Advanced renewable fuels in EU Transport

Evaluation of a realistic target for the upcoming RED review

March 2021

A study by TRANSPORT & ENVIRONMENT

Transport & Environment

Published: April 2021

Author: Thomas Earl
Modelling: Thomas Earl
Expert group: Laura Buffet, Carlos Calvo Ambel.

Editeur responsable: William Todts, Executive Director

To cite this report
Transport & Environment. (2021). Advanced renewable fuels in EU Transport. Evaluation of a realistic target for the upcoming RED review.

Further information

Thomas Earl
Director, Modelling and Data Analysis
Transport & Environment
thomas.earl@transportenvironment.org
Square de Meeûs, 18 – 2nd floor | B-1050 | Brussels | Belgium
www.transportenvironment.org | @transenv | fb: Transport & Environment

Acknowledgements

The authors would like to express their gratitude to Chelsea Balladino of the ICCT for critical feedback in the preparation of this report. This report was the culmination of inputs from T&E staff, including Andrew Murphy, Faïg Abasov, Julia Poliscanova, and Lucien Mathieu. The findings and views put forward in this publication are the sole responsibility of the authors listed above.

Addendum: This study was updated to correct van, heavy duty vehicle, and 2-wheeler results that were reported as EU27+UK, rather than EU27. The update also updates the van inputs, that are now implemented in a stepwise manner to better reflect the regulation.

Executive Summary

As part of a package of measures to increase climate ambition across the EU, the Renewable Energy Directive (RED) is expected to be reviewed in June 2021. The overall renewables ambition is expected to go up. But what can we expect specifically on the side of transport and what could be a realistic target for renewables in transport going forward?

Since its inception, the RED has been criticised for its lack of proper sustainability safeguards regarding bioenergy. Because of a high transport target and major sustainability gaps, it has primarily driven the use of unsustainable crop based biofuels, such as palm oil, soy and rapeseed. Advanced fuels such as advanced biofuels or renewable electricity only have a relatively small share of the overall transport energy.

Higher ambition in renewables for transport does **not** de facto mean higher quality and sustainability of the fuels, nor to reduce emissions, especially when increased ambition still keeps a major share of crop biofuels. The first renewable transport target was set at 10% in 2020 and increased to 14% (with inbuilt flexibility for member states to decrease it) in the revised RED framework for 2030. As part of its Climate Target Plan (CTP), the European Commission signalled its intention to increase the target for renewables in transport to 24% in 2030. In order to ensure the highest level of sustainability of the fuels framework, it is crucial to scrutinize the type of fuels and assumptions considered to meet such a target.

Based on our modelling of two scenarios, we recommend not to set a target of 24%. Such a high target would most likely perpetuate the use of unsustainable biofuels in transport, overshadowing other cleaner sources of energy that the bloc needs in transport. Based on a scenario with enhanced policies compared to today, we recommend setting it instead at around 16% for renewable advanced fuels (excluding crop biofuels and fossil-based fuels such as blue hydrogen). Going beyond would require a substantial increase in ambition compared to the changes expected to be made by the Commision in the Clean Target Plan. This would include a substantial increase in sales of zero emissions vehicles (ZEV) across all road transport modes, especially in the upcoming review of the CO_2 standards for cars. This includes a significant enhancement to remove flexibilities that severely weaken the targets. It would also require an ambitious uptake of renewable hydrogen and synthetic fuels in shipping and aviation. Because of major uncertainty on the upcoming road regulations and technology uptake for hydrogen, ammonia and e-kerosene, it is possible that such a high level of ambition is unlikely to happen. Without all of these measures for all modes, a higher target than 16% would rely on unsustainable fuels, including crop biofuels, to meet it. Both scenarios are analysed in detail in this study.

Setting a 2030 target level is a highly complex and uncertain exercise. This is especially true in the absence of certainty on the outcome of ongoing discussions on the uptake of zero emission vehicles in cars, vans and heavy duty vehicles, which are expected to make the majority of the target achievement in 2030. In that context, the timeframe and level of increased ambition for zero emission vehicles for each mode of transport will be crucial for the target determination. With this in mind, it is only at the level of individual member states that some flexibility could be applied and that the 16% target could be increased incrementally. Should countries be so inclined and have the right policies in place, they could overachieve on this target while keeping sustainability (and scalability) criteria as their foremost priority. This would mean focusing on renewable electricity being used directly in road transport, and green hydrogen/e-fuels in both aviation and shipping.

Combining the findings of RES-T and and greenhouse gas emissions savings reveals that rather than the RED and RES-T target being a driver for lower transport emissions, it is rather strong policies to increase the uptake or zero-emission vehicles that can help reduce emissions the most substantially. The RED should thus be designed in a new manner, ensuring that it accompanies the transition towards increased direct electrification and use of renewable hydrogen (in sectors where electrification is not feasible). A dedicated mechanism should be put in place to reward the use of renewable electricity in electric vehicles. Eventually, a high level of flexibility for member states will be needed, to be able to adapt their target level to their capacity to deploy sustainable volumes of advanced biofuels and their transition to zero emission vehicles.

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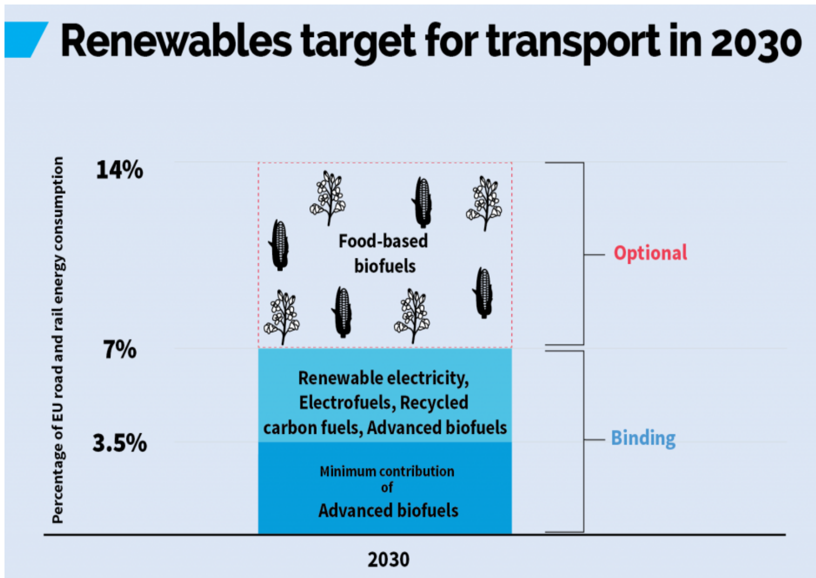
1. Introduction

As part of the EU Green Deal, the European Commission is expected to release a proposal for a review of the Renewable Energy Directive (RED) in June 2021. The current RED sets a target for renewables in transport at 14%, with the only binding part being a 7% target for advanced fuels. Compared to the RED applicable for 2020, there is no longer a binding target for food & feed based biofuels.



As part of its Climate Target Plan released in September 2020, the Commission indicated that the share of renewable energy in transport "*has to increase to around 24% through further development and deployment of electric vehicles, advanced biofuels and other renewable and low carbon fuels as part of a holistic and integrated approach*". This proposal raises a concern on whether there is sufficient availability of sustainable advanced fuels to reach such a high level of renewable energy in 2030.

1.1. A brief history of the RED

Adopted in 2009, the first Renewable Energy Directive (RED I) promoted the use of biofuels and other alternative fuels by setting a national target for the use of renewable energy in the transport sector – 10% of the energy consumed in transport must come from renewable sources by 2020. On the other hand, the Fuel Quality Directive (FQD) set a carbon intensity reduction target of 6% on each fuel supplier in 2020. This drove a rapid uptake of biofuels, mainly from food crops like rapeseed and palm oil with negative environmental and climate impacts. In an attempt to tackle the deforestation impacts linked to crop biofuels (Indirect Land Use Change), EU legislators limited at maximum 7% the amount of food-based biofuels that can be counted to achieve the 10% target. The text also set an indicative 0.5% target for advanced biofuels.

In 2016, the European Commission published a proposal for a recast of the Renewable Energy Directive (RED II) for the period 2021 to 2030, including a proposal for a lower limit on crop biofuels at 3.8%. This proposal has been amended by the European Parliament and the Council, leading to the adoption of a final text in June 2018. The final deal removes the EU driver for crop-based biofuels and focuses the EU support on advanced fuels, such as advanced biofuels and renewable electricity. Member states need to limit “food & feed based biofuels'' at their level in 2020 (with 1% flexibility). The support to palm oil, identified as a high emitting biofuels, will also end in 2030, although exemptions remain. Finally, advanced biofuels receive specific support with a target of 3.5% and there is a soft limit on used cooking oil (UCO) and animal fats at 1.7%.

We are in 2021 and it is unclear whether and how member states have fully met or not their 2020 obligations. What is clear is that crop biofuels are the dominant alternative fuel used to meet the renewable target and that advanced biofuels haven’t really increased significantly (see Section 2.1).

1.2. Scope of this study

This study assesses the feasibility of the proposed Clean Target Plan (CTP) targets for renewable energy in fuels in 2030, focusing specifically on the suggested 24% for renewable energy in transport. The goal is to assess whether this target is realistically feasible, taking into account the expected availability of different sustainable advanced fuels in 2030. To carry out this work, we employed the suite of our transport models along with projections from the CTP itself. For road transport, we used our inhouse model, the EUTRM[1]. For passenger cars however, we use a stock model version of the EUTRM, which has temporal resolution at one year increments from the year 2000 to 2050. For aviation we make use of our in-house developed techno-econometric model (described further in our aviation decarbonisation report[2]) with updated forecasts from IATA. For shipping, we developed a shipping stock model based[3] on the fleet of vessels as per the 2018 MRV[4] scope and projections from the Fourth IMO Greenhouse Gas Study[5]; Therefore shipping has a larger geographical scope than EU27. More information on the models can be found in the Appendix. We do not consider costs in this study.

2. Renewable Energy in Transport - state of play and scenarios

This section gives an overview of the current state of play, the results of the Clean Target Plan that pertain to transport and the scenarios we used to arrive at our results. Importantly for this section is the formal definition of the renewable energy share in transport (RES-T) in the RED, which is defined as:

$$RES\text{-}T = \frac{\sum_{m}^{all\ modes}\left(\sum_{Ft}^{renewable} E_{m,Ft} \cdot multipliers_{Ft,m}\right)}{\sum_{m}^{road}\left(\sum_{Ft}^{all} E_{m,Ft}\right) + E_{rail} \cdot multiplier_{rail}}$$

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 Table A5 in the Appendix. The numerator sums the renewable energy consumed in all transport modes, where the denominator only includes the energy from road and rail[1]. In the existing REDII (for the period 2020 to 2030), the multipliers have changed from the first period: renewable electricity used in road transport now has a multiplier of 4 and its use in rail transport has a multiplier of 1.5.

In parallel to the review of the RED, dedicated legislative initiatives for the uptake of alternative fuels in the aviation and shipping sectors are currently being drafted by the European Commission. ReFuel Aviation and FuelEU Maritime are likely to have separate, regulatory tools, but still strongly associated with the RED framework. As a result, the renewable advanced fuels that will be supplied on the EU market and driven in these two sectors will then be counted towards the overall RES-T target (and subject to a multiplier of 1.2 if the current RED provisions remain). It's important to specify that the RED regulates fuels *supplied* within the EU market. Provided that the scope is not changed in the upcoming review, alternative advanced fuels supplied to aviation and shipping outside of the EU would not count towards the RES-T target.

2.1. Current trends about renewable energy in transport

Transport is heavily dependent on liquid fossil fuels for its energy. The commercial aviation sector flies on kerosene, the shipping industry sails on heavy fuel oil or marine diesel oil, and road transport runs largely on diesel and petrol, with some limited ingress of other fossil fuels such as liquified or compressed natural gas or liquified petroleum gas. Only rail is predominately electrified, but its total energy use in the EU is in the order of 2% of road transport [6].

The aim of the RED is to mandate and incentivise renewable energy to replace fossil fuels transport (i.e. to increase the RES-T). According to the Short Assessment of Renewable Energy Sources (SHARES) database, the EU27 reached a RES-T of 8.9%, equivalent to about 6.6% of energy in 2019. Biofuels are the key source of renewables; compliant (but not necessarily sustainable) biofuels account for 90% of the renewable energy content and 82% of the RES-T, whereas renewables in rail (electricity) contributes 8.5% renewable energy, or 15.5% to the RES-T. Renewable electricity in road transport contributes only 0.5% energy content, or 1.7% to the RES-T (all after applying multipliers).

[1] Note that the multiplier for rail only is applied in the denominator.

Electricity used in road transport is 2.5 to 3 times more efficient at delivering transport work than burning fuels in a combustion engine[2]. The multiplier of 4 given to renewable electricity is thus explained by the objective of the RED to incentive a higher RES-T; in a similar way, advanced biofuels have a multiplier of 2 despite having the same efficiency of delivering transport work as conventional biofuels. The combination of both electricity production becoming greener and the increase in electric vehicle sales (and thus, electric vehicles in the car fleet) has resulted in an increase in renewable electricity in road transport of 674% from 2011 to 2019. Despite this large increase, the total contribution to the RES-T is modest; Figure 1 shows that the RES-T from renewable electricity rose 0.5 percentage points from 2011 to 2019. Meanwhile, the contribution from conventional biofuels almost doubled, and those compliant biofuels that fall under Annex IX (so called advanced) saw a more than 6 fold increase; in 2019, there were 167 PJ of Annex IX biofuels consumed in the EU27. However this increase is partially explained by the increased reliance on used cooking oil (UCO), with a tripling of its use for EU biodiesel production between 2011 and 2019[8, 9]. There have been serious concerns about the sustainable potential of UCO and whether UCO imports are used or virgin oil[8].

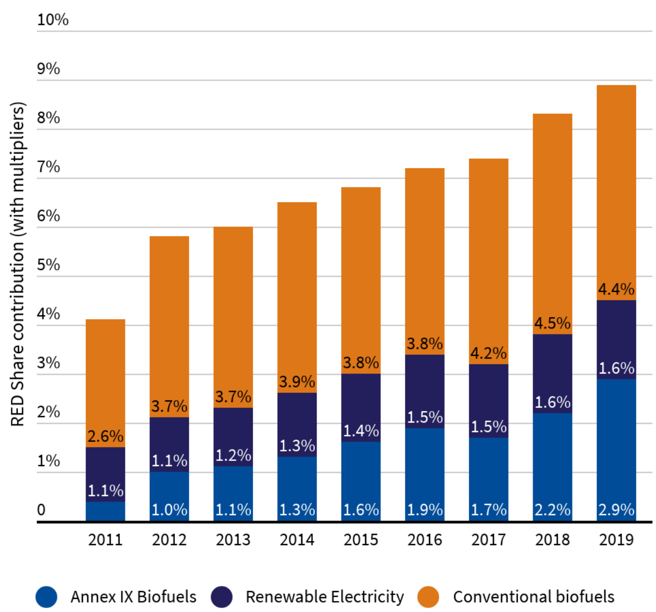


Figure 1: Renewable energy shares in transport under the renewable energy directive (SHARES)

[2] From a tank-to-wheel perspective. See [7]

2.2 What the Climate Target Plan projects

The Climate Target Plan[10] presented different scenarios. Of most interest to us is the **REG** policies for its 'high ambition increase' on transport measures and the **ALLBNK** (for all bunkers) scenario, which includes international shipping and aviation emissions with transport measures specifically aiming to address these modes, albeit less ambitious regulation on transport[3]. The change in transport policies affects the car and truck CO_2 standards from 2025; that is, the current 2025 targets remain (15% reduction compared to 2021), and the Commission is only considering revising the 2030 targets. The *high ambition increase* is said to correspond to a 60% reduction target for cars in 2030; the ambition for other modes is not defined. These measures are coupled with deployment of recharging and refuelling infrastructure and also include different levels of fiscal stimulus, for example favourable taxation for low/zero emission vehicles and petrol-diesel fuel tax harmonisation. The REG scenario relies on member state action through increased EU and national action.

The results of the REG and ALLBNK[4] scenarios for transport, in terms of emissions, fleet activity, and the shares of power train technologies in the fleet of vehicles most closely matches those of the European Commission's Clean Planet for All[11] 1.5LIFE and 1.5TECH scenarios. As these scenarios are the only scenarios able to limit the Bloc's emissions to be somehow consistent with the objectives of the Paris Agreement, any other scenario is deemed suboptimal or incompatible with rapid decarbonisation in a sustainable, cost effective, and social justice way. Further, other scenarios rely on less ambitious regulatory measures but put the onus on price signals in order to change technology; we have argued[12] that this is not a key driver for technological change in road transport, and thus we do not consider the other scenarios of the CTP.

Despite the different scopes and levels of ambition of the REG and ALLBNK scenarios, the results in terms of RES-T are remarkably similar (Figure 2). Both scenarios attain a RES-T greater than 24%. The projections include around 5% of conventional biofuels, those biofuels that rely on food & feed crops and compete with food production and in many cases associated with deforestation. Worryingly, the ALLBNK scenario has a slightly higher share of conventional biofuels, meaning a greater volume of these fuels will be supplied. The Commission de facto assumes that the share of these biofuels won't reduce substantially compared to today. It is not clear what assumptions were made regarding high deforestation risk biofuels like palm oil, which should be phased out by 2030 at the latest (with exceptions), according to EU law.

[3] See Table 3 p46 of [10]: REG has TRA_4 policy levels, whereas ALLBNK has TRA_3, but aviation and maritime policies.
[4] Meaning "all bunkers", to account for the inclusion of international shipping and extra-EU aviation

In 2030, the CTP projections show that renewable electricity generation overall will almost double from 2019 levels to 70% in 2030. The resulting RES-T from renewable electricity is projected to be 11% in 2030. The CPT projects a 9% share for Annex IX biofuels and biogas, or 4.5% of energy. The availability of sustainable advanced biofuels will always remain limited, due to the limited amount of sustainable feedstocks available and the competing uses for these[13]. Biogas is not a scalable solution for transport decarbonisation, owing to the limited sustainable feedstocks and the very high price required to extract the Bloc's biogas potential[14].

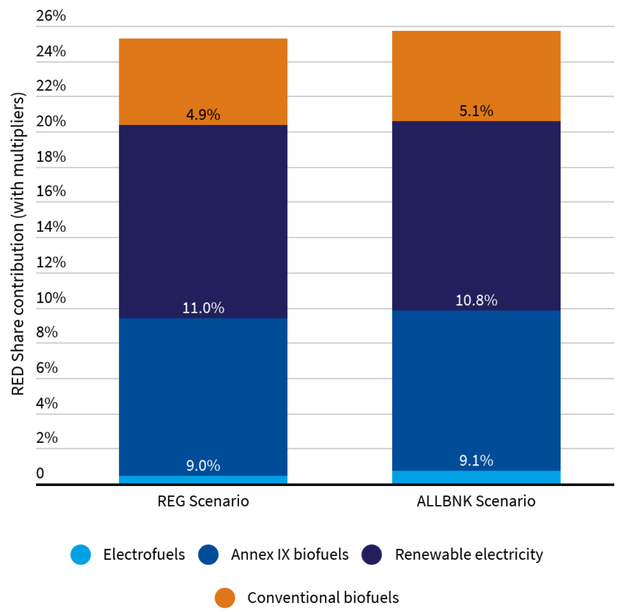


Figure 2: Clean Target Plan results for the shares of renewable energy in fuels, by fuel type, in 2030

2.3. T&E scenarios

We have developed two scenarios with the aim of assessing the RED targets and the CTP projections and to show an optimal way for transport decarbonisation and the subsequent required targets in the RED. The scenarios that focus on vehicles are described in Table 1 and full details are provided in the Appendix. In short, we assess the **enhanced current policies (ECP)** versus what we define as **Road2Zero**. The ECP aligns as closely as possible with the REG and ALLBNK scenarios of the CTP, although the final CO_2 targets for vans and trucks is not explicitly defined; at the same time, we assume that the regulations themselves remain unchanged, and only the targets are increased. Road2Zero on the other hand is a policy and technology trajectory that will rapidly increase electrification in road transport leading to the phase out combustion engines in light duty vehicles and 2-wheelers by 2035, most trucks by the same time, and ensure a sustainable but ambitious trajectory for aviation and shipping, all to achieve zero GHG emissions by mid-century.

In our modelling, we mainly focus on the standards and fuel mandates elements. Demand reduction in passenger transport activity does not vary significantly in the CTP for all scenarios (a maximum of 1.2% compared to the baseline for the REG scenario); aviation international extra-EU passenger demand reduces 1.1% in the ALLBNK scenario. For road freight, there is an additional growth in rail transport and a more significant, but modest reduction of 3.1% compared to the baseline scenario in 2030. Therefore, we apply some modal shift and demand reduction to road freight activity to be more aligned with the CTP scenarios, and no surface transport activity reduction in our scenarios. As per the CTP projections, we assume that renewable electricity generation overall will reach 70% of the total in 2030. An important difference between the shipping scenarios is the use of regulated operational efficiency measures to reduce emissions and energy use in the sector. The European Commission is currently considering a fuel standard for European shipping, but not operational efficiency measures such as slow steaming and technical efficiency measures such as hull and propeller optimisation. In our upcoming shipping decarbonisation roadmap, we find that adding the efficiency measures to shipping cuts the CO_2 abatement cost by a factor of 3 while simultaneously delivering 3 times greater CO_2 reductions compared to a business as usual scenario.

Table 1: Description of scenarios for each transport mode. *UNFCCC scope, i.e. derived from fuel sales.

Mode (EU27 2019 emissions)*	**Enhanced Current Policies (ECP) scenario**	**Road2Zero scenario**
Passenger cars (476 Mt CO_2)	Current CO_2 standards, with stepwise improvement at 2025 and 2030, until 50% improvement. 2030 target reached with a combination of fuel efficiency improvements and EV sales.	More ambition in 2025 (25% reduction), intermediate target in 2027 (40% reduction), and a 65% target in 2030. 2030 target reached with a combination of fuel efficiency improvements and EV sales.
Trucks (178 Mt CO_2)	Annual fuel efficiency improvements from 2020 to 2030, with low sales (< 5%) of zero emission vehicles. Limited demand reduction based on Eurovignette directive implementation.	Annual fuel efficiency improvements from 2020 to 2030, with high sales (~ 30%) of zero emission vehicles based on OEM announcements and TCO considerations. Demand reduction as per ECP.
Shipping (154 Mt CO_2)	Shore side electrification reduces emissions at port by 40%, 85 PJ uptake, or 4.8% fuel blend, of	Significant operational and technological efficiency measures employed (e.g. slow steaming,

	operational energy from green ammonia.	hull/propeller optimisation); shore side electrification reduces emissions at port by 100%, 85 PJ, or 7% fuel blend, of operational energy from green ammonia.
Aviation (148 Mt CO_2)	1% e-fuels uptake (20 PJ), 2.8% advanced biofuels (55 PJ, or 1.3 Mtoe) in 2030. Fuel blends applied after demand reduction results due to the uptake of more expensive fuels and a CO2 price equivalent of €70/t CO_2.	2% e-fuels uptake (40 PJ), 2.8% advanced biofuels (55 PJ, or 1.3 Mtoe) in 2030. Fuel blends applied after demand reduction results due to the uptake of more expensive fuels and a CO2 price equivalent of €70/t CO_2.
Vans (94 Mt CO_2)	Fuel efficiency improvements at 2% p.a. Low electrification in order to meet current CO_2 standards, at 23% in 2030.	Fuel efficiency improvements at 2% p.a. High electrification, at 53% in 2030.
Buses (31 Mt CO_2)	No fuel efficiency improvements. Urban buses reach 30% zero emission powertrain share, coaches 5%, in 2030	No fuel efficiency improvements. Urban buses reach 100% zero emission powertrain share, coaches 25%, in 2030
2-wheelers (10 Mt CO_2)	No fuel efficiency improvement with medium penetration of battery electric powertrains (40%).	No fuel efficiency improvement with high penetration of battery electric powertrains (50%).
Rail (4 Mt CO_2)	Rail final energy use and electrification rate is linearly extrapolated levels in both scenarios. With increased renewable electricity, rail's RES-T (without multipliers) reaches 61% in 2030.	

To assess the fuel supply and final share, **we assume that there are no conventional crop biofuels in 2030.** For advanced biofuels, we have previously calculated that there is a maximum amount available in the EU27 plus the UK amounting to 7.5 Mtoe[15] in 2030. By mid century, our Decarbonisation Roadmaps[16] show that this total amount will be eventually consumed only in aviation (as road transport is fully electrified); therefore to allocate advanced biofuels to the Bloc, we subtract the UK's aviation demand share so that in 2030, 5.8 Mtoe (245 PJ) will be available in the EU27. An s-curve uptake is assumed for aviation (assuming a slower uptake rate based on fuel quality requirements for jet fuel) while the remainder is supplied and consumed by road transport. Our definition of sustainable advanced biofuels is not as wide as the current Annex IX of the RED. It excludes feedstocks that do not fall within the strict definition of a waste or a residue and focuses on the most voluminous wastes and residues[15].

While renewable electricity is a feasible way to increase renewables in road transport, aviation and shipping are not able to switch to direct electrification en masse. Owing to the technical limitations of batteries, these transport modes will require renewable liquid fuels to reduce dependence on fossil fuels. For aviation, the most deployable, scalable fuel would be e-kerosene, made from direct air capture (DAC) and green hydrogen. As a drop-in fuel, this solution will be able to reduce CO_2 emissions to all aircraft in the current fleet, a big advantage of developing and deploying new technologies, such as hydrogen aircraft. While hydrogen aircraft could be a significant technology change, they will likely come to market after 2030. An upcoming study addresses what these quantities entail in terms of number of refineries and renewable electricity generation[17]. Its findings suggest that a 2% blend would be highly ambitious and would not be likely to happen without a highly coordinated global push. In shipping, more electrofuel options are possible, ranging from liquified green hydrogen either driving a combustion engine or used with fuel cells to power electric motors, to synthetic hydrocarbons deployed as drop-in fuels. Ultimately, the alternative fuel that is the optimum combination of cost, space, and deployability will prevail. Ammonia produced from green hydrogen appears to fit the bill, having higher density than liquid hydrogen, easier storage, and a proven supply chain given its use as a key ingredient in fertilisers. Additionally, it is cheaper than synthetic hydrocarbons as it does away with the need to capture CO_2[18].

2.3. Results

Here we present the findings of the renewable energy content and share of fuel in transport, the RES-T as defined by the RED, and the resulting CO_2 emissions in transport. Figure 3 shows the results of the renewable energy content in the fuels, both as RES-T and in terms of total energy. As described above, conventional crop biofuels are assumed to be phased out. **We find that the ECP scenario could deliver 15.9% to the RED**, or around 690 PJ of renewable energy to the transport sector. This implies that a target higher than this would drive and perpetuate unsustainable conventional biofuels in the sector. If we consider the 5% amount for crop biofuels that is projected from the CTP, this would imply a RES-T of 20.9%, still well below 24%.

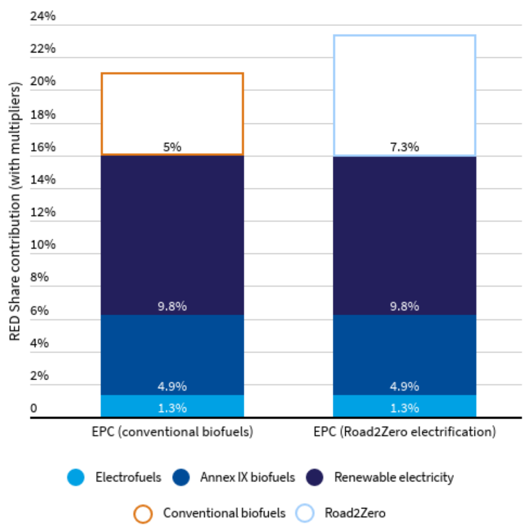
Our analysis shows that under the Road2Zero scenario, the RES-T would also not achieve a 24% target. Recall that in the Road2Zero scenario, where we assume (and advocate for) ambitious CO_2 standards driving high electrification in all road transport modes (coupled with reformed policy to ensure a progressive sales ramp up, rather than stepwise increase in electrification as per the ECP scenario[5]), and where there is an ambitious share of renewable hydrogen and synthetic fuels in aviation and

[5] See Appendix for more detail.

shipping. Should all of those ambitious objectives be passed into law, we project that the RES-T would be 23.2%. If the proposed RES-T target does not deviate from 24%, the only way for member states to have a chance to meet that target *sustainably* would be to ensure electrification rates in road transport are at least those in the Road2Zero scenario, along with the uptake of e-fuels in aviation and shipping, and that renewable electricity generation is even higher than the 67% as assumed in the CTP.

The ECP scenario achieves a similar level of RES-T contribution from direct use of renewable electricity as the CTP REG and ALLBNK scenarios, at 9.8%. On the other hand, the Road2Zero scenario's RES-T from renewable electricity is more than 70% higher, at 516 PJ in 2030 (143 TWh). We project that in the ECP scenario transport could consume 690 PJ of renewable energy, the Road2Zero scenario would consume 886 PJ.

Figure 4 shows that all modes contribute to this increase. While the share of advanced biofuels remains mainly constant (it varies slightly between scenarios based on the allocation by total energy in 2030, which varies depending on the number of electric vehicles in the fleet), renewable electricity in passenger cars increases by 67 PJ, vans by 23 PJ and maritime (mainly through increased shore side electrification, SSE), 35 PJ. In terms of renewable synthetic fuels, the aviation sector is projected to be supplied with 10 PJ to 20 PJ in the ECP and Road2Zero scenarios respectively.



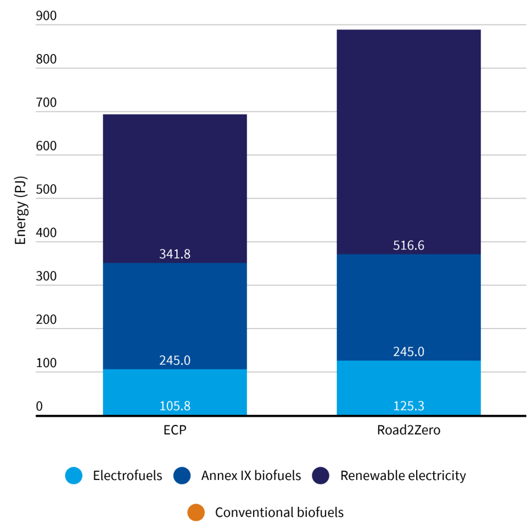


Figure 3: (Left) ECP scenario, showing a higher target would push conventional biofuels, or what the Road2Zero could deliver with strong CO2 standards; (right) energy content of RED fuels, in 2030.

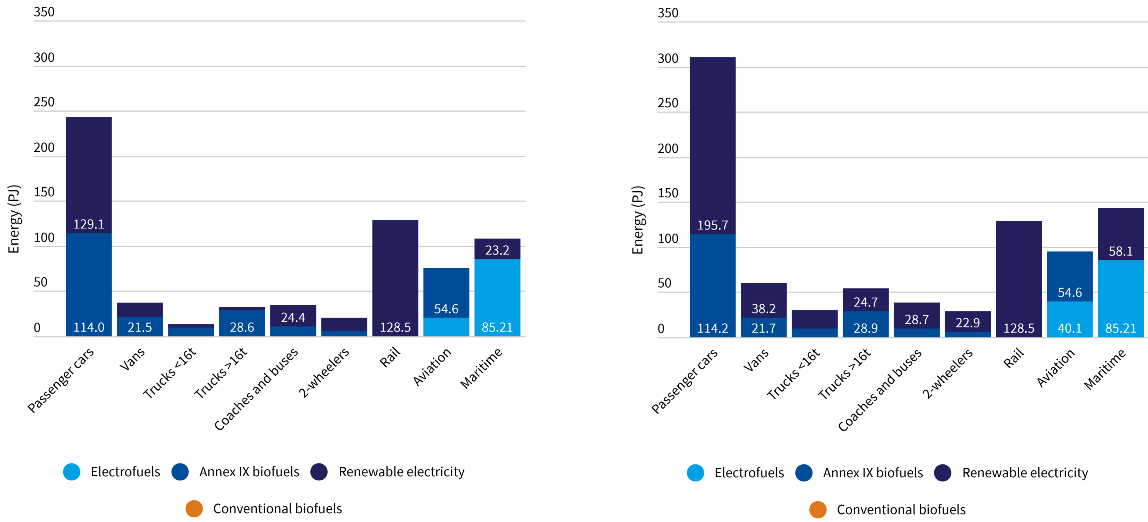


Figure 4: Comparison of the ECP scenario (left) with the Road2Zero scenario(right) by transport mode, in terms of energy content, in 2030.

The contribution of each mode of transport to the overall target (Figure 5) is relevant for the target determination. Road transport makes up the bulk of the RES-T, with 11.4 percentage points (or 71.6%) in the ECP. In road transport, passenger cars are the largest source of RES-T, contributing 7.4% in the ECP. Figure 5 also shows the additional amount of RES-T that could be achieved for different modes if the Road2Zero policies were adopted. For example, if van CO_2 standards were ratcheted up in order to drive the electrification of the Road2Zero scenario, it would mean that a sustainable RES-T could be 1 percentage point higher; in the case of passenger cars, 3 percentage points higher, and for heavy duty vehicles, 1.9 percentage points higher.

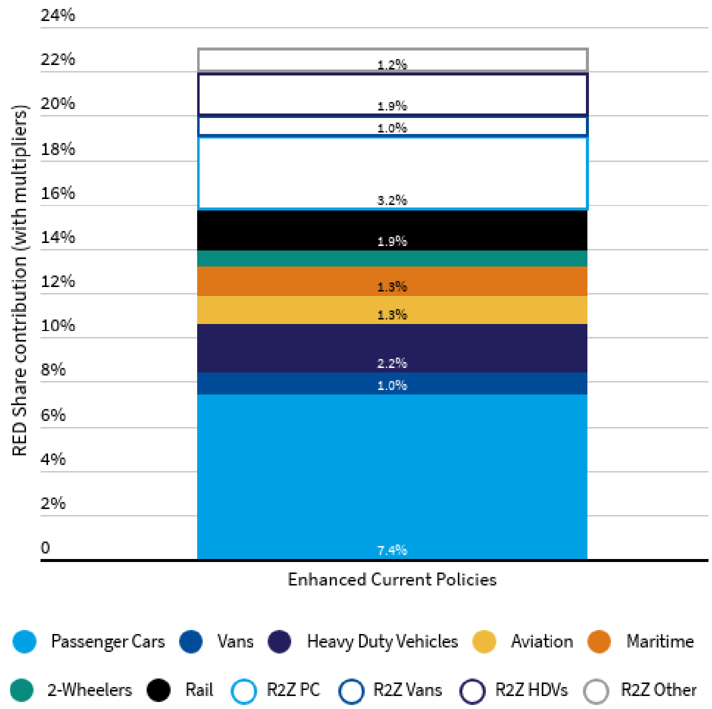


Figure 5: Contribution of transport modes to the target, in 2030. R2Z refers to the Road 2 Zero scenario, and how that ambitious uptake of electric vehicles could change the target. Note: PC is passenger cars, HDVs is heavy duty vehicles, Other refers to remaining modes of transport.

In terms of CO_2 equivalent, the tank-to-wheel results between scenarios in 2030 are presented in Figure 6, and compared to 1990 and 2019 emissions. The emissions in 1990 are relevant as they are the baseline for the EU's climate ambition, to which a 55% reduction target is defined (dashed line). The 55% target is economy wide (i.e. to be achieved by all sectors combined, not necessarily by each sector). In 2030, both scenarios are higher than 1990 levels in total emissions; only rail and shipping are lower (or equivalent). Importantly, the Road2Zero scenario significantly increases the greenhouse gas emissions reductions to 216 Mt CO_2e, compared to savings of 132 Mt CO_2e from the ECP. Transport is the only sector to have increased its emissions from 1990; despite the ambitious policies of the Road2Zero scenario, the 55% target would not be met for transport, implying other sectors (such as power generation) would have to cut their emissions beyond what their 55% target would be.

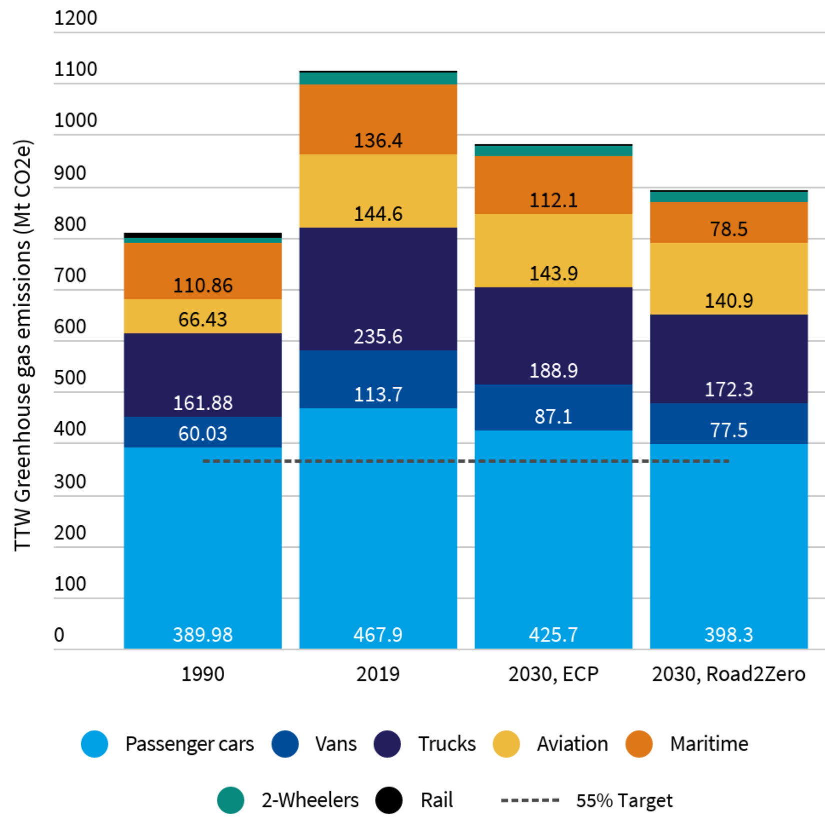


Figure 6: Comparison of the ECP scenario (left) with the Road2Zero scenario(right) by transport mode, in terms of GHG emissions, in 2030.

3. Discussion

Projecting transport activity is fraught with uncertainty; predicting the ambition and enforcement of upcoming regulations adds to that. Our scenarios intend to cover a range from, at the low side, an improvement on the current vehicle standards and the implementation of the ReFuel Aviation and FuelEU Maritime regulations, to a highly ambitious scenario that goes well beyond this for all modes of transport. Considering Figure 3 and Figure 5, several important points should be considered when setting a RES-T:

1. Renewable electricity generation must reach the CTP projections to be at least in line with the REG scenario, reaching 67%. If renewable electricity generation were to only achieve the share

considered in the BSL scenario (56%) of the CTP, for example, the RES-T would be 14.4% and 20.5% for the ECP and Road2Zero scenarios, respectively.

2. As stated, we do not view conventional crop biofuels as sustainable. We have therefore considered that they make no contribution to the RES-T.
3. We argue that not all Annex IX fuels are sustainable, that the EU should not import these fuels or feedstocks, and thus the maximum sustainable, economically viable amount available in 2030 and beyond is 245 PJ (5.8 Mtoe).
4. Based on the sustainable available quantities available, we assume that aviation fuel suppliers will be able deploy 55 PJ of advanced biofuels (or 2.8% of energy) and that between 20 PJ to 40 PJ (1% and 2%) of aviation final energy use comes from e-kerosene from renewable electricity. Crucially, the shares of energy are highly dependent on the energy reduction efforts of the sector. An upcoming study addresses what these quantities entail in terms of number of refineries and renewable electricity generation[17]. Its findings suggest that a 2% blend would be highly ambitious and would not be likely to happen by 2030.
5. Our scenarios for shipping assume a high degree of shore side electrification and 7% e-ammonia uptake. In order to produce the 85 PJ of e-ammonia would entail the installation of 7.5 GW electrolysers.
6. The total regulation of the maritime sector has many possible degrees of freedom in terms of geographical scope (full MRV or a subset) and whether or not the regulations will also cover energy efficiency. In our Road2Zero scenario, we assume significant energy efficiency measures in shipping, which significantly reduce final energy consumption.
7. Road transport requires 2030 targets to be moved forward to 2027 as intermediate targets, and stronger 2030 targets to be enforced. We assume that all truck makers would be regulated to electrify their fleets to a similar level to recent market leader announcements.

The first 5 points above specifically address the energy delivered to the transport sector. The first point is not driven by the RES-T target, as the main driver for renewable electricity uptake will come from a combination of the ETS price making coal power plants unviable[19] and the rapidly decreasing prices of wind and solar. It should be noted that aviation and shipping fuels (points 4 and 5) have specific rules in the making to ensure renewable fuels uptake. The last 2 points above focus on the vehicles and vessels themselves, and the regulation that improves their energy efficiency or their switch to electrification.

As stated above, road transport (point 7) is expected to make up 70% to 80% of the RES-T target, the majority of the RES-T from renewable electricity consumed thanks to the electrification of the fleet. We know that the CO_2 standards are what actually changes the new vehicle sales, as seen most remarkably in the passenger car segment[20] where electrification increased by a factor of 3.5 times in

2020 compared to 2019, when CO_2 regulation targets began to kick in. The average CO_2 emissions from new cars reduced by 11 gCO_2/km from this uptake in electric vehicle sales. Meanwhile, the RES-T target in 2019 was 8.9%, steady on its trajectory to the 10% target in 2020 (Figure 1).

The results show that with very ambitious vehicle CO_2 standards that drive a rapid uptake of electric vehicles and very optimistic assumptions on the uptake of electrofuels in shipping and aviation, a 23.2% RES-T could be achievable while avoiding the use of unsustainable, crop based biofuels. Conversely, anything short of the measures modelled in this paper implies that the only way to achieve a 24% target would be through crop based biofuels or other unsustainable fuels. Considering the caps placed on these fuels, the ECP would also fall short of 24% in a scenario where these fuels were exploited to the maximum extent possible under the law.

Given that the majority of the RES-T target relies on the stringency of CO_2 standards in new vehicles, it follows that the CO_2 standards, not the RED, are the main contributors to the RES-T in 2030. For this reason, setting a more ambitious RES-T target will not increase the uptake of sustainable renewable energy in transport, rather what cannot be achieved by the CO_2 standards will have to be made up with unsustainable crop biofuels, perpetuating an ecological problem stemming from the beginning of the RED with no climate benefit.

4. Conclusions and policy recommendations

We analysed two scenarios to determine the suitability of a 24% RES-T target as part of the European Commission's ongoing work to increase the Bloc's climate reduction strategy. We can derive the following conclusions from our work:

- **Our results show that the expected update on the CO_2 standards for road vehicles and the ReFuel Aviation and FuelEU Maritime regulations by the European Commission are compatible with a RES-T target of 15.9%, not 24%.** A target higher than that would either require substantial increase in ambition on ZEV obligations in the upcoming review of the CO_2 standards for cars (and trucks) or otherwise would rely on unsustainable biofuels to meet it.
- It is only with ambitious, direct electrification in road transport and a very strong ramp up of e-kerosene (2% in 2030) in aviation and e-ammonia in shipping (7% in 2030) that a 23.2% RES-T target could be achievable.
- Because of major uncertainty on road regulations and technology uptake for hydrogen, e-ammonia and e-kerosene, it is possible that such a high level of ambition is unlikely to happen.
- In the absence of ambitious changes in the road transport CO_2 standards regulations and clear calls to phase-out crop biofuels, these unsustainable biofuels as well as other unsustainable

fuels would be the main way to reach a higher target and they would likely find willing markets particularly in the aviation and shipping sectors.

- Combining the findings of RES-T and greenhouse gas emissions savings reveals that rather than the RED and the RES-T target being a driver for lower transport emissions, it is rather strong policies to increase the uptake or zero-emission vehicles that can help reduce emissions the most substantially and increase the uptake of renewable energy in transport.

On the basis of these results, we recommend policy-makers to follow the below recommendations. These will ensure that the transport provisions in the revised RED deliver the highest GHG savings while providing the highest level of protection for biodiversity and the environment:

- **The dedicated target for transport should not be set at 24% for all renewables in transport fuels. Based on the enhanced current policies, we recommend setting it at around 16% for renewable advanced fuels only.** It is crucial for the EU policy framework to focus on the quality of the fuels and not only on the share they represent. Should the European Commission want to increase this target, it should do so only when strongly increasing ambition for zero emission vehicles in the upcoming review of the CO_2 standards in parallel.
- **Only if a very high level of ambition is agreed, which is equivalent to or exceeds the input assumptions as detailed in our Road2Zero when reviewing vehicle CO_2 standards for road vehicles and proposing specific ambitious rules for aviation & shipping, could the RES-T in 2030 be increased incrementally from 16%, preferably at country level.** It is only at the level of individual member states that some flexibility could be applied to increase the target. Should countries be so inclined and have the right policies in place, they can overachieve on this target while keeping sustainability (and scalability) criteria as their foremost priority. This would mean focusing on renewable electricity being used directly in road transport, and green hydrogen/e-fuels in both aviation and shipping. Assuming very high ambition and timely implementation across all modes, the EU could reach a share of 23.2% renewable energy. In practice, this would require higher ambition in CO_2 standards for cars: 25% reduction in 2025, 40% reduction in 2027 and a 65% target in 2030. For trucks, this would mean annual fuel efficiency improvements from 2020 to 2030, with high sales of zero emission vehicles based on OEM announcements and TCO considerations. The equivalent CO_2 standards for trucks would reach 50% compared to a 2019/2020 baseline. Vans will also need much stronger electrification, with particularly stringent new CO_2 standards to drive this change. Finally, urban buses will need to reach 100% zero emission powertrain share in 2030 and 25% for coaches. For aviation, this would require 2,8% advanced biofuels and 2% efuels in 2030, while for shipping, it would require 7% e-ammonia.

- **A high level of flexibility for member states will be needed, to be able to adapt their target level.** The level of uncertainty on the availability of sustainable advanced biofuels is quite high and the uptake of electrification is unlikely to happen at the same pace in all EU countries. In case crop biofuels are not fully phased-out, it will be particularly crucial to keep the flexibility for member states to reduce the overall target if they lower their share of crop biofuels.
- **The RED should be designed in a new manner, ensuring that it accompanies the transition towards increased direct electrification and use of renewable hydrogen** (in sectors where electrification is not feasible) in transport. The RED shouldn't be seen as a mechanism to incentivize fuels that can be 'blended'. A dedicated mechanism should be put in place to reward the use of renewable electricity in electric vehicles (more information [21]).
- **The scope of the revised RED should exclude crop based biofuels and fossil based fuels** (e.g. recycled carbon fuels, blue hydrogen, etc.). It should also ensure stricter safeguards and a narrower list of acceptable advanced biofuels. Finally, the sustainability of electrofuels should be ensured, in part by ensuring additionality of renewable electricity (more information [21]).

5. Appendix key assumptions and inputs

This appendix provides more granular input assumptions for the modes of transport.

5.1. Passenger cars

The current post 2020 CO_2 standards are analysed in more detail in our annual car CO_2 study[20]. The stepwise change in the regulation, whereby the CO_2 reductions required in 2029 are the same as those for 2025, are a result of the law. As was seen in the lead up to the first compliance year in 2020, carmakers did not gradually reduce their emissions in order to reach the target, but there was a surge of EV sales and a resulting drop in compliance emissions from 2019. The Road2Zero scenario addresses this by having an intermediate target in 2027. The following tables show the assumed fuel efficiency improvement and EV sales (for both battery electric vehicles and plug-in hybrid vehicles, PHEVs). As described in Table 1, the combined fuel efficiency and EV sales result in an ECP 2030 target equivalent to 50% compared to 2021, whereas the Road2Zero scenario is equivalent to 65% reduction compared to 2021. These scenarios were implemented in the stock model version of the EUTRM, solving for the car fleet emissions at annual temporal resolution.

Fuel efficiency improvement

Scenarios	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ECP	0.0%	1.5%	3.0%	4.5%	6.0%	6.9%	7.9%	8.8%	9.8%	10.7%
Road2zero	0.0%	1.5%	3.0%	4.5%	6.0%	6.9%	7.9%	8.8%	9.8%	10.7%

Battery electric vehicle sales

Scenarios	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ECP	8.0%	8.0%	8.0%	11.5%	15.0%	15.0%	14.5%	14.5%	14.5%	33.3%
Road2zero	8.0%	8.0%	8.0%	14.7%	21.3%	21.3%	31.5%	31.5%	31.5%	46.1%

PHEV sales

Scenarios	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ECP	8.0%	8.0%	8.0%	9.0%	10.0%	10.0%	7.8%	7.8%	7.8%	14.3%
Road2zero	8.0%	8.0%	8.0%	11.1%	14.2%	14.2%	17.0%	17.0%	17.0%	19.7%

5.2. Road transport

The remaining road transport emissions were modelled in the EUTRM. Reductions in the remaining road transport modes are a result of combined improvement in fuel efficiency for internal combustion engine vehicles and an uptake of battery electric vehicles. Vans include a strengthening of the 2025 targets, justified by the weak 2020 targets that all van makers are projected to meet with very few zero emission sales in the Road2Zero scenario. Similarly to cars, improvements for vans are implemented in a stepwise manner. T&E has an upcoming study on van CO_2 emissions due for publication in May, 2021, where more details will be provided. For Trucks, these scenarios rely on decarbonisation roadmaps that were recently produced for France[22] and the UK[22, 23], and include demand reduction as detailed below.

Fuel efficiency

	2-Wheelers		Vans		Trucks <16t		Trucks>16t		Buses		Coaches	
	2025	2030	2025	2030	2025	2030	2025	2030	2025	2030	2025	2030
ECP	0.0%	0.0%	9.6%	18.3%	11.4%	22.5%	11.4%	22.5%	0.0%	0.0%	0.0%	0.0%
Road2zero	0.0%	0.0%	9.6%	18.3%	11.4%	29.0%	11.4%	29.0%	0.0%	0.0%	0.0%	0.0%

Zero emission vehicle sales

	2-Wheelers		Vans		Trucks <16t		Trucks>16t		Buses		Coaches	
	2025	**2030**	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**
ECP	15.0%	40.0%	3.0%	23.0%	0.0%	5.0%	0.0%	2.5%	30.0%	30.0%	0.0%	5.0%
Road2zero	15.0%	50.0%	11.0%	53.0%	2.5%	30.0%	1.5%	15.0%	100%	100%	5.0%	25.0%

Demand reduction for trucks - Applied to both ECP and Road2Zero scenarios.

Measure	Amount	By year
FREIGHT TRUCK LOGISTICS IMPROVEMENTS - ACTIVITY REDUCTION FROM BASE CASE (%)	5.0%	2025
FREIGHT TRUCK PAYLOAD (METRIC TONS/VEHICLE) - PERCENT INCREASE FROM BASE CASE	6.3%	2025
SHARE OF HHDV ACTIVITY SHIFTED TO RAIL (%)**	5.0%	2030

5.3. Aviation

The aviation projections are derived from an update of T&E's inhouse aviation techno-economic projection model, described in detail in our decarbonisation roadmap for aviation[6] (which will be updated in mid 2021). Key updates include the baseline being that the underlying passenger and fuel demand is no longer from the European Commission's 2016 Reference Scenario, but from IATA air travel demand projections[24]. Similarly to the 2018 study, we also assume an underlying efficiency improvement of fuel burn per passenger km of the aircraft fleet of 1.1% per annum.

5.4. Shipping

For this work, T&E built a shipping fleet turnover model, as shown schematically in Figure 5. The basis of the model draws on the shipping activity and operational performance as reported in the 2018 MRV as a baseline; therefore, the geographical scope for shipping is greater than the EU27, as the MRV also covers the UK, Norway, and Iceland. The Clarkson database for the ships' characteristics, such as size/capacity (for example DWT and GT) and age, was combined with the ships in the MRV so that 87%

[6] See Appendix of [2]

of ships, responsible for 96% of EU MRV emissions (i.e. ships greater than 5000 GT), were assigned characteristics. We were then able to class ships into size and type categories, and their average annual transport work calculated. Knowing the age of the ships enabled us to determine their expected retirement year, and it also enabled us to define the efficiency of new ships, which were taken to be equivalent to the average of the ships built in the last 5 years, for each class.

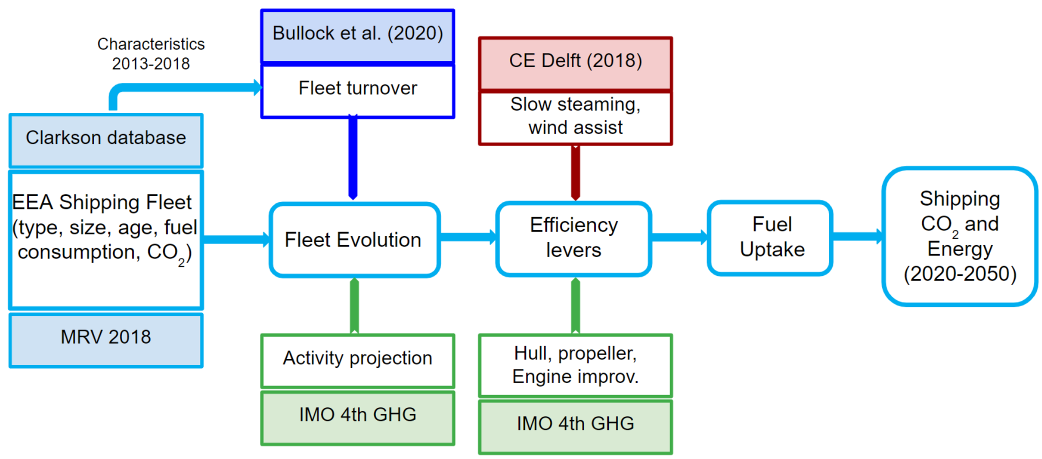


Figure 5: Schematic of the shipping energy and GHG model developed for this study

Projections for activity are taken from the IMO 4th GHG study (the SSP2_RCP2.6_G growth scenario, which is deemed to be compatible with the well-below 2°C target of the Paris Agreement). New ships enter the fleet to meet the combined increase in projected new transport demand as well as to cover the transport activity of retired ships. This enables us to keep track of both the number of ships in the fleet and of new ships by year of introduction. Technologies are then applied to either new vessels, retrofitted to the fleet of existing vessels, or a combination of both. We assume technology penetration increases linearly between the year of introduction of the technology, taken to be 2024 as the assumed date of entry of the relevant EU regulations (with the exception for e-ammonia, 2025) and the year when it has been fully adopted. More Information will be provided in the upcoming study, *Decarbonising European Shipping - Technological, operational, and legislative roadmap*, due for publication in April 2021.

6. Appendix - RED multipliers and RES-T 2011 to 2019 analysis

Table A5: SHARES database for renewable energy sources in transport

Transport	**Multiplier RED (2011-2019)**	**Multiplier REDII (2020-2030)**	**2011 (ktoe)**	**2019 (ktoe)**	**2011-2019**
Renewable electricity in road transport	5	4	10.7	82.6	674%
Renewable electricity in rail transport	2.5	1.5	1026.8	1511.5	47%
Renewable electricity in all other transport modes	1	1	208.9	251.5	20%
Compliant biofuels			7360.9	15938.0	117%
of which Annex IX	2	2	526.5	3989.0	658%
of which 3(4)d first paragraph	1	1	6773.9	11052.5	63%
of which 3(4)d third paragraph subsection (i) and (ii)	2	2	1.5	0.0	-100%
of which other compliant biofuels	1	1	58.9	896.5	1421%
Non-compliant biofuels	0	0	5325.5	72.2	-99%
Other renewable energies	1 (1.2 for aviation and shipping)	1 (1.2 for aviation and shipping)	0.031	0.035	12%
Total (RES-T numerator with multiplicators)			10716.6	24370.0	
Total (RES-T denominator with multiplicators)			264330.0	274260.8	
RES-T [%]			4.1%	8.9%	119%

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