European Commission

Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

Annex 1 Report on Task 1

Research and Innovation

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Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels

Annex 1 Report on Task 1

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Table of contents

1. Introduction

Task 1 aims at quantifying the demand potential of alternatives to fossil fuels, with an emphasis on advanced biofuels, within the transport sector. In particular, the focus is to understand the additional role that liquid and gaseous advanced biofuels can have in the transport sector compared to what is projected according to an anticipated policy context and framework conditions.

At EU level several policies and measures are implemented to regulate the transport sector and drive emission reduction, to align the sector with the emission reduction requirements under the EU Climate Law. These policies have a direct or an indirect effect on the uptake of advanced biofuels (see section 2.1).

The scenarios developed under this task aim at:

- Determining plausible ranges for the use of advanced biofuels in the transport sector, including both liquid and gaseous biofuels;

- Understand the scope for increased advanced biofuel demand compared to base cases, following the set-up of EU policy frameworks and targets.

2. Context

The EU is signatory to the Paris Agreement as well as previous Climate Agreements. For this purpose, the EU has implemented the EU Climate Law which includes the obligation to reduce net Greenhouse Gas (GHG) emissions by 55% compared to 1990 in 2030 and to achieve climate neutrality by 2050, that entails net-zero GHG emissions for the EU. To achieve such steep emission reduction and reach the EU climate neutrality goal all sectors will need to eliminate emissions or compensate for any remaining emissions. In this context transport is particularly relevant as it is a sector which has historically seen emissions rising and includes segments that by many are considered as hard to abate (e.g., road freight, aviation and maritime).

The transport sector includes different transport modes, fuel types and technologies ranging from rail, which has very low emissions intensity owing to electrification in most Member States, to road transport that sees a gradually increasing uptake of electric vehicles, to maritime and aviation which to date rely almost exclusively on fossil fuels and require specific fuel types and densities to perform. Developments are ongoing: (a) in making current technologies more efficient, in energy and emission terms, (b) in developing new renewable fuels of biological and non-biological origin, which are compatible with today’s technologies and infrastructure, (c) in developing new powertrains (e.g. battery or fuel-cell powered vehicles), (d) in increasing the transport system efficiency by supporting more efficient means of transport and modal shifts, e.g. by developing infrastructure and providing other incentives to facilitate the uptake of public transport and active modes that have lower CO_2 intensity than private modes of transport.

Policies are in place and are being further strengthened through several legislative proposals of the “Fit for 55” policy package in order to ensure that the emission reductions in the transport sector will take place in an efficient, equitable, and sustainable manner.

Two recent events that influenced the transport sector and the overall energy sector are the COVID pandemic and the invasion of the Ukraine by Russian forces. The COVID pandemic has greatly influenced the transport sector: in the short-term some transport segments such as aviation came to an almost complete halt in 2020 (with variations across MS) but the segment is expected to recover fully by 2025, whilst in the longer-term some trends such as reducing commuting-related travel owing to teleworking may to some extent remain. Studies are ongoing to assess how much of the transitionary trends will remain (see e.g., Kikstra et al. 2021[1]). More recently, in February 2022, Russia invaded the Ukraine leading to an energy crisis as Russia was a crucial exporter of natural gas and to a lesser extent petroleum to the EU. In response, the EU has prepared the RePowerEU Communication to reduce its energy dependence on Russian energy products and in addition foresees a strengthening of the "Fit for 55" policy package targets with regard to renewable energy expansion, energy efficiency improvements and clean fuel uptake.

2.1. Framework conditions

The quantification of scenarios to assess the demand potential for alternatives to fossil fuels developed for Task 1 takes place in the context mentioned above, which includes the following crucial elements:

- Contribution of transport to GHG emission reduction by 55% in 2030 and climate neutrality by 2050 in the context of the EU Green Deal;
- Transport activity and macro-economic developments including the effects of the COVID-19 pandemic;
- Energy prices that include the effect of the invasion of the Ukraine on energy markets.

The sections below address elements pertinent to these crucial elements.

2.1.1. GHG emissions

The policies and measures that are considered within this analysis are included in section 2.2. The effective implementation of these policies should ensure the fair contribution of the transport sector to the achievement of the climate goals as set out in the EU Climate Law.

2.1.2. Activity

The EU Reference Scenario 2020[2] and the quantitative analysis underlying the "Fit for 55" policy package[3], include the updated economic and activity outlook that account for the effects of the COVID pandemic including in transport activities by mode. The same transport activity levels have been used also for the subsequent analysis of the RePowerEU Communication and will also be used for the analysis in Task 1 to ensure consistency and comparability across scenarios. The transport activity levels fell in 2020 due to the pandemic and are projected to rebound in the period to 2025, recovering fully before 2030. These trajectories follow recent DG ECFIN economic projections and are in

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1 https://www.nature.com/articles/s41560-021-00904-8

2 https://op.europa.eu/en/publication-detail/-/publication/96c2ca82-e85e-11eb-93a8-01aa75ed71a1/language-en/format-PDF/source-219903975

3 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

line with other European Commission assessments.

Transport activity (passenger or tonne- kilometres; pkm or tkm, respectively) is the useful service for the transport sector: the activity is influenced by population, economic parameters (e.g., economic growth, trade) and transport infrastructure development. In the process of preparation of the EU Reference Scenario 2020 the transport activity projections are prepared by transport mode and by Member State, based on their respective historical trends as well as projected population growth, economic development, and infrastructure development.

A baseline transport activity is used in line with the above. However, the PRIMES-TREMOVE model further modifies endogenously the activity levels for a specific scenario based on energy carrier prices, vehicle costs, and policies and measures in place leading to different activity levels by mode induced e.g., by modal shifts.

2.1.3. Relatively increased transport activity case

In the context of this project, an increased mobility scenario is also developed in order to simulate a case in which fossil fuel demand is higher than in the scenario counterparts (RITA variants).

The relative increased transport activity scenarios combine a number of existing trends that include:

- **Higher population.** Due to recent events higher migration cases than what assumed in the baseline assumptions, may seem more and more credible. This case is based on the EUROSTAT “sensitivity test: higher migration” from EUROPOP2019 - Population projections at national level (2019-2100) last updated in February 2021.[4] Higher population will affect both freight and passenger transportation:
  - Passenger transportation will increase because more people require transportation services. It is assumed that the additional population will quickly adapt to the average mobility patterns of the destination country;
  - A rising population will also have additional needs for goods, which require additional trade and freight transportation.
- **Pandemic impact.** In its outburst, the pandemic resulted in a short-term strong reduction of transport activity, especially in aviation. As of yet it is unclear what the impact of the pandemic will be on long term transportation trends: in the relative increased transport activity case it is assumed that private actors will avoid travelling in mass transport modes. This is expected lead to a number of impacts:
  - Low modal shift towards public transportation such as buses and rail;
  - Higher utilization of private cars: particularly in economies with mobility per capita below average rates this would be assumed to quickly increase;
  - Higher purchasing of private cars: actors will value travelling in their own car highly, therefore increasing the private expenditures for transportation purposes;

[4]https://ec.europa.eu/eurostat/databrowser/view/PROJ_19NP__custom_5033399/default/line?lang=en

- **Digitalization and home deliveries:** digitalization implies that there is a shift towards working from home, online ordering and home delivery. This trend is changing both short distance commuting to work and freight requirements (home delivery), as well as changing the supply chains (to potentially more imports from further destinations). Reduced commuting activity and reduced travelling activity for shopping may lead to higher leisure travelling activity (e.g. owing to less time spent travelling to work and shopping). Both these aspects are expected to lead to higher freight transport activity.

2.1.4. Energy Prices

Fossil energy prices, in particular for natural gas, but also oil and coal, saw a very sharp increase in the period after the invasion of the Ukraine, peaking during the crisis. The projections used in this project are the ones used and published in the RePowerEU Communication[5]. The international fuel prices see a short-term spike and a stabilisation of prices in the longer term reflecting a balance to the new market conditions. Compared to previous projections (e.g., EU Reference scenario 2020), the natural gas price is higher in the entire time horizon (by a factor 1.5-2.5 in the short term and 20%-25% in the long term), while the oil price is only moderately higher; current market developments seem to be confirming these trends.

International fossil fuel prices influence the fuel, vehicle, and modal mix in any given scenario. However, in the transport sector since taxation weighs very heavily on the end-user price, a significant price variation on pre-tax prices would need to be considered to lead to shifts in choices and/or disutility in 2030 or beyond. During the recent energy crisis, governments have temporarily modified the taxation levels or provided other incentives in order to limit the effect of increased fossil fuel prices on end-consumers. With respect to a lower fossil fuel price variation, their uptake will also be determined by policy targets such as the GHG intensity target in transport in 2030 (see next section), thus limiting a potential higher uptake owing to lower pre-tax prices. Beyond 2035 the level of fossil fuel consumption in the transport system will be decreasing significantly, owing to higher blends of alternative fuels (e.g., biofuels and/or e-fuels), hydrogen and electricity; therefore, changes in fossil fuel prices will have limited effect on the transport sector. Given the above considerations it is not considered as a priority to conduct sensitivity analysis on international fossil fuel price variations.

2.2. Policies and measures

There are several policies and measures that regulate the transport sector, that vary from Roadworthiness and General Safety Regulations to Infrastructure, Renewable Energy use, Air Pollutant and Fuel Quality regulations, and CO_2 emission standards on new vehicles. Many of these policies have a direct or an indirect impact on the uptake of alternative fuels, including advanced biofuels.

In the following, there is a list of key EU policies and measures that are either horizontal (addressing goals at an energy systems level, and contribution of sectors thereof) or apply directly to the transport sector which have an impact on the update of alternative fuels. The policies and measures have an effect both on the time period to 2030 (e.g., RED II targets/RED II amendment), and on the 2050 time period (e.g., CO_2 standards for cars and

[5] SWD(2022) 230 final.

vans and HDVs[6], ReFuelEU Aviation, FuelEU Maritime).

It should be noted that at the time of writing this report, several proposals of the European Commission have either been adopted or have reached the level of provisional political agreement between the European Council and the Parliament, waiting formal adoption. At the same time, a number of ambitious proposals put forward by the European Commission are also in the pipeline. The modelling adopts the policy framework of the legislative package "Fit For 55" (July 2021) and the targets of the RePowerEU communication. The expected impacts of the developments since, are addressed qualitatively and quantitatively, through the development of a scenario that meets the provisional agreement by the conditional GHG intensity target.

Renewable Energy Directive II (RED II): The RED II forms the continuation of the RED and sets the EU renewable energy policy for the period 2021-2030. Overall, RED II is considered as the strongest policy driving the deployment of RES in the EU, including the transport (road, maritime and aviation) sector as well. RED II establishes an overall renewable energy target of 32% by 2030. For each Member State, it sets a target for renewable energy in transport of at least 14% (RES-T). This target may be lowered based on a Member State's cap on crop-based biofuels. The cap may be at most 7% of energy consumed in the road and rail sectors and may not exceed a Member State's contribution of crop-based biofuels in 2020 plus 1%. Member States may implement a cap of 2% regardless of their crop-based contribution. It sets a cap of 1.7% on feedstocks from Annex IX Part B of RED II, such as used cooking oil and animal fats, that may be lifted with the consent of the European Commission. In addition, they have a specific sub-target starting at 0.2% in 2022, at least 1% in 2025, and increasing to at least 3.5% in 2030 by 2030 for advanced biofuels produced from feedstocks listed in Annex IX Part A of RED II (double-counted). Annex IX Part A and Part B biofuels are incentivized through the use of multipliers in their contribution to the RES-T target (a multiplier of 2 is used). The Directive also foresees a multiplier of 1.2 for biofuels supplied to the marine and aviation, a multiplier of 3 for renewable electricity for electric vehicles, and a multiplier of 2 for e-fuels (including green hydrogen, etc.).

In the framework of the "Fit for 55" package of July 2021, the EC proposed an amendment for RED II in order to align the Directive with the aspirations of the Green Deal and the 2030 Climate Target Plan. To that end, there has been a substantial increase in both the share of renewable energy in transport and of the sub-target for advanced biofuels. More specifically, the proposal introduces a target for reducing the GHG intensity of transport fuels by 13% by 2030 (i.e. emissions-based benchmark covering all transport modes that is equivalent to an energy-based target of 28% using the methodology in the current Directive), with an additional sub-target of 2.2% for advanced biofuels (single-counted). This represents a substantial increase of ambition in this sector compared with the current 14% transport target (energy-based) with a 3.5% advanced biofuels sub-target (double-counted). Moreover, with a view to supporting the strategic goal for 2x40 GW electrolyser capacity outlined in last year's Hydrogen Strategy, a new sub-target for renewable fuels from non-biological origin (RFNBOs) of 2.6% in transport (single-counted), and a new target for a 50% share of renewables in hydrogen consumption in industry (including non-energy uses).

Compared to the EC proposal as implemented in the "Fit For 55" policy package, the

[6] The same HDV standards as used in the scenarios undertaken for other Commission services will be used. The proposal includes standards up to 90% (not 100%). If a political agreement on the HDV regulation will take place during the course of the project the scenario will be updated accordingly.

provisional agreement for RED III, besides setting new targets, it also sets a renewable energy target for the transport sector or a GHG intensity target for the fuel mix used in transport in 2030, leaving the option to the Member States. The policy also sets sub-targets and/or caps for specific fuel types (e.g., RFNBOs, biofuels), i.e. 5.5% for advanced fuels use in 2030 (hydrogen, RFNBOs, advanced biofuels; double-counted), with a minimum sub-target for RFBNOs at 1% (double-counted).

FuelEU Maritime: The FuelEU Maritime seeks to steer the EU maritime sector, which currently predominantly relies on fossil fuels, towards decarbonisation. The main goal is to increase the use of low carbon fuels by introducing limits to the GHG intensity of energy used on board ships, and an obligation to use onshore power supply or zero emission technology in EU ports. To support the uptake of sustainable maritime fuels, the Commission proposes to limit the average carbon intensity of the energy used on board ships. It starts in 2025, with a modest 2% reduction until eventually achieving a 75% reduction of greenhouse gas intensity (gCO2eq/MJ) of marine fuels in 2050. This would apply to all big commercial vessels, which are the most polluting ones regardless of their flag. Importantly, the target is technology neutral, in that it does not prescribe by means of sub-targets the contribution of different types of alternative fuels (biofuels and RFNBOs).

The provisional agreement for FuelEU Maritime includes a higher GHG intensity reduction target after 2035, compared to the EC proposal as implemented in the “Fit For 55” policy package. In the provisional agreement, the target increased to 14.5% in 2035 (instead of 13% in the EC proposal) and to 80% in 2050 (instead of 75% in the EC proposal).

ReFuelEU Aviation: The ReFuelEU Aviation proposed regulation obliges fuel suppliers to distribute Sustainable Aviation Fuels (SAF), with an increasing share of SAF (including synthetic aviation fuels, commonly known as e-fuels) over time, in order to increase the uptake of SAF by airlines and thereby reduce emissions from aviation. According to this timetable, the minimum share of SAF supplied at each EU airport should be 2 % in 2025 and 5 % in 2030, increasing to 20 % in 2035, 32 % in 2040, 38 % in 2045, and 63 % in 2050. Within the SAF requirement, a sub-obligation is envisaged for synthetic aviation fuels, increasing from 0.7 % in 2030 to 5 % in 2035, 8 % in 2040, 11 % in 2045, and 28 % in 2050. The remainder of SAF shares is met by biokerosene.

The provisional agreement for ReFuelEU Aviation increases the SAF content in energy use in aviation compared to the SAF mandate in the EC proposal as implemented in the “Fit For 55” policy package from 2030 onwards. In the provisional agreement, the target increased to 6% in 2030 (instead of 5% in the EC proposal) and to 70% in 2050 (instead of 63% in the EC proposal).

EU Emissions Trading Scheme (EU ETS): The EU ETS is under amendment in the framework of the “Fit for 55” policy package. In December 2022, a political agreement was reached which includes the extension of the ETS to the buildings and road transport sectors. This implies that all fuels in the road transport sector will also be subject to carbon pricing under the new framework of the new ETS.

EU Energy Taxation Directive (EU ETD): The EU ETD is in force since 2003 and stipulates minimum excise duty rates for the taxation of energy products used in transport, as heating fuel and electricity to be set by Member States. The proposed revision of the EU ETD takes into account the new climate and energy policy framework for the EU for mid- and long-term emission reduction by introducing new structure of the tax rate based on the energy content and environmental performance of the fuels and electricity. Moreover, it includes more products in its scope, thus keeping pace also with development of alternative fuels such as cleaner and sustainable biofuels and hydrogen, and by removing some of the current exemptions and reductions on fossil products.

CO_2 standards for cars and vans as well as CO_2 standards for heavy duty vehicles: These proposed regulations limit the WTLP CO_2 emissions of new vehicles sold in the EU and as such stimulate zero emission technologies. The CO_2 standards for light-duty vehicles have been strengthened in the “Fit for 55” policy framework, with the political agreement to reach 0 (zero) emissions from 2035 onwards for new car registrations. The “Fit for 55” policy package considers strengthened CO_2 standards for Heavy-Duty Vehicles and extended scope compared to the adopted regulation in 2019. The proposed legislation for both light-duty and heavy-duty vehicles does not include the possibility of accounting for ICEs powered exclusively from biofuels or other zero- or low- carbon fuels.

Alternative Fuel Infrastructure Regulation: This proposed piece of legislation will be substituting the Alternative Fuel Infrastructure Directive and will be implemented as a Regulation, without the need of being transposed into national legislation. This legislation should allow for the EU-wide development of the infrastructure required for all fuel alternatives to fossil fuels. While not directly influencing the uptake of biofuels, the presence (or absence) of refuelling/recharging infrastructure contributes to the uptake of certain powertrains and allows the possibility to refuel on alternatives to fossil fuels.

Fuel Quality Directive (FQD): This Directive aims at ensuring a single market for fuels used in the EU for both road vehicles and through its amendment also for non-road mobile machinery. It also aims to ensure a high level of environmental and health protection through the use of those fuels. To this end the Directive introduced a GHG intensity target that road transport fuels should achieve by 2020, and after compared to a baseline. The FQD further regulates the quality of fuels used for transportation setting upper limits for oxygenates used in petrol blending constraints and in the FAME content of diesel blends.

RePowerEU Communication: RePowerEU is about rapidly reducing Europe’s dependence on Russian fossil fuels by fast-forwarding the clean transition and joining forces to achieve a more resilient energy system and a true Energy Union. In that respect, the Commission is proposing to increase the target in the Renewable Energy Directive to 45% of renewable energy sources in the overall gross final energy consumption by 2030, up from 40% in last year’s proposal. This would bring the total renewable energy generation capacities to 1236 GW by 2030, in comparison to 1067 GW by 2030 envisaged under the Fit-for-55 for 2030. In the transport sector, the Commission calls upon the European Parliament and the Council to align the sub-targets for renewable fuels of non-biological origin under the Renewable Energy Directive for industry and transport with the RePowerEU ambition (75% for industry and 5% for transport) and to rapidly conclude the revision of the Hydrogen and Gas Market package. The RePowerEU strategy includes a target for biomethane, however with not specifications in this regard for the transport sector.

Global policies (IMO and ICAO/CORSIA): The International Maritime Organization (IMO) is not new to the idea of reducing GHG emissions in shipping: it adopted its initial strategy in this regard in 2018, setting itself the goal to reduce average carbon intensity (CO2 per tonne-mile) by at least 40% by 2030 and by 70% in 2050, as well as to cut total emissions by at least 50% by 2050 (compared to 2008) and phase them out as soon as possible. It should be noted that these targets are not supported by any legislation. While the IMO is to review its initial strategy in 2023, international pressure has been mounting on it to act faster. In 2016, the International Civil Aviation Organization (ICAO) adopted a global market-based mechanism, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), to address CO2 emissions from international aviation. CORSIA is the first global market-based measure for any sector and represents a cooperative international approach. The international standards for the implementation of CORSIA have been adopted as an Annex to the Chicago Convention. CORSIA aims to stabilize international civil aviation net CO2 emissions at 2019 levels, from 2021, using offsetting programs.

The modelling used in this task includes among others the above-mentioned energy and climate policies and instruments that are different in nature (e.g. taxes, subsidies, measures that remove barriers, technology/emission/performance standards, targets), thereby accounting for their interactions towards energy and climate goals. By including horizontal policies, and framework conditions compliant with the overall decarbonization efforts of the EU, the transport sector is not assessed in isolation, but it considers the overall ambition of the EU Green Deal targets and the effort required from supply and demand sectors system in the set framework, as well as respective policies. As such, synergies and distractions of energy system policies are taken into account[7].

3. Methodology

The uptake of alternatives to fossil fuels in the transport sector is influenced by policies and economic choices for fuels and powertrain technologies. To understand these complex interactions between multiple -often cross-sector- policies and rational economic choices, as well as behavioural interactions, this project will use the PRIMES-TREMOVE transport model.

3.1. The PRIMES-TREMOVE transport model

The PRIMES-TREMOVE transport model is a large-scale economic-engineering model of passenger and freight transport and is part of the PRIMES modelling suite, a family of linked models covering all aspects of the energy system and the demand and supply sectors. The PRIMES-TREMOVE transport model is specifically developed to project the long-term evolution of passenger and freight transport by transport mode (road, rail, air, waterborne)[8], vehicle (for example, cars, vans, trucks and others) and fuel (e.g. oil products, biofuels, electricity, hydrogen, synthetic fuels). It should be mentioned that the model does not produce short-term forecasts (i.e. it does not predict) but rather projects the evolution of the transport sector, and among others its fuel use into the future under a certain set of framework conditions (section 2.1) and assumptions, assuming the attainment of policy targets (section 2.2). The dynamic projections cover the period until 2050 by 5-year steps and for each European Member State. The base year of the model is 2015, with semi-calibration to 2020.

PRIMES-TREMOVE represents a dynamic system of multi-agent choices under several constraints (not necessarily simultaneously binding). The fuel and vehicle choice of agents is endogenous in the model and is based on internal costs, perceived costs (e.g. market acceptance for each technology) and infrastructure availability for the energy carriers (e.g. recharging infrastructure). For the purchasing of new vehicles, several technology options are considered. The vehicle technology includes different configurations and technologies with an impact on fuel consumption and fuel types. The purchase choice of vehicle

[7] The interplay of energy and climate policies with policies outside the energy system is not assessed in the present study, as it would require an extended modelling framework and linkages with other models. As biofuels lie at the nexus of several sectors and policies (e.g. food, biodiversity, water) such an assessment may be an important future endeavor.

[8] Other pipeline transport, and other transport consuming sectors such as machinery use in agriculture are not part of the model's scope.

technologies and fuels follows the approach of discrete choice modelling. Cost elements include all costs over the lifetime of the potential transport means: purchasing cost for vehicles, annual fixed costs for maintenance, insurance and ownership/circulation taxation, variable costs for fuel consumption depending on trip type and operation conditions, other variable costs including congestion fees, parking fees and tolled roads; these are exogenous inputs to the model. The PRIMES-TREMOVE model includes a vehicle stock sub-module that calculates the stock of transport means from previous time periods in order to determine the changes needed to meet demand. It tracks vehicle vintages and formulates the dynamics of vehicle stock turnover by combining scrapping and new registrations.

A key model output is the energy demand (in energy units) for the transport sector by transport mode, vehicle type and fuel type, as well as the resulting emissions and costs of the overall sector. The stock of vehicles is also a model output. The activity by transport mode is also a result of the model: modifications to the baseline activity levels may occur endogenously or exogenously owing to different policies or pricing levels.

The model has been specifically developed to model a large range of policies and measures for transport including:

- soft measures, e.g., eco-driving, deployment of Intelligent Transport Systems, and labelling;
- economic measures, e.g., subsidies and taxes on fuels, vehicles and emissions, pricing of congestion and other externalities i.e. pollution, accidents, and noise;
- infrastructure policies for alternative fuels, e.g., deployment of refuelling and recharging infrastructure for electricity, hydrogen, biofuels, LNG, CNG and LPG;
- regulatory measures.

The policies mentioned in section 2.2 are among those included in the model.[9]

3.2. Scenario definition

In Task 1, the purpose of the scenario quantification is to assess the range of the potential demand for advanced biofuels in transport. To undertake this quantification, a set of scenarios is developed, and subsequently incorporated in the PRIMES-TREMOVE model. Interactions with the biomass supply (in terms of bioenergy prices or feedbacks with biomass availability) or interactions with the rest of the energy system, stemming from the PRIMES modelling ecosystem are not considered within this Task, as off-model comparisons are performed in the other Tasks of this project. The scenarios are developed across two dimensions and two different contexts (“Fit For 55” and “RePowerEU”; Figure 1):

- The first dimension (vertical) is the level of ambition of policy targets;
- The second dimension (horizontal) assumes alternative conditions that may increase the uptake of advanced biofuels, within the same overall policy context mentioned above.

[9] Additional policies are included but not listed in section 2.2, as the section aimed at addressing key transport policies.

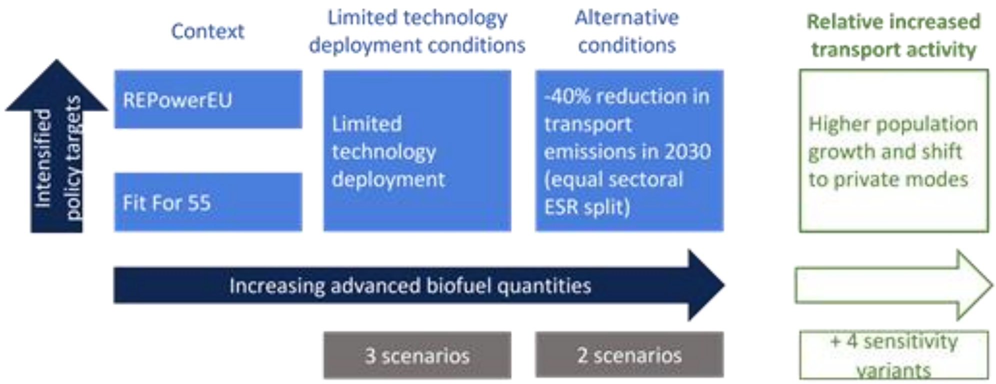

Figure 1: Schematic representation of scenarios

3.2.1. Dimension: policy targets under limited technology deployment conditions

This dimension looks into two different contexts, namely the "Fit for 55" context and the "RePowerEU" context. These contexts and several policy elements therein are not (yet) fully implemented, and therefore the scenarios will explore the potential uptake of advanced biofuels by 2030 and beyond.

3.2.1.1. Fit for 55 context

On July 14, 2021, the EC presented the "Fit for 55" policy package which introduced new or included amendments to 13 policy instruments in order to help achieve the EU Climate Law target of 55% GHG emission reduction in 2030. On occasion, policy instruments address also the trajectory after 2030 to help achieve the climate neutrality target (e.g., ReFuelEU Aviation, FuelEU Maritime).

The scenario developed in this context (i.e. FF55_LTD) will explore the potential uptake of advanced biofuels in the Fit for 55 context, by assuming the attainment of the GHG intensity target of 13%, a minimum 2.2% contribution of advanced biofuels to that target, within a RES share in transport of 28.5%. These are the binding targets applied in the modelling. It should be highlighted that in the implementation of RED as part of the Fit For 55 policy proposal package, the RES-T target was replaced by the GHG intensity target. In the scenario implementation, it was discussed that both targets should be met and are implemented as such. The interplay of these targets is such that the RES-T target/indicator is overshot when an ambitious GHG intensity target is achieved. Moreover, owing to multipliers, RES-T is higher than what the renewable energy share calculation without multipliers would yield.

Drivers for additional biofuel uptake will include lower attainment of contribution to electrification (e.g., owing to slower ramp up of recharging infrastructure deployment, or slower uptake of electric vehicles). Moreover, scenario drivers will include a slower uptake of e-fuels (e.g., owing to slower deployment of electrolysers for hydrogen production, and/or slower developments of Direct Air Capture; DAC). As such, the scenario will explore the potential additional uptake of biofuels in maritime as the target is set on a technology neutral basis, and for Aviation it will consider the mandate at the level of Sustainable Aviation Fuels (SAF and not the sub-obligation of RFNBOs in 2030, and possibly a lower contribution of RFNBOs than what stipulated in the RED II recast.

Other policies and related targets of indirect influence on the advanced biofuel uptake (e.g., CO_2 standards for cars and vans) will remain unchanged.

Key policy	Policy target assumed in the scenario context in 2030	Direct influence on advanced biofuel uptake	Indirect influence on advanced biofuel uptake
RES-T share	28.5%		✓
RED II recast			
GHG **intensity target**	-13%		✓
Minimum s**hare of** advanced **biofuels**	2.2%	✓	
RFNBO share*	2.6%		✓
ReFuelEU Aviation (Biofuel blending target) **(RFNBO blending target)***	4.3% 0.7%	✓	
FuelEU Maritime (GHG intensity reduction)	-6%	✓	
CO_2 standards for cars and vans	-55% for cars -50% for vans		✓
CO_2 standards for HDVs	As implemented in the Fit For 55/RePowerEU scenario (i.e. -35% for extended scope of HDVs)		✓
AFIR	As in the proposal		✓
Energy Taxation Directive	As in the proposal	Direct effect on end-user price	
New ETS **(**often referred to as ETS2)	Road transport included		✓
GHG emissions	-55% overall (incl. LULUCF)	No direct transport target	

*Including H_2 use in refineries for transport fuels. In the scenario the RFNBO sub-target will be assumed as non-binding.

Table 1: Key policies and targets in the scenario developed within the Fit For 55 context for 2030

Within the Fit For 55 context, an additional scenario (FF55_RED) is explored that complies with the provisional agreement on RED by meeting the conditional requirement on GHG intensity reduction in the transport fuel mix (-14.5% in 2030; thus, overshooting the RES-T target), while maintaining the lower bound on the share of RFNBOs (i.e. 1%, including multipliers), and additional barriers on the uptake of electric vehicles, thereby exploring the potential additional contribution of advanced biofuels. The outcomes of this scenario are discussed separately (see section 4.2.3).

3.2.1.2. RePowerEU context

The RePowerEU context aims at strengthening the policies which reduce the dependence of the EU on Russian imports of gas (and oil). This has led to the suggestion to strengthen a number of policies included in the “Fit for 55” policy proposal package resulting in an upward revision of several “Fit for 55” targets of July 14, 2021.

The scenarios developed in this context explore the potential uptake of advanced biofuels based on RePowerEU targets, by assuming the attainment of the GHG intensity target of 16%, a minimum 2.2% contribution of advanced biofuels to that target, within a RES share in transport of approximately 32%. It should be highlighted that in the implementation of RED as part of the RePowerEU Communication the RES-T target was replaced by the GHG intensity target, more ambitious than the one of the Fit For 55 policy proposal package. In the scenario implementation, it was discussed that both targets should be met and are implemented as such.

Similar to the scenarios under the Fit For 55 context, the drivers for additional biofuel uptake will include lower attainment of contribution to the targets of electrification (e.g., owing to slower ramp up of recharging infrastructure deployment, or slower uptake of electric vehicles). The RePowerEU scenario envisions that a large part of the strengthened targets compared to the “Fit for 55” goals will be delivered by hydrogen and e-fuels. This scenario (i.e. RePower_LTD) will therefore explore the situation in which the additional hydrogen and e-fuel quantities do not become fully available (e.g., owing to slower deployment of electrolysers for hydrogen production, and/or slower developments of Direct Air Capture; DAC). Therefore, the scenario will explore the potential uptake of biofuels in several road (e.g., heavy duty trucks) and non-road transport sectors (e.g., maritime, aviation), leading to a lower contribution of RFNBOs than what envisioned in the RePowerEU Communication.

Other policies and related targets of indirect influence on the advanced biofuel uptake (e.g. CO_2 standards for cars and vans) will remain unchanged.

Key policy	Policy target assumed in the scenario context in 2030	Direct influence on advanced biofuel uptake	Indirect influence on advanced biofuel uptake
RES-T share	32.1%		✓
RED II recast			
GHG intensity target	-16%		✓
Minimum share of advanced biofuels	2.2%	✓	
RFNBO share*	5.7%		✓
ReFuelEU Aviation (Biofuel blending target) (RFNBO blending target)*	4.3% 0.7%	✓	
FuelEU Maritime (GHG intensity	-6%	✓	

Key policy	Policy target assumed in the scenario context in 2030	Direct influence on advanced biofuel uptake	Indirect influence on advanced biofuel uptake
reduction)			
CO_2 standards for cars and vans	-55% for cars -50% for vans		✓
CO_2 standards for HDVs	As implemented in the Fit For 55/RePowerEU scenario (i.e. -35% for extended scope of HDVs)		✓
AFIR	As in the proposal		✓
Energy Taxation Directive	As in the proposal	Direct effect on end-user price	
New ETS **(often** referred to as **ETS2)**	Road transport included		✓
GHG emissions	-55% overall (incl. LULUCF)	No direct transport target	

*Including H_2 use in refineries for transport fuels. In the scenario the RFNBO sub-target will be assumed as non-binding.

Table 2: Key policies and targets in the scenario developed within the RePowerEU context for 2030[10]

3.2.1.3. Assumptions pertaining heavy duty road transport, aviation and international maritime

More specifically, with respect to heavy duty road transport (lorries, buses and coaches), aviation and international maritime the following policy assumptions have been made:

- **Heavy Duty Road transport**: from 2026 onwards, CO2 standards apply to an extended group of lorries, buses and coaches (i.e. not only to the currently regulated in vehicle groups 4, 5, 9 and 10). The assumed targets progressively increase from - 35% in 2030 to -70% in 2040 and to -100% in 2050, corresponding to reduction of tailpipe emissions of new heavy duty vehicles sold in the EU compared to the EU average over the period 2019/2020. In terms of scope, the EC proposal and its implementation in the model have is identical, i.e. applied to the same heavy duty vehicle groups. In terms of stringency, the applied CO2 standards are less stringent compared to those proposed by the EC on the 14th of February 2023 (i.e. -45% in 2030 and -90% in 2040)[11]. This means that in the scenarios presented here, slightly less stringent CO2 standards apply to the same group of heavy duty vehicles compared to the EC proposal. Therefore, in the scenarios prepared for the present study, the impact of this policy essentially entails a higher uptake of ICEs, hence liquid fuels, compared to what the implementation of the EC proposal would yield. This would also entail, especially in 2030, that the segment emits more compared to what the implementation of the EC proposal would entail, as the segment would have a lower number of zero emission vehicles in the fleet

[10] Modelling results may diverge slightly from the official targets reported in the EC Communication.
[11] https://ec.europa.eu/commission/presscorner/detail/en/IP_23_762

(owing to the less stringent standard). By 2050, the difference on GHG emissions would phase out, as the remaining fuel mix used by ICE engines will be decarbonized.

- **Aviation**: the main policy assumption affecting the aviation sector is the assumed SAF mandate, as per the ReFuelEU Aviation initiative (EC proposal). In the scenarios prepared for the present study, the blending mandates are applied at the SAF level, (i.e. the 0.7% sub-mandate on RFNBOs in 2030 is assumed as non-binding, thereby leading to higher uptake of biokerosene in order to meet the SAF mandate). From 2030 onwards the sub-mandates on RFNBOs on SAF are assumed as binding thereby converging with the EC proposal. Compared to the provisional agreement of 25 April 2023[12], the SAF blending mandate applied in the present study are somewhat lower (i.e. 5% compared to 6% in 2030, 63% compared to 70% in 2050). Ultimately, this leads to lower uptake of biokerosene and synthetic kerosene in the scenarios of the present study compared to what the uptake would be following the provisional agreement. Implementing a 6% SAF target in 2030, and assuming the RFNBO sub-target as non-binding would lead to about 0.4 Mtoe additional quantities of biokerosene demand (in addition to the 1.8 to 2.1 Mtoe presented in the results of the present study; see section 4).

- **International Maritime**: the main policy input that affects the uptake of alternative to fossil fuels in the maritime sector is the GHG intensity of the FuelEU Maritime initiative. The target is set as annual average carbon intensity reduction compared to 2020. Compared to the provisional agreement of 23 March 2023[13]

Besides the above-mentioned segment-specific policies, other horizontal policy assumptions also affect the scenario results (e.g. Renewable Energy Directive GHG intensity target, ETD, inclusion of aviation in ETS, inclusion of road transport to the ETS).

3.2.2. Dimension: Alternative conditions

This dimension explores two variations of the policy contexts under limited technology deployment conditions (section 3.2), which may lead to a higher uptake of advanced biofuels.

In particular, under the same context based on the limited technology deployment conditions scenarios (i.e. FF55_LTD and RePower_LTD), the two variants developed in this dimension (i.e. FF55_ESR, RePower_ESR) include a sectoral specific Effort Sharing Regulation (ESR) target for the transport sector. Specifically, the transport sector will need to achieve a 40% emission reduction target in 2030 compared to 2005. This implies an overshoot of specific targets as laid out in the context of the under limited technology deployment conditions (i.e. GHG intensity target reduction).

This additional effort in transport will be met under the same limitations as the under limited technology deployment conditions and is expected to lead to a combination of low- and zero-carbon alternatives, including higher uptake of advanced biofuels, electrification as well as RFNBOs.

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[12] https://www.consilium.europa.eu/en/press/press-releases/2023/04/25/council-and-parliament-agree-to-decarbonise-the-aviation-sector/
[13] https://www.consilium.europa.eu/en/infographics/fit-for-55-refueleu-and-fueleu/

3.2.3. Outlook to 2050

For the time horizon 2050 the achievement of the EU Climate Law targets is assumed (i.e. net zero EU GHG emissions in 2050): the transport sector will therefore need to have close to zero emissions at above 90% emission reductions from 2005.

The targets/objectives of policies which are already in place for 2050 are summarised in Table 3.

Key policy	Policy target assumed in scenario in 2050	Direct influence on advanced biofuel uptake	Indirect influence on advanced biofuel uptake
ReFuelEU Aviation (Biofuel blending target) (RFNBO blending target)*	35% 28%	✓	
FuelEU Maritime (GHG intensity reduction)	-75%	✓	
CO_2 standards for cars and vans	-100% for cars and vans		✓
CO_2 standards for HDVs	As implemented in the Fit For 55/RePowerEU scenario (i.e. -100% for extended scope of HDVs)		✓
Energy Taxation Directive	As in proposal throughout the projection period	Direct effect on end-user price	
New ETS **(often referred to as ETS2)**	Road transport included; extension of framework to 2050		✓
GHG emissions	Net Zero	No direct transport target	

Table 3: Key policies and targets for the 2050 timeframe (common for both scenarios)

The limited technology deployment assumed for the horizon 2030/2035 are assumed to phase out, so as to achieve the net-zero target in 2050.

4. Analysis and results

Currently the EU is adapting its set of policies to comply with the 55% GHG emissions reduction target for 2030 and plans next steps for the decades to come in order to achieve the net zero GHG emission reduction target in 2050. The scenarios quantified within this Task seek to understand the potential level of alternatives to fossil fuels with a focus on advanced biofuel consumption in the transport sector by developing and providing scenario variants within the EU Climate Law targets under different policy context for 2030 (Fit For 55 and RePowerEU).

An overview of the scenarios presented in this study is presented below:

	Limited Technology Deployment	Higher ESR contribution	Relative increased transport activity and Limited Technology Deployment	Relative increased transport activity demand and Higher ESR contribution	RED provisional agreement
Fit for 55 context	FF55_LTD	FF55_ESR	FF55_LTD_RITA	FF55_LTD_RITA	FF55_RED
RePowerEU context	RePower_LTD	RePower_ESR	RePower_LTD_RITA	RePower_LTD_RITA	–

Table 4: Abbreviations used for scenarios developed in Task 1

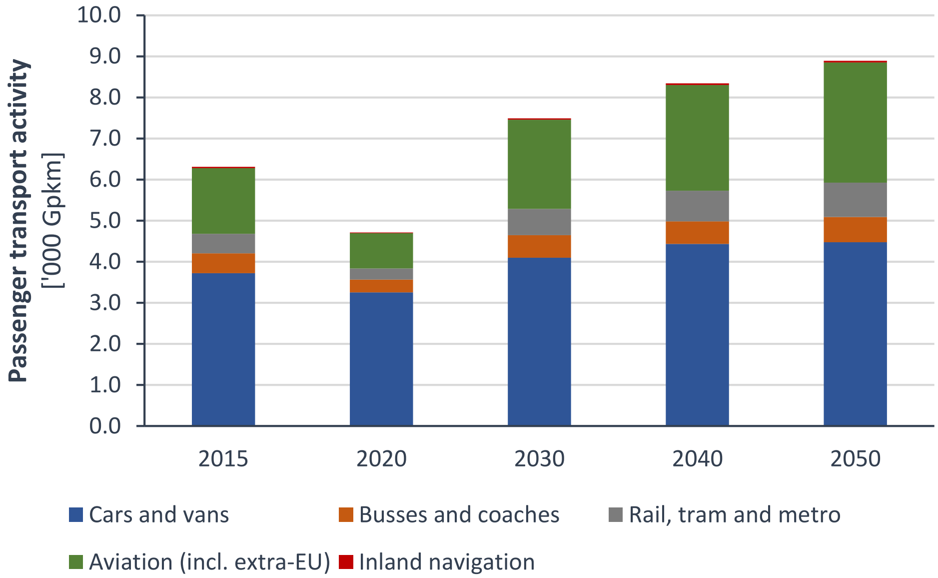
4.1. Analysis of main indicators in the Fit For 55 and the RePowerEU context

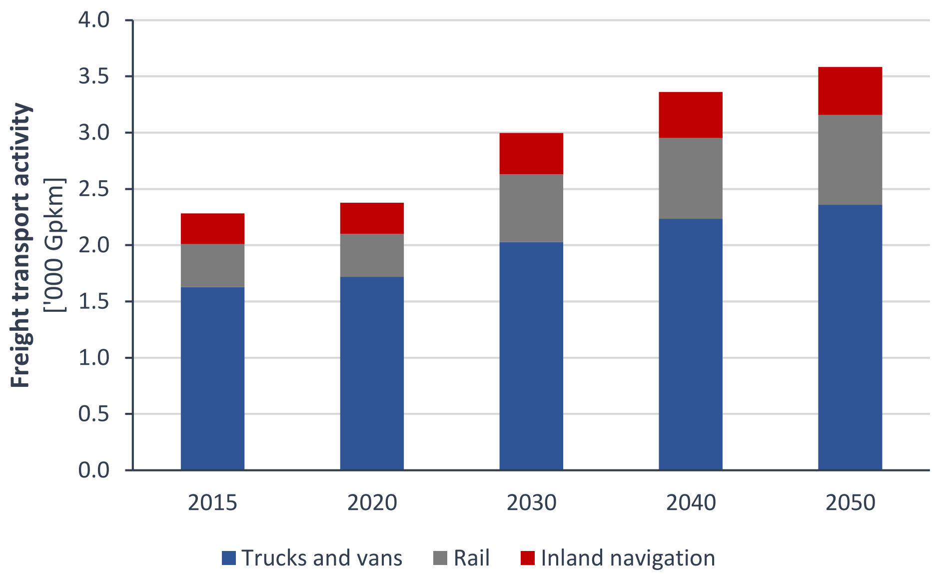
4.1.1. Activity

Activity projections for passenger and freight transport, and for international maritime are presented in Figure 2 and Figure 3, respectively. The demand for passenger and goods mobility is driven by economic and demographic growth as explained in the Framework Conditions (see section 2.1). As such, with increasing economic and population growth, transport activity in the EU continues to increase to 2050, both in passenger and freight transport.

In 2020, road transport is the predominant transport mode, in both passenger and freight transport, accounting for about 75% and 70% of total transport activity, respectively. In passenger transport, this high share is partly due to the contraction of the aviation sector in 2020 owing to flight restrictions during the COVID19 pandemic. In the years after 2020, the aviation sector is projected to recover, and while road transport loses modal share to 62% in 2030 and 57% in 2050, it remains the predominant transport mode. In its vast majority, road transport activity is met by cars and vans, as public modes (busses and coaches) account for about 7% during the projection period. In passenger transport, currently implemented and envisaged policies are not expected to lead to substantial amounts of modal shift, though high-speed rail and tram and metro increase modestly their modal share at the expense of private cars and vans. Modal shifts are more pronounced in freight transport, as inland navigation and rail increase their modal share compared to road transport. International maritime, both passenger and freight, retains its growth rates throughout the projection period, largely driven by the continued growth of trade within and across countries. It should be noted that the activity levels and patterns are similar across all scenarios developed in this Task and comparable with those developed in the “Fit For

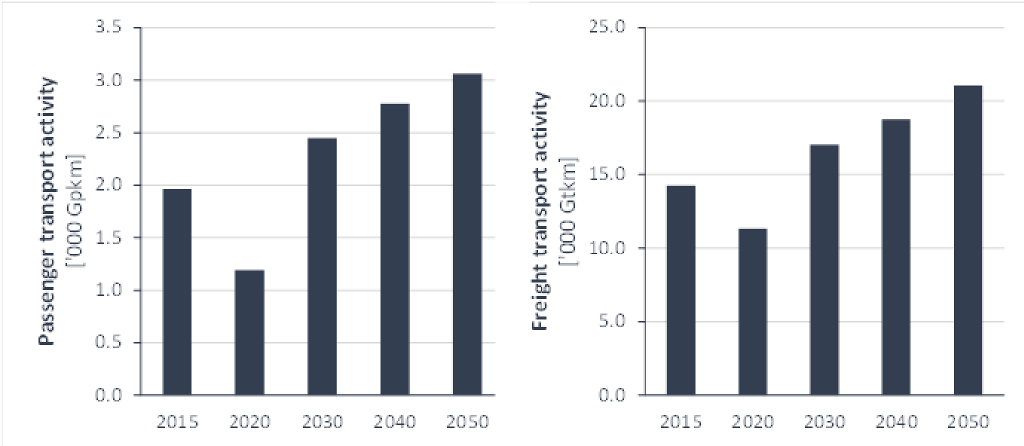
55" and the "RePowerEU" policy contexts (minor differences owing to cost-induced endogenously projected modal shifts are observed). An exception are the high activity variants that were developed as a driver for higher fossil fuel consumption (see section 2.1)





Source: PRIMES-TREMOVE transport model

Figure 2: Activity levels of passenger transport (top) and freight transport (bottom)



Source: PRIMES-Maritime transport model

Figure 3: Activity levels of international maritime passenger (left) and freight (right)

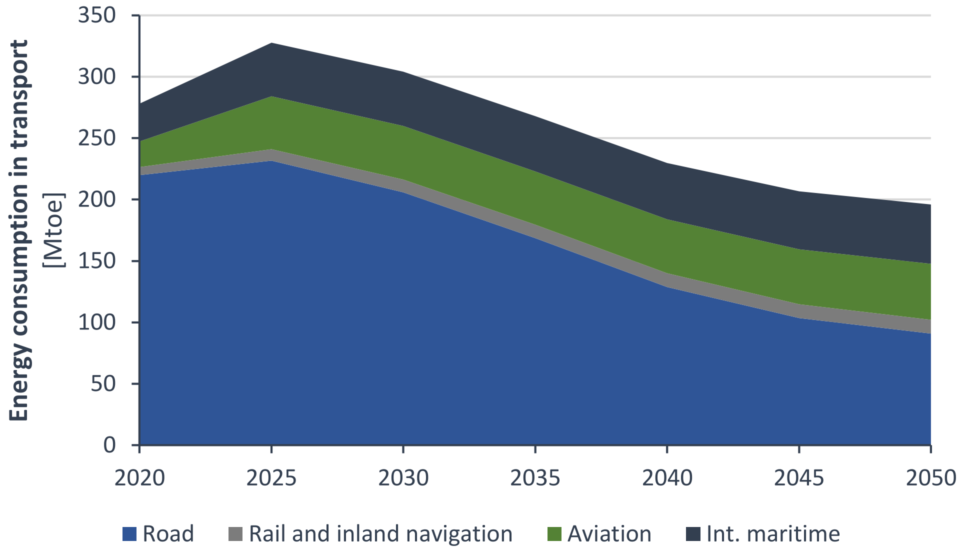
4.1.2. Energy demand and fuel mix

4.1.2.1. Transport sector overview

The fuel mix of transport is currently dominated by liquid fossil fuels accounting for almost 92% of the overall energy consumption in transport and international maritime. The largest alternative fuels in the transportation sector are biofuels representing approximately 6% of energy consumption in transport. The penetration of biofuels is mainly driven by blending mandates which apply in the majority of EU countries in order to help the achievement of the RES-T targets and contribute to emission reduction.

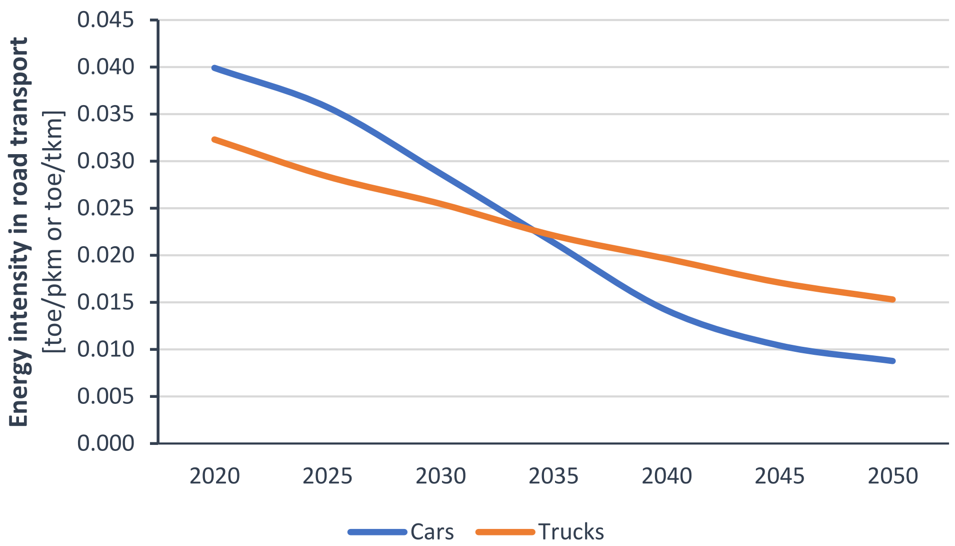
In order to contribute to the 55% GHG emissions reduction target in 2030, and to the net-zero goal by 2050, the transportation sector needs to significantly reduce emissions. There is a general consensus in scenarios developed for the EC, starting from 2030 and moving towards 2050 there will be a significant shift towards electrification and to a lesser extent hydrogen in the road transportation sector, both for light and heavy-duty vehicles, triggered by regulatory policies like CO2 emission standards; biofuels and e-fuels will mainly contribute as transitionary fuels in road transport as internal combustion engines will be gradually phased out, owing to the ICE ban on new car and vans sales from 2035 onwards and the more stringent CO2 emission standards for heavy-duty vehicles. The long-term demand outlook for (advanced) biofuels and e-fuels is projected in aviation and maritime sectors, where the impact of alternative powertrains is considered minimal to 2050.

Figure 4 shows projections of energy consumption in transport by mode. It is seen that most notable reduction in energy demand comes from the road transport sector, owing to the uptake of electric and hydrogen vehicles to the detriment of internal combustion engine. Electric and hydrogen vehicles come with significant efficiency savings per km driven, compared to internal combustion engines (i.e. 2 to 4 times more efficient). This is also demonstrated in Figure 5, that presents energy intensity in road transport (cars and trucks) over time, explaining the significant drop of energy consumption in road transport between 2020-2050 (i.e. about 60% reduction) while road passenger and road freight transport activity increases by about 40%. Energy consumption in aviation and maritime remails relatively stable over the projection period owing to efficiency improvements of jet turbines (i.e. about 30% between 2020 and 2050) and marine fuel engines (i.e. by about 15% between 2020 and 2050), that counterweigh the notable activity increase increases in these transport segments.



Source: PRIMES-TREMOVE transport model

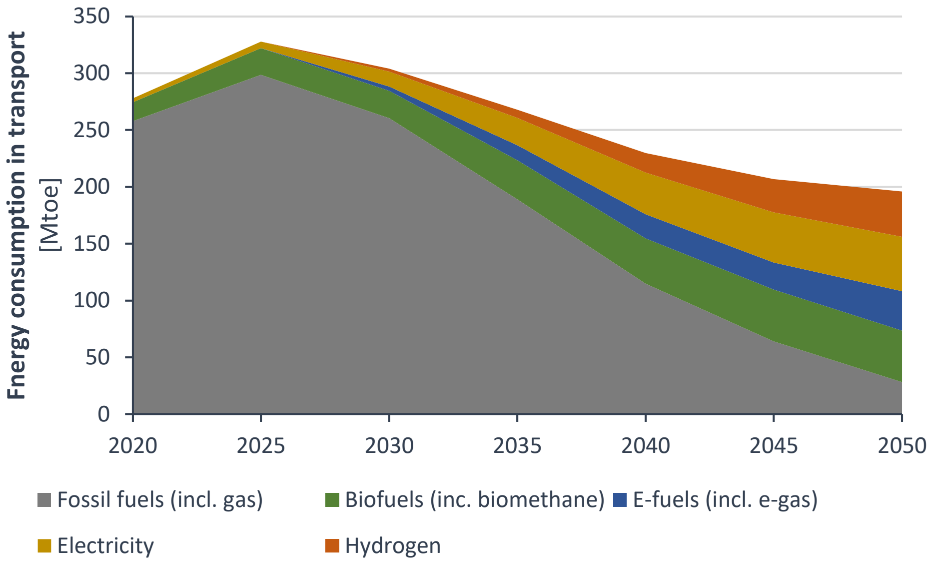
Figure 4: Energy consumption in transport by mode in a Fit For 55 context



Source: PRIMES-TREMOVE transport model

Figure 5: Energy intensity in road transport

As implied by the reduction in energy demand in transport (Figure 4), the fuel mix is projected to change radically compared to today. Figure 6 breaks fuel consumption by fuel type and presents the trajectory from 2020 to 2050. Fossil fuels (mainly liquid oil products) are expected to reduce from about 260 Mtoe in 2020, representing over 92% of the energy mix in transport, to about 30 Mtoe representing 15% of the energy consumption in 2050. Nonetheless, liquid fuels continue to represent over 95% of the energy mix in the transport sector in 2030 and 55% in 2050, due to the uptake of biofuels, e-fuels, and the remaining fossil fuels.



Source: PRIMES-TREMOVE transport model

Figure 6: Energy consumption in transport by fuel type in a Fit For 55 context

In the short-term, biofuels (and to a lesser extent e-fuels) are projected to be consumed mainly in road transport, albeit their uptake also in aviation and maritime driven by dedicated policies. In the long-term however, their use is projected to shift to mainly non-road transport segments (aviation and maritime), firstly because road transport (both private cars and HDVs) is projected to see high penetration of electric powertrains (whether fully battery electric vehicles or fuel cell vehicles) thus limiting the demand technologies where liquid fuels can be used, and secondly due to the increasing ambition of SAF use and GHG intensity target in aviation and maritime sectors, that have limited alternatives to decarbonization, other than (predominantly) liquid fuels.

First generation biofuels are capped in EU legislation and there are expectations owing to policy incentives that they will shift towards advanced biofuels. As such, in the future, it is expected that there will be a shift towards advanced fuels, including RFNBOs. In order to develop the market, the EU has set targets for advanced biofuels in the Renewable Energy Directive, as well as additional policies for the aviation and maritime sectors (ReFuelEU aviation and FuelEU maritime). The biofuel mix is further analyzed in section 4.2.2.

4.1.2.2. Fuel mix in the Fit For 55 and RePowerEU context in 2030

The RePowerEU context aims at reducing further the EU's dependence on imported fossil fuels (particularly natural gas) in order to increase security of supply and reduce reliance in particular on imports from Russia. For this purpose, domestic resources such as electricity and biofuels, as well as indirect consumption of electricity through e-fuels and/or hydrogen should be strengthened. The RePowerEU scenario, therefore, sees an increase in the consumption of hydrogen and e-fuels compared to the Fit For 55 context.

In 2030, the energy demand level and the energy mix in transport between the Fit For 55 context and the RePowerEU context is comparable. In the RePowerEU context, the energy demand level is by 1% lower than in the Fit For 55 context, while transport activity levels are largely similar. This is stimulated by energy efficiency reduction owing to the deployment of more efficient ICEs and to fuel switch to more efficient hydrogen-powered fuel cell vehicles, mainly in the trucks segment. The latter is driven by the higher sub-target on RFNBOs (5.6% in RePowerEU compared to 2.6% in Fit For 55) so as to meet the higher GHG intensity target in transport (14.5% in RePowerEU compared to 13% in Fit For 55). The consumption of other fuel types (e.g. electricity and e-fuels) remains at similar levels between the two contexts. It should be noted that after 2030 the outlook of Fit For 55 and RePower converge, leading to more than 90% emission reduction in transport contributing to the EU Green Deal goals, and in particular to climate neutrality by 2050.

4.2. Scenario analysis for higher uptake of advanced biofuels in transport

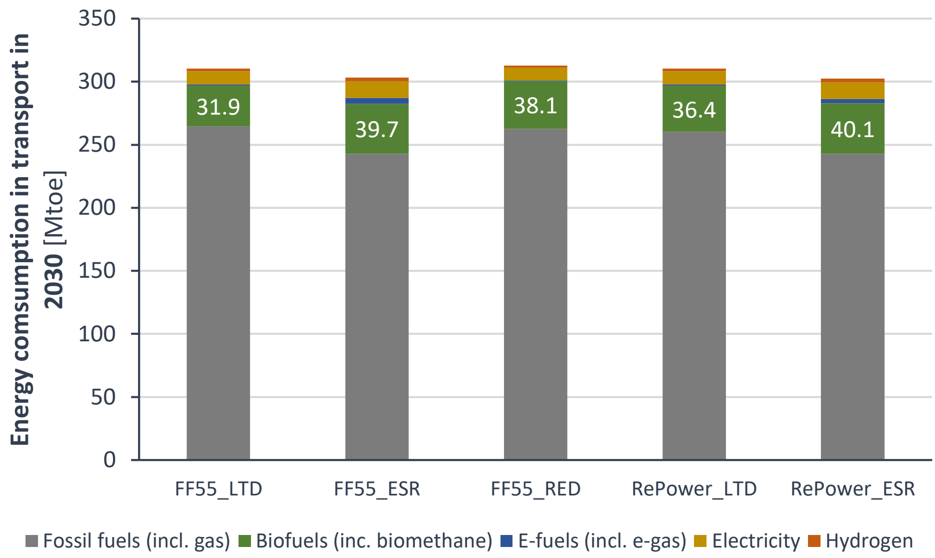
In the present study we analyze a number of different scenarios developed within the Fit For 55 and the RePowerEU context to understand possible ranges of biofuel demand from the transport sector.

4.2.1. Energy demand and fuel mix

In the horizon to 2030, the energy mix in transport is characterized by fossil fuel use across all variants to levels similar to the Fit For 55 and RePowerEU context.

The energy mix in transport to the time horizon of 2030 is still primarily linked to the use of fossil fuels. However, until 2030 the transportation sector should contribute to the overall emission reduction effort of the EU by reducing its fossil fuel consumption.

In the short-term (2030), the overall energy demand is comparable across the different variants at around 300 Mtoe (Figure 7). Despite the subtle differences in energy demand in transport, there are impacts on the transport sector and most notably on the uptake of electric vehicles and electricity, and subsequently also on the uptake on biofuels (first generation, advanced biofuels and biofuels from waste oils and fats).



Source: PRIMES-TREMOVE transport model

Figure 7: Energy mix of the transportation sector in 2030 across the different variants

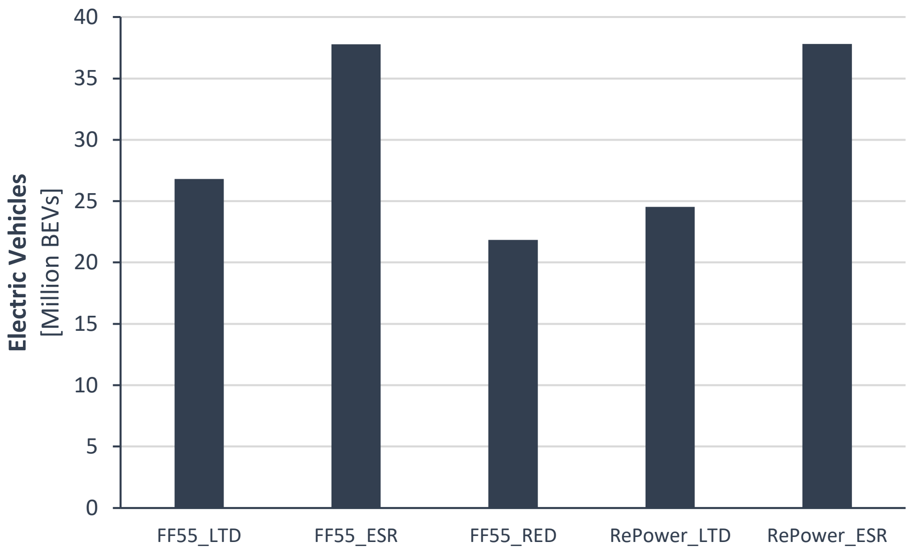
Under a Fit for 55 or RePower context (e.g. FF55 and RePower scenarios in Figure 7), electric vehicles are expected to increase from just over one million vehicles in the EU today to over 37 million in 2030 (Figure 8). This implies a significant growth of industrial production of electric vehicles, and it is linked to the development and deployment of the required recharging infrastructure. Further such a large market penetration of EVs is also linked to techno-economic improvements of vehicles, particularly expected economies of scale which would lead to cost reductions of EVs, and in particular the battery components.

LTD variants

The Limited Technology Deployment variants (LTD) quantify the amount of biofuels, which would be required should the electric vehicle (EV) deployment not follow the pathway envisaged and cost reduction, infrastructure deployment, market acceptance etc. do not materialize as rapidly. In such a case, two dynamics take place: on the one hand, the CO2 standards on new vehicle sales will still stimulate the uptake of zero emission technologies as the manufactures would have to reduce tailpipe emissions by 55%[14]; however, owing to the barriers applied in the Limited Technology Deployment variants, new car sales will decrease (and notably more in the RED variant; see section 4.2.3), and legacy internal combustion engines will remain in the fleet retaining the consumption of both liquid fossil

[14] It should be noted that CO2 standards are explicitly integrated in the modelling (measured in gCO2/km) and apply on new vehicle registrations as constraints influencing the consumers' choices upon purchasing new vehicles; the choice is formulated as a cost minimization problem in the model's vehicle supply module. The CO2 standards apply on tailpipe emissions: (fully) battery electric vehicles and fuel cell vehicles have no tailpipe emissions (0 gCO2/km), regardless of the emissions intensity of electricity generation. Internal combustion engines and hybrid vehicles are characterized by a CO2 label (ingCO2/km) different by technology type; as per definition, CO2 standards do consider the fuel blend.

fuels and biofuels. Even in such a context, EV sales will continue to increase to just under 25 to 27 million (Figure 8; and 22 million in FF55_RED see section 4.2.3) driven by cost reductions and technology improvements, but conventional vehicles and hybrid vehicles will maintain a larger share. Even the notably lower volume of EVs in the LTD variants could imply high vehicle (and battery) imports from outside the EU and thus dependency of the region to supply chains outside the EU. PRIMES and PRIMES-TREMOVE being a partial equilibrium model does not perform a closed-loop energy-economy analysis. Therefore, it does not point towards technology-specific challenges and opportunities outside the energy system, unless is linked with a general equilibrium macro-economic model (e.g. GEM-E3). Such considerations and the impacts of are not part of the present analysis.



Source: PRIMES-TREMOVE transport model

Figure 8: Uptake of battery electric vehicles across scenarios in the EU in 2030

On the other hand, the transport sector will still be required to meet its emission reduction targets as stipulated in the scenarios (notably the GHG intensity target, and the sub-target of advanced biofuels and RFNBOs in transport). With higher use of internal combustion technologies in the fleet, the uptake of biofuels will also increase. Therefore, the LTD variants project that the emission reduction is achieved through the use of additional quantities of biofuels. In such context, the biofuel demand in 2030 may reach 32-36 Mtoe (Figure 7) (and notably more in the ESR and RED variants; see next section and section 4.2.3, respectively). Hydrogen reaches 2 Mtoe in the FF55_LTD scenario, and 2.3 Mtoe in RePower_LTD. Under the LTD variants, the contribution of e-fuels is also expected to be more limited (i.e. around 1 Mtoe). Overall, the RFNBO share (i.e. hydrogen and e-fuels) in transport reduces to 1.6% as the RED target of 2.6% in the development of these variants is considered as non-binding - see section 3.2), as also these technologies are assumed to develop at a lower pace and will not be able to contribute as much to emission reduction. Similar trends are also observed in the HDVs segment.

Applying the “limited technology deployment” assumptions to an RPE context implies a shift away from reliance on hydrogen and e-fuels, as well as electricity, towards higher levels of biofuel consumption in order to maintain the emission reduction target. The RFNBO sub-target of 5.6% of RePowerEU, contracts to 3.2% in RePower_LTD as hydrogen and e-fuels are replaced by biofuels.

ESR variants

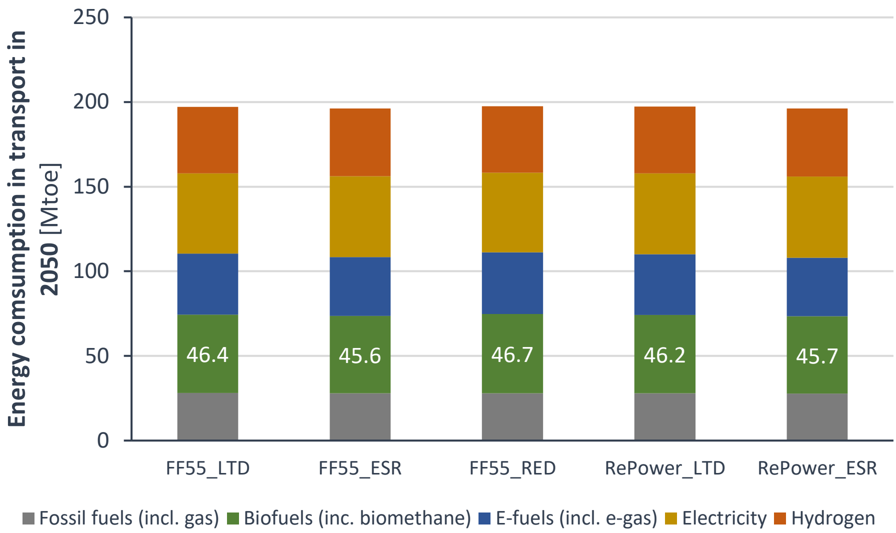
In addition to the LTD variant, a more ambitious context was analyzed, with respect to emissions reduction. Within this context the transport sector contributes equally to the ESR reduction target (i.e. 40% in 2030 compared to 2005). These variants are developed on the basis of the Limited Technology Deployment variants in which the emission reduction in ESR transport segments reaches 32% (under Fit For 55) and 35% (under RePowerEU) in 2030 compared to 2005. The additional emission reduction effort in the ESR variants leads to a significantly additional uptake of biofuels, in which biofuels consumption increases to almost 40 Mtoe. Yet, all other mitigation options and technologies still need to increase their uptake for the sector to achieve a 40% emission reduction by 2030. For instance, electric vehicle uptake would increase to 38 Million vehicles (Figure 8).

Energy outlook to 2050

In the long-term (2050); total energy demand in transport reaches 190 Mtoe and biofuels consumption is about 45-46 Mtoe, depending on the variant (Figure 9). The small difference is due to the state of play in 2030, and in particular on the uptake of ICEs in the sector, as scenario assumptions after 2030 are similar. It should be noted that some policies continue post-2030 (e.g. ReFuelEU Aviation, FuelEU Maritime, CO2 standards in road transport), whilst other targets (such as the ESR target) are non-binding and are overshot in the period after 2030.

The projected demand for biofuels in 2050 (i.e. 45-46 Mtoe), entails almost a factor 3 increase compared to today’s consumption. Compared to the projections for 2030, the increase ranges from 17% to 45%, depending on the variant (lowest in the ESR variants as they already consider a high biofuels uptake in 2030).

In 2050, the projections show that 85% of the fuel mix in transport is decarbonized (on a Tank-to-Wheel basis). Fossil fuels are still consumed in the aviation and the maritime sector as the FuelEU Maritime and the ReFuelEU Aviation long-term targets do not imply a complete decarbonization of the energy mix. The emissions from these sectors will need to be compensated in other parts of the energy system through the deployment of Carbon Dioxide Removal technologies.



Source: PRIMES-TREMOVE transport model

Figure 9: Energy mix of the transportation sector in 2050 across the different variants

4.2.2. Biofuel mix

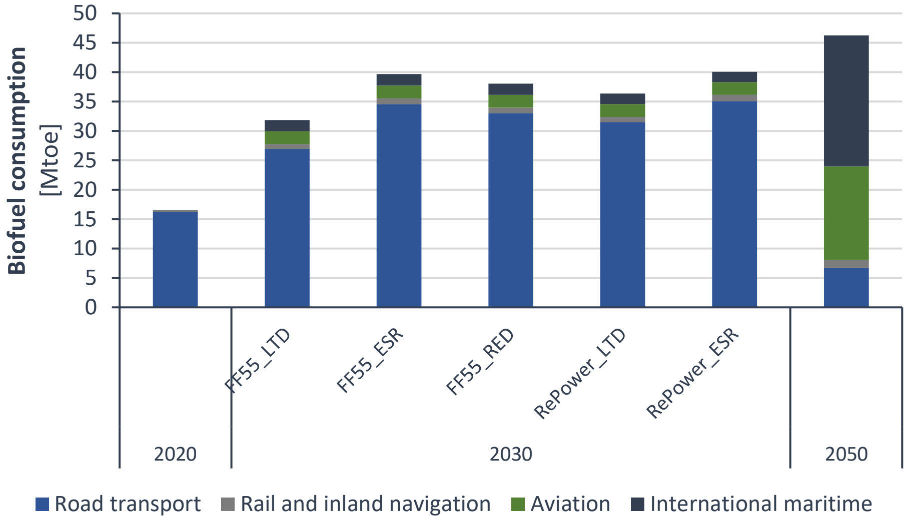
The PRIMES-TREMOVE model calculates the demand for first generation, advanced biofuels (Annex IX Part A) and biofuels produced from waste oils and fats (Annex IX Part B), based on policy constraints (e.g. food-based cap, contribution of advanced biofuels to meeting emission reduction targets).

Biofuel demand in transport

The pattern of biofuel consumption by sector is projected to change considerably over the projection period (Figure 10).

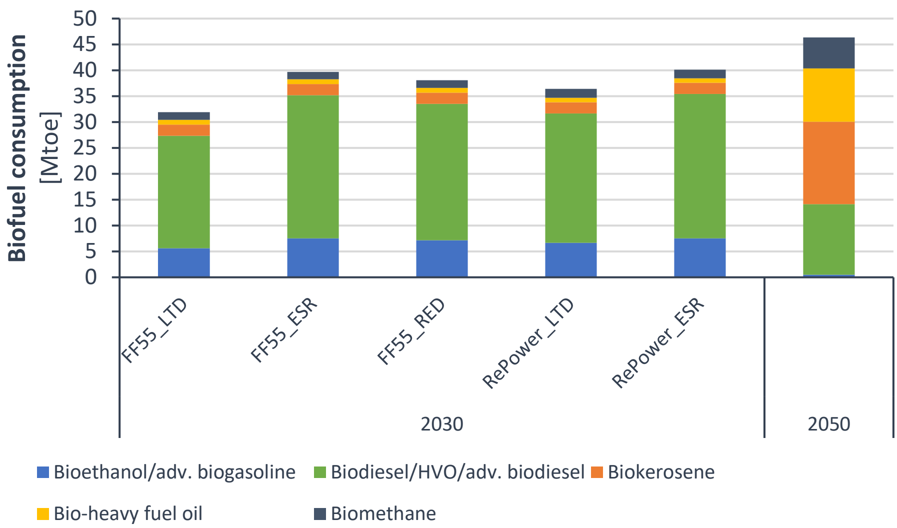
In the timeframe to 2030, most of biofuel consumption will remain in road transport and is expected to be mainly biodiesel (first generation, HVO or advanced drop biodiesel), and to a less extent ethanol blends or drop in advanced biogasoline (Figure 11). Owing to ReFuelEU Aviation and FuelEU maritime, the penetration of biofuels in the aviation and maritime sectors will increase considerably in 2030, as biokerosene and marine biofuels, together will account for about 10% to 13% of total biofuel consumption in transport, depending on the scenario. In Figure 10 it is also seen that the increase of biofuel consumption comes mainly from road transport. In the time period to 2030, the higher the emission reduction target of the transportation sector the higher the consumption of biofuels (e.g. comparing FF55_LTD with FF55_ESR). Biodiesel both first generation and advanced is the key biofuel in this time period.

Further gaseous fuels of biogenic origin are also a zero carbon option which is considered in the modelling and is projected to represent approx. 4% of biofuel demand in 2030.



Note: For 2050 results for FF55_LTD are shown, as scenario results converge (see also Figure 9). Source: PRIMES-TREMOVE transport model

Figure 10: Biofuel consumption by segment



Note: For 2050 results for FF55_LTD are shown, as scenario results converge (see also Figure 9). Source: PRIMES Biomass Supply model

Figure 11: Biofuel consumption by biofuel type

In the longer-term, on the pathway to 2050, the consumption of biofuels is expected to increase overall and divert to sectors for which electrification or hydrogen is not considered as a feasible option at wide scale -given today's technological maturity, i.e. aviation and navigation. This also implies a change in the type of fuels required: by 2050 in a net zero context it is expected that biokerosene will represent a third of biofuel demand (almost 16 Mtoe), marine biofuels will represent about 50% of total demand (around 22 Mtoe), and the remainder will be consumed in road transport (mainly heavy duty segments) and inland navigation (about 7 Mtoe). Biodiesel quantities are projected to be lower than their 2030 level as they are mostly used in road transport, which in the long-term is projected to be almost fully electrified, due to the application of CO2 standards both in passenger cars and HDVs. At the same time, according to the projections bio-heavy marine fuel oil will penetrate the system in significant quantities. While, due to uncertainties, the main marine biofuel type in the future can be contested as to whether it is biodiesel or bioheavy, it is projected that there will be a high demand for liquid biofuels in maritime. Further gaseous fuels of biogenic origin are also a zero carbon option which is considered in the modelling and is projected to represent approx. 12% of biofuel demand in 2050.

Biofuel consumption by RED classification

Figure 12 shows the consumption of biofuels in transport in 2030 split based on the classification of RED (i.e. to food-based biofuels, to advanced biofuels according to the definition of Annex IX Part A, and to biofuels from waste oils and fats according to the definition of Annex IX Part B)[15]. The projections are based on the scenario assumptions applied on the LTD variant (i.e. limited technology deployment of zero-emission technologies electric vehicles, charging infrastructure, hydrogen, e-fuels and DAC; these and additional assumptions are also applied in the FF55_RED variant; see section 4.2.3) and in the ESR variant (i.e. on the basis of LTD additional effort from transport to the overall EU emission reduction in 2030), while meeting the respective targets of the two contexts (i.e. 29% RES-T and 13% GHG intensity target in the Fit For 55 context and 32% RES-T and 14.5% GHG intensity; see also Table 1 and Table 2)[16]. Under such scenario conditions advanced biofuels become a key lever to meeting the scenario targets, as they contribute both to the RES-T target owing to the use of a high multiplier and they have lower Well-To-Tank (WTT) GHG emissions footprint than food-based biofuels (see next section), while at the same time electricity and RFNBOs are assumed to face technological and implementation barriers in 2030.

According to the scenario projections, the demand for advanced biofuels may increase to between 15 Mtoe and 19 Mtoe in 2030 (depending on the scenario). A significant, but somewhat smaller growth is also projected for Annex IX Part B biofuels, that, although capped, also contribute to the targets. Based on PRIMES Biomass Supply results, large part of the feedstock required for the production of Annex IX Part B biofuels (e.g. used cooking oil) projected for the present study and/or Annex IX Part B biofuels will need to be imported to the EU. The volume of food-based biofuels is about 8 Mtoe in the LTD variants,

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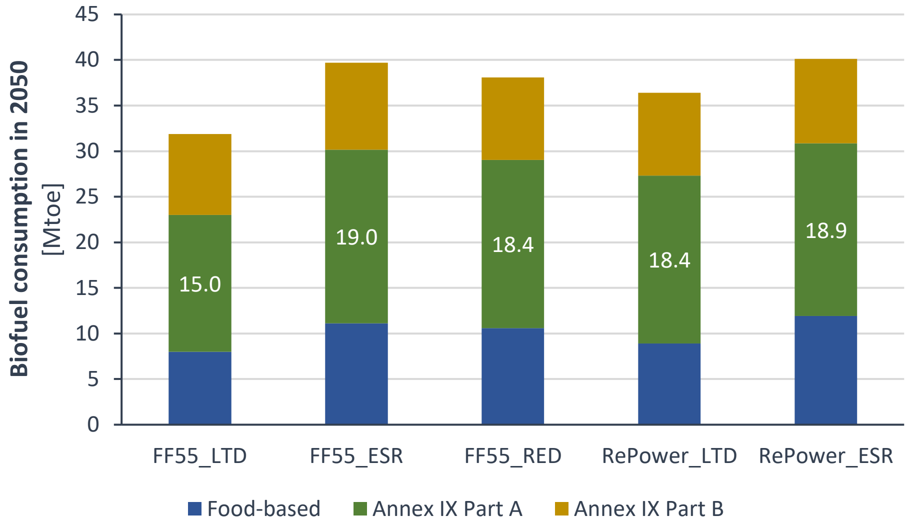
[15] As discussions on feedstock classification are ongoing, it is not expected that different grouping of feedstocks may change the overall demand and contribution of biofuels. It may however be that the results on different biofuel sub-categories may be affected.

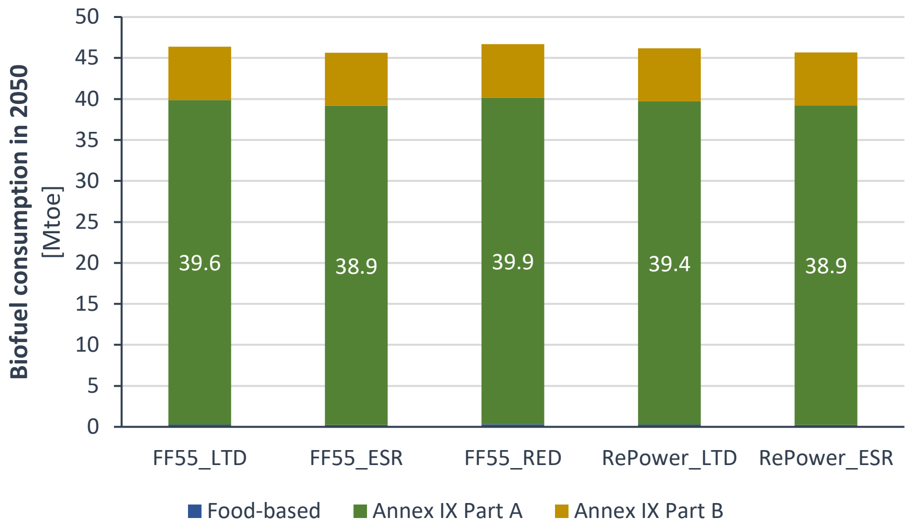
[16] It should be highlighted that in the implementation of RED as part of the Fit For 55 policy proposal package, the RES-T target was replaced by the GHG intensity target. In the scenario implementation, it was discussed that both targets should be met, and are implemented as such. This effectively affects the level and the ratio of different biofuel types in meeting the targets, as electricity uptake is largely driven by CO2 standards in road transport and RFNBOs by sub-mandates (though several assumed as non-binding in the present study). For example, the contribution of advanced biofuels in road transport contributes more than conventional biofuels in the RES-T share, whilst their impact in the GHG intensity target is less pronounced owing to the fact that their well-to-tank emissions are more comparable.

and comparable at the ESR variants (i.e. about 11-12 Mtoe, similar quantities also in the RED variant, see section 4.2.3). In 2050, conventional biofuels are phased out and are replaced by advanced biofuels and biofuels from waste oils and fats that are more environmentally sustainable than food-based biofuels (Figure 13).



Source: PRIMES-TREMOVE transport model

Figure 12: Biofuel consumption in transport in 2030, split based on RED classification



Source: PRIMES-TREMOVE transport model

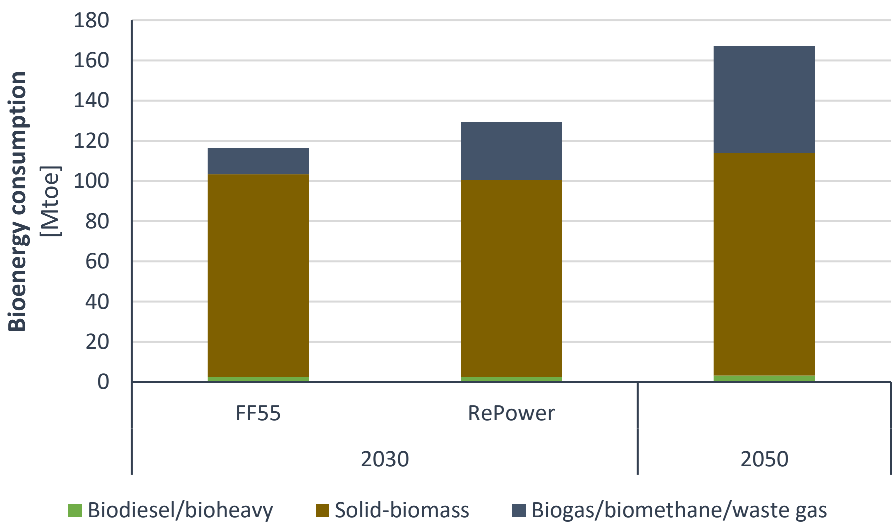
Figure 13: Biofuel consumption in road transport in 2050, split based on the RED classification

Bioenergy demand in non-transport sectors

The PRIMES-TREMOVE model is part of the overall PRIMES modelling suite, and underlying the analysis for this study, are considerations of the consumption of bioenergy products beyond the transportation sector. Figure 14 shows bioenergy demand consumption by non-transport sectors (i.e. households, industry, power and heat, and tertiary sectors).

Bioenergy for non-transport sectors is mainly linked to large- and small-scale solid biomass consumption (e.g. in the form of wood pellets) as well as bioenergy in gaseous form either from waste streams (e.g. manure, sewage sludge, animal waste) or from dedicated crops (e.g. energy maize in some countries, but also lignocellulosic crops and agricultural or forestry residues in the future). The consumption of bioenergy from stationary uses remains relatively constant in the scenarios quantified within this project, once for the Fit For 55 and once for the RePowerEU context. In 2030, the two contexts differ with respect to biomethane demand, due to the implementation of the 35 bcm target in the RePowerEU Communication. In terms of final bioenergy consumption, it is seen that transport consumes from 15% to 25% of total bioenergy demand of the energy system, depending on the context and variant.

Demand for stationary bioenergy use is expected to increase in the long-term to allow the system to comply with the net-zero target, as the use of biomass with carbon capture and storage (BECCS) is a key mitigation option which allows for negative emissions in the system to compensate for remaining emissions, among others from the transport sector. (e.g. from the aviation and maritime segments).



Note: In 2050 results in the two contexts converge. Source: PRIMES and PRIMES Biomass Supply models

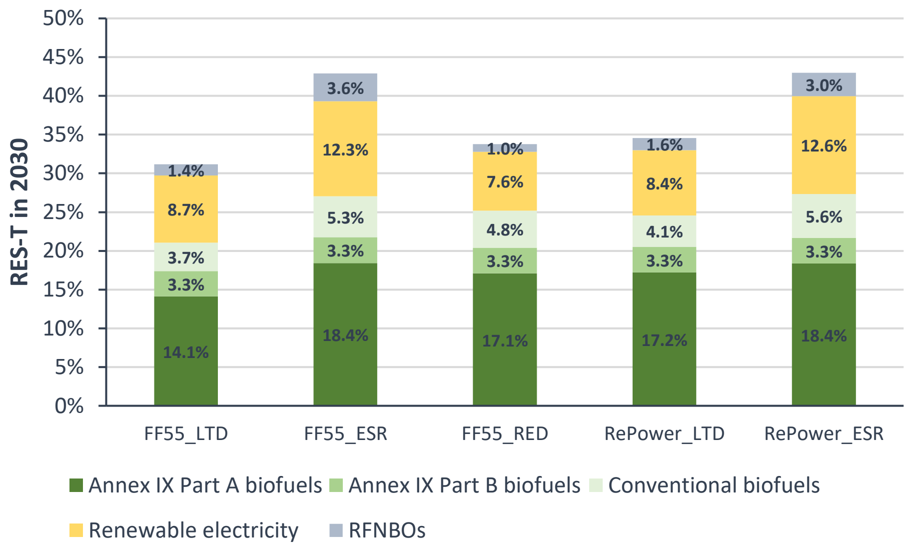
Figure 14: Bioenergy consumption in non-transport sectors by type of fuel

4.2.3. Contribution to transport policy targets

This section analyzes the contribution of the different fuels used to various transport policy indicators and targets in 2030, namely the RES-T indicator[17], the GHG intensity target in transport, and sub-obligations on advanced fuels (advanced biofuels, RFNBOs, etc.).

4.2.3.1. RES-T

Figure 15 shows the contribution of different renewable fuels in the calculation of the RES-T indicator. The calculation follows the RED II methodology, in that the contribution of Annex IX biofuels is double counted, the contribution of Annex IX Part B and of conventional (food- and feed-based) biofuels is capped (by 7% and 1.7%, respectively) and the contribution of electricity use in road and rail transport is multiplied by a factor 4 and 1.5 respectively. In addition, the contribution of advanced fuels (i.e. advanced biofuels and RFNBOs) in aviation and maritime is multiplied by a factor of 1.2. The formula is presented in Annex II of the present report.



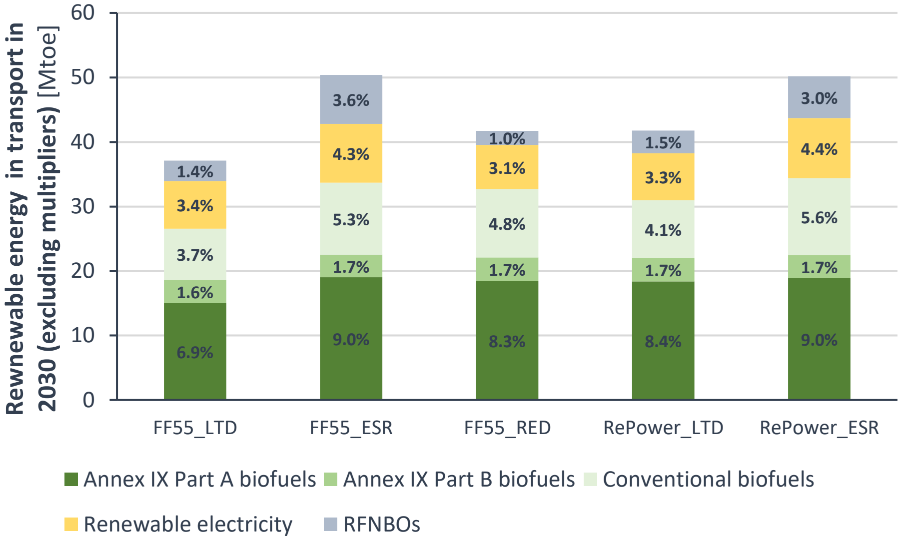
Note: Including multipliers and caps, as per RED II. Source: PRIMES-TREMOVE transport model

Figure 15: RES-T by fuel type in 2030

It is shown the contribution of advanced biofuels to the RES-T indicator in the Fit For 55 context is higher than that of electricity, despite the weight of the latter counting more towards the RES-T target (i.e. multiplier of 4 for electricity vs a factor of two for advanced biofuels). The increase in contribution of advanced biofuels comes to the detriment also of the contribution of RNFBOs, again owing to assumptions on limited technology deployment and assuming that RFNBO sub-mandates are non-binding. Looking into the share of renewable fuels used in transport (excluding multipliers; Figure 16), it is seen that under limited technology deployment conditions (LTD variants) or, in addition, when there is a higher ambition for emission reduction in transport (ESR variants), advanced biofuels are

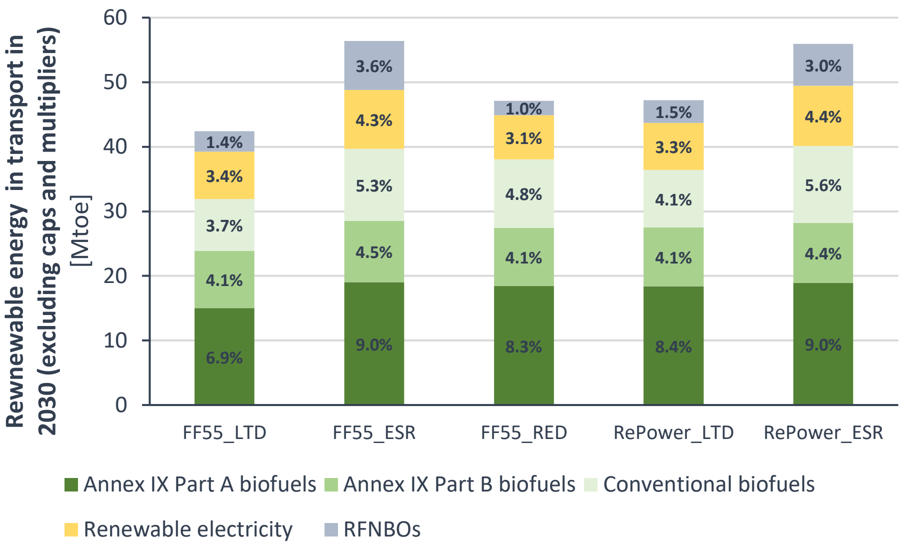
[17] Here, RES-T is referred to as an indicator as opposed to target as the EC proposal for revision of RED II under the Fit For 55 policy proposal package had replaced the RED II RES-T target with a GHG intensity target in transport. The term RES-T target is reinstated in the provisional agreement on the RED recast.

by far the highest contributor in energy terms, followed by conventional biofuels and electricity. The quantity of Annex IX Part B biofuels exceeds the one that contributes to the RES-T target (that according to RED only the level under the 1.7% cap counts towards the target) (excluding caps and multipliers; Figure 17).



Note: Including caps, as per RED II. Source: PRIMES-TREMOVE transport model

Figure 16: Renewable fuels in participating in the Renewable share in transport (excluding multipliers)



Note: Excluding caps and multipliers. Source: PRIMES-TREMOVE transport model

Figure 17: Renewable energy in transport in 2030 (excluding caps and multipliers)

4.2.3.2. GHG intensity target

The GHG intensity reduction of the fuel mix used in transport in 2030 is calculated against a fossil fuel comparator of 94.1 gCO_{2eq}/MJ. The formula is presented in Annex II of the present report. The Well-to-Tank emission factors of biofuels used in the modelling are presented in Table 5. These are estimated bottom-up based on the PRIMES-Biomass Supply model. Depending on the demand for biofuels across the different scenarios a small variation on their WTT emission factors is expected. It should be noted that for bioethanol the WTT factors used in the modelling are somewhat higher than what experts claim in Task 3 (e.g. for bioethanol 77% savings as per Task 3 compared to 65% as per Table 5).

In the modelling, the WTT emission factors of RFNBOs are zero, as they are produced by green hydrogen from renewable electricity. If RFNBOs are produced by grid electricity then they would be characterized by a WTT emission factor as well (somewhat higher for e-fuels compared to hydrogen owing to the synthesis step).

The WTT emission factor of electricity in 2030 ranges from 26 to 29 gCO_{2eq}/MJ, as the decarbonization of the electricity supply system progresses rapidly to meet the EU Green Deal goals. The emission factor of electricity supply is based on the PRIMES energy system model under the same scenario context of the present study (i.e. "Fit For 55" and "RePower" EU). Should the emission factor of electricity be higher than model projections (e.g. owing to lower penetration of RES), additional biofuel quantities would be needed for the transport sector to meet the GHG intensity target.

In the modelling, biofuels, RFNBOs and electricity have zero Tank-to-Well (TTW) CO_2 emissions factor (slippage emissions are taken into account in international maritime).

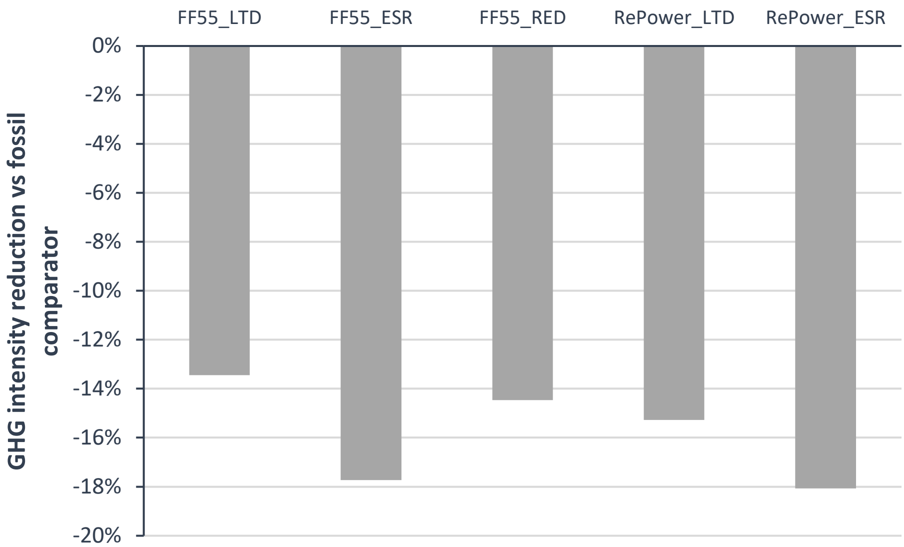
Fuel	gCO_{2eq}/MJ
Conventional biofuels	
Bioethanol	33.3
Biodiesel	28.2
Annex IX Part A biofuels	
Biogasoline	7.7
Advanced biodiesel	18.7
Biokerosene	23.4
Bioheavy	13.2
Biomethane	5.3
Annex IX Part B biofuels	
HVO	16.6
HEFA	15.4
Bioheavy	7.7

Note: Derived by detailed estimates using the PRIMES Biomass Supply model

Table 5: Well-to-Tank emission factors of biofuels in 2030

The resulting GHG intensity reduction is shown in Figure 18. The ESR variants lead to an overshot of the GHG intensity target owing to the higher GHG emission reduction from transport (assuming equal contribution to ESR reduction target), that is achieved primarily by a cleaner fuel mix in the transport sector. To note that under the EC proposal of the Fit For 55 policy package of July 14, 2021, the GHG intensity target for transport in 2030 was 13% (met by the FF55_LTD scenario and exceeded by the FF55_ESR scenario). Under the provisional agreement of RED the conditional target was increased to 14.5% (met under the FF55_RED scenario). Similarly, the Repower variants implement a higher target of 14.5% in 2030, that is met or exceeded under all scenarios.

The lower demand for electricity and for RFNBOs leads to a higher uptake of biofuels overall. Under the stated uncertainties concerning WTT emission factors, the energy mix driven by the GHG intensity target may differ slightly; additional quantities of biofuels may be required so as to meet the target, replacing fossil fuels. Lower emission factors (e.g. of bioethanol) would improve their CO2 cost abatement performance and would therefore increase to some extent their penetration in the fuel mix. Lower WTT emission factors of conventional biofuels would also imply a higher reduction of emissions in road transport emissions.



Source: PRIMES-TREMOVE transport model

Figure 18: GHG intensity target in the scenarios

4.2.3.3. Sub-mandates on advanced biofuels and RFNBOs in 2030

In the proposal for the revision of RED submitted as part of the Fit For 55 policy proposal package of July 2021, sub-targets on advanced biofuels and on RFNBOs were set for 2030 (2.2% and 2.6%, respectively; including a multiplier of 1.2 in advanced fuels such as advanced biofuels and RFNBOs used in aviation and maritime, including green hydrogen use in refineries). With command and control measures the minimum target on RFNBOs increases notably in the RepowerEU Communication, to 5.6%.

	Fit For 55 context			RePowerEU context		
	FF55	**FF55_LTD**	**FF55_ESR**	**Repower**	**Repower_LTD**	**Repower_ESR**
Advanced biofuels	**2.2%**	5%	6.4%	**2.2%**	6.1%	6.4%
RFNBOs[(a)]	**2.6%**	1.6%	3.0%	**5.6%**	3.2%	4.1%

[(a)] Including green H2 use in refineries. In the LTD and the ESR variants, the sub-mandate on RFNBOs is considered as non-binding.

Table 6: Performance on sub-targets on advanced biofuels and RFNBOs in the developed scenarios

Table 6 shows the performance of the LTD and ESR variants developed in this project with respect to sub-targets, while meeting the RES-T and the GHG intensity target in their respective context. It is seen that in both variants, (LTD and ESR), the advanced biofuels share is notably higher than in FF55 and in RepowerEU, to the detriment of the RFNBOs sub-target. The latter is also the key driver for the uptake of hydrogen and e-fuels in the Fit For 55 and the RepowerEU context.

Comparison with the RED provisional agreement of 30 March 2023

In March 30, 2023 a provisional agreement was reached between the Parliament and the Council, on raising the share of renewable energy in the EU's overall energy consumption, as well as on setting more ambitious sector-specific sub-targets in transport compared to the EC proposal as part of the Fit For 55 policy proposal package. The updated transport targets provide the option to the Member States to achieve:

- at least 29% renewable energy share in transport (RES-T) in 2030;
- or 14.5% GHG intensity reduction of the fuel mix used in transport in 2030.

At the same time, the provisional agreement sets a combined minimum sub-target on clean advanced fuels used in transportation (i.e. advanced biofuels and RFNBOs) of 5.5%, in which RFNBOs should account for at least 1% of total energy use in transport in 2030. The contribution of advanced fuels to the 5.5% is double counted.

The compliance on the RED provisional agreement via the RES-T target is met through the FF55_LTD scenario. Across the scenarios developed in the present study, the energy demand in transport is about 300 Mtoe in 2030 (range of approx. 302 – 310 Mtoe). This implies that at least 1.5 Mtoe of RFNBOs and at least 6.8 Mtoe of advanced biofuels will be supplied so as to comply with the sub-targets. These targets set a minimum, and higher contribution may be needed to comply with the RES-T or the GHG intensity target. It should be noted that about one-third of RFNBOs are supplied in aviation and maritime stimulated by the ReFuelEU Aviation and FuelEU Maritime initiatives, respectively. The scenarios prepared in the present study project quantities of about 3 Mtoe of RFNBOs (e.g. FF55_LTD scenario), that is higher by about 1.5 Mtoe compared to the minimum quantities implied by the provisional agreement and are mainly directed to road transport. This is within a reasonable range considering the developments on fuel cell vehicles in road transport and that the scenario already considers delayed technology development.

Assuming, however, that the minimum target on RFNBOs will be achieved, would imply that the remaining quantities (about 1.5 Mtoe) will be shifted to advanced biofuels (as benefited by a multiplier of 2 when counting towards RES-T), conventional biofuels (in countries that consumption is below the cap) or to electricity (as is benefited by a multiplier of 4 if used in road transport when counting towards RES-T).

The compliance with the RED provisional agreement via the GHG intensity target is assessed through an additional scenario under the Fit For 55 context (i.e. FF55_RED scenario). The scenario is built on FF55_LTD, including additional assumptions as follows:

- additional barriers on the uptake of EVs, owing to lower rate of infrastructure (charging points) deployment
- additional barriers on long-distance trips with EVs, owing to slower improvement rate of battery range
- potential contribution of advanced biofuels to meeting CO2 standards in 2030 (i.e. contribution up to 2 gCO2/km or less than 4% of the target; n.b. ICE ban is fully implemented from 2035 onwards)
- the utilization of production capacity for conventional biofuels is at least 45%

Table 7 presents an overview of key scenario results. The detailed results of the FF55_RED variant are presented in Figure 7 through Figure 18.

The increase of the GHG intensity target from 13% to 14.5% in 2030 based on the RED provisional agreement, under the additional assumptions stated above, is met by an increase of biofuels of all types to the detriment of fossil fuels, electric vehicles and RFNBOs. Overall biofuels consumption exceeds 38 Mtoe in 2030. Conventional biofuels demand reaches about 11 Mtoe in 2030 (i.e. higher by about 2.6 Mtoe compared to FF55_LTD). The projections for this scenario demonstrate higher demand also for advanced biofuels in 2030, compared to FF55_LTD, i.e. 18.4 Mtoe, which is higher by 3.4 Mtoe compared to FF55_LTD. Annex IX Part B biofuels reach 9 Mtoe (i.e. about 0.1 Mtoe higher than FF55_LTD). Biofuels increase due to (a) liquid fossil fuels reduction (i.e. 2 Mtoe less in FF55_RED compared to FF55_LTD), and (b) reduction of the electrification rate of the car fleet to 9% (i.e. EVs share in the passenger car fleet), compared to 11% in FF55_LTD. In FF55_RED electric vehicles in 2030 reach 22 million, which is the minimum projected across all scenarios (see also Figure 8 in section 4.2.3). While in FF55_RED there is contraction of the EV fleet (and partly also of the FCEV fleet) compared to FF55_LTD owing to the assumed barriers and due to the contribution of advanced biofuels to the CO2 standards (up to 4%), still one out of five vehicles sold is electric under FF55_RED compared to one out of four vehicles under FF55_LTD.

Key indicators in 2030	FF55_LTD	FF55_RED
GHG intensity of the fuel mix vs 94,1 gCO2eq/MJ, in %	-13%	-14,5%
RES-T, in %	31%	34%
Electric vehicles, in million passenger cars	27	22
Electric vehicles share in passenger car fleet, in %	11%	9%
Electric vehicles share in passenger new sales, in %	24%	19%
Fossil fuels in transport, in Mtoe	264,6	262,6
Electricity consumption in transport, in Mtoe	10,7	9,8

Key indicators in 2030	FF55_LTD	FF55_RED
RFNBOs consumption in transport, in Mtoe	3,1	2,2
Biofuels consumption in transport, in Mtoe	31,9	38,1
of which conventional	8,0	10,6
of which advanced	15,0	18,4
of which Annex IX Part B (excl. cap)	8,9	9,0

Table 7: Key indicators in 2030 in three scenarios developed under the "Fit For 55" context

Moreover, it should be mentioned there could be additional demand for biofuels beyond what the scenario results show, in the place of RFNBOs, as the FF55_RED scenario overshoots by a small margin the RFNBO sub-target (i.e. reaching 0.7%-0.8% instead of 0.5% excluding multipliers in 2030). The difference of 0.2%-0.3%, could entail about 0.6-0.9 Mtoe additional quantity of conventional (in road transport[18]) and/or advanced biofuels to the detriment of e-fuels, while at the same time meeting the GHG intensity target. Considering also the additional uptake of biokerosene that can be stimulated based on the higher SAF target in provisional agreement on ReFuelEU aviation (about 0.4 Mtoe additional; see section 3.2.1), the overall biofuels quantities could be higher by up to 1.3 Mtoe than what shown above.

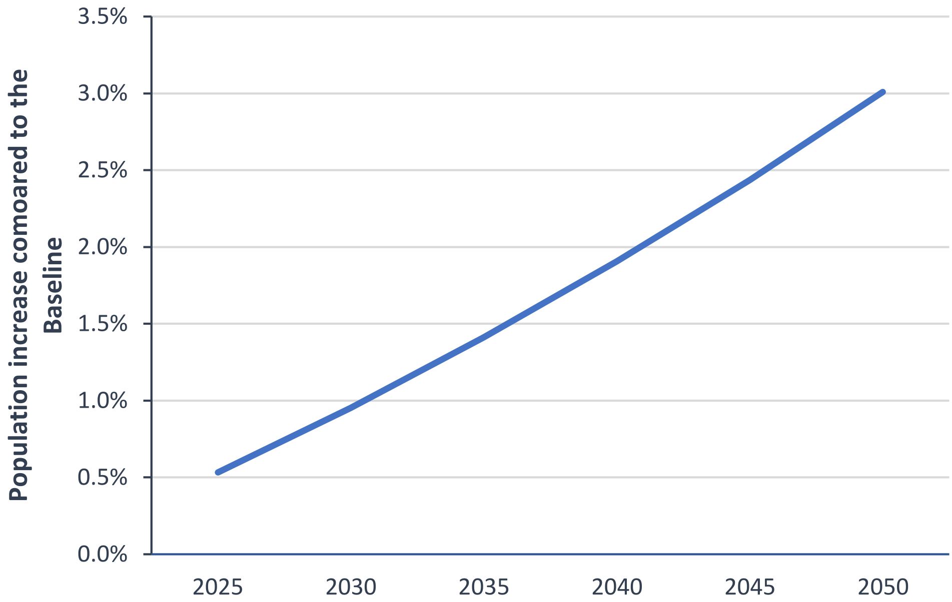
Other constraints or strategies to limit the dependency on vehicles or battery imports from non-EU countries, should EU production capacity not follow the pace of demand, could also lead to lower uptake of EVs in road transport and thus to a higher uptake of conventional biofuels so as to meet the GHG emission reduction target goals of the EU Green Deal. However, such considerations are outside of the modelling scope and scenario definitions.

4.2.4. Sensitivity analysis: Relative increased transport activity variants

This task has further explored variants with increased activity levels, mainly for the road transport sector. The Relative increased transport activity (RITA) variants are applied on the LTD and the ESR cases as described above, i.e. by varying activity levels of transport modes as the main driver for additional uptake. The key drivers are higher population growth, owing to migration, persistence to private modes of transport instead of public or active transport modes, owing to a risk averse behavior due to the COVID 19 pandemic, and digitalization trends that promote home deliveries, working from home, etc. The drivers for activity increase are described in detail in section 2.1.3. Increased road transport activity levels lead to increased energy demand in road transport owing to increased mobility (and aviation), and thus higher uptake of liquid fuels including both oil products and biofuels. As such, the Relative increased transport activity levels explore cases with higher biofuel uptake, owing to activity drivers. These variants affect the consumption level and to a lesser extent the consumption pattern, as no structural changes for additional contribution of biofuels are assumed. As such, the ESR variants in the increased road transport activity case deliver lower emission reduction than 40% (about 34%), as structural changes in the energy mix would also be required.

[18] According to the initiatives covering aviation and maritime (ReFuelEU Aviation and FuelEU Maritime), these sectors can use only non-food based/conventional biofuels in meeting their obligations. As such, road transport is the only sector that could drive additional demand for conventional biofuels in 2030.

Based on Eurostat projections, in 2030, population growth in the Relative increased transport activity variants is assumed to be higher by 1% compared to the other scenarios. However, increase in activity is not affected on a one-to-one basis, as it depends on the elasticity, feedback and tradeoffs induced by other scenario drivers. For instance, increase on activity owing to online shopping increases the demand for urban deliveries but reduces the demand for private trips to purchase goods.



Source: **EUROPOP2019 - Population projections**

Figure 19: Increase in population growth in the increased road transport activity cases compared to Baseline population projections

Besides population growth, the assumptions on the Relative increased transport activity case variants consider on the one hand a shift of about 50% of the commuting demand to shift from public to private transport owing to risk aversion for the Covid pandemic and at the same time a reduction of the overall commuting demand due to digitalization and remote working of about 15%. New vehicle owners, that would otherwise commute, use private road transport as means for non-commuting travel (e.g. leisure), pushing the increase of private road passenger transport demand even further, while moderating the increase of public passenger transport (e.g. by coaches, rail or short distance flights). Besides new road transport demand, also occupancy factors of vehicles have been assumed to reduce, on average, by 0.1% to 0.5% compared to the Basic scenarios, so as to capture a reduced impact of shared mobility (e.g. car-pooling) due to the fear of pandemic or other drivers such as failure to comply with travel schedules. The increase in population growth also leads to higher freight activity, that is further enhanced by on-line shopping (i.e. noted by the increase of freight transport by vans and smaller trucks), higher consumption due to increase in disposable from reduced commuting due to digitalization trends, limited shifts from freight transport by rail and inland waterways, assuming that efforts on improving land transport logistics take place. The implemented drivers lead to the activity increase shown in Figure 20, which is about 10% in private road transport and about 3% in aviation.

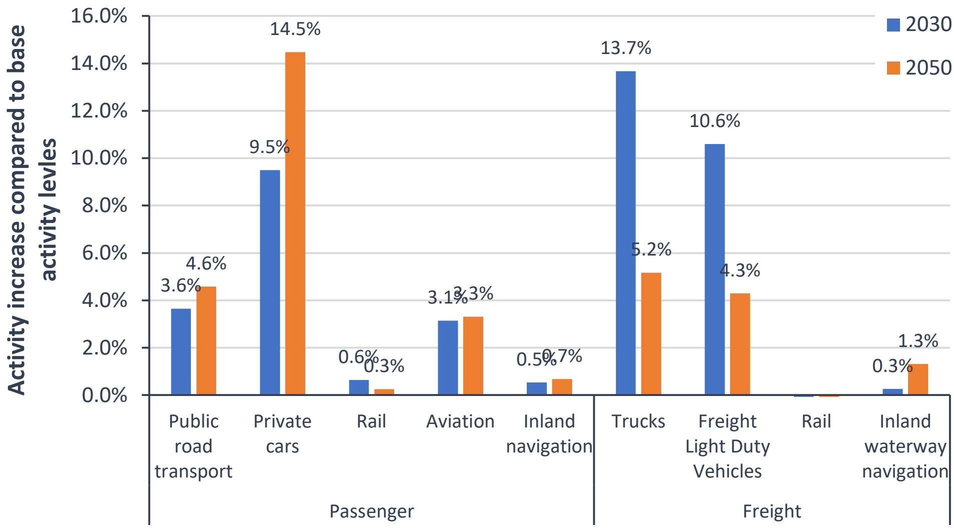
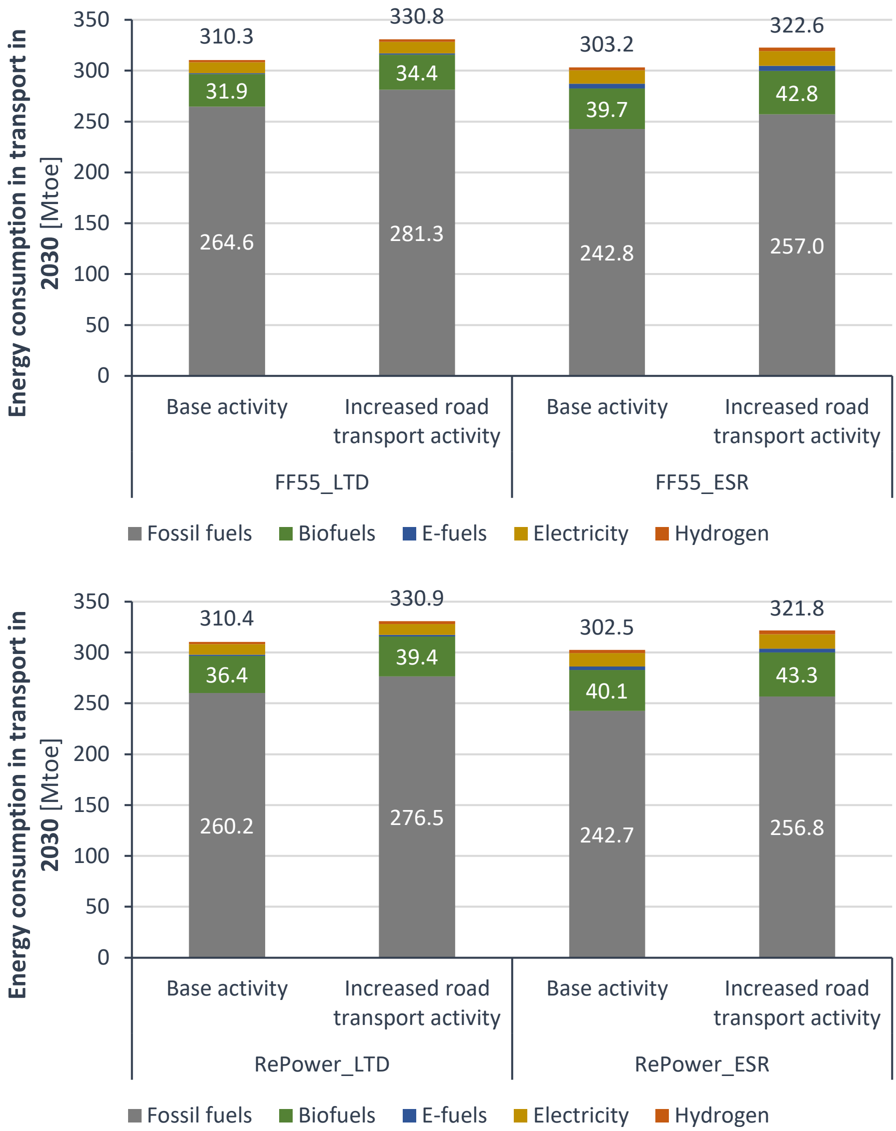


Figure 20: Activity increase in the Relative increased transport activity case variants compared to Basic scenarios

It is observed that as expected activity increase is higher in private road transport and to road freight transport compared to e.g. public road or rail transport modes. Such activity increase leads to a higher energy demand in road transport by almost 10%. The assumptions on activity growth lead to an increase in energy consumption in transport by about 20 Mtoe in 2030 and about 10 Mtoe in 2050 the FF55 variants (Figure 21). This is about 6-7% higher energy demand than in the Base variant[19]. The increase in energy consumption trickles down also to biofuels leading to about 2.5-3.1 Mtoe in 2030 and to slightly less than 1 Mtoe in 2050 of additional biofuel consumption compared to the LTD and ESR variants. No additional drivers for additional uptake of biofuels are assumed in the Relative increased transport activity cases other than their participation in the blending mix of fossil fuels. As such, no differentiation in the relative fuel shares is expected. Nonetheless, the impact on the level of advanced biofuels consumption is prominent, i.e. higher consumption by about 1.2-1.6 Mtoe in 2030, compared to the LTD and the ESR variants respectively. The volume of Annex IX Part B biofuels also increases by about 0.6 Mtoe. In the Relative increased transport activity cases electricity increases by 0.6 to 1.1 Mtoe and RFNBOs (including hydrogen) by about 0.6 to 1 Mtoe compared to the LTD and ESR variants, respectively. Yet, in the high demand variants, liquid fossil fuel quantities also increase (by about 16 to 17 Mtoe in the LTD variants and about 14 Mtoe in the ESR variants). The additional liquid fossil fuel quantities in the Relative increased transport activity cases thus entail an additional opportunity for uptake of advanced biofuels that are the main drop-in alternative. The extent to which such uptake can be realized would depend on drivers that can lead to a change in the structure of the fuel mix (relevant for the LTD case and also the ESR case, as in the latter under Relative increased transport activity the 40% GHG emission reduction ESR target in transport in 2030 is not met and additional quantities of low-carbon and clean fuels would be needed). In 2050, while activity growth is notably higher than in 2030 (e.g. increase in private road transport is 14.5% in 2050 compared to 9.5% in 2030), energy consumption does not increase as much. The reason is

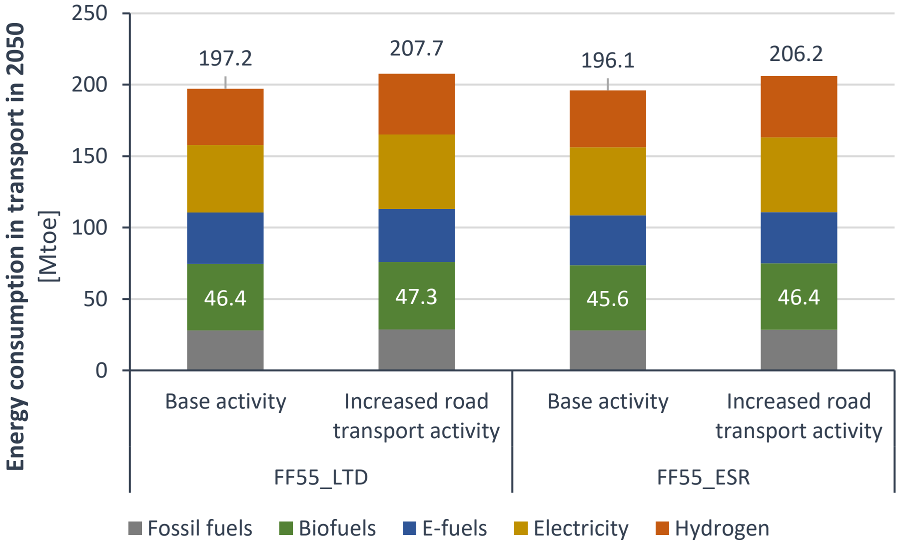
[19] This is a deviation from the Terms of Reference that stipulated a higher increase in energy demand was anticipated, e.g. by additional drivers for increase of aviation activity and international maritime.

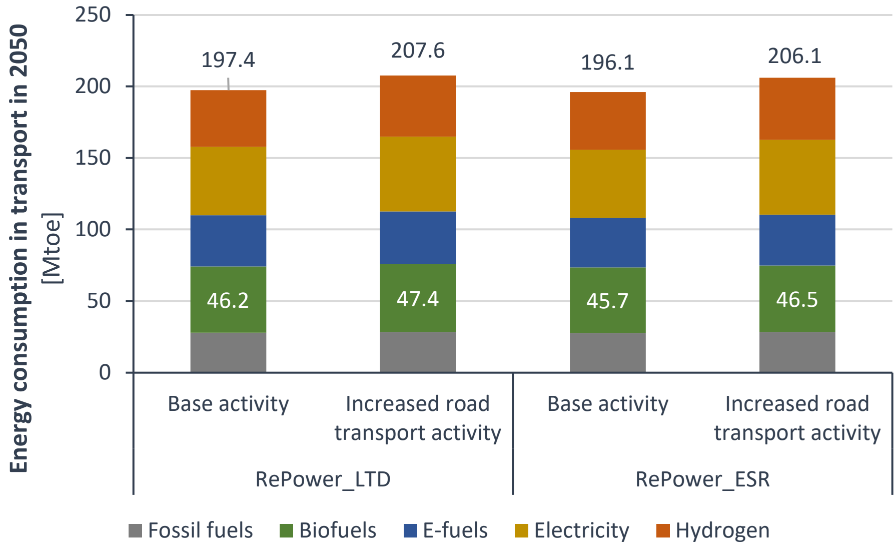
that by 2050, the increase in energy demand is met by a highly electrified fleet that yields significant efficiency benefits thereby limiting the increase of total energy consumption. More specifically, in 2050, the fleet is significantly more efficient than 2030, owing to higher penetration of electric vehicles due to phase out of ICEs, as post-2035 the ICE ban is implemented, in line with the EC proposal of the 14th of July 2021. This is the key driver for the proportionally lower increase in demand despite the higher population level. Similar findings are also observed for the RepowerEU Relative increased transport activity variants.



Source: PRIMES-TREMOVE transport model

Figure 21: Energy consumption in transport in the Relative increased transport activity (RITA) variant under the Fit For 55 (upper) and the RePowerEU (lower) context in 2030





Source: PRIMES-TREMOVE transport model

Figure 22: Energy consumption in transport in the Relative increased transport activity (RITA) variant under the Fit For 55 (upper) and the RePowerEU (lower) context in 2050

5. Summarising conclusions

Biofuels have a vital role to play in the emission reductions in the transport sector as part of the Fit for 55 package and climate neutrality goals.

Today biofuels play a role in fossil blends to reduce the emission footprint of fossil liquids in the transport sector; however, their role is expected to increase in the future as advanced biofuels become increasingly available, while ambitious emission reduction policies and sectoral targets will drive their increased future deployment.

In the long-term, biofuels will play an essential role in the reduction of emissions from the navigation and aviation sectors; in the time horizon to 2030 they play a crucial role also for the road transportation sector, where they represent a readily available solution which can work with the currently existing infrastructure and ICE vehicles. In the scenarios the emission reduction in transport is about 32% in 2030 while in the ESR variants the reduction in transport emissions reach 40% in 2030.

Should the electrification of private cars fall short of current expectations, biofuels will need to increase their uptake in achieving the emission reductions in the transport sector and quantities between 32 Mtoe and 40 Mtoe can be expected. Advanced biofuel quantities may reach from 15 Mtoe to 22 Mtoe in 2030, depending on the scenario. Such quantities are higher than those projected under scenarios that do not assume barriers on technology deployment. Biofuels from waste fats and oils (Annex IX Part B biofuels) are projected to range from 6.5 to 10.4 Mtoe in 2030, depending on the scenario.

More specifically, Annex IX biofuels (i.e. advanced biofuels and biofuels from waste fats and oils) demand in aviation ranges from 1.9 to 2.2 Mtoe in 2030, depending on the scenario (with an additional 0.4 Mtoe under the provisional agreement on ReFuelEU aviation, assuming non-binding mandates on RFNBOs) and about 16 Mtoe in 2050. In maritime Annex IX biofuels range from 1.7 to 1.9 Mtoe in 2030, depending on the scenario and about 22.3 Mtoe in 2050. Finally, in road and rail transport Annex IX biofuels range from 9 to 27 Mtoe in 2030 and about 7 Mtoe in 2050. Conventional biofuels on the other hand are consumed only in road and rail and range from 8 Mtoe to 12 Mtoe in 2030 and to 0.3 Mtoe in 2050.

The uptake of advanced biofuels could potentially be higher than the range projected by the scenarios, should certain model assumptions and projections not apply in 2030. In particular, should the emission factor of electricity be higher than model projections owing, for example, to lower penetration of electricity from renewable energy sources or should RFNBOs also carry a well-to-tank emission factor, owing to production from grid electricity (characterised by an emission factor), then additional quantities of advanced biofuels would be needed in the place of fossil fuels so as to meet the GHG intensity target. Moreover, higher quantities of conventional biofuels (e.g. bioethanol) could also find inroads based on evidence from other Tasks demonstrating lower emissions factors from their production compared to those calculated and used by the model. The Relative increased transport activity (RITA) scenarios, also reveal a potentially higher uptake for advanced biofuels than what indicated by the quantitative modelling, in the place of the increased demand for liquid fossil fuel quantities (by about 16 to 17 Mtoe in the LTD variants and about 14 Mtoe in the ESR variants).

Critical to the emission reduction is also the development of biokerosene to achieve the obligations under the ReFuelEU Aviation and further to allow aviation to significantly reduce sectoral emissions.

Over the projection period to 2050 the size of the biofuels market is expected to continue to grow, reaching approx. 45 Mtoe in the EU, by then all the quantities are expected to be almost exclusively advanced biofuels and biofuels from waste fats and oils.

The study reveals opportunities for further improvements and analysis. A key question with increasing significance is on regional differences of the energy transition, and how may different countries perform against the policy targets. The modelling factors Member State specificities in several ways: (a) each Member State is modelled separately, and the EU is a result of the aggregation of all EU Member States, (b) several policies and measures are included at the national level (as informed by NECPs, end-2019, as in the Reference scenario) with specificities as applicable (e.g. island countries), (c) is compatible and calibrated at a high sectoral level of detail as described in MS data and statistics, (d) supply characteristics of different countries is taken into account e.g. of biomass potential. While a country-based analysis was not within the scope of the present task, developing the study further in this direction could shed light on disparities and similarities across Member States and distributional impacts of the policies. Moreover, the demand-side analysis on the potential deployment of advanced biofuels, can be complemented with a closed-loop energy-economy analysis using a macro-economic model, so as to point towards technology-specific challenges and opportunities outside the energy system. This also may prove important for a country-by-country assessment (e.g. employment in different regions). The demand-side analysis can be further complemented by detailed bottom-up assessments of industry's voluntary commitments on uptake of specific fuels and other industry targets so as to assess the gap that the policies are called to close. This perspective was outside of the scope of the present study, yet ESR variants address the demand for biofuels by implying higher contribution from transport to GHG emissions reduction.

ANNEX I Calculation formulas

RES-T

The formula for the estimation of the RES-T target in transport is as follows (from Shares tool as in T&E report[20]):

Where E is energy consumed and the multipliers are dependent on the fuel type, Ft, and mode of transport, m. The multipliers are listed in the table below. The numerator sums the renewable energy consumed in all transport modes, where the denominator only includes the energy from road and rail. A maximum cap of 1.7% applies for Annex IX Part B biofuels and a 7% cap on conventional, food- and feed-based biofuels. Owing to multipliers, RES-T is higher than what the renewable energy share calculation without multipliers would yield.

$$RES - T = \frac{\sum_{m}^{all\ modes}(\sum_{F_t}^{renewable} E_{m,F_t} \cdot multi_{F_t,m})}{\sum_{m}^{road}(\sum_{F_t}^{all} E_{m,F_t}) + E_{rail} \cdot multi_{rail})}$$

[20] https://www.transportenvironment.org/wp-content/uploads/2021/07/202103_Advanced_renewable_fuels_EU_Transport_Final.pdf

RES-T formula element	Multiplier
Renewable electricity in road transport	4
Renewable electricity in rail transport	1.5
Renewable electricity in other transport modes	1
Compliant biofuels	1
of which Annex IX	2
Other renewable energies (e.g. RFNBOs)	1 (1.2 for aviation and shipping)[a]

[a]In the RED provisional agreement RFNBOs in transport are double-counted and those used in international maritime and aviation contribute by an additional factor of 1.5.

GHG intensity target

The formula for the estimation of GHG intensity in transport is as follows:

$$GHG\ intensity_t \left[\frac{gCO2eq}{MJ}\right] = \frac{\sum_i^{m\,fuel} M_i \cdot CO_{2eq\,WTT,i} \cdot LCV_i + \sum_m E \times CO_{2eq\,electricity}}{\sum_i^{m\,fuel} M_i \cdot LCV_i + \sum_m E} + \frac{\sum_i^{m\,fuel} \cdot M_i \cdot LCV_i \cdot CO_{2eq,TTW}}{\sum_i^{m\,fuel} M_i \cdot LCV_i + \sum_m E}$$

Where, M_i is the mass of the fuel i consumed in transport mode m , LCV_i is its lower calorific value in MJ/g, $CO_{2eq\,WTT,i}$ its WTT emissions and $CO_{2eq\,TTW,i}$ its TTW emissions in gCO2eq/MJ. E is the electricity consumption by transport mode m and $CO_{2eq\,electricity,k}$ the WTT GHG emission factor associated to electricity production.

The GHG intensity target in year t is then estimated as:

$$GHGint.target = \left(\frac{GHG\ intensity_t}{94.1} - 1\right) \cdot 100$$

In the modelling, RFNBOs (incl. hydrogen) are assumed to be produced by green electricity and therefore do not have an emission factor (i.e. that of the electricity grid 26-29 gCO2eq/MJ).

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The demand potential of alternatives to fossil fuels is quantified, with an emphasis on advanced biofuels, within the transport sector. In particular, the focus is to understand the additional role that liquid and gaseous advanced biofuels can have in the transport sector compared to what is projected according to an anticipated policy context and framework conditions. Advanced biofuel quantities may reach from 15 Mtoe to 22 Mtoe in 2030, depending on the scenario and about 45 Mtoe in 2050 together with biofuels from waste lipids.

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