, this would depend on an array of technical and non-technical factors, not necessarily limited to the cost and GHG savings; the authors listed enablers such as technical maturity, safety regulations, operators' expertise, etc. According to the evaluation, bio LNG and biodiesel appear to be the most technically mature and commercially ready alternatives to reduce the GHG intensity of the sector.

In terms of expected volumes, the FuelEU maritime proposal [12] does not provide specific figures for possible shares of alternative fuels in 2030. The proposal aimed to define a common EU regulatory framework to increase the share of alternative fuels in the mix of international maritime transport without creating barriers to the single market. The FuelEU proposal was expected to stimulate the European shipping sector, sending a clear signal and providing appropriate support. Given the dimension of the demand, and the lack of a specific certification process required for the fuel use, the authors proposed to assume a target similar to the aviation's proposal for the use of alternative fuels in 2030.

With an expected demand of 60 Mtoe, a 5% share would account for 3 Mtoe. This figure is close to the results of a meta-analysis carried out by Chiaramonti et al. [14]. To derive the share of bioLNG and biodiesel, and assuming a similar substitution rate, we used the current LNG to heavy fuel oil (HFO) ratio, which valued 3% of LNG over the total fuel consumed in 2018 [17]. Consequently, the expected biodiesel demand would account for 2.91 Mtoe and the bioLNG for 90 ktoe.

3.4. Aggregated Alternative Fuel Demand

The volumes of the specific alternative fuels per transport mode were estimated based on the previously described analysis (see Table 2).

Table 2. Expected alternative fuel demand per transport mode (Mtoe) in 2030.

Transport Mode	Sub-Sector	Min	Max
Road	LDV	7.0	17.7
	HDV	8.1	9.5
Aviation	-	2.4	
Maritime	-	3.0	
		20.4	32.6

As reported in Table 3 the larger portion of the demand is expected to be covered with biodiesel/HVO, which could be used both for the passenger cars/LDV as well as for services requiring high-energy dense fuels, such as road HDV and the maritime sector. It is worth noting that HEFA demand in the aviation sector is also expected to rely on the same pool of biomass feedstocks. It could be noted that the road sector, especially with regard to passenger cars/LDVs, is expected to progressively shift towards other technologies than internal combustion engines (ICE), thus reducing the demand for such alternative fuel. However, the short time frame of this analysis did not allow us to assume that this shift would be fast enough to significantly affect the expected demand in the road sector.

Table 3. Alternative fuel types per transport mode (Mtoe) in 2030.

Transport Mode	Sub-Sector		Biodiesel/HVO	BioEthanol	Biomethane (CBM–LBM)	HEFA	ATJ
Road	LDV	%	82	17	1	-	-
		Mtoe	5.7–14.5	1.2–3.0	0.07–0.18	-	-
	HDV	%	98	-	2	-	-
		Mtoe	7.9–9.3	-	0.16–0.19	-	-
Aviation	-	%	-	-	-	70	30
		Mtoe	-	-	-	1.7	0.7
Maritime	-	%	97	-	3	-	-
		Mtoe	2.9	-	0.1	-	-

3.5. Feedstock Potential

The three studies included in this paper assessed biomass potentials for feedstocks from agriculture, forest, and biowastes. The main feedstock categories that were included are described in Table 4.

Table 4. Feedstock categories included in the biomass assessment studies.

	Agricultural Feedstocks	Forest Feedstocks	Biowastes
JRC ENSPRESSO	biofuels crops from rotational arable crops also used for food and feed purposes (e.g., oil seed rape, sunflower, wheat, maize, etc.); primary residues from arable crops (straw and stubbles), pruning, cutting, and harvesting residues from permanent crops, dedicated perennial crops, energy maize and grassland cutting solid and liquid manure	stemwood for fuelwood, primary residues and secondary residues from wood processing industries (sawmill residues, which are generally converted in chips and pellets before they are sold further; saw dust; and black liquor)	Biomass fraction of municipal solid wastes (MSW) Mixed wastes of food preparation (including utilised cooking oil) Post-consumer wood Sewage sludge
DG RTD	crop residues from arable crops (straw and stubbles), pruning, cutting, and harvesting residues from permanent crops, dedicated energy crops (on below average quality land. Only the land that is released from other crops in a business-as-usual baseline has been used in the modelling for growing of energy crops).	stemwood, primary residues (stem and crown biomass from early pre-commercial thinnings. Logging residues from thinnings and final fellings; Stump extraction from final fellings and thinnings) and secondary residues from forest industries (sawmill residues, sawdust, black liquor).	Biomass fraction of municipal solid wastes (MSW) Mixed wastes of food preparation (including utilised cooking oil) Post-consumer wood Sewage sludge
Concawe	agricultural residues (primary residues from arable crops (straw and stubbles), pruning, cutting, and harvesting residues from permanent crops, dedicated perennial crops	stemwood, primary residues (logging residues-same with the DG RTD categories) and secondary residues from forest industries (sawmill residues, sawdust) post-consumer wood	Biomass fraction of municipal solid wastes (MSW) Mixed wastes of food preparation (including utilised cooking oil) Post-consumer wood Sewage sludge

Source: adapted from Concawe: Sustainable biomass availability in EU.

The values reported in Figure 1 are based on conservative estimations, which explain why some figures might be lower than in other studies.

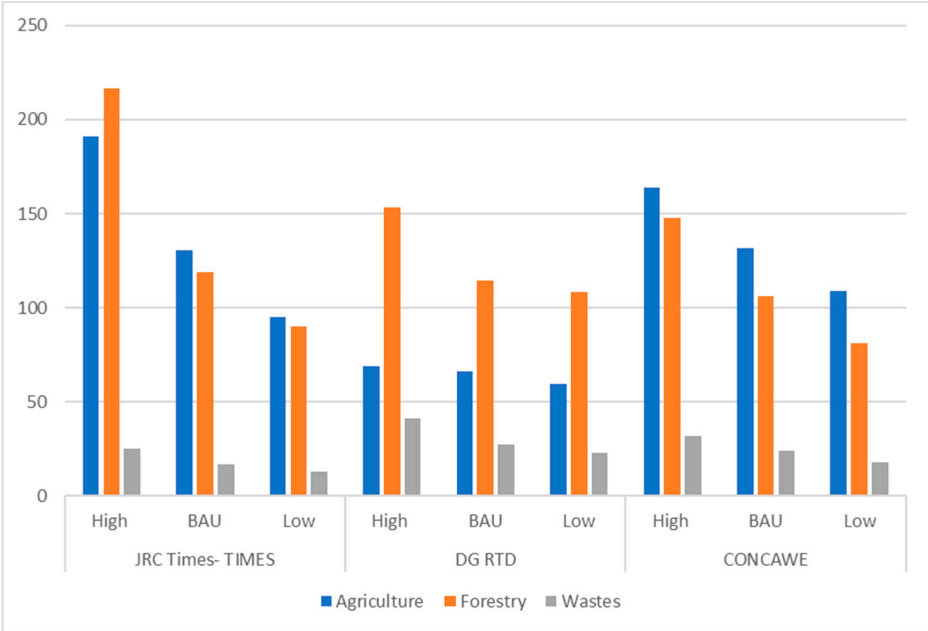

Figure 1. Feedstock potentials (Mtoe) from the three selected studies for 2030.

Agricultural feedstocks: The JRC ENSPRESSO study resulted in higher figures as regards biomass availability (95–191 Mtoe by 2030). This is due to the fact that the study included biomass feedstocks from first generation biofuel crops and energy maize for biogas. Moreover, in the high scenario biofuel crops (sugar, starch, and oil crops) and energy maize are estimated and grow in competition for land with food and feed crops, but this is no impediment for their use as energy. Additionally, dedicated crops can be cultivated in high biodiversity lands. In all the scenarios of this study, biofuel crops grow in competition for land with food and feed crops.

The DG RTD study did not include conventional crops in the estimated potentials (first generation biofuels from sugar, starch, and oil crops in conventional cultivation mode), and the resulting biomass availability ranges from 60–69 Mtoe for 2030. Biomass potentials were assessed in the context of research and innovation improvements across the supply chain. Moreover, it accounts for the sustainability criteria as set within the REDII.

The Concawe study focused on the feedstocks of agricultural, forest, and waste origin included in Annex IX of RED II (Part A and B). Food and feed crops were not included in this study. The estimated agricultural biomass availability ranged from 109 to 164 Mtoe.

The biomass availability for oil feedstocks which can be used for biodiesel/HVO and HEFA are estimated as follows:

- from 22 to 25 Mtoe from rapeseed, sunflower, and soy, as well as from 2 to 3 Mtoe of utilised cooking oils for 2030 in the JRC ENSPRESSO,
- from 1 to 2 Mtoe from oil crops and 1 Mtoe of utilised cooking oil for 2030, in the DG RTD study and
- from 2 to 3 Mtoe of utilised cooking oils for 2030 in the study conducted for Concawe.

It is worth mentioning here that the DG RTD and the Concawe study did not analyse the so-called first-generation crops, the category where rapeseed, sunflower and soy are included.

Forestry feedstocks: The JRC study in the high scenario assumes that stemwood and forestry residues are available for energy production, that there is increased woodland productivity, increased mobilisation of wood from small private forest owners, reduced competing demand for non-energy purposes, and increased mobilisation of primary forestry residues because of the increased demand for biomass for energy which results in increased stump and residue removal. The estimated biomass availability ranged from 90 to 217 Mtoe for 2030.

The DG RTD study adopted more conservative assumptions on the use of stemwood for energy and took into account an increased demand from biobased industries. The estimated biomass availability ranged from 108–154 Mtoe for 2030.

The Concawe study acknowledged the current debate and increasing concerns over the use of forest biomass for energy purposes. For this reason, and although current uses of stemwood are shared almost equally between biobased products and energy use, this study assumed that only 25% of the stemwood would be used for energy purposes in the low scenario, 30% in the medium, and 50% in the high scenario. The estimated biomass availability ranged from 81 to 148 Mtoe for 2030.

Biowastes: The JRC ENSPRESSO study assessed the waste feedstock potentials using the Eurostat waste generation (NACE—Statistical Classification of Economic Activities in the European Community) and waste treatment data from 2010 as input. For the medium scenario, it was assumed that the collected waste per category developed over the years according to the population growth for household waste and according to the gross domestic product (GDP) growth rate for the NACE waste categories. In the high scenario, the percentage going to energy increased 10% as compared with the medium level, due to a decrease in competing use and disposal and incineration. In the low scenario, the amount of waste sent for energy decreased by 10% as compared with the medium situation, due to an increase in competing use. The estimated biomass availability ranged from 13 to 25 Mtoe for 2030.

The work in the DG RTD study focused on similar categories to those in the JRC ENPRESSO. The study assumed ambitious advances in the separation, collection, and energetic usage of UCO/FOG, and the organic waste fraction and the estimated biomass availability ranged from 23 to 41 Mtoe for 2030.

The Concawe study considered the Circular Economy Package (Commission recently adopted ambitious new Circular Economy Packages) which states that 55% of municipal waste needs to be reused and recycled by 2025, 60% by 2030, and 65% by 2035. The amount of municipal waste landfilled must be reduced to 10% or less of the total amount of municipal waste generated by 2035. This study applied the above rates to 2030 and to 2050 (the 65% announced for 2035) in the low scenario. The estimated biomass availability ranged from 18 to 32 Mtoe for 2030.

4. Discussion

At the time of publication, there is considerable uncertainty on how the expected push towards transport decarbonisation will be realised. If passenger cars and light-duty mobility seem to be more oriented towards electrification and gaseous fuels (i.e., H_2) [31], the trend for the heavy-duty sector is less clear. The road and maritime freight sector, as well as the airborne segment, are expected to keep relying on current propulsion technologies due to the longer turnover of the vehicles and the need for energy dense fuels. Conversely to what is expected to happen in the light-duty road sector with electrification, the use of alternative liquid fuels can be considered as a short-term option for hard-to-abate sectors, such as maritime and aviation. In this framework, liquid alternative fuels will play a crucial role at least till 2030.

It is worth recalling that the methodology used contains some limitations, such as the inhomogeneity and the limited number of literature sources available. However, within these limits, the followed methodology allowed us to derive a consistent set of information. In particular, what emerged from the analysis was that the volumes will be further defined by the legislative initiatives, and this is already under development for the maritime and aviation sectors, which have not yet started to use alternative fuels in large amounts to reduce their environmental impacts. Adding to the layer of uncertainties created by COVID-19, which disrupted previous assessments, the quantification of the potential demand for alternative fuels is a challenging task. However, as of today the estimate ranges between 20.4 and 32.6 Mtoe. This is an important outcome, which illustrates that adequate quantities of sustainable feedstock can be made available to supply the development of the low carbon transport markets.

Under a very conservative approach, expected feedstock availability appears to be sufficient to cover the projected demands. This allows the drawing of a picture where feedstock quantity may not actually be the limiting factor, with respect to a significantly increasing use of alternative fuels by 2030. The only caveat is that high-ILUC lipid materials and food/feed feedstock-based production chains are planned to be progressively phased out. This implies that a shift towards other productions will be needed, to cover this expected cut in the feedstock pool. However, even when this general approach is focused on specific feedstock/fuel pathways, the overall picture does not change. The expected HEFA use in aviation could, for instance, be entirely supplied by waste streams. In the medium term, the forestry residues are expected to sustain growing demands, progressively reducing pressure and lipid materials, as technological conversion processes will be increasing their technology readiness level (TRL).

Clearly, factors other than the feedstock availability are related to the actual pace with which these alternative fuels will be taken up. For example, the final production cost is widely recognised as a limiting factor, especially for aviation [32] and maritime sector [4]. Additionally, for specific pathways, such as liquefied biomethane in maritime, the need for creating a dedicated infrastructure may also be a relevant barrier.

5. Conclusions

Nowadays, addressing the growing pressure to reduce the climate impact is urgent for the transportation sector. While passenger cars and light-duty vehicle segments are showing a consolidated trend in emission reduction, and a clear trend toward electrification, the freight and the aviation sectors are progressively shifting toward the use of alternative fuels as a short-term means for reducing their emissions. In spite of the numerous challenges posed by the uncertain legislative framework and on the demand side, related to the effects of the COVID-19 pandemic, in this work we estimated the potential European demand for alternative fuels: it ranged between 20 and 33 Mtoe by 2030.

The fragmentation and the inhomogeneity of the available sources added uncertainty to the results; however, the evaluation carried out on feedstock availability consistently confirmed—even under very conservative assumptions—that this may not represent the major barrier within this time frame. Average feedstock costs, price volatilities, the need for technological improvements, and widely distributed infrastructure are other relevant aspects contributing to the puzzle. Given the availability of feedstock to support demand, additional research is needed to create robust models and more integrated analyses, aimed at defining proposals to remove these bottlenecks and allow for increasing the uptake of sustainable alternative fuels, as a means to decarbonise transport.

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